Mold Dryness and the Impact upon Shell Strength

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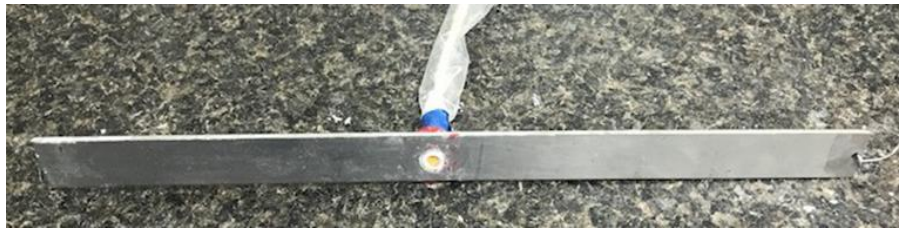
Some Conclusions from Last Year's Drying Paper

- Brienza/ Oles:
  - Increasing MOR and reduced test specimen cracking was seen with greater return to ambient dry bulb temperatures.
  - No leveling off of green strength was found for increased shell dryness.
  - Determining the water remaining in discrete areas of the mold was challenging. Methods used were pointed out as not an absolute measurement.
  - *Additional studies were warranted*.

Testing Plans for this Effort

- Gain further understanding of shell dryness/ strength by performing additional testing with a location specific humidity meter.
- Tests planned:
  - Green MOR
  - Hot/wet (Boiled) MOR
  - Fired tested cold MOR (ambient)
  - Fired tested hot MOR (2000°F)
  - Hot/wet (Boiled) Burst Strength
  - Green Permeability
  - <u>Over three (3) shell humidity/wetness conditions:</u>
    - **75% RH, 60% RH, 45% RH**

- Using a system which measures specific areas of a shell and the resulting humidity/ water present as well as local ambient conditions.



Slurry/ Shell Build Details

- 3M™ Fused Silica Advanced Shell System WDS2 was used to make up the slurry which creamed in at 20 sec on EZ #5 dip cup.
- A five dip shell was used with 3M™ Fused Silica Grains as shown:
  - (1) dip WDS2 with 50x100 fused silica
  - (3) dips WDS2 with 30x50 fused silica
  - (1) seal dip WDS2
- Shell Drying- aim for 72+/-2°F, 40% RH
- Shells Evaluated
  - MOR bars & Perm/ Burst Pipes

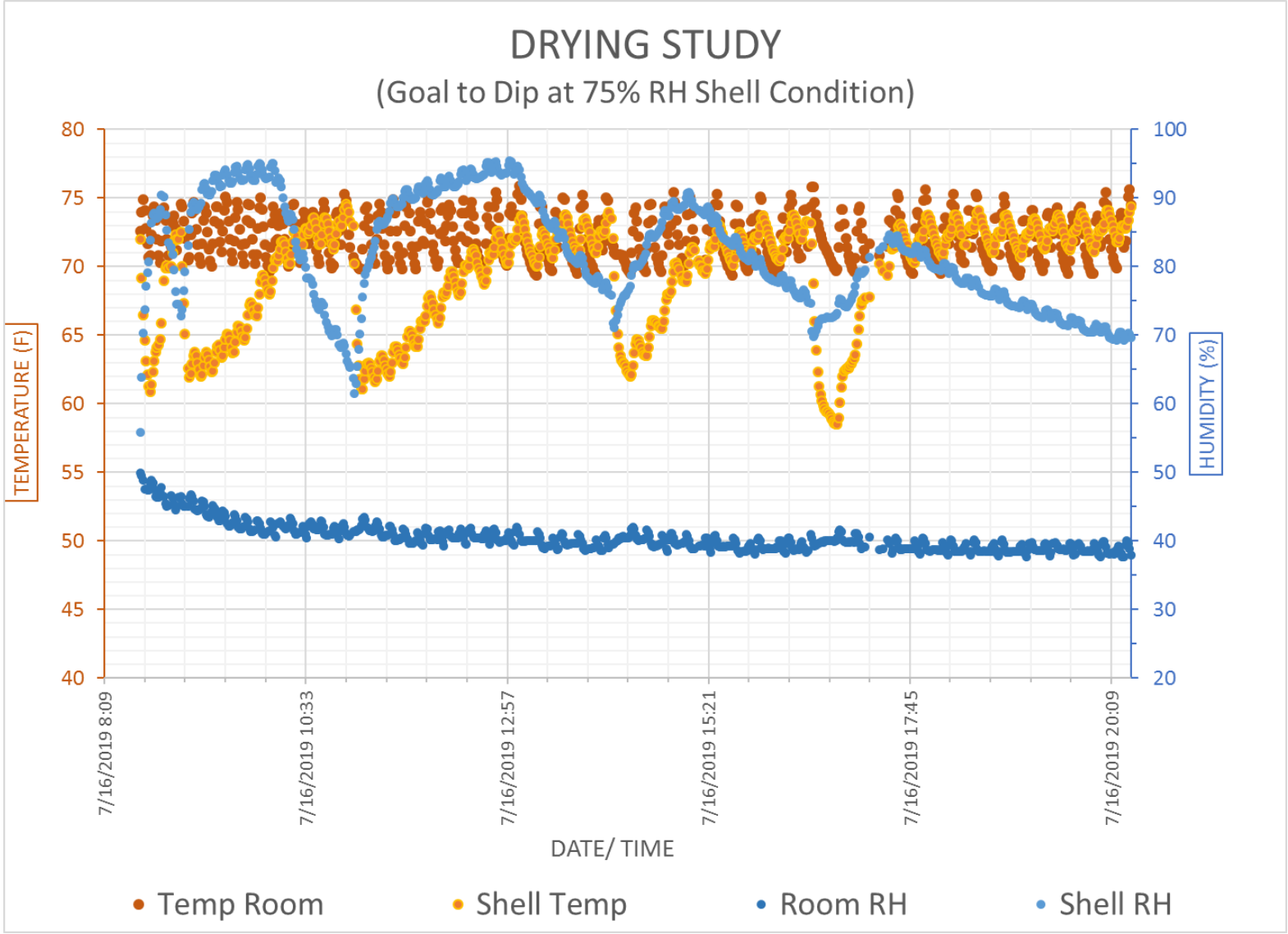
	Wt(g)
WDS2 flour	13500
1130 colloidal	4883
DI-H2O	600
HP Latex	501
Antifoam	10
Total	19494
%SiO2	24.4%
%latex	8.4%

Measuring Shell and Room Humidity

- Datalogging system recorded room conditions as well as shell conditions at the sensor.
- Shells were dried until sensor indicated the ‘shell humidity’ condition was reached.
- Sensor was cleaned off
- Shells were re-dipped and repeated.
- Equipment
  - 5’x8’ closed room. Separate A/C & resistance heater. Programmable controller.
  - Dri-Eaz LGR Dehumidifier
  - 2 wall mounted oscillating fans
    - Each separately move air at 12 mph/ 1000 fpm 8” from fan
    - 0-2.5 mph / 0-220 fpm center of room.

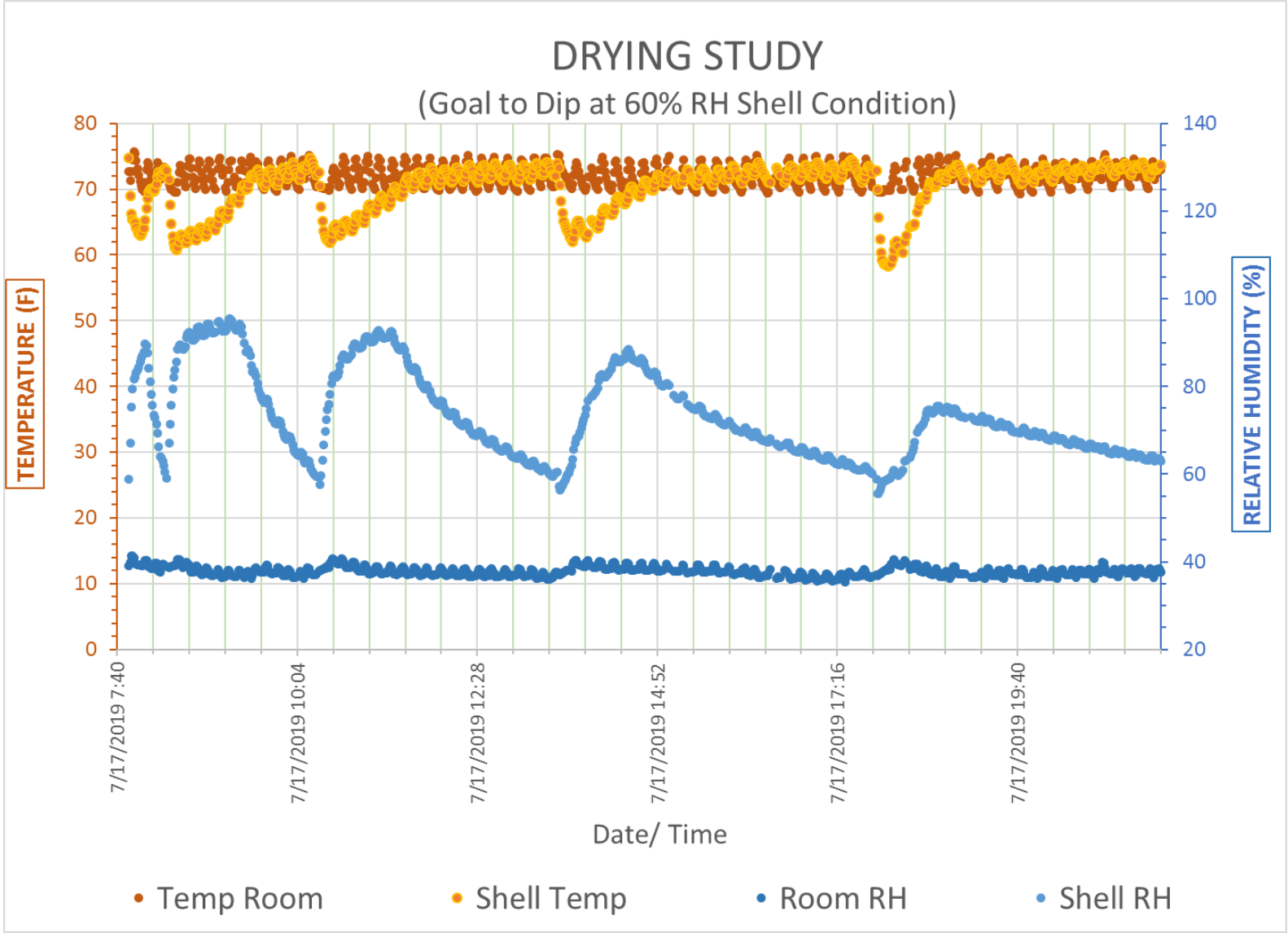
Data Collection: 75% RH Shell Sample Environment

- **Room temps** held 70-76°F
- **Shell temps** 64-74°F
- **Room humidity** started at 50%RH and dropped down to 40%RH in 5 hrs.
- **Shell humidity** during dipping ranged from 95% when dipped to 75-60%. Not consistently re-dipped at 75%.
- Final dry shell humidity finished at ~50%RH.
- Response time for humidity slower compared to temperature response. Shell temperatures suggested dry condition when shell humidity sensor showed 75%RH.



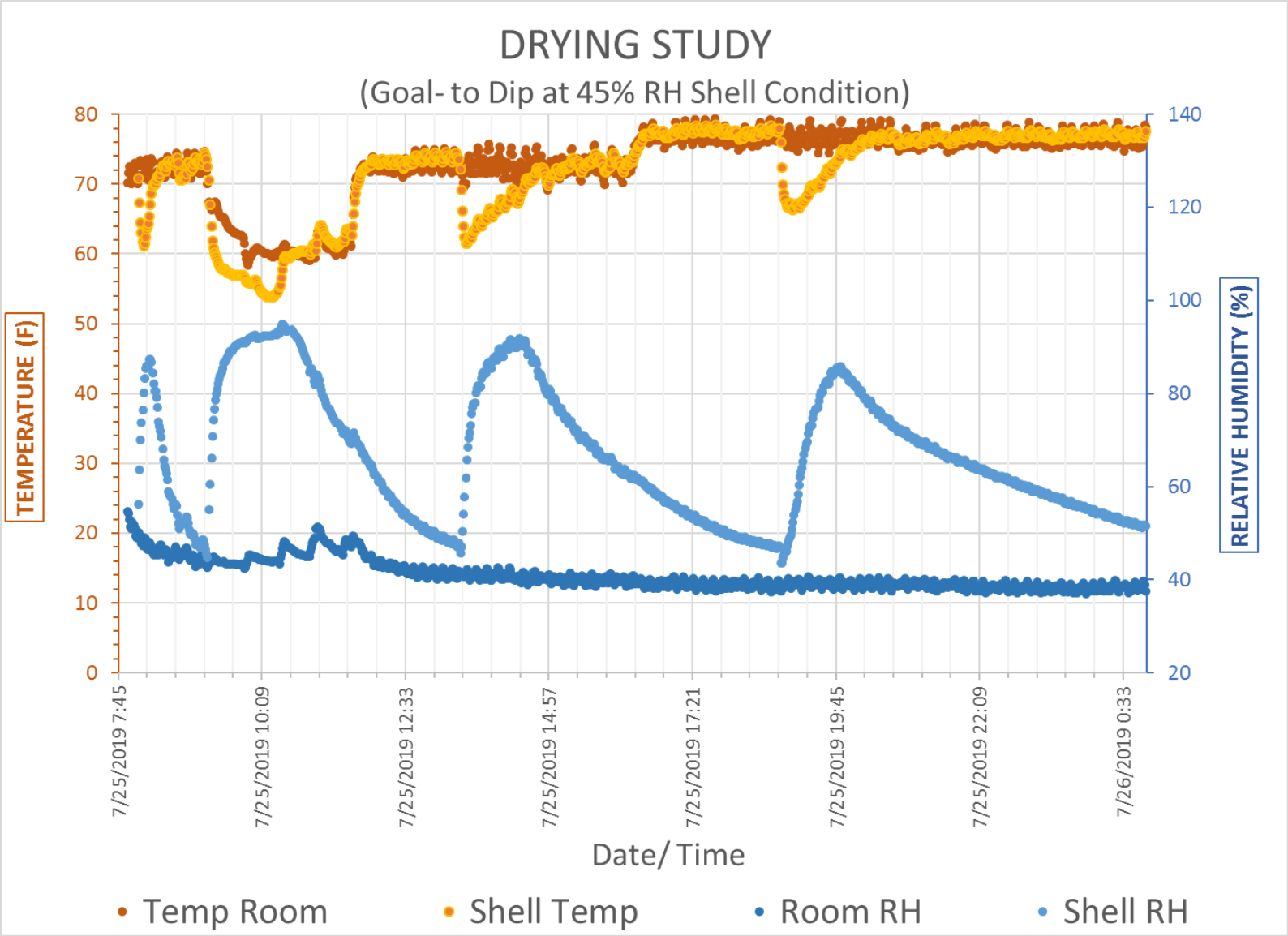
Data Collection: 60% RH Shell Condition

- **Room temps** held 70-75°F
- **Shell temps** 62-74°F
- **Room humidity** held ~40%RH
- **Shell humidity** during dipping ranged from 95% after dipping and dropped to a fairly consistent 60%RH. Timing of re-dipping was more 'on-time' for these samples
- Response time for **shell humidity** was slow again compared to temperature response. **Shell temperatures** suggested a dry condition much earlier than humidity sensor recorded (here ~80% RH)



Data Collection: 45% RH Shell Condition

- We struggled with **Room temperature** for the first 5 hrs. and tried to use manual override to adjust for dry front that came through. Temps were 60-75°F and up to 79F for a period of overnight drying.
- **Shell temperature** held 55-78°F **Room humidity** held ~54%RH at max but held 40%RH after first 5 hrs.
- **Shell humidity** during dipping ranged from ~95% after dipping and dropped to a ~45%RH prior to next dip.
- Final dry shell humidity finished at ~50%RH.
- Response time for humidity sensor appeared slow here also.



Shell Drying Final Thoughts

- Re-dipping at set RH was not always accomplished on time, but it approximated the test plan.

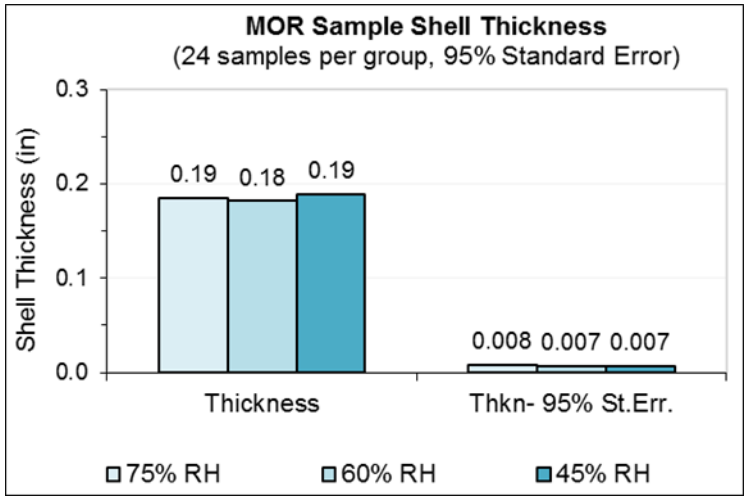
- Flat MOR bars appeared to have dried fully (particularly on later dips) before sensor recorded desired RH setting.
  - KPI made changes to the sensor after these tests to help with better sensitivity, but we haven’t tested them yet.

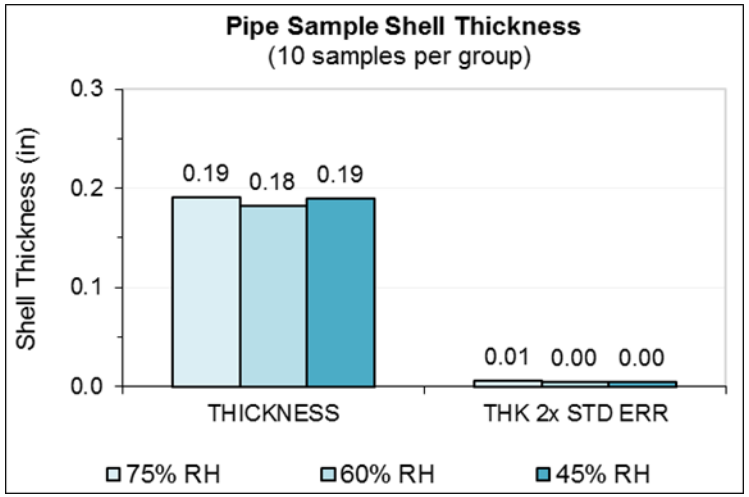
- Now that we understand the equipment and with sensor response changes, we hope to re-run these tests again.

Shell Properties Summary

- MOR bars were broken in four conditions:
  - Tested Dry (Green)
  - Tested Boiled (Hot/ wet)
  - Tested Fired and Cooled to Ambient (Fired/ cold)
  - Tested Fired @2000°F (Fired/ hot)
- Permeability/ Burst Pipes
- Shell thicknesses for bars and pipes

Shell Build Thickness



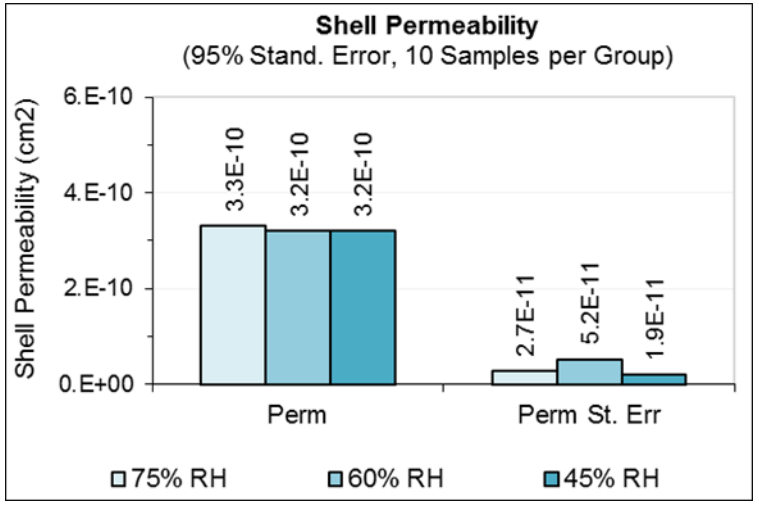


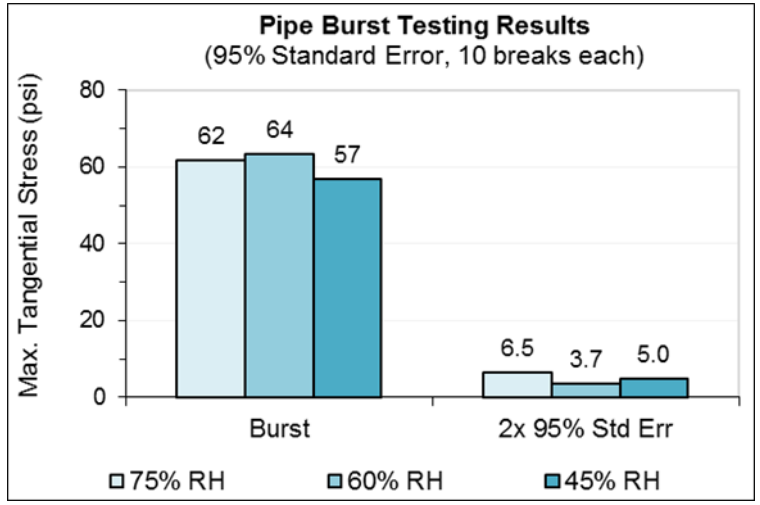
Shells were removed from the substrates and measured for thickness.

No change in shell build was noted regardless of shell dryness prior to re-dipping.

We now realize all shells were completely dried prior to re-dipping.

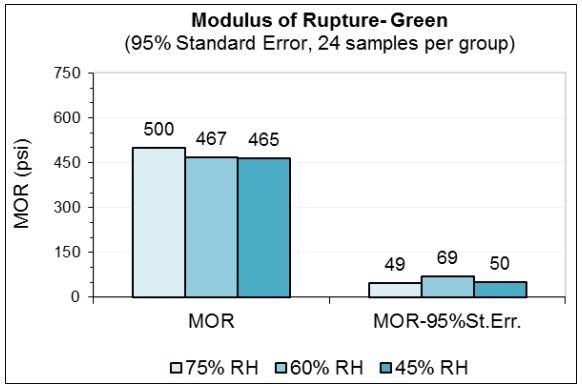
Shell Permeability and Burst Strength

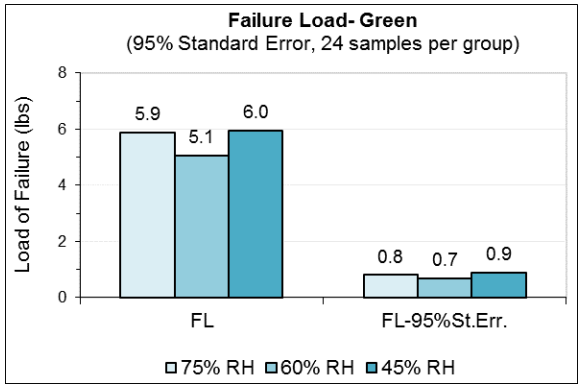


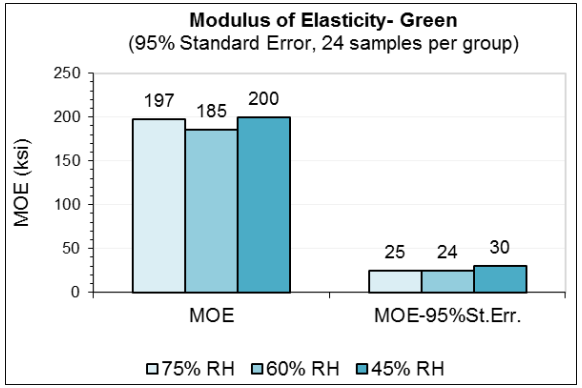


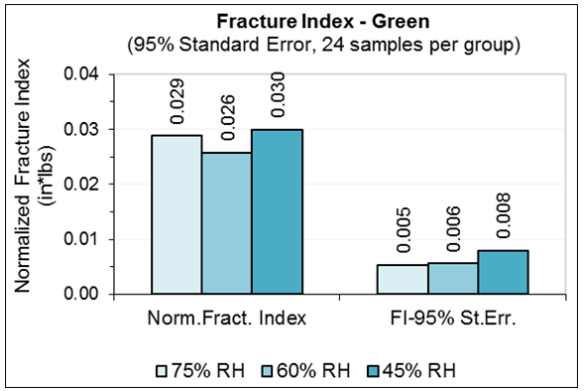
Shell permeabilities and shell burst strengths both suggest equivalently dry shells.

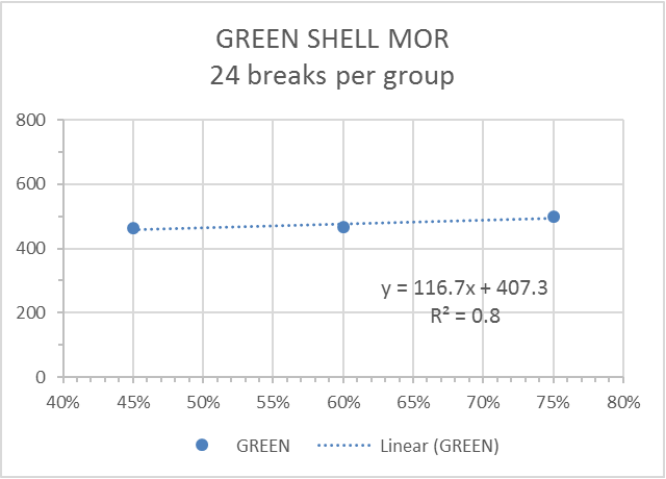
Green Shell Summary





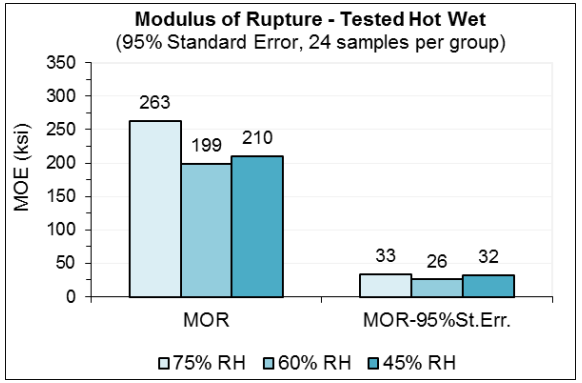


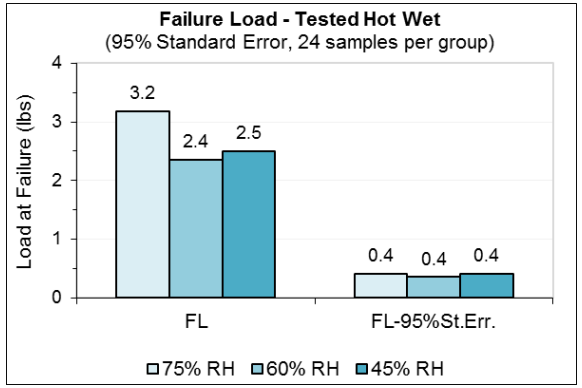


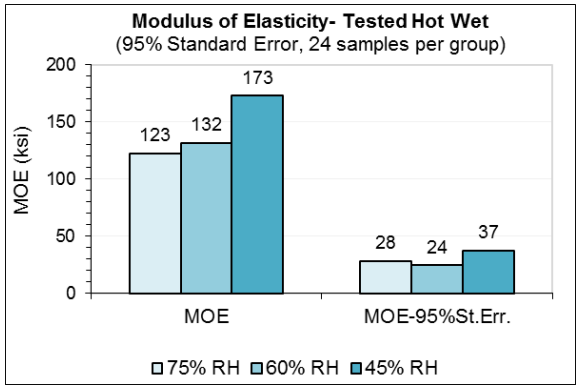


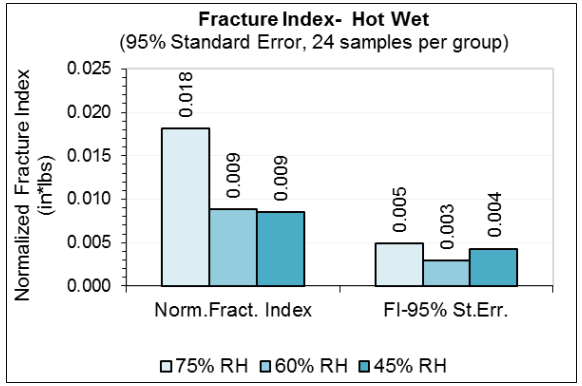
Dried shell properties also confirm no change between the three groups.

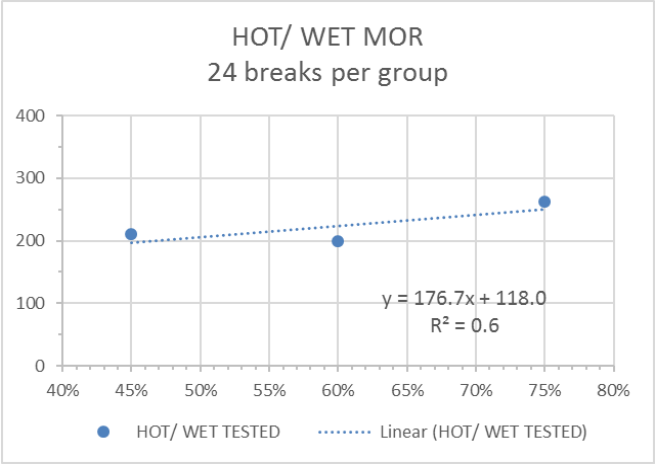
Hot/ Wet (Boiled) State





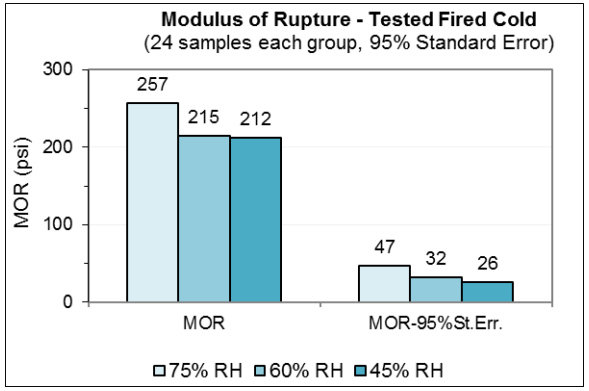


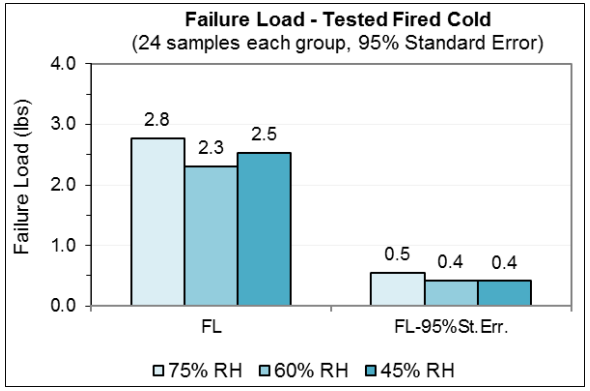


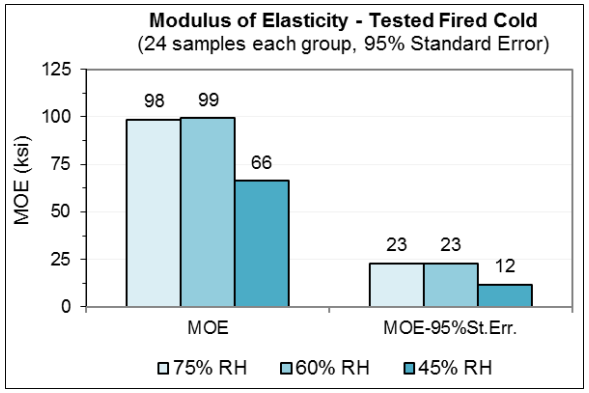


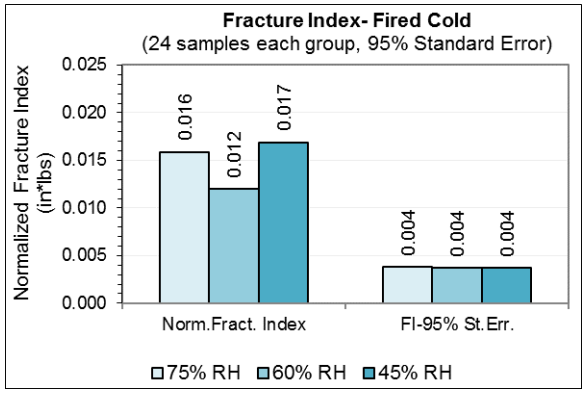
Hot/wet shell data suggested best shell properties for the 75%RH shells. This was not confirmed by the hot/wet burst testing and is suspect.

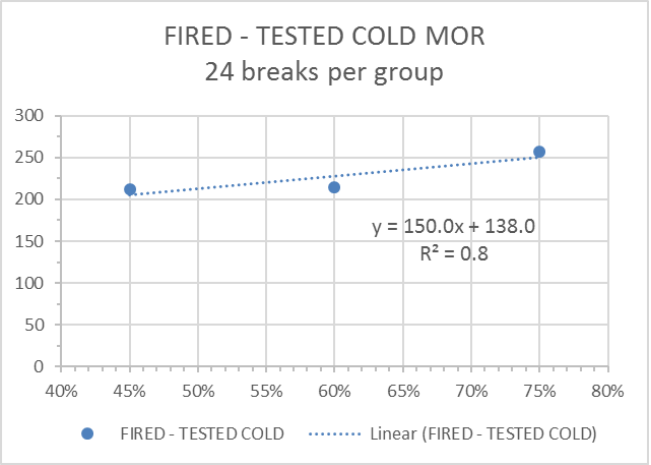
Fired/ Cold (Knockout) State





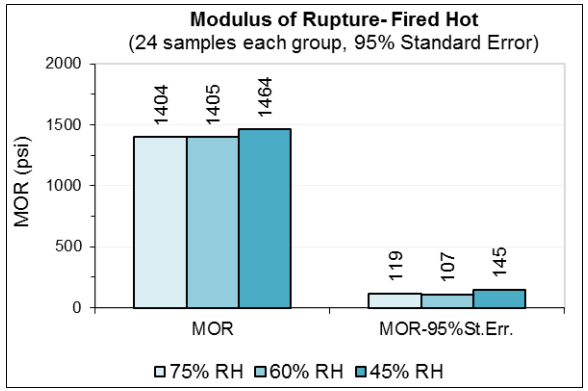


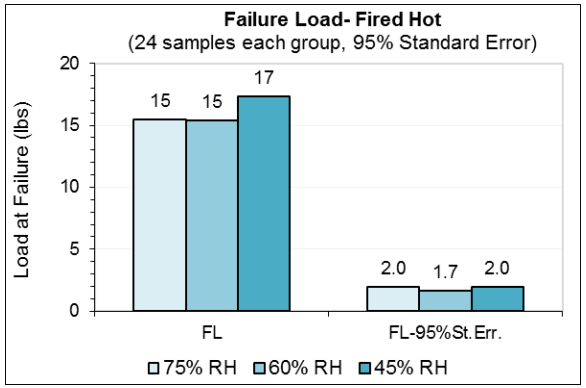


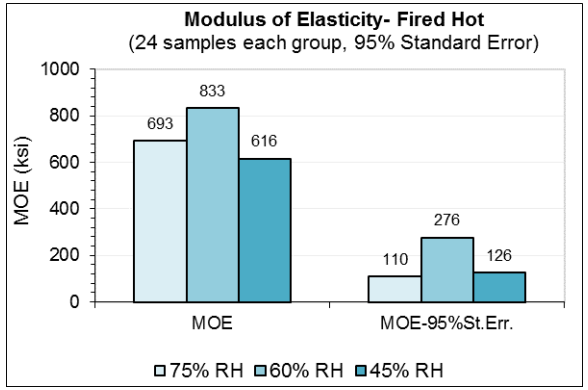


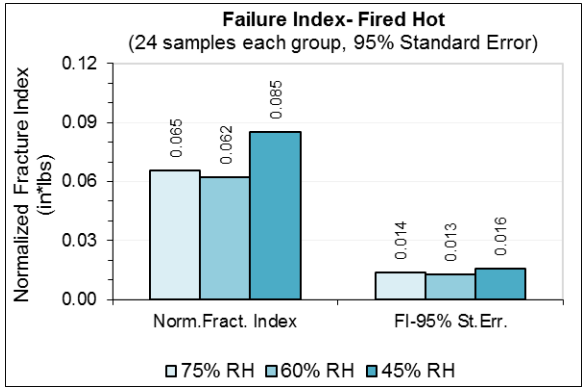
Shell knockout performance was largely again unchanged as expected as well.

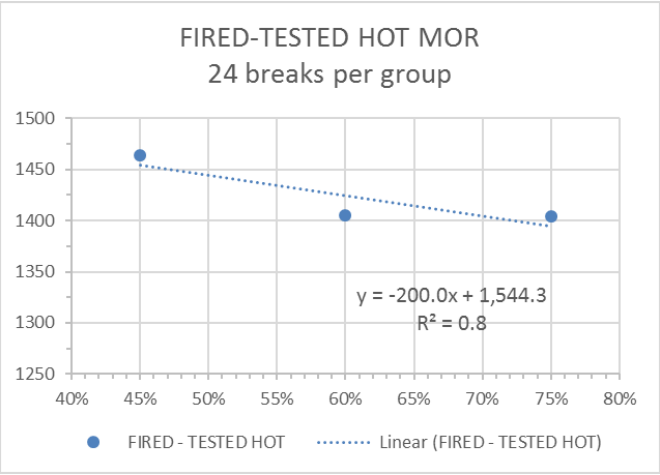
Fired/ Hot (2000°F) State











Shell performance was largely again unchanged also.

Take-a-Ways:

1. Shells dried to completion showed similar properties- no surprise.

2. Simple MOR bar geometry dried faster than humidity sensor could measure.

3. Perhaps more complicated geometries with more difficult to dry areas would have shown different results.

4. Another follow on test with such a geometry may be helpful.

Thank you for your kind attention