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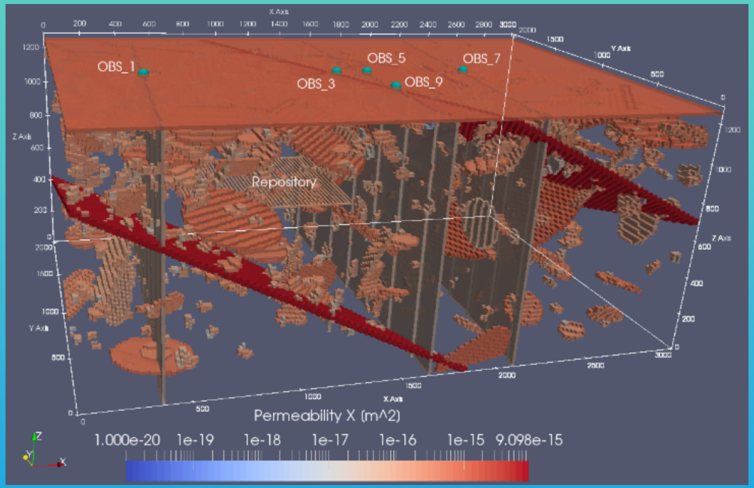

Canister Sampling Methodology for the Canister Deposition Field Demonstration

SFWST May Meeting

May 12, 2022

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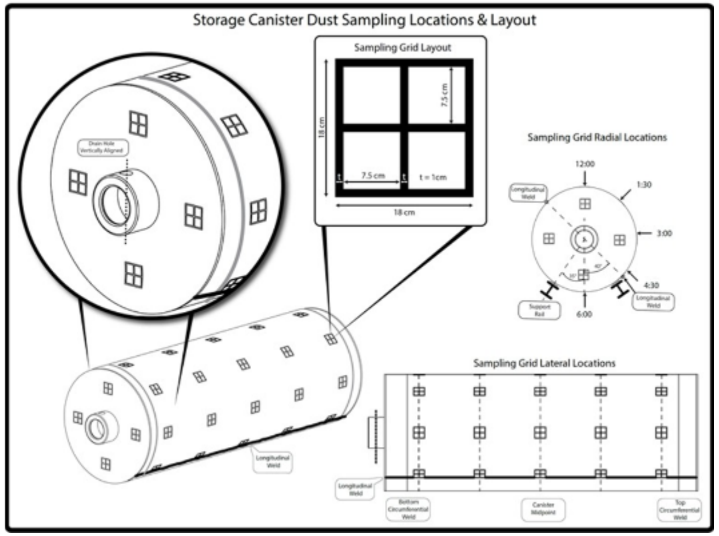
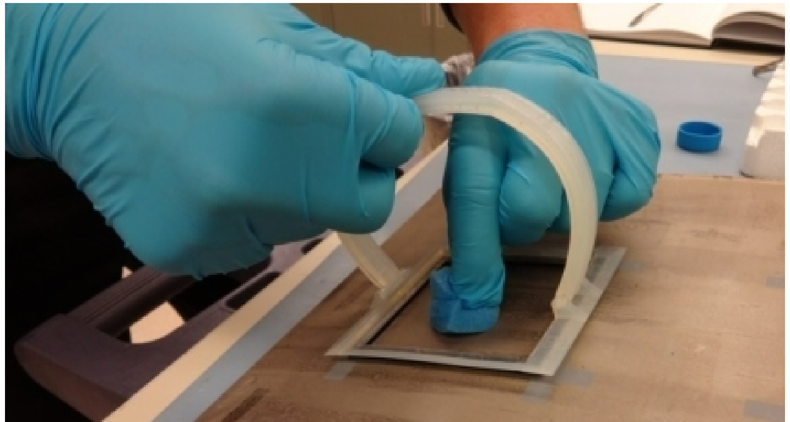
Sampling Dust on the Canister Surfaces

Goal: Evaluate dust/salt deposition on canister surfaces under realistic storage conditions

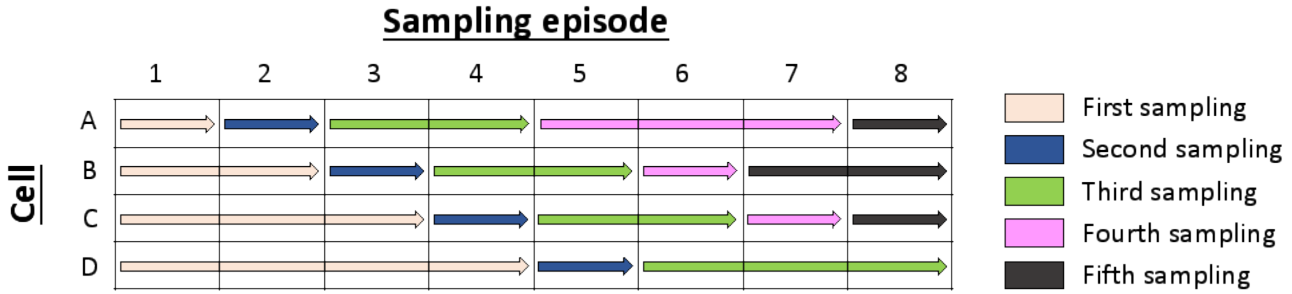
- Identified 29* sample locations
  - Equally spaced longitudinally and radially on one side to capture deposition as a function of location and orientation
- Periodic, Episodic Sampling
  - Capture cumulative and interval dust loads
- Hand Sampling
  - Ensure (near) Quantitative Salt Collection





Developing hand-sampling techniques in the lab

A	B
C	D

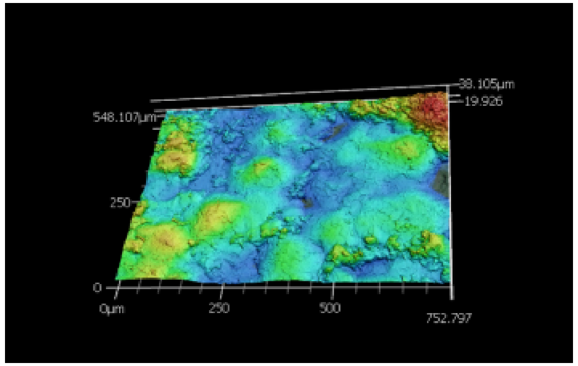


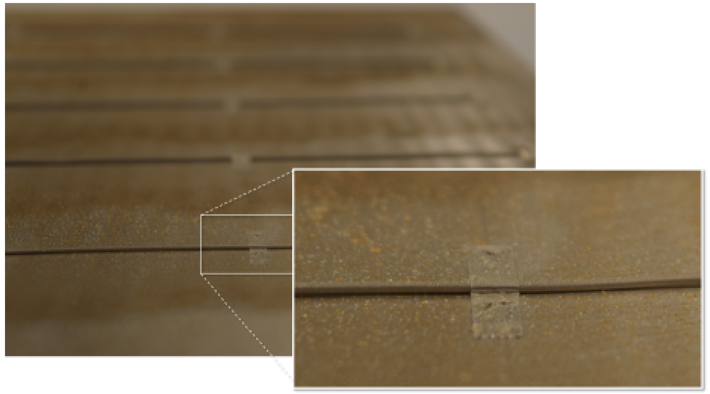
4 grid cells at each location, sampled over time to capture interval and cumulative dust accumulation

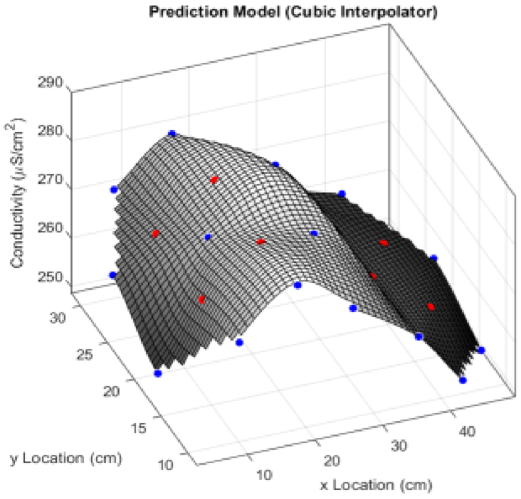
*some locations may not be accessible

Surface Sampling Activities

1. Surface Roughness Sampling
   - Characterize surface features as input for deposition modeling and corrosion studies
2. Canister Marking and Template
   - Evaluate material degradation for surface markings
3. Develop Hand Sampling Methods for Quantitative Salt Collection
   - Perform tests to evaluate salt sampling efficiency

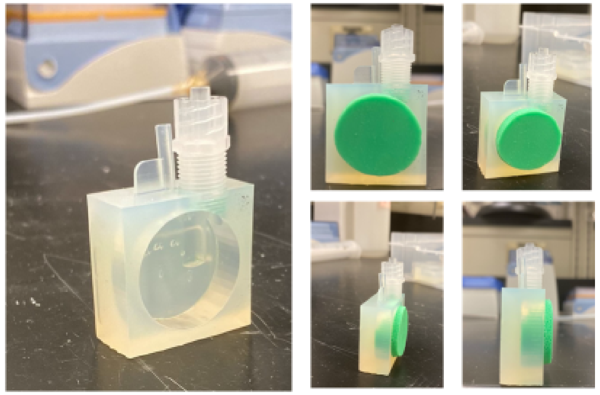


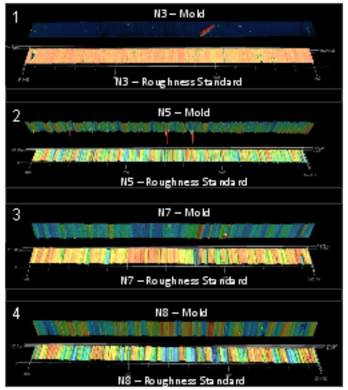


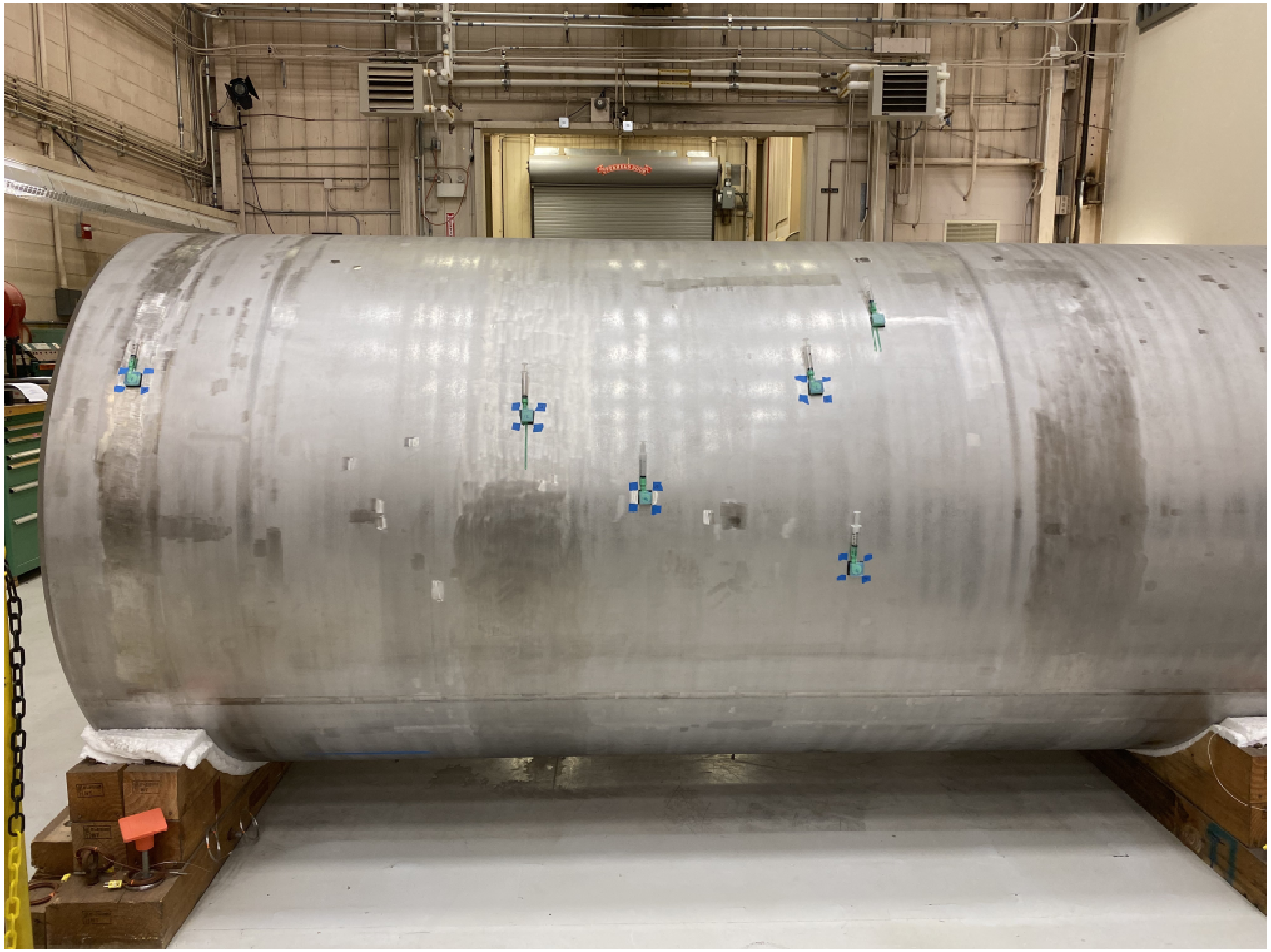


Visible Surface Variability

- Developed surface analysis techniques
  - Photometric Mapping (Tanbakuchi, A., 2021)
  - Surface roughness replication
    - PlatSil 73-25 using 3-D printed sample cells
      - Analyzed by laser profilometry
      - Verified with surface roughness standards

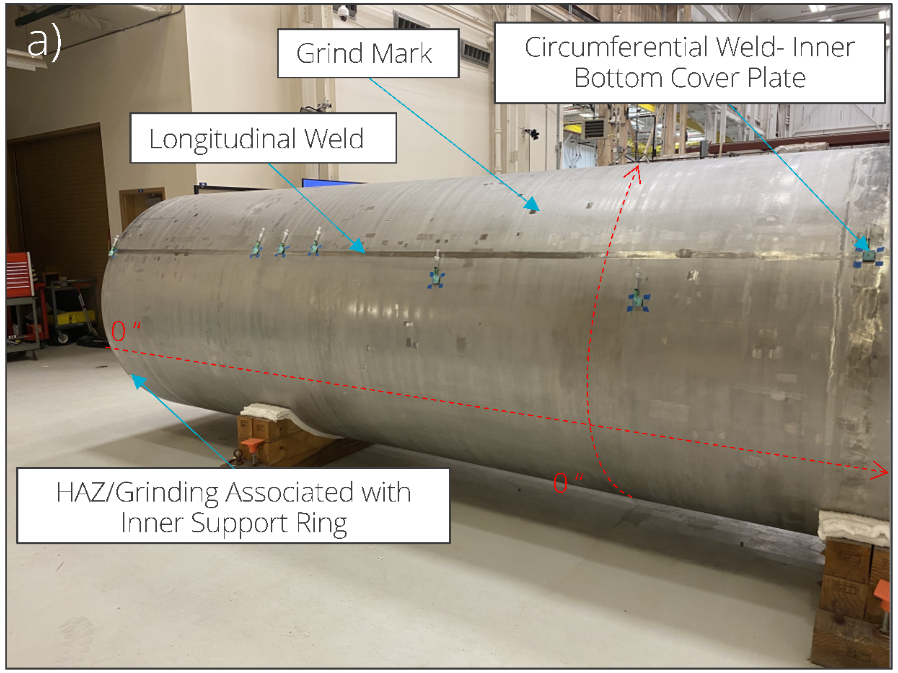


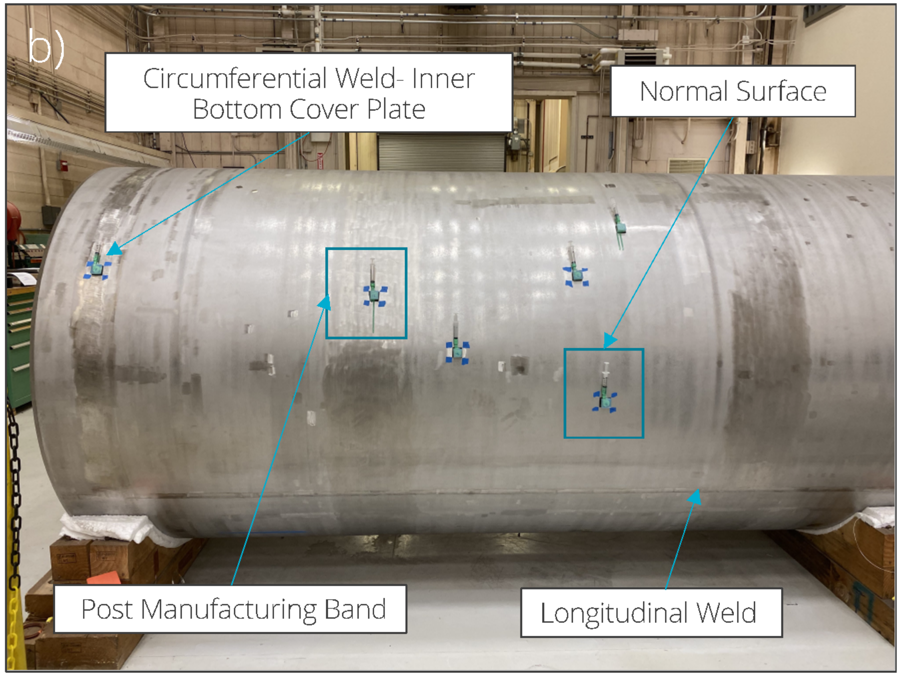


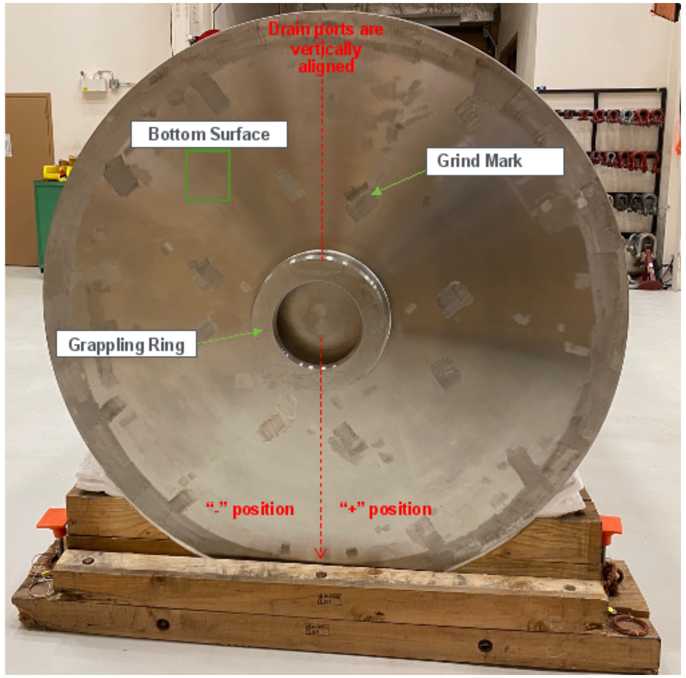


Sampling Locations

- 17 samples were collected to evaluate deviations in surface roughness
  - Dominant Features
    - Nominal (mill finish) surface, post manufacturing band, welds
  - Less Common Features
    - Lathe turning grooves on canister bottom, grind marks

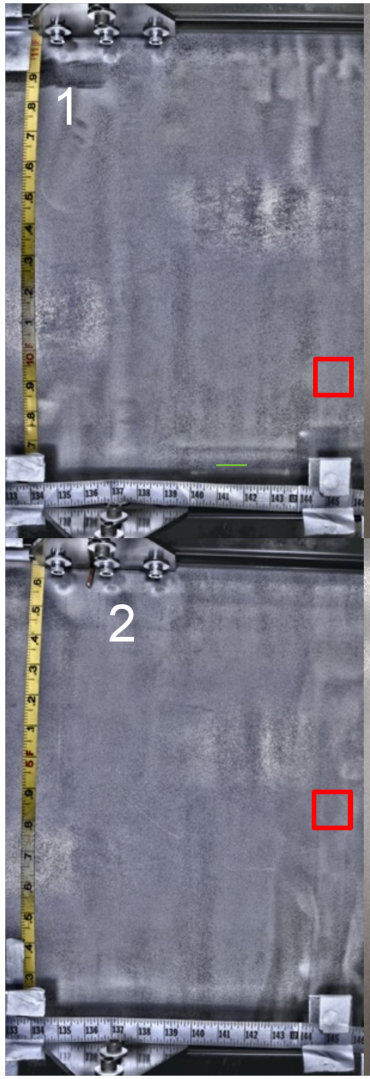




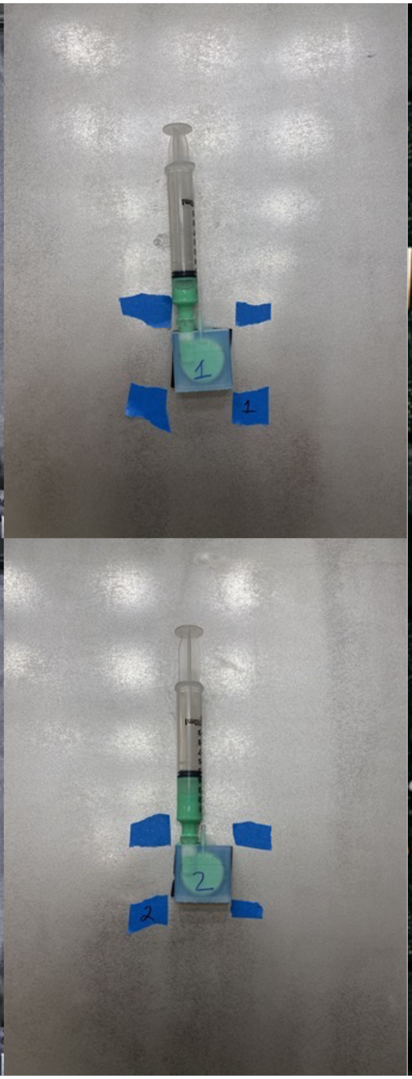


Normal Surface

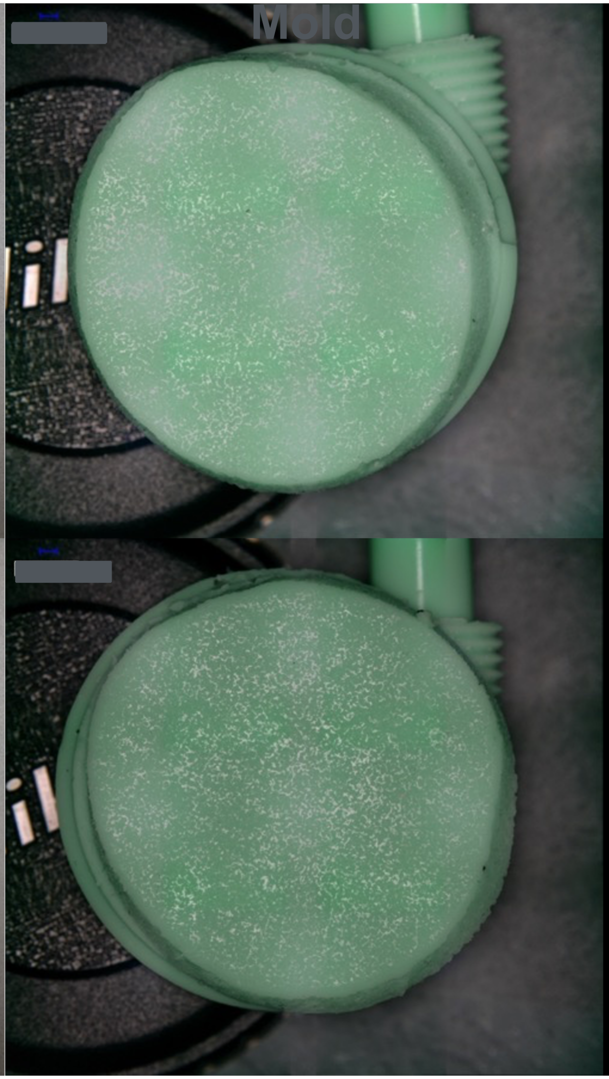
Photometric Map



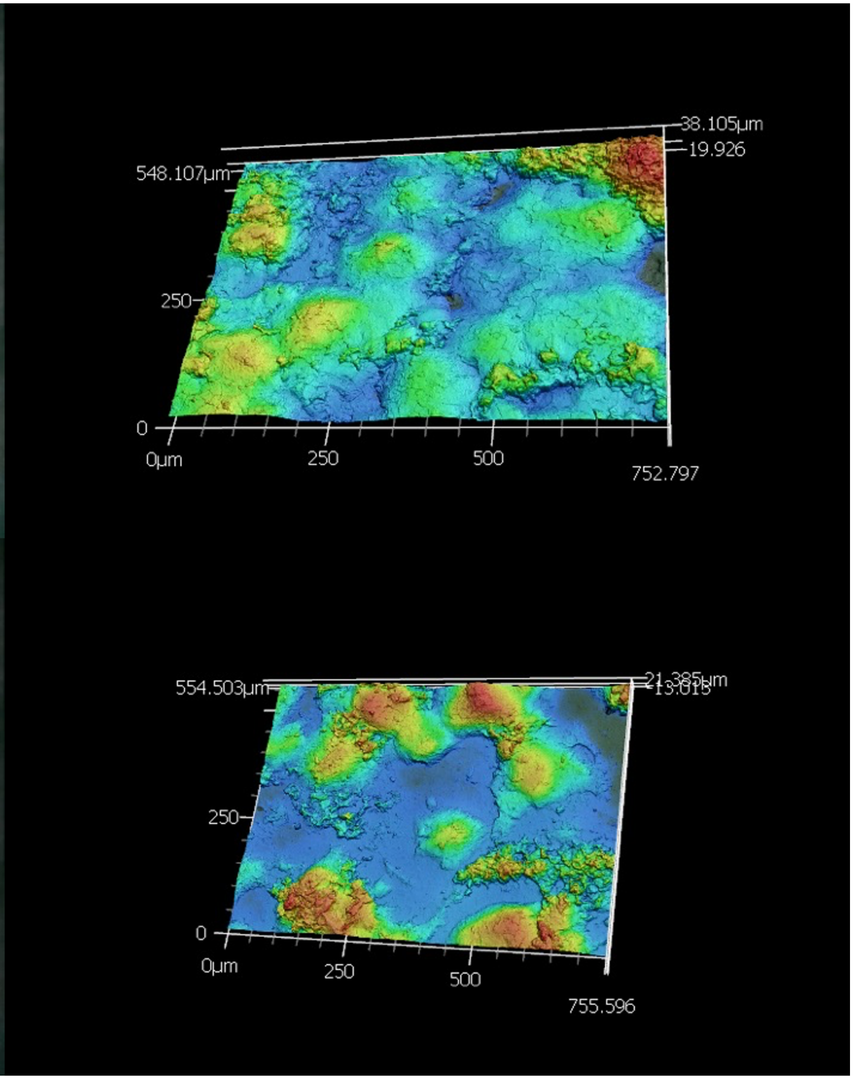
Mounted Cell



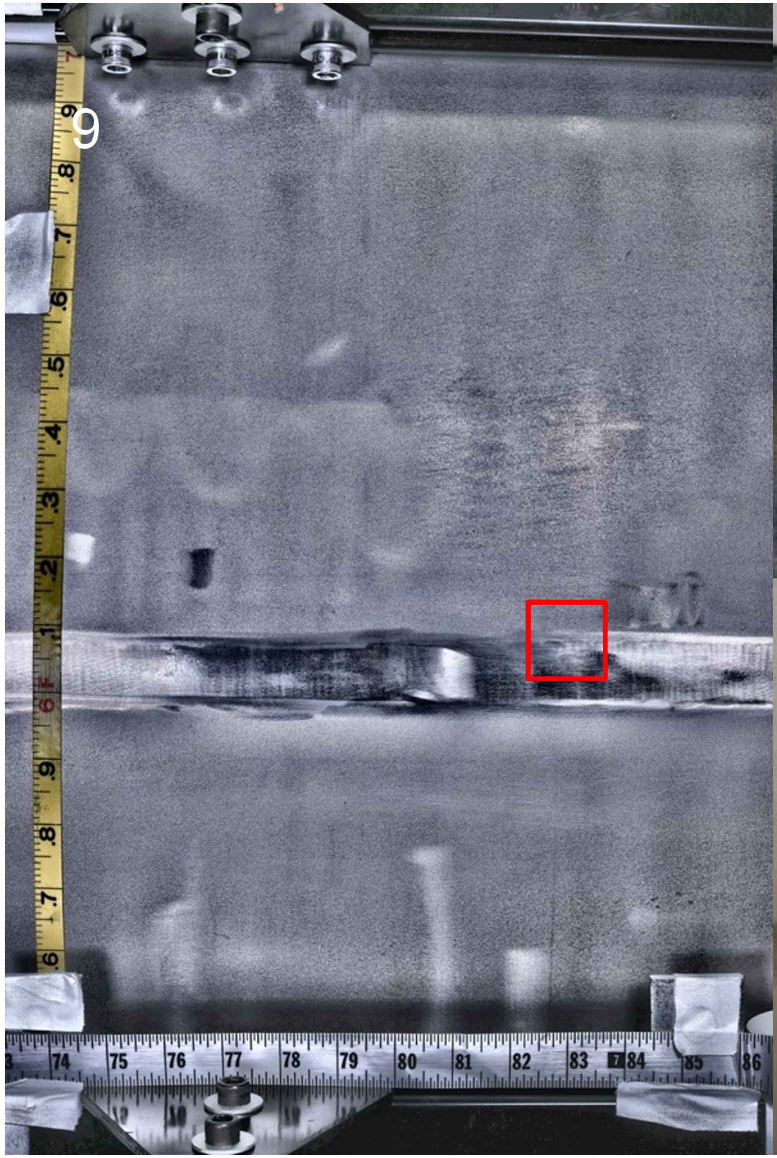
Optical Inspection of Mold

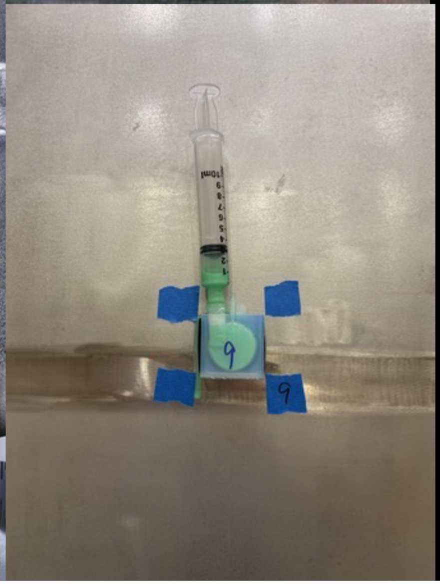


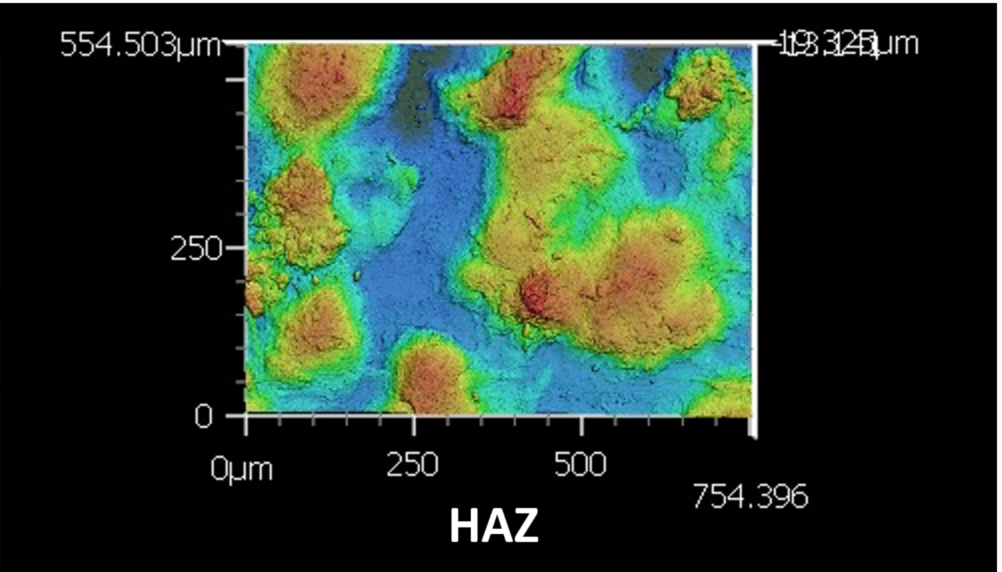
Topographic Map

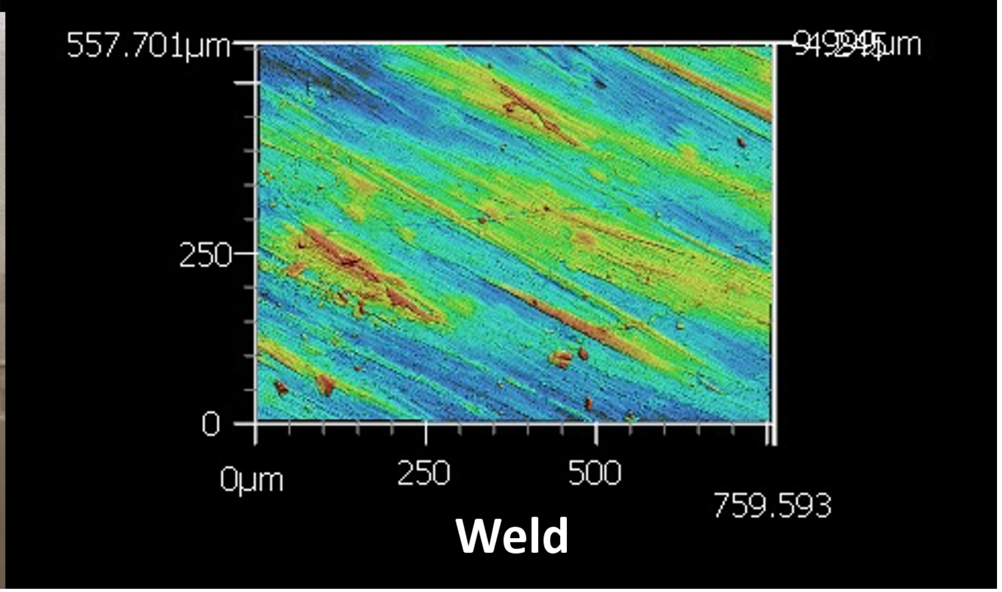


Longitudinal Weld

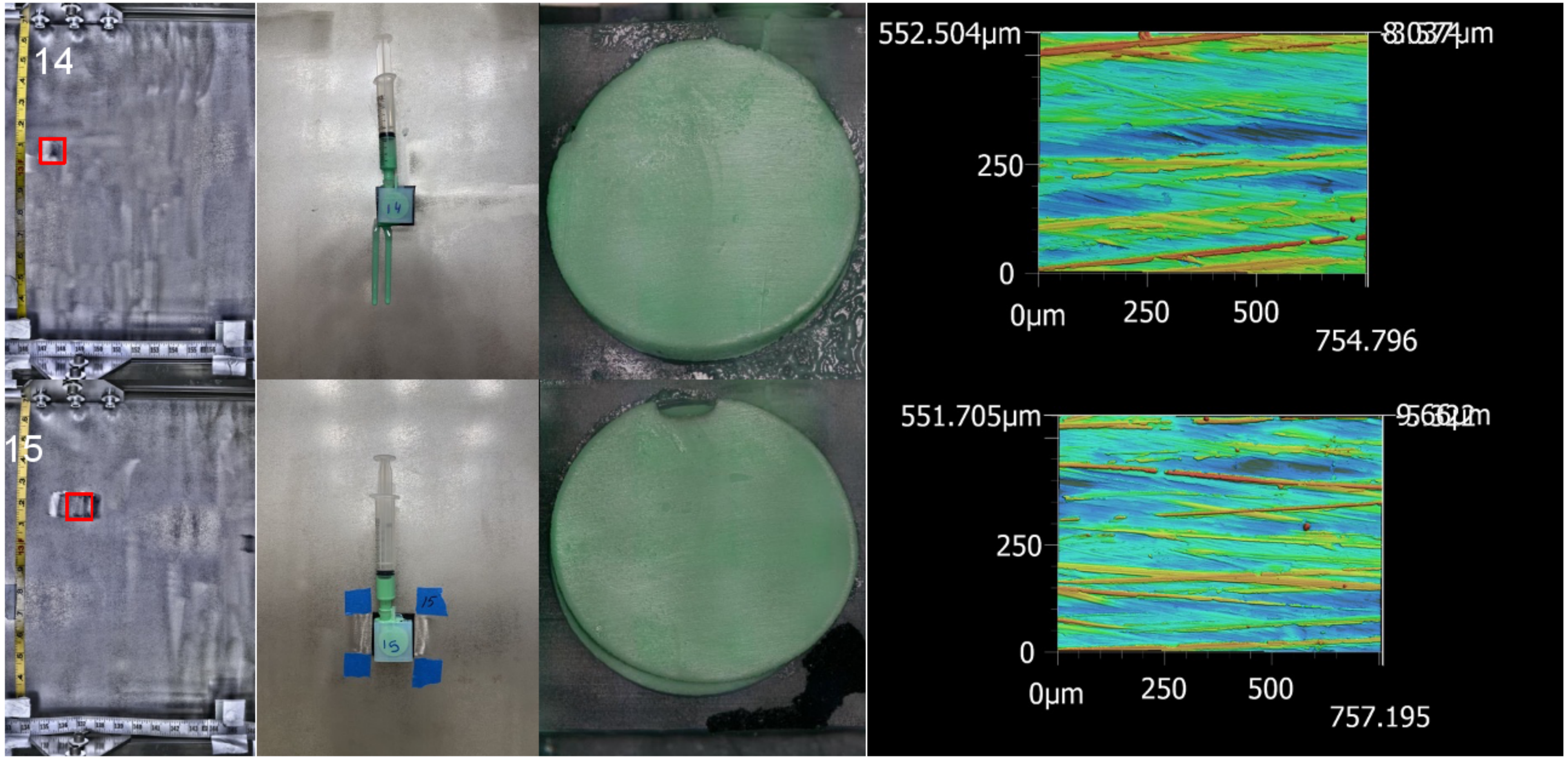


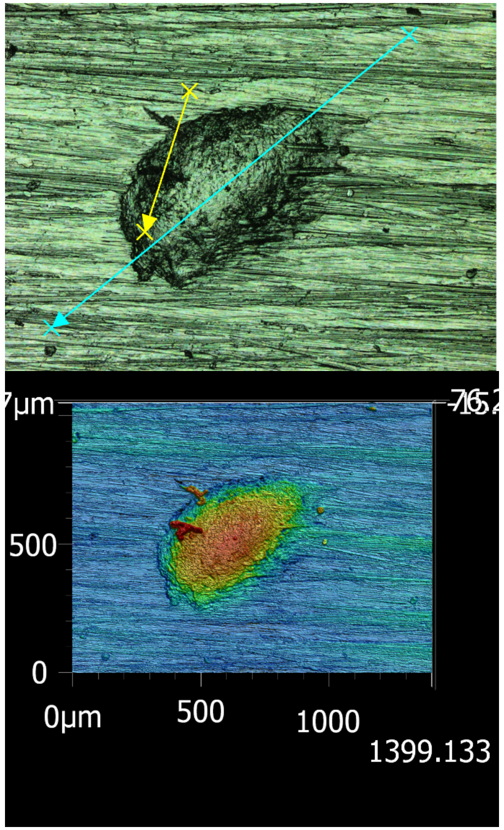




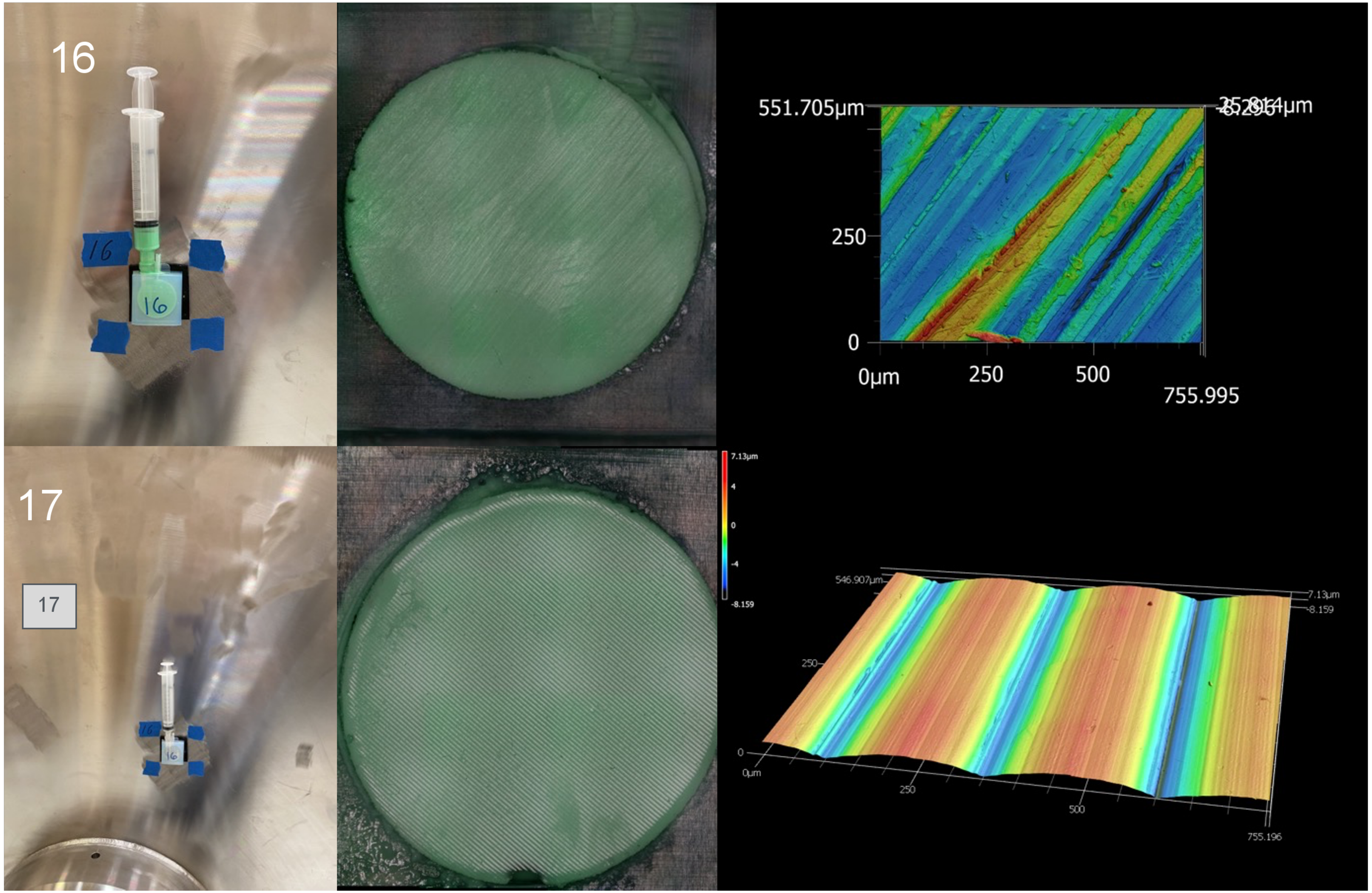


Grind Marks and Small Pits





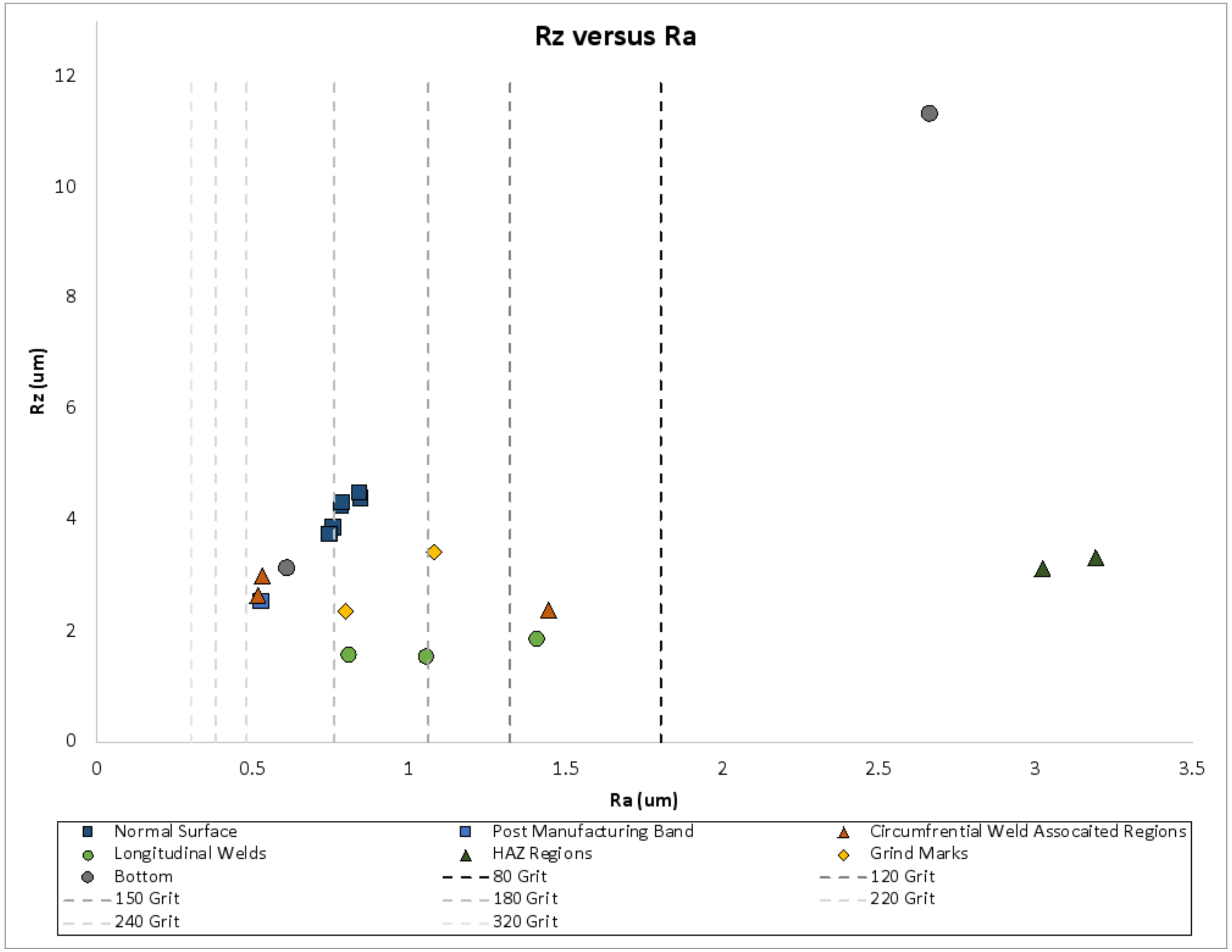
Canister Bottom



Canister Surface Roughness

- Normal surface roughness is ~ 180 grit
- Largest roughness deviations in R_a occur in welded and HAZ regions
- Machined regions generally have a lower R_z than the normal surface

Sample #	Canister Feature	R_a (µm)	R_z (µm)
1	Normal Surface	0.78	4.27
2	Normal Surface	0.78	4.33
3	Normal Surface	0.84	4.40
4	Normal Surface	0.84	4.51
5	Normal Surface	0.76	3.88
6	Normal Surface	0.75	3.75
7	Circumferential Weld (Inner Bottom Cover Plate)	0.52	2.65
8	Circumferential Weld (Inner Bottom Cover Plate)	0.53	3.00
9-Weld	Longitudinal Weld	1.41	1.86
9-HAZ	HAZ	3.19	3.33
10-Weld	Longitudinal Weld	1.05	1.54
10-HAZ	HAZ	3.02	3.15
11	Longitudinal Weld	0.81	1.58
12	Post Manufacturing Band	0.53	2.54
13	HAZ/Grinding Associated with Support Ring Inner Circumferential Weld	1.30	2.34
14	Grind Mark	0.80	2.36
15	Grind Mark	1.08	3.43
16	Canister bottom – Grind Mark[2]	0.61	3.14
17	Canister bottom[2,3]	2.66	11.34

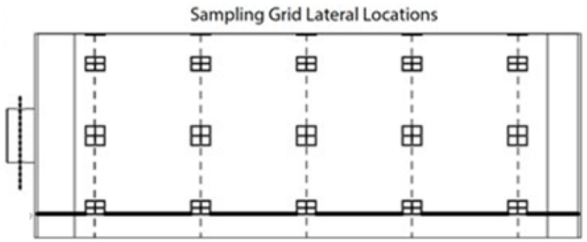


Canister Marking

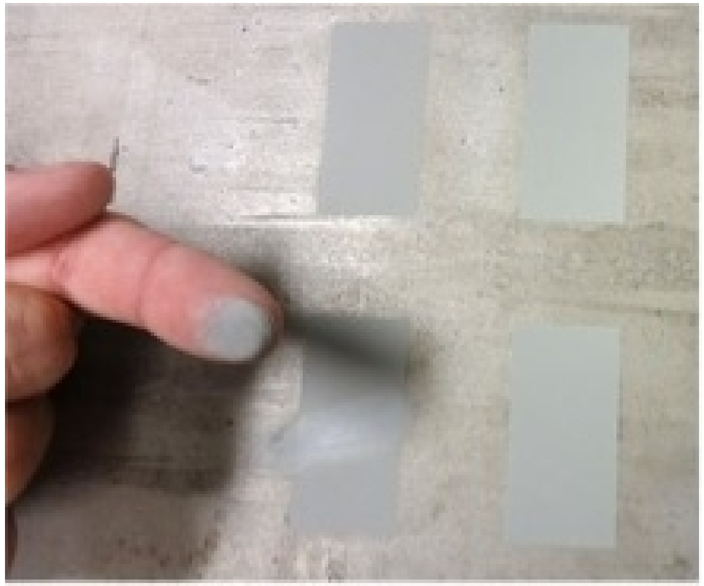
Mark a sampling grid on the canister for field sampling episodes

- Material must be robust (>200º C, 10 years), cause no surface damage, and not impact air flow

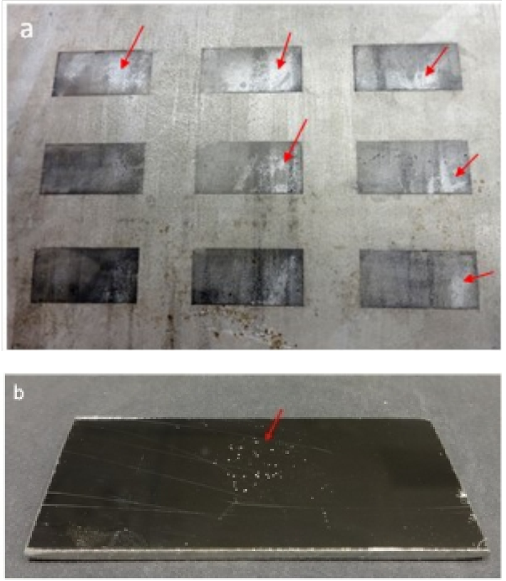
Method	Issues?
Surface Scribing	Change metal stresses, promote corrosion
VHT Hi-Temp Engine Enamel	After 2 weeks at 200 ºC became brittle and could be rubbed off
SS Blackening Agent	Degraded after 2 weeks at 200 ºC and caused corrosion (HCl in the agent)
Spot Welds, Shims and Thermocouple wires	Under investigation



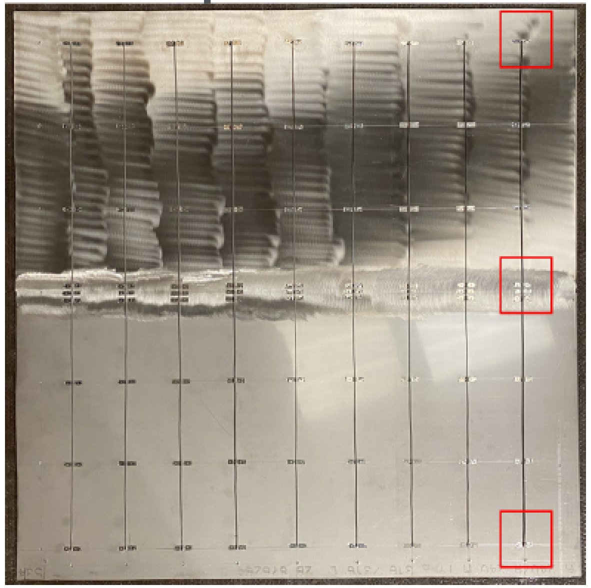
Engine Enamel



Blackening Agent



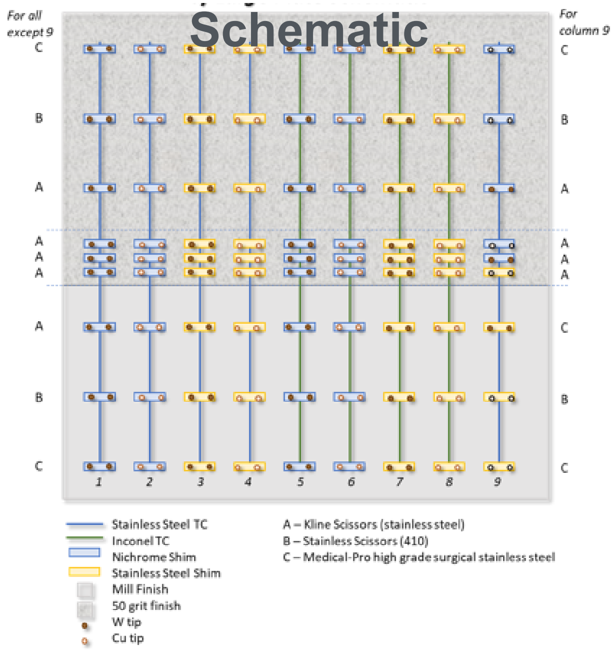
Spot Welds



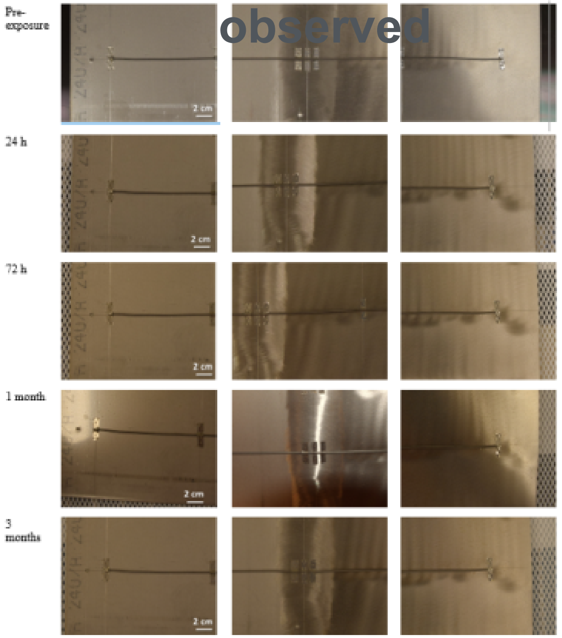
TC Wire, Shim, and Spot Weld Corrosion Tests

- Mockup plate designed to test TC wires, shims, and spot welds
  - Various materials, cutting techniques and surface grinding applied (50 grit)
  - Salt Coated (300 ug/cm^2 ASW), exposed under cyclic atmospheric conditions (up to 3 months) to assess ageing
- No obvious issues with the thermocouple wires, shims, or spot weld; however experiment is on going with additional accelerated testing planned

Mock Up Plate Schematic



No significant changes observed



Some Corrosion Product Visible on ground SS316L Surface

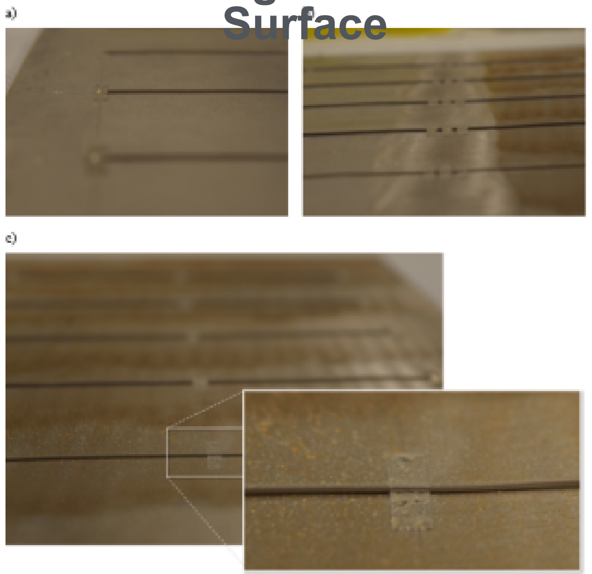
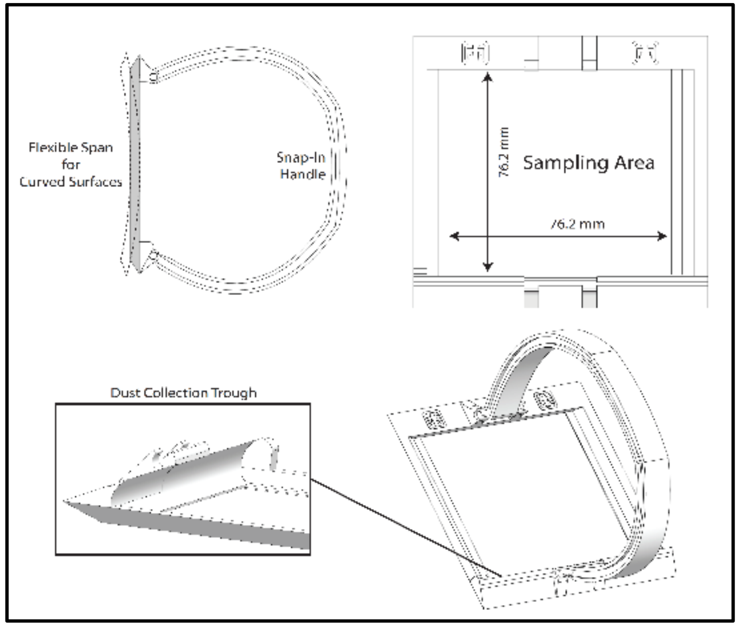
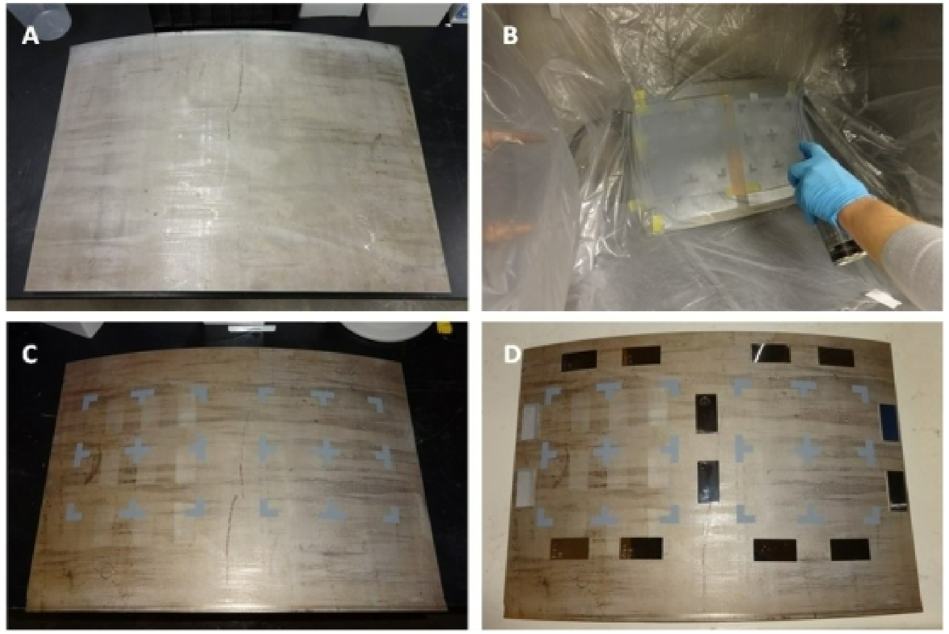


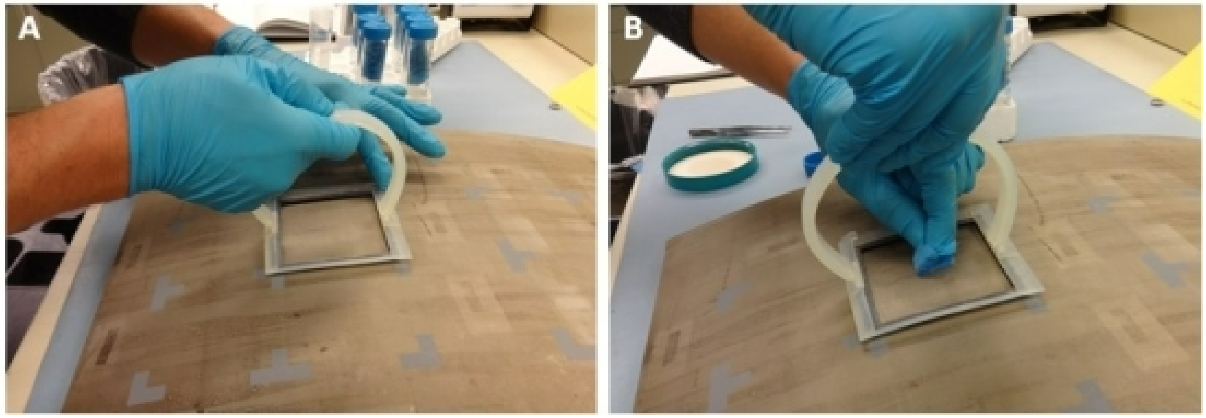
Figure 27. Representative shim locations after 3 months exposure for a) mill scale, b) within the weld, and c) rough grind. Images are angled to better view salt and potential corrosion product.

Hand Sampling Method Verification

- Sampling grid was marked with engine enamel (test at ambient temperature)
- Mock up plate was coated with ASW using nebulizer chamber
  - Equipped with witness coupons
  - Surface was sampled using sampling mask and 2 nominally moist sponges (mass of water in sponge was quantified after measurement)



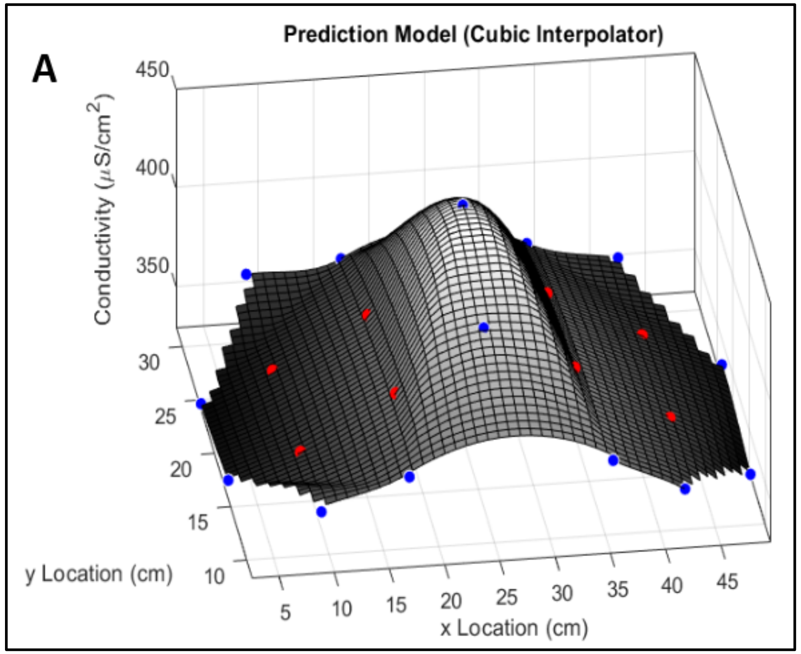




Hand Sampling Tests –Test 1 & 2

- Salt was quantified by conductivity probe and deposition map using witness coupons to estimate expected values for sample area

Fitted surface for Test 1



Results for Test 1

Undersampling 12 % ± 6

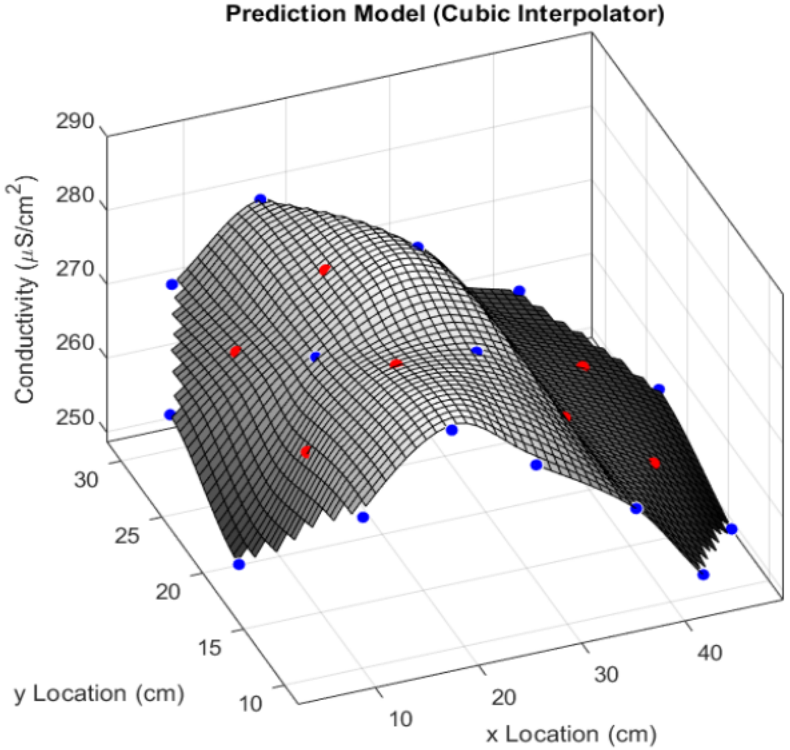
Lessons Learned:

1. **More witness coupons will allow for a more accurate surface map to be generated (steep gradient from the middle)**
2. **Careful leaching is very important**

Hand Sampling Tests –Test 3

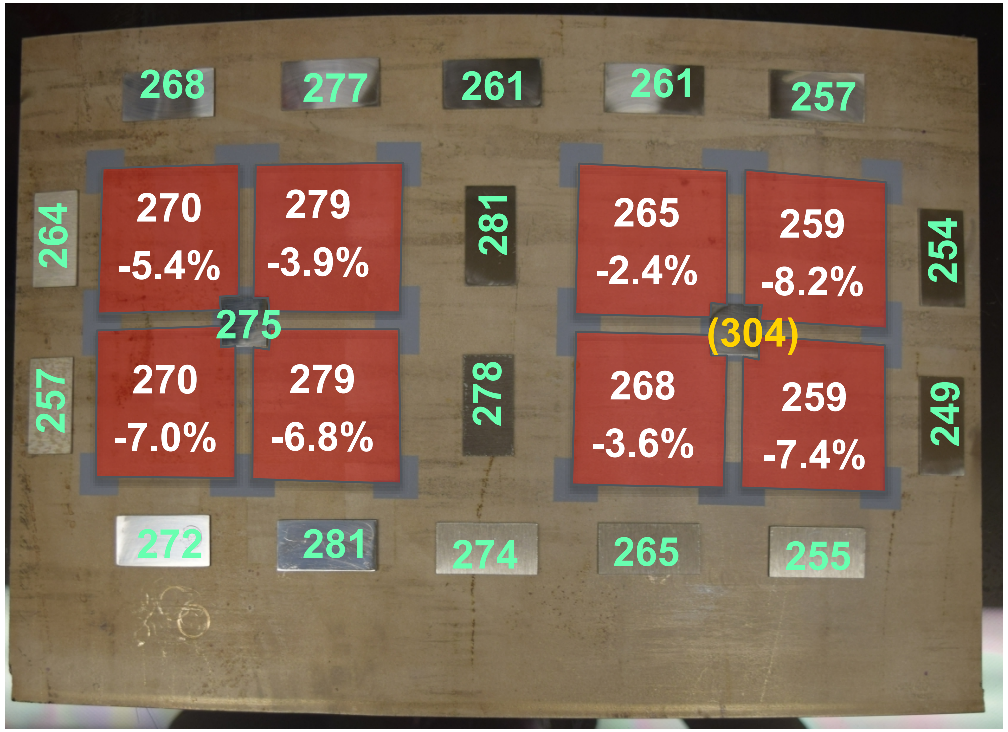
- Added additional witness coupons around the parameter and in the middle of the sampling grid

Fitted surface for Test 3



Results for Test 3

Undersampling 6% ± 6

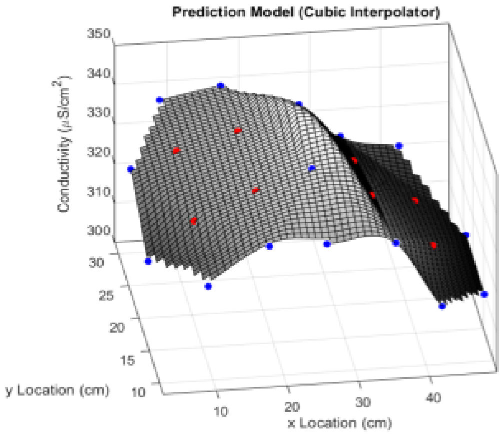


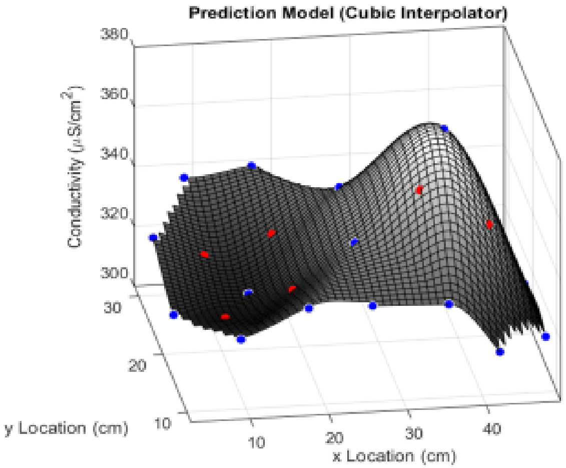
Lessons Learned:

1. **One mid-point witness coupon produced unexpectedly high result and was omitted**
2. **Variability in sponge wetness is not a big deal**

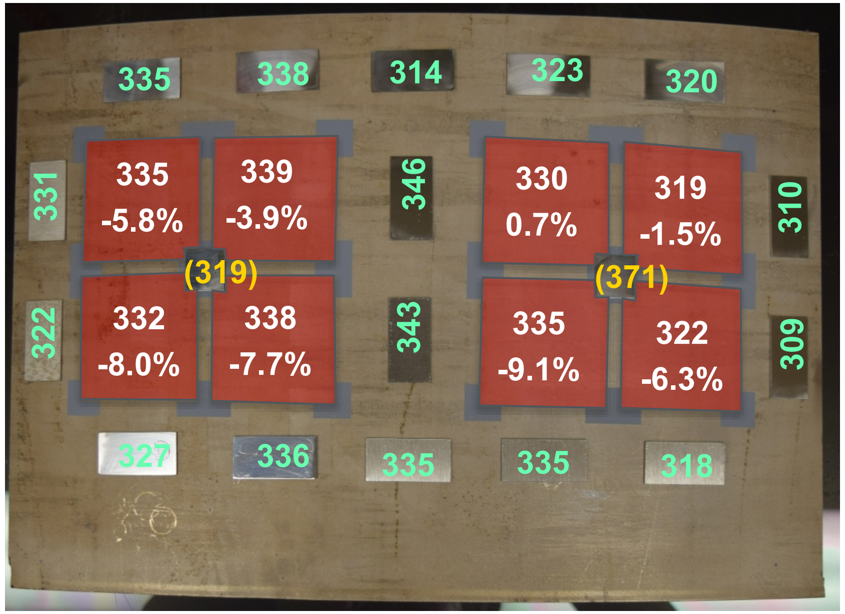
Hand Sampling Tests –Test 4

With center witness coupons-
Undersampling 7% ± 5





Omitting center witness coupons-
Undersampling 5% ± 3



Lessons Learned:

1. Center witness coupons consistently deviate from what is expected and impact the results

- **Potentially due to static**

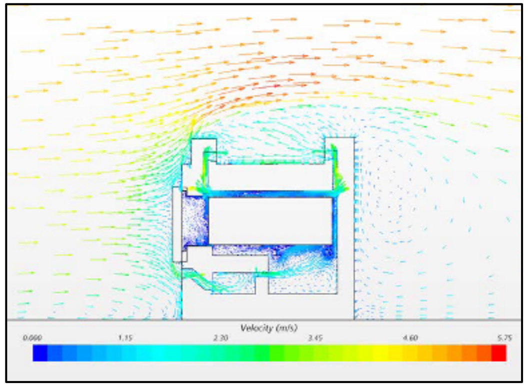
Summary

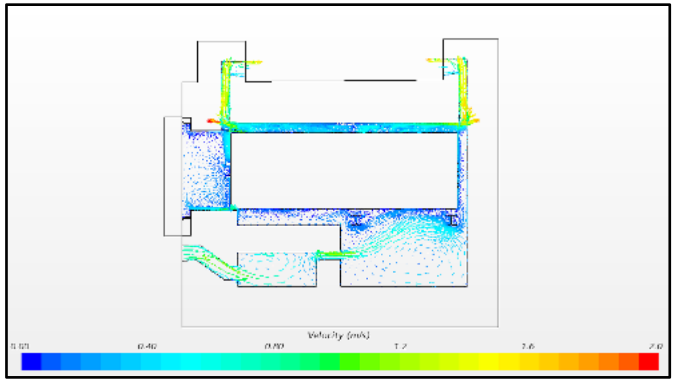
- Surface roughness measurements have been collected and can be used to inform deposition modeling, future corrosion tests, and dust/salt collection observations
- Dual purpose TC wires, shims, and spot welds may be used for marking the sampling locations
  - Further corrosion testing ongoing to rule out ageing and lifetime concerns
- Hand sampling method on mockup plate is consistent with collection of > 90% of deposited salt
  - Additional tests with methodology improvements will allow for a better estimation of actual sampling deficiencies.
    - Future tests with dust on a real canister in relevant configuration
  - To date, hand sampling is the only method with verified efficiency
    - Efficiency of robotic methods is entirely unknown (may evaluate this)

PNNL Dust Deposition Model

Results will feed into PNNL dust deposition model

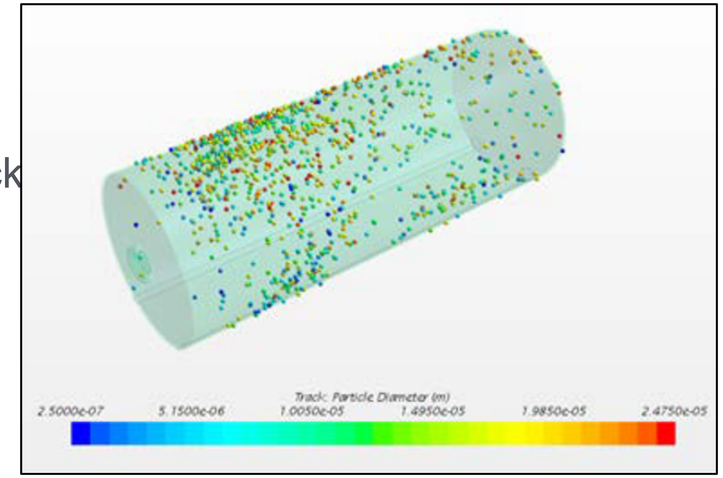
- STAR-CCM+ canister thermal models modeling airflow around and through overpacks
- Dust deposition, including several different processes
  - Brownian motion, thermophoresis, turbophoresis, etc.
  - Range of particle size distributions
  - Both horizontal and vertical canisters

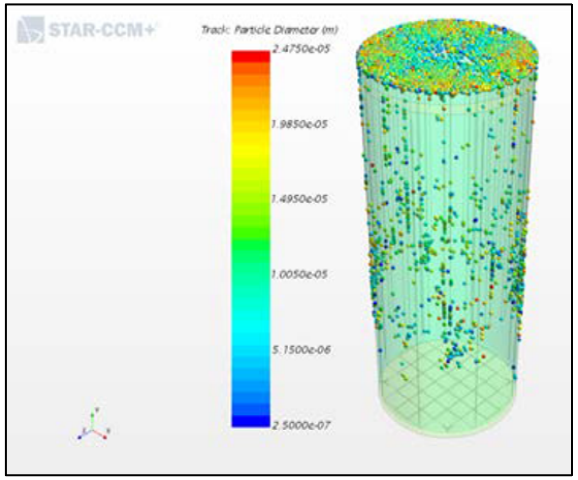




How to calibrate/validate dust deposition model? Need to know:

- Canister and overpack geometry
- Canister heat load and surface temperature distributions
- Air flow rates and velocities into and through the overpack
  Concentration and distribution of salts deposited on canister surface
- Boundary conditions:
  - Ambient temperatures
  - Wind directions and speeds
  - Ambient aerosol concentrations and particle size distributions
  - And how these change on a daily, seasonal, and yearly basis…

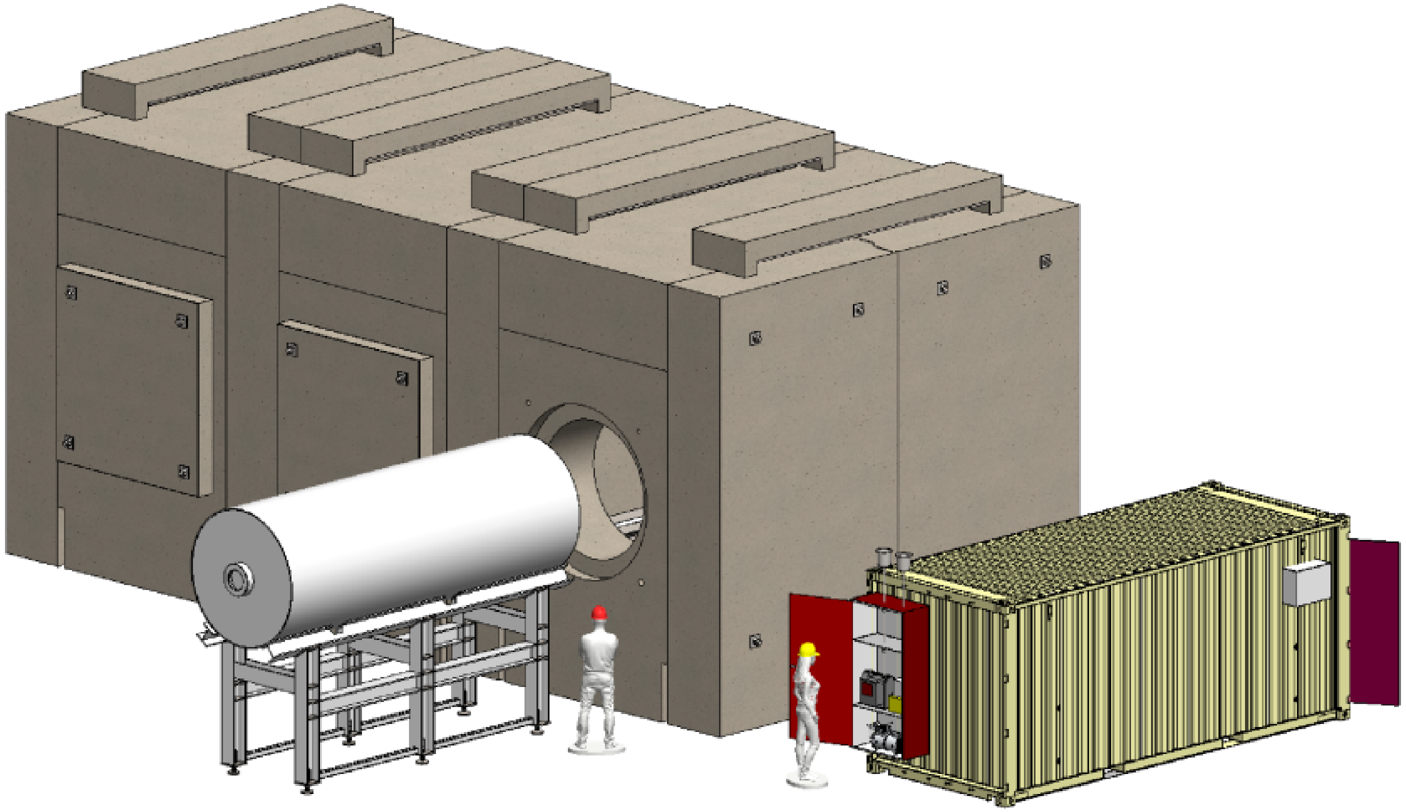




*Jensen et al., 2020. Status Update: Deposition Modeling for SNF Canister CISCC, PNNL-30793

Realistic Sampling

- Mock-up testing will be performed at SNL
  - Will require a scissor lift
  - Potentially awkward positioning
  - Some sampling locations may not be accessible



Realistic Sampling

- Mock-up testing will be performed at SNL
  - Will require a scissor lift
  - Awkward positioning
  - Some sampling locations may not be accessible
- Actual Transfer Skid
  - Will increase complexity due to large geometry

Acknowledgements

We would like to acknowledge the contributions of the following Sandians: Jason Taylor, Greg Koenig, Thad Vice, Jessica Faubel, Ryan Katona, and Makeila Maguire. Also, our DOE collaborators Phil Jensen for discussions on the dust deposition model.

Questions?