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NFML FY 2021 Annual Review Presentation

November 2021

Kelly A Cunningham

Changing the World's Energy Future

Idaho National Laboratory

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Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

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The Nuclear Science User Facilities

The Nuclear Fuels and Materials Library

Kelly Cunningham
NFML Coordinator

FY 2021 Annual Review
November 2021

nsuf.inl.gov

Nuclear Science User Facilities

The NUCLEAR FUELS AND MATERIALS LIBRARY
Overview

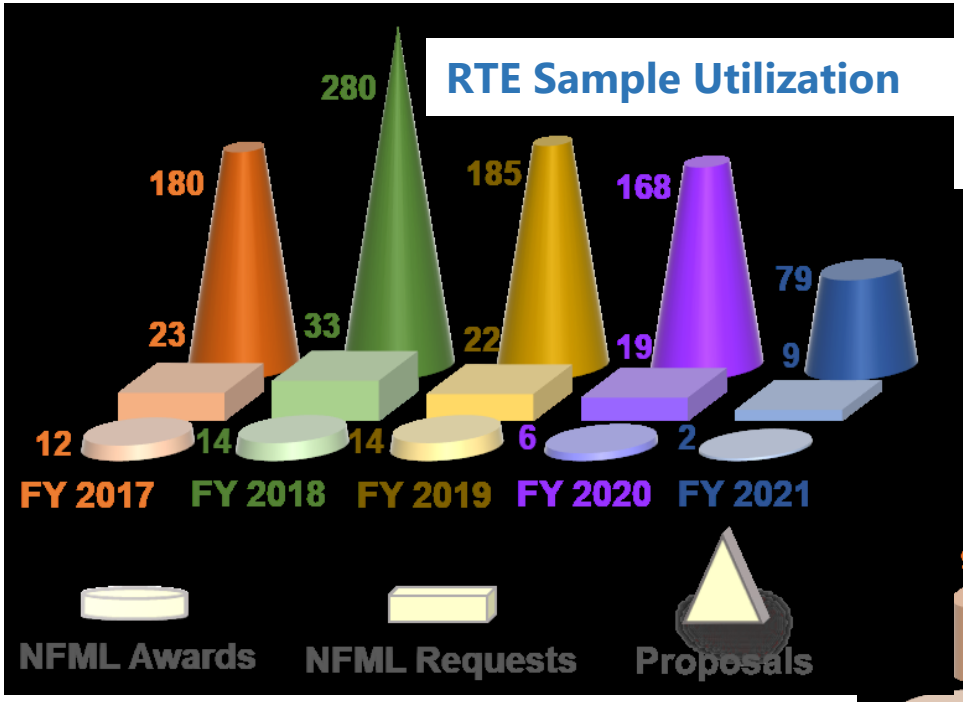
The Nuclear Fuels and Materials Library (NFML), established shortly after the NSUF in 2007, is **owned** by the U.S. Department of Energy's Office of Nuclear Energy (DOE-NE), and **curated** by the Nuclear Science User Facilities (NSUF).

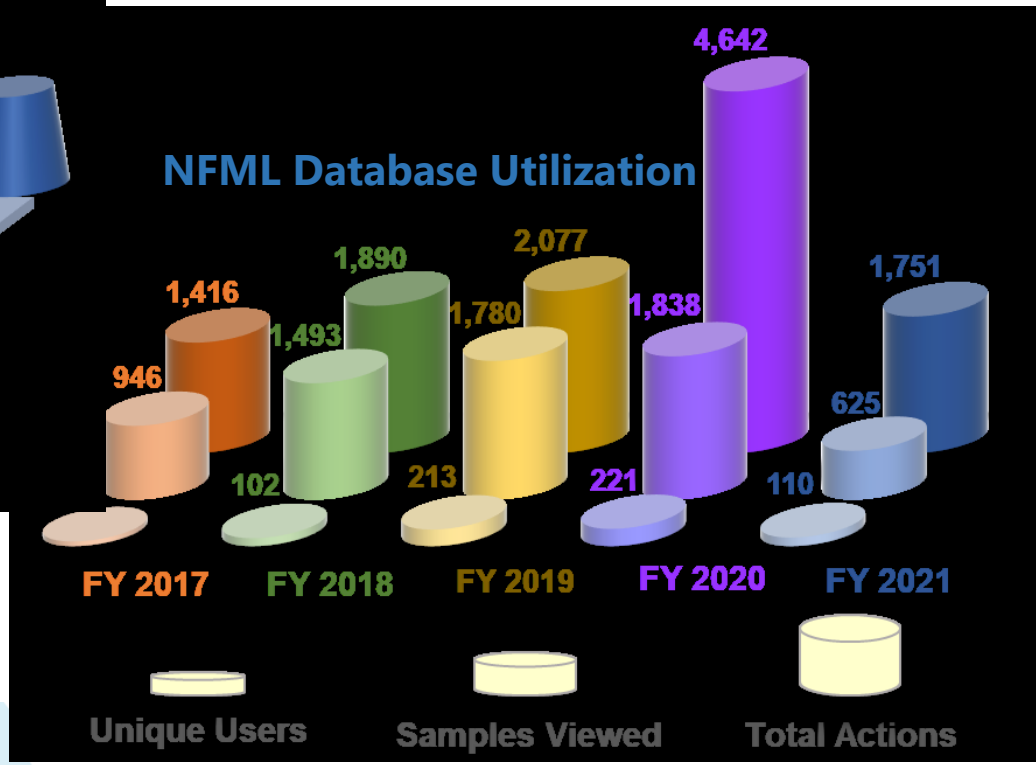
The NFML has evolved into the largest global open archive of high-value irradiated fuels and materials.

- Samples resulting from NSUF-awarded projects
- Legacy samples from the Experimental Breeder Reactor (EBR-II) shutdown in 1994
- Samples from real-world components retrieved from decommissioned power reactors
- Donations from other sources
- Technical information and publications associated with all NFML projects with samples

The NUCLEAR FUELS AND MATERIALS LIBRARY

FY 2021 Utilization





Normally 3 RTE Calls per year
FY 2020 –2 RTE Calls
FY 2021 –1 RTE Call

The NUCLEAR FUELS AND MATERIALS LIBRARY
FY 2021 Sample Utilization

Awarded Institution	Awarded Title	Requested Samples	NFML Samples
RTE			
Pacific Northwest NATIONAL LABORATORY	Microstructural characterization of neutron irradiated NF616 (Grade 92) as a function of doses and temperatures	Alloy NF616	Irradiation Test Plan for the ATR Nuclear Science User Facilities - University of Wisconsin Pilot Project
INL Idaho National Laboratory 4280	Microstructural Examination of Irradiation Effects on Metal Matrix Composite Neutron Absorber	Ceramic HfAl	Irradiation Effect on Thermophysical Properties of Hf3Al-Al Composite: A Concept for Fast Neutron Testing at ATR
CINR			
INL Idaho National Laboratory 21-24335	Deployment and In-Reactor Test of an Instrument for Real-Time Monitoring Thermal Conductivity Evolution of Nuclear Fuels	Ur Alloy	Low Fluence Behavior of Metallic Fuels
Pacific Northwest NATIONAL LABORATORY 21-24327	Effect of neutron irradiation on friction stir welded Ni-based ODS MA754 alloy	Alloys MA956 MA754	Influence of Fast Neutron Irradiation on the Mechanical Properties and Microstructure of Nanostructured Metals/Alloys

The NUCLEAR FUELS AND MATERIALS LIBRARY
CY 2021 NFML-Related Publications

NFML Samples	Publications
INL Idaho National Laboratory	Microstructure and microchemistry of laser welds of irradiated austenitic steels, Materials and Design, V. 206, 109764
	Use of combined linear and nonlinear ultrasound to examine microstructural and microchemical variations in highly irradiated 304 stainless steel, Journal of Nuclear Materials (JNM), V. 545, 152644
UC SANTA BARBARA	Precipitation in reactor pressure vessel steels under ion and neutron irradiation: On the role of segregated network dislocations, Acta Materialia, V. 212, 116922
UCSB-2	An Atom Probe Tomography Study of the Through Wall Attenuation Effect on Cu-rich Precipitate Formation in a Reactor Pressure Vessel Steel, JNM, V. 545, 152740
WISCONSIN UNIVERSITY OF WISCONSIN-MADISON 08-331	Neutron irradiation induced defects and clustering in NF616 and T91, JNM, V. 552, 153001
ILLINOIS	Early-stage microstructural evolution and phase stability in neutron-irradiated ferritic-martensitic steel T91, JNM, V. 557, 153207
08-92	Phase stability and microstructural evolution in neutron-irradiated ferritic-martensitic steel HT9, JNM, V. 557, 153252
SCHOOL OF MINES 1874 COLORADO	Impact of neutron irradiation on the thermophysical properties of additively manufactured stainless steel and Inconel, JNM, V. 549, 152861
University of Central Florida	Molecular dynamics simulations of radiation cascade evolution near cellular dislocation structures in additively manufactured stainless steels, JNM, V. 549, 152872
	An atomistic study of defect energetics and diffusion with respect to composition and temperature in γU and γU-Mo alloys, JNM, V. 552, 152970
	Fuel-cladding chemical interaction of a prototype annular U-10Zr fuel with Fe-12Cr ferritic/martensitic

The NUCLEAR FUELS AND MATERIALS LIBRARY
FY 2021 Updated NFML Policy

The updated NFML policy guidelines are as follows:

1. All materials and samples in the NFML are owned by the DOE-NE and curated by the NSUF.
2. Materials offered to and accepted into the NFML for curatorship must be transferred to the NSUF.
   a. Materials or samples from DOE programs that were not funded by the NSUF will be transferred from the DOE program to the NSUF through a documented agreement. The documented agreement should come from the offering DOE Federal Program Manager or their DOE delegate.
   b. Materials or samples from third parties (industry, foreign entities, other non-DOE federal agencies, etc.) should be transferred to the DOE-NE per a legal Agreement on Transfer of Title and Ownership.

   Upon transfer, the curation of the materials or samples will be administered solely by the NSUF. The transferring party will have no further authority regarding the disposition of the transferred materials or samples.
3. Samples offered and accepted into the NFML should be accompanied by an adequate pedigree. Pedigree documents may include, but are not limited to:
   a. Material certifications and compositions,
   b. Irradiation conditions (temperature, dose, flux, fluence)
   c. Fabrication methods,

The NFML Policy can be found at https://nsuf.inl.gov/Page/nfml_request

The NUCLEAR FUELS AND MATERIALS LIBRARY
FY 2021 Updated NFML Policy (continued)

d. Sample geometry, and

e. Related publications.

The pedigree information will be publicly available. In the rare instance a portion of the pedigree is proprietary, an appropriate arrangement may be agreed upon that excludes sensitive information from the public domain.

4. All available samples in the NFML can be requested for use through the NSUF CINR and RTE solicitation processes. Request for samples outside of the solicitation processes can be made directly to the NSUF Director.

5. Samples transferred into the NSUF as a result of an awarded CINR or requested for an RTE are managed according to the policies of the NFML.

6. Following the completion of the sample irradiation portion of an awarded experiment, the Principal Investigator (PI) will be given exclusive rights to the samples for a three-year period of post-irradiation examination (PIE) unless other conditions are agreed upon. After the three-year period, the samples will be made available to the general research community for subsequent competitively awarded proposals.

   a. As a courtesy, subsequent proposers will be provided the contact information of the original project PI for potential collaboration opportunities. The original PI may collaborate or not but may not deny access to NFML sample requests included in an awarded proposal.

The NUCLEAR FUELS AND MATERIALS LIBRARY
FY 2021 Updated NFML Policy (continued)

7. The NSUF reserves the right to fabricate, irradiate, and add to the NFML additional material samples as part of any irradiation project supported by the NSUF.

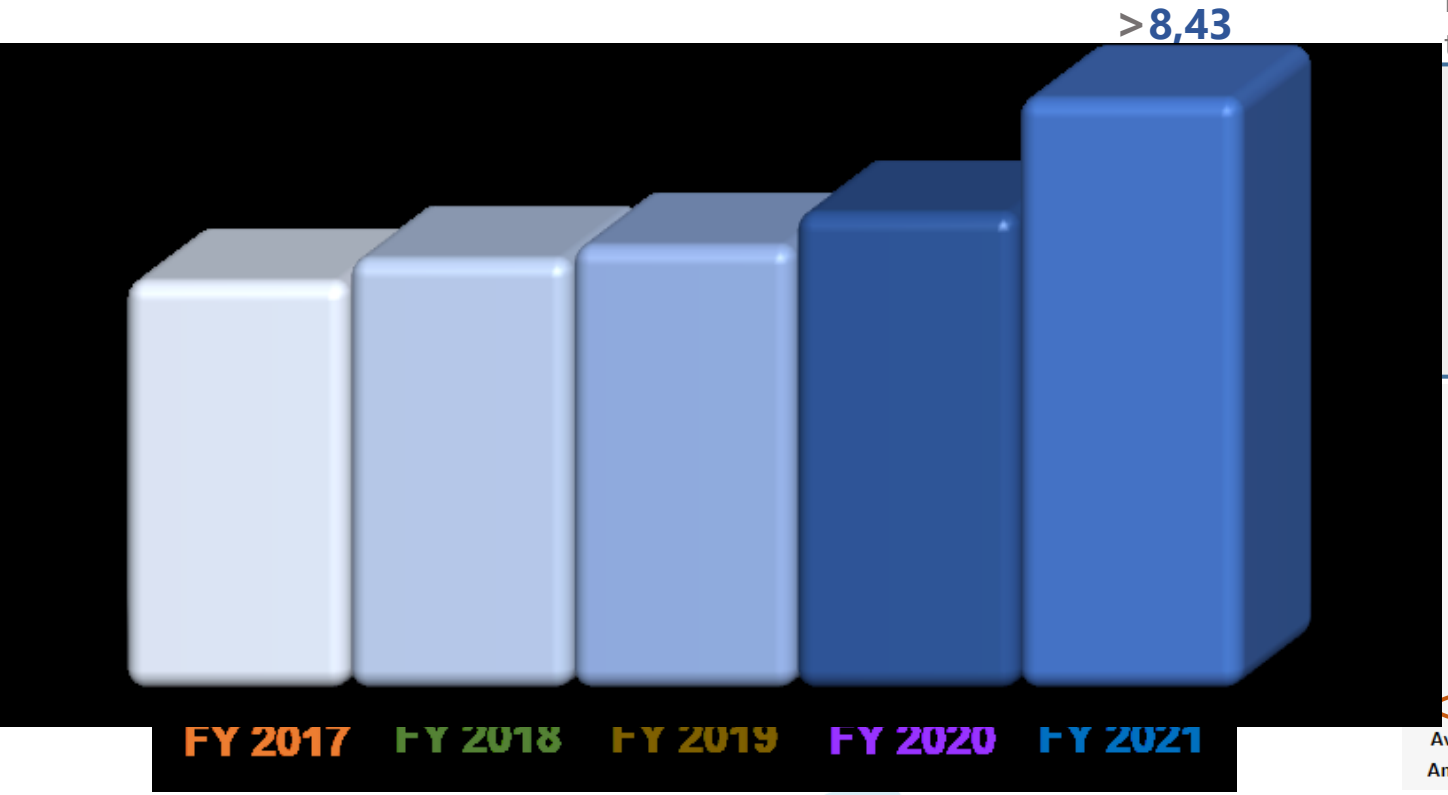
8. In the case of a dispute regarding the use of NFML samples or the admittance of samples into the NFML, the final arbiter of decision will reside with the DOE-NE.

9. NFML samples may be requested for projects/experiments outside of NSUF proposal processes. Requests must be made to and granted by the NSUF Director. As these requests are not specifically related to the NSUF proposal process, alternative or additional guidelines may be established on an individual basis.
   a. The requesting party may be responsible for costs to retrieve and ship samples as well as return the samples to the original NSUF storage location.
   b. All samples and materials in the NFML are generally intended for non-proprietary work. Samples requested to perform proprietary work will be subject to additional review and conditions.

10. Any and all publications resulting from the use of NFML samples must acknowledge the NSUF and NFML by including the following citation: "Materials or samples employed in this study are from the Nuclear Fuels and Materials Library and were provided by the U.S. Department of Energy, Office of Nuclear Energy under DOE Idaho Operations Office Contract DE-AC07- 051D14517 as part of the Nuclear Science User Facilities".

The guidelines are not immutable. As NSUF users and NFML sample requests increase, new situations and questions may compel the need for flexibility or additional guidance. The NSUF reserves the right to amend or add new guidelines as needed.

The NUCLEAR FUELS AND MATERIALS LIBRARY
FY 2021 Inventory Growth



Many IDs/KGTs have more than one identical sample

Reactor Position	B-2
Sample Id Code	09-157-011
Capsule	A1
Packet	N/A
Material Code	Hafnium aluminide/aluminu
Material Name	Hafnium Aluminide
Material Description	28.4% AL3Hf composite
KGT Num	1404
Specimen Type	tensile
Dimensions (mm)	16 mm x 4 mm x 1
Number Of Samples	5
Available for Research	Yes
Anticipated Availability	February 11, 2015

The NUCLEAR FUELS AND MATERIALS LIBRARY
FY 2021 Added Inventory – NSUF Projects

FY 2015 Award - Irradiation Influence on Alloys Fabricated by Powder Metallurgy and Hot Isostatic Pressing for Nuclear Applications

- 3 DPA Steel Alloys *(available ~2024 when PIE is completed)*
- BSU 1 DPA added in FY 2020 *(available ~2023 when PIE is completed)*
- Extra Hf-Al samples irradiated in BSU capsules *(available now)*

FY 2016 Award - Nanostructured Steels for Enhanced Radiation Tolerance (N-SERT)

- 2 DPA Fe-Cr and High Entropy Alloys *(available ~2024 when PIE is completed)*

FY 2010 Award - Low Fluence Behavior of Metallic Fuels

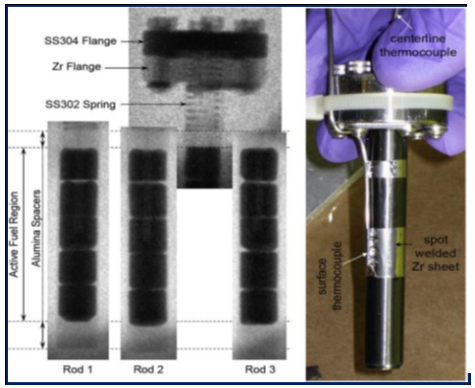
- UCF-2 *Unirradiated* metallic fuels (available now)

The NUCLEAR FUELS AND MATERIALS LIBRARY
FY 2021 Added Inventory – NSUF Projects

2010 NSUF Project: Hydride LWR Fuel Rod Irradiation

- Mini hydride metallic fuel rodlets with Zr cladding (irradiated and unirradiated)
- Irradiated at MIT with PIE completed at PNNL in 2017

Hydride fuel element and capsule stack

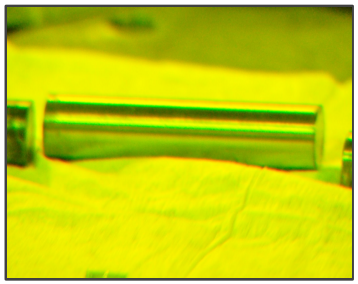


Fuel rodlets as fabricated

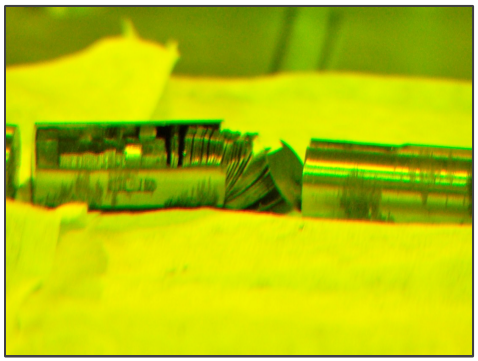
Photos courtesy of Kurt Terrani (ORNL)

2009 NSUF Project: High Fluence Embrittlement Database and ATR Irradiation Facility for LWR Vessel Life Extension

- Over 950 specimens of various types, composed of 172 alloys irradiated in the ATR over a range of flux, fluence, and temperature.
- Design, construction of capsule, and irradiation funded by the NSUF.



Intact specimen cup



Mulit-purpose disc specimens spilling out of cup

Photos courtesy of Thomas Rosseel (ORNL)

- Research collaboration (UCSB, ORNL, UCB) funded by LWRS Program.
- An international consortium of participants, including the main collaborators, EPRI, several US utilities, and organizations from the United Kingdom contributed sample materials.

The NUCLEAR FUELS AND MATERIALS LIBRARY
Future Inventory – NSUF Projects

Future NSUF-awarded ATR irradiation samples to be added to the NFML

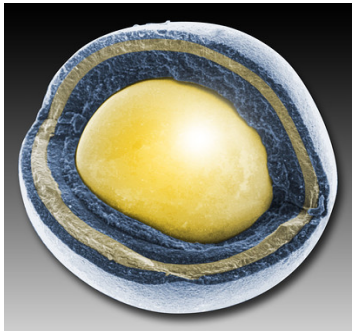
Project	Material	Samples	Irradiation/PIE	*Availability *(projected)*
CRADA - EPRI Pilot Program – Baseline Fracture Toughness and Crack Growth Rates Testing of Alloys	Ni-based Alloys	X-750 & XM-19	Irrad & PIE complete	2022
ISU 16-10537 Nanostructured Steels for Enhanced Radiation Tolerance (NSERT)	Steels & Alloys	Fe-Cr & high-entropy alloys	2 dpa undergoing PIE 6 dpa PIE to start 2022	~2024 ~2025
High Temperature In-Pile Irrad Test of Single Phase U_3Si	Fuel	U_3Si_2	Cpsl 1 PIE to start 2022, Cpsl 2: irrad to be complete 2024	~2025 ~2027
CRADA - EPRI Zirconium Growth Experiment	Ceramics	Zr alloys	ZG-C: PIE to start 2022, ZG-D irrad complete 2022	~2025 ~2026
Aeroprobe Test of Additively Manufactured Materials (ATAMM)	Steels	AM 316L	PIE to start in 2022	~2025
SAM-2 - neutron transmutation doping (NTD) of high-purity SiC by thermal neutron-capture reactions during irradiation	Ceramics	SiC	Irrad complete PIE in FY 2022 (*dependent on funding*)	*3-year exclusive use for PIE 2022

The NUCLEAR FUELS AND MATERIALS LIBRARY
FY 2021 Added Inventory – Repository Donations

Added in 2021:

U.S. DEPARTMENT OF ENERGY Nuclear Energy

Program to Program Transfer
Advanced Gas Reactor Program



- Residual unirradiated 5-layer tri-structural isotropic (TRISO) particles from the New Production Reactor Program (1988-1992)
- Research using these particles has the potential to advance the DOE-NE mission by contributing further understanding in TRISO fuel improvements as well as fabrication and fuel qualification for future gas-cooled reactors.

Donations in Progress:

U.S. DEPARTMENT OF ENERGY Nuclear Energy

Program to Program Transfer
Advanced Reactor Technology and Advanced Fuels Campaign

- Russian Reactor BOR-60 irradiated steel/alloy TEM samples
- Original CRADA between Terrapower, LANL, and ORNL
- Samples used for Integrated Research Project to benchmark ion irradiations against neutron irradiations.
- To be added early FY 2022 upon receipt of official program-to-program transfer

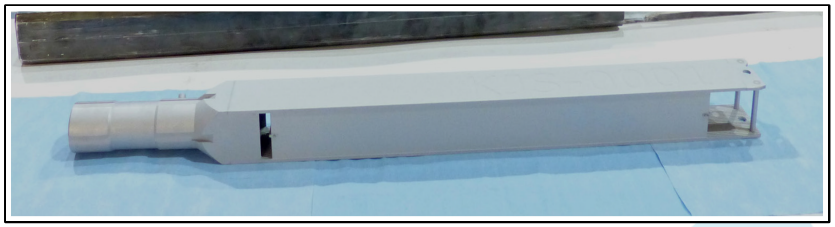
The NUCLEAR FUELS AND MATERIALS LIBRARY
FY 2021 Added Inventory – Repository Donations

Donations in Progress:

Program to Program Transfer

CRADA - Ki-Jang Research Reactor (KJRR) Fuel Assembly Irradiation

- U-7Mo dispersed in Al-Si matrix, Al-clad fuel plates (CRADA included title transfer to DOE-ID)
- Primary purpose of the campaign was to provide date about the irradiation performance of the KJRR fuel assembly.
- Korea Atomic Energy Research Institute (KAERI) fabricated the KJRR fuel experiment and shipped to the INL to be irradiated in the ATR, PIE in the HFEF, and as-Run irradiation conditions analysis performed.
- To be added in FY 2022 when PIE is completed.



Lead Test Assembly

Fuel Plates

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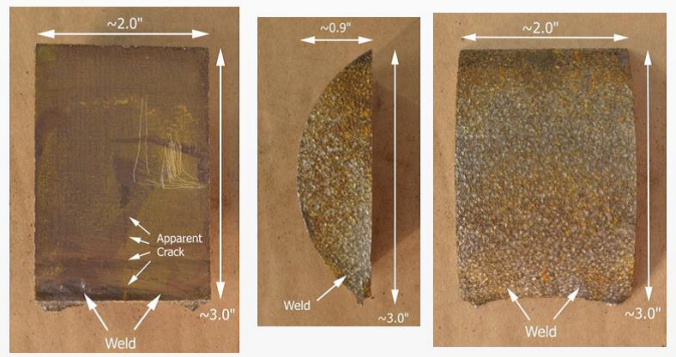
FY 2021 Added Inventory – Repository Donations

Donations in Progress:

Industry to DOE-NE Title Transfer

EPRI, BWXT, Southern Nuclear

- 304 SS core shroud samples from a commercial nuclear power plant



FY 2019

FY 2020

FY 2021

FY 2022

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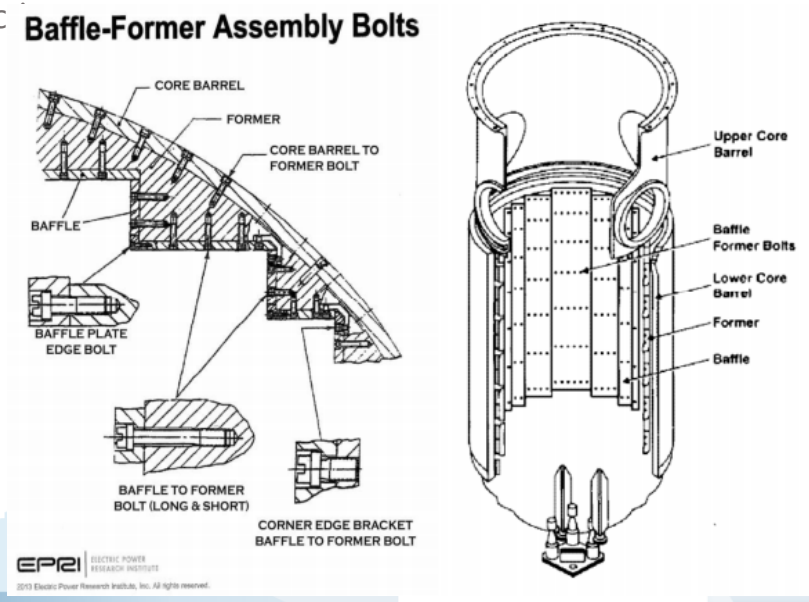
FY 2021 Harvesting Activities

Crystal River (Florida)

- Orano, as part of the Accelerated Decommissioning Partner (ADP), is currently decommissioning and dismantling the Crystal River 3 Nuclear Power Plant (NPP).
- NSUF contracted with Orano Federal Services (FS) to complete Phase I, Data Gathering and Feasibility Study for Crystal River Unit 3 Nuclear Power Plant Sample Harvesting.
- Study detailed the basis for execution of harvesting samples from the Reactor Vessel Internals (RVI), including logistics for extrac packaging, and transportation of harvested materials.
- The components of interest identified to harvest included:
  - Core Barrel base metal and weld material,
  - Baffle former bolts, and
  - Surveillance coupons.
- Phase II, Sample Harvesting, dependent on funding.



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FY 2021 Harvesting Activities

San Onofre Nuclear Generating Station (California)

- NSUF (DOE) is collaborating with NRC to harvest irradiated materials from SONGS reactor
- Planning to acquire material pedigree information needed for harvesting
  - Design and fabrication information
  - Fluence and temperature analysis
- Planning for on-site preparation activities
  - Cask license to support the shipment from SONGS to INL
  - Coordination and logistics for shipment
  - Preparation for receipt and handling of SONGS material at INL
- Preparation for shipping the materials from SONGS to INL
- Coordination with SONGS Decommissioning Solutions (SDS), Southern California Edison (SCE), Westinghouse, Orano and others.

Must be inserted into and consistent with SONGS decommissioning critical path.

The NUCLEAR FUELS AND MATERIALS LIBRARY
FY 2021 Harvesting Activities

Potential Additions:

Halden Reactor Project (Norway)

- May 2020 - DOE-NE/NRC/EPRI/INL submitted a request to the Institute for Energy Technology for structural material samples from the soon-to-be decommissioned Halden research reactor
- June 2020 - Reply stated requested samples would not be available until late 2022-23, if at all
- June 2021 – Few select samples available immediately
- August 2021 – DOE-NE approvals requested

Zion Nuclear Power Station (Illinois) – Decommissioned 1998

- LWRS Program currently testing harvested material
- Process of transferring the Zion materials to the NSUF when testing is complete ~ FY 2022 year-end

The NUCLEAR FUELS AND MATERIALS LIBRARY
FY 2021 Outreach

- Continued discussions with the United Kingdom Irradiated Materials Archive Group (IMAG).
  - IMAG was established with representatives from UK universities, UKAEA, NNL, the Nuclear Decommissioning Authority, etc. to conduct an Irradiated Materials Archive Options Study to develop the concept of a national archive containing irradiated material to be accessed by UK academics and other researchers.
  - The NSUF Director and the NFML Coordinator participated in several discussions with IMAG to share our knowledge, lessons learned, and progress of the NFML.
  - The NSUF Director and the NFML Coordinator reviewed and provided comments on the Final Draft Report of the Options Study.
- The NFML was represented in monthly discussions and updates regarding national and international harvesting activities. Representatives of the harvesting workgroup include NRC, DOE-NE, EPRI, national labs, and others.

The NUCLEAR FUELS AND MATERIALS LIBRARY
FY 2021 Summary

- NFML samples requests maintaining between 11 and 12% of RTE proposals submitted. Database usage decreased, may be due to only one RTE call.
- Projects using NFML samples resulted in publications with more to be added before the end of the calendar year.
- Increases in proposals and sample donations necessitated an updated policy that provides more guidance and clarification regarding NFML samples.
- The NFML inventory increased significantly due to samples from NSUF projects and donations.
- NFML sample title transfers prove to be time consuming and complex, but well worth it.
- NSUF-awarded projects will generate many additional samples over the next 3–7 years.
- The NSUF and NFML are taking advantage of harvesting opportunities and participating in harvesting workgroup meetings to stay up-to-date and involved with national and international harvesting activities.
- The NFML is being nationally and internationally recognized and sought out as a repository for valuable materials.

As always, the NFML staff welcome your questions, suggestions, comments, and constructive critiques.

The NUCLEAR FUELS AND MATERIALS LIBRARY

Contact Information

Kelly Cunningham

(208) 526-2369

Kelly.Cunningham@INL.gov