U.S. DEPARTMENT OF ENERGY | Office of NUCLEAR ENERGY

Advanced Sensors and Instrumentation

The Development of an in-pile Sensor Qualification Strategy & Device

Austin Fleming, PhD

Irradiation Testing of Instrumentation

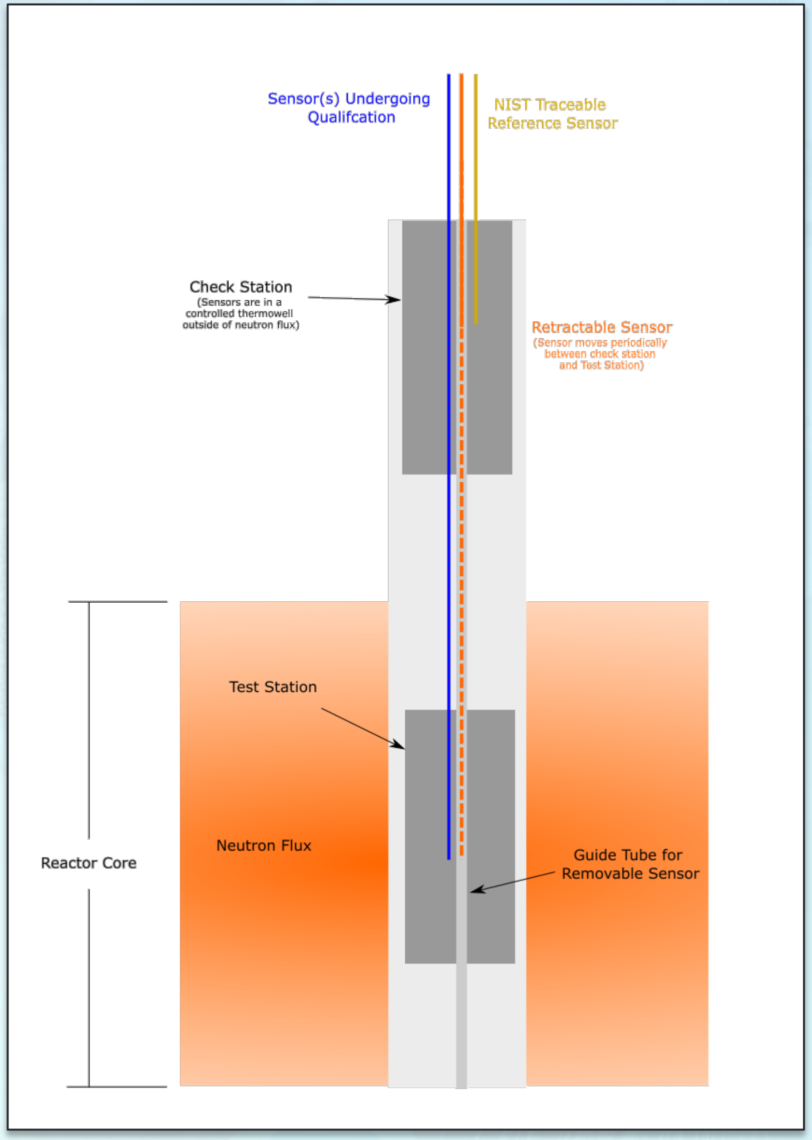
- A broad range of needs exist for the development and qualification for in-core sensors
- Low Overhead Testing
  - Provide fast and affordable results on sensor performance (quick and efficient access is prioritized over control and verification of irradiation conditions)
- Performance Testing
  - Measurand is controlled
  - Sensors are generally compared to a modelled value or other sensors
  - Most common type of testing
- Qualification testing
  - Highly controlled experiments with rigorously quantified uncertainties
  - NIST traceability references where possible with statistically significant data sets for a given sensor design

Qualification Testing

- Measurands to qualify
  - Temperature
  - Radiation (neutron & gamma)
  - Pressure
  - Displacement/Strain
- From a survey of needs temperature & radiation are the most needed
- Essentially putting a calibration laboratory inside a reactor
  - Need to provide the conditions in which the sensor is to be qualified
  - Need to know what the conditions are withing some allowable uncertainty band
  - Need to have a statistically significant number of sensors experiencing the conditions to provide an estimation of the performance of sensor design
- For most conditions, if we had a sensor we "trusted" or was qualified for these conditions, we wouldn't need to qualify one… Chicken and Egg problem

Qualification Testing (continued)

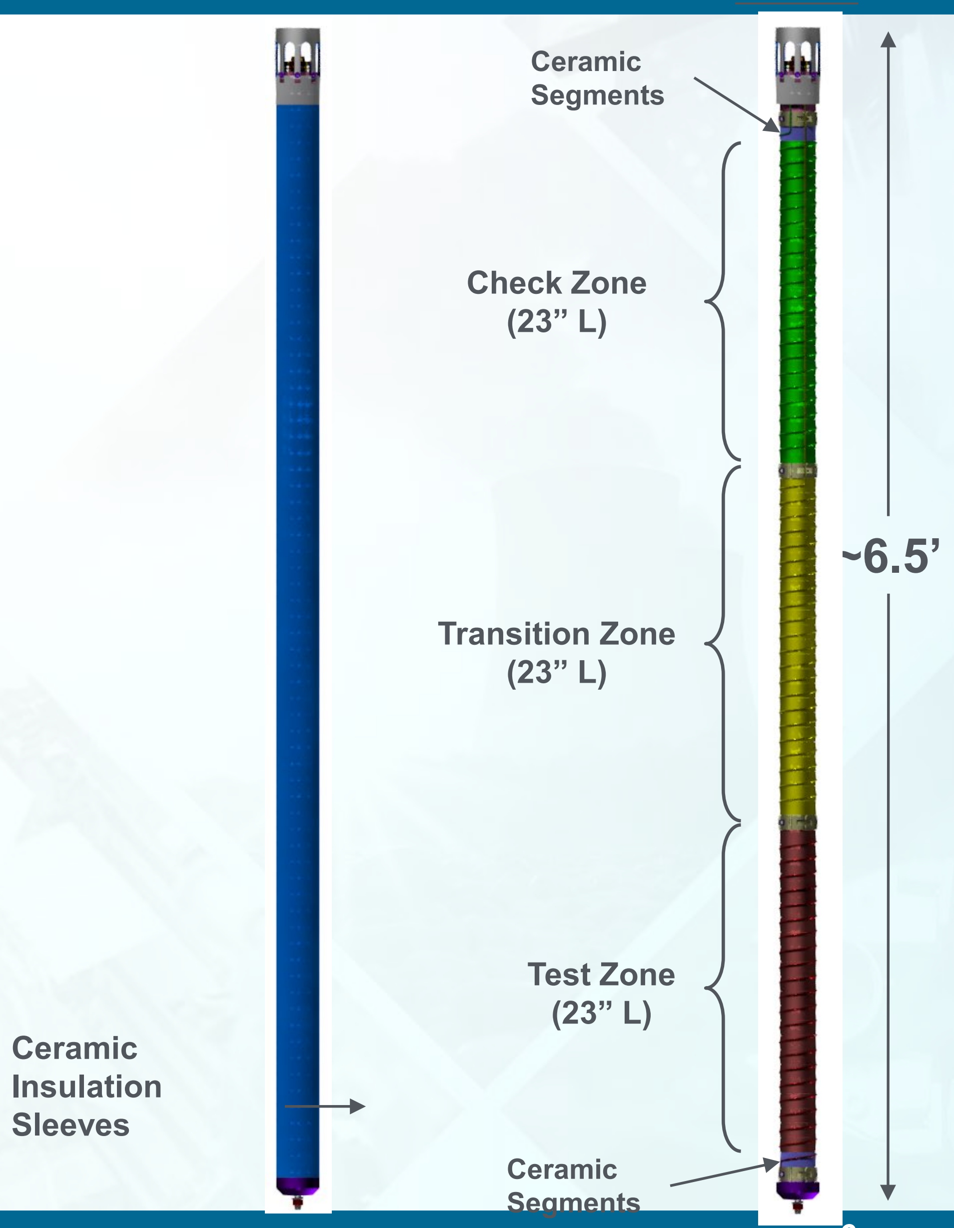
- First device is for temperature sensor qualification
  - Using a two measurement region approach
  - A “retractable” sensor “transfers” the traceability to the in-core sensors
  - At the end of the experiment a closure calibration is conducted to quantify any drift error in the reference sensors
- Different versions will be developed with different target temperatures
  - Low temperature ~500C, aluminum fabrication, low neutron worth and activation
  - Moderate temperature ~800-900 C, covers range of high interest to many advanced reactor designs, higher activating/neutron worth materials
  - High Temperature, refractory metals, ceramics

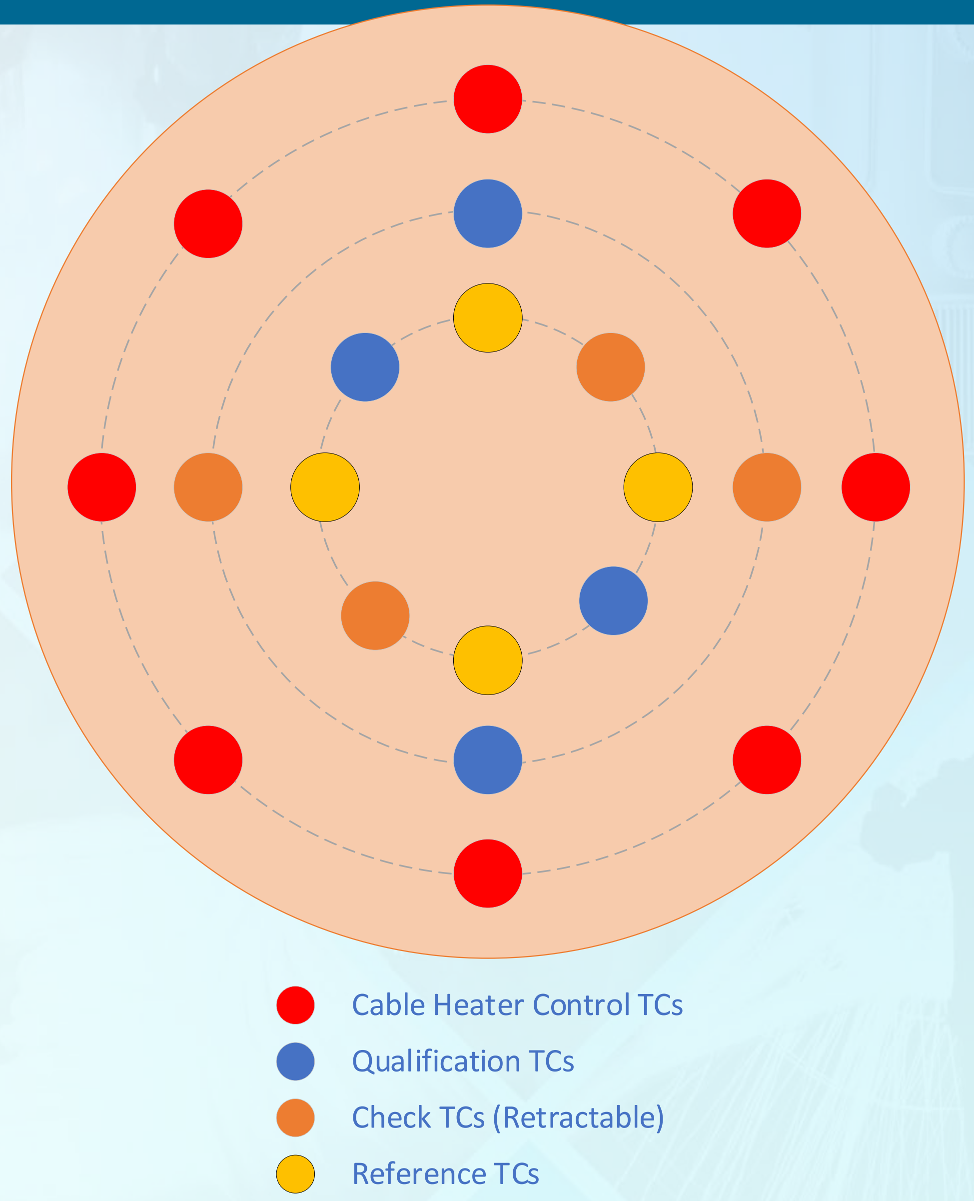


Qualification Testing positions

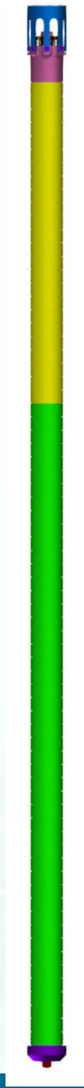
- NEET-ASI program is currently identifying possible irradiation positions to perform this qualification testing
- Ideally the device is compatible with several facilities
  - Large positions are desired because of the temperature uniformity requirements, and statistically significant samples
  - Possible positions identified
    - ATR medium I ($3.4*10^{13}$ thermal, $1.3*10^{12}$ fast, 3.25” diameter)
    - MIT 3GV ($4*10^{12}$ thermal, 3” diameter)
    - OSU 6.5”/9.5” Tubes ($\sim5*10^{11}$ thermal, $4*10^{11}$, 6.5” or 9.5” diameter)
    - NCSU standpipe ($1*10^{11}$ thermal, $5*10^{9}$ fast, 3.5”)
- Conceptual design which would fit within a 3” diameter irradiation position

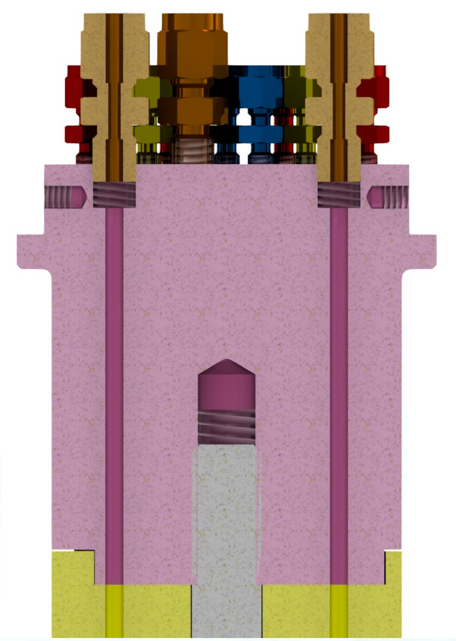
Device Design

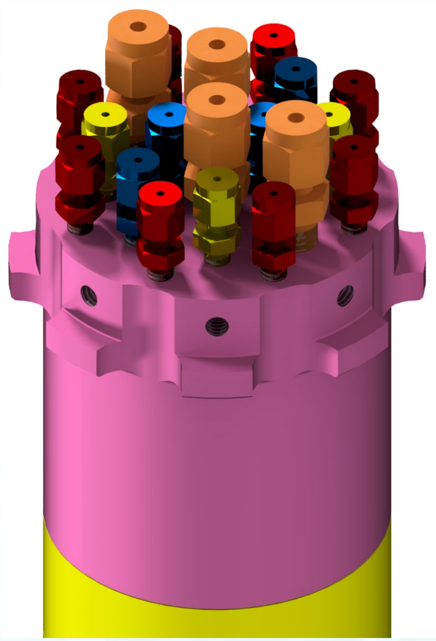


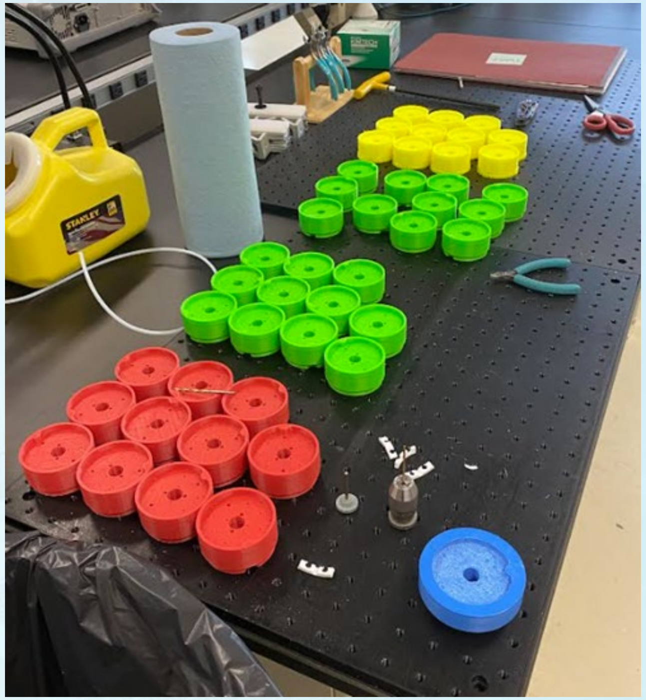


Device Design & Prototyping









Device Design & Prototyping

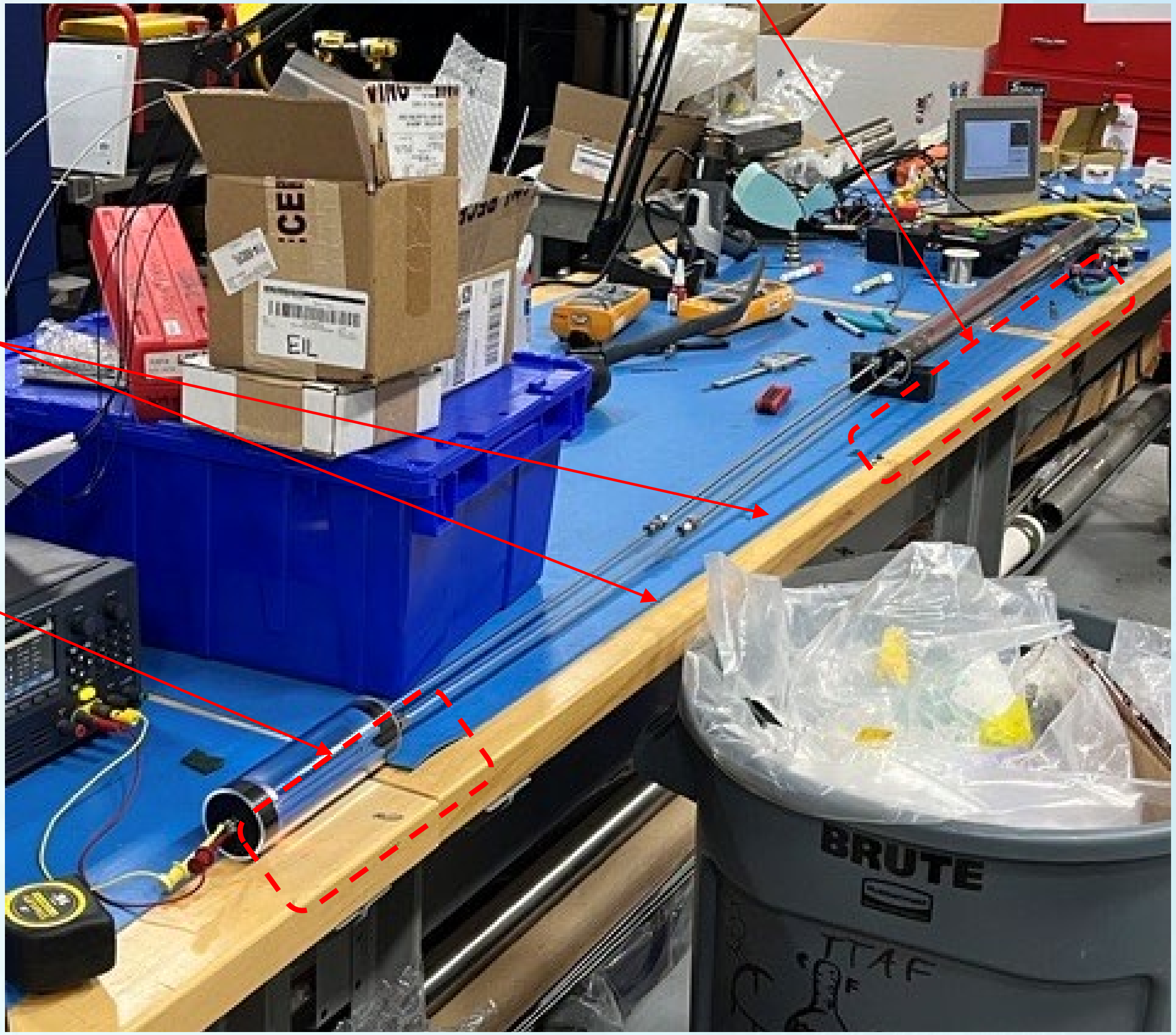
Retraction Assembly

- Lead screw moves TC(s) in and out of TQD
- Concentric tubing is required to address TC buckling during insertion

Lead screw assembly

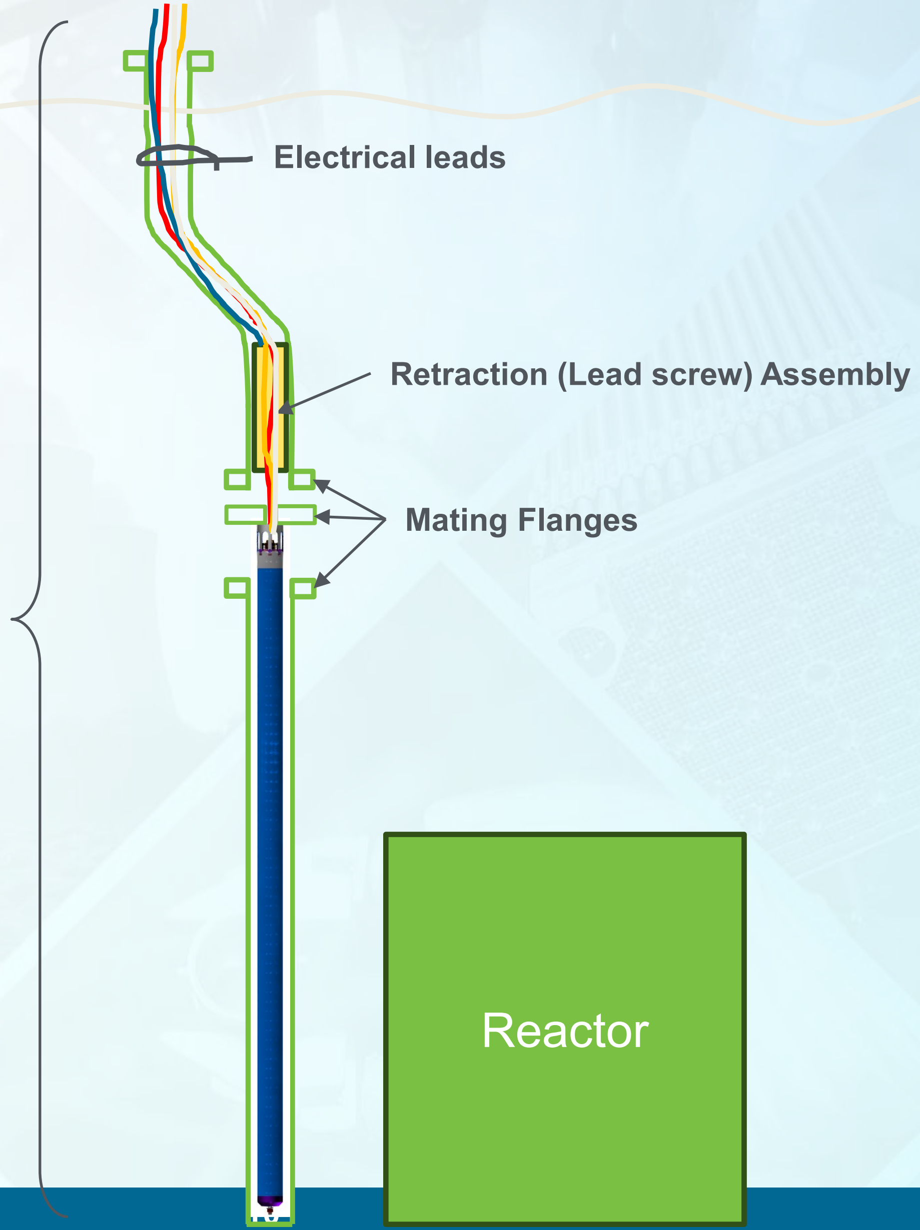
Swagelok tubing

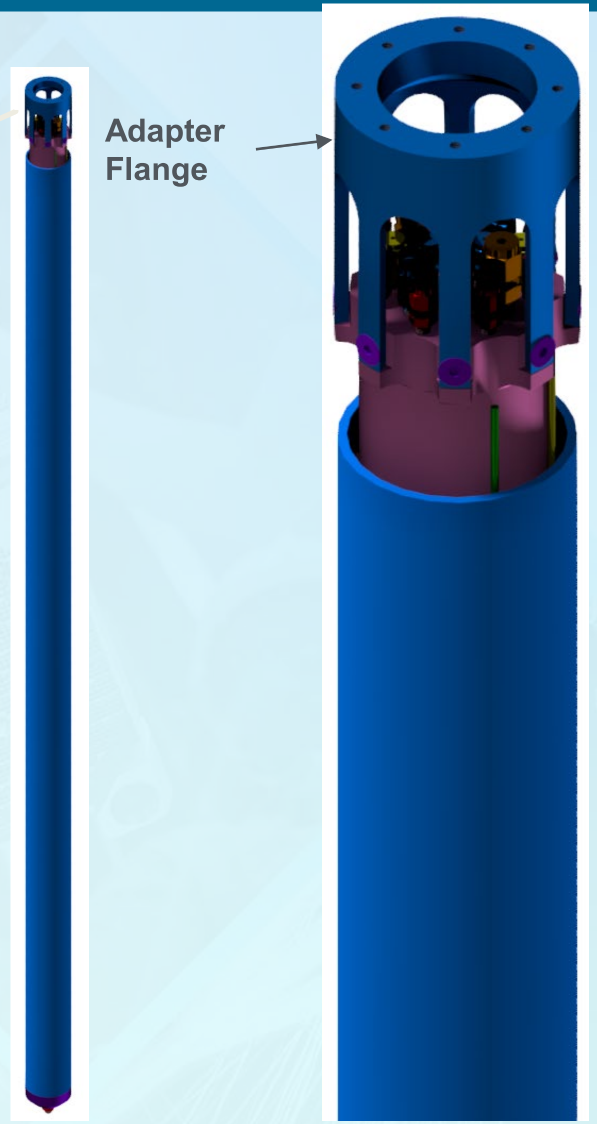
Simulated heat sink



Installation Concept

- Dry well/standpipe assembly is totally assembled dry and by hand
- Inserted into pool adjacent to reactor

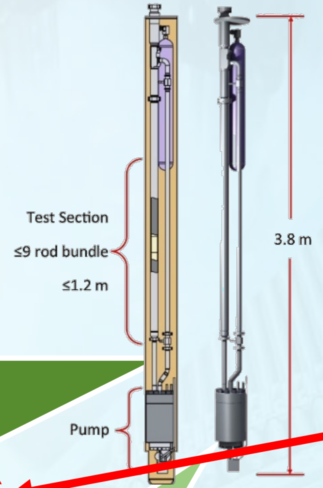




Qualification Testing

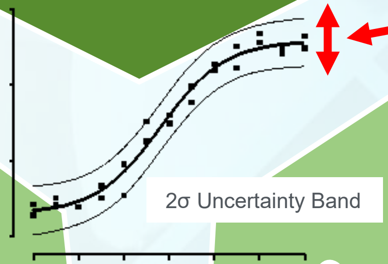
Qualification: science-based approach to show an instrument will operate in established limits for its intended purpose

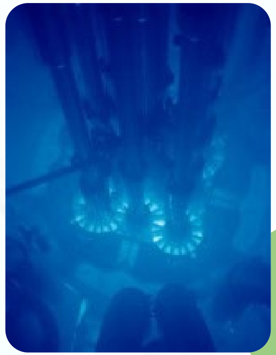
Experimental Device Integration (mechanical/ logistical)



- Geometry
- Feedthroughs
- Connectors
- Leads

Adequate definition = GOAL!





In-Pile Characterization & Testing

- Flux/fluence
- Electromagnetic environment
- Facility integration

Out-of-Pile Characterization & Testing

- Temperature/Pressure
- Coolants
  - Chemistry/Flow
- Transient response

Summary & concluding thoughts

- We’ve identified a need to provide more rigorous sensor qualification for several parameters and ranges
- This will rigorously qualify a sensors ability to accurately measure under the ideal conditions. It does not mean the same performance would be achieved under any given application (experiment device integration from previous slide)
    - Ideally no cross-sensitivity to irradiation conditions and sensor integration effects. Therefore out-of-pile testing can establish a bounding uncertainty by combining effects (Cladding TC example)

Thank You