Epoxy setup test results

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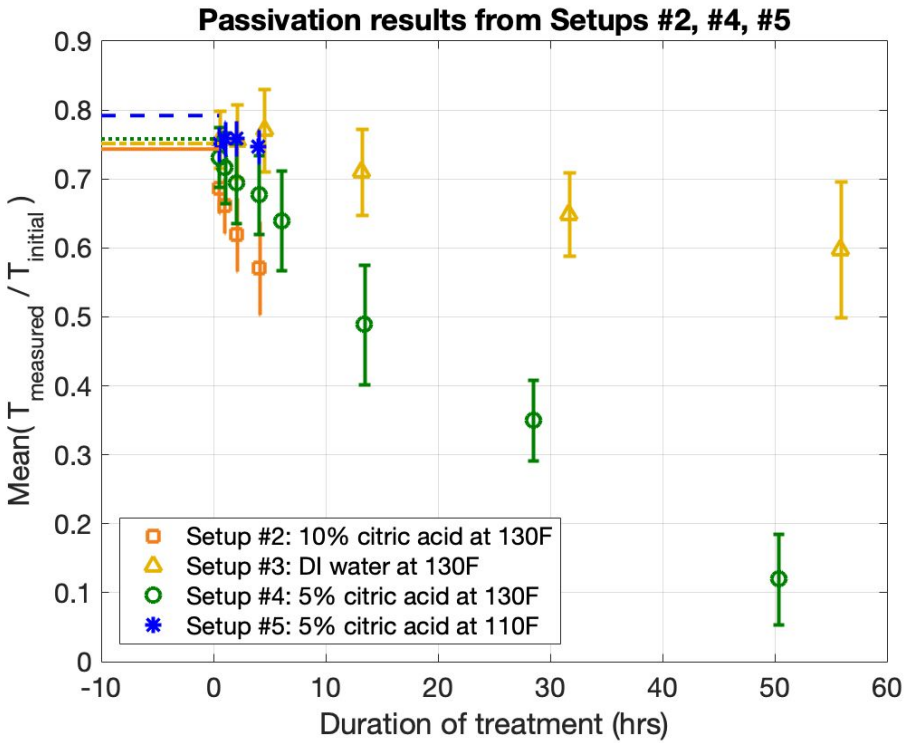
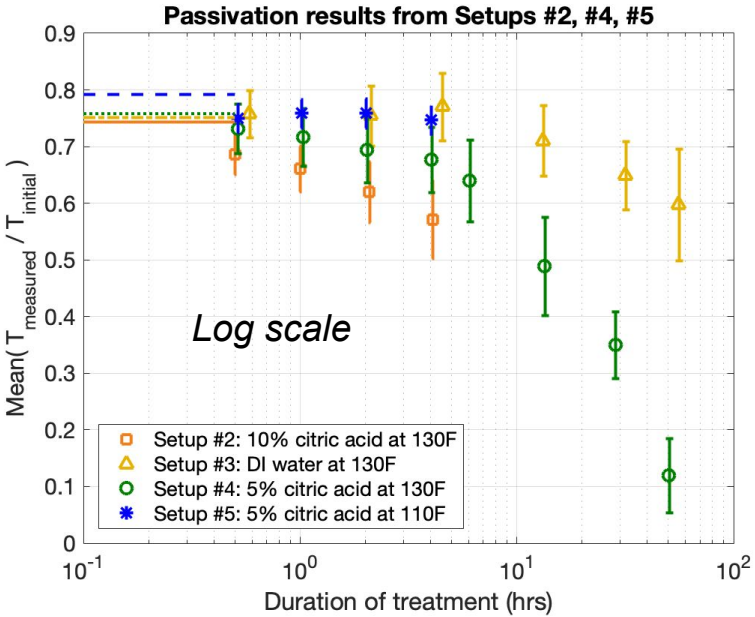
25 February 2019

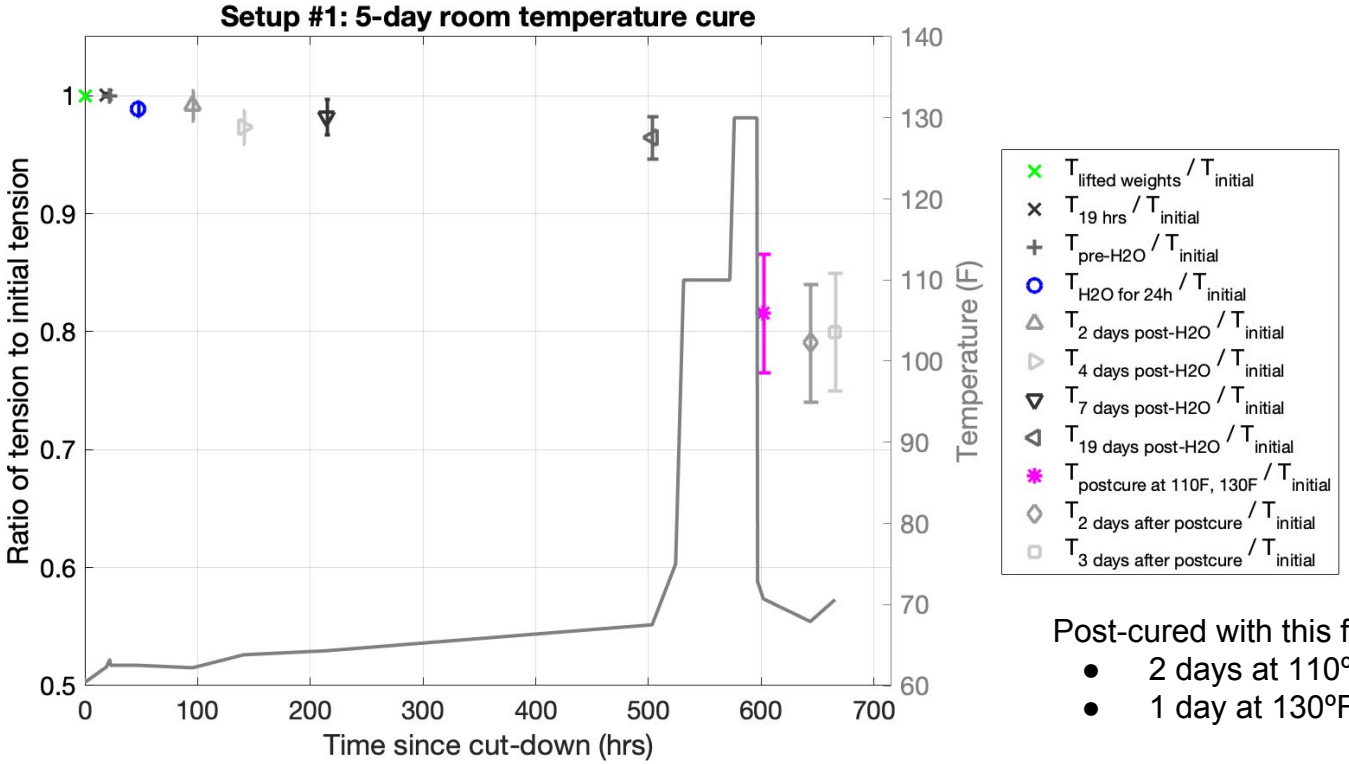
Composite plots: passivation and water soak results





Lines represent the mean wire tensions measured before starting passivation or 130F water soak.

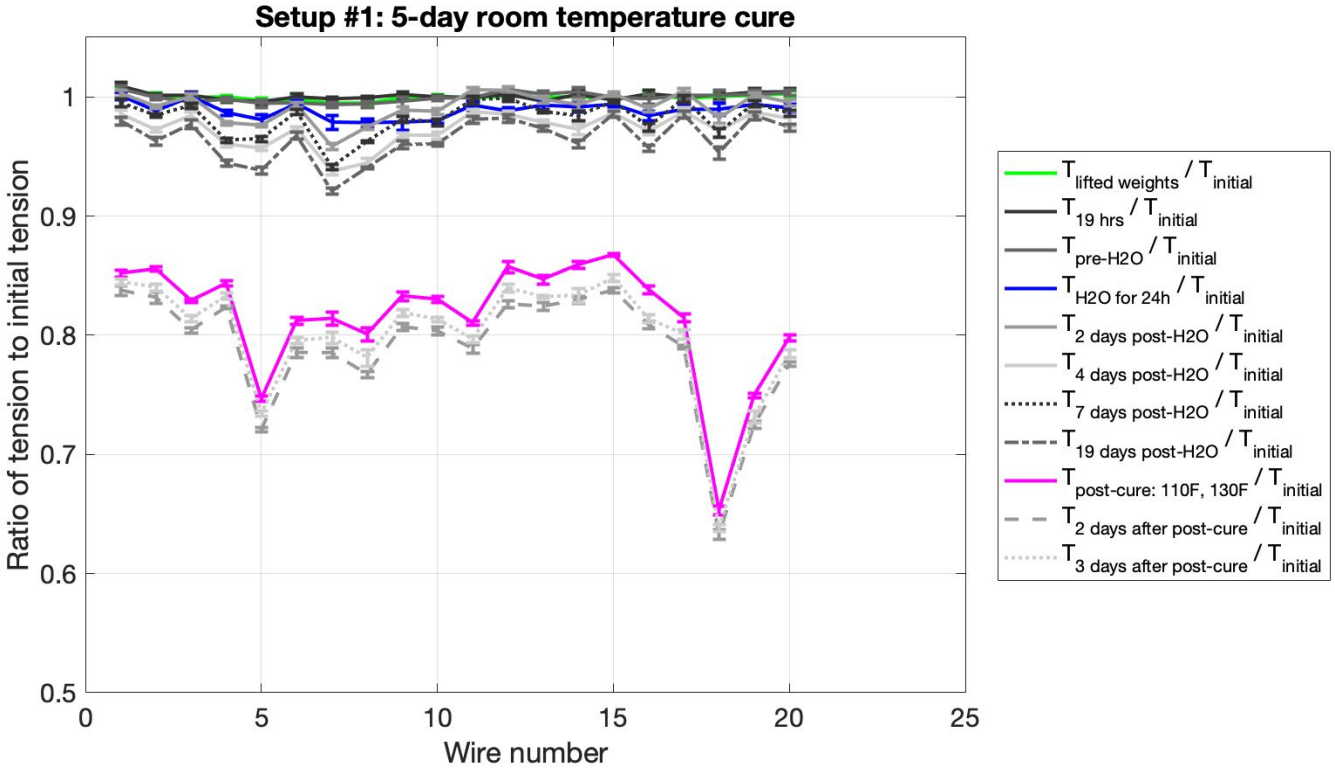
Setup #1: 24h room temp water soak, then post-cured up to 130ºF



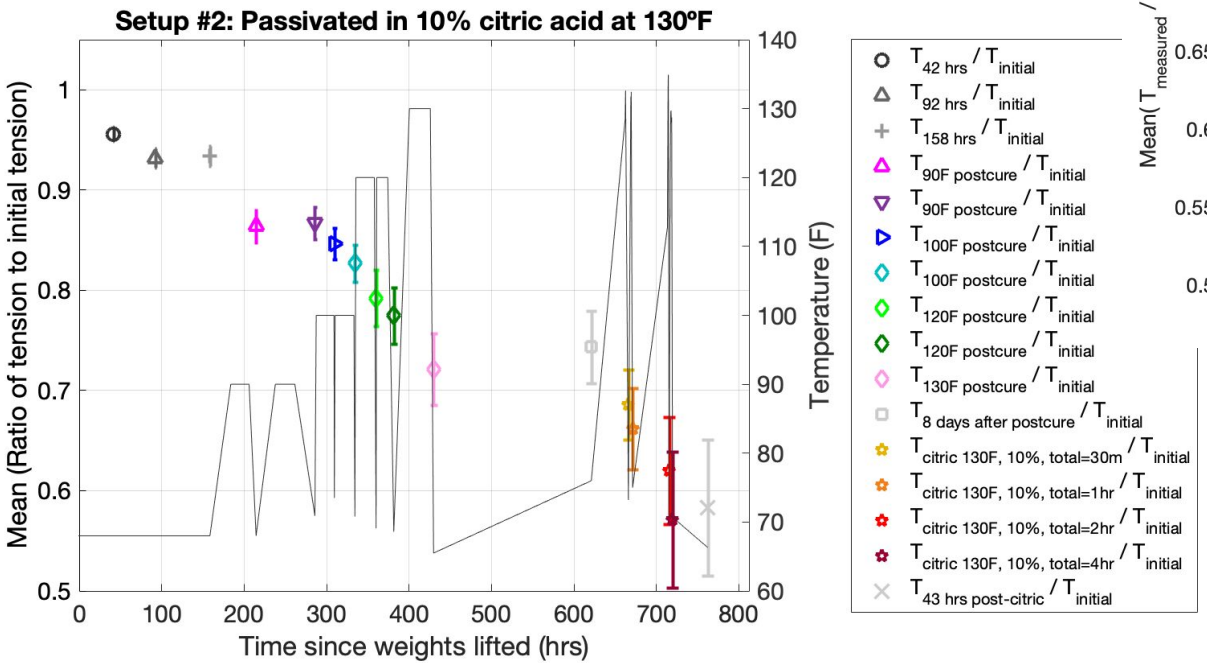
Post-cured with this faster 3-day schedule:

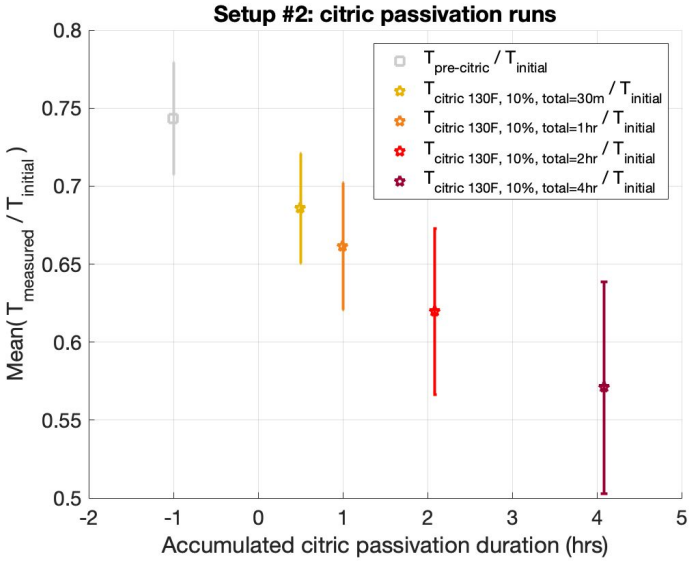
- 2 days at 110ºF (includes 5ºF/hr ramp)
- 1 day at 130ºF (includes 5ºF/hr ramp.

Setup #1 dispersion of data



Setup #2: post-cured up to 130ºF and passivated at 130ºF in 10% citric acid

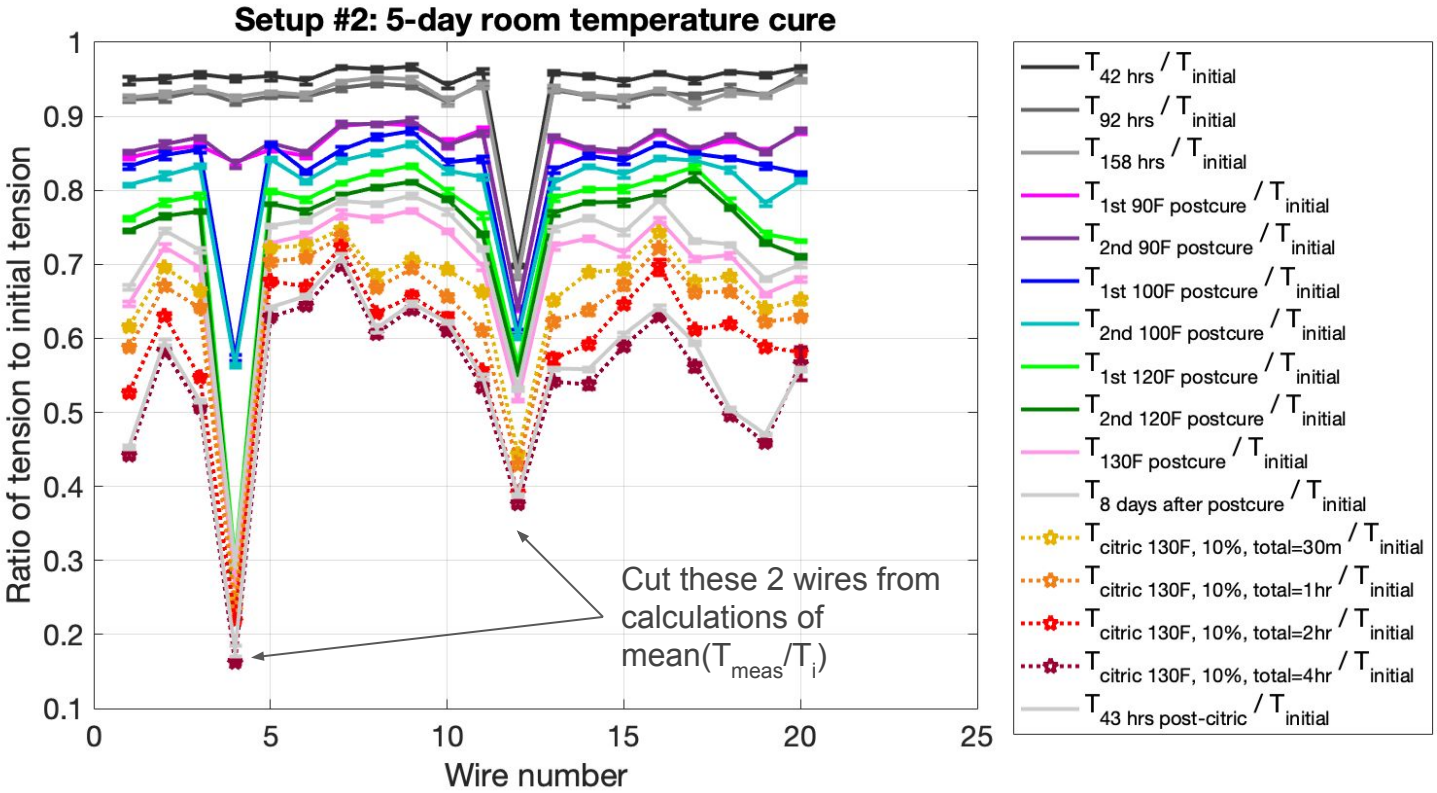




Post-cured with the slowest schedule:

- 46 hrs at 90ºF (measure in between)
- 44 hrs at 100ºF (measure in between)
- 36 hrs at 120ºF (measure in between)
- 24 hrs at 130ºF

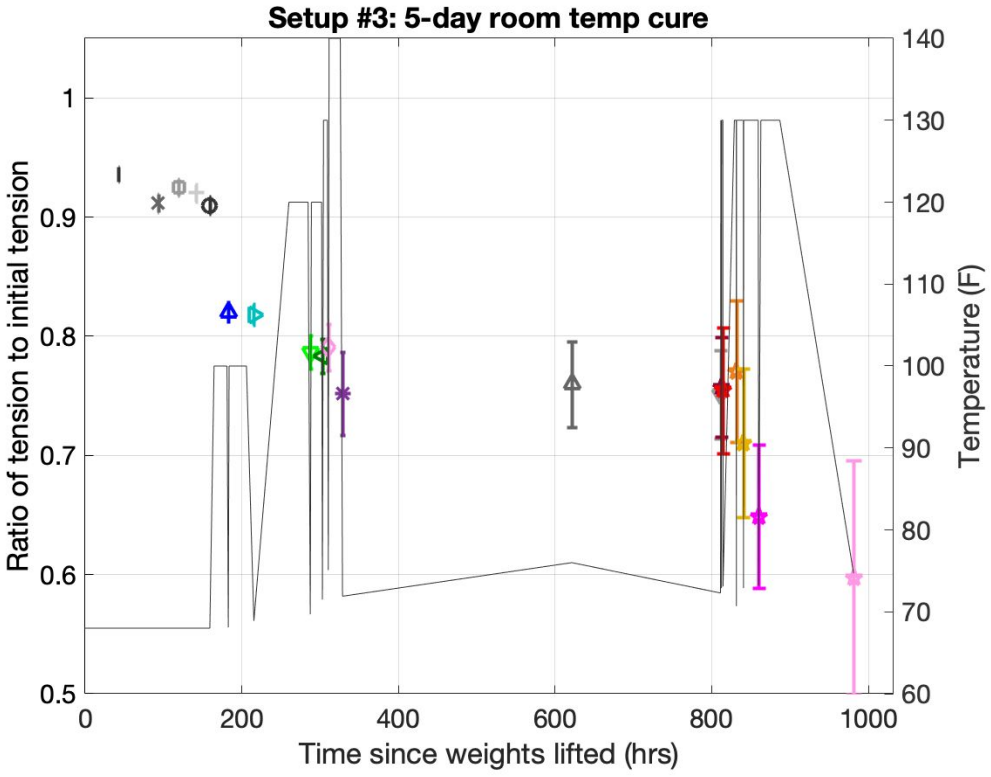
Setup #2: data dispersion

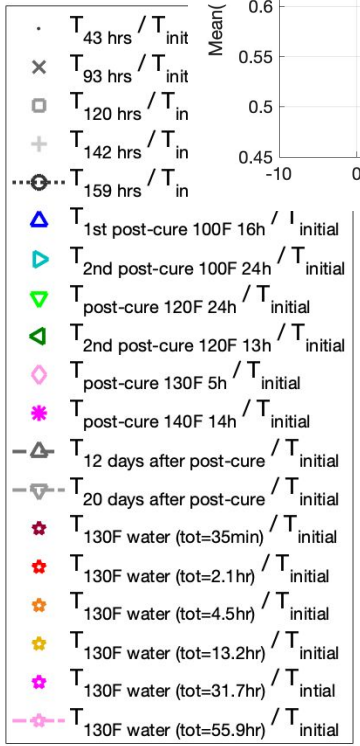


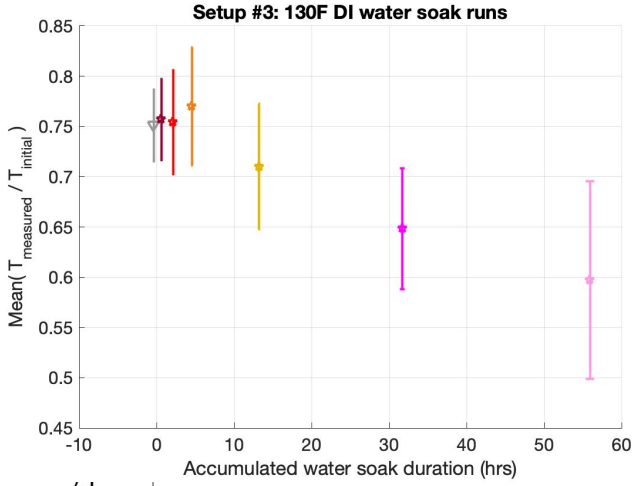
Wire 4 became loose during post-cure cycle; it may have been damaged.

Wire 12 had an incorrect initial tension measurement; thus, the ratios are all incorrect.

Setup #3: post-cured up to 140ºF, submersion in 130ºF water



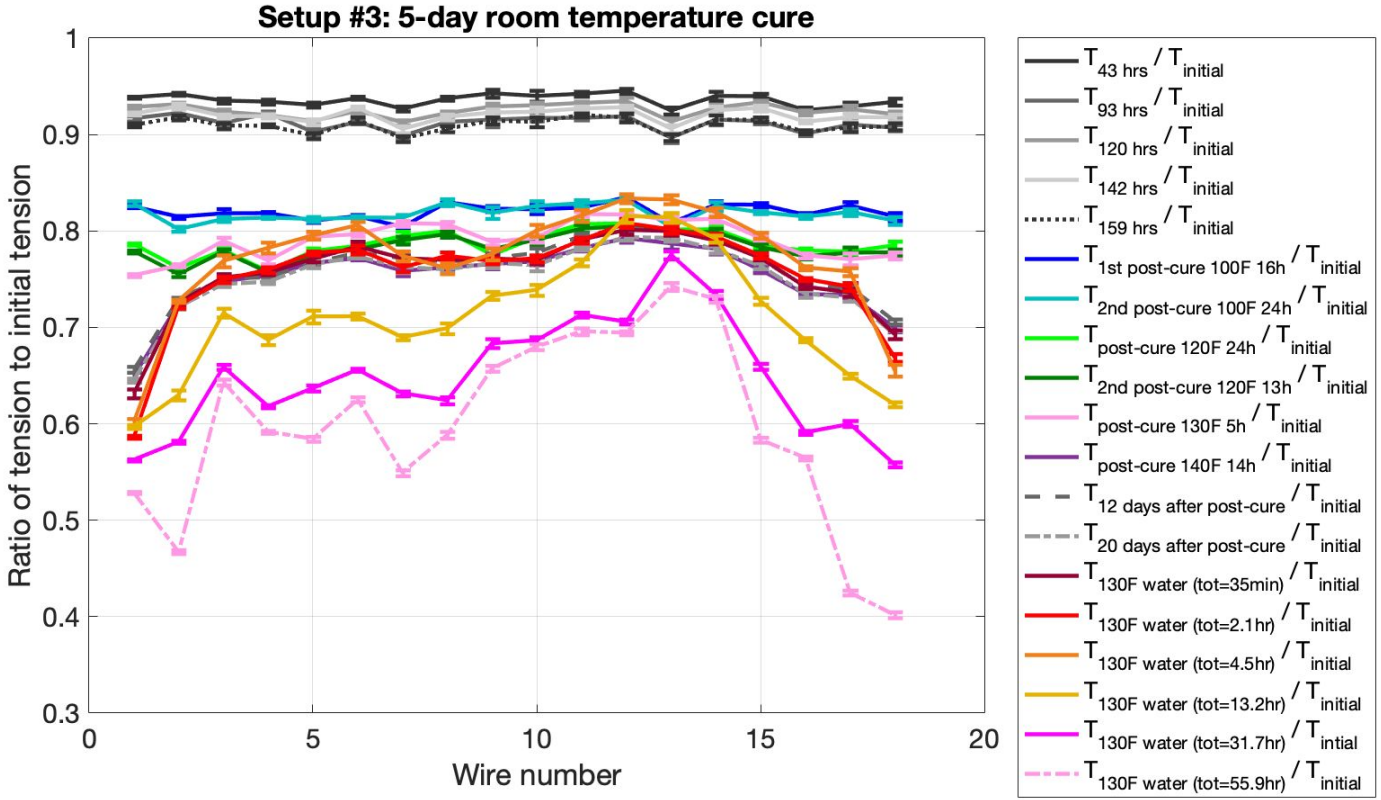




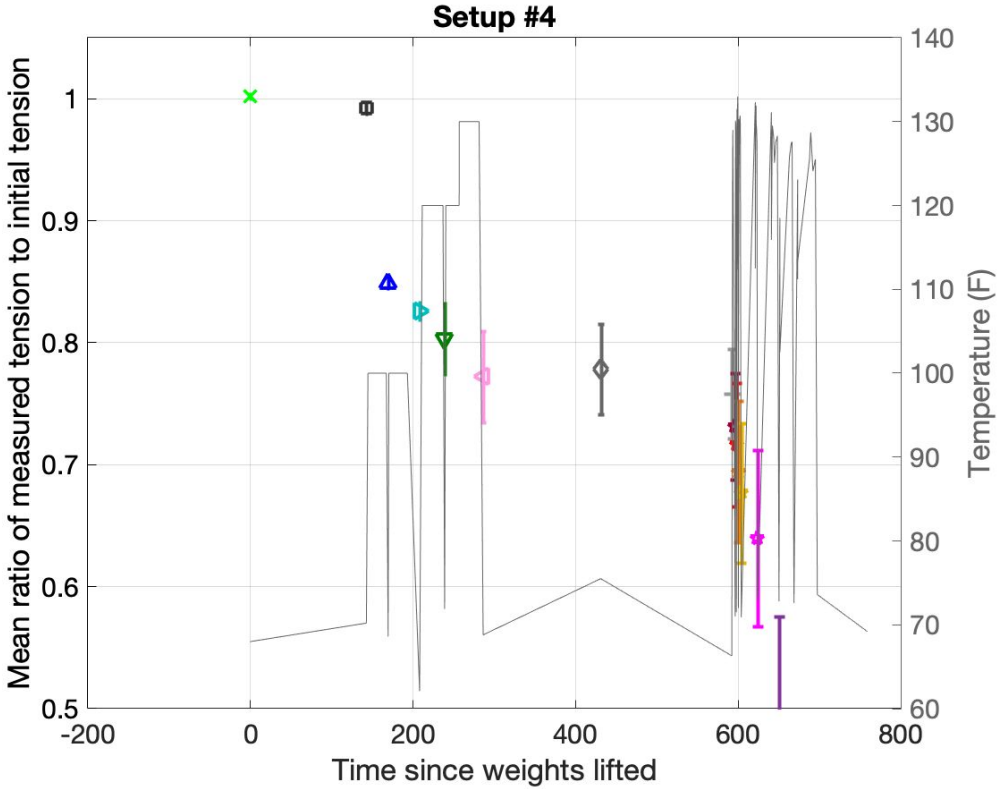
1st setup post-cured & to the highest temperature:

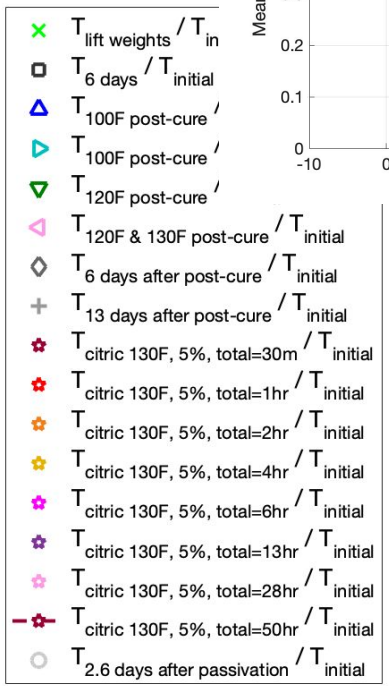
- 39 hrs at 100ºF (measure in between)
- 37 hrs at 120ºF (measure in between)
- 5 hrs at 130ºF
- 14 hrs at 140ºF

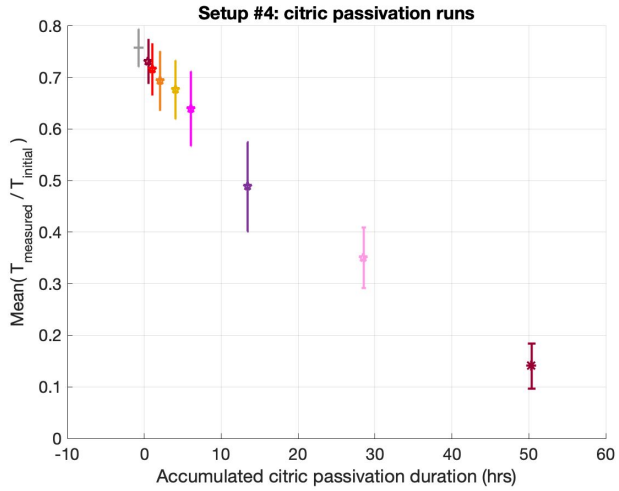
Setup #3 dispersion of data



Setup #4: post-cured up to 130ºF



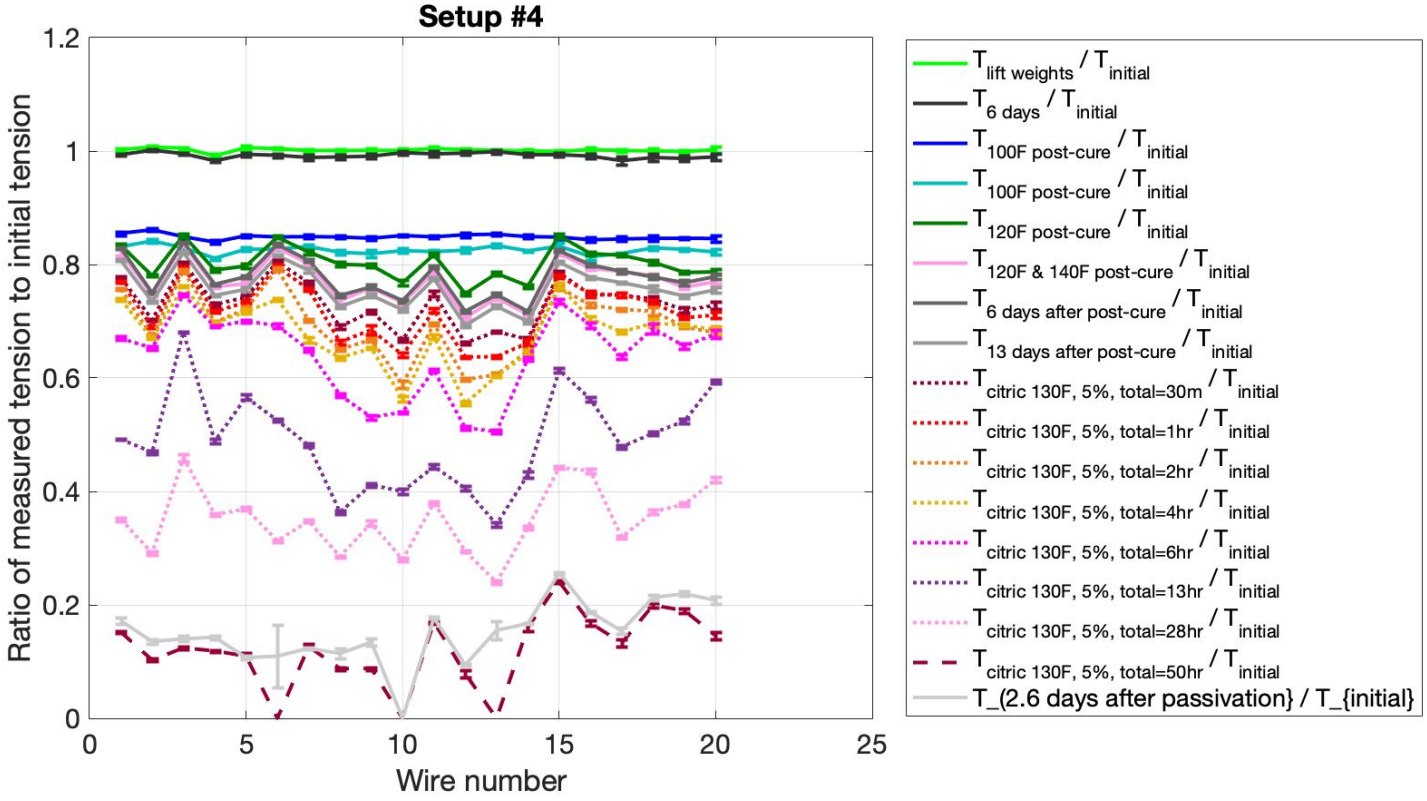




- 2nd post-cure at 120ºF and the 130ºF post-cure were done consecutively.
- For this last post-cure, bags were dry with ~2% relative humidity.

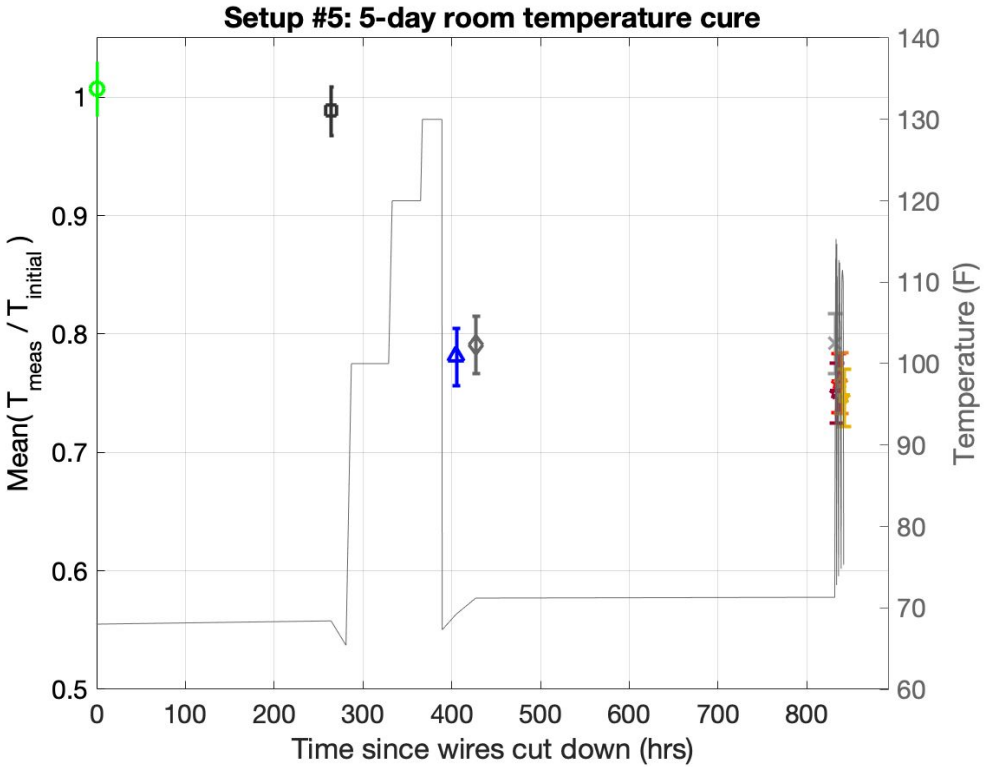
Setup #4 dispersion

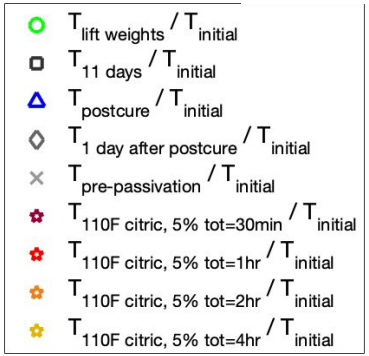
Dispersion of data increases after the post-cures at 120ºF.

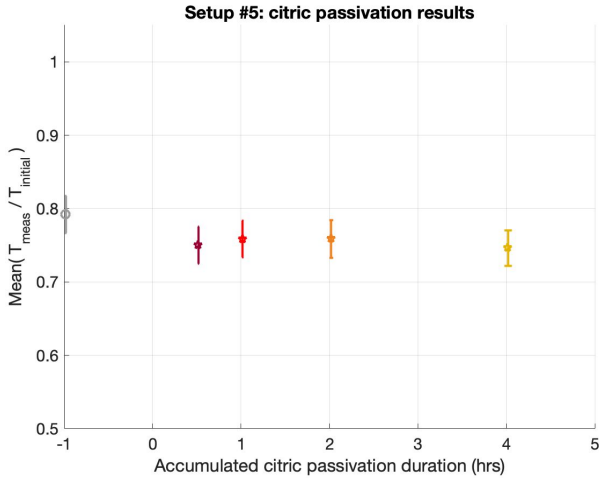


After 50 hours of passivation, couldn't measure wires 6, 10, and 13.

Setup # 5: post-cured up to 130ºF, passivated at 110F



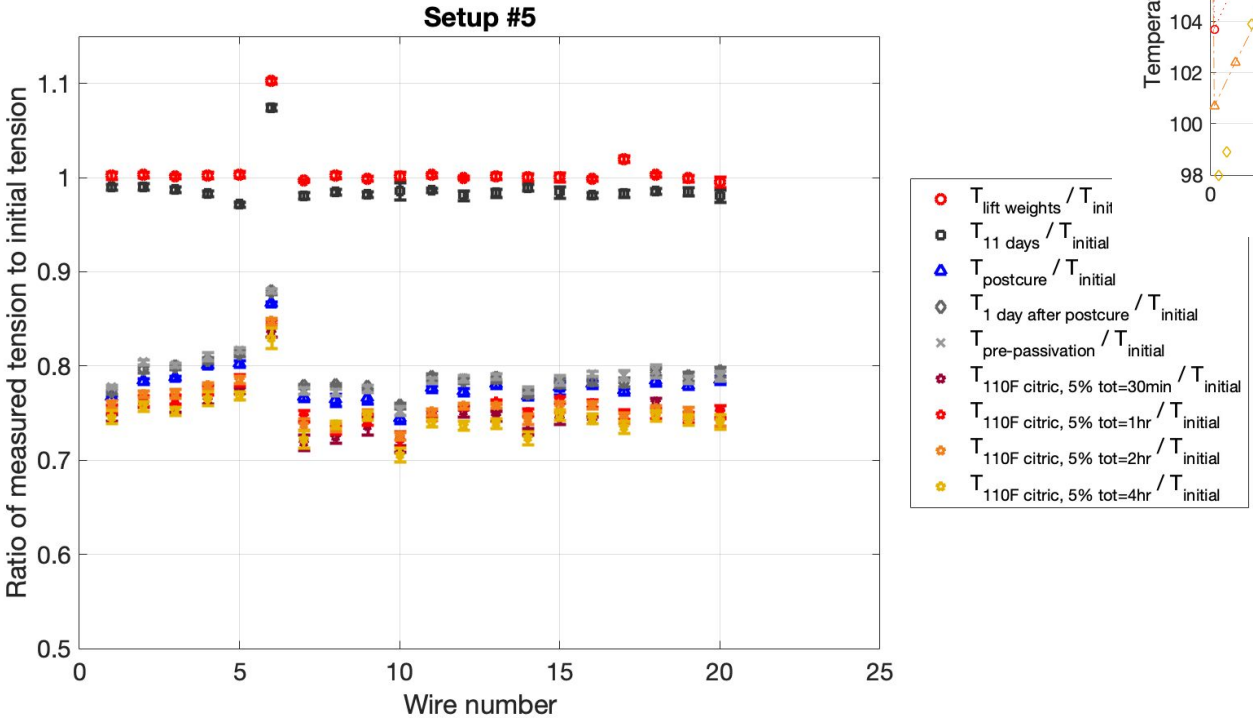


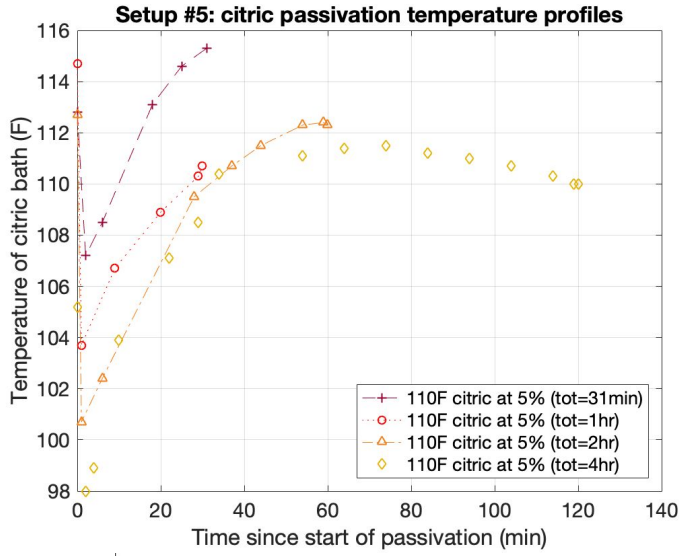


Post-cured with this normal 4.5 day schedule (same as #2):

- 2 days at 100ºF (including 5ºF/hr ramp rate)
- 1.5 days at 120ºF (including 5ºF/hr ramp rate)
- 1 day at 130ºF (including 5ºF/hr ramp rate)

Setup #5 dispersion of data



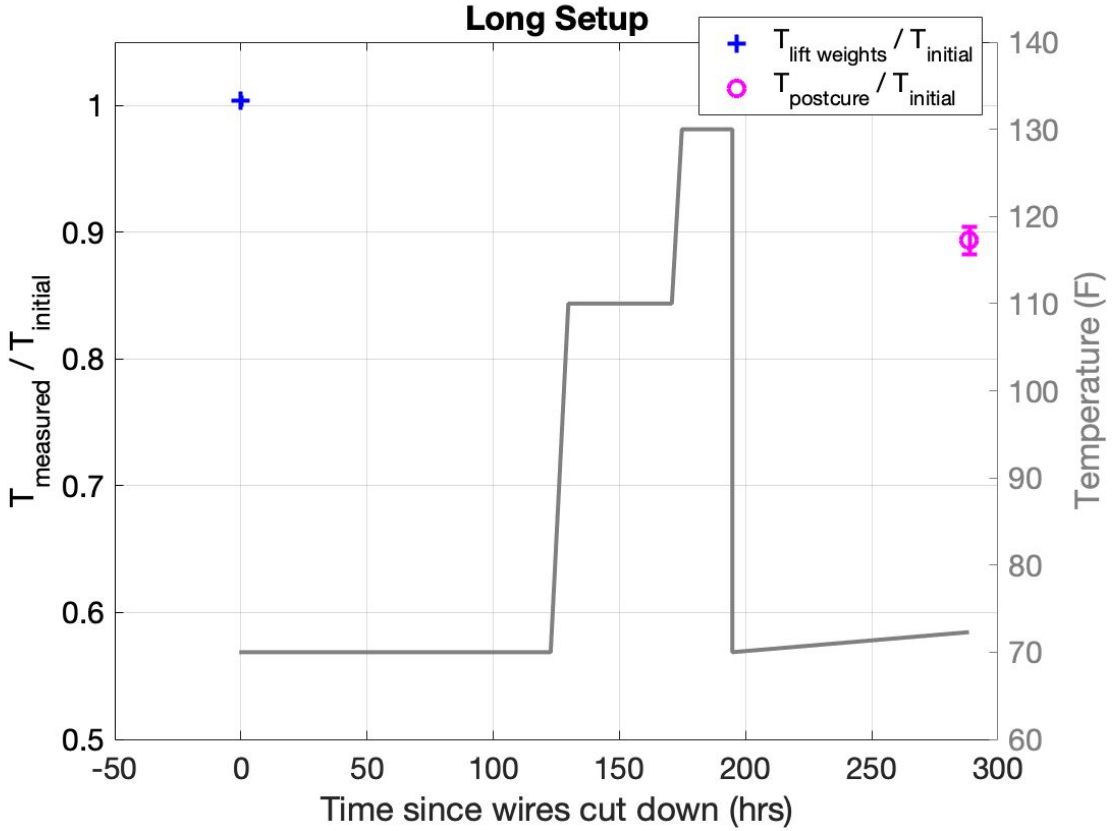


(above) The variation in temperature of the citric acid passivation bath. After installing the room temperature setup, the bath cools.

Long setup

110F for 2 days

130F for 1 day



Additional context for post-cure measurements

- Water exposure
  - Setup #1 was submerged in room temperature water for 24 hrs on February 19.
  - Post-curing involves bagging a setup, then submerging the bag in water heated by a sous vide for fine temperature control.
    - **Setup #2:** All post-cures exposed to humidity.
    - **Setup #3:** All post-cures exposed to humidity.
    - **Setup #4:** Early post-cures exposed to humidity. Last post-cure is dry.
    - **Setups #1 and #5:** Post-cures are dry.
- Timing of post-cure steps
  - Setups #2, 3, 4 were cooled to room temperature and measured periodically.
  - Setups #1, 5 were designed to ramp at 5ºF/hr (oven max ramp is ~50ºF/hr) and complete the post-curing schedule uninterrupted. Their postcure results are measured at the end of the schedule.

History of humidity of post-cure bagging

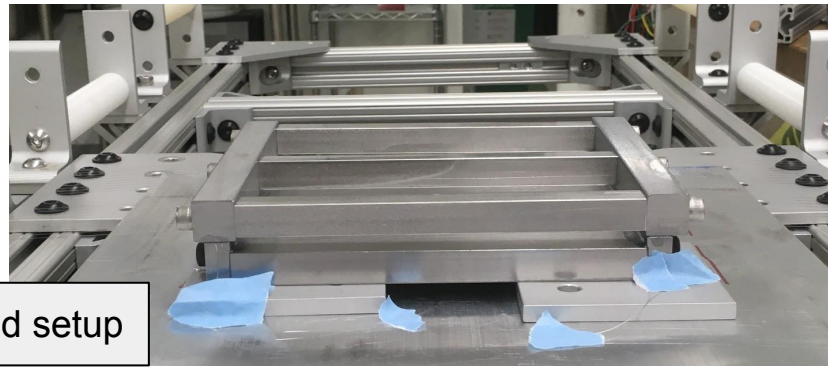
Blue = solved humidity problem

	1st 100ºF	2nd 100ºF	110ºF	1st 120ºF	2nd 120ºF	130ºF	140ºF
1	n/a	n/a	Backfilled and sealed sous vide bag inside purged SS bag	n/a	n/a	Backfilled and sealed sous vide bag inside purged SS bag.	n/a
2	Double-bagged in ziploc bags Feels dry		n/a	SS outer bag, plastic inner bag Feels damp	Only SS bag. High humidity	Double-bagged in sous vide bags. 100% humidity in both.	n/a
3	Double-bagged in ziploc bags Feels dry		n/a	Double-bagged in ziploc bags Feels a little damp at higher temperatures. No humidity measurements.			
4	SS outer bag, plastic inner bag. Feels dry.	Only SS bag. Hole let water in.	n/a	Double-bagged in sous vide bags. 100% humidity in both.	Backfilled and sealed sous vide bag inside purged SS bag Very low humidity (~2%).		n/a
5	Backfilled and sealed sous vide bag inside the purged SS bag		n/a	Backfilled and sealed sous vide bag inside the purged SS bag			n/a

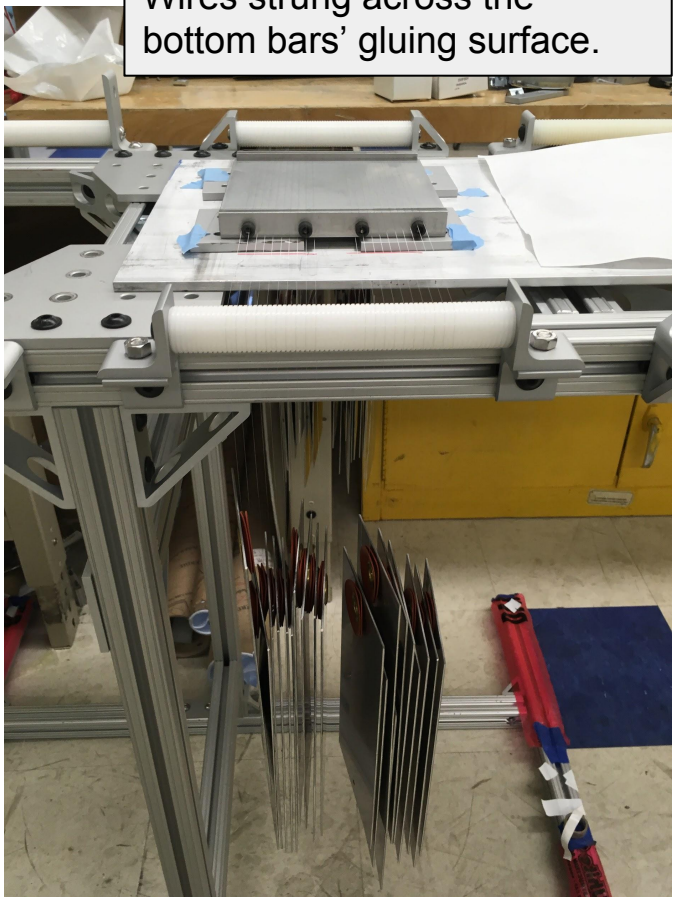
Design details

Setup design

- Each redesigned setup has a 6”x6” base plate with 2 bars bolted to the sides.
  - These bars are machined flat and serve as the bottom gluing surfaces.
- The top part is a frame with 2 flat bars for the top gluing surfaces and 3 perpendicular bars for stability.



Glued setup



Wires strung across the bottom bars’ gluing surface.

Gluing history

Setup #	Date glued	Date cut-down	Cure time	Cure location
1	2/13/19	2/18/19	5 days, 50 min	IR2
2	2/15/19	2/20/19	5 days, 45 min	IR2
3	2/15/19	2/20/19	5 days, 45 min	IR2
4	2/23/19	2/28/19	5 days, 5 hrs	B33
5	2/23/19	2/28/19	5 days, 5 hrs	B33

- All setups have epoxy mixed in the normal way with the 250-300 μm diameter beads appropriate for the 100 μm wire.
- B33 has good temperature and humidity control.
- LZ gate has a 5-day room temperature cure.

Treatment plans

- The goal is to answer:
  - Can we passivate at room temperature and maintain wire tension?
  - Can a post-cure increase the glass transition temperature enabling an elevated temperature passivation?
    - Evidence that 140℉ gives reduced electron emission.
    - Phase I will test room temperature & low temperature passivated grids to check if these processes reduce electron emission.
  - Secondary questions:
    - Does the epoxy creep after long periods of time?
- Summarized here: https://docs.google.com/document/d/16-8A6FcbJC7WavAqC98X0LGmx7SdQTD_AP_tMEx7Pag/edit
- Subject to change as results come in.

Translation of results from small test setups to LZ

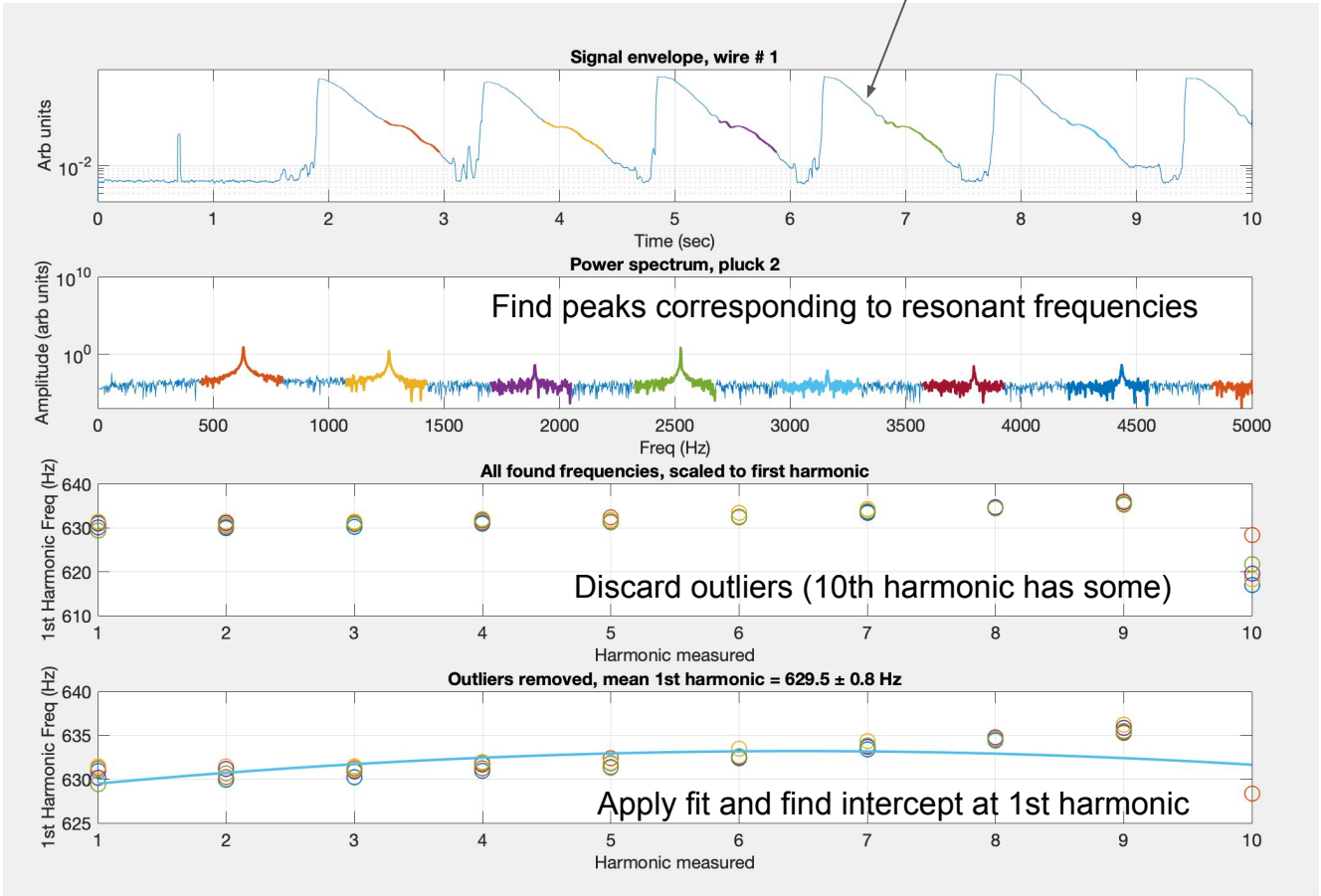
- Wire tension: $T = (2*L*f)^2 * \mu$
  - L = wire length, f = fundamental frequency, μ = linear density
- Wire tension $\propto L^2$
  - If tension loss observed in small setups is due to the epoxy deforming and letting wire slip, the length of wire slip (ΔL) will be less impactful for the LZ grid.
  - L_{setup} = 15.5 cm, L_{LZ} = 1.5 m → longest wires are 10x longer than setups' wires
- If tension measured in the small setup is high (no significant de-tensioning), it is still a reliable indicator of tension loss

Treatment plan after room temperature cure on loom

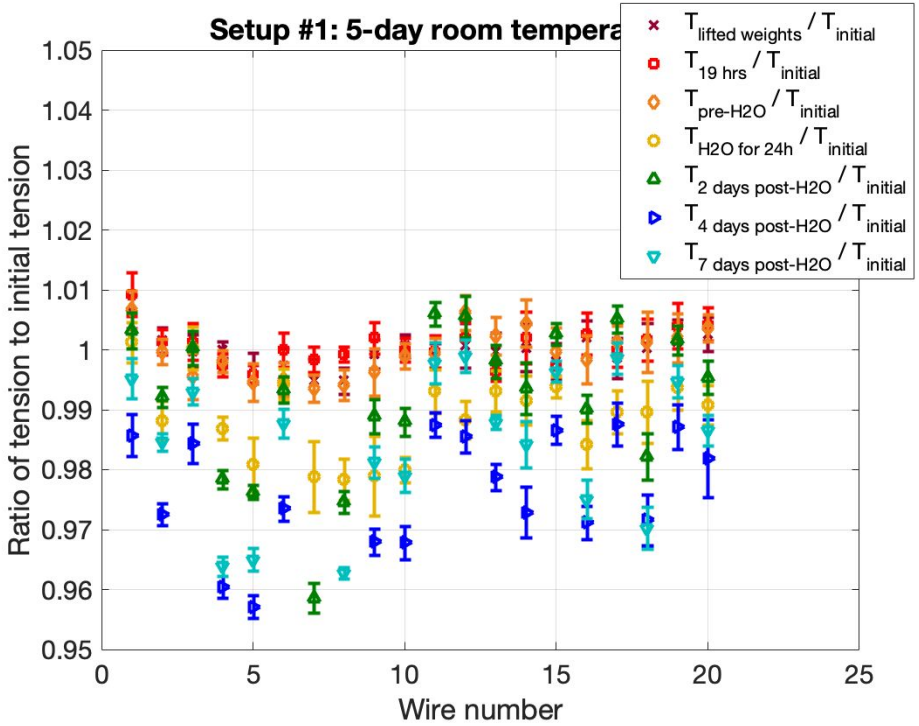
Setup #	1st	2nd	3rd	4th+
1	RT water soak (opportunistic)	RT degreasing	RT passivation	Higher temp passivation
2	Post-cure at 90F	Post-cure(s) at higher temp.	RT passivation	Higher temp. passivation
3	Post-cure at 100F	Post-cure(s) at higher temp.	RT passivation	Higher temp. passivation
4	These can fill in gaps in testing plan. If evidence shows that an initial post-cure at 80F (for example) may be beneficial, we have these in hand to test. One may be saved for long-term creep measurements.			
5				

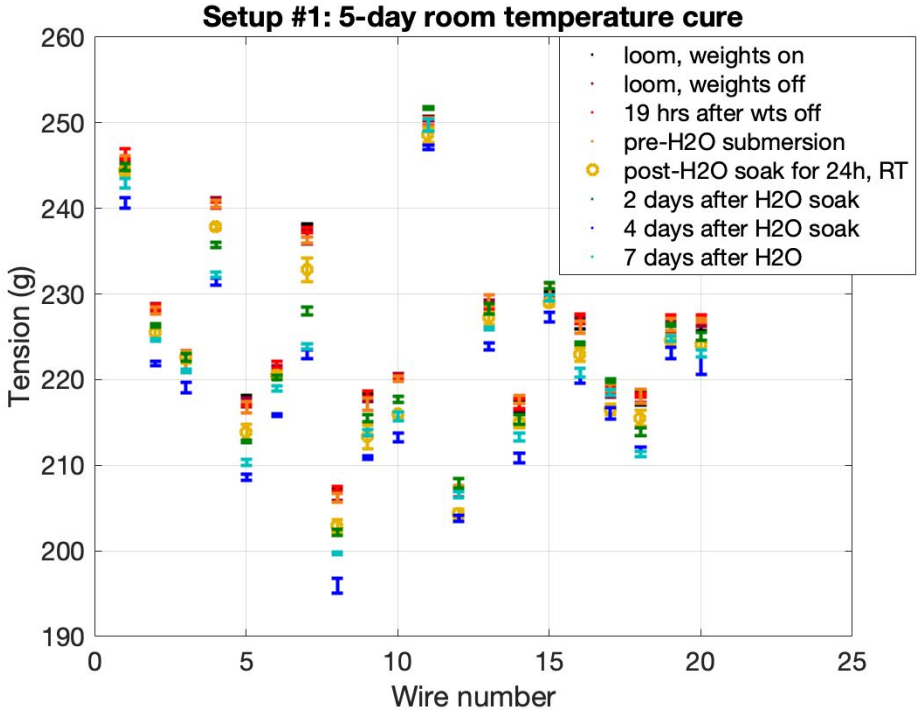
Tension measurements

- Use a guitar pickup over the wires to detect wire plucks.
- Tom wrote code & a GUI to calculate the fundamental frequency from the pluck using higher harmonics to fit.



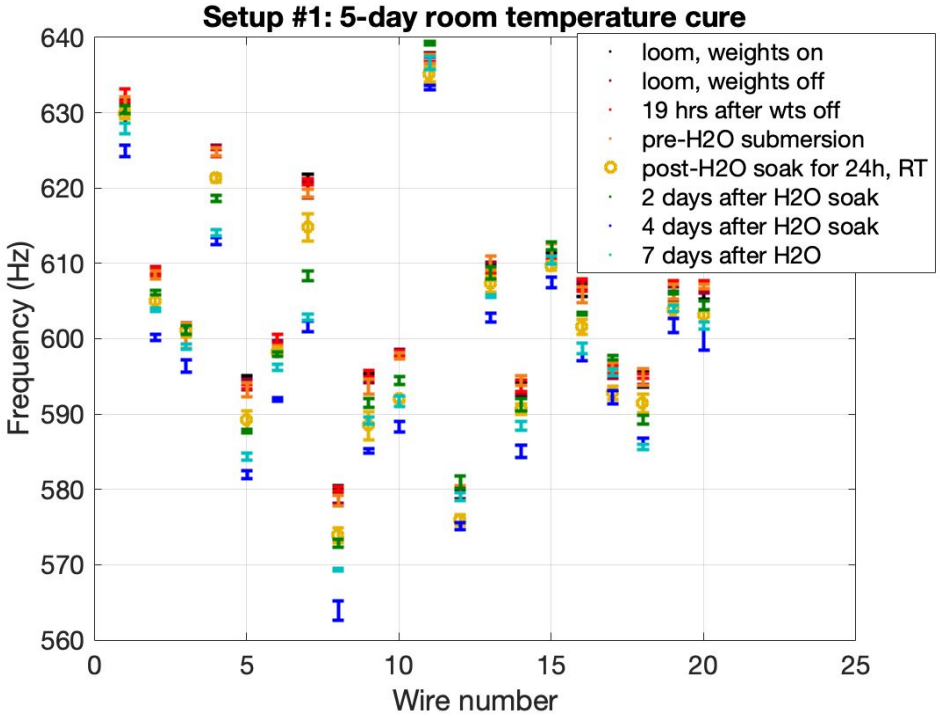
Setup #1: tension measurements

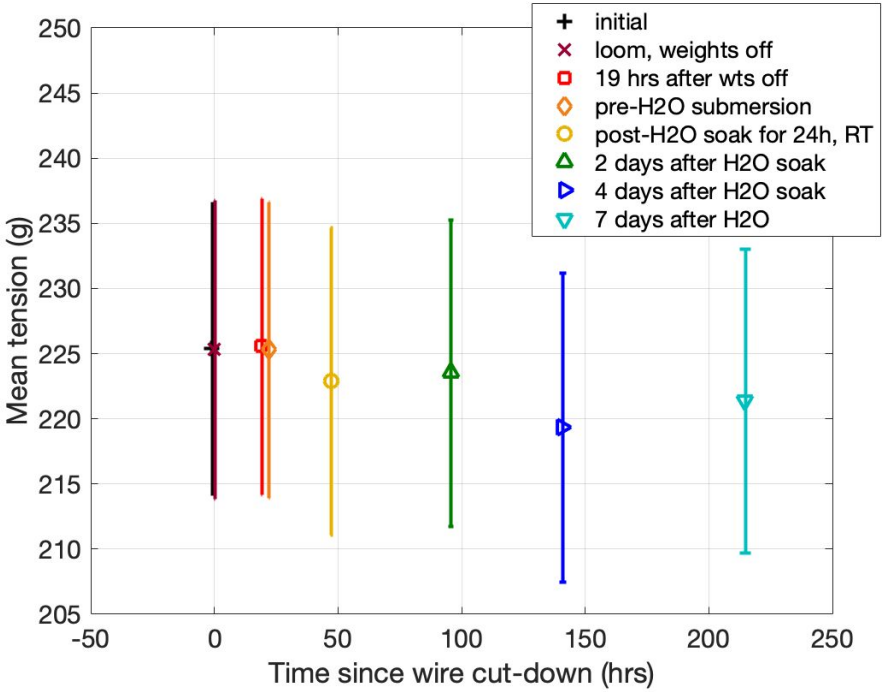




Initial tension measured on the loom with weights on is not 250g. Loss probably due to friction on pitching bars. Woven mesh designed for correct tension.

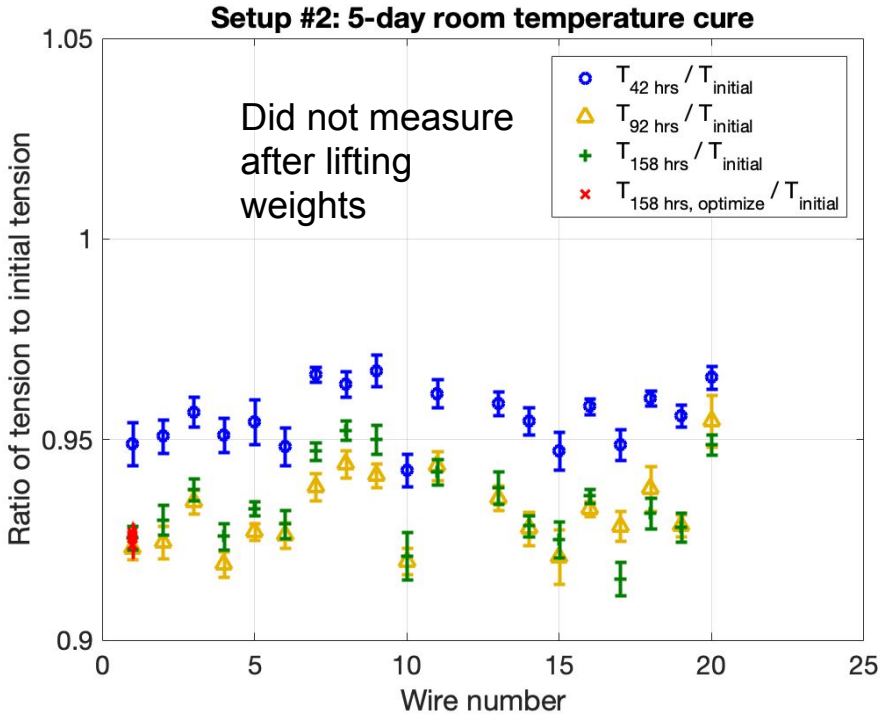
Setup #1: fundamental frequency & tension vs. time

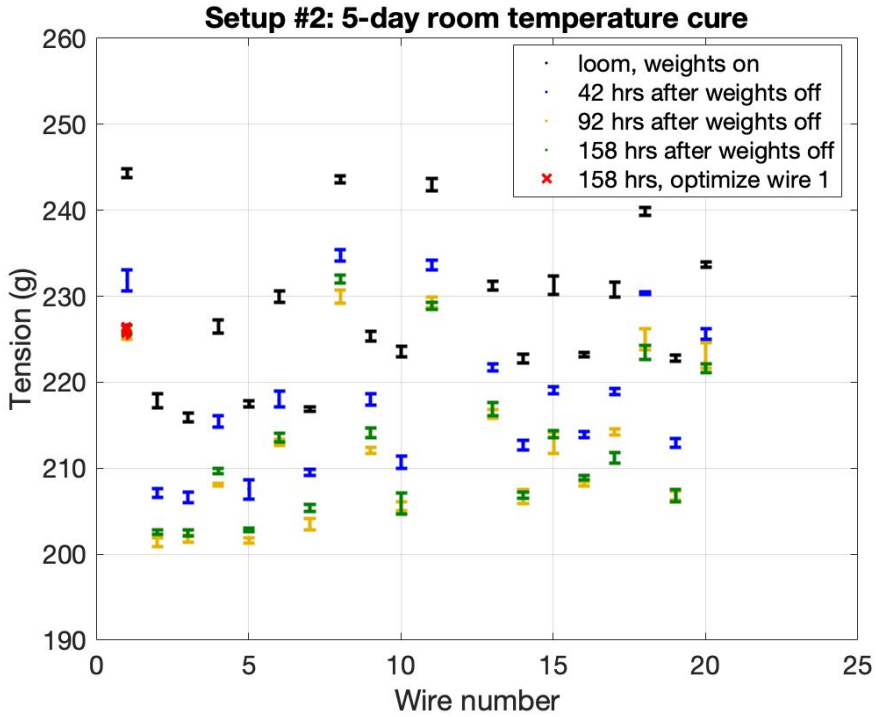




Mean tension is plotted with error bars from the standard deviation of the tensions.

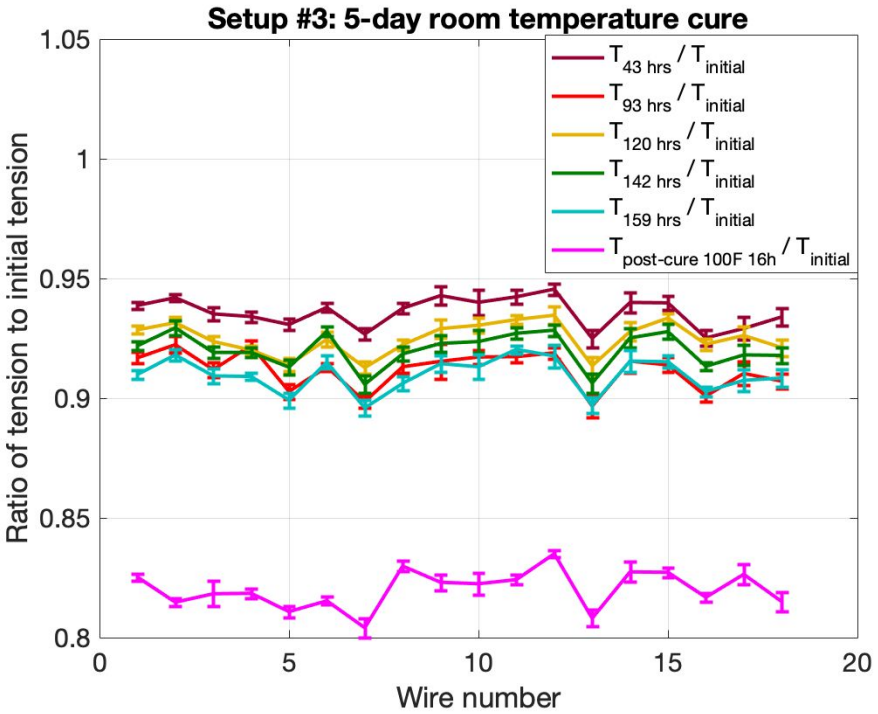
Setup #2: tension measurements

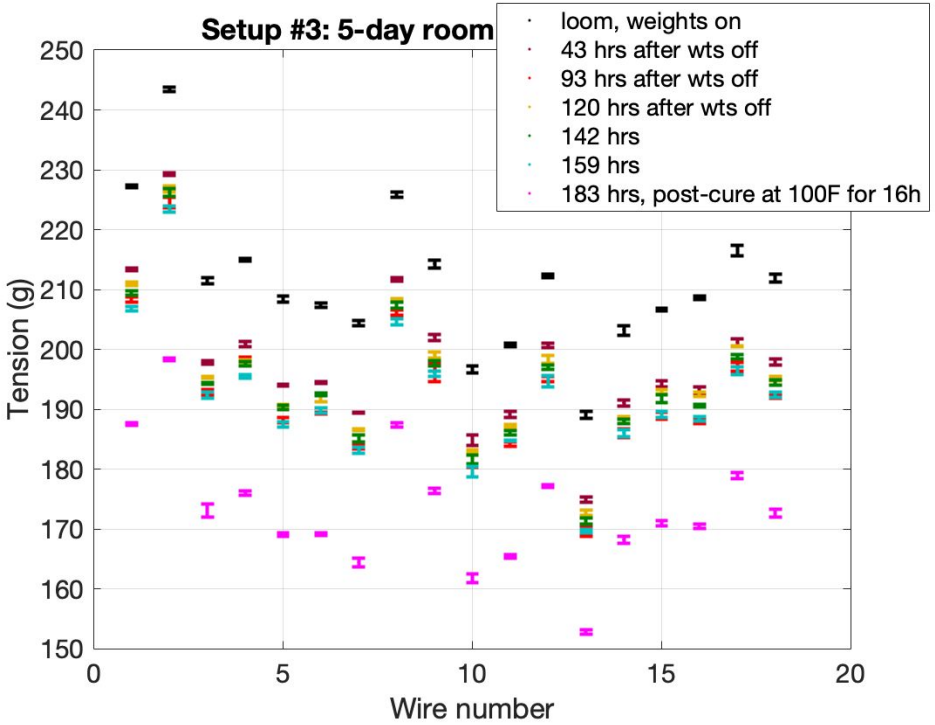




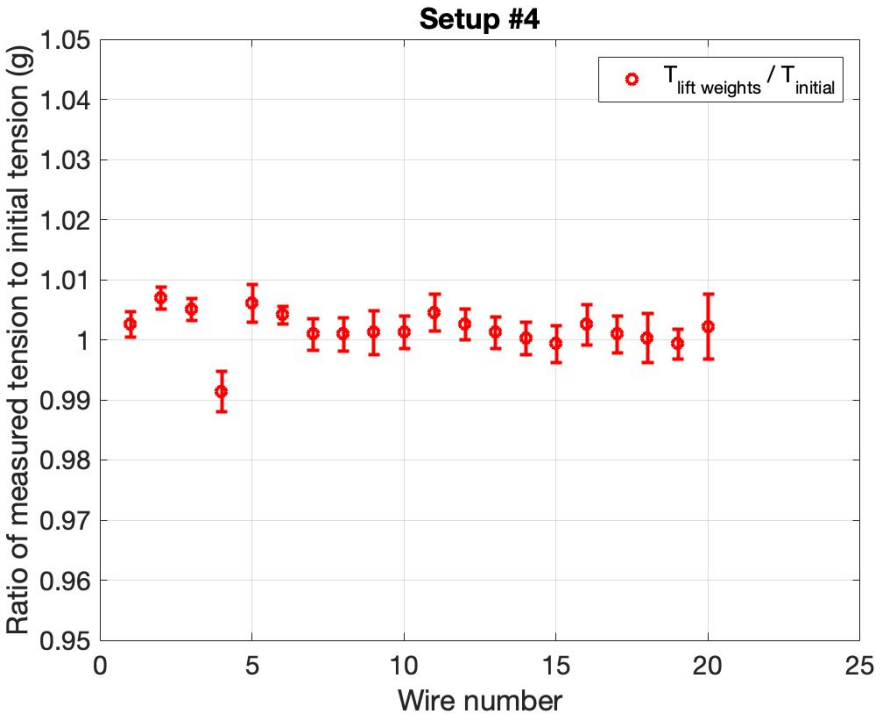
Red = measured wire 1 six times varying pluck-finding maximum amplitude.

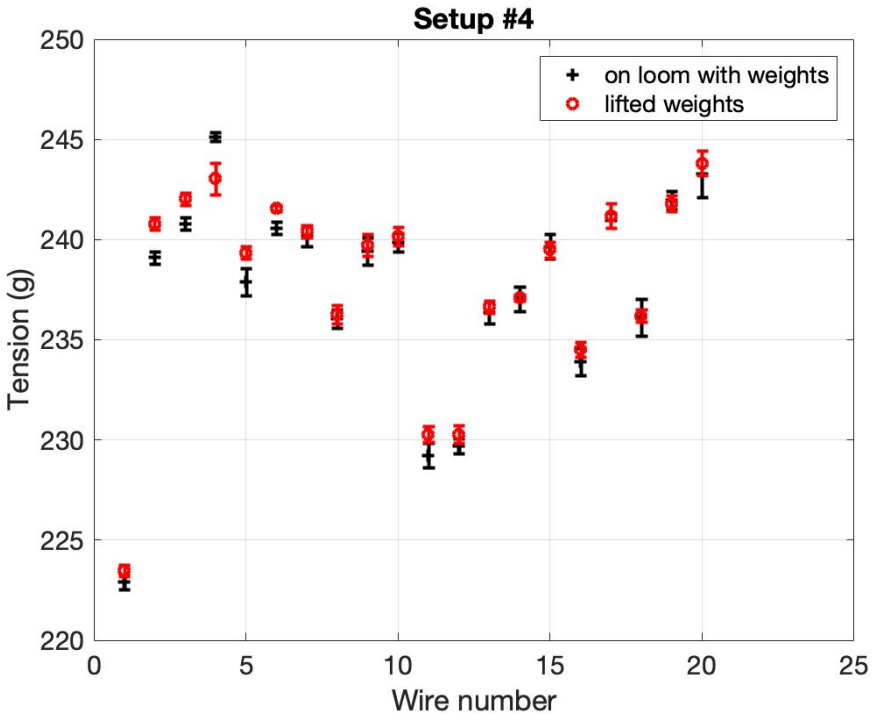
Setup #3: tension measurements



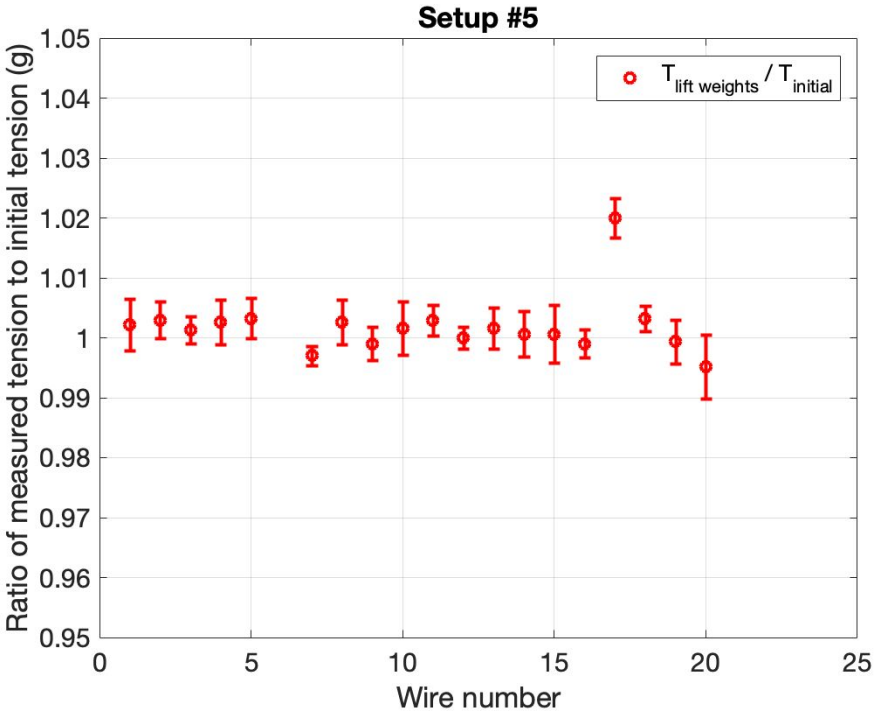


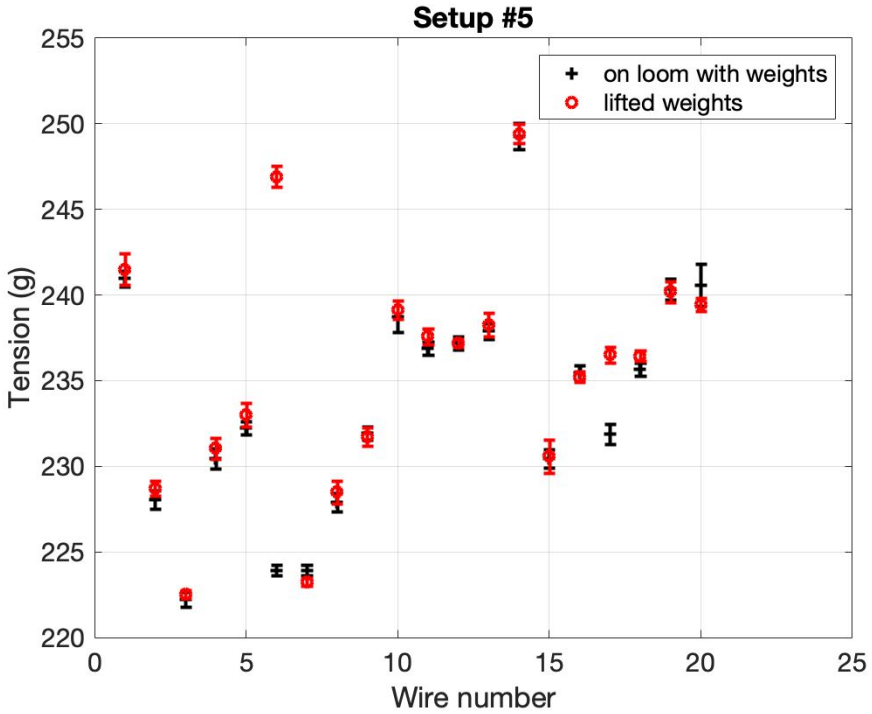
Setup #4: tension measurements





Setup #5: tension measurements



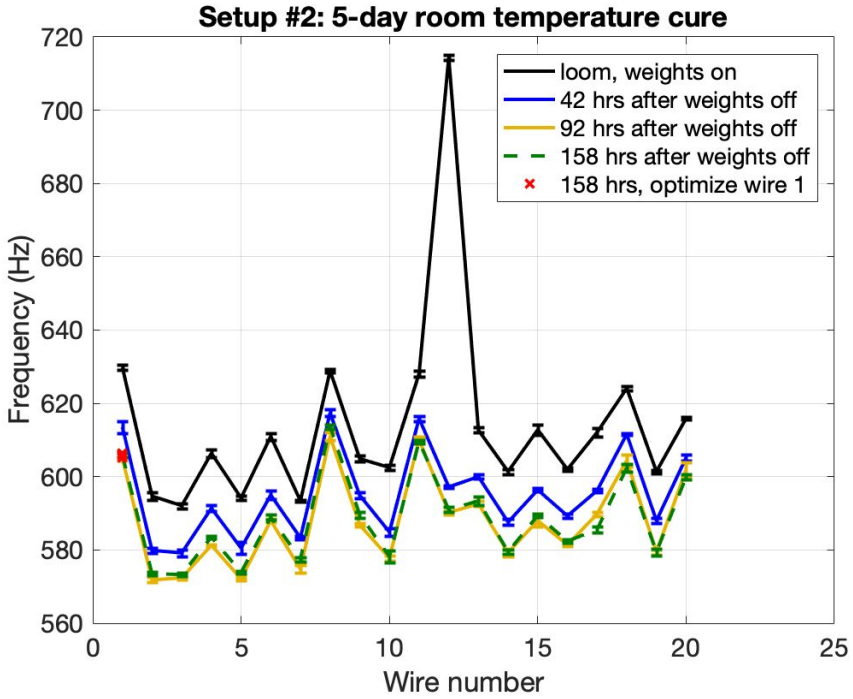


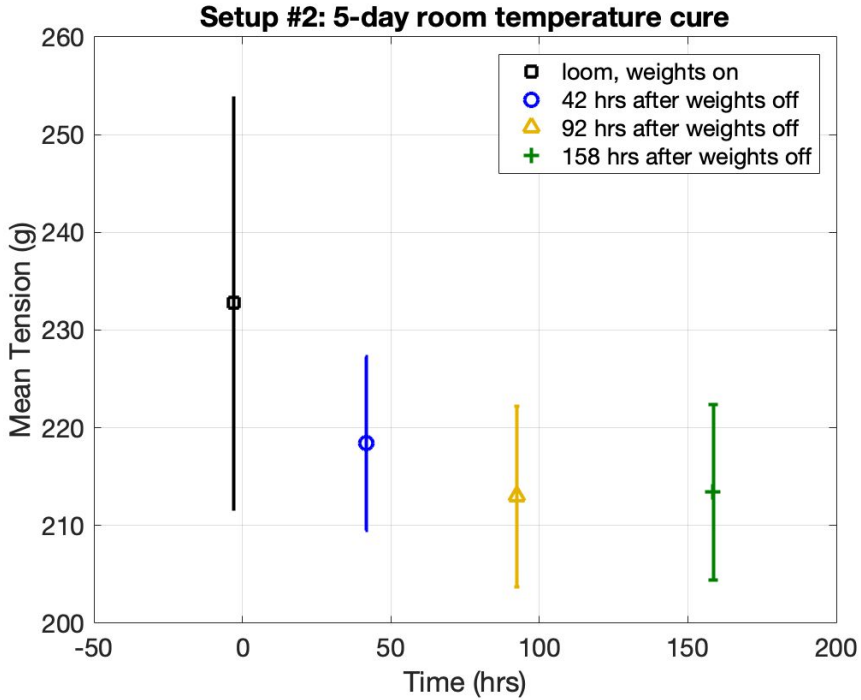
Summary

- Caveat: Still working out systematic errors.
  - All setups had variation in measured tension over time (before any treatment). Error bars in plots are not including systematic errors.
- Setups #1:
  - Initial tension measurements on the loom with weights hanging *do not* change over the course of the next few days.
  - May be 1-2% tension loss from 24 hr room temperature water immersion.
- Setups #2, 3:
  - Neither were measured immediately after lifting weights. Assumed the same behavior as #1.
  - First ‘off loom’ measurement seems to show slight tension loss (~6% drop in mean tension) compared to the initial measurements on the loom.
  - Subsequent measurements (‘creep’) are fairly consistent. (range of ~6-9% tension drop).
  - Paused post-cure of #3 to measure tensions → Seem to have ~10% tension loss.
    - Measured when setup #3 attained room temperature. It was not wet.
- Setups #4, 5: Cut down from loom on Thursday, Feb 28. No tension loss.

Extra slides

Setup #2: fundamental frequency & tension vs. time





Setup #3: fundamental frequency & tension vs. time