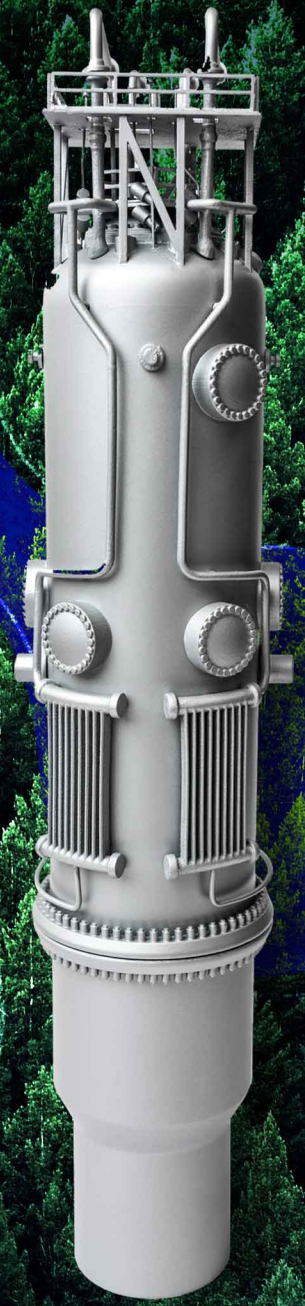

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NSUF Program Review
NuScale Power

April 15, 2024

Carlen Donahue
Materials Engineer

Outline

- Experiment Inputs
- Specimen Fabrication
- Pre-Experiment Testing
  - Baseline Mechanical Testing
  - Open Capsule Corrosion Test
- Experiment Design
- Status and Schedule

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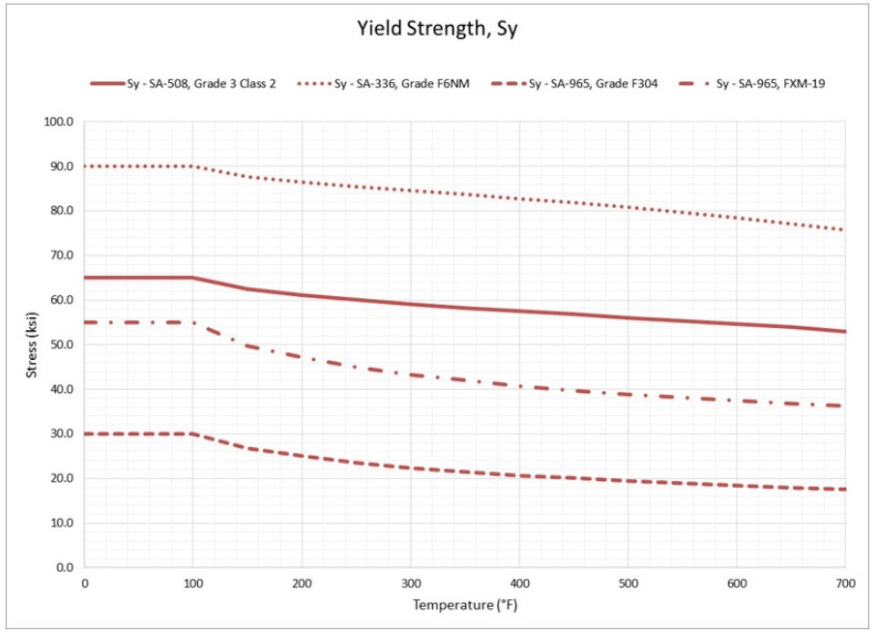
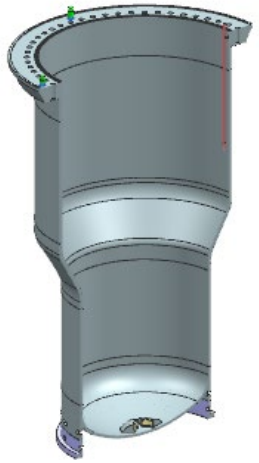
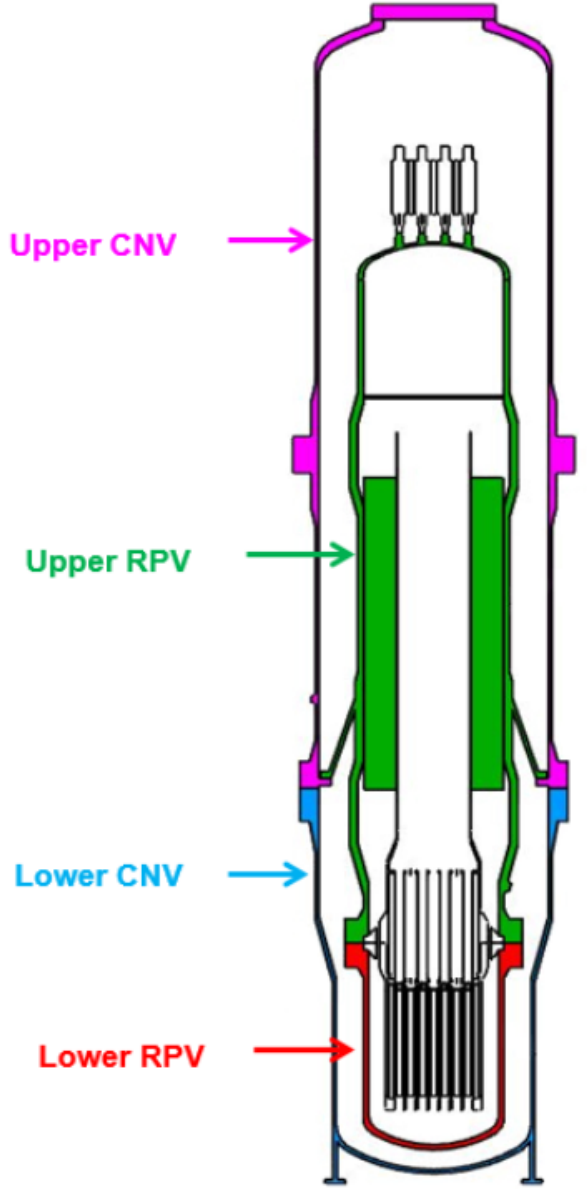
Experiment Inputs

- NuScale applied for the NSUF access (19-16547) to investigate irradiation embrittlement behavior of high strength vessel materials suitable for NuScale containment vessel design conditions.
- NuScale utilizes F6NM (martensitic stainless steel) for the majority of containment vessel. Areas exceeding a threshold fluence of 10^{17} n/cm^2 are being constructed with austenitic/nitronic stainless steels.
- The irradiation embrittlement behavior of F6NM and SA-508 Grade 3 Class 2 is being investigated for future design potential







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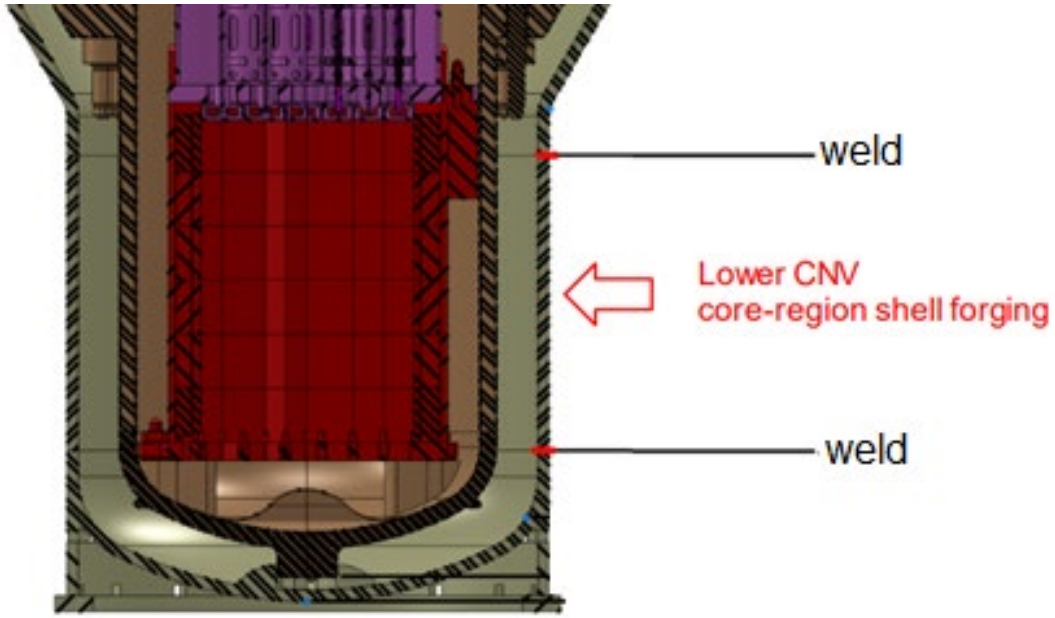
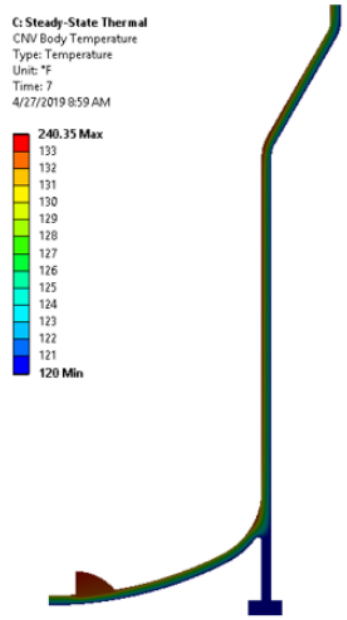
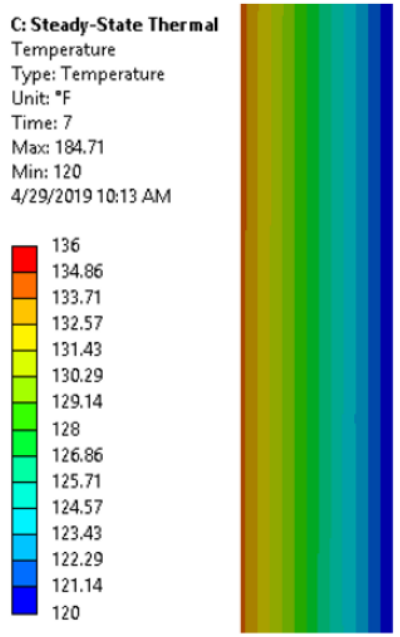
Experiment Inputs

- Unique NuScale Conditions:
  - Fluence:
    - 5.10 x 10^{18} n/cm^2 (E>1 MeV) for Base Metal specimens
    - 2.60 x 10^{18} n/cm^2 (E>1 MeV) for Weld Metal and HAZ specimens
    - Requirement: Experiment shall be within 20% of target
  - Temperature
    - All at <140°F (<160°F target for test)







Specimen Fabrication

- 3 heats of F6NM weldments were developed for the purpose of irradiation embrittlement testing at INL
- 1 heat of SA508 Grade 3 Class 2 weldment (higher strength grade) was developed for the purpose of irradiation embrittlement testing at INL.

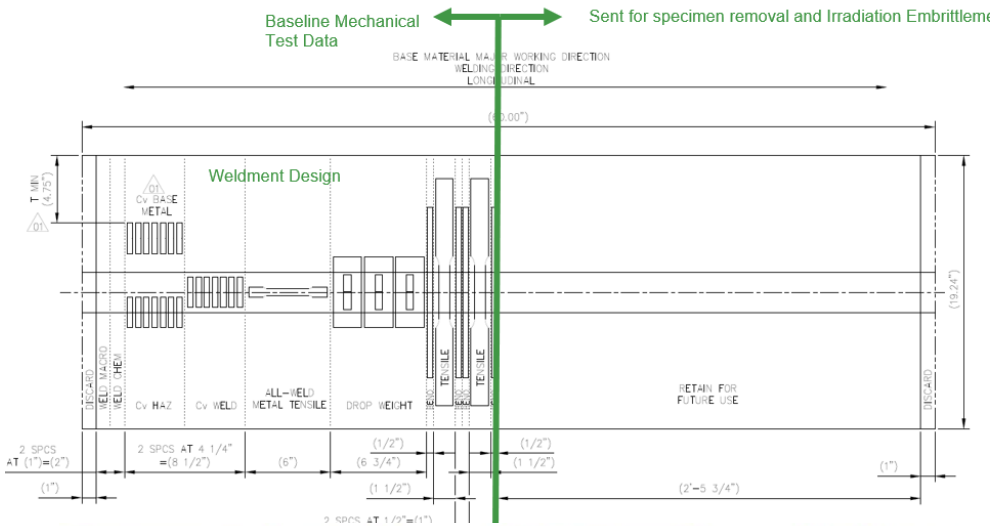


Table 2. NuScale Irradiation Matrix for each heat of material.

Metal	# of tensile specimens	# of charpy specimens
Base	3	18
Weld	3	18
Heat Affected Zone (HAZ)	--	18
Total	6	54

- Irradiate one set of specimens for each heat of material

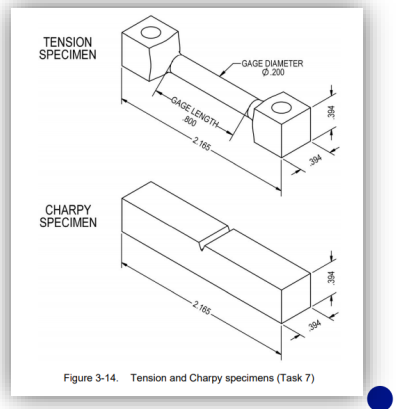


Figure 3-14. Tension and Charpy specimens (Task 7)

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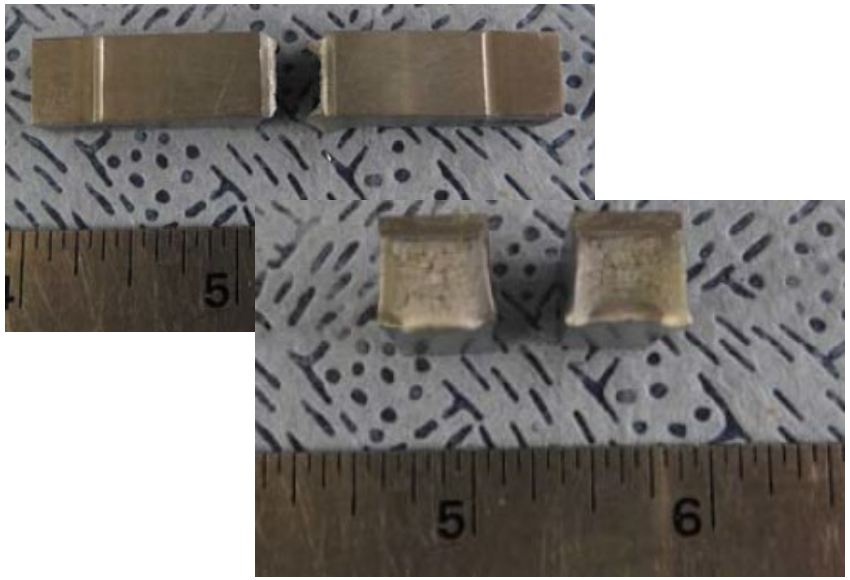
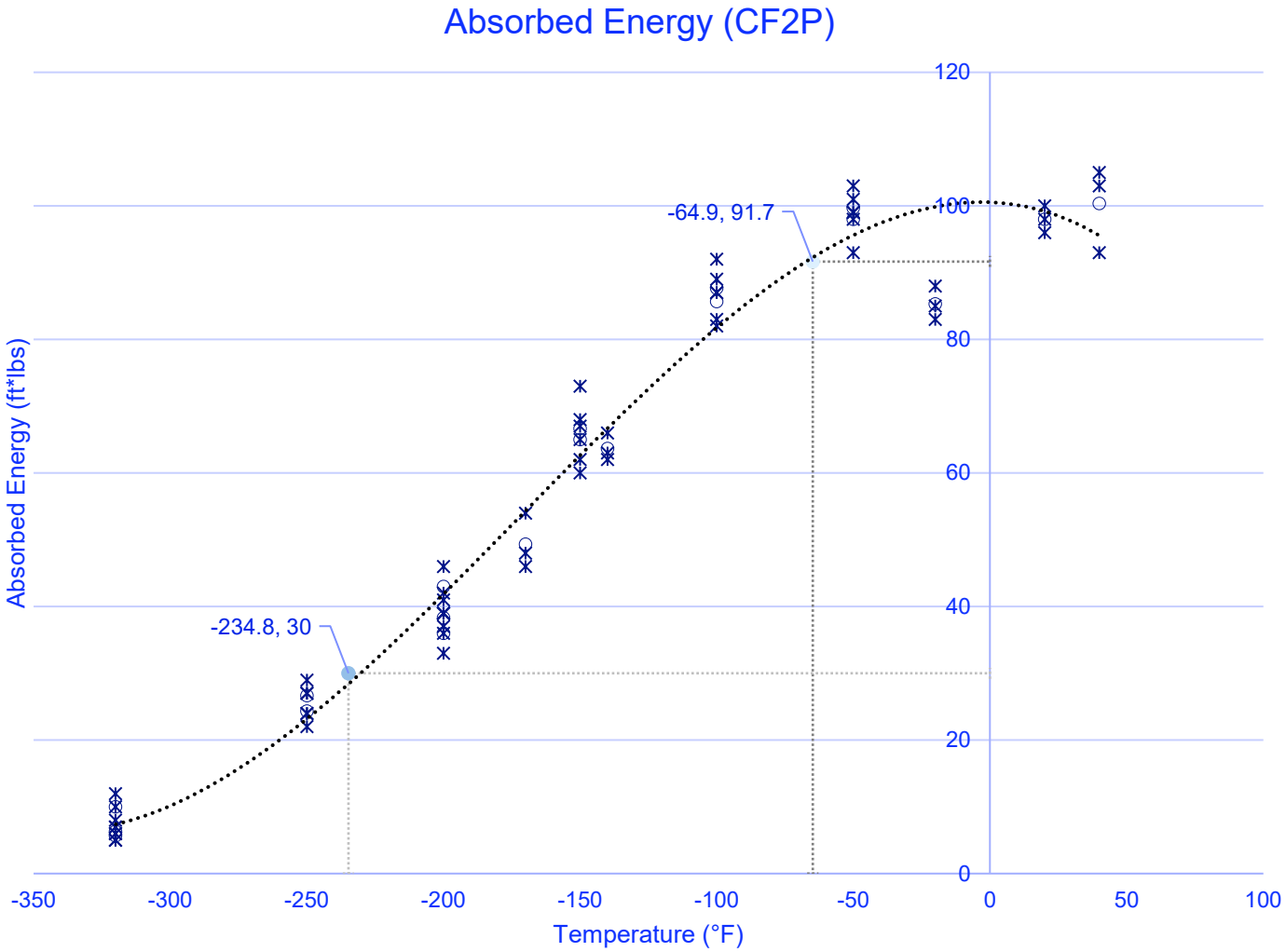
Pre-Experiment Testing – Baseline Mechanical Testing

- 3 F6NM weldments baselined for impact/tensile properties of base/HAZ/weld
- 1 SA508 Gr 3 Cl 2 weldment baselined for impact/tensile properties of base/HAZ/weld
- 30 ft*lb index temperatures and upper shelf energy quantified for each specimen type



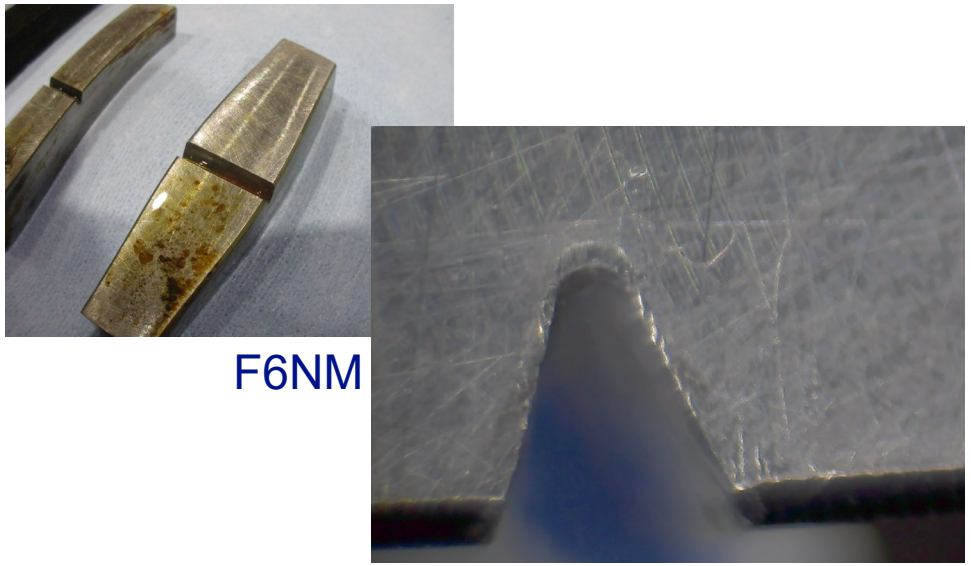


Pre-Experiment Testing – Open Capsule Corrosion Test

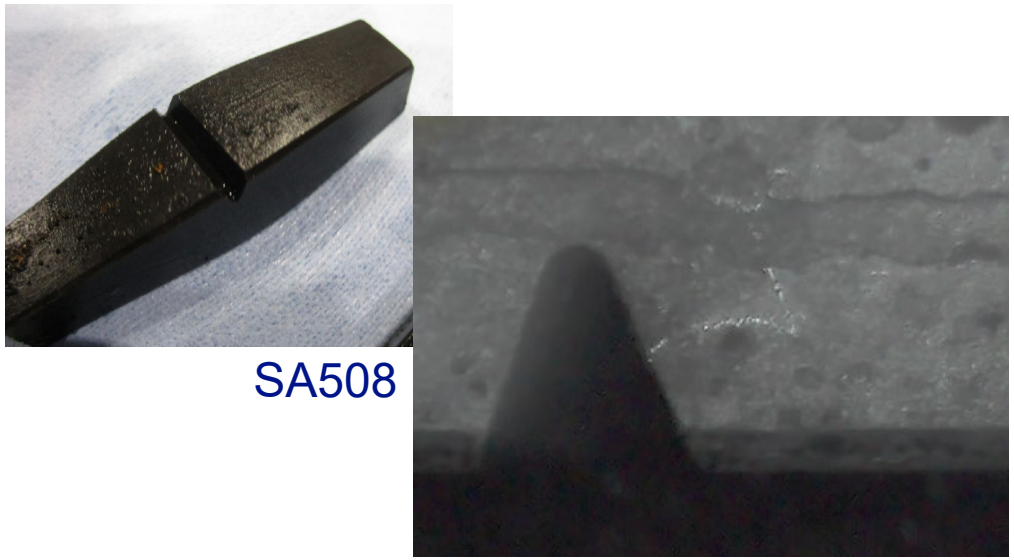
- Due to low embrittlement temperature required by the statement of work, an “open capsule” design was selected to allow the specimens to be in direct contact with ATR coolant.
- The open capsule design required assurance that exposure to ATR coolant did not result in unacceptable material loss in the specimen (most notably near the v-notch within the tolerances of the Charpy v-notch geometry specification)
- “Dummy” specimens of both F6NM and SA508 were submerged in the ATR canal for 197 days followed by examination for material loss in the notch region.

Conclusions:

- SA508 specimens experienced noticeable general corrosion; However, the degree of material loss was considered acceptable for the Charpy v-notch specimens to still be valid when tested. Experiment design was modified to minimize SA508 specimen exposure time to ATR coolant by making all SA508 specimens fit within a single cycle.
- The F6NM specimens saw no noticeable material loss in the notch region.



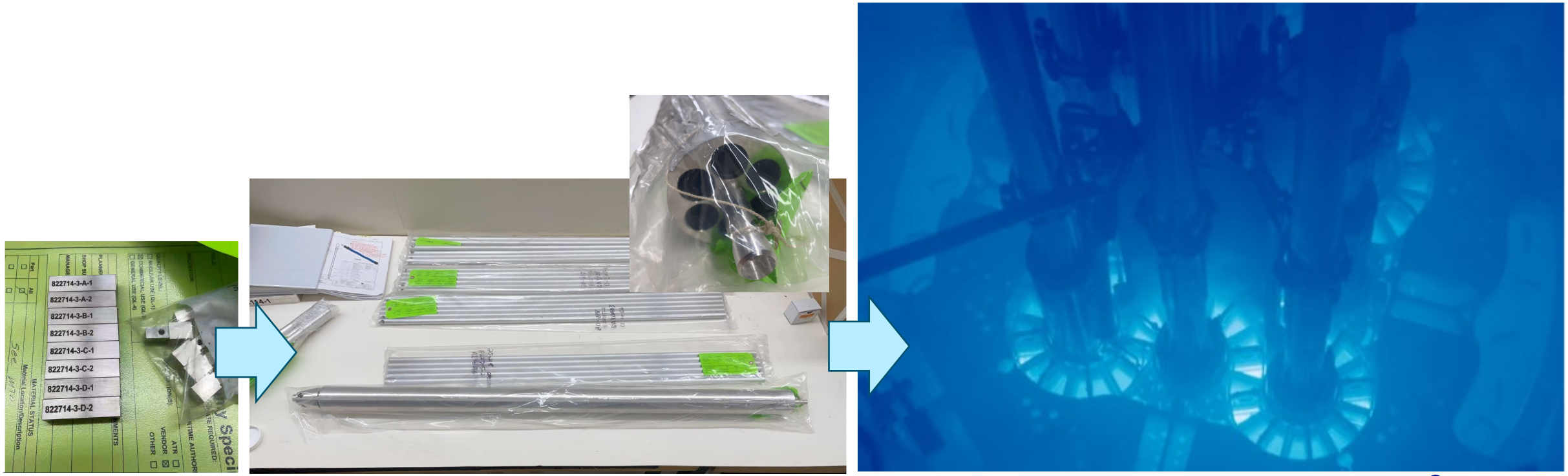
F6NM



SA508

Experiment Overview

- Overview:
  - 60 specimens per heat (54 charpy, 6 tensile)
  - 4 heats total (3 F6NM, 1 SA508)
  - 123 specimens tested to HIGH FLUENCE (All SA508, F6NM Base Metal)
  - 117 specimens tested to LOW FLUENCE (F6NM Weld, F6NM HAZ)



Experiment Overview

- Overview:
  - In order to meet NuScale fluence targets, INL staff designed a specimen loading plan that split specimens into 20 groups, each group representing like-specimens for comparison (i.e. common material, heat, location)
  - As designed, each specimen is within 1.1% of the group mean and each group was within 16% of the target fluence (except where the SA508 specimen plan was modified to minimize corrosion).
  - Low fluence groups required the use of three (3) PALM cycles, with a unique loading for each cycle to meet experiment requirements
  - High fluence groups required the use of one regular cycle to meet experiment requirements

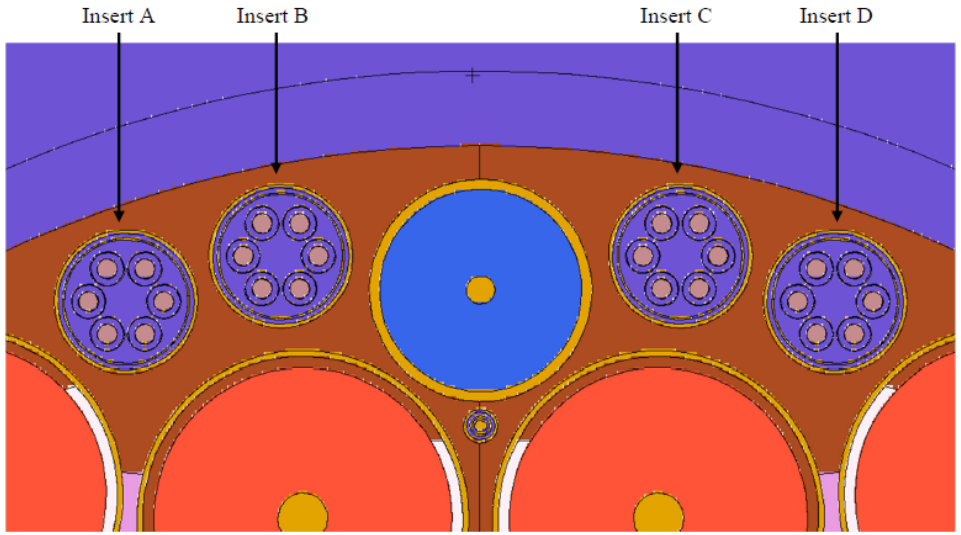


Figure 1. MCNP Geometry Plots of the NuScale inserts in ATR positions I-19, I-20, I-2, and I-3. **Note: These 4 inserts are depicted together, but will not all be inserted concurrently.**

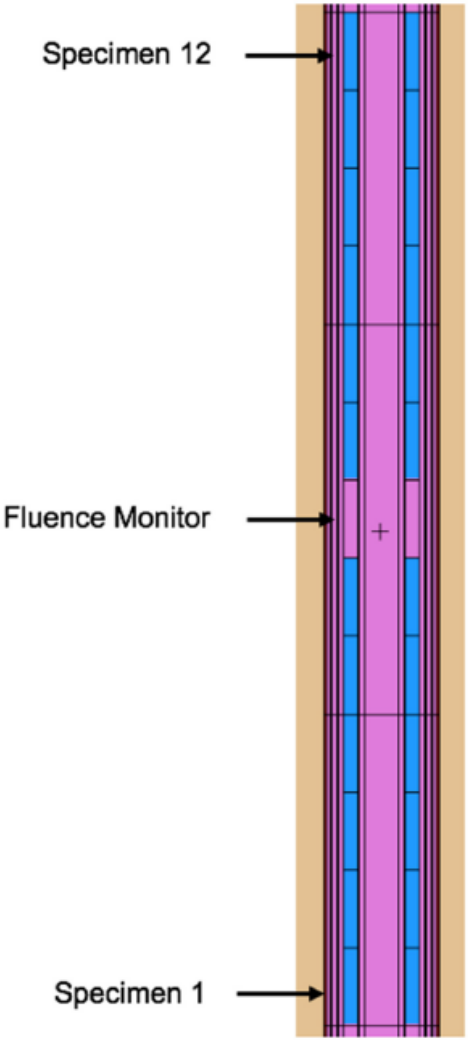
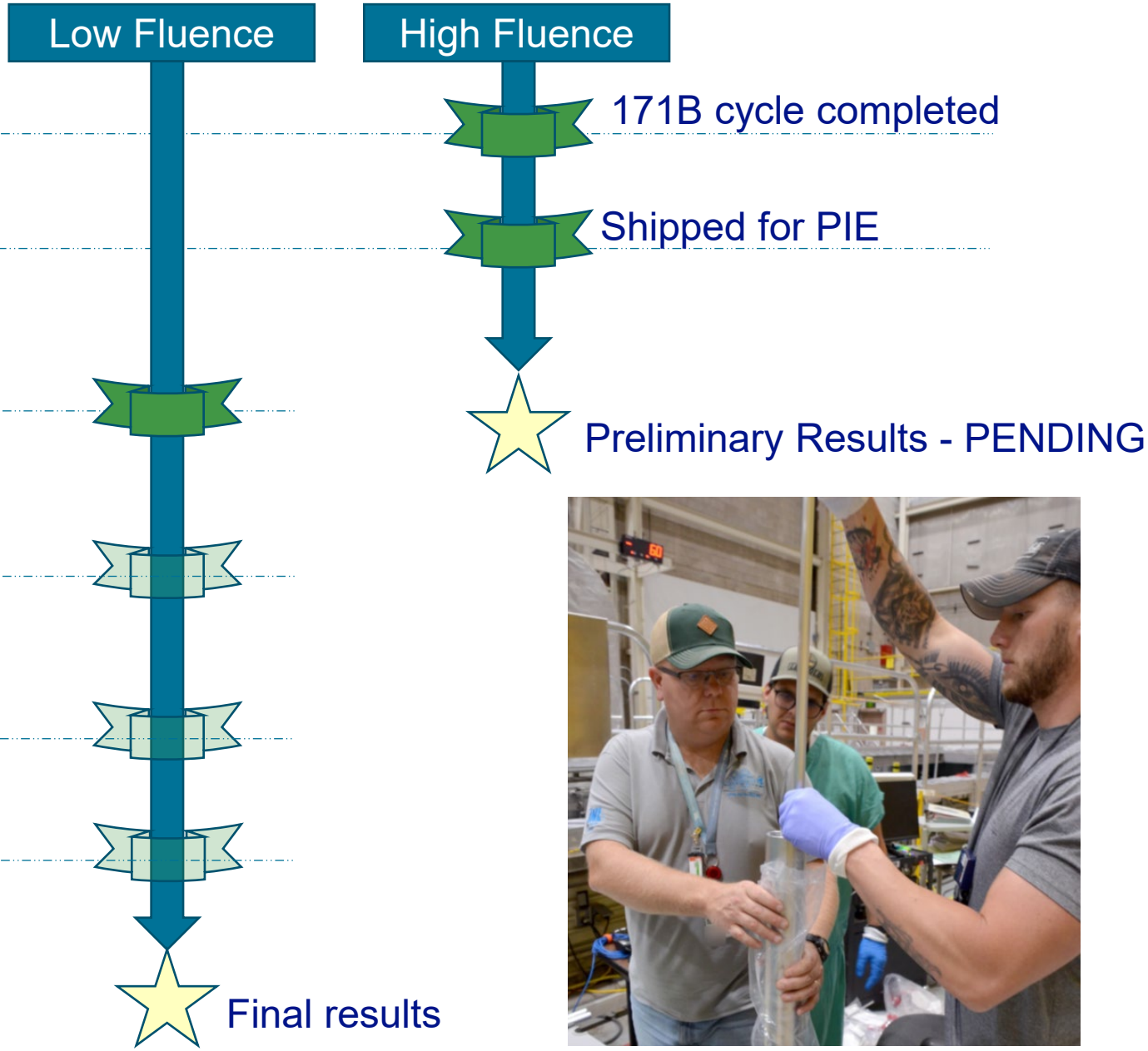


Figure 2. Axial (YZ Plane) MCNP geometry plot of a NuScale insert. Specimens are in blue.

Schedule

- Cycle 171B (FULL)
  - Finish: 09.26.2023
- 1st Shipment: 02.12.2024
- Cycle 172A-1 (PALM)
  - Finish: 03.16.2024
- Cycle 174A-1 (PALM)
  - Finish: 04.12.2025
- Cycle 174B-1 (PALM)
  - Finish: 05.10.2025
- 2nd Shipment: TBD



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Carlen Donahue
Materials Engineer 3
cdonahue@nuscalepower.com