N. Woolstenhulme, NSUF Program Review Apr 2024

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INL Irradiation Testing Capabilities

Idaho National Laboratory

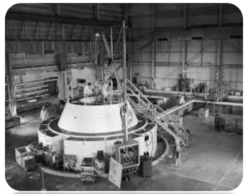
Intro & Outline

- Short presentation, skipping some types of “irradiation” (e.g., gamma, ions, isotopes)
  - Focus on Material Test Reactor missions: High flux or extreme conditions neutron irradiation of nuclear fuels and materials
  - In other words, only covering Advanced Test Reactor (ATR) and Transient Reactor Test facility (TREAT)
- Describe ATR and TREAT in context of national capabilities historic and current.
- Background on types of ATR and TREAT experiments in context of “irradiation testbeds”
  - Centered around reactor technologies DOE is most invested in (LWR, VHTR, and SFR)
- Sneak peak of near-future developments that may be interesting to NSUF

A Legacy of Pioneers

MTR

ETR

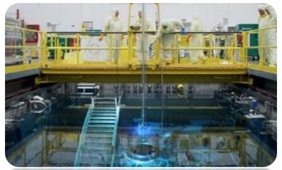


Thermal Spectrum

ATR

MITR

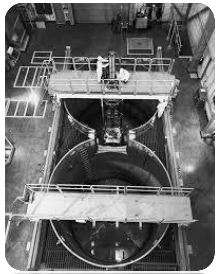
HFIR



Transient

TREAT

SPERT



PBF

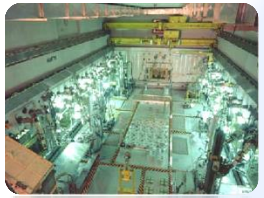
LOFT

Fast Spectrum

EBR-II

FFTF

The Survivors who Carry On

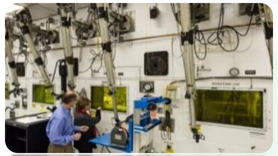


ATR

-High flux, large volume, agility in spectral tailoring
-Water loops for fuels testing
-Unique dynamic testing capabilities

MITR

-Representative flux
-Unique efficiencies in sensors & corrosion loop testing



HFIR

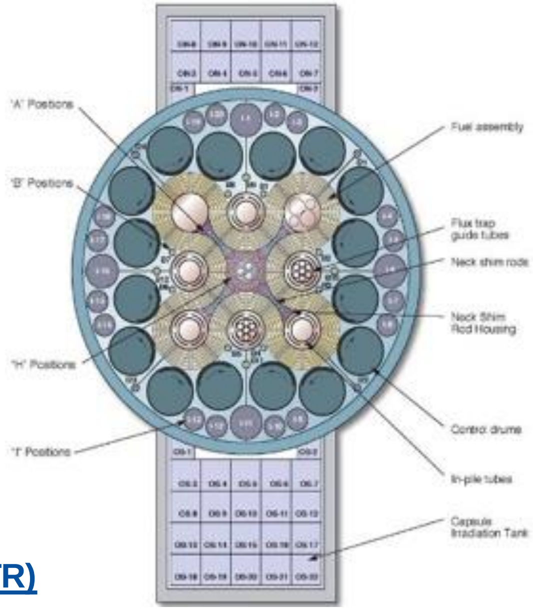
-Very high flux on subsize tests
-Unique capabilities for accelerated material testing

TREAT

-Extreme power maneuvers
-Unique fuel safety testing abilities

-Abilities to Produce, Receive, and Instrument Specimens
-World Class Hot Cell Exam/Test Capabilities on Site
-Multi-Lab Expertise in Test Design and Data Quality
-Proactive Planning, Use, and Stewardship of Testbeds

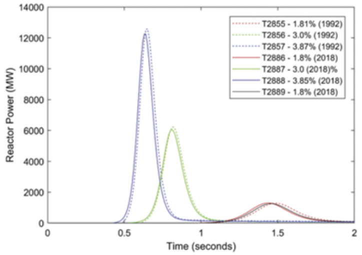
INL’s Test Reactors



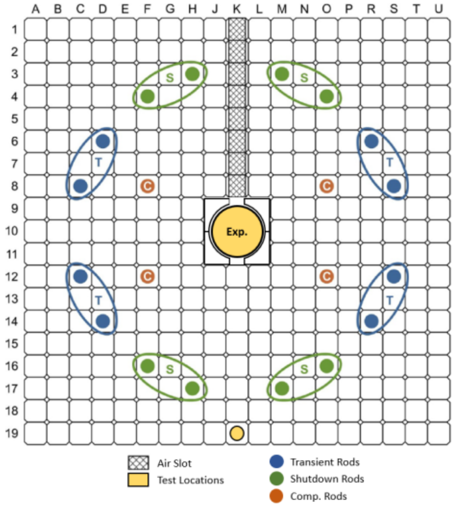
Advanced Test Reactor (ATR)

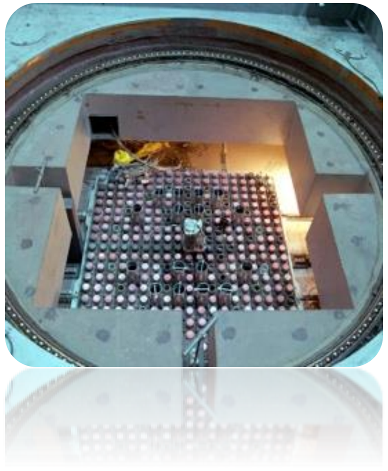
- Water-cooled plate-type MTR started 1967, still one of the newest and most advanced MTRs today
- Serpentine driver core creates nine flux traps and numerous other test positions
- High flux, large useable test geometries (1.2 m long core), and high capacity factor (for an MTR, ~200 day/yr)
- Rich history of capsule, lead out, and loop irradiations
- Unmodified neutron spectra (thermal to fast ratio): Inner core ~1:1, reflector ~10:1

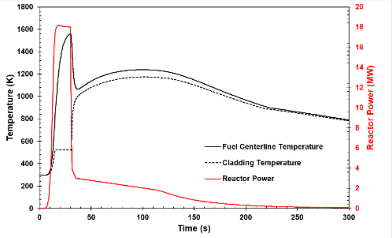
Position	Diameter (cm/in)[a]	Thermal Flux (n/cm^2-s)[b]	Fast Flux (E>1 MeV) (n/cm^2-s)
Northwest and			
Northeast Flux Traps	13.3/5.250	4.4×10^{14}	2.2×10^{14}
Other Flux Traps	7.62/3.000[d]	4.4×10^{14}	9.7×10^{13}
A-Positions			
(A-1 - A-8)	1.59	1.9×10^{14}	1.7×10^{14}
(A-9 - A-16)	1.59/0.625	2.0×10^{14}	2.3×10^{14}
B-Positions			
(B-1 - B-8)	2.22/0.875	2.5×10^{14}	8.1×10^{13}
(B-9 - B-12)	3.81/1.500	1.1×10^{14}	1.6×10^{13}
H-Positions (14)	1.59/0.625	1.9×10^{14}	1.7×10^{14}
I-Positions			
Large (4)	12.7/5.000	1.7×10^{13}	1.3×10^{12}
Medium (16)	8.26/3.500	3.4×10^{13}	1.3×10^{12}
Small (4)	3.81/1.500	8.4×10^{13}	3.2×10^{12}



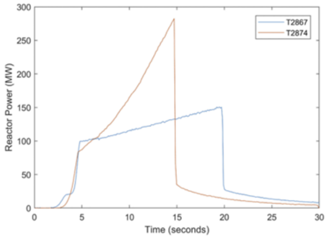
GW-Class Fast Pulses







LOCA Shaped Transient



Overpower Ramps

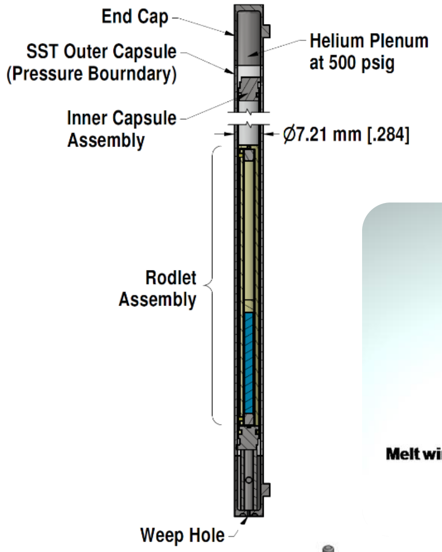
Transient Reactor Test facility (TREAT)

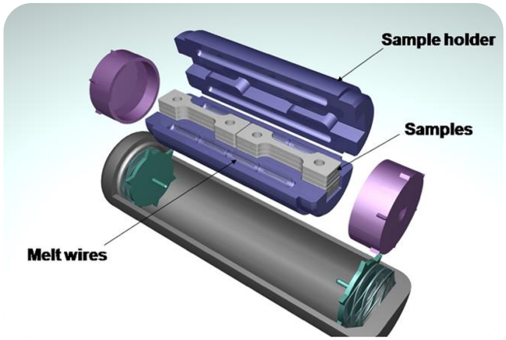
- Graphite-based transient reactor ran from 1959-1994, refurbished and restarted in 2017
- Unparalleled transient shaping capability, rich history of fuel safety research
- Reactor layout facilitates real time data monitoring

Types of ATR Experiments

ATR Experiment Categories

- Drop-in capsules:
  - Inert gas gap to elevate temperature, passive flux & temperature monitoring (measured in PIE)
  - Cd-lined basket used to absorb thermal neutrons for fast reactor fuels tests
- Gas Lead-outs:
  - Thimble tube with gas and instrumentation lines
  - Real time sweep gas composition control to adjust temperature and enable gamma spec monitoring (e.g., AGR series)
- Loop System
  - Instrumented specimens in PWR loops, chemistry and thermal hydraulic control via support equipment in shielded cubicles
- All ATR experiment types used for fuel and materials





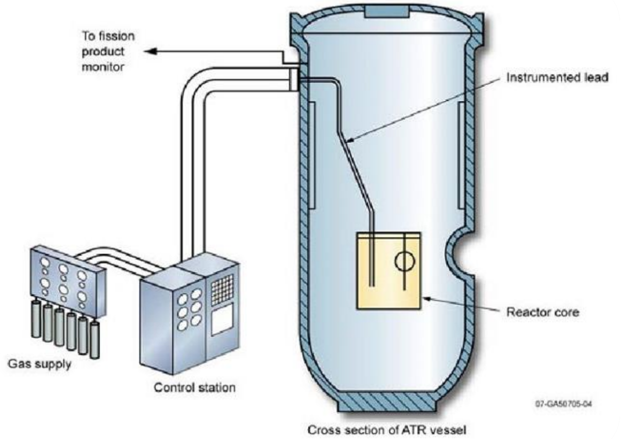
Key

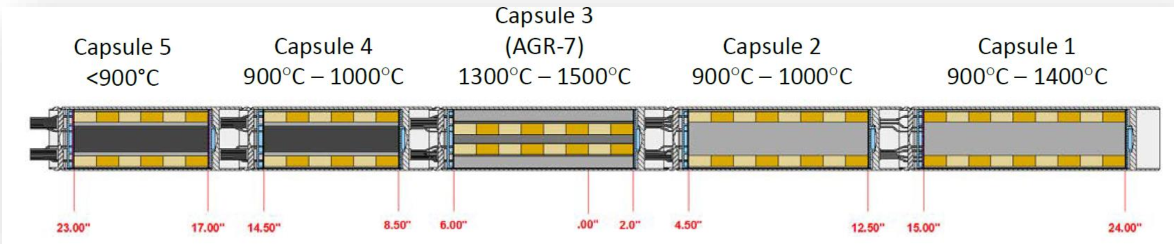
Separate effects, multiple testbeds

LWR Testbed

SFR Testbed

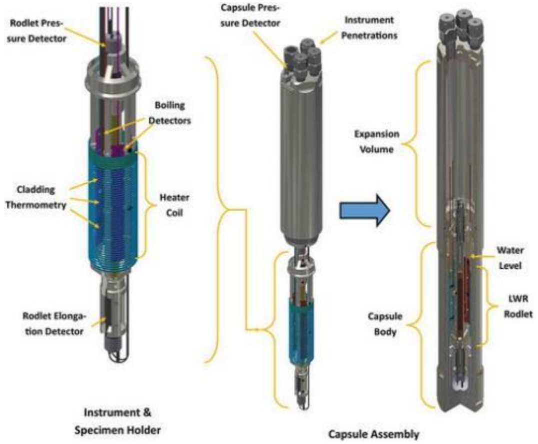
VHTR Testbed

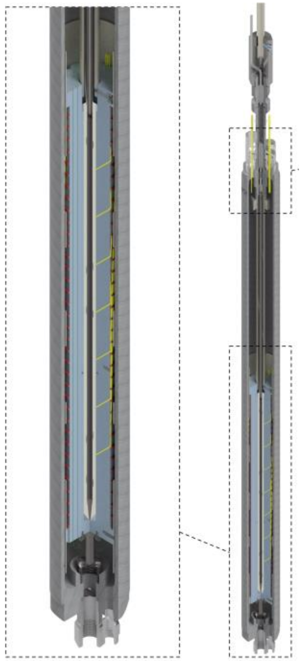




Types of TREAT Experiments

- Static capsules (transient power shape create desired specimen response under capsule heat transfer conditions)
  - SETH, inert gas capsule
  - SERTTA, liquid water capsule
  - THOR, sodium bonded metal heat sink capsule
  - GHOST, graphite heat sink capsule
- Active capsules (transient power shape and active thermal hydraulic controls used to create desired specimen response)
  - TWIST water-blowdown capsules for LOCA testing
  - TWERL recirculating water loop for fast ramp/DNB testing (concept under development)
  - Mk-IIIR recirculating sodium loop
- All fuel-bearing TREAT tests are instrumented (there is little desire for "drop-ins" in transient testing)





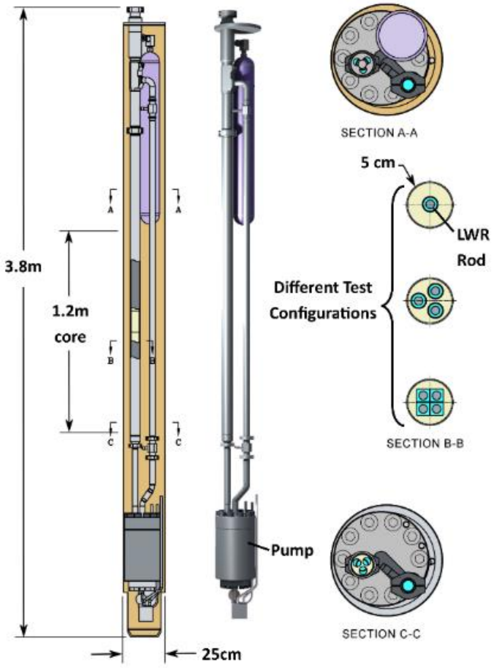
Key

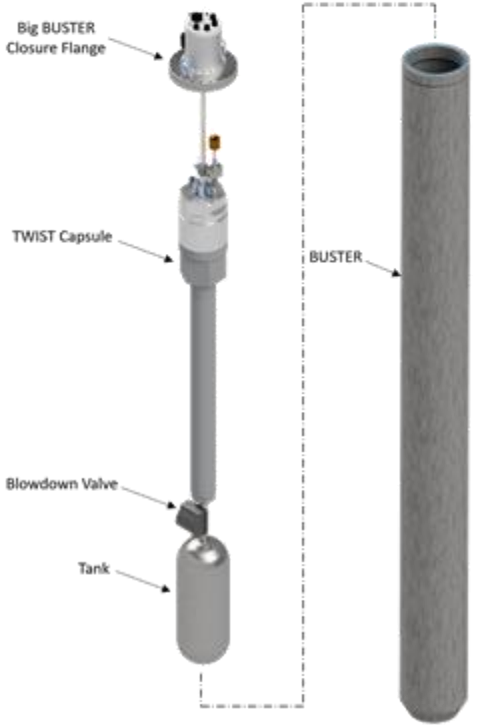
Separate effects, multiple testbeds

LWR Testbed

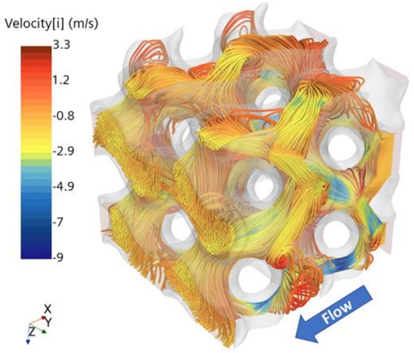
SFR Testbed

VHTR Testbed

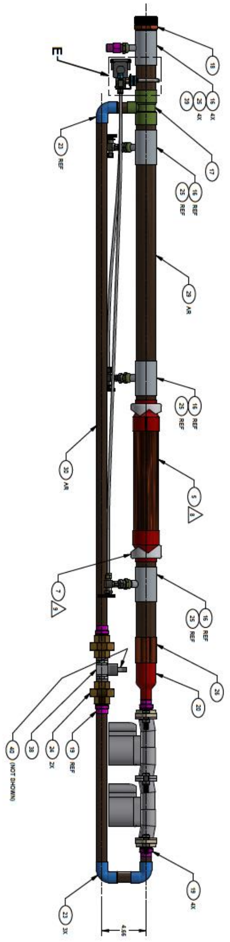


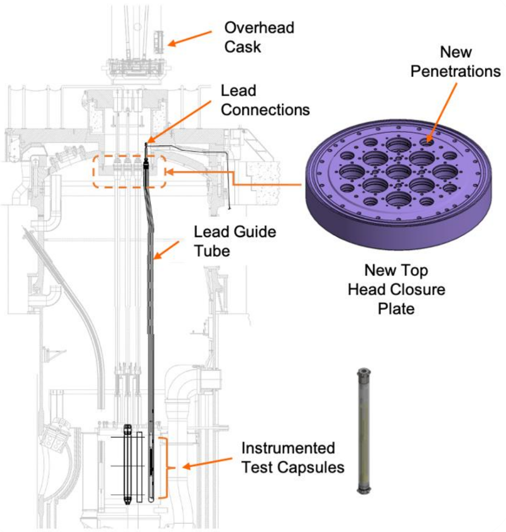


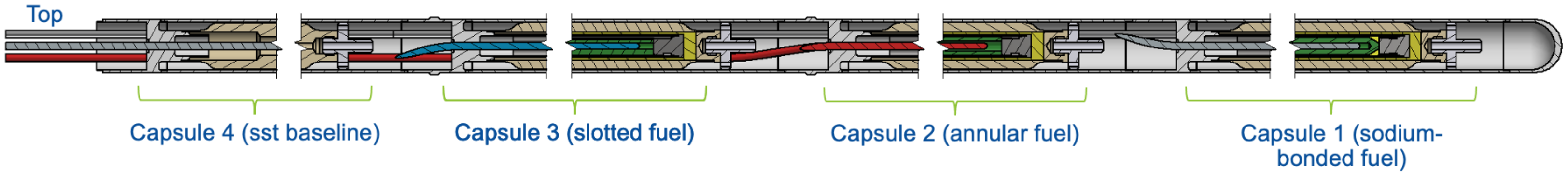
Near-Future Capabilities
(a short selection that may interest NSUF PI's)



- Early 2025: Low-cost warm-water loop for "Nuclear-Heated Flow Testing" in TREAT
  - Novel approach to measuring heat transfer behavior in advanced fuel geometries that cannot be simulated with electrical heating
  - To be deployed for Intertwined Nuclear Fuel Lattice for Uprated heat eXchange (INFLUX)
- Later 2025: New design "instrumented capsules" to be deployed in ATR
  - Fits between drop-in capsules and gas lead-outs in cost/capability spectrum
  - First test (IMPACT-1) to measure thermal conductivity evolution of metallic fuel
  - Other adaptations envisioned (ceramic fuel, fission gas release measurement)







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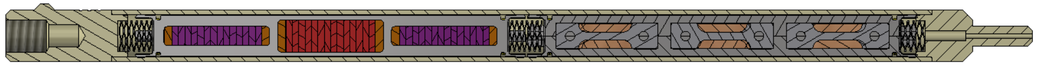
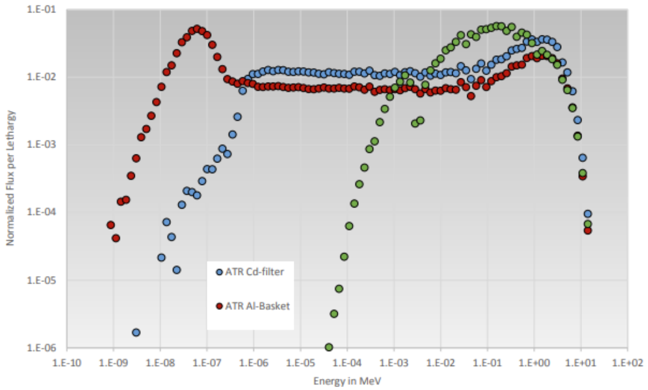
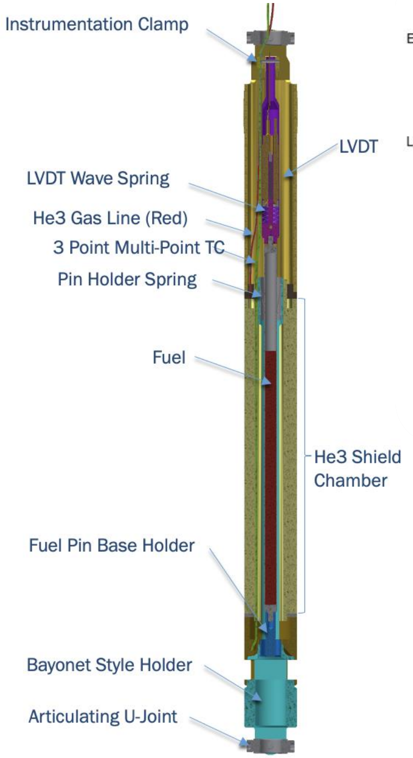
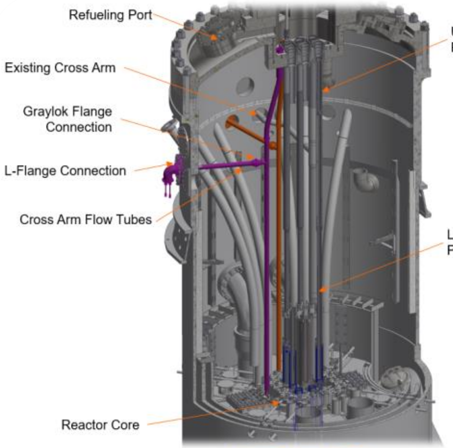


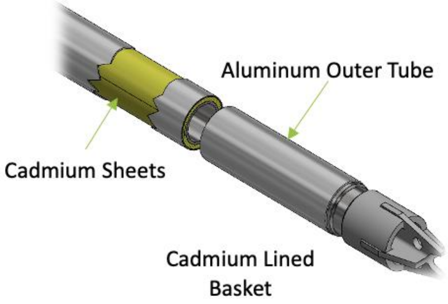


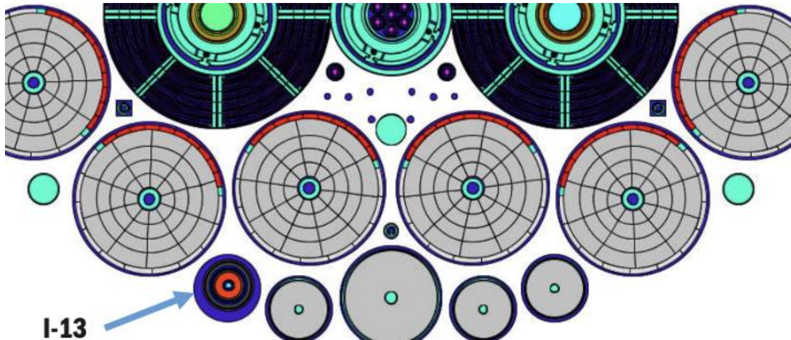
- ~2026: New INM investigation for fast reactor materials specimens (i.e., unfueled)
  - Assessing fast reactor specimens in various neutron energy spectra, comparing transmutations to true fast reactor (e.g., He production)
  - Some materials should go to HFIR flux trap (~10 dpa/yr, very limited neutron filtering)
  - Other materials should go to ATR OA position (~6 dpa/yr, with thermal neutron filtering), design forthcoming for INM-OA capsule in established Cd-basket
- ~2027: New water loops, and PCI ramp testing
  - AFC to install two new water loops in ATR Med-I positions "I-Loops" for LWR-ATF testing
  - 1 Loop for PWR condition, 1 Loop for BWR condition, either capable of flux manipulation for PCI ramp testing with ^{3}He screen





I-Loop Tubes in ATR





Thanks for your attention, any questions?