Cool Carbon Creations: Harnessing Air and Foam for Cooling

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Further Goals We Have

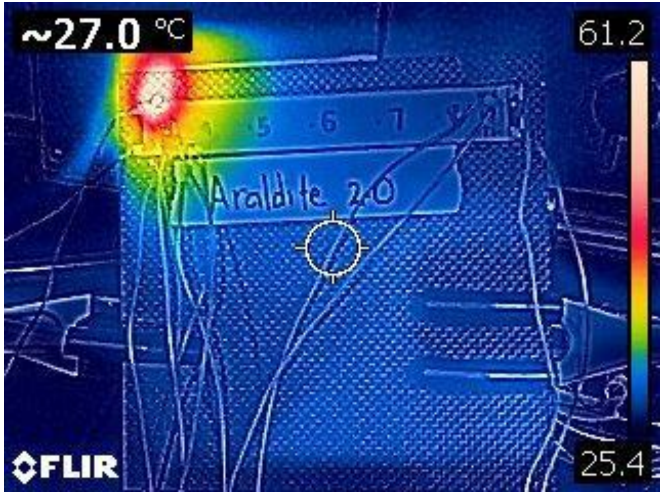
- ❖ Get more accurate temperature measurements using PT100s. This includes setting up a circuit and corresponding code.

- ❖ Obtain a higher CFM (cubic feet per minute) using a fan setup. To achieve this, we need to connect a 4-pin fan to an Arduino with some corresponding code that allows us to control the fan speed.

    - ➢ One problem we ran into was that we had a dual fan setup, and unfortunately, Arduino cannot easily or reliably control two fans separately. So instead, we opted to connect our fans in parallel, which allowed us to control both fans as one unit.

    - ➢ Additionally, we need to figure out how to funnel the air into our setup. We tried implementing a simple funnel system, but the fan is so powerful that the air gets pushed off the funnel walls and pushes back.

Why We Want PT-100s



The old methods gave us a vague average of just a single spot and was susceptible to error.

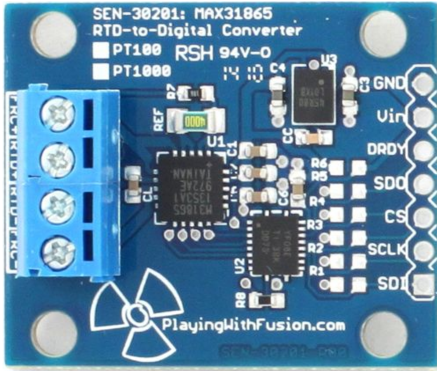
- ❖ Using the PT-100s we are able to get the reading of the at the exact spot the sensor is placed.
- ❖ Allowing for us to see the gradient of temperatures
- ❖ Easier to exclude problem points like soldered that heats up quicker than the rest of the kapton

```
RTD Sensor 1:
Resistance = 118.13 ohm
Temperature = 46.41 deg C
Fault Status = OK
RTD Sensor 2:
Resistance = 117.72 ohm
Temperature = 45.34 deg C
Fault Status = OK
RTD Sensor 3:
Resistance = 113.71 ohm
Temperature = 35.09 deg C
Fault Status = OK
```

How We Got the Current PT-100 Set Up

- ❖ Utilized MAX31865 RTD to Digital Converter for PT100 setup.
- ❖ Slightly modified the provided code to enable 4 channels.
- ❖ Further modified the code to accommodate 12 channels
- ❖ Conducted tests to check the reasonability of the temperature readings, comparing them from room temperature to body temperature.

How The PT-100 Reading Is Calculated



For T ≥ 0 °C: $R_{(T)} = R_{(0)} * (1 + a * T + b * T^{2})$

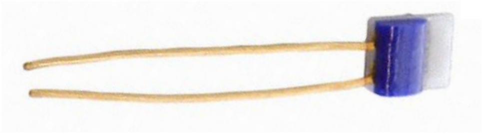
For T < 0 °C: $R_{(T)} = R_{(0)} * [1 + a * T + b * T^{2} + c * (T - 100°C) * T^{3}]$

Coefficients:

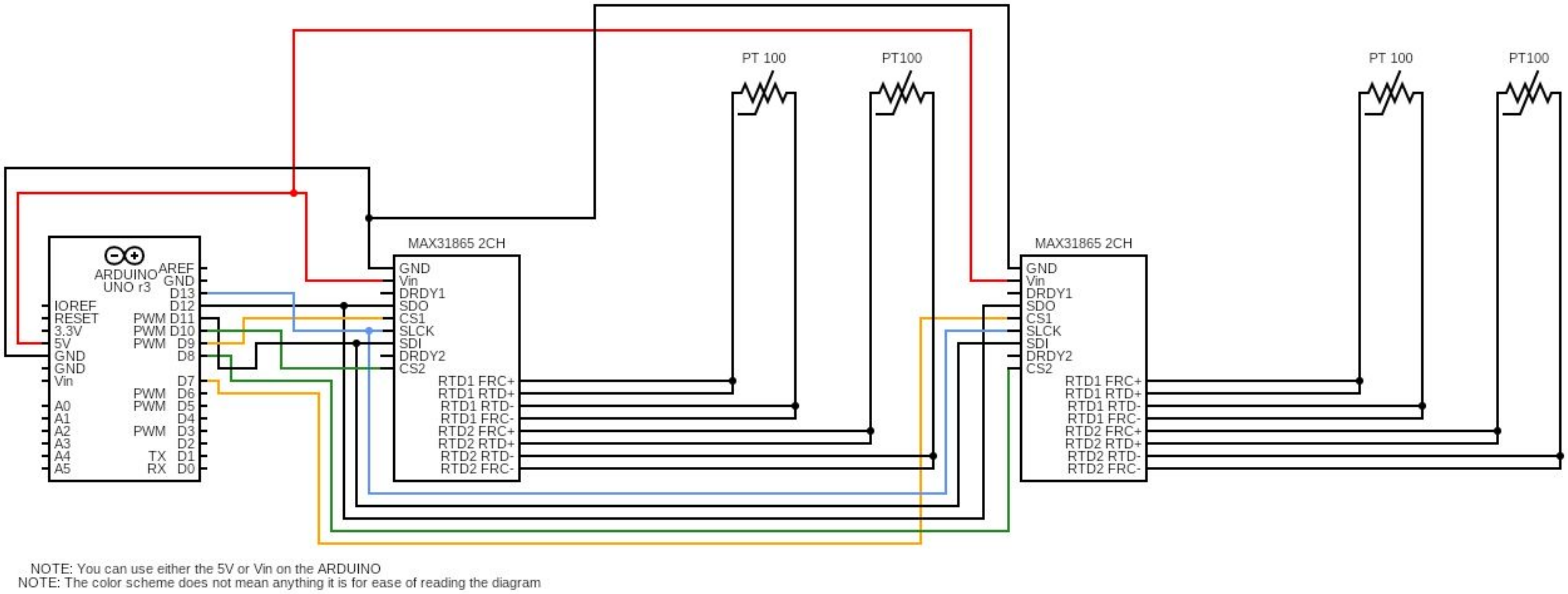
a = 3.9083E-03
b = -5.775E-07
c = -4.183E-12

Tolerances:

Class F 0.1 (T = AA):	± (0.10+0.0017*|T/°C|) °C	(-30…+200 °C)
Class F 0.15 (A)	± (0.15+0.002*|T/°C|) °C	(-30…+300 °C)
Class F 0.3 (B):	± (0.30+0.005*|T/°C|) °C	(-50…+600 °C)
Class F 0.6 (C):	± (0.60+0.06*|T/°C|) °C	(-50…+600 °C)

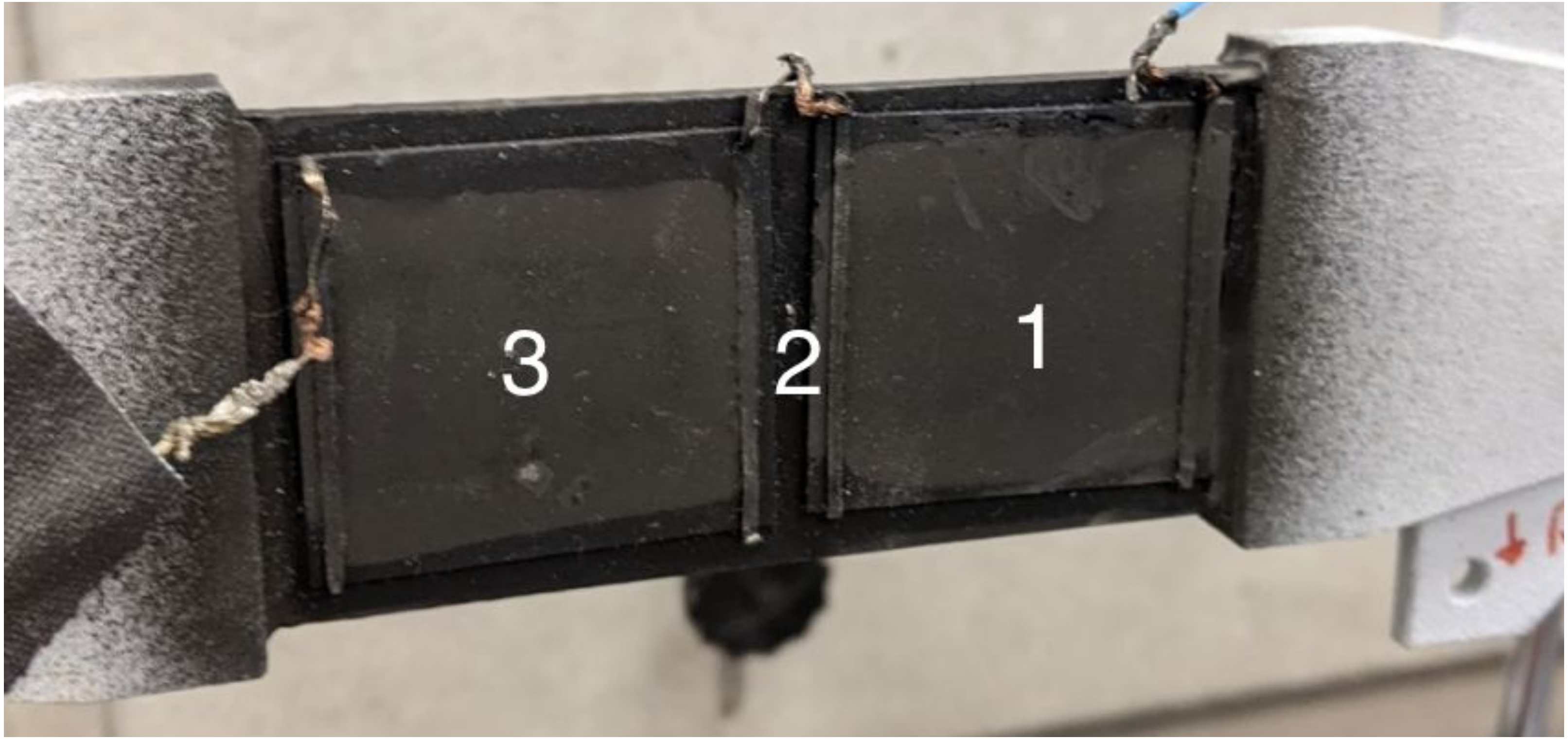


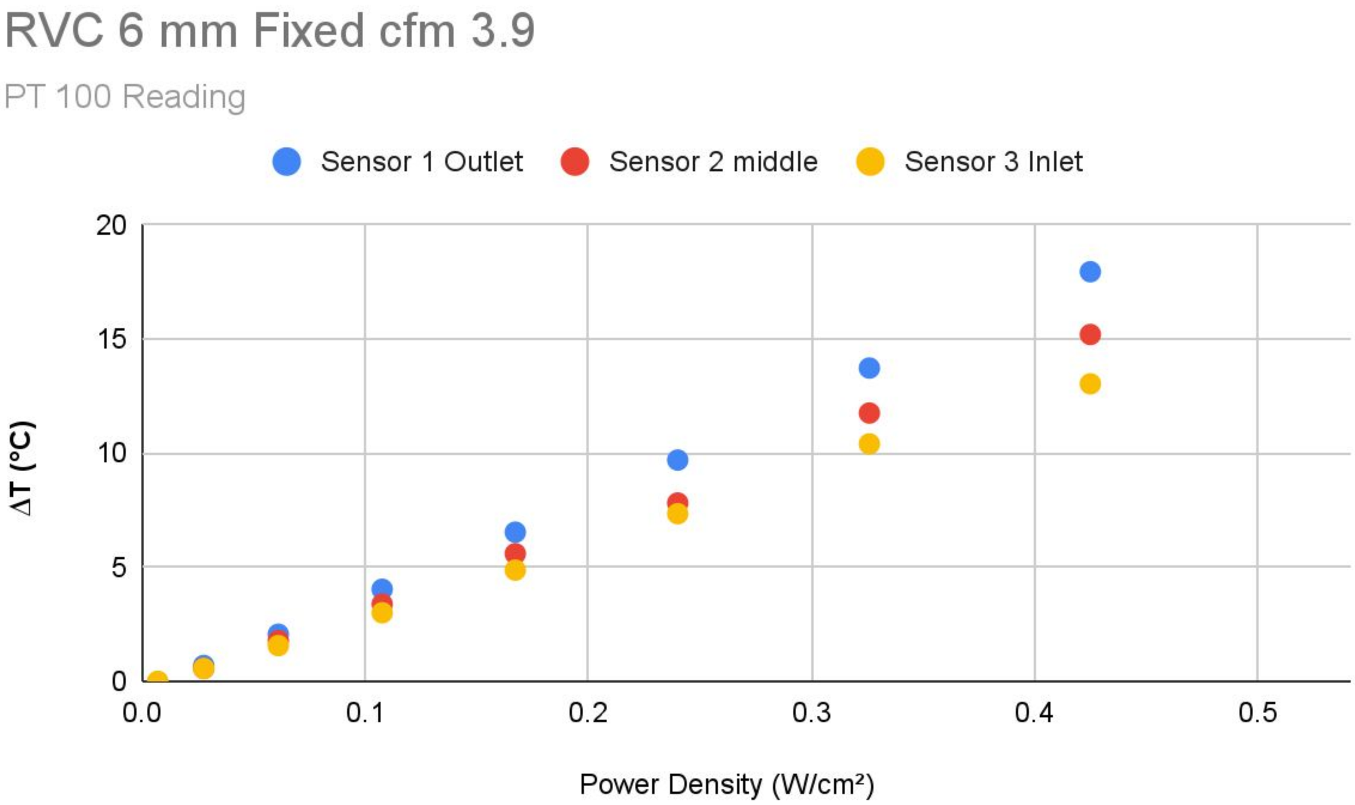
How To Add Channels to PT-100



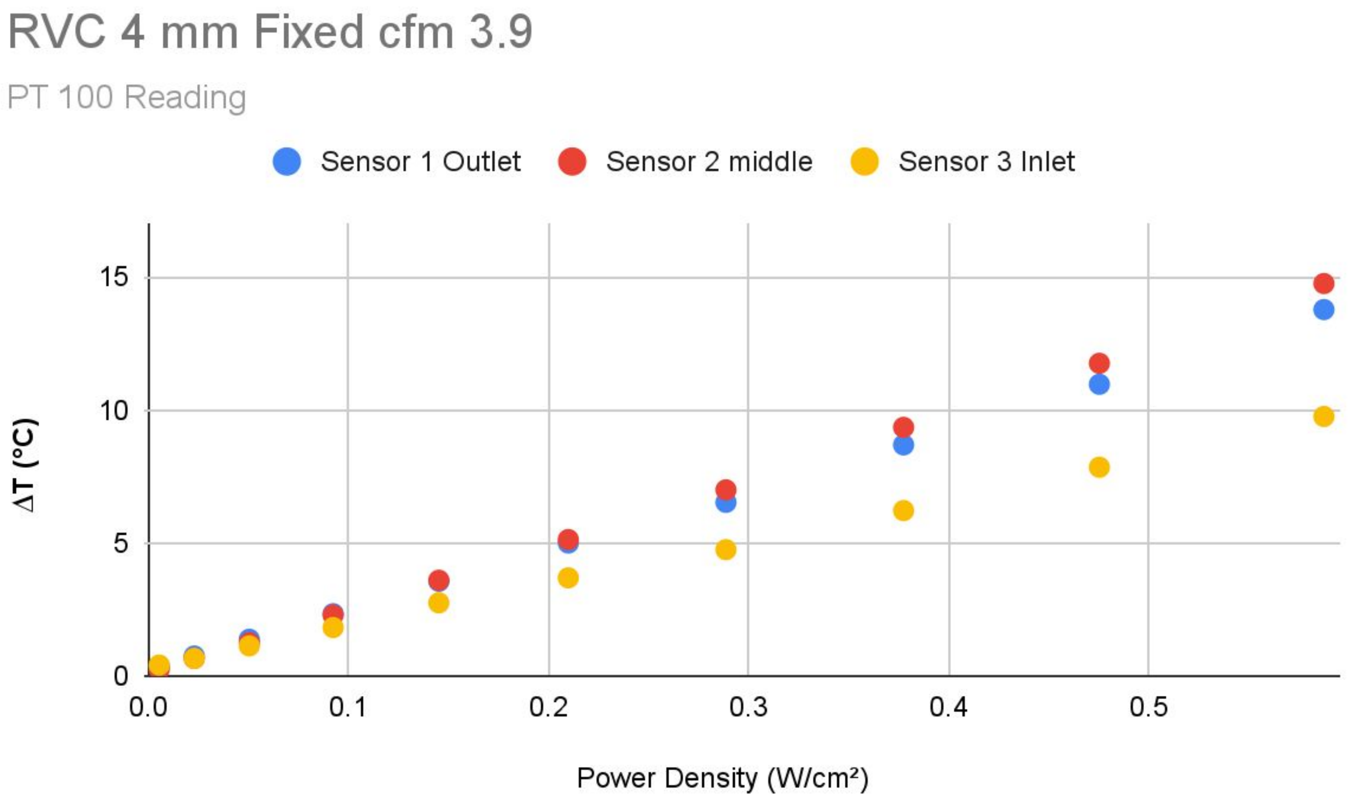
We are hoping to eventually have 8-12 sensors

Placement For PT-100 On Staves





For the 4 mm RVC foam with the PT 100 setup, we observe less change between the middle and far right, unlike when using the thermal camera



For the 4 mm RVC foam with the PT 100 setup, we observe less change between the middle and far right, unlike when using the thermal camera

Overall from the 2 graphs we noticed that the inlet tends to be cooler

New Heater Zones

How To Estimate Power Density

Periphery: Power(W)/(1.95 cm *1.0 cm) Range ≈ 0.04-0.8 W/cm²

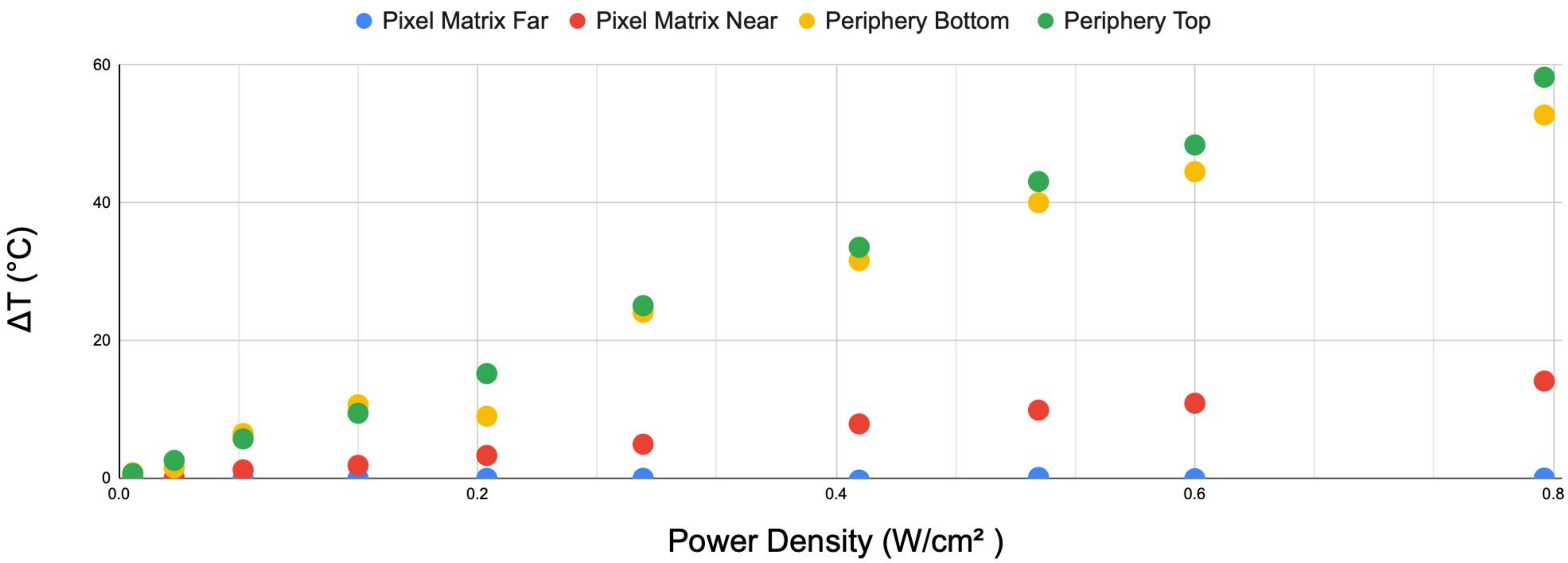
Pixel Matrix: Power(W)/(1.95 cm *12.0 cm) Range ≈ 0.002-0.02 W/cm

Where The sensors are placed

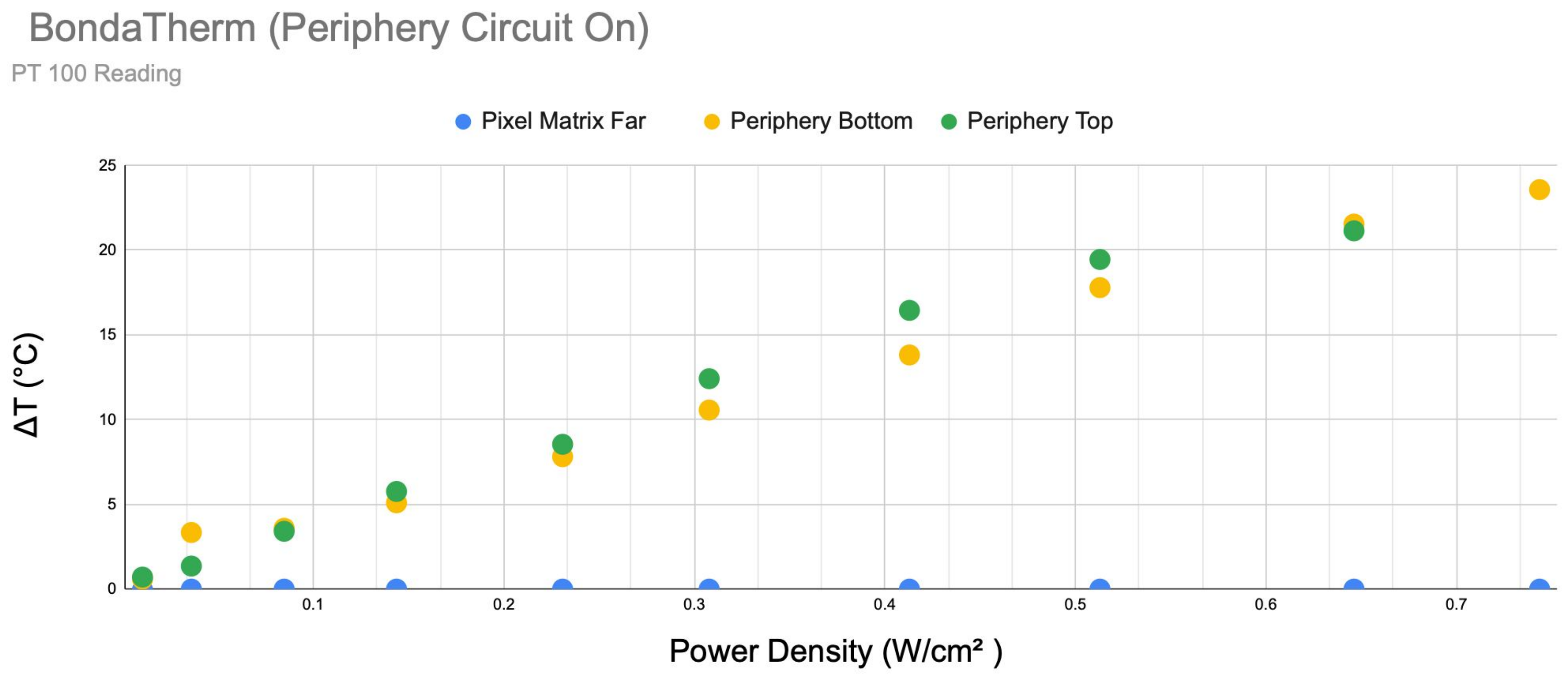
Sensor 0 is the far right corner on the bottom pixel matrix
Sensor 1 is far left corner up top pixel matrix
Sensor 2 bottom of Periphery
Sensor 3 is top of Periphery

Araldite (Periphery Circuit On)

PT 100 Reading

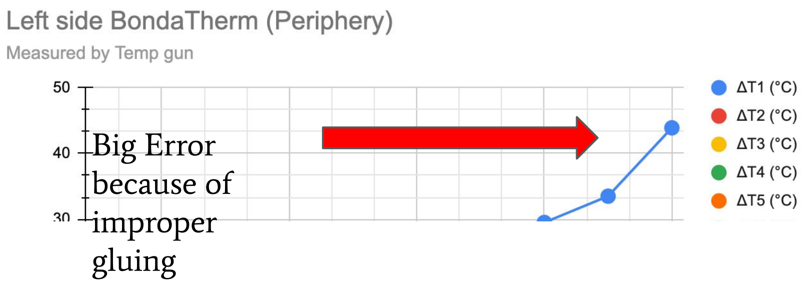


With the PT 100 setup, we observe comparable ΔTs to when the thermal camera was used for measurements. The stave gets hotter on the outlet side, as the air has passed through and become hotter.



As expected the BondaTherm performs Better than the Araldite. With the PT-100 set up we do see lower ΔT compared to when measurements were taking with a temp gun. Readings can become inaccurate if PT-100 start to peel off (that data point was excluded from this data set)

Epoxy Gluing Procedures



Spot 1 had a much higher ΔT due to that spot having to be reglued

We need a uniform and thin spread of glue

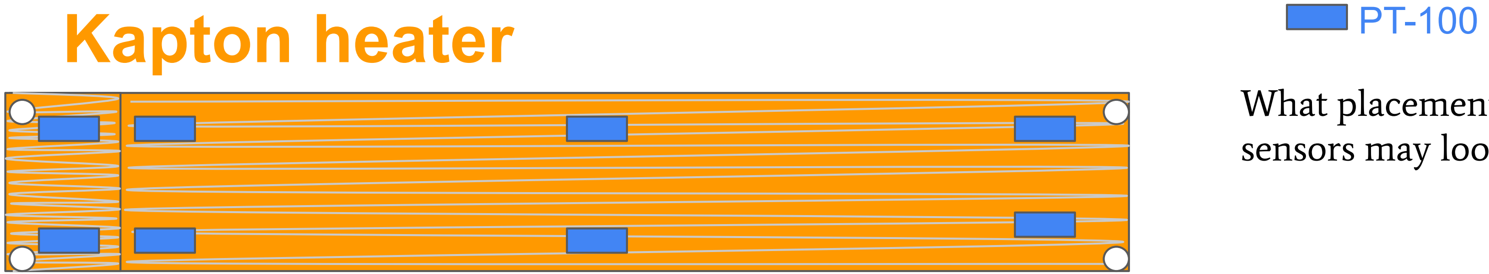
To do this we

1. Clean surface with aclephrobal alcohol
2. Using masking tape to create template for the epoxy
3. Apply the Kapton strip and use an aclephroal alcohol wipe to clean excess glue

PT 100 Placements

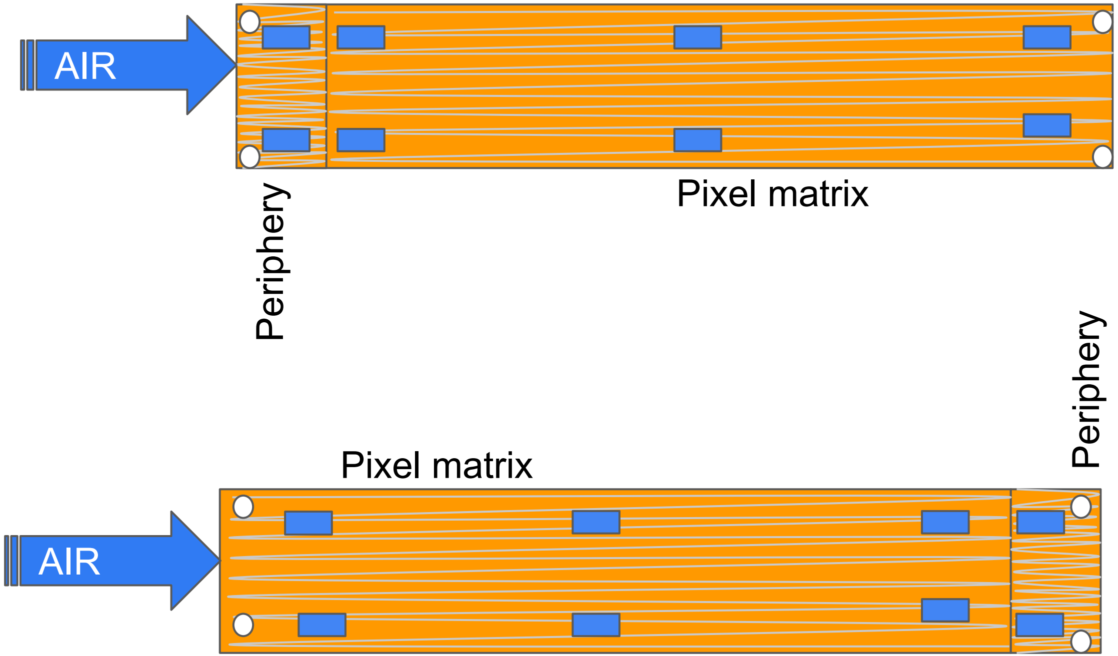
- Another way to negate some error is to strategically place our PT-100 sensors
- We know that the while the latitude of the Kapton strips matter for the measuring temperature. The longitude doesn’t seem to matter as much
- We still need to put more than one sensor at each point of a specific longitude just for redundancy
- Further testing needs to take place before we decide the final number of PT-100s and where to place them

Kapton heater



What placement of sensors may look like

Where Should The Periphery Be In Relation To The Inlet



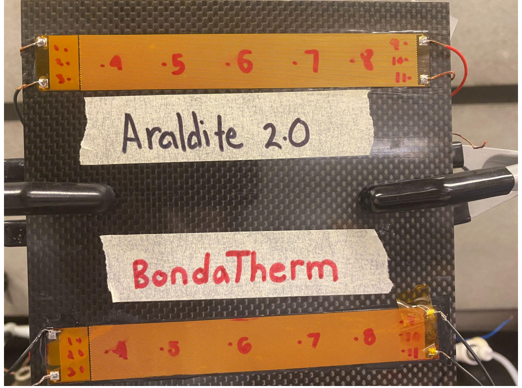
- Air passing by the periphery first will be heated up faster than if it passed by the matrix first.
- Is it better to have a larger initial ΔT for the air temperature but an overall cooler periphery
- Or is it better to have air travel from the matrix to periphery, maybe allowing for a cooler matrix but a periphery that is warmer

Conclusion And Things To Do In The Future

- ❖ CVD is the better performing foam but we are hopefully that by using a higher cfm RVC can be a viable option
- ❖ Put new heaters on stave and test it
- ❖ Calibrate the PT-100 sensors
- ❖ Optimize PT 100 placements and permanently attach PT 100s
- ❖ Test out some thermally conductive glues

BACK UPS

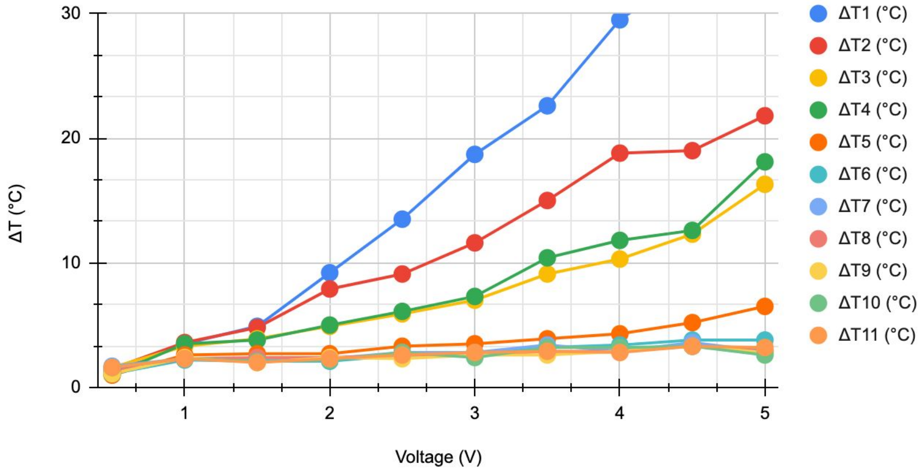
Let's see how it looks if we don't consider ΔT1



Bondatherm:

Left side BondaTherm (Periphery)

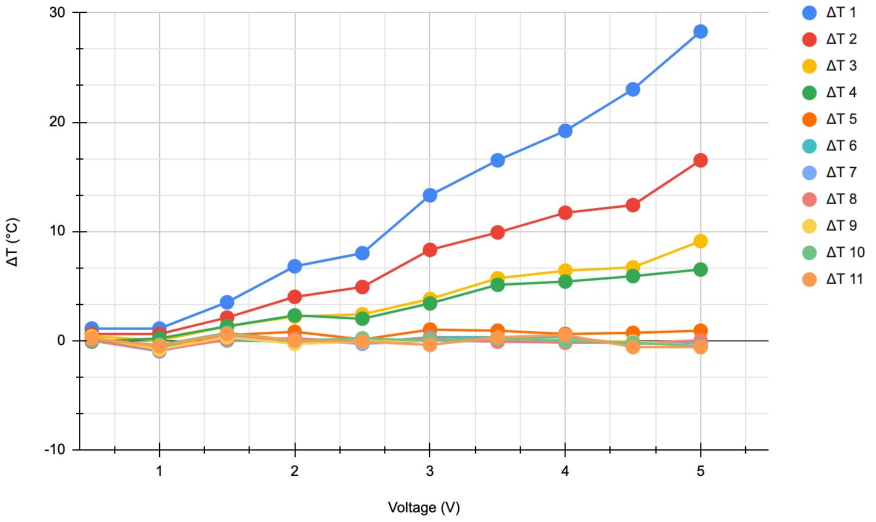
Measured by Temp gun



Araldite:

Left Side Araldite 2.0 (Periphery)

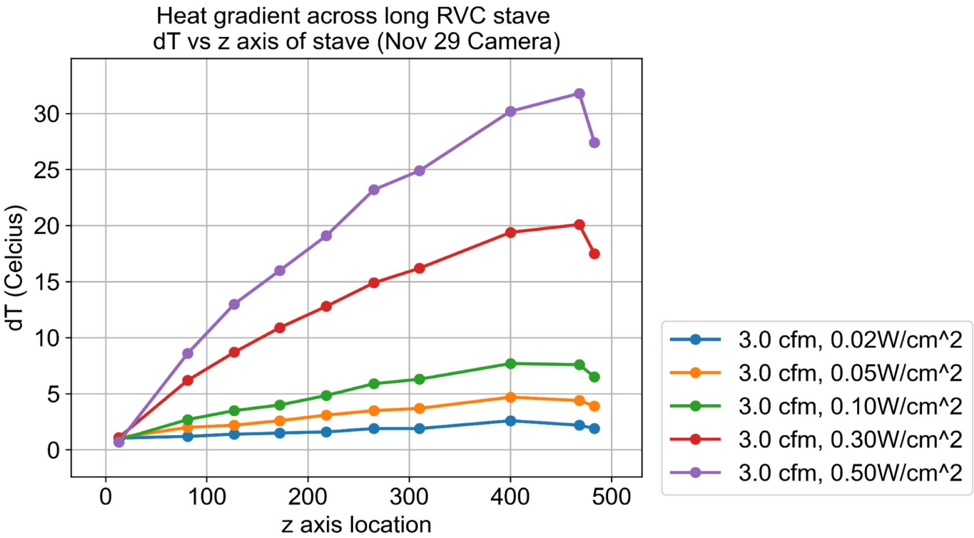
Measured by Temp gun



Since spot 1,2, and 3 are fairly close to each other geographically so we could conclude that data clearly shows that BondaTherm has a better thermal conductivity due to smaller ΔT under the same voltage applied.

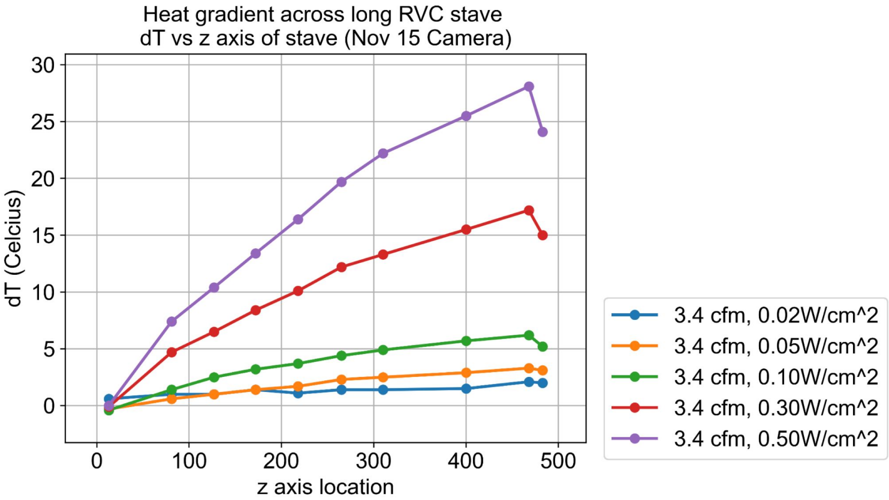
Long stave cooling results from last year

3.0 cfm, RVC Foam



For power densities up to 0.10 W/cm^2, $\Delta T < 10°C$

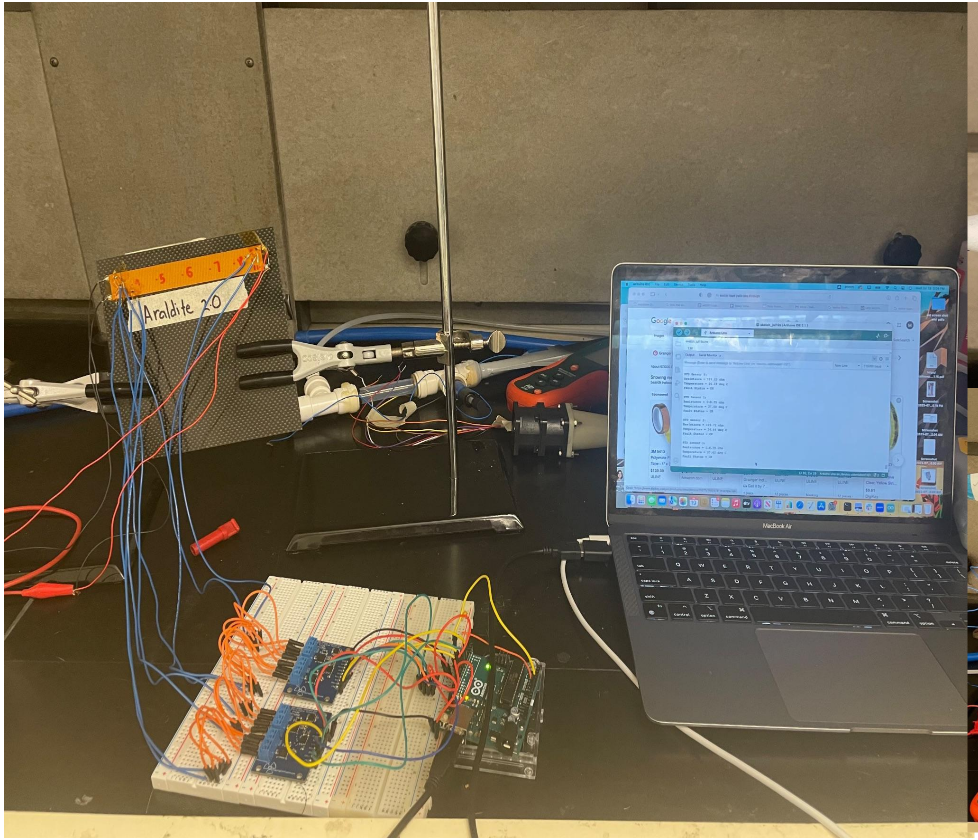
3.4 cfm, RVC Foam



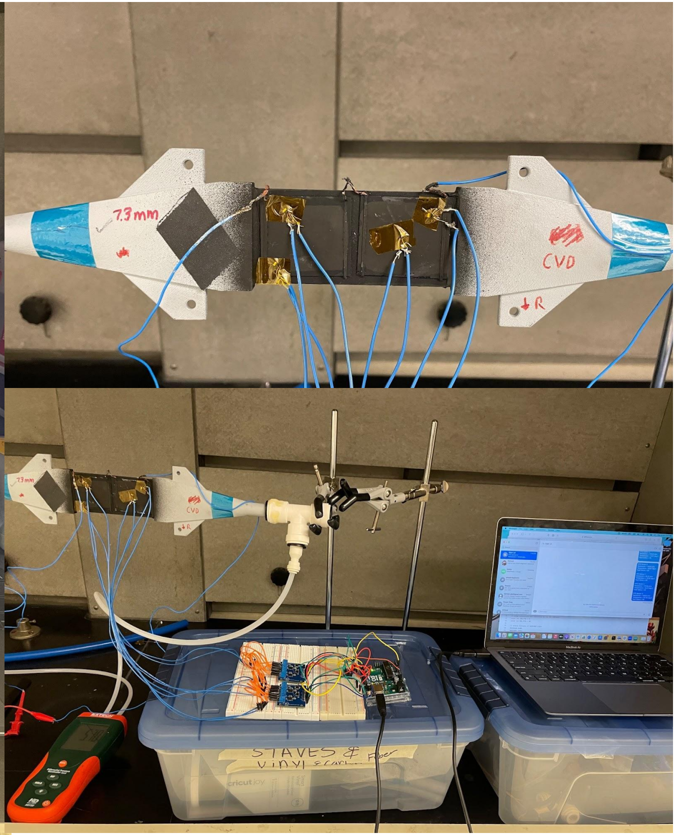
For power densities up to 0.10 W/cm^2, $\Delta T < 10°C$

Higher flow rate → lower temperatures across the same power densities

PT-100 Temperature measurement using Arduino



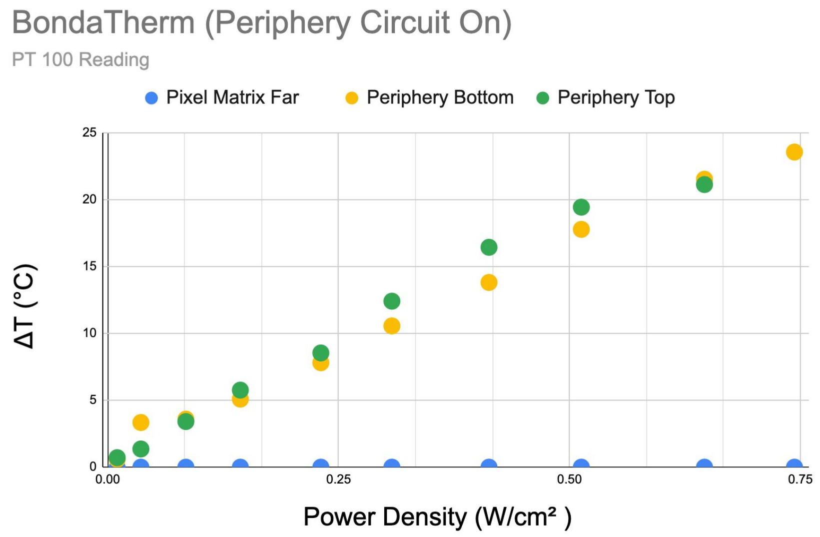
PT-100 measurement on Kapton Heater

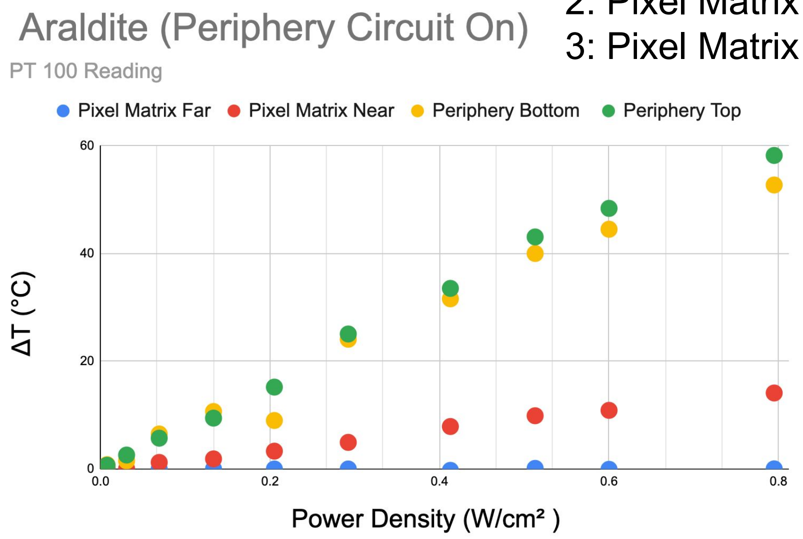


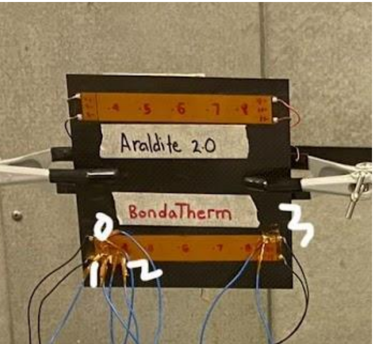
PT-100 measurement on **Stave**

Verifying Glues results measured by PT-100

0: Periphery Top
1: Periphery Bottom
2: Pixel Matrix near
3: Pixel Matrix far



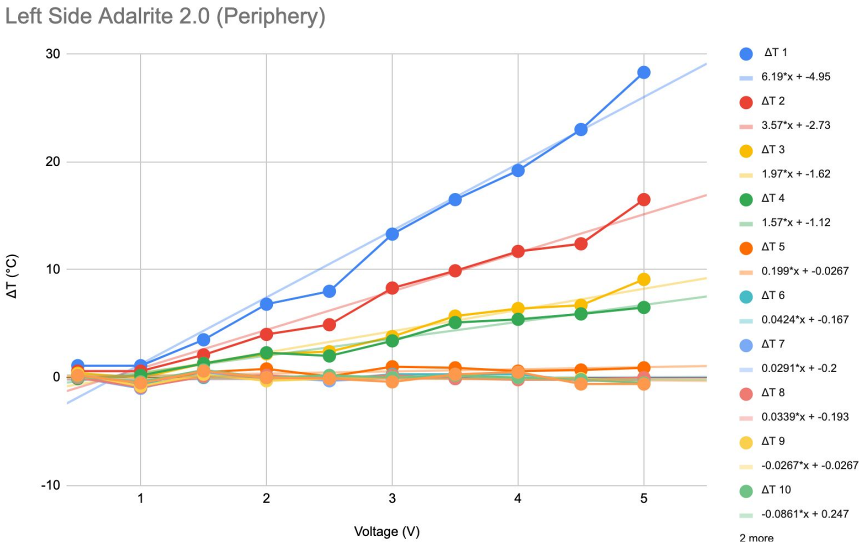


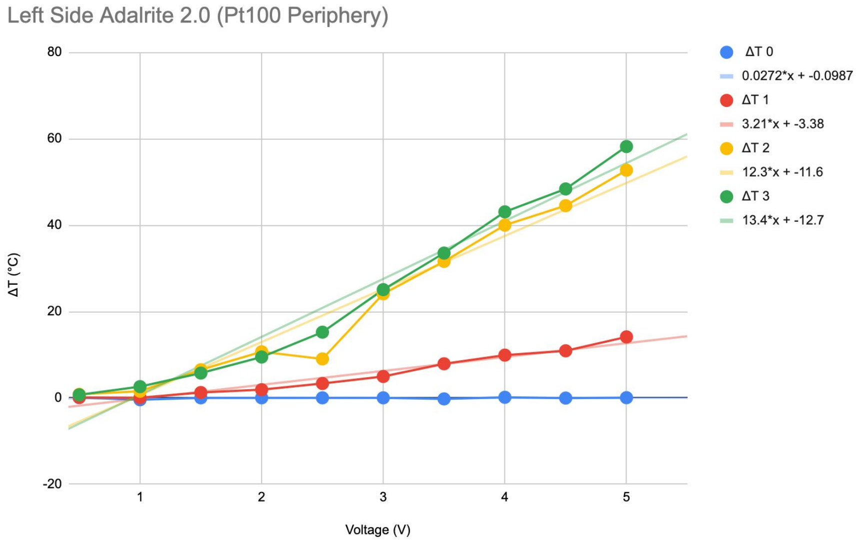


- We are seeing ΔT differences between PT-100 and temp gun measurements on Araldite under the same power densities.
  - Human error
    - different people taking at different times
    - Different distance from gun to spot
- PT-100 calibration

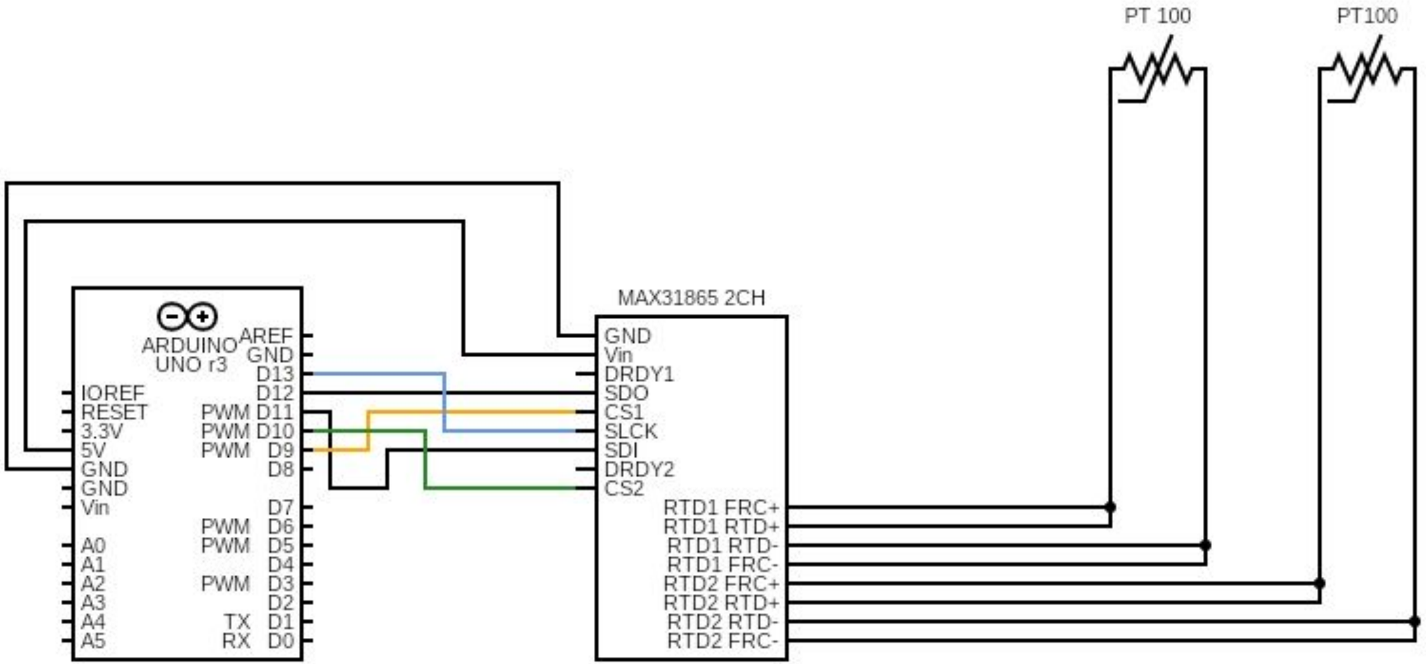
We propose that comparing the two temperature measurements, PT-100 is more reliable due to adhesive properties being applied on the stave for measurement.

Showing Consistency of Temp gun and PT-100 measurements





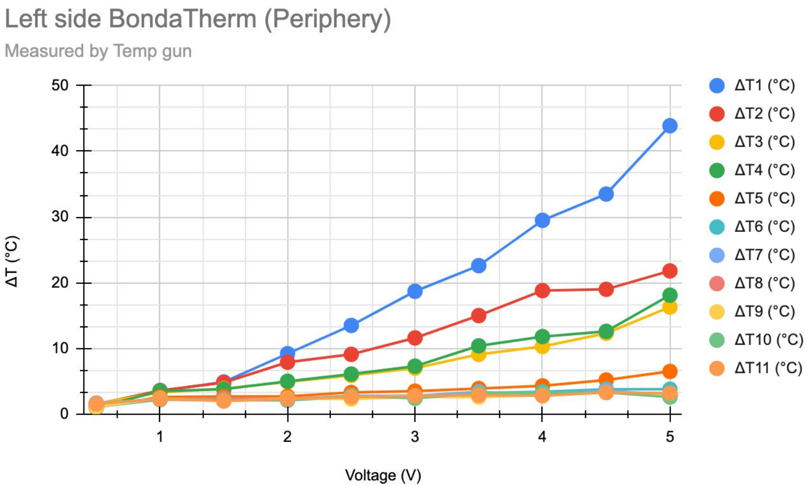
PT-100 2 Channel Configuration



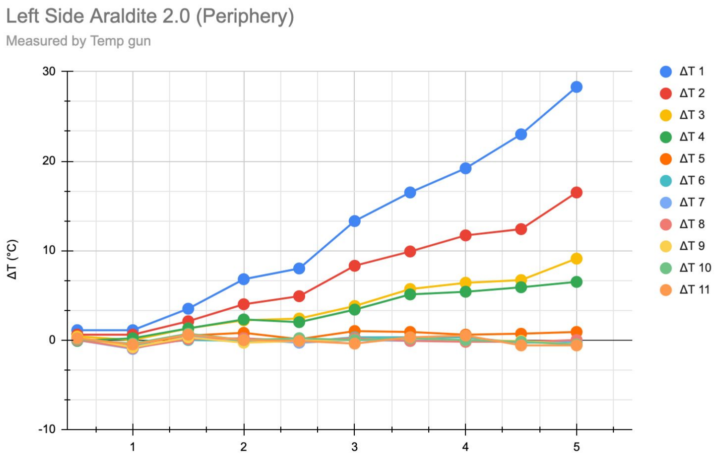
NOTE: You can use either the 5V or Vin on the ARDUINO
NOTE: The color scheme does not mean anything it is for ease of reading the diagram

Glues results measured by temp gun

Bondatherm:



Araldite:



ΔT1 for Periphery BondaTherm is not having an accurate reading for the following reasons (mostly human error):

- Extra glue: ΔT1 was taken at a spot with extra glue under the heater. We applied more glue onto the spot after it got tipped off (We did see more glue → higher temp in thermal camera)
- Reflection: The laser could be reflected to the soldering point when we pointed to spot 1 with an angle (not perpendicular to the surface)
- Radiation: excess heat from the soldering point