

Prototype Nuclear Qualification Device Testing for Advanced Neutron Sensor Experiments at AFRRI

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Outline

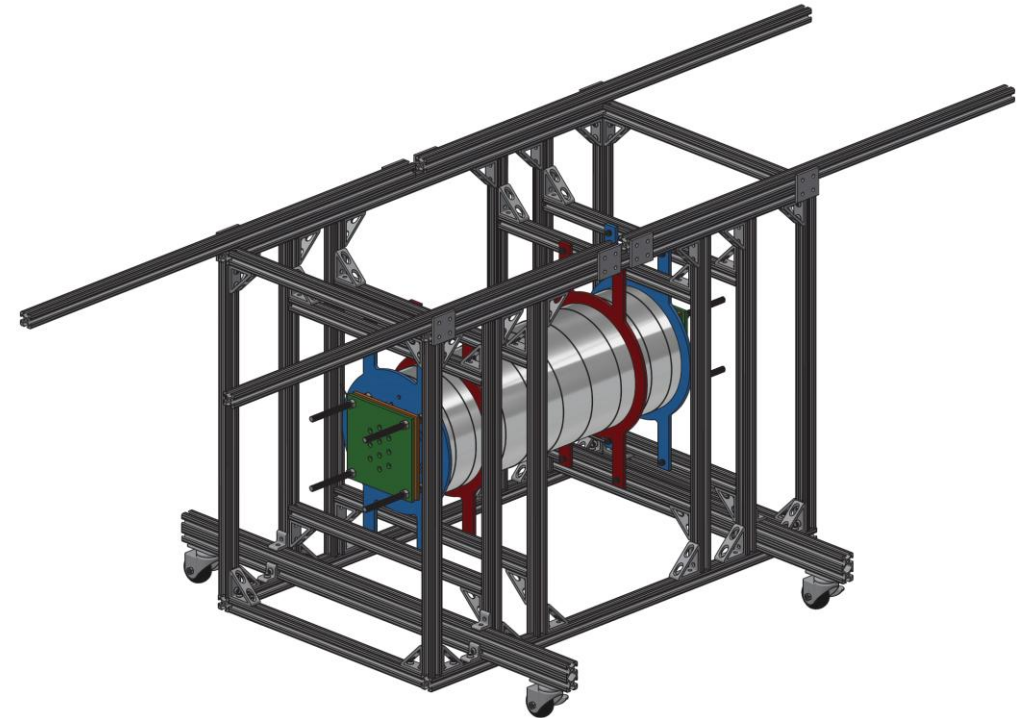
- **Purpose of NQD**
- **Design of Prototype NQD**
- **Preliminary Testing at INL**
- **Performance of NQD During AFRRRI Testing**
- **Conclusion/Future Work**

Purpose of the Nuclear Qualification Device (NQD)

- **Need for a device capable of repeatable, temperature-controlled irradiation of multiple sensors at the same time for sensor testing and qualification**
 - Temperature testing of at least 300°C, with eventual goals of 700°C
 - Reliable monitoring and control of sensors and heaters during irradiation
 - Capable of operation over large fluences without electronic failures
 - Low activation of device to enable post-irradiation handling
 - Adequate dosimetry package for repeatable spectrum unfolding

Prototype NQD Design

- Alumina tube furnace with internal tubes for instrumentation placement
- Grade 2 titanium plates used for mounting alumina tubes
- Instrumentation tubes are arranged to minimize shadowing effects
- 10 instrumentation tubes with capability of housing 2 instruments (one from each side), providing 20 experiment locations
- 3 cable heaters wrapped around each of the 3 zones
- Boron free alumina-silica insulation wrapped outside of furnace and secured with thin sheet of aluminum
- Furnace assembly mounted in aluminum frame



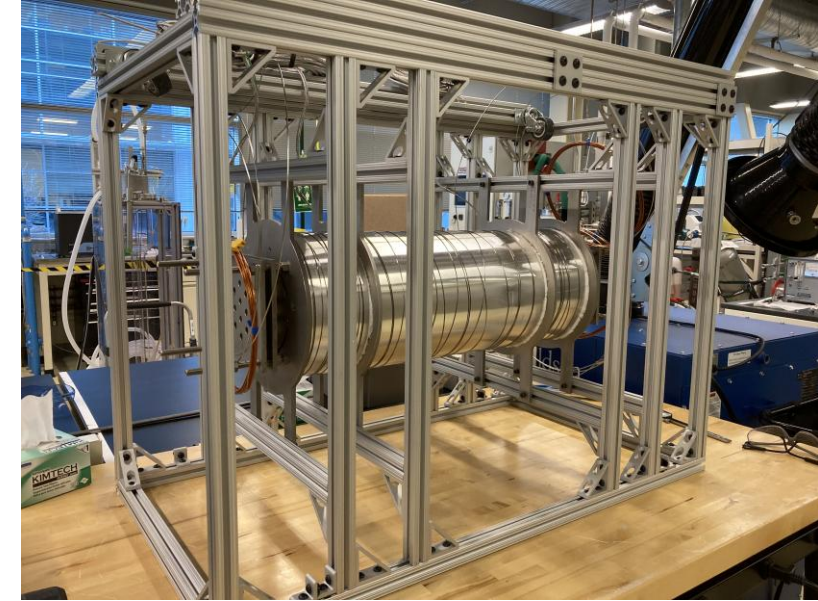
Prototype NQD Design



- Central alumina furnace with cable heaters for the 3 zones



- Alumina-silica insulation wrapping over the central furnace



- Thin aluminum sheet covering insulation to hold in place

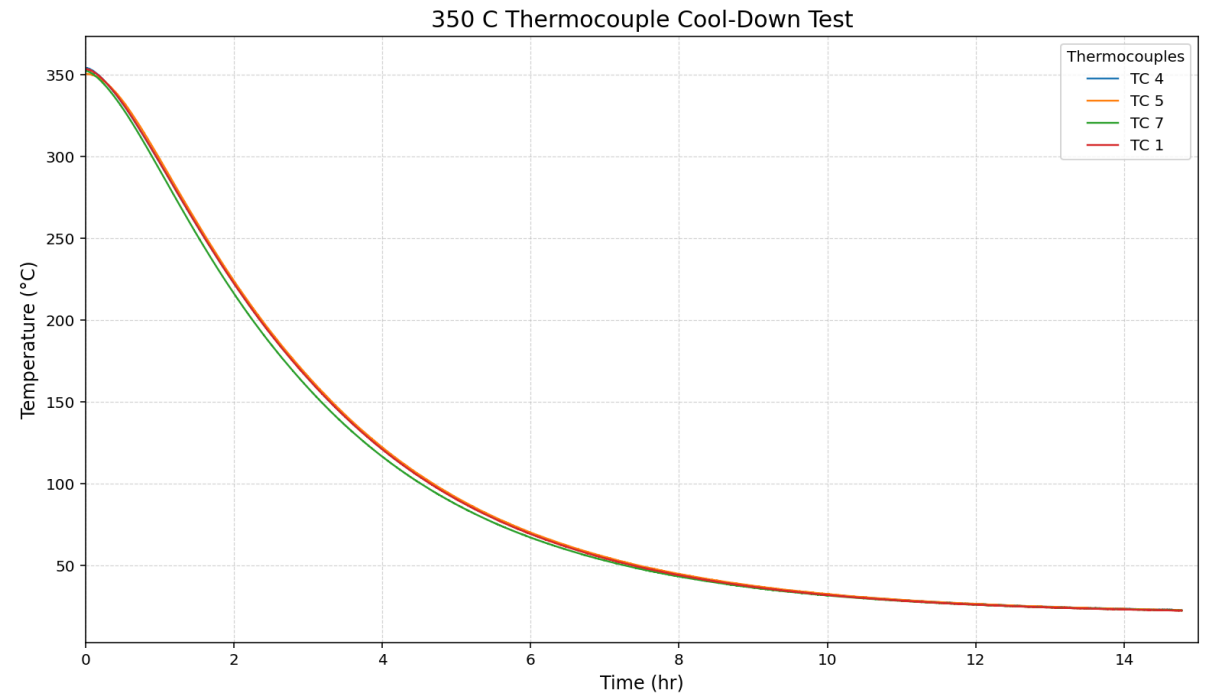
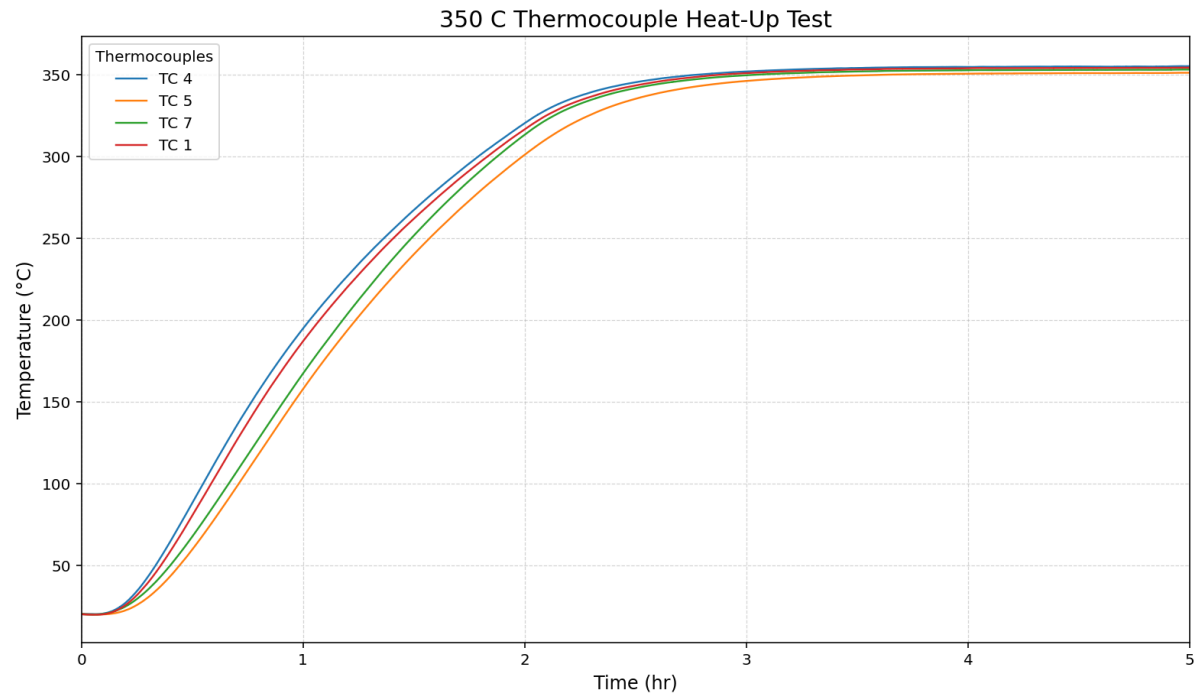
Preliminary Testing at INL

- **For performance tests, K-type TCs were installed in positions 1, 2, 3, 4, 5, and 7 and externally to measure:**
 - Heat-up and cool-down times to 350°C
 - Axial temperature distributions at 350°C
 - External temperatures
- **Additional testing was performed with cartridge heaters installed in position 6 to measure:**
 - Heat-up and cool-down times to 650°C
 - Axial temperature distributions at 650°C



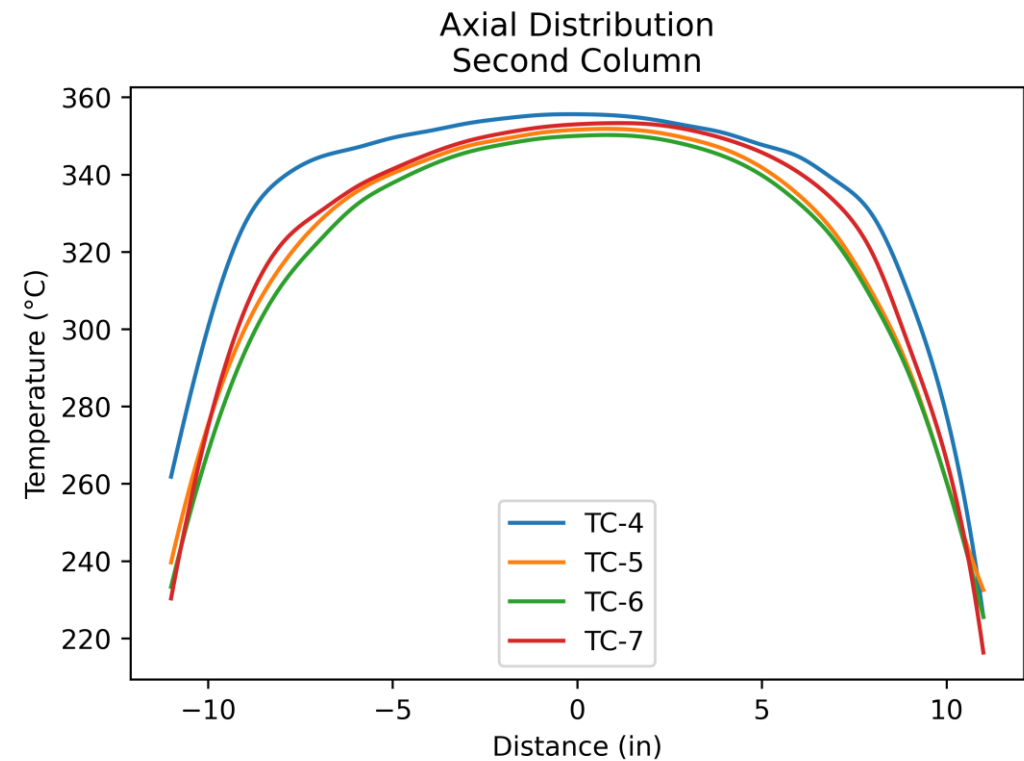
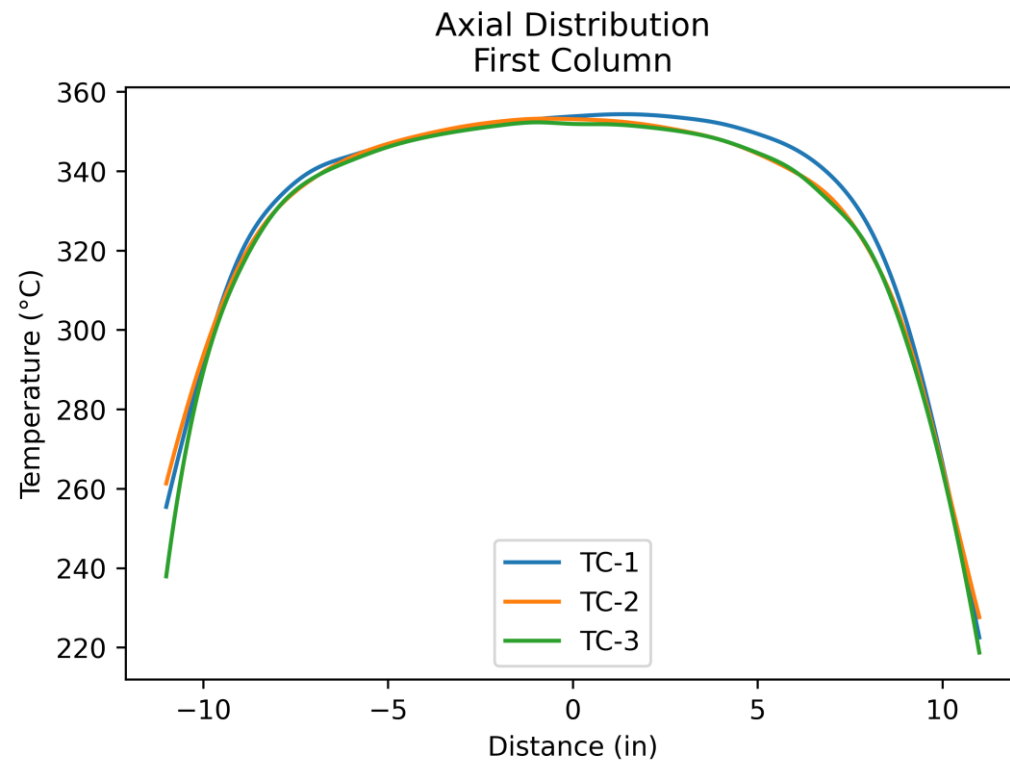
Preliminary Testing at INL

350°C Test Heat-Up/Cool-Down



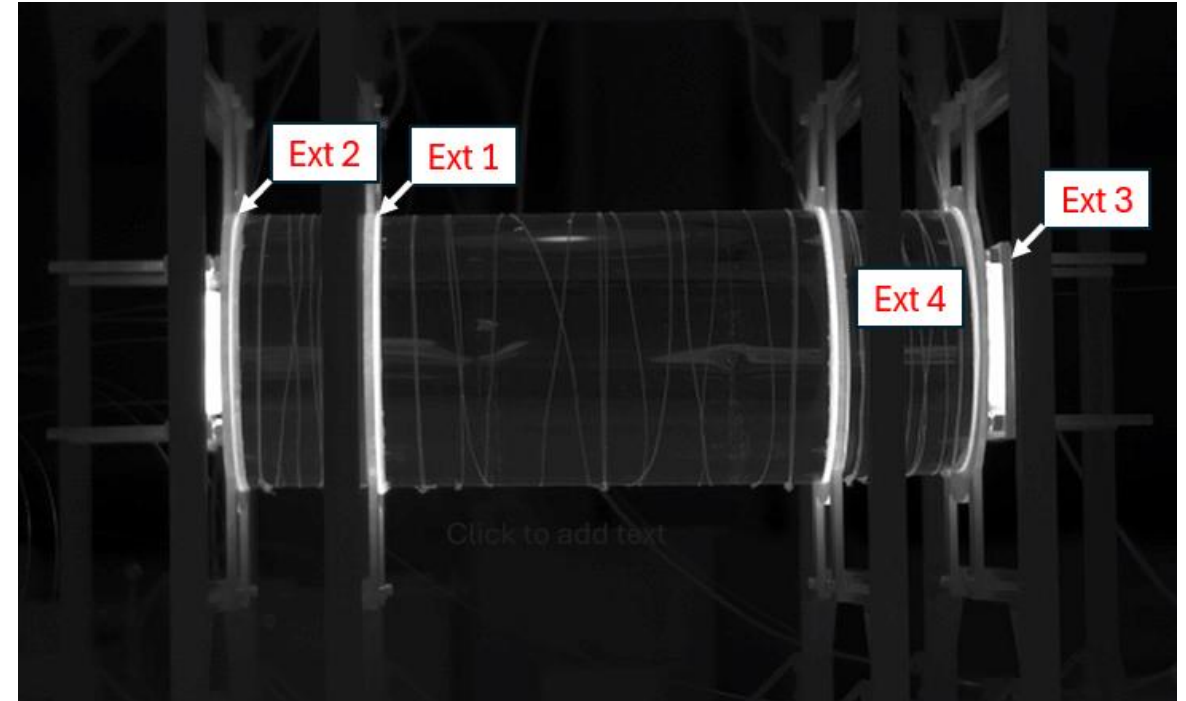
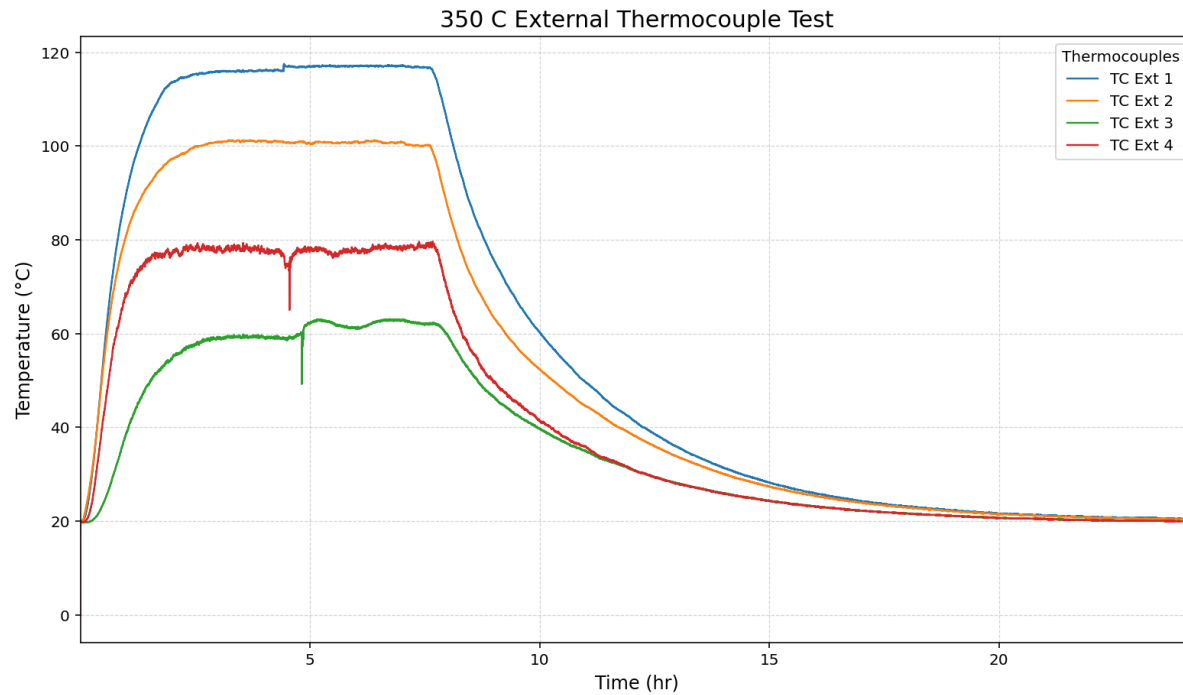
Preliminary Testing at INL

350°C Temperature Distribution



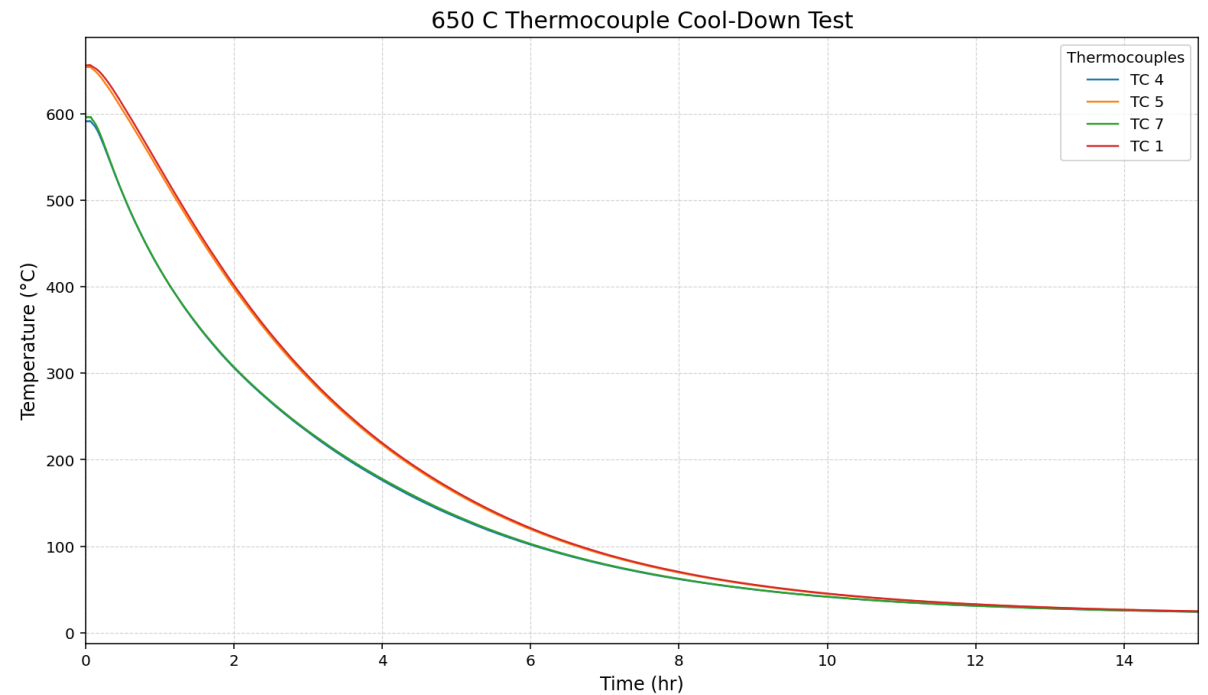
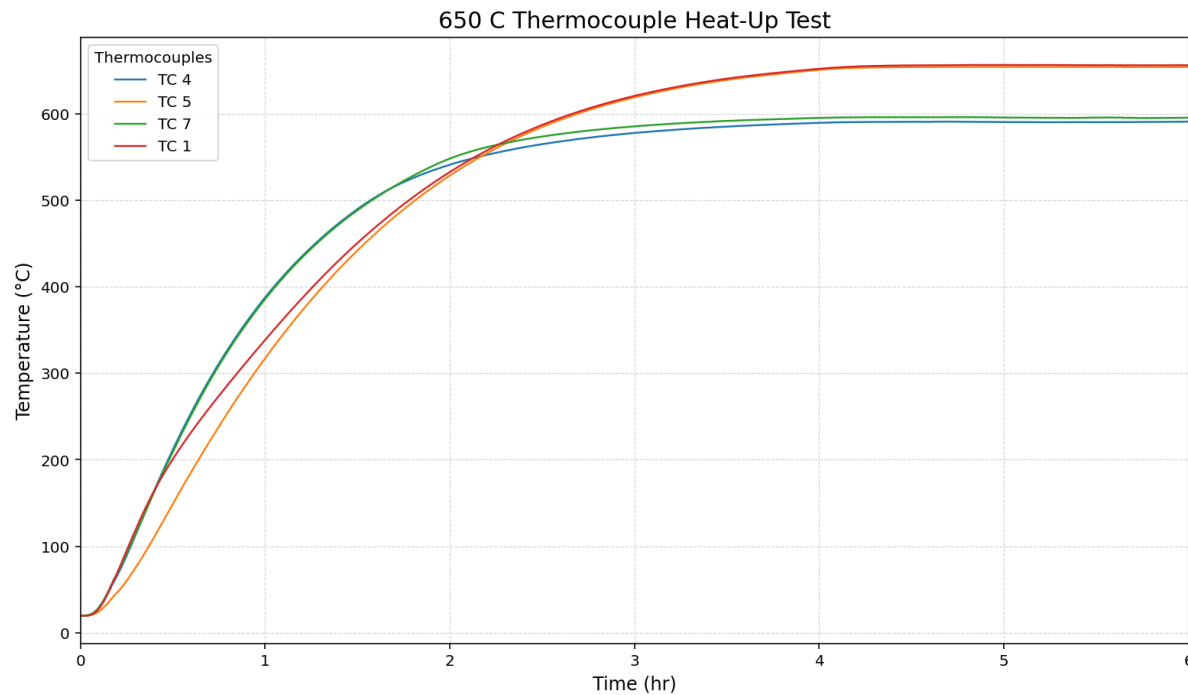
Preliminary Testing at INL

350°C Test External Heat-Up/Cool-Down



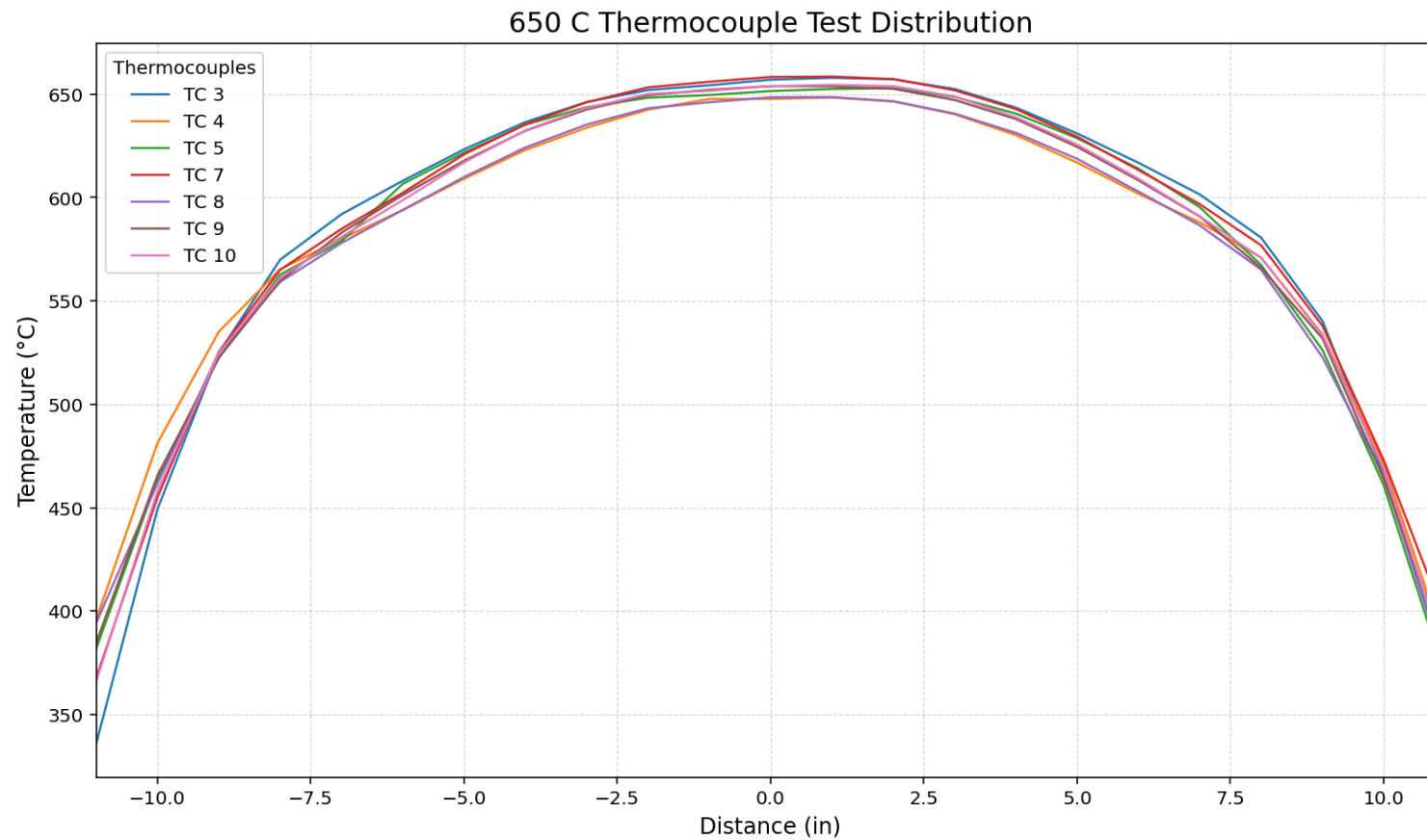
Preliminary Testing at INL

650°C Test with Cartridge Heaters Heat-Up/Cool-Down

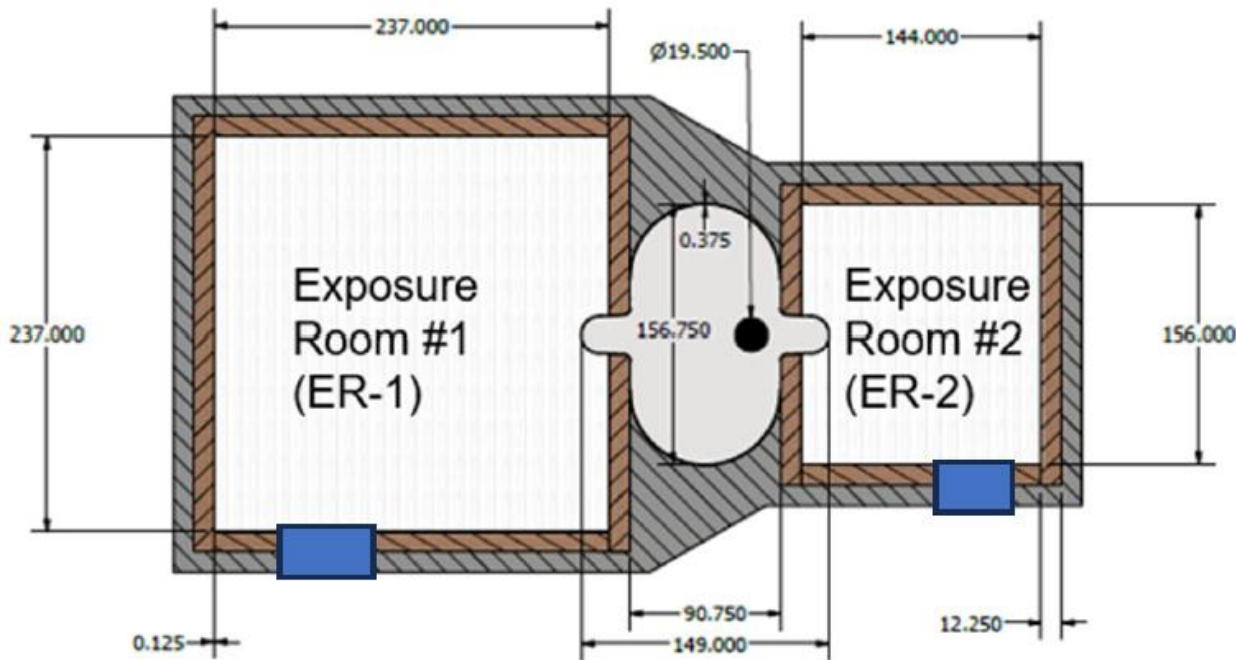


Preliminary Testing at INL

650°C Temperature Distribution



Performance of NQD During Irradiation at AFRRI



Experiment Goals:

- Test performance of NQD in high radiation environment
- Use NQD to collect data on prototype SPND responses under various radiation and thermal conditions (350°C)
- Test dosimetry package for accurate spectrum unfolding of radiation environment NQD is exposed to

Why AFRRI:

- Two exposure rooms with distinct spectrums (ER 1 shielded with Cd, ER 2 bare)
- Ease of access between rooms for quick movement of NQD
- Access ports for cabling allowing for heater control and sensor observation by experimenter

Proposed Dosimetry Package

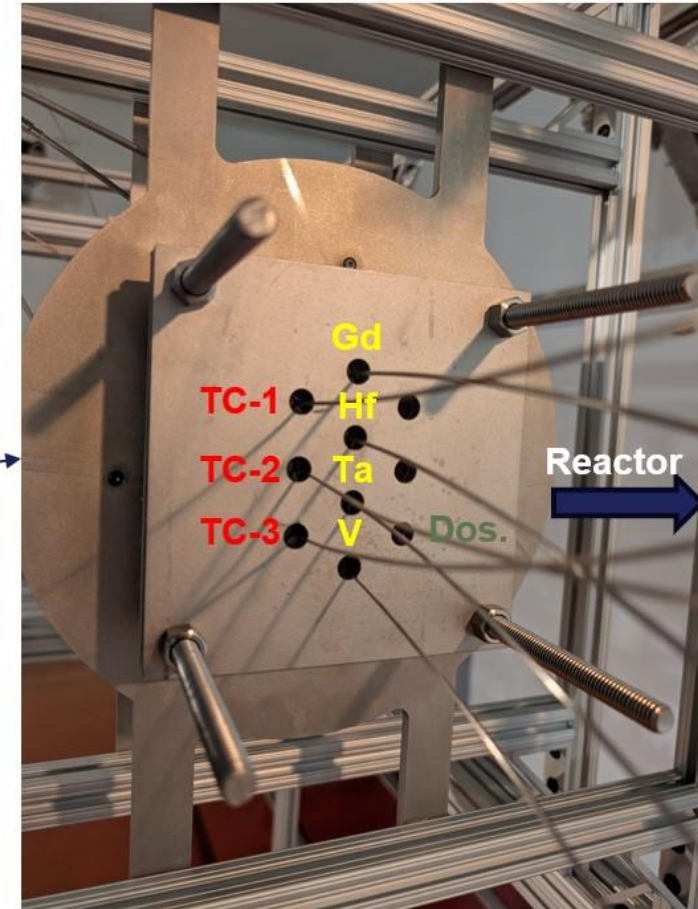
Reaction	Spectrum Weighted Cross Section (b)	Energy "Coverage" Range (MeV)	
		Beginning	End
Sc-45(n, γ)Sc-46	2.78E-01	3.73E-07	7.15E-02
Co-59(n, γ)Co-60	1.48E+00	4.43E-07	3.50E-04
Cu-63(n, γ)Cu-64	6.65E-02	3.83E-07	1.04E+00
Ag-109(n, γ)Ag-110m	1.54E+00	9.09E-07	1.14E-03
In-113(n, γ)In-114m	5.50E+00	9.35E-07	7.36E-02
Ta-181(n, γ)Ta-182	1.63E+01	2.15E-06	2.94E-03
W-186(n, γ)W-187	1.03E+01	8.34E-07	2.08E-04
Au-197(n, γ)Au-198	3.62E+01	9.09E-07	7.18E-04

ER-1 Dosimetry Package

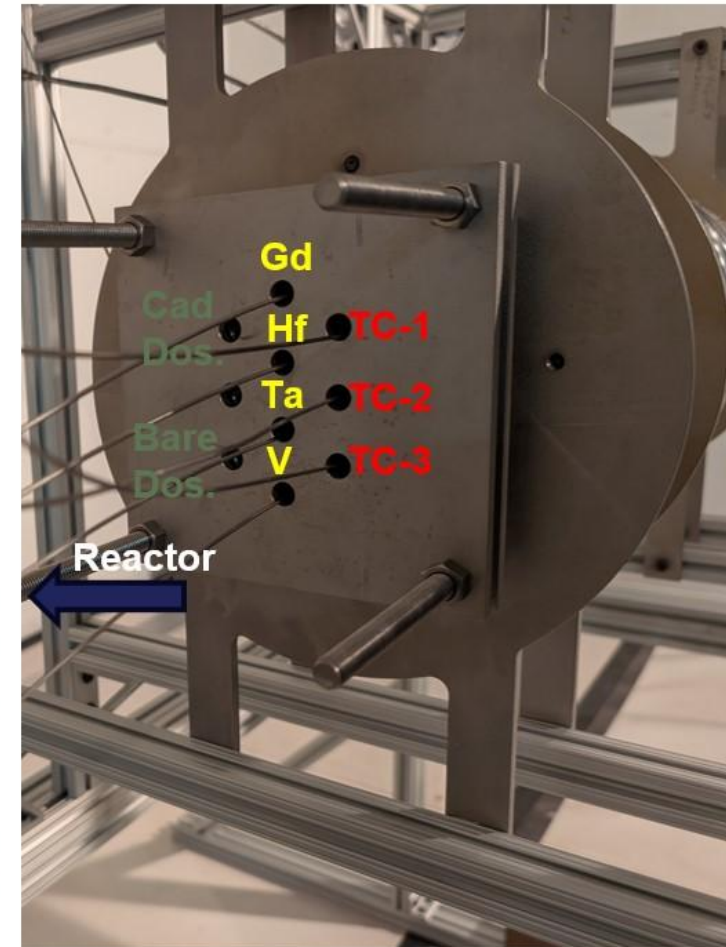
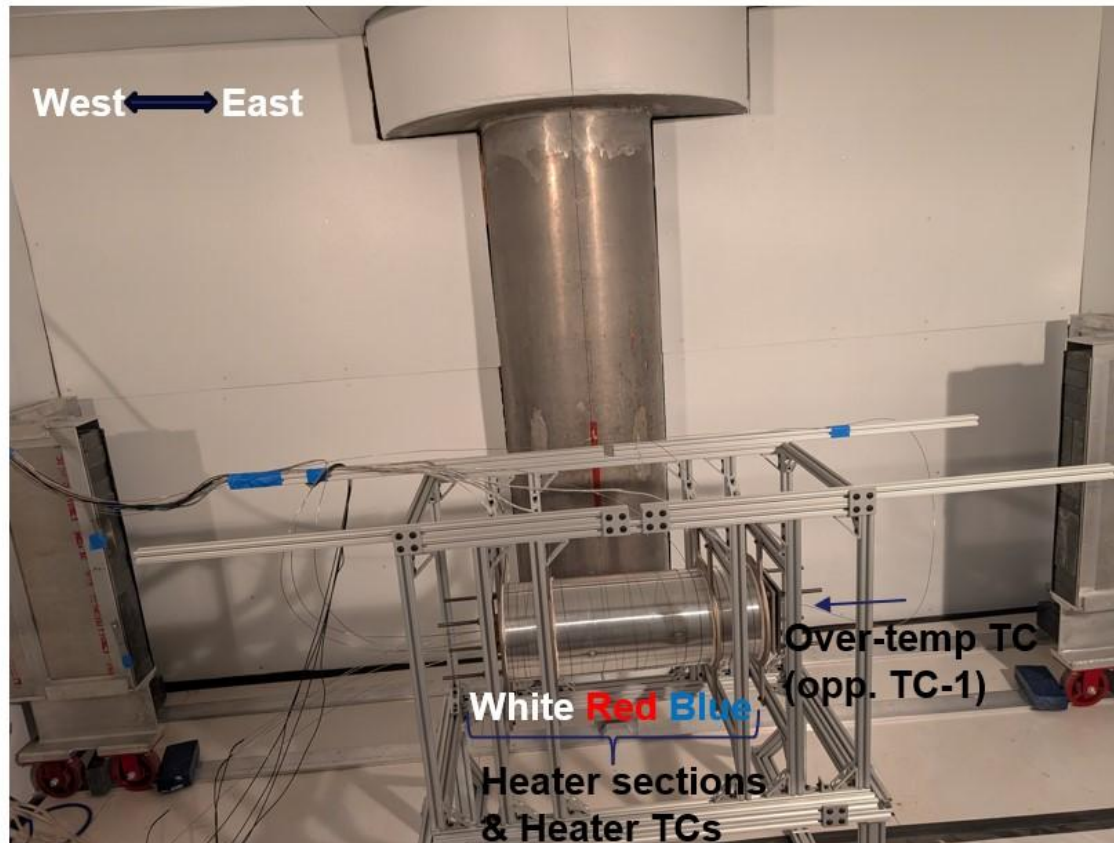
Reaction	Spectrum Weighted Cross Section (b)	Energy "Coverage" Range (MeV)	
		Beginning	End
Sc-45(n, γ)Sc-46	1.09E+01	3.96E-09	1.81E-06
Co-59(n, γ)Co-60	1.61E+01	4.08E-09	1.28E-04
Cu-63(n, γ)Cu-64	1.81E+00	3.96E-09	4.66E-04
Ag-109(n, γ)Ag-110m	2.88E+00	5.13E-09	5.24E-05
W-186(n, γ)W-187	2.31E+01	4.71E-09	1.61E-04
Au-197(n, γ)Au-198	6.75E+01	5.13E-09	3.50E-04
Co-59(n, γ)Co-60 w/ Cd Cover	1.51E+00	3.33E-08	2.03E-04
Cu-63(n, γ)Cu-64 w/ Cd Cover	6.00E-02	2.22E-08	9.24E-01
In-113(n, γ)In-114m w/ Cd Cover	4.34E+00	7.43E-07	7.15E-02
Ta-181(n, γ)Ta-182 w/ Cd Cover	1.28E+01	1.40E-06	2.94E-03

ER-2 Dosimetry Package

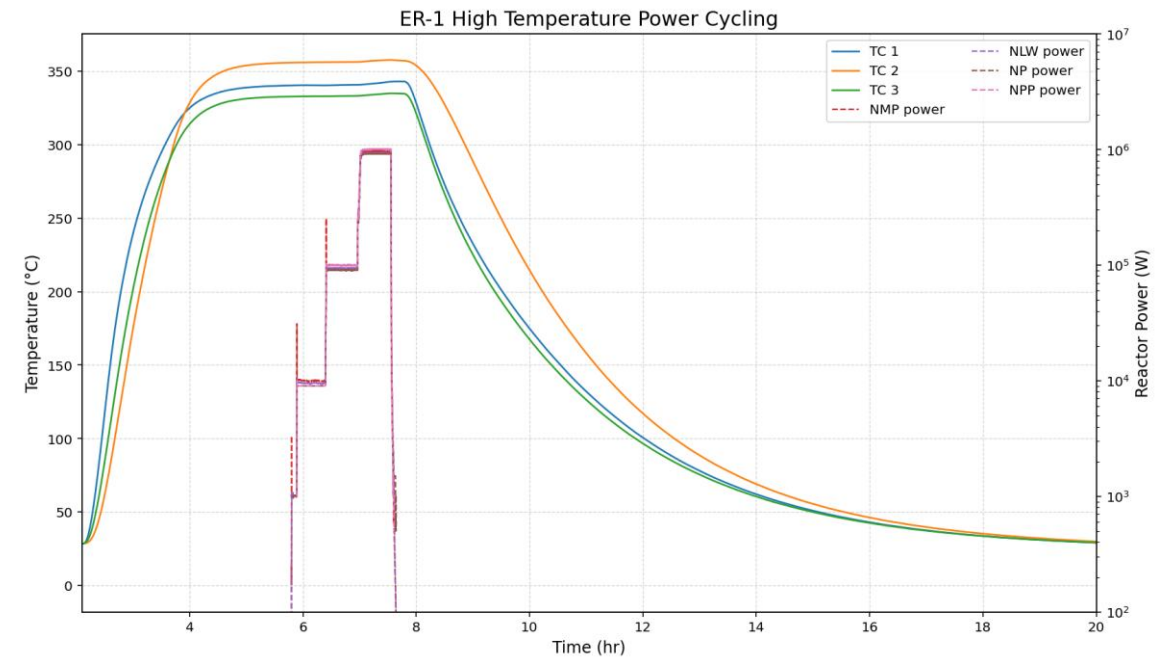
Performance of NQD During Irradiation at AFRRI Setup for Exposure Room 1



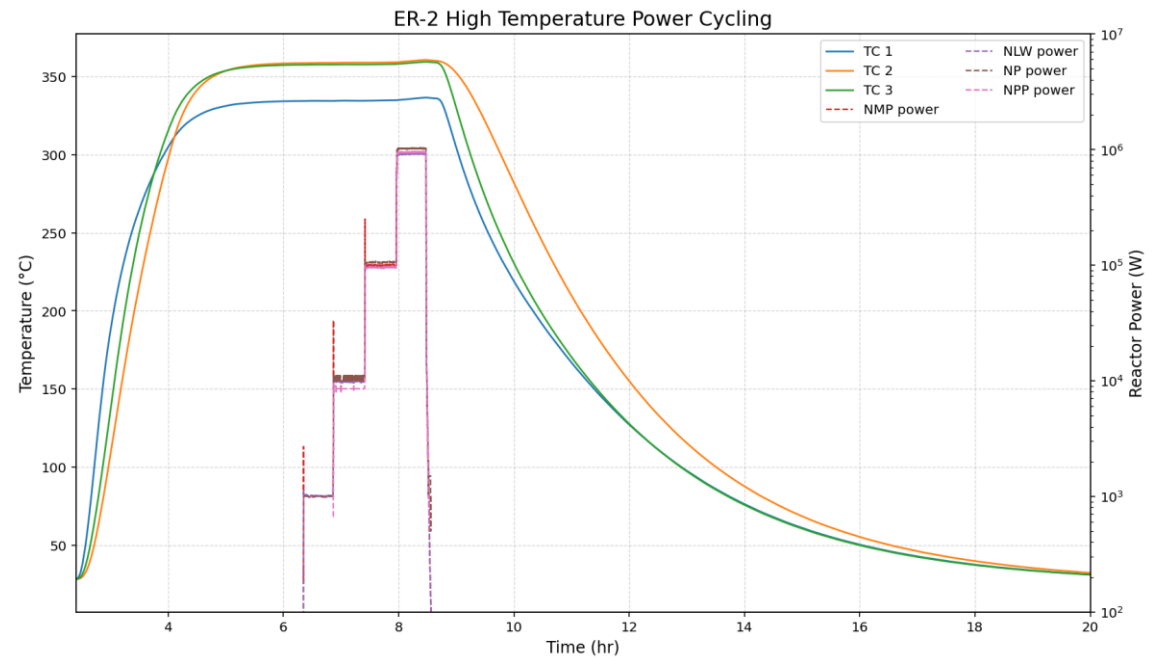
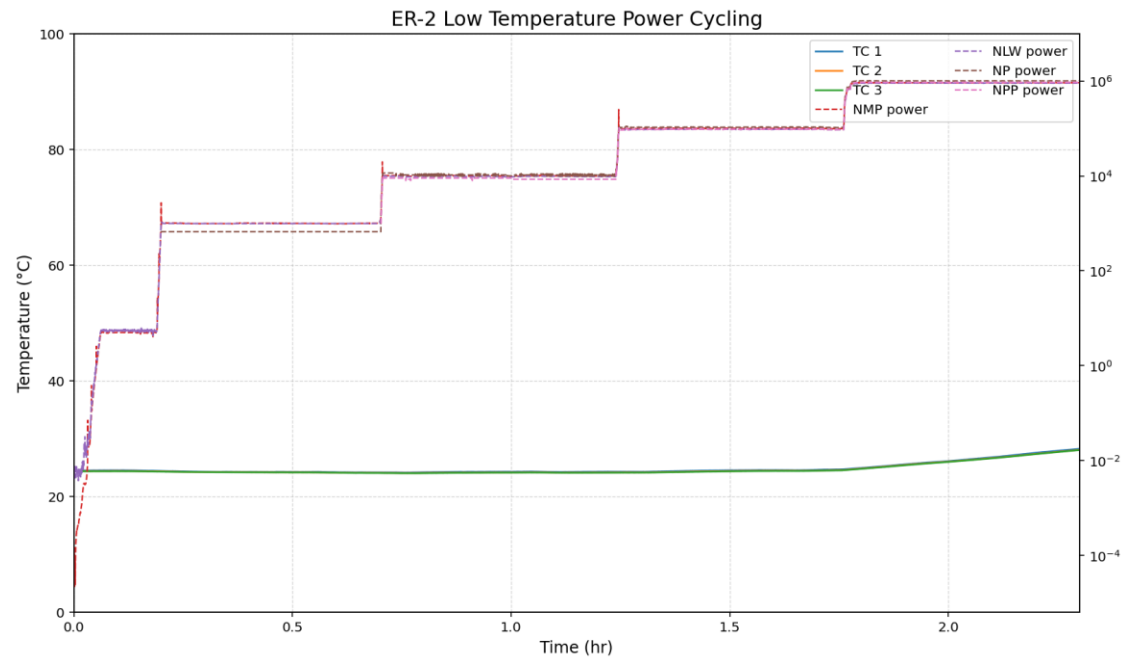
Performance of NQD During Irradiation at AFRRI Setup for Exposure Room 2



Performance of NQD During Irradiation at AFRRI Exposure Room 1 Low and High Temperature Tests



Performance of NQD During Irradiation at AFRRI Exposure Room 2 Low and High Temperature Tests



Performance of NQD During Irradiation at AFRRI

Dosimetry Results

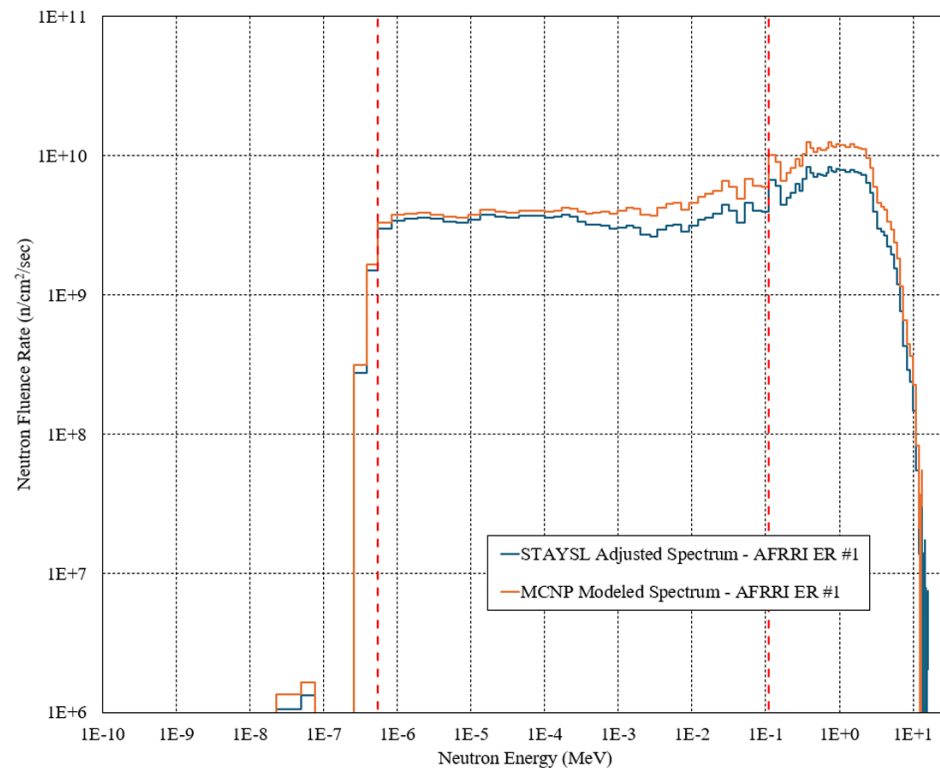


Figure 2. Neutron Spectrum for Exposure Room #1

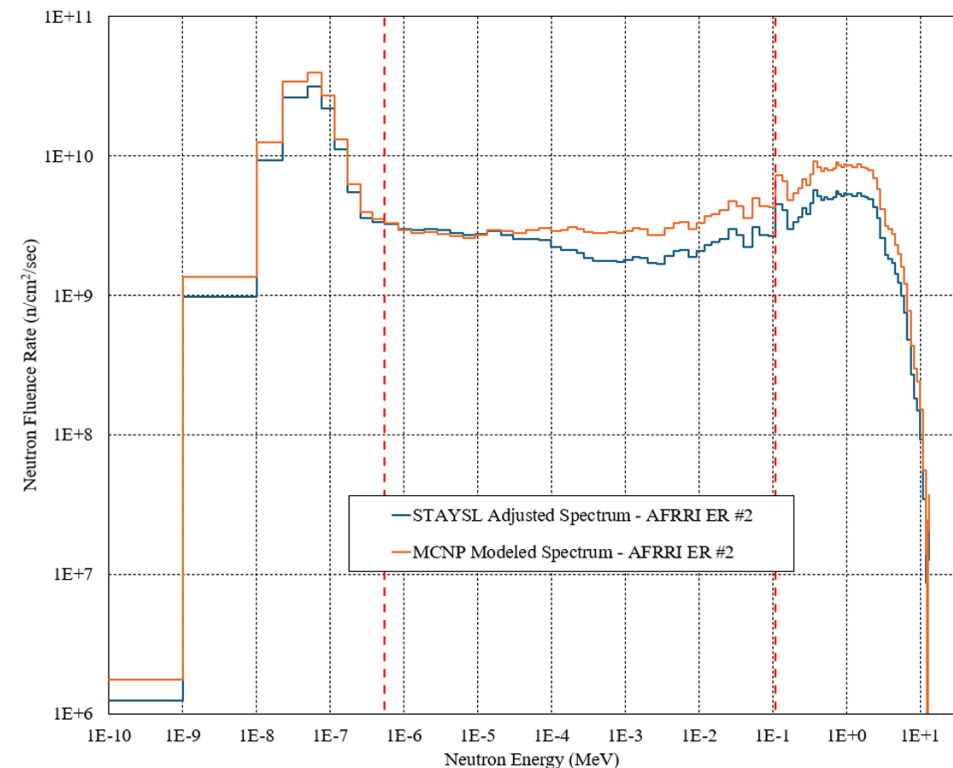
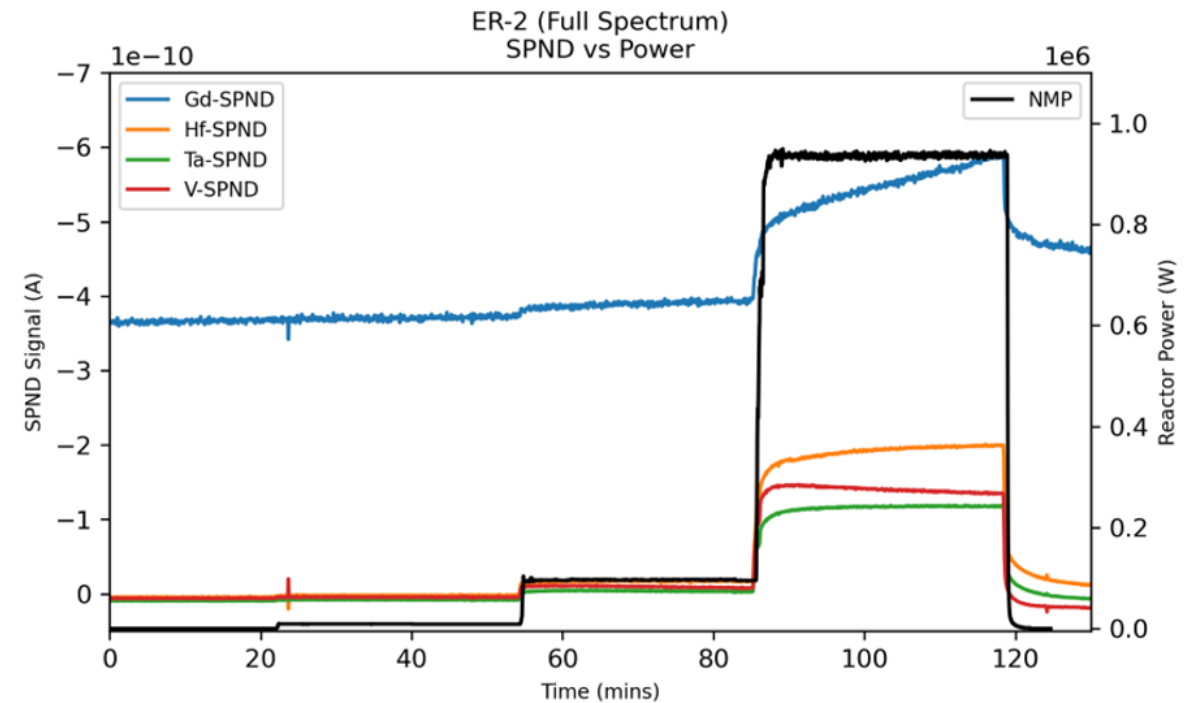
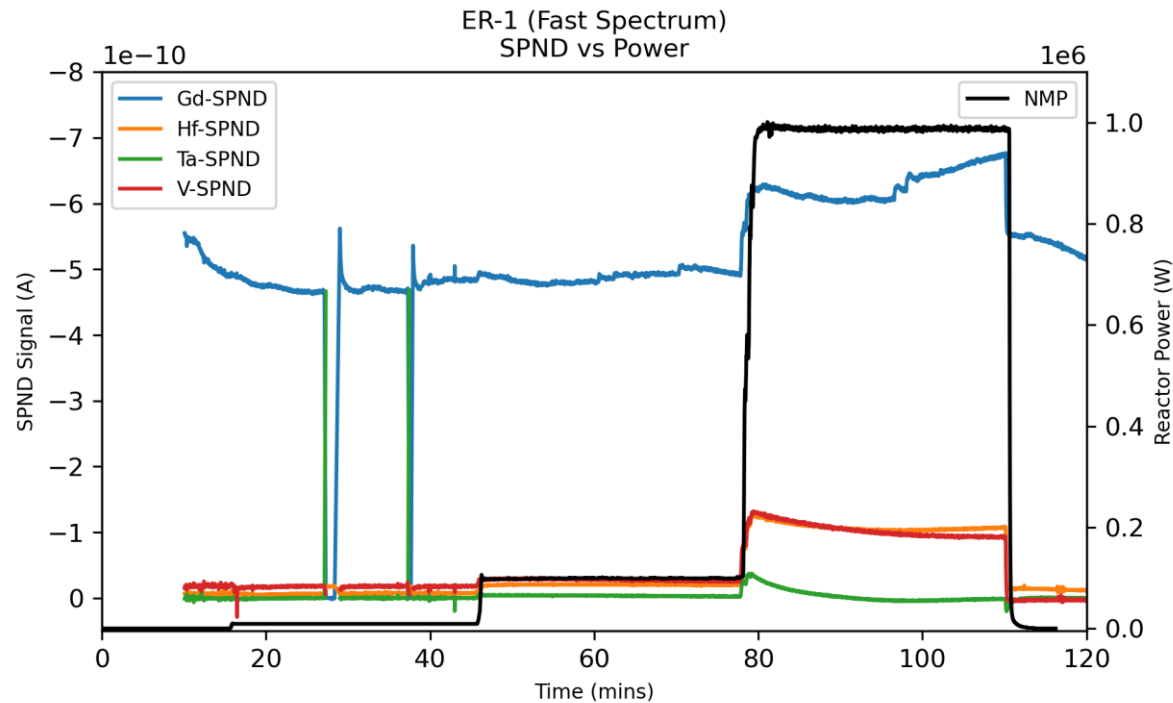


Figure 4. Neutron Spectrum for Exposure Room #2

Performance of NQD During Irradiation at AFRRRI

Preliminary SPND Results (Low Temperature)



Conclusions & Future Work

- **First experiment using the NQD went well**
 - Maintained desired temperatures repeatedly and reliably
 - No issues with DAQ or other electronic failures
 - Heat-up and cooling times were consistent with preliminary lab testing
- **High temperature SPND data is still being analyzed (will be in 2026 ASI annual report)**
- **Future Work**
 - Future testing for higher temperature operations (700°C next goal)
 - Tentatively planning on FY28 irradiation for ASI sensor testing, however, earlier experiments can be scheduled if there is interest

Acknowledgements





Idaho National Laboratory

Battelle Energy Alliance manages INL for the U.S. Department of Energy's Office of Nuclear Energy. INL is the nation's center for nuclear energy research and development, and also performs research in each of DOE's strategic goal areas: energy, national security, science and the environment.

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