Advanced Test Reactor National Scientific User Facility Advancing Nuclear Technology

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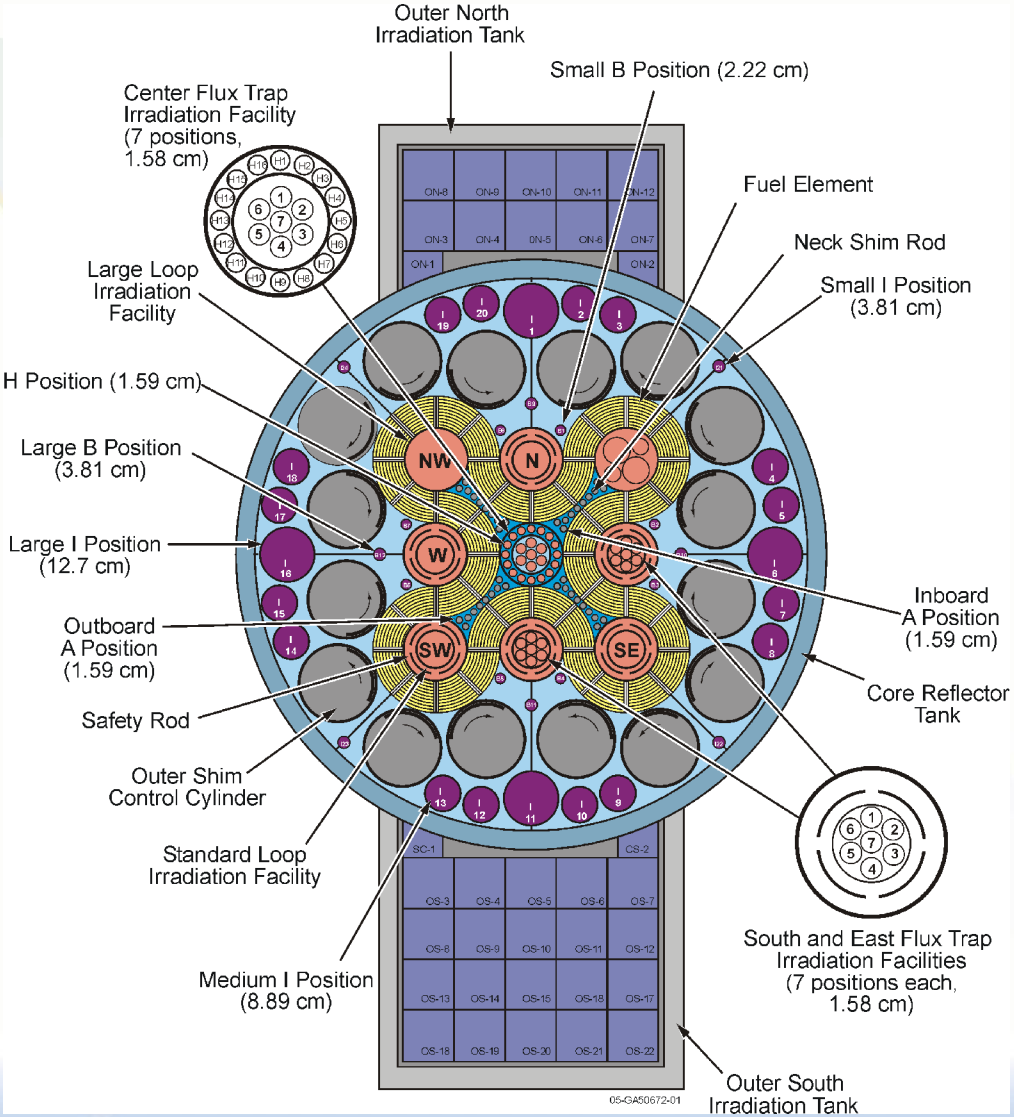
Idaho National Laboratory

ATR National Scientific User Facility

ATR Core Cross Section

- Test size – up to 5.0” diameter
- 77 Irradiation Positions
  - 4 Flux Traps
  - 5 In-pile tubes
  - 68 in Reflector
- Approximate Peak Flux
  - 1 x 10^{15} n/cm^2-sec thermal
  - 5 x 10^{14} n/cm^2-sec fast
- Rotating Hafnium Control Cylinders – symmetrical axial flux
- Power/Flux Adjustments (Tilt) across the Core



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ATR Operations

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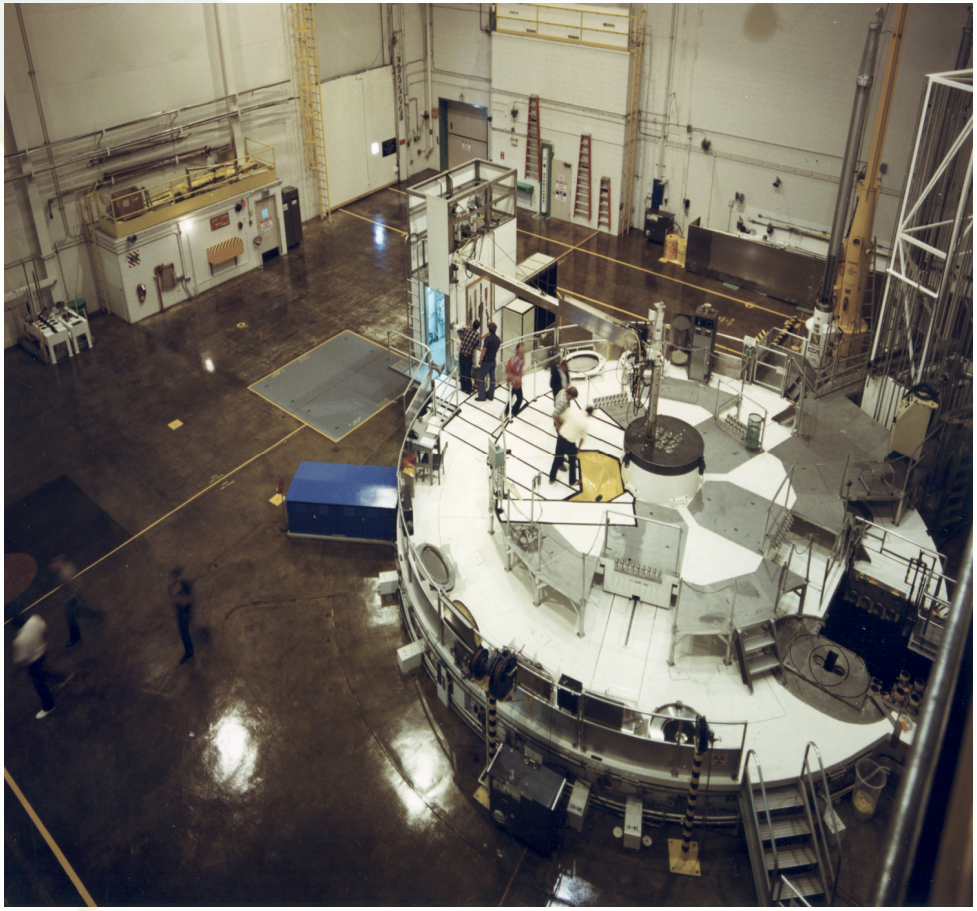
- In Operation since 1967
- Operating Cycles
  - Standard operating cycle is 6 to 8 weeks
  - Occasionally short high power cycles of 2 weeks
  - Standard reactor outages are 1 or 2 weeks
  - Operations for approximately 250+ days per year
- Off-load and reload all fuel each outage
- Core Internals Changeout every 7 to 10 years



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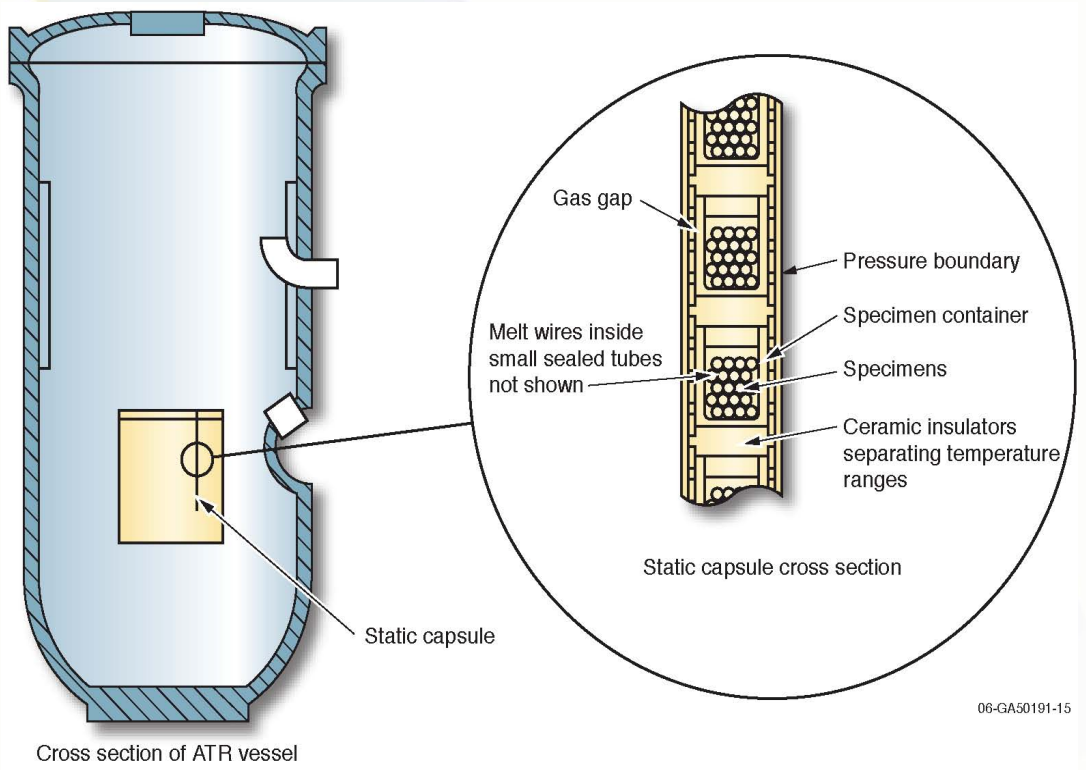
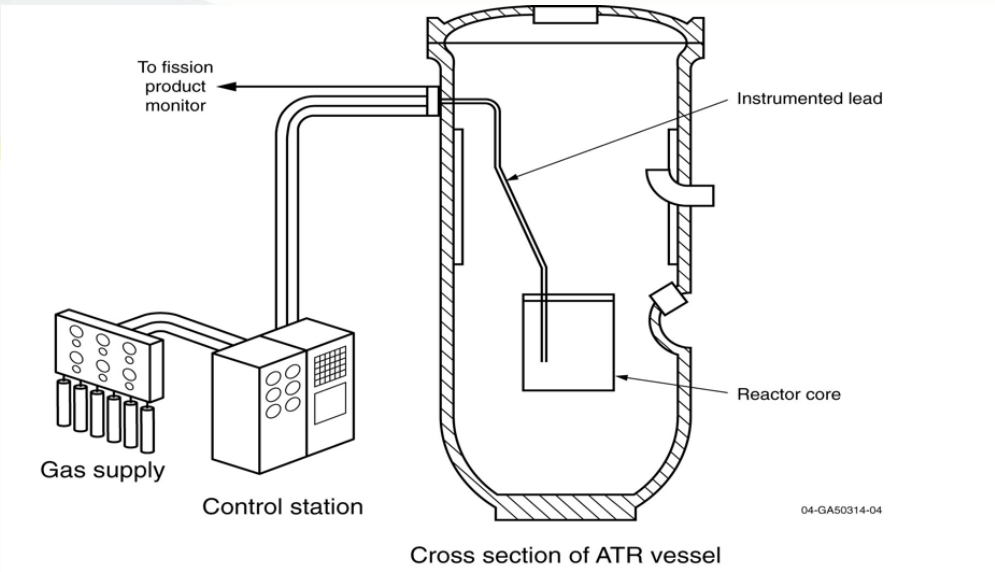
Simple Static Capsule Experiments

- Passive instrumentation (flux wires, melt wires)
- Temperature target controlled by varying gas mixture in conduction gap and with material selection
- Lengths up to 48”; diameter 0.5” – 5.0”
- Six month preparation
- AFCI, MOX, isotopes, RERTR, JNC
- Can tailor flux, Cd baskets, booster fuel



Instrumented Lead Experiments

- On-line experiment measurements
- With or without active temperature control
- Temperature control range 250-1200°C, within +/- 5°C
- Monitoring of temperature control exhaust gases for experiment performance (e.g., fission products, leaking materials, etc.)
- Specialized gas environments (oxidized, inert, etc.)
- Removal and replacement of experiment through discharge chute
- ~18 months preparation for new test design and installation
- Magnox, NPR, AGR, TMIST

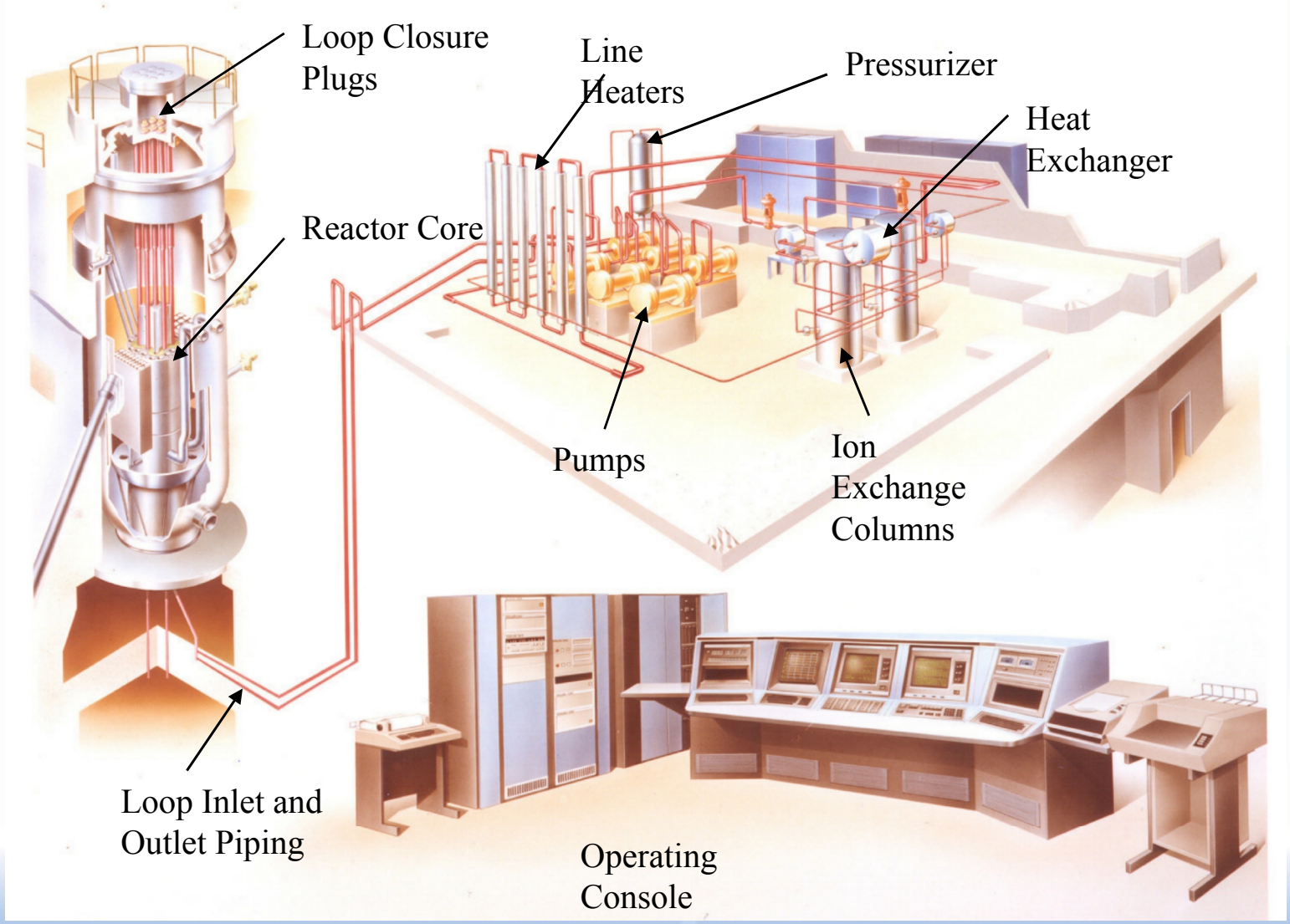


Cross section of ATR vessel

Pressurized Water Loop Tests

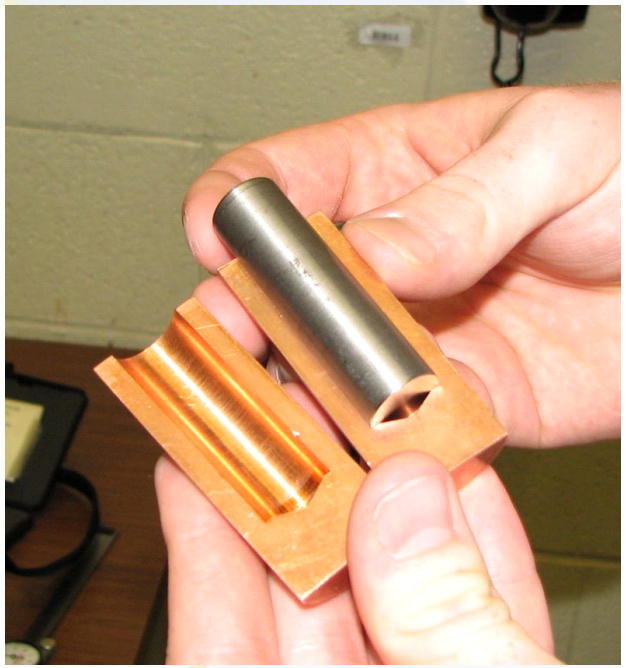
- Five flux trap positions currently have pressurized water in-pile loop tests (1 large diameter, 4 small diameter). New loop in 2010
- Separate from ATR primary coolant system
- Each loop has its own temperature, pressure, flow, and chemistry control systems – can exceed current PWR operating conditions (2250 psig, 650F)
- Transient testing capabilities (cycle/seconds)
- Potentially feasible to simulate boiling water reactor void conditions
- Up to two year preparation for new test programs

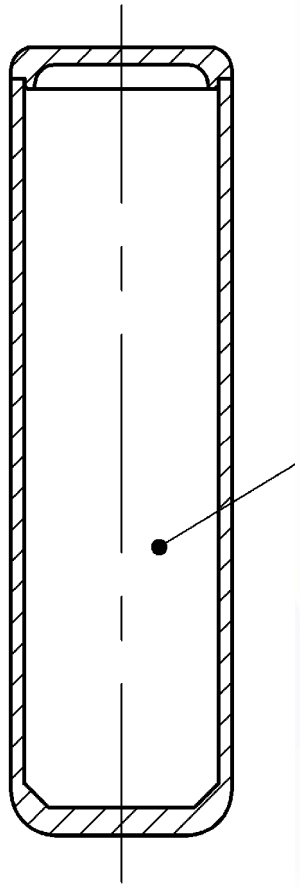
ATR Standard Loop Layout



Hydraulic Shuttle Irradiation System

- 14 – 18 shuttle capsules
- Simultaneously irradiated
- Flux: ~ 7.0E14 n/cm^2-s
- Dimensions:
  - ~ 0.55” ID, ~2.1” IL
  - ~ 7 cc useable volume
- Shuttle Wall Temp:
  - ~ 180 F to 240 F
- Max. Internal Pressure
  - < 215 psig





Experimental Infrastructure for LWR Materials R&D

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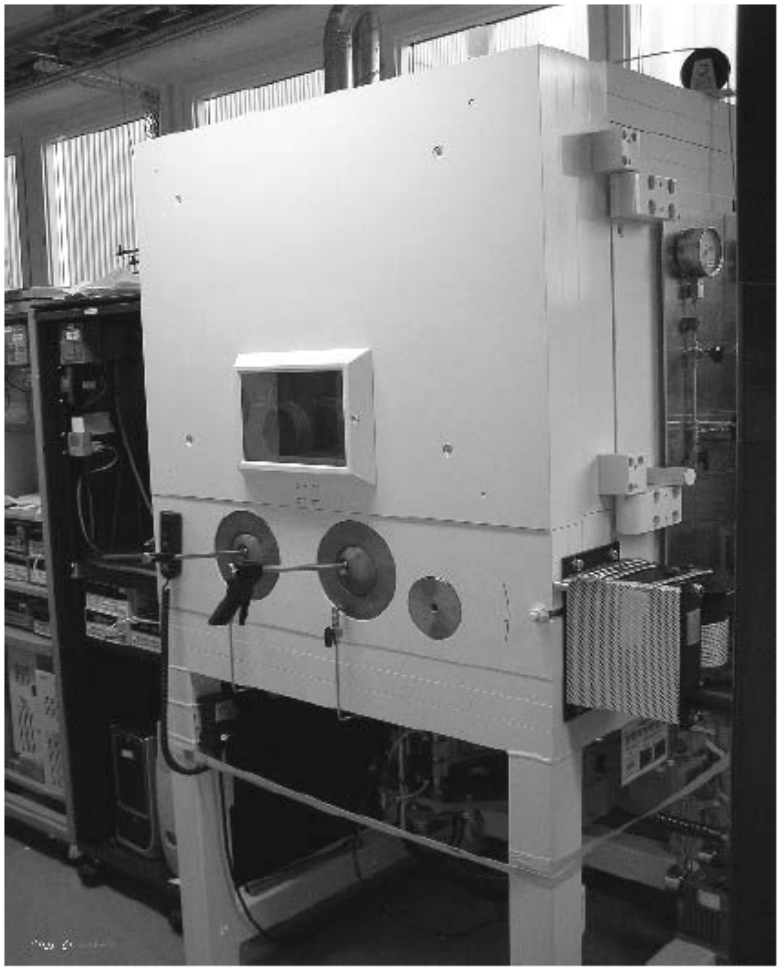
- PWR Loop
- Assembly/Disassembly station in ATR canal
- Environmental testing equipment
- AFCI PIE equipment
- HFEF equipment upgrades (sample preparation, gamma scanner, visual exam machine, NRAD elevator)



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Analytical Equipment Upgrade Support Plan: Current INL PIE Equipment Upgrades

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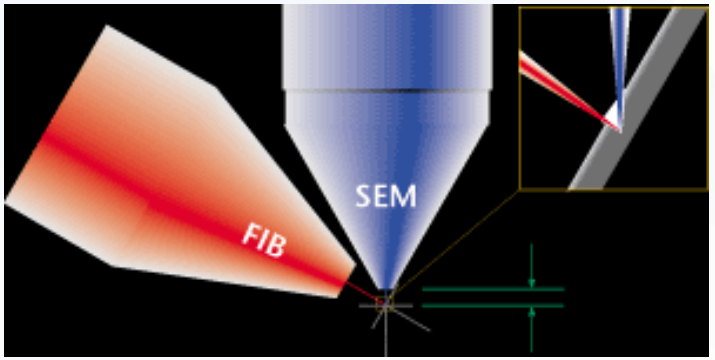
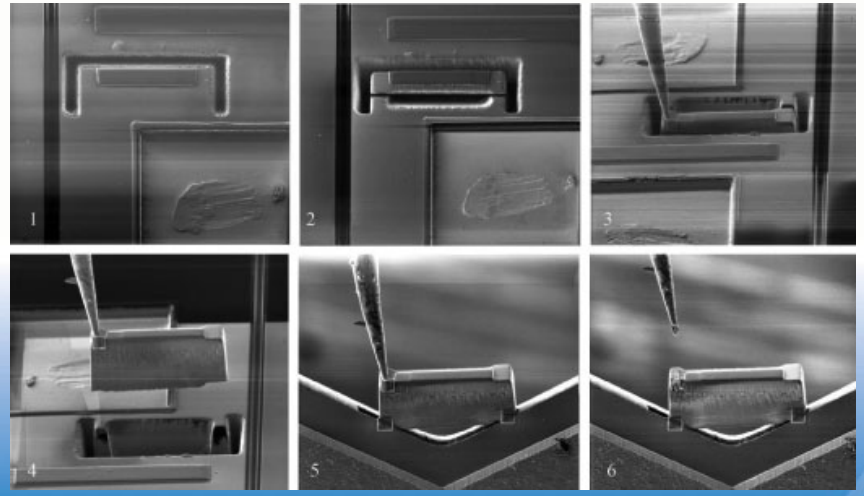
- Dual-Beam Focused Ion Beam (FIB)
- Microscale X-Ray Diffractometer (MXRD)
- Thermal Ionization Mass Spectrometer (TIMS)
- Scanning Thermal Diffusivity Microscope (STDM)
- Electron Probe Micro-Analyzer (EPMA)
- IASCC test rigs
- In-Cell tensile tester
- In-Cell EDM



Two columns for simultaneous imaging and microscale milling and sectioning



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Analytical Equipment Upgrade Support Plan: INL PIE Equipment Upgrade Investments

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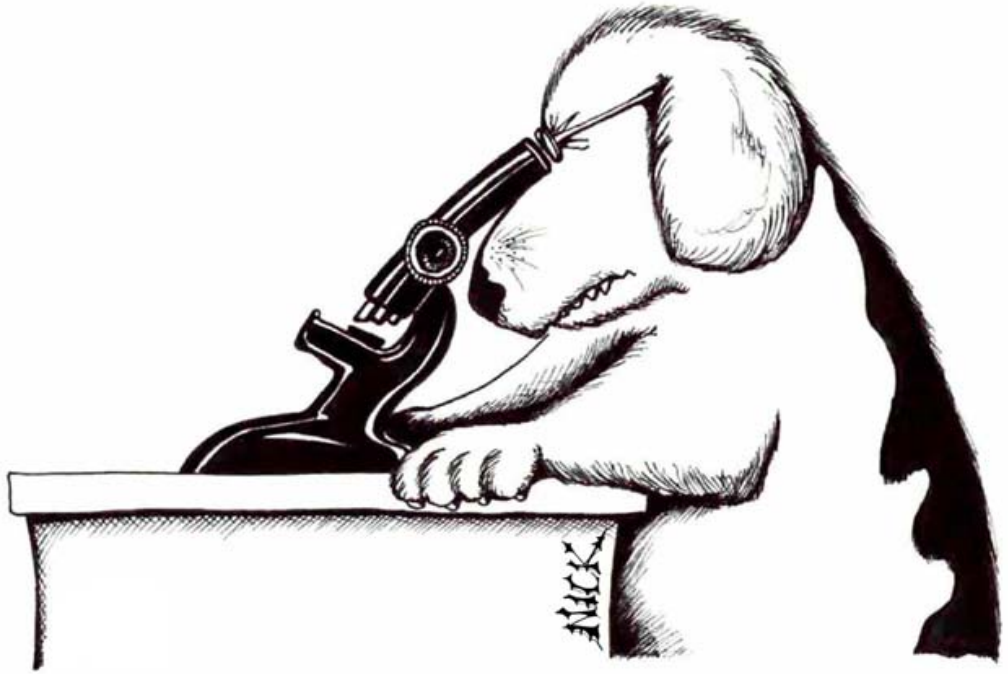
- Upgrades to Existing Equipment
  - HFEF Metallography Box
  - Gamma Scanner
  - NRAD Elevator
  - Visual Exam Machine
- Irradiation Testing Upgrades
  - Fuel Rod Re-fabrication
  - BWR Loop
- Signature Analysis Equipment
  - Atom Probe
  - Field Emission Gun Scanning Transmission Electron Microscope (FEG-STEM) (EELS, Imaging filter, etc. as possibilities)
  - Auger
  - Raman
  - Atomic Force Microscope



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Analytical Equipment Upgrade Support Plan: Shielded Facility for PIE Equipment

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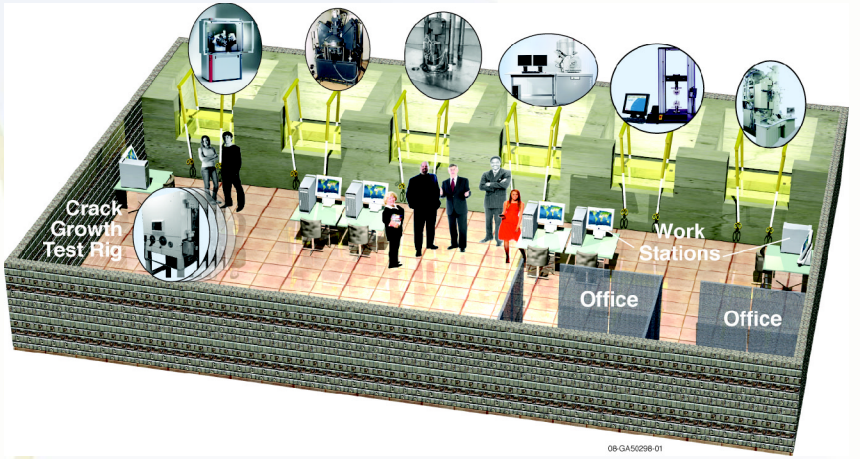
- New Irradiated Materials Characterization Laboratory under development
  - Consolidates new post-irradiation analytical capability
    - Shield enclosures for handling multiple irradiated fuel samples
    - Inert glove boxes within enclosures and interfaced with instruments.
  - Arrangement of shielded cells allows easy transfer between instruments
  - Mechanical/environmental (IASCC) testing equipment



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Advanced In-reactor Instrumentation

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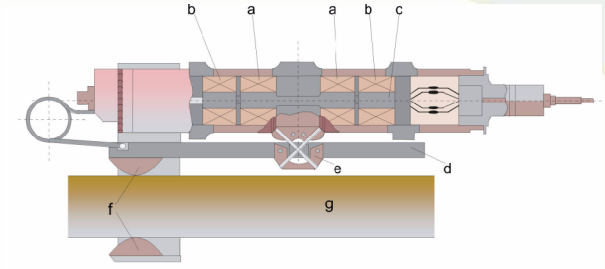
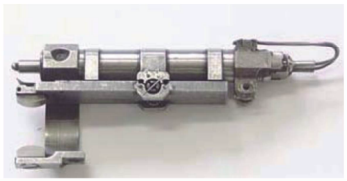
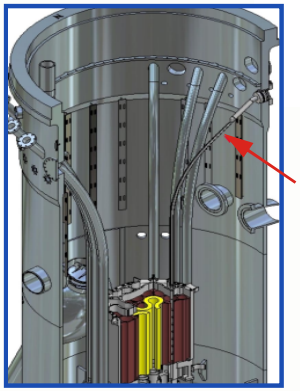
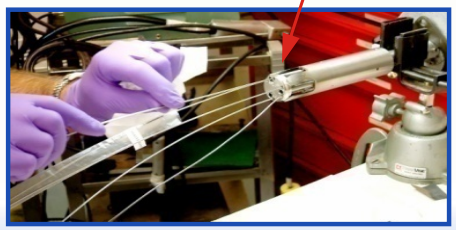






AGR-1 Test Capsule Installed in ATR with INL HTIR-TCs



Focus 2008- 2013 LDRD funding on instrumentation to improve ATR capability

- Measurement Examples
  - Dimension
  - Conductivity
  - Material flaws
- Potential Technologies
  - Fiber optics (cracks, temperature, etc.)
  - Ultrasonic techniques (cracks, temperatures, length changes)
  - SiC (temperature)
  - Wireless technologies (temperature, pressure, etc.)
- Strategy
  - Collaborate with Halden, Jules Horowitz, and Bettis
  - LDRD funding used for advanced concepts
  - Leverage capabilities developed using DOE program (GNEP, NGNP) and WFO funding. Collaborate with small business by participating in SBIRs

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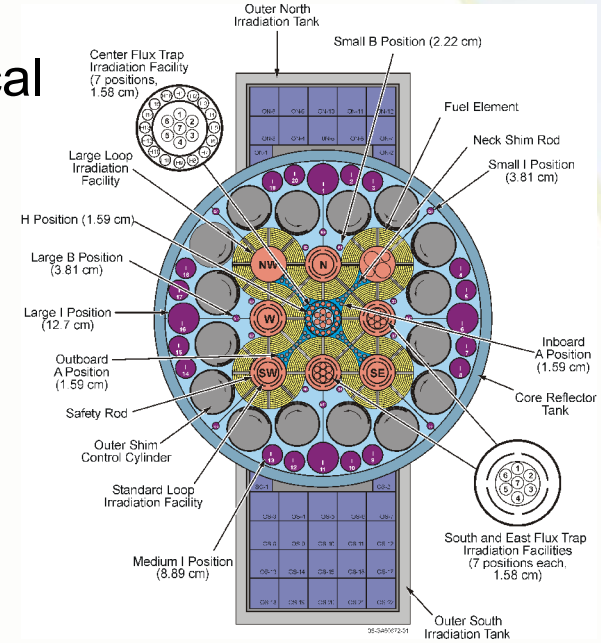
What is the ATR NSUF?

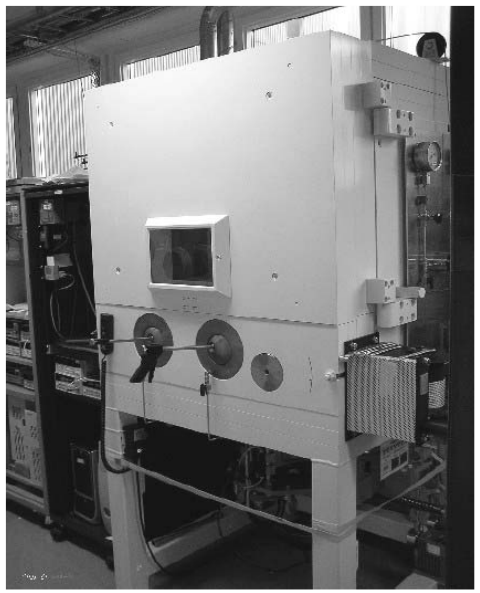
ATR National Scientific User Facility

A means to provide the research community access to national capability to conduct cutting edge nuclear technology research and development

Test Reactors and Critical Facilities (ATR, ATR-C, NRAD, MITR, Pulstar)

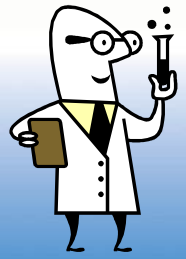


Examination Facilities (INL MFC, UNLV, NCSU, Michigan, Wisconsin)



Other National User Facilities (APS, SHaRE)

External Users



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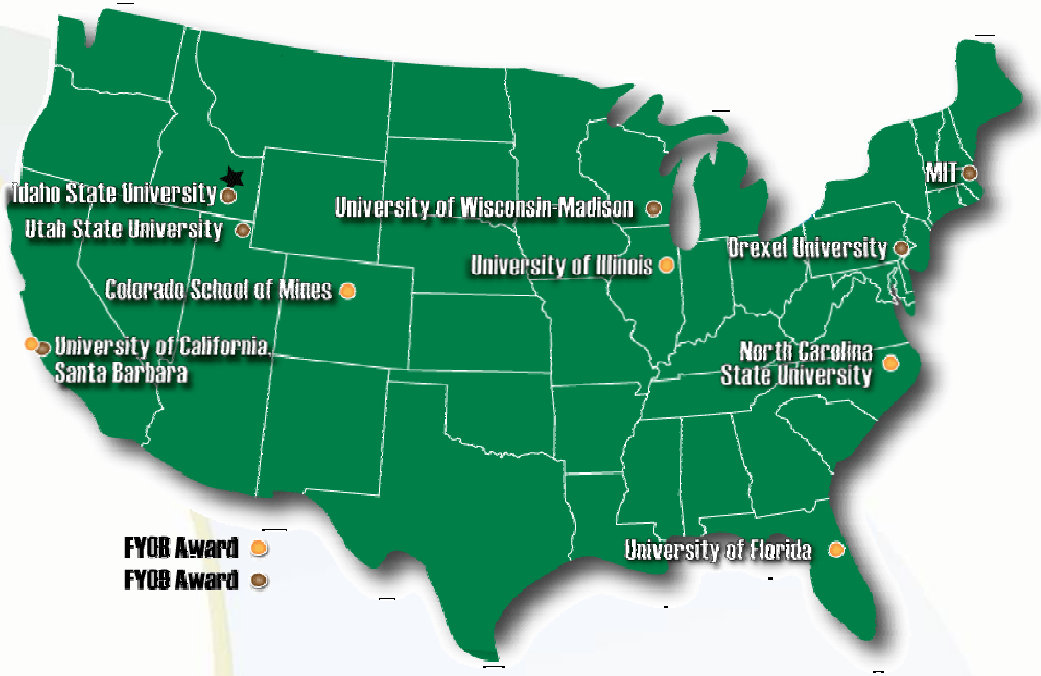
University Projects

- **ATR/ATRC/MFC/NRAD**
  - Wisconsin pilot project inserted in 2008
  - Four university projects selected for ATR irradiation in 2008:
    - Florida and North Carolina State are in ATR
    - University of Illinois and University of California, Santa Barbara inserted in Aug 2009
  - Two university projects selected for ATR irradiation in February 2009 (Utah State, University of California, Santa Barbara)
  - One university project selected for ATR irradiation in August 2009 (Drexel)
  - First ATR-C project selected in Aug 2009 (Idaho State University)
  - First PIE-only experiment selected in February 2009 (University of Wisconsin)
  - ***New User Experiment in 2010***
  - ***Offering Advanced Photon Source in FY2010***



Fifty project proposals submitted as part of the first three solicitations, twelve ongoing projects

University Education Programs Build a Cadre of Experimenters

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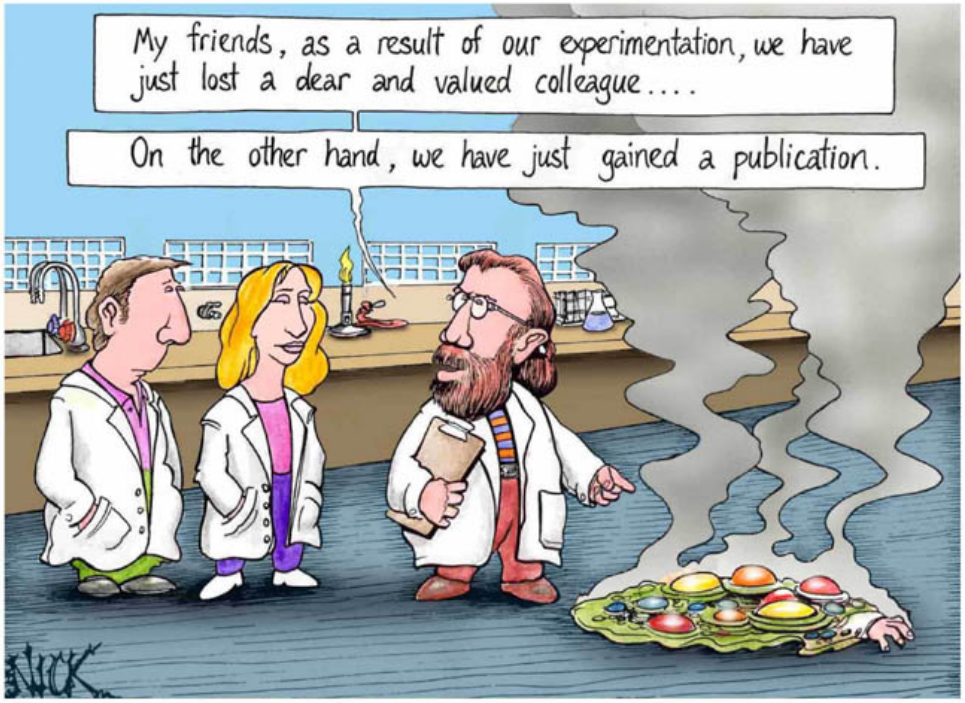
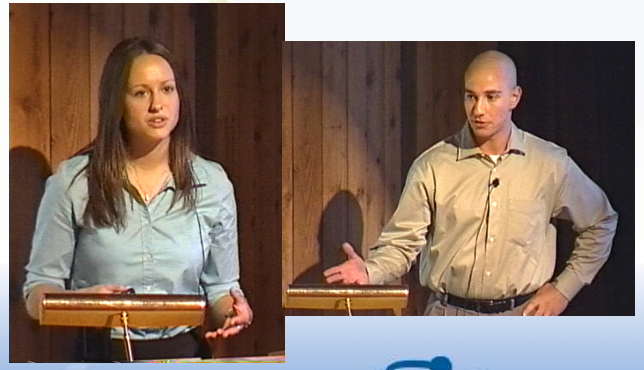
- Users Week June 1-5, 2009
  - Fuels and materials performance course
  - Experimenter course
  - New user workshop
  - NSUF Research Forum
  - Facility tours
  - Advanced Photon Source workshop
  - Scientific Review Board
- Workshops at Conferences
- Increased number of summer internships, including scholarships to the Users Week and Faculty-student teams.
- Colloquium Series
- Reactor Testing Textbook





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2009 User's Week Demographics

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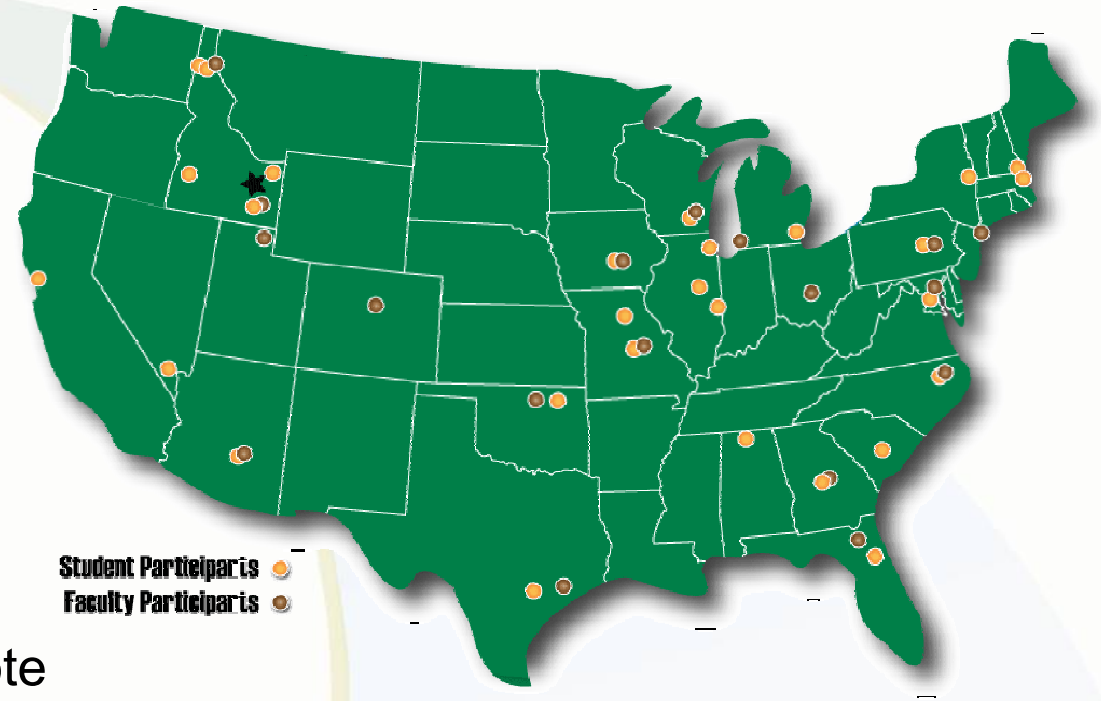
Total Applicant: 126
Universities Represented: 37

- 52 students
- 24 faculty members
- 7 industry participants
- 43 other national laboratories, government and foreign nuclear agencies



Lectures are taped to develop a "remote learning library."

"Bad dog! Stop trying to kill the cat!"

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ATR NSUF Partnerships

- ATR NSUF aims to meet customer needs
- ATR NSUF will include additional capability that benefits users
  - University research reactors
  - Hot cells or hot laboratories
  - Accelerator facilities
  - Analytical capability
- Process
  - Potential university partners self-nominate
  - Expert group evaluates nominations
  - Capabilities added to next proposal solicitation

Current partners are IIT, Michigan, MIT, NCSU, UNLV, and Wisconsin

Sample -- University-led ATR NSUF Projects

Florida

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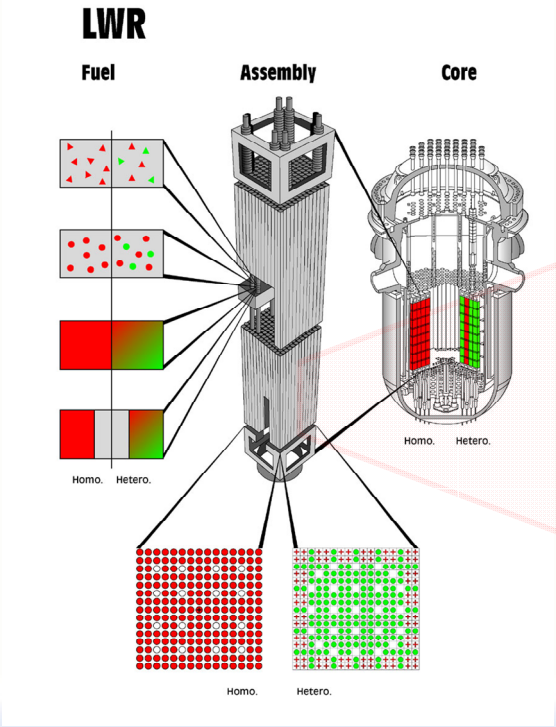
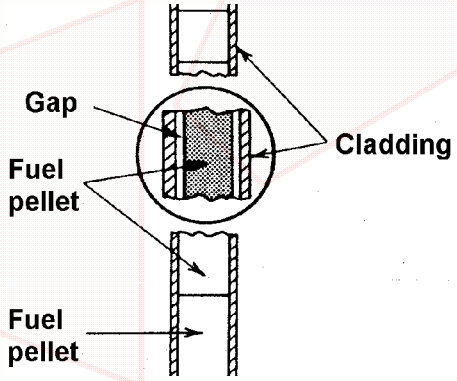
Reduction of the nuclear waste inventory in light water reactors requires development of new inert matrix fuel (IMF) concepts.

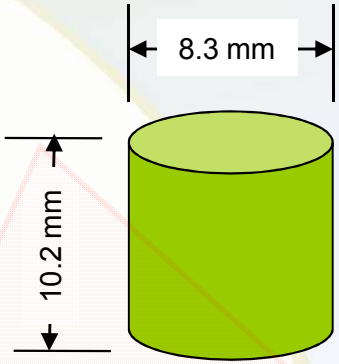


LWR Reactor

Courtesy C. Degueldre, PSI



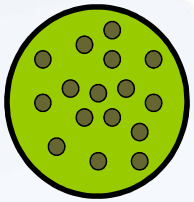
Fuel Pin



Fuel Pellet

Two Phase Composite: (Macrodispersion)

IM & dispersed fuel particles (0.1- 1.0 mm)



We have investigated, tested, and identified a series of single phase ceramics and ceramic-ceramic composites as potential candidates for IMF.

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Florida

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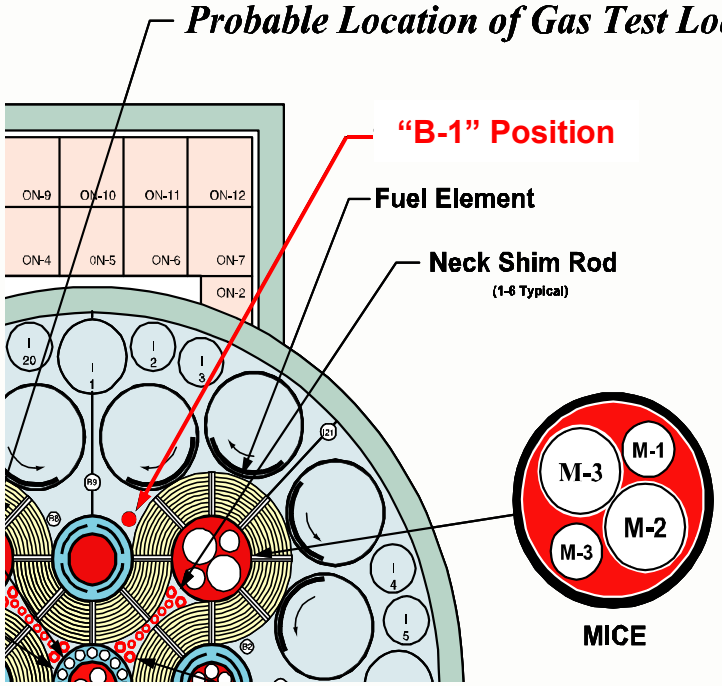

Six compositions have been selected at UF for irradiation tests in the ATR B-1 position. Three capsules have been planned with two target doses (1 & 2 dpa) with insertion for the ATR cycle 144A .

Compositions
$MgO{\cdot}1.5Al_2O_3$
$MgAl_2O_4$
MgO
$Nd_2Zr_2O_7$
$0.7MgO\text{-}0.3Nd_2Zr_2O_7$
Mg_2SnO_4

UF Experiment Designation Capsule ID	Sample Type	Target Dose	Fast Neutron Fluence	Height (in.)
Capsule A, B	Diffusivity samples, TEM samples	1 dpa	10^{25} n/m^2	9
Capsule C	Diffusivity samples, TEM samples	2 dpa	2×10^{25} n/m^2	9

Nino Research Group - University of Florida - NERI & ATR 2008

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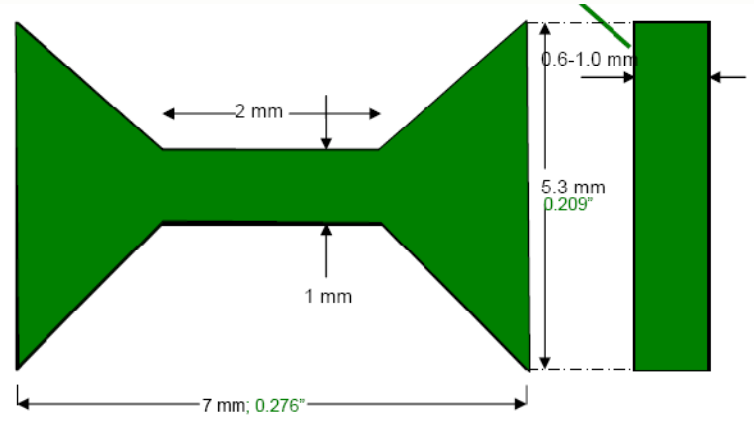
Illinois

Alloy	Temperature (°C)	Dose (dpa)	Specimen Types
Model Alloys: Fe, Fe-9Cr, Fe-12Cr, Fe-14Cr, Fe-19Cr	300, 450, 550	0.01, 0.1, 0.5, 1.0, 5.0	TEM, Miniature Tensile
Commercial Alloys: Mod 9Cr-1Mo, HT-9	300, 450, 550	0.01, 0.1, 0.5, 1.0, 5.0	TEM, Miniature Tensile
Development Alloy: MA-957	300, 450, 550	0.01, 0.1, 0.5, 1.0, 5.0	TEM, Miniature Tensile

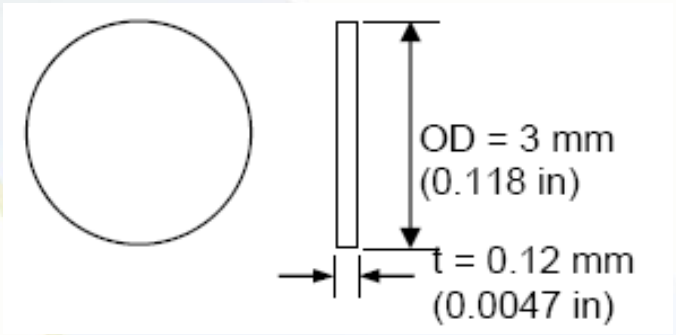
Note: For each condition there will be:
2 tensile bar for mechanical test,
5 TEM discs for microstructural analysis (3 mm diameter, 0.25 mm thickness)

Illinois Samples

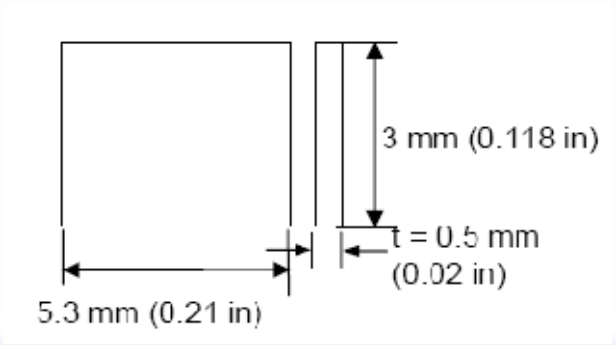
- **The following samples will be considered for irradiation**



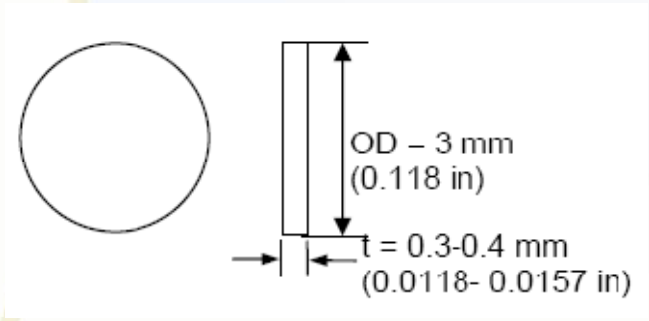
Sub-size tensile sample



TEM specimen schematic



Hardness sample



"Thick" TEM specimen schematic for SPT

UC Santa Barbara

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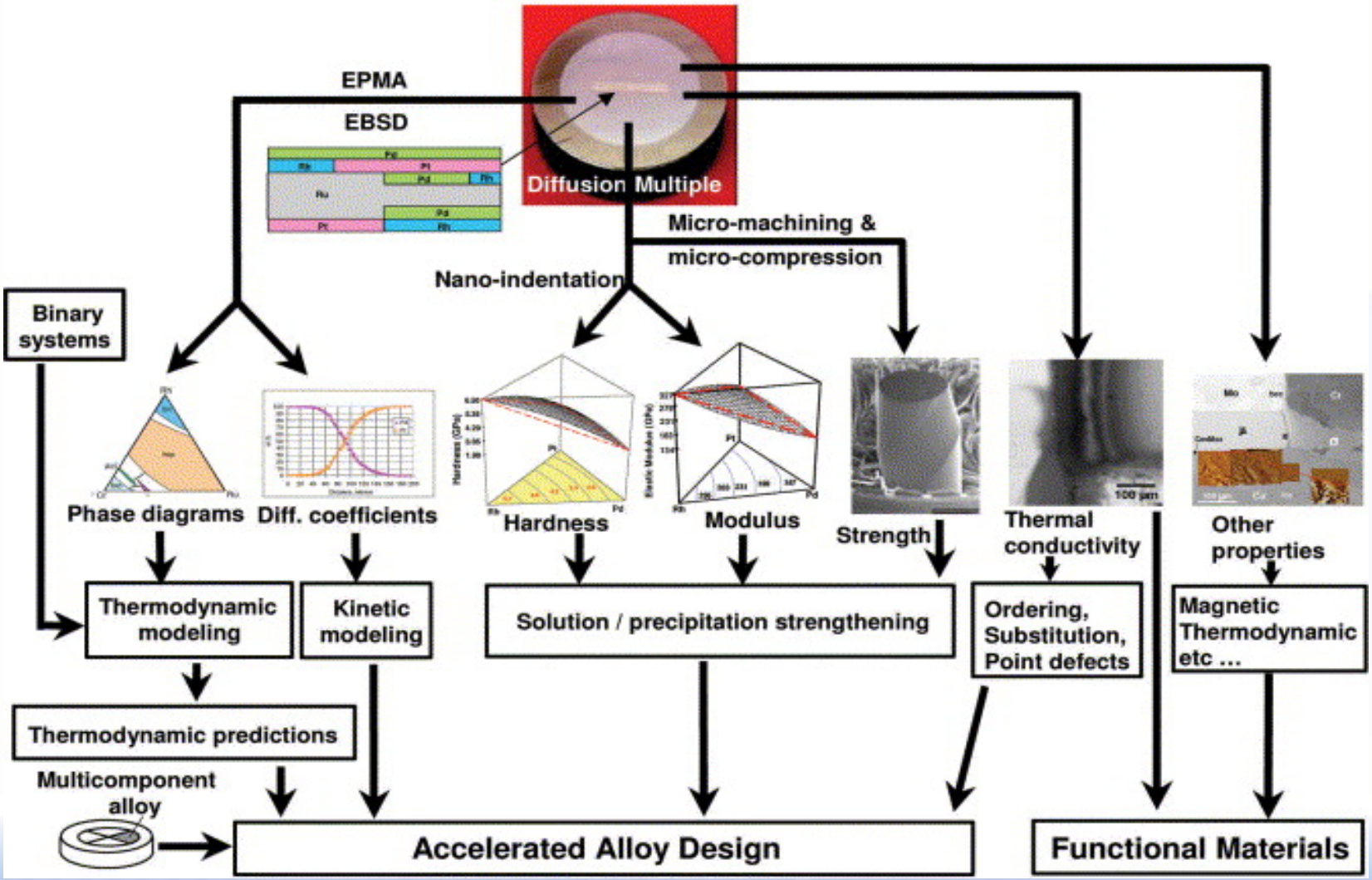

Ref. J.-C. Zhao, Annu. Rev. Mater. Res. 2005. 35:51-73

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