U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Nuclear Science User Facility

NSUF Irradiation Experiments

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Acting Chief Irradiation Scientist

Annual NSUF Program Review
DOE Headquarters
Germantown, MD
November 1, 2016

NSUF Nuclear Science User Facilities

INL/LTD-16-40338

U.S. DEPARTMENT OF ENERGY

Nuclear Energy

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IRRADIATION EXPERIMENTS

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Experimental Parameters of Interest to Users

NSUF Nuclear Science User Facilities

1. Temperature (magnitude & variation)	**Passive or Active in-pile**
2. Neutron Fluence & Spectrum	**Passive or Active in-pile**
3. Gamma Fluence & Spectrum	Active in-pile only
4. Microstructure	PIE
5. Density	PIE
6. Swelling	PIE
7. Cracking	PIE
8. Hardness	PIE
9. Mechanical Strength (tension)	PIE
10. Thermal Conductivity	PIE
11. Heat Capacity	PIE
12. Coefficient of Thermal Expansion	PIE
13. Creep	PIE
14. Chemistry/Corrosion	PIE

Drop-in / Static Capsule Experiments

Project	Reactor	Position	Material	Parameters
UCF-242(3)	ATR	B_S 0.875”	Advanced Fuels	1,2,4,5,6,14
BSU-269(A)	BR-2	I-14 3.25”	Advanced fuels	1,2,4,5,6,7,10,11,12,13,14
BSU-8242	ATR	A_I 0.625”	AM metal	1,2,4,6,7,8,9,14
INL-8389	MITR	ICSA	sensors	1,2,3, performance
GEH-10393	ATR	B_L 1.5” or loop	AM metal	1,2,4,7,9
ISU-10537	ATR	B_S 0.875”	AM metal	1,2,4,9,13,14
CSM-10584	ATR	B_S 0.875”	AM metal	1,2,4,10,11,14

Doses range from ~0 to 6 dpa in these experiments

Rabbit Experiments

Project	Reactor	Position	Material	Parameters
UCF-242(2)	ATR	B-7(HSIS) 0.875”	Advanced Fuels	1,2,4,5,6,14
ORNL-10468	HFIR	CFT (HTS) 0.500”	Various SiC materials	1,2,4,6,10
ORNL-10764	HFIR	CFT (HTS) 0.500”	PyC-SiC (TRISO)	1,2,4,14

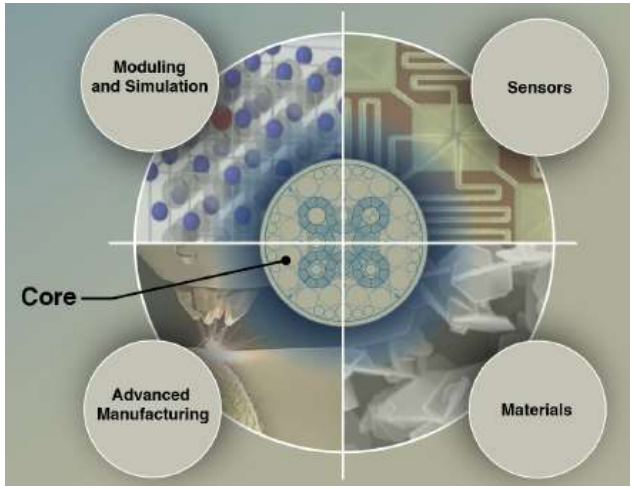
These experiments cannot have instrument leads connected.

Doses range from ~0 to 2 dpa in these experiments

- ATR ~1 dpa in 1.5 cycles (84 days)
- HFIR ~2 dpa in 1.0 cycle (25 days)

In-Pile Sensor Initiative

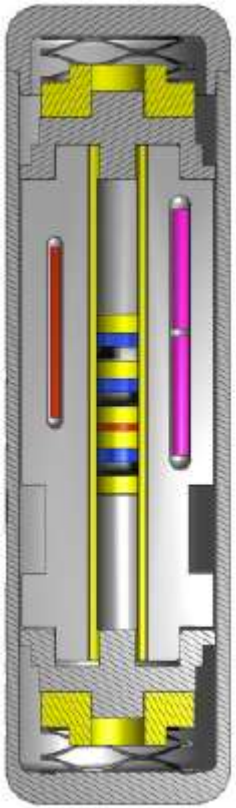
- **Collaboration between Boise State University and the INL.**
- **Multidisciplinary effort:**
  - Material Science
  - Modeling and Simulation
  - Advanced Manufacturing
  - Sensor Design and Testing



- **Goals**
  1. Provide new, **needed capabilities** for in-pile measurement of critical materials behavior
  2. Reduce the **development lifecycle** for new in-reactor instrumentation
  3. Improve **data quality and quantity**
  4. Accelerate **data availability**
  5. Increase probability for uses of **breakthrough technologies** in in-pile instrumentation
- Supported through NSUF access and Infrastructure grants

University of Central Florida (FY 2010)

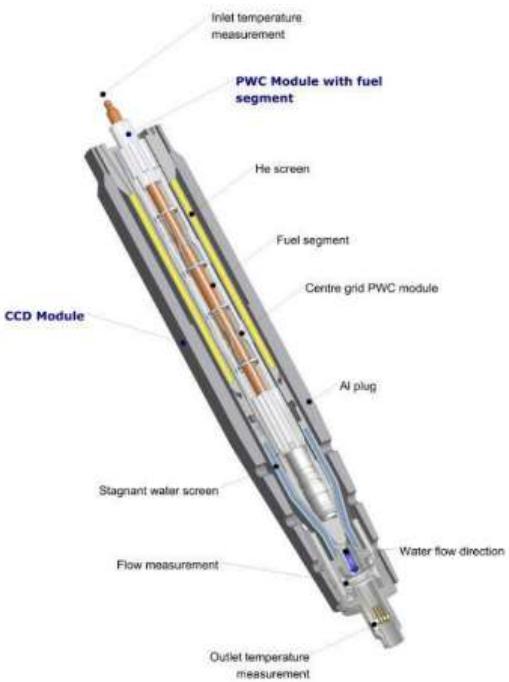
	UCF-242(2)	UCF-242(3)
Purpose	Metallic fuels at low fluences (AFCI, MMM)	
Reactor	ATR	ATR
Position	B-7	B-8
Type	HSIS (2x6 capsules)	Drop-in (13 capsules)
Damage/Fluence	0.01 & 0.1 dpa	1.0 dpa
Environment	150-700ºC	150-800ºC
Principle Investigator	Yongho Sohn	
Technical Lead	Emmanuel Perez	
Irradiation Manager	Nick Mecham	
Materials	DU, Al, $DU_{10}Mo$, Zr, Fe, $Fe_{15}Cr_{20}$, $Fe_{15}Ni_{20}$	
Forms	Diffusion couples	DC, TEM, MPC
Status	On hold	RTI 160B



Note: 1 dpa in steel ≈ 0.7 x10^{21} n/cm^2 fluence

Boise State University (FY 2010)

	BSU-269A	BSU-269B
Purpose	U_3Si_2 fuel interaction (PCI)	U_3Si_2 fuel corrosion
Reactor	ATR	BR-2
Position	I-14	TBD
Type	Drop-in	PWC Module (BR-2)
Damage/Fluence	10 & 20 GWD/MTU	
Environment	300, 750,1200°C	Water / Steam <350°C
Principle Investigator	Darryl Butt (Univ. of Utah)	
Technical Lead	Jason Harp	
Irradiation Manager	Nick Mecham	
Materials	U_3Si_2, Zr, FeCrAl, SiC	U_3Si_2, UN/U_3Si_2
Forms	Diffusion couples	Water interaction
Status	Design review underway	Early planning stages



Boise State University (FY 2015)

	BSU-8242
Purpose	HIP-PIM metals (weldability/inspectability)
Reactor	ATR
Position	A (4 positions)
Type	Drop-in
Damage/Fluence	1 & 3 dpa
Environment	300 & 400ºC
Principle Investigator	Janelle Wharry (Purdue Univ.)
Technical Lead	Donna Guillen
Irradiation Manager	Katie Anderson
Materials	Alloy 625, 690, Grade 91, 304L, 316L SA 508 (cast/forged and PM-HIP)
Forms	TEM disks and tensile bars (16x4x1mm)
Status	Conceptual Design Review (10/24-27), RTI (May 2017)

General Electric-Hitachi (FY 2016)

	GEH-10393
Purpose	Direct Metal Laser Melting (DMLM) - reactor internal repair parts, fuel debris resistant filters, and fuel spacers
Reactor	ATR
Position	TBD (large B-pos)
Type	Drop-in
Damage/Fluence	0.5-1.4 dpa
Environment	Gas-cooled (280-300ºC)
Principle Investigator	Ronald Horn
Technical Lead	John Jackson
Irradiation Manager	Nick Mecham
Materials	316L SS & Alloy 718(PH)
Forms	Tensile bars, crack-growth rate, fracture toughness bars
Status	Conceptual Design Review underway

Idaho State University (FY 2016)

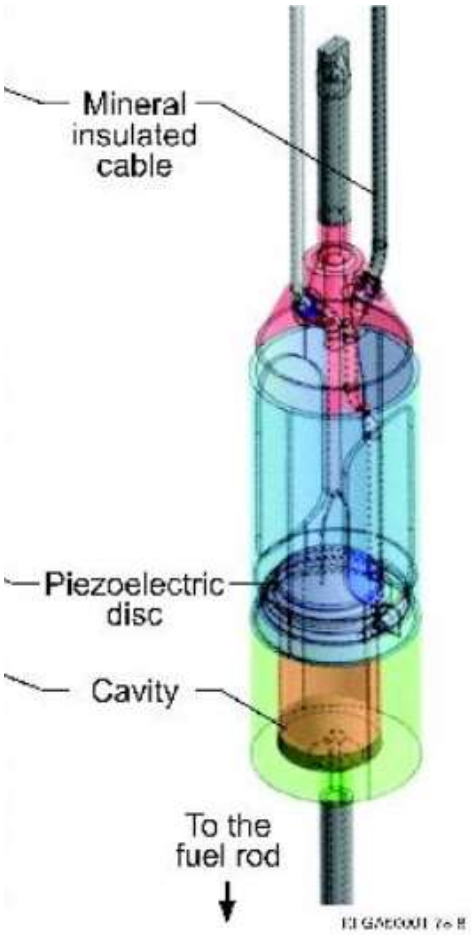
	ISU-10537
Purpose	Nanostructured austenitic and ferritic/martensitic (F/M) steels that are anticipated to have enhanced irradiation tolerance
Reactor	ATR
Position	B-6 (8 capsules)
Type	Drop-in (8 capsules)
Damage/Fluence	2 & 6 dpa
Environment	Gas-cooled (300 & 500ºC)
Principle Investigator	Haiming Wen (ISU/INL)
Technical Lead	Keith Jewell
Irradiation Manager	Leslie Soderquist
Materials	Steel specimens manufactured using equal-channel angular pressing (ECAP) and high-pressure torsion (HPT)
Forms	Tensile, hardness, and TEM
Status	Initiated experiment design process (complete 5/31/2017)

Colorado School of Mines (FY 2016)

	CSM-10584
Purpose	First-ever irradiation performance data for stainless steel and Inconel specimens produced using commercially available additive manufacturing techniques
Reactor	ATR
Position	B-5
Type	Drop-in
Damage/Fluence	0.05, 0.1, 1.0 dpa
Environment	Gas-cooled (325ºC)
Principle Investigator	Jeffrey King
Technical Lead	Donna Guillen
Irradiation Manager	Katie Anderson
Materials	Adv. manufactured 316L SS and Inconel-718
Forms	Tensile bars and multi-purpose disks
Status	Initiated experiment design process (complete 6/30/2017)

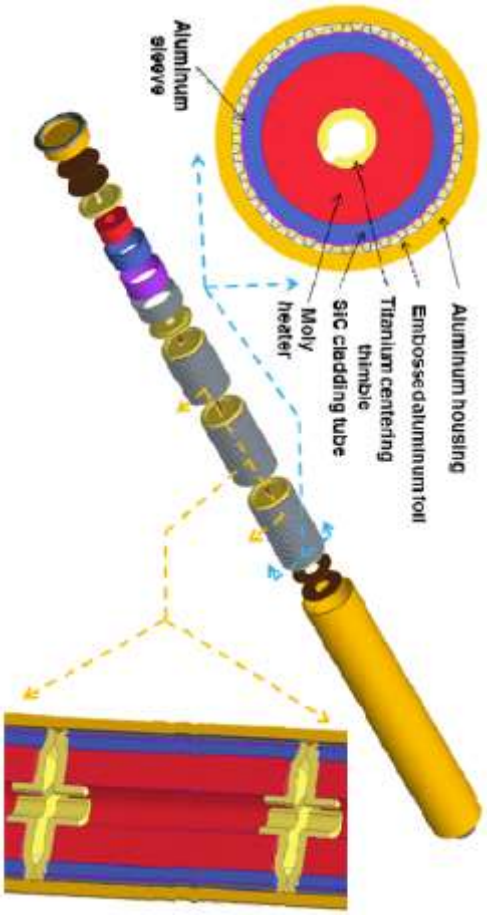
Idaho National Laboratory (FY 2015)

	INL-8389
Purpose	Sensor qualification: fission gas release, fission gas composition, and axial temperature measurement.
Reactor	MITR-II
Position	In-Core Sample Assembly (ICSA)
Type	Instrumented Lead
Damage/Fluence	1.0×10^{21} n/cm^2
Environment	Dry He/Ar mix (< 900ºC)
Principle Investigator	Joshua Daw (INL)
Technical Lead	Joshua Daw (INL)
Irradiation Manager	Lin Wen Hu (MIT)
Materials	INL-enhanced CEA pressure sensor, ultrasonic thermometer and fiber optics.
Forms	
Status	Design of test capsule is ongoing. RTI by 1/31/2017



Oak Ridge National Laboratory (FY 2016)

	ORNL (YK) - 10468
Purpose	SiC-based cladding w/ radial heat flux
Reactor	High-Flux Isotope Reactor (HFIR)
Position	CFT HTS
Type	Rabbit (6 capsules)
Damage/Fluence	2 dpa
Environment	300ºC (with added heat flux in ½)
Principle Investigator	Yutai Katoh
Technical Lead	Kory D. Linton (ORNL)
Irradiation Manager	Chris Bryan (ORNL)
Materials	CVD SiC, composite SiC and coated SiC tubes with Mo heating liner
Forms	Straight tube – 16(l)x8.5(d)x0.7(t)mm
Status	RTI – 9/29/2017



Oak Ridge National Laboratory (FY 2016)

	ORNL (TG) - 10784
Purpose	Radiation-Enhanced Diffusion of Ag, Ag-Pd, Eu, and Sr
Reactor	HFIR
Position	CFT HTS
Type	rabbit
Damage/Fluence	0.5, 1.0 dpa
Environment	1100ºC
Principle Investigator	Tyler Gerczak
Technical Lead	Kory D. Linton (ORNL)
Irradiation Manager	Chris Bryan (ORNL)
Materials	Ion-implanted PyC/SiC
Forms	Diffusion Couples (6x6x1mm)
Status	Thermal analysis due 8/30/2017

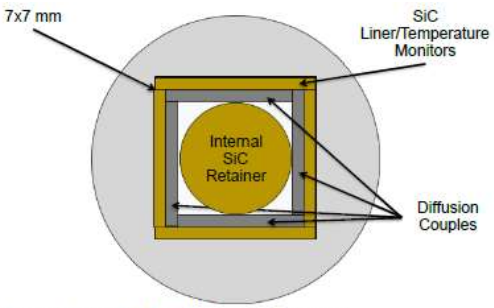
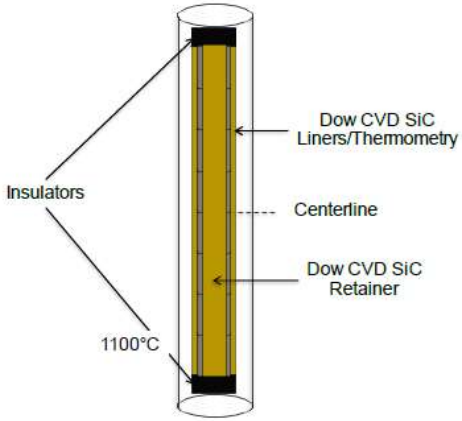
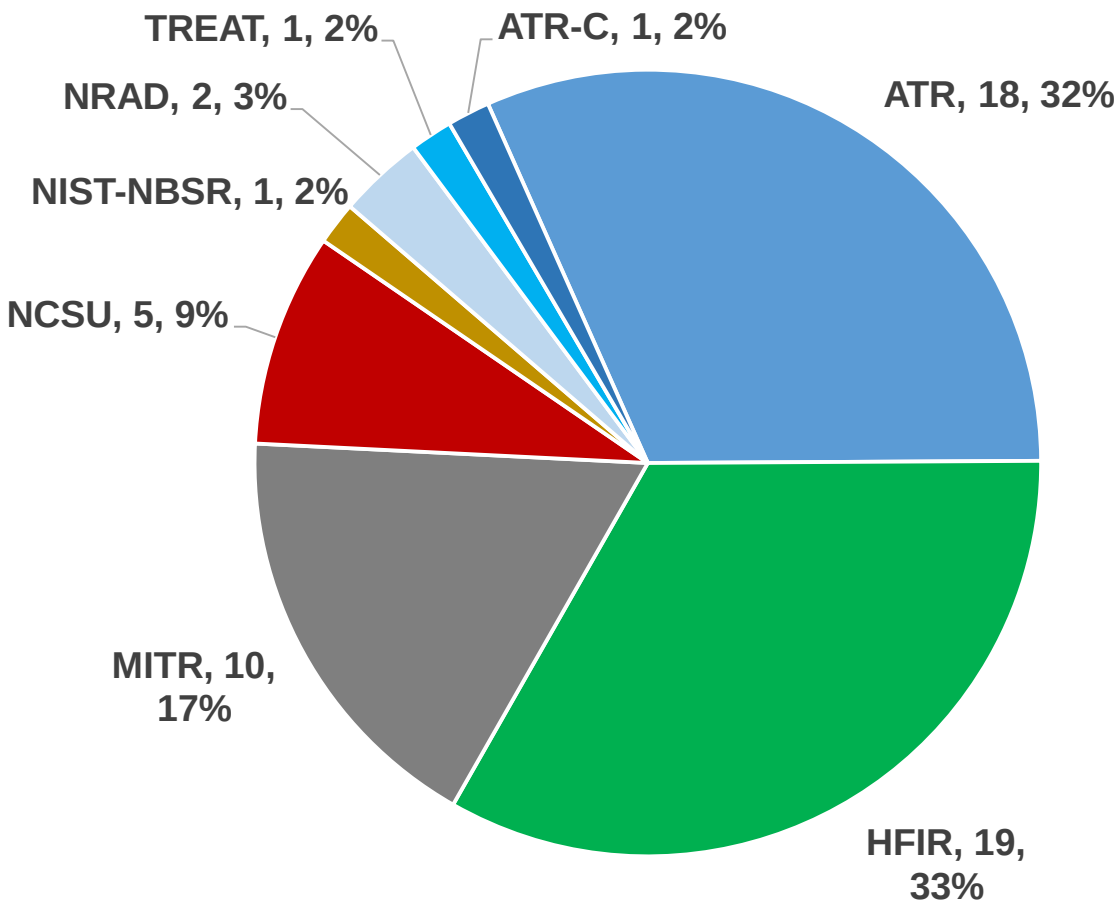


Figure 2: Capsule Radial Cross-Section



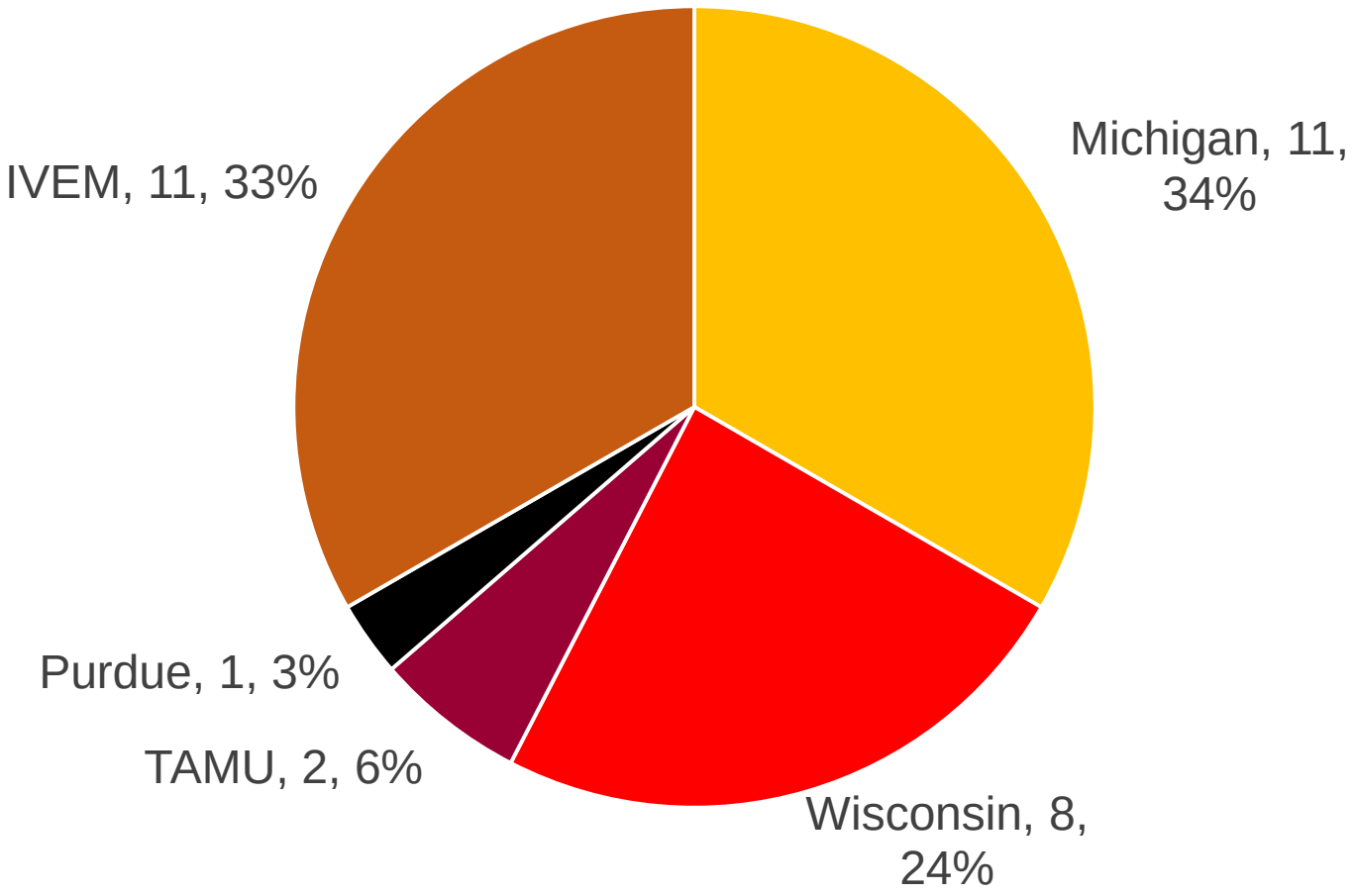
Neutron Irradiations



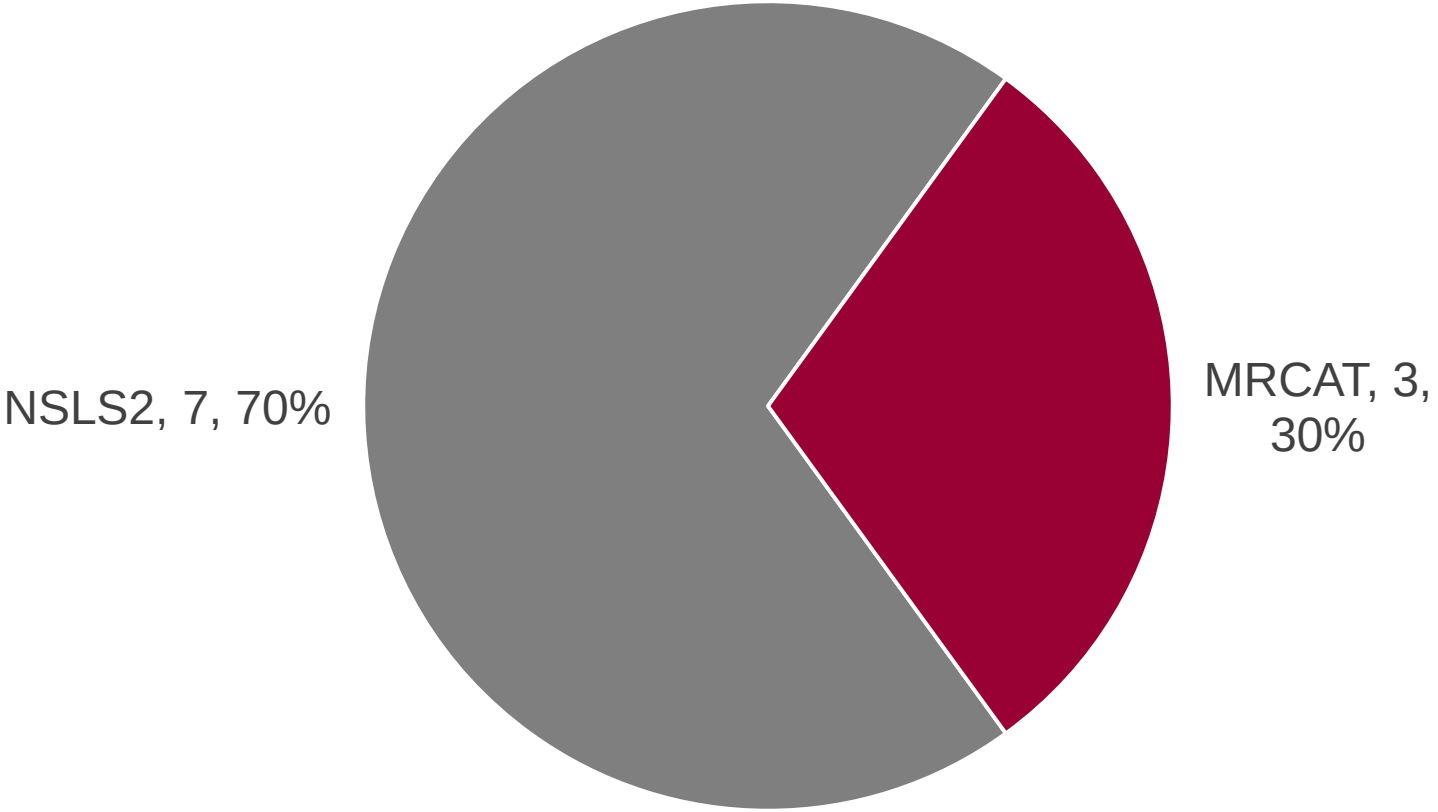
Including:

- **Gamma Irradiation**
  - 2x ATR
  - 2x HFIR
- **PWR Loop**
  - 1x ATR
  - 1x MITR
- **Instrumented Lead**
  - 1x ATR

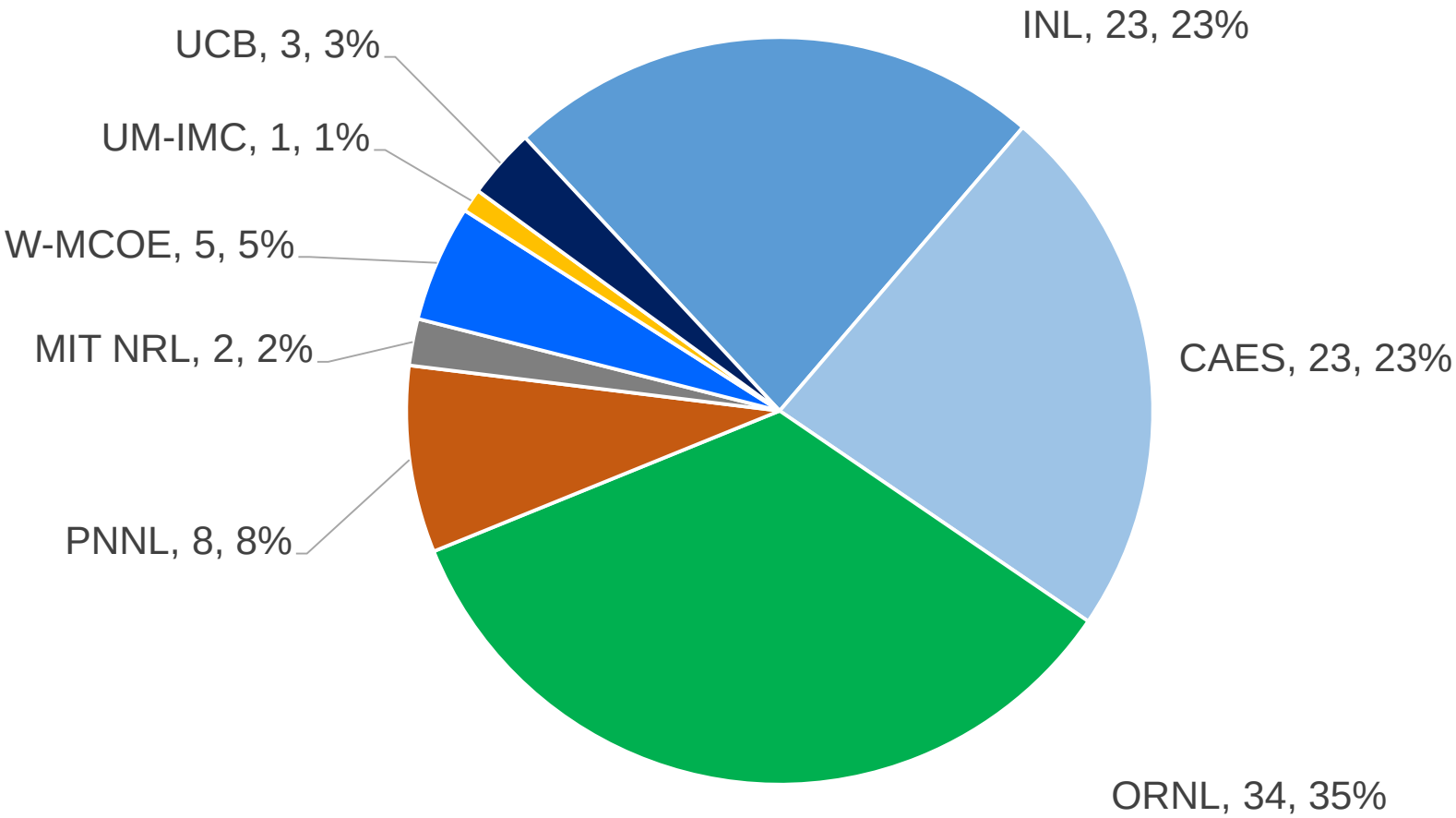
Ion Irradiation Requests



Light Source (X-Ray) Requests



Post-Irradiation Examination Requests



Usability Improvements

In order to better support the users of the NSUF access programs:

- Developing web-based tools to help users and NSUF Tech Leads:

1. **ATR Experiment Database**
   - Leslie Soderquist (NSUF Exp. Mgr.) and Monica Gehrig (intern)
2. **Irradiation resource selection**
   - Neutron flux and spectrum for NSUF reactors
     - Most efficient allocation of resources
   - Convert Neutron Fluence to DPA
     - Materials scientists request dpa
     - Reactor engineers think in terms of fluence
     - Compound materials can be difficult
3. **Estimate sample activity following irradiation**
   - Estimate time to be able to ship samples
   - Determine facilities that can accept materials
   - Estimate dose from characterization procedures
   - Also for materials in the NFML

1. ATR Irradiation Testing Tool

- **https://nst.inl.gov/irradiationtesting**

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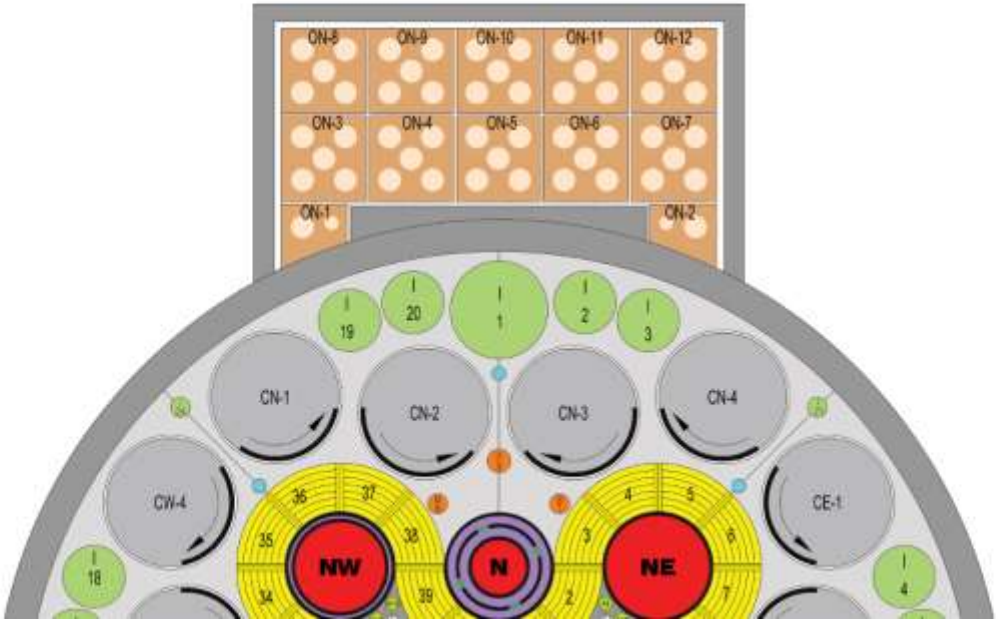
Irradiation Testing in the ATR
Notebook
Site Contents

Irradiation Testing

Nuclear Material Experiments Irradiated in the Advanced Test Reactor

This page is designed to assist users with aquiring information about positions and the experiments in each position. To view information about each group of positions or to see a list of experiments irradiated in each position, click on the position. To see a position's diameter, mouse over the position in the image.



Additional Useful Tools

DPA Calculator

To download the files that can calculate an estimate of the displacements per atom of a sample after it has been irradiated in ATR, click the link below. After the file is downloaded, you need to extract the contents to a folder. Further instruction is included in the zipped file under nit1_manual.pdf.

Tool to Calculate DPA of a Sample

List of Experiments

To see the list of experiments directly, click the following link.

Experiment List and Documents

Updating Instructions

Click on the link to open instructions on how to update the experiment list and experiment positions.

Updating Tutorial: Adding a New Experiment

Updating Tutorial: Adding a Document

Intern Expo Presentation

To see the video presentation and overview of this project, click on either of the links below.

Presentation (.wmv)

Presentation (.mov)

2. Irradiation Guidance Input (dpa target)

What material will you be using? Fe

Would you like to examine
1) A certain core position.
2) A certain reactor.
3) All reactor positions in the database. 3

Would you like to calculate
1) damage from flux?
Or
2) flux from damage? 2

How long was your sample exposed (in seconds)? 9e+6

What is the DPA level of your sample after removal? 9

2. Irradiation Guidance Flux Output (dpa target)

Flux magnitude for the experiment was 3.904159E+01 in core position ATR Small-I
Flux map has been output to "fluxmap.csv".

Flux magnitude for the experiment was 9.631117E+01 in core position ATR Medium-I

Flux map has been output to "fluxmap.csv".

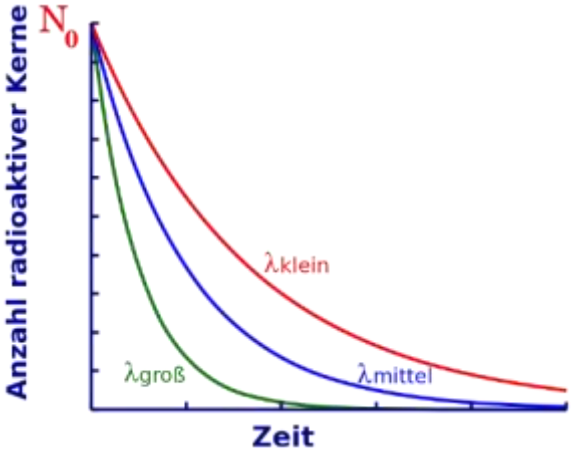
Flux magnitude for the experiment was 1.386013E+02 in core position ATR Large-I
Flux map has been output to "fluxmap.csv".

Collapsed cross sections output to "xscollapsed.csv".
Analysis complete, enter any value to exit.

39x normal flux in that position

3. Specimen Activity Calculation Tool

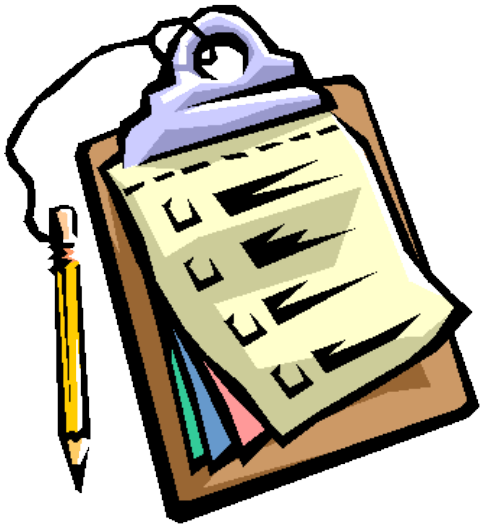
- Tracks isotopic transmutations over an irradiation exposure, keeping tracks of in-core decay, decay during cycle down time and sample cooling after removal.



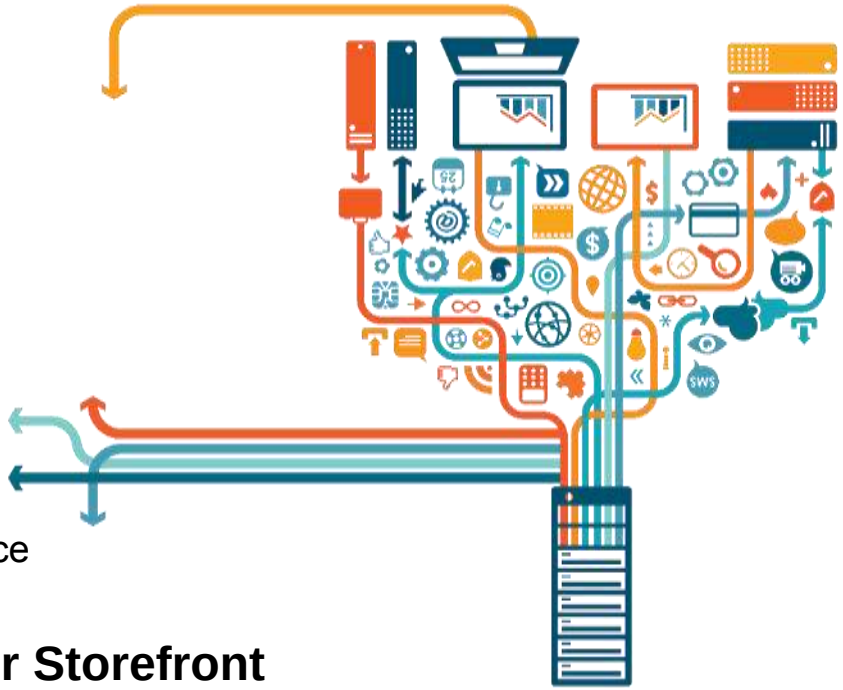
- This system can determine isotopic abundances after an experiment or for a specimen in the NFML.
- The user can input any combination of initial isotopic abundances, as well as supporting a number of well known compound materials.
- The user can request a specific activity or dose rate, and the program will accurately predict the amount of cool down time needed for the sample.

FY2017 Plans (1/2)

- **Integrated Infrastructure Enhancement Program**
  1. **NEID**
     - Gap Analysis Activities (6/30/2017 Milestone)
       - Ion Beam Roadmapping Workshop (9/28/2017 Milestone)
       - Thermal Hydraulics Workshop (9/28/2017 Milestone)
         - likely molten salt, liquid metal, gas and light water
         - Informed by GAIN Technology Workshops
     - Partner and potential partner site visits
     - Capability RFI rewrite and reissue
  2. **NFML**
     - Inventory consolidation and standardization
     - Site visits to ORNL, ANL, LANL and PNNL
     - Materials RFI (3/30/2017 Milestone)
     - International collaborations
     - Report on the status of the NFML and the future plans (9/28/2017 Milestone)



FY2017 Plans (2/2)



3. **Project Database**
   - NSUF funded projects
   - Proposals
   - Reports & papers
   - Data (eventually)
4. **Expertise Database**
   - Internal & External SME
     - start with the NS&E Sourcebook
     - Collaboration or “match-making” resource
     - Supports GAIN
5. **Deployment of NSUF Experimenter Storefront**
   - Linking of databases and completion and deployment of tools to the web
   - Experiment design tool
6. **NE-52 Infrastructure Program management**
   - FOA through awards (new NSUF web portal by 11/23/2016)

Contact Information for NSUF

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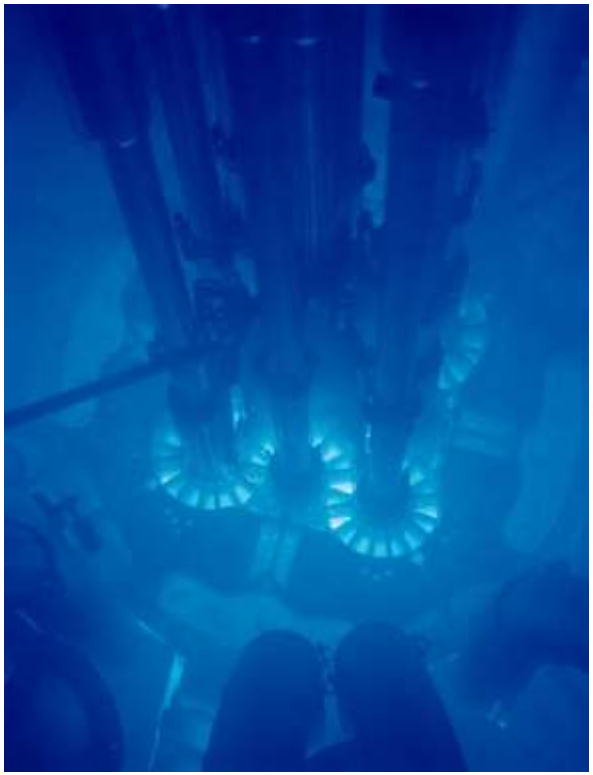

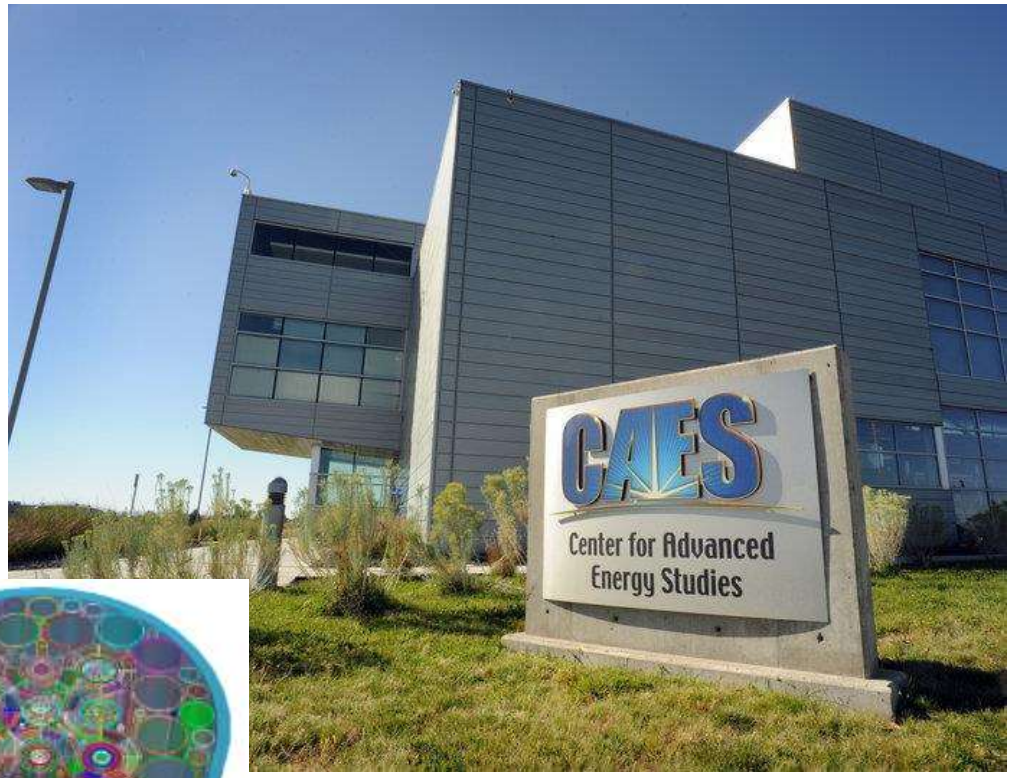

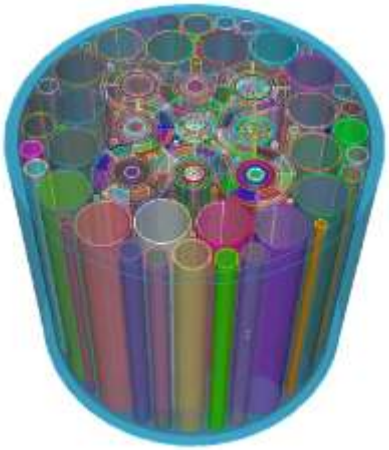

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NSUF Nuclear Science User Facilities

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NEUTRON IRRADIATION CAPABILITIES

Global Research & Test Reactors

Reactor	Country	Thermal Flux [10^{14}nv]	Fast Flux [10^{14}nv]	Utilization
JOYO	Japan		**40**	Material, fuel
BOR-60	Russia	**2**	**35**	Material, isotopes
HFIR	**US-TN**	**25**	**10**	**Isotopes, beam, fuel, material**
BR-2	Belgium	**10**	**7.1**	Fuel & material, isotopes
ATR	**US-ID**	**10**	**5**	**Material, fuel, isotopes**
HANARO	S. Korea	**4.5**	**3**	Isotope, beam, fuel, material
SAFARI-1	S. Africa	**2.4**	**2.8**	Isotopes, beam, radiography
OSIRIS	France	**0.27**	**2.6**	Material and fuel
OPAL	Australia	**3**	**2.1**	Beam science
NBSR	US-MD	**4**	**2**	Neutron scattering, beam
MITR	**US-MA**	**0.5**	**1.7**	**Material, beam, silicon**
MURR	US-MO	**6**	**1**	Material, silicon, isotopes
HBWR	Norway	**1.5**	**0.8**	Material, fuel
PULSTAR	**US-NC**	**0.3**	**0.3**	**Isotope, silicon, beams**

Test Reactor (ATR) Irradiation Types

Simple Static Capsules

- Reflector positions or flux traps
- Structural materials, isotopes, fuel specimens

Instrumented Lead Experiments

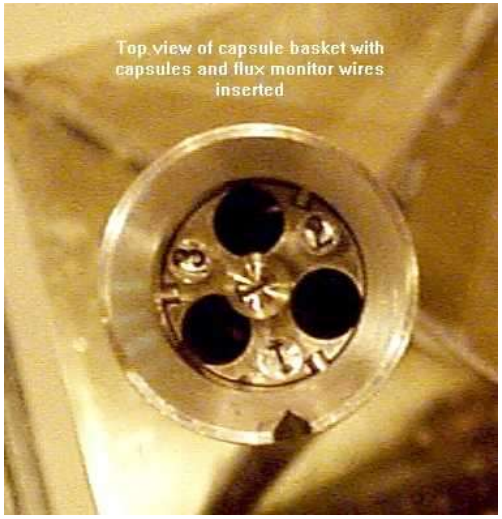
- On-line experiment measurements
- With or without temperature control
- Structural materials, cladding tubes, fuel pins

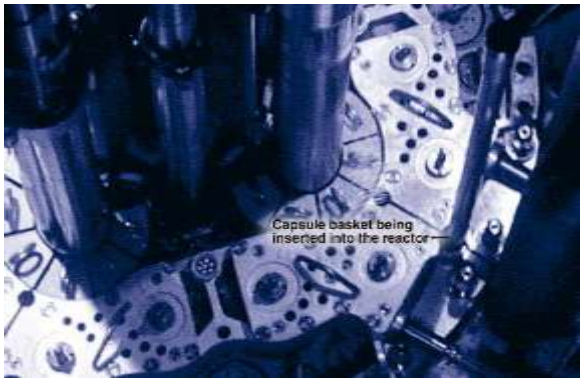
Pressurized Water Loops

- Five presently installed in flux traps
- Control pressure, temperature & chemistry
- Structural materials, cladding tubes, fuel assemblies

Hydraulic Shuttle Irradiation System

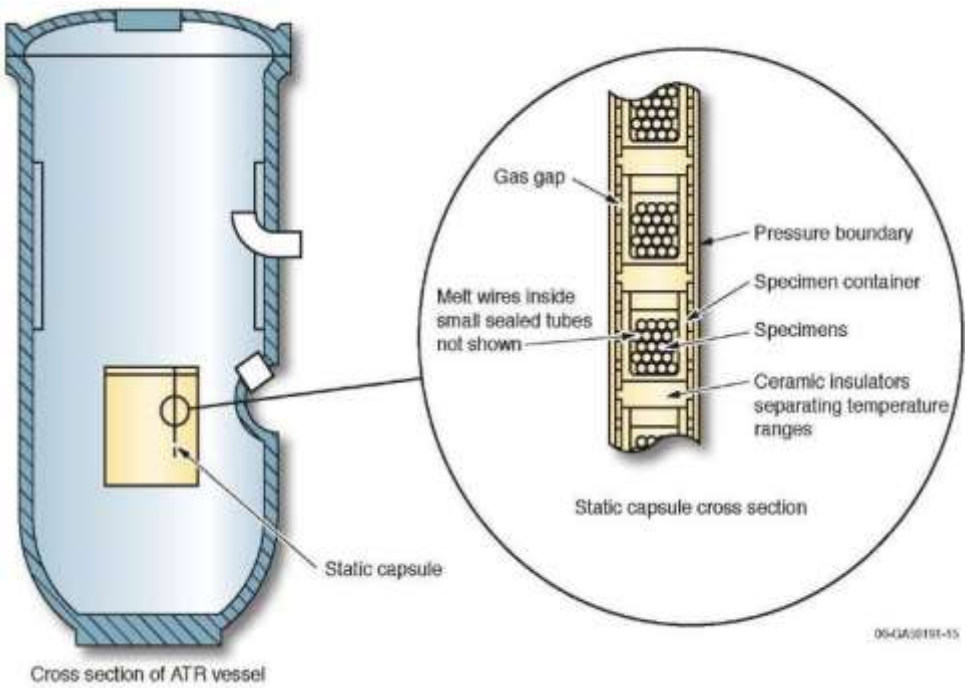
- ≤14 capsules in a set
- Inserted and removed during reactor operations



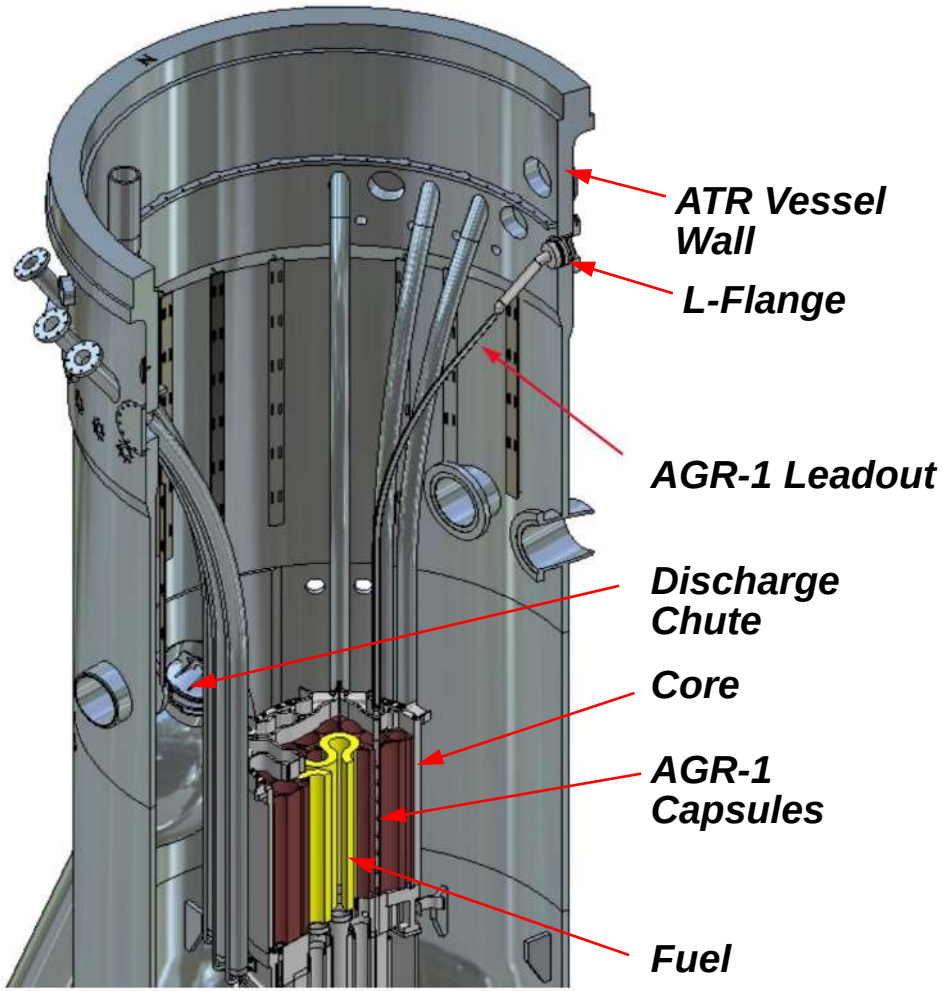


Simple Static Capsule Experiments

- Passive instrumentation (flux wires, melt wires)
- Enclosed in sealed tube, or fuel plates
- Temperature target controlled by varying gas mixture in conduction gap and with material selection
- Lengths up to 48”; diameter 0.5” – 5.0”
- Used for isotope production, fuel and material testing



Instrumented Lead Experiments



- On-line experiment measurements
- 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.)

Hydraulic Shuttle Irradiation System

- 14 shuttle capsules
- Simultaneously irradiated

- <u>Flux, at 110 MW</u>:

  Thermal Flux: 2.5×10^{14} n/cm^2-s

  Fast (>1MeV): 8.1×10^{13} n/cm^2-s

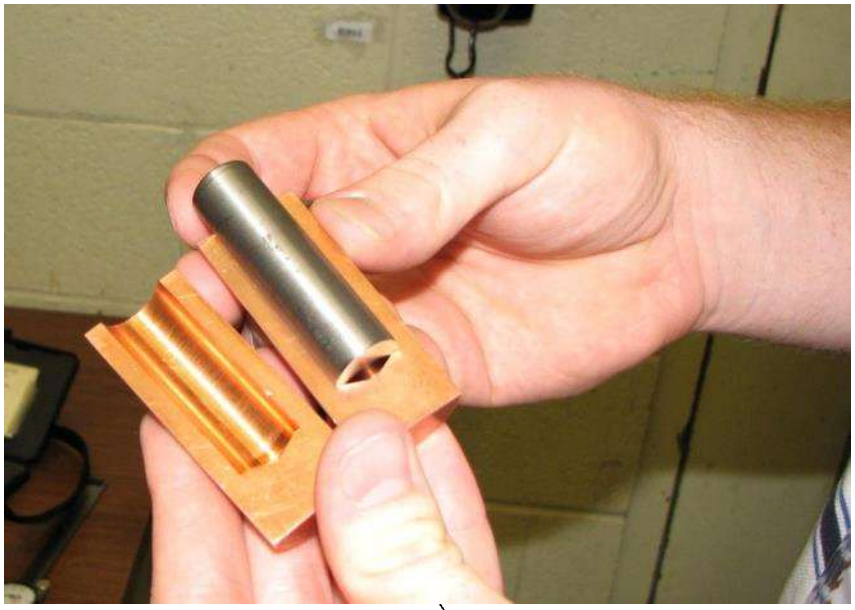
- <u>Dimensions</u>:

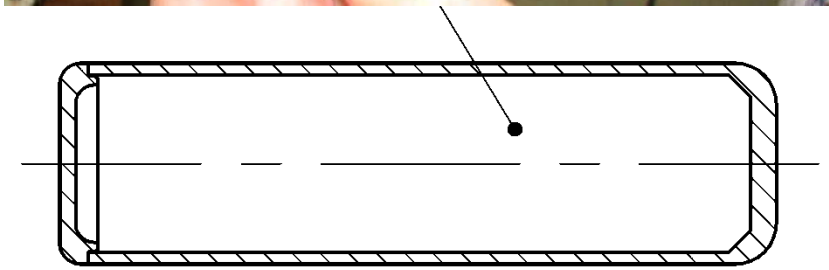
  ~ 0.55” ID, ~2.1” IL

  ~ 7 cc useable volume

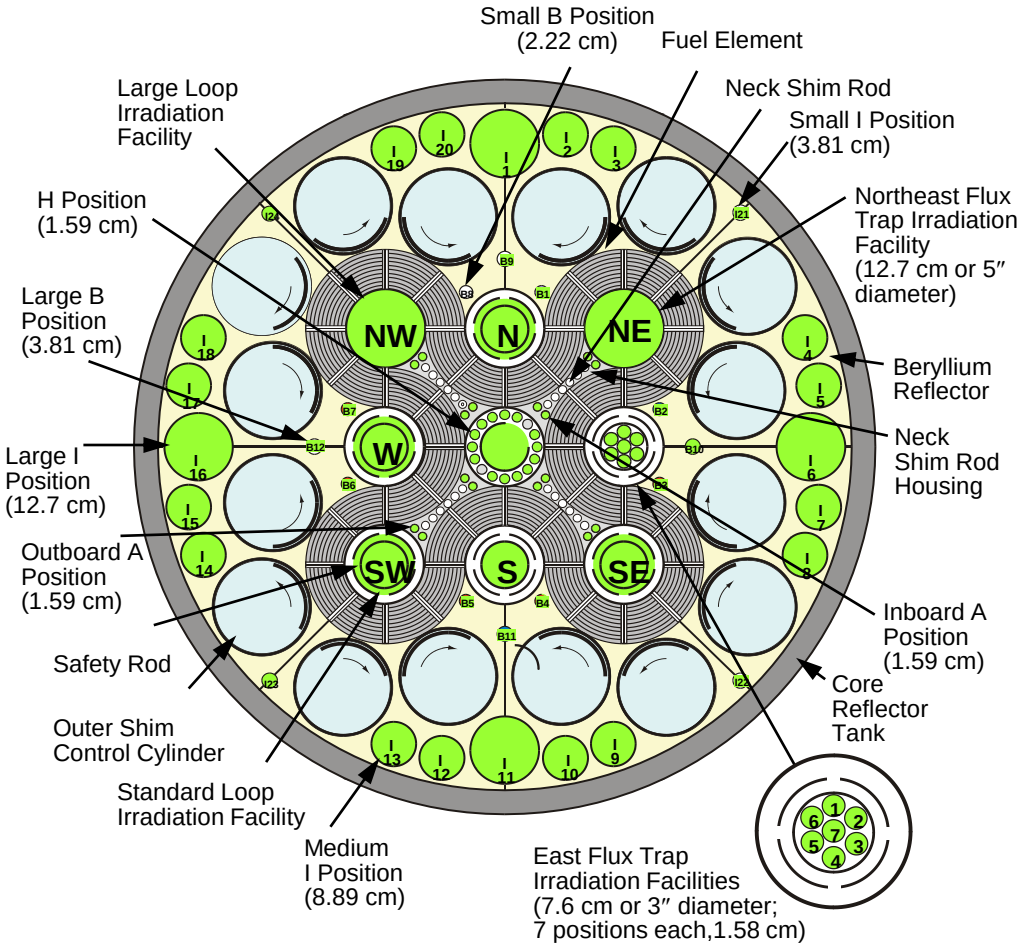
  ~35 gm Contents

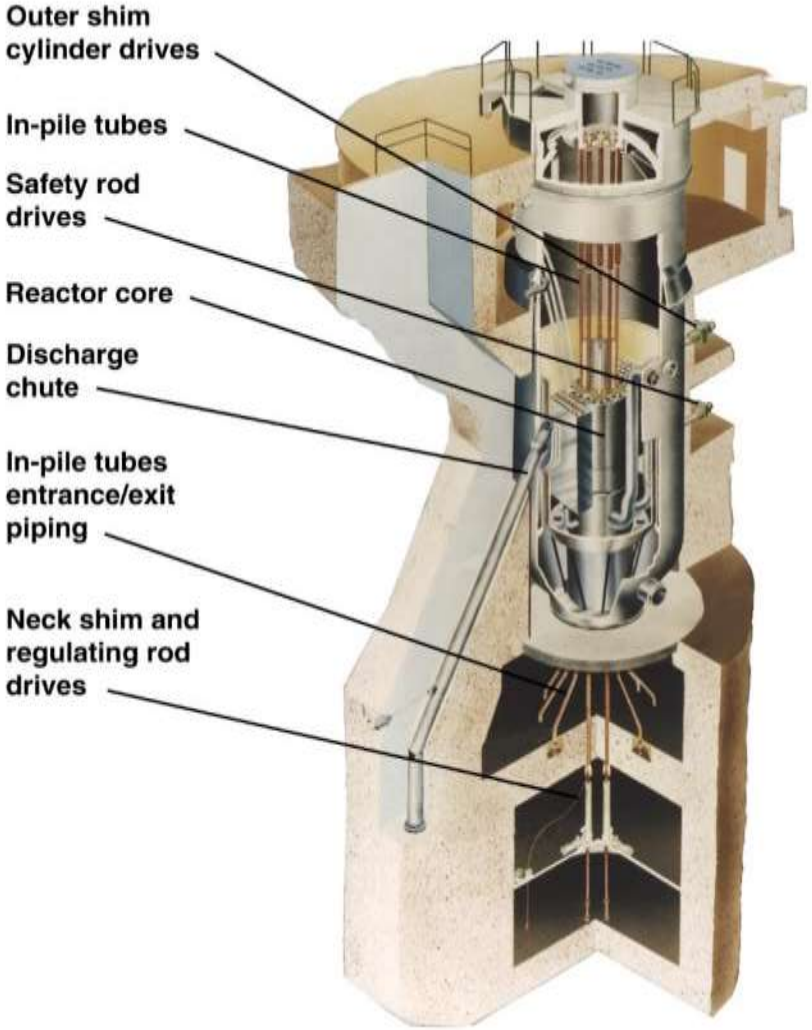
- Can irradiate small amounts of fissile material (10mg)





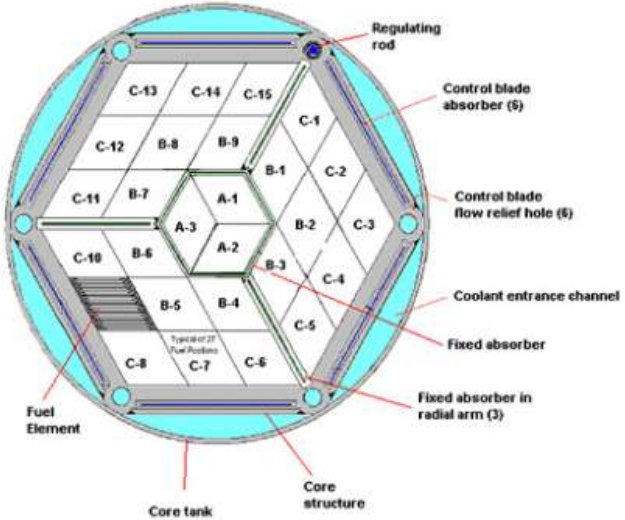
Advanced Test Reactor

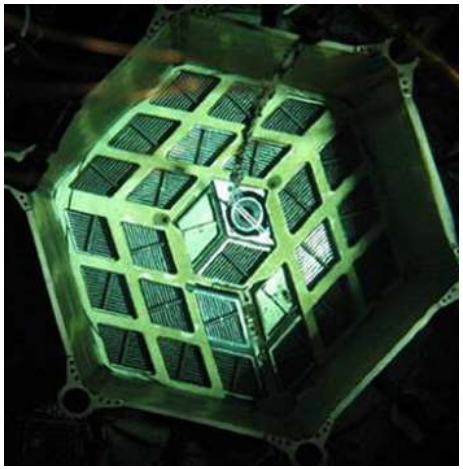




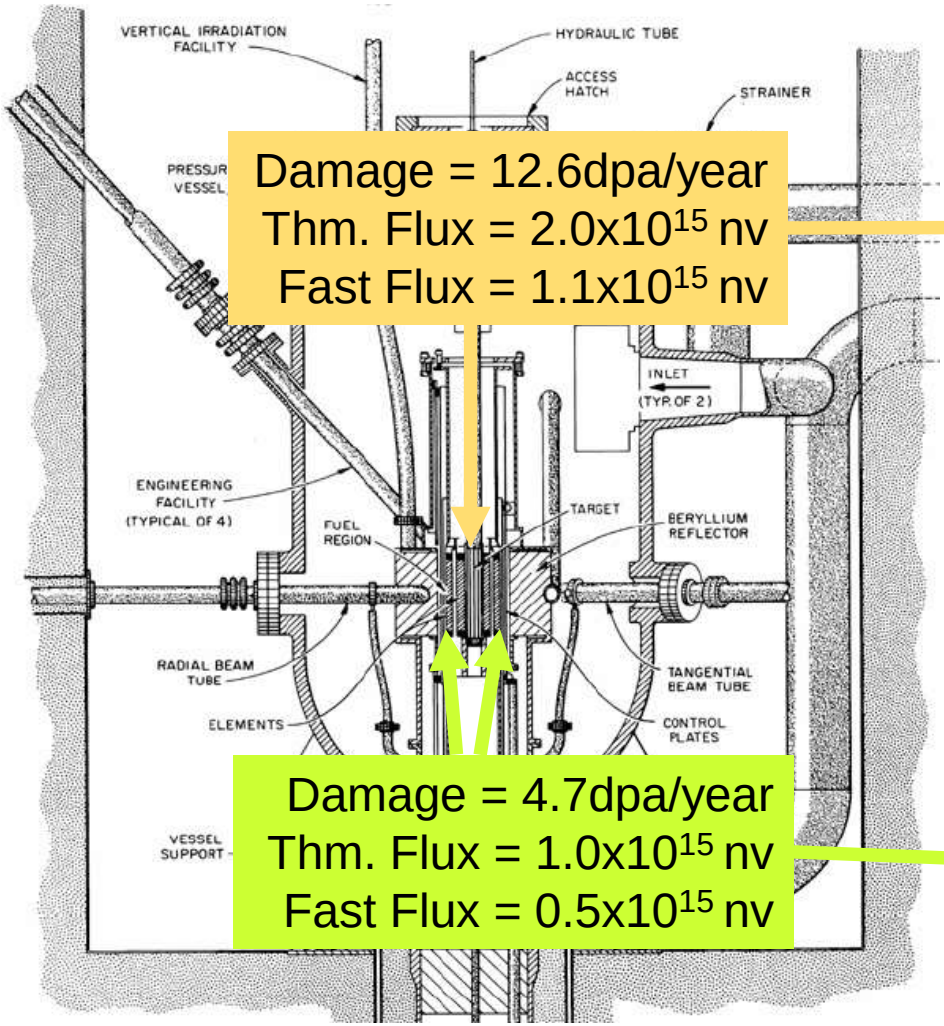
MIT Nuclear Reactor Laboratory

- The MITR has the capability to perform a <u>wide range of experiments</u> in the reactor core.
  - An inert **gas-filled irradiation** tube (ICSA) for sample capsule irradiation at <900 °C (instrumented or un-instrumented)
  - Forced-circulation **coolant loops** that replicate conditions for both PWR and BWR
  - **High temperature** (>900°C) irradiation facility for materials irradiations in He/Ne mixture
  - Custom, dedicated facilities for irradiations in unique conditions (e.g., molten fluoride salts).
  - Thermal flux 0.4×10^{14} n/cm^2-s
  - Fast flux (>0.1 MeV) 1.2×10^{14} n/cm^2-s.

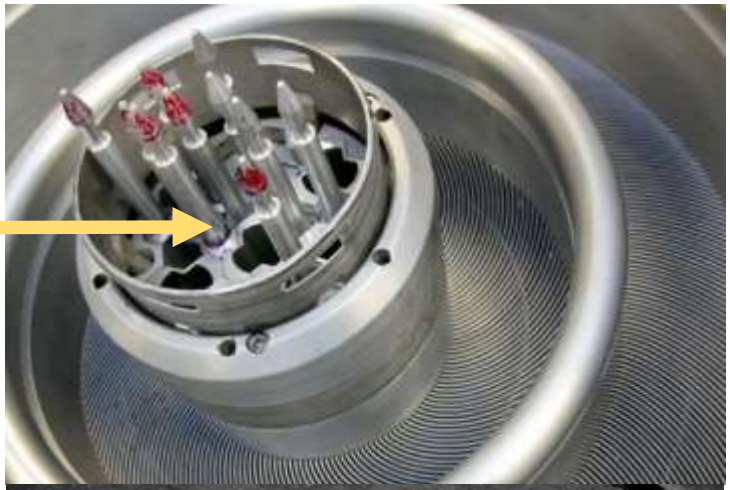




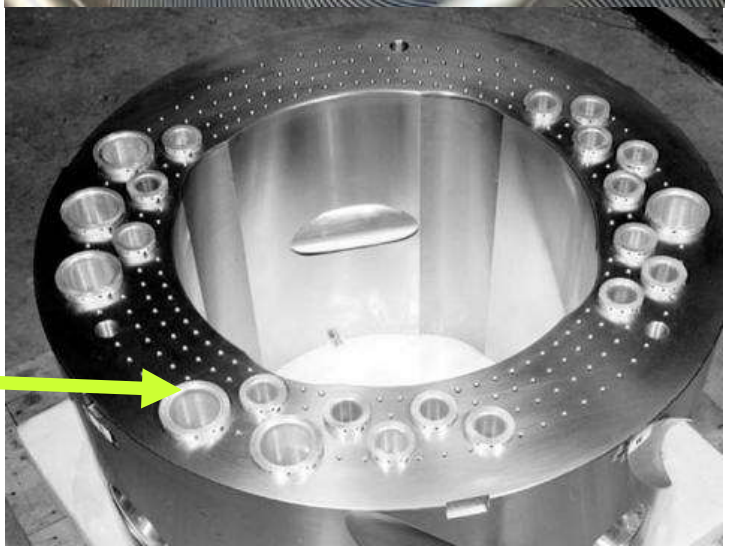
High Flux Isotope Reactor (HFIR)



Damage = 12.6dpa/year
Thm. Flux = 2.0×10^{15} nv
Fast Flux = 1.1×10^{15} nv



Damage = 4.7dpa/year
Thm. Flux = 1.0×10^{15} nv
Fast Flux = 0.5×10^{15} nv



U.S. DEPARTMENT OF ENERGY

Nuclear Energy

1. Experiments in ATR Positions

NSUF Nuclear Science User Facilities

INL Idaho National Laboratory | Irradiation Testing

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- Notebook
- Site Contents

Large I Positions

Click on each experiment to view the associated documents.

Experiment Positions

✓	Cycle	I-1	I-4	I-11	I-16
	160A-1	...			
	159A-1	...			
	158B-1	...			
	158A-1	...			
	157D-1	...			
	157C-1	...			
	157A-1	...			
	156A-1	...			
	155B	...			
	155A	...			
	154B	...			
	154A	...			
	153B	...			
	153A	...			
	152B	...			
	152A	...			
	151B-2	...			
	151B-1	...			
	151A	...			
	150B	...			
	150A	...			
	149B	...			

General Information

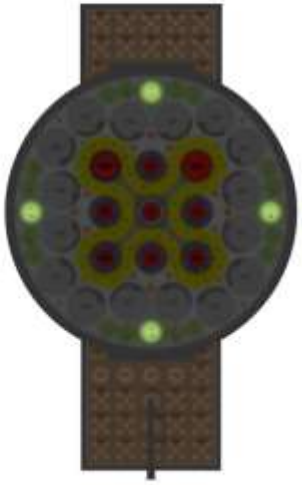
Information for total power average of 110 MW_{th}, 22 MW_{th} in each lobe

Location	Diameter (inches)	Thermal Flux ($n/cm^2 \cdot s$)	Fast Flux ($n/cm^2 \cdot s$)
North Flux Trap	3.250	4.4E+14	9.7E+13
West Flux Trap	3.250	4.4E+14	9.7E+13
East Flux Trap	3.250	4.4E+14	9.7E+13
South Flux Trap	3.250	4.4E+14	9.7E+13
Center Flux Trap	3.160	4.4E+14	9.7E+13
Northwest Flux Trap	5.375	4.4E+14	2.2E+14
Northeast Flux Trap	5.375	4.4E+14	2.2E+14
Southwest Flux Trap	3.250	4.4E+14	9.7E+13
Southeast Flux Trap	3.250	4.4E+14	9.7E+13
Small B Position	0.875	2.5E+14	8.1E+13
Large B Position	1.500	1.1E+14	1.6E+13
Inner A Position	0.625	1.9E+14	1.7E+14
Outer A Position	0.500/0.625	2.0E+14	2.3E+14
H Hole	0.625	1.9E+14	1.7E+14
Small I Position	1.500	8.4E+13	3.2E+12
Medium I Position	3.250	3.4E+13	1.3E+12
Large I Position	**5.000**	**1.7E+13**	**1.3E+12**

Position Elevation Drawing

Back to Experiment Positions in the Advanced Test Reactor

Click on the image to return to the previous page.



U.S. DEPARTMENT OF ENERGY

Nuclear Energy

1. ATR Experiment Documentation

NSUF Nuclear Science User Facilities

Idaho National Laboratory | Nucleus

Home | Organizations | Researcher | Safety | Services | Tools | A-Z

- Home
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Irradiation Testing

Experiment Documents

All Items 2A-C-BU AECL ... Find an item

Experiment Name	Experiment Document	Document Type

- Experiment Name : 2A-C-BU (12)
  - Document Type : DP (1)
  - Document Type : Drawing (6)
  - Document Type : ECAR (3)
  - Document Type : ESAP (1)
  - Document Type : TEV (1)
- Experiment Name : AECL (7)
  - Document Type : Drawing (4)
  - Document Type : ECAR (2)
  - Document Type : TEV (1)

Experiment Name : 2A-C-BU (12)
Experiment Name : AECL (7)
Experiment Name : AFC-1D (19)
Experiment Name : AFC-1G (26)
Experiment Name : AFC-1H (28)
Experiment Name : AFC-2A (18)
Experiment Name : AFC-2B (19)
Experiment Name : AFC-2C (16)
Experiment Name : AFC-2D (16)
Experiment Name : AFC-2E (12)
Experiment Name : AFC-3A (18)
Experiment Name : AFC-3B (18)
Experiment Name : AFC-3C (16)
Experiment Name : AFC-3D (18)
Experiment Name : AFC-3F (19)
Experiment Name : AFC-4A (13)
Experiment Name : AFC-4B (36)
Experiment Name : AFC-4C (12)
Experiment Name : AFIP-1 (8)
Experiment Name : AFIP-2 (12)
Experiment Name : AFIP-3 (9)
Experiment Name : AFIP-4 (12)
Experiment Name : AFIP-6 (25)

Experiment Name : AFIP-7 (23)
Experiment Name : AGC-1 (27)
Experiment Name : AGC-2 (17)
Experiment Name : AGC-3 (14)
Experiment Name : AGC-4 (10)
Experiment Name : AGR-1 (42)
Experiment Name : AGR-2 (25)
Experiment Name : AGR-3/4 (30)
Experiment Name : ATF-1 (31)
Experiment Name : ATF-2 (1)
Experiment Name : DREXEL (29)
Experiment Name : EPRI-1 (16)
Experiment Name : EPRI-2 (15)
Experiment Name : EPRI-3 (15)
Experiment Name : EPRI-ZG (17)
Experiment Name : GD (7)
Experiment Name : GFR-F1-2 (11)
Experiment Name : GTL (17)
Experiment Name : HAFNIUM (7)
Experiment Name : ISORAY (8)
Experiment Name : JNC (8)
Experiment Name : KJRR (13)
Experiment Name : LACE (3)
Experiment Name : LSA COBALT (8)
Experiment Name : LUNA (11)
Experiment Name : MANTRA-1 (11)

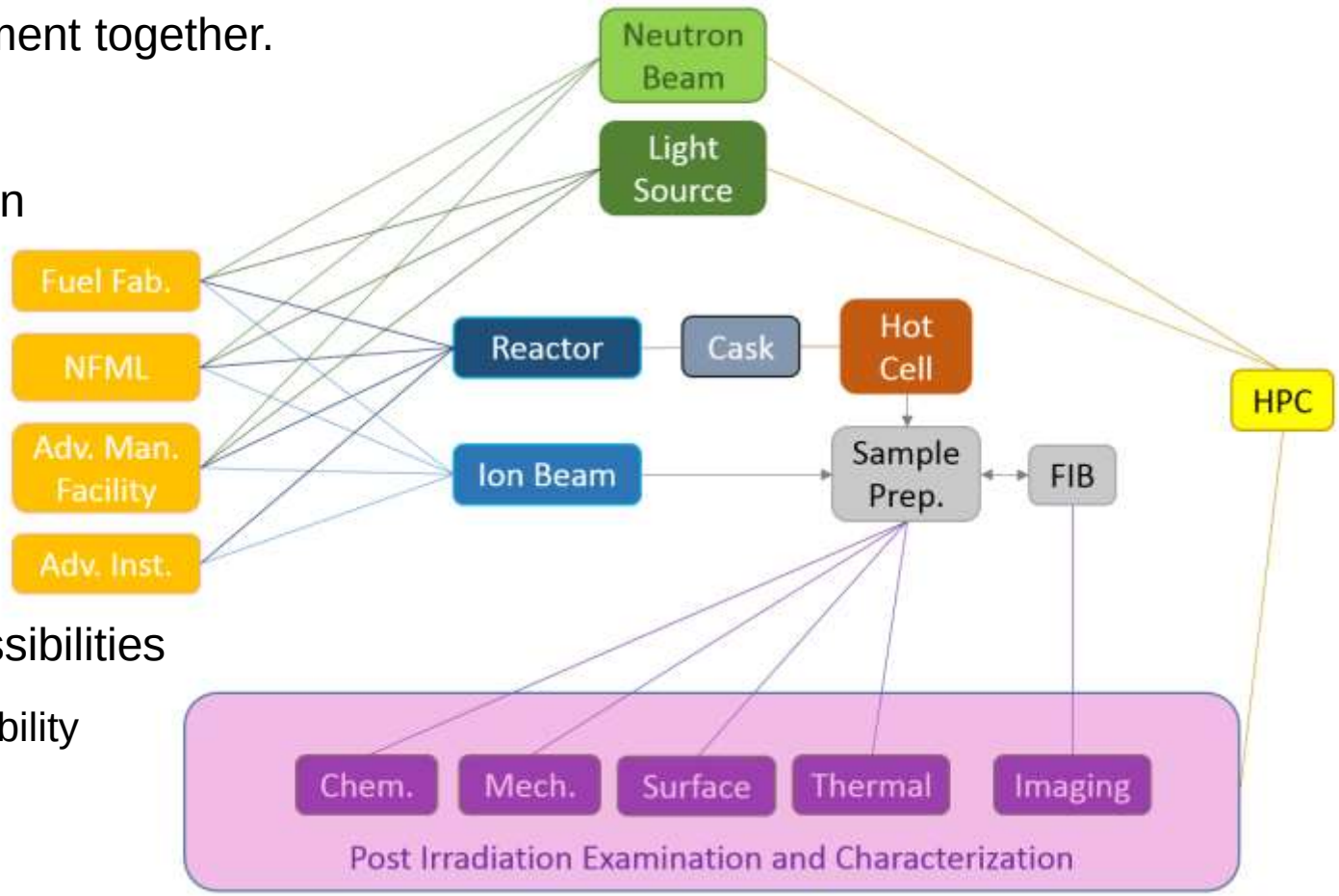
Experiment Name : MANTRA-2 (11)
Experiment Name : MANTRA-3 (10)
Experiment Name : NCSU (16)
Experiment Name : NEW HSA COBALT
Experiment Name : OLD HSA COBALT
Experiment Name : OLD HSA COBALT
Experiment Name : RERTR-10 (21)
Experiment Name : RERTR-12 (26)
Experiment Name : RERTR-13 (21)
Experiment Name : RERTR-6 (19)
Experiment Name : RERTR-7 (25)
Experiment Name : RERTR-8 (22)
Experiment Name : RERTR-9 (24)
Experiment Name : SAM-1 (8)
Experiment Name : TMIST-1 (16)
Experiment Name : TMIST-2 (20)
Experiment Name : TMIST-3 (26)
Experiment Name : UCF-1 (15)
Experiment Name : UCF-3 (1)
Experiment Name : UCSB-1 (11)
Experiment Name : UCSB-2 (17)
Experiment Name : UF (12)
Experiment Name : UI (18)
Experiment Name : USU (10)
Experiment Name : UW (14)

NSUF Experiment Storefront

Build on NEID to help users and Technical Leads put an experiment together.

Experiment Types:

1. Neutron Irradiation
2. Ion Irradiation
3. PIE-only
4. Beamline



Process:

1. User picks type
2. NEID supplies possibilities

- Error checking capability
- Could minimize
  - Cost
  - Shipping
  - Availability conflicts

Testing Strategy for Novel Materials

Irradiation Testing Hierarchy

1. **Ion Beams Irradiation Facilities**
   - Allow immediate feedback of performance
   - Ease of instrumentation
   - Ease of environmental tuning

2. **Low-Power Research Reactors**
   - First 1% and 10% testing
   - Instrumentation development (pulsing for TREAT)
   - Neutron radiography
   - Experiment modeling & validation efforts

   URR advantages:
   - Ease of use & lower cost
   - Expertise in handling and shipping/receiving RAM
   - Co-located with Hot Cell facilities (sample preparation)

THE UNIVERSITY of WISCONSIN MADISON

NC State University Raleigh, NC

Massachusetts Institute of Technology

Standardized Capsule Design for New Materials

1. **HSIS Test** (closest to "standard")
2. **Standardized "Drop-In" Capsule**
   - Low Cost
   - More Experiments
   - Easier and Faster Accomplishment

■ **Example**

- Single Design for both I and A/H positions in ATR (idea from ^{60}Co work)