DOE-ID NEPA CX DETERMINATION
Idaho National Laboratory

CX Posting No.: DOE-ID-INL-20-017

SECTION A. Project Title: Enhanced Accident Tolerant Fuel

SECTION B. Project Description and Purpose:

Following the Fukushima events in 2011, The Department of Energy Office of Nuclear Energy, Science, and Technology (DOE-NE), in collaboration with the nuclear industry, shifted the emphasis of research and development (R&D) activities on light water reactors (LWRs) from enhancing fuel performance for waste minimization and increased power density for power upgrades to accident performance of fuels under extended loss of active cooling and steam exposure. Subsequently, the congressional appropriation language for Fiscal Year (FY) 2012 included specific language directing DOE-NE to initiate an aggressive Research, Development, and Demonstration (RD&D) program for LWR fuels with enhanced accident tolerance. Fuels with enhanced accident tolerance are those that, in comparison with the standard system currently used by the LWR industry, can tolerate loss of active cooling in the core of the reactor for considerable time periods (depending on the LWR system and accident scenario) while maintaining or improving fuel performance during normal operations, operational transients, and design-basis events.

The purpose of the Accident Tolerant Fuels (ATF) program is to develop the next generation of LWR fuels with improved performance, reliability, and safety characteristics during normal operations and accident conditions and with reduced waste generation. Enhancing accident tolerance of the fuel is the focal point of the initiative. The initial RD&D efforts focus on applications in operating reactors or reactors with design certifications. What is learned and developed during this process may be applicable to the design of the next generation of LWRs.

Per congressional direction, the Fuel Cycle Research and Development Advanced Fuels Campaign’s goal is to support the insertion of lead test rods (LTRs) or lead test assemblies (LTAs) of an ATF into a commercial LWR within ten years (i.e., by the end of FY 2022). Since 2012, Idaho National Laboratory (INL) has supported the ATF program, including irradiation experiments in the Advanced Test Reactor (ATR) and the Transient Reactor Test (TREAT) Facility for assessing the performance of ATF concepts and demonstrating improved fuel and cladding concepts.

Irradiation Testing

The environmental impacts of INL activities supporting the ATF program have been evaluated in the following environmental checklists (ECs):

- INL-12-020 (OA 12) “Uranium Silicide/Nitride Fabrication Demonstration”
- INL-12-061 (OA 15) “Support EPRI's Development of LWR Fuels with Enhanced Accident Tolerance”
- INL-12-062 (OA 10 & 12) Support Westinghouse's Development of LWR Fuels with Enhanced Accident Tolerance”
- INL-13-059 “Irradiation Testing of Accident Tolerant Fuels (ATF) in the Advanced Test Reactor”
- INL-16-019 “Irradiation Testing of Accident Tolerant Fuels (ATF) in the Advanced Test Reactor (ATR) Water Loop” and Revisions 1-4.

These ECs evaluated INL ATF R&D efforts performed in cooperation with industry led teams from AREVA (now Framatome), General Electric (GE), and Westinghouse. Table 1 lists general activities associated with these efforts. One DOE team from Oak Ridge National Laboratory (ORNL) also furnished fuel rodlet samples for ATR insertion in 2015. The scope of this EC is limited to ATF effort at INL supporting Framatome (formerly Areva), General Electric (GE), and Westinghouse.

Table 1. Summary of Industry Led Accident Tolerant Fuel Development Projects.

Framatome (formerly AREVA)	GE	Westinghouse

• **Develop coated r-alloy cladding for improved accident performance**
• **Increase pellet conductivity: fuel with reduced stored energy that must be accommodated during design basis events (DBEs)**
• **Additives achieved:**
  ○ **SiC powder or whiskers**
  ○ **Diamond**
  ○ **Chrmia dopant**
	• Develop advanced ferritic/martensitic steel alloys (e.g., Fe-Cr-Al) for fuel cladding to improve behavior under severe accident scenarios
	• Objectives:
	  ○ Characterize candidate steels
	  ○ Study tube fabrication methods, neutronics, fuel economy, thermo-hydraulic calculations, regulatory approval path
	  ○ Initiate ATR testing with UO_2 and two cladding materials
		• Cladding concepts:
		  ○ SiC and SiC ceramic matrix composites
		• High density/high thermal conductivity fuel pellets
		• First batch of U_3Si_2 pellets were sintered using finely ground powder
		• Pellets were pressed using pressures of 6,000-10,000 psi and sintered at temperatures of 1400°C

Table 2 shows an overview of the ATF irradiation testing program in 4 phases: 1) ATF-1 drop-in capsule testing in ATR, 2) ATF-2 loop testing in ATR, 3) ATF-3 transient testing of fuel rodlets (from the ATF-2 series) in TREAT, and 4) ATF-4 transient testing of fuel rods from the commercial power plant irradiated LTR/LTA program in TREAT. Each phase is a series of irradiation experiments conducted with specific objectives. More detail on each of the four phases of the irradiation testing program and their objectives is given in subsequent sections.

Table 2. Irradiation Testing Program for Accident Tolerant Fuels.

Test Series	**ATF-1**	**ATF-H-x**	**ATF-2**	**ATF-3**	**CM-ATF-x**	**ATF-y**
Test Reactor	ATR	ATR	ATR	TREAT	Commercial Power Plant	TREAT
Test Type	Drop-In	Instrumented	Loop	Loop	LTR-LTA	Loop

Test Series	**ATF-1**	**ATF-H-x**	**ATF-2**	**ATF-3**	**CM-ATF-x**	**ATF-y**
Test Strategy	Many Compositions Nominal Conditions	In-Pile Creep 3-D Instrumented Boiling Water Reactor (BWR) Conditions	Focused Compositions Pressurized Water Reactor (PWR) Conditions	Focused Compositions Accident Conditions	Focused Compositions Nominal Conditions	Focused Compositions Accident Conditions
Fuel	UO_2, U_3Si_2, UN	Selected	Down-selected Concepts	Fuel Rodlets from ATF-1 and Test Rods from ATF-2 Irradiations	Concepts Selected in 2016	Test Rods from LTR/LTA Irradiations
Cladding	Zr-alloy, Coated Mo-L, Stainless Steels, Advanced Alloys, SiC	Selected	Selected	Selected	Selected	Selected
Key Features	Fuel-cladding Interactions	Integral Testing	Fuel-cladding-coolant interactions	Integral Testing	Steady State Irradiation	Integral testing
Timeframe	FY14-FY18+	FY16-FY25	FY16-FY22	FY18-FY25	FY22-?	FY?

ATF-1 Test Series: Drop-in Capsule Testing in ATR

The ATF-1 test series investigates the performance of a wide variety of proposed ATF concepts under normal LWR operating conditions. The program uses data generated in this test series to assess the feasibility of certain ATF concepts and screen among concepts. The ATF-1 test series is a series of drop-in capsule tests irradiated in the ATR. INL initiated the ATF-1 test series in 2015 and began irradiating fuel rodlets isolated from the ATR primary coolant by a secondary capsule filled with an inert gas; the rodlet cladding does not contact reactor coolant water during irradiation. The ATF-1 test series investigates the irradiation behavior of new fuels (i.e., pellets/compacts) and their interaction with the cladding. The program did not design the ATF-1 series to assess the cladding interaction with reactor coolant water. The ATF-1 test series evaluates fuel behavior and fuel-cladding interaction to down-select one or more promising concepts to carry into the next phase of the irradiation testing program (i.e., ATF-2). ATF-1 is an early screening evaluation experiment series. Industry-led ATF fuel development teams at Framatome, GE, and Westinghouse supplied the initial complement of test fuels.

ATF-2 Test Series: Loop Testing in ATR

The ATF-2 test series evaluates the most promising concept(s) from the ATF-1 series by completing loop testing in the ATR. In the ATR loop, experimental ATF rods directly contact high-pressure water coolant having active chemistry control to mimic PWR primary coolant conditions. In addition to continuing the fuel behavior and fuel-cladding interaction investigations in ATF-1, the ATF-2 experiment series includes evaluating cladding-coolant interaction. ATF-2 assesses the performance of ATF concepts under normal LWR operating conditions. Currently the experiment is being designed to accommodate as many instrumented fuel pins as possible accommodating both 12 inch (30.5 cm) and 6 inch (15.2 cm) fuel pin lengths.

The ATF-2 test series produces irradiated fuel rods for comprehensive non-destructive and destructive post-irradiation examination (PIE). The project non-destructively examines a large portion of the irradiated fuel rods so they can be used as prototypic test articles in the next phase of the irradiation testing program (ATF-3). The program may also use irradiated fuel rods from this test series for out-of-pile experiments to simulate loss-of-coolant-accidents (LOCAs).

ATF-3 Test Series: Transient Testing of ATF-2 Rods in TREAT

The ATF-3 test series uses the most promising concept(s) from the ATF-2 phase for transient testing in TREAT. ATF-3 subjects experimental ATF rods to reactivity-initiated accident (RIA) scenarios in TREAT to investigate their integral performance under RIA conditions. The program anticipates beginning this testing phase with fresh (unirradiated) fuel rodlets/rods to assess performance under a beginning-of-life (BOL) scenario and progress to the irradiated fuel rodlets/rods having multiple burnup levels obtained from the ATF-1 and ATF-2 test series. The ATF-3 experiment series continues through the design phase over the next few years.

DOE evaluated the environmental impacts of transient irradiations in the TREAT reactor, including 1) transporting experiment materials between MFC and TREAT, 2) pre- and post-irradiation radiography, 3) PIE of test components at HFEF or other MFC facilities, and 4) waste generation and disposal in the *Environmental Assessment (EA) and Finding of No Significant Impact (FONSI) for the Resumption of Transient Testing of Nuclear Fuels and Materials* (DOE/EA-1954, February 2014).

CM-ATF-x: Lead Fuel Rod or Lead Fuel Assemblies Irradiated in Commercial Nuclear Power Plant

The near term goal of the DOE Accident Tolerant Fuel development program is to insert a lead fuel rod or lead fuel assembly into a commercial nuclear power plant by 2022. This lead fuel irradiation will then progress for 1 to 3 years in the commercial nuclear power plant and then will be removed, examined, and subjected to further testing and qualification.

In April 1995, DOE completed the *Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement* (DOE/EIS-0203) (hereafter, 1995 EIS) (DOE 1995a). The 1995 EIS contains an analysis of the potential environmental impacts associated with managing DOE's complex-wide spent nuclear fuel (SNF) Program from 1995 until 2035 and includes an analysis of a broad spectrum of fuel element designs.

In the June 1995 Record of Decision (ROD) for the 1995 PEIS, DOE selected Alternative 4a (Regionalization by Fuel Type) and decided to transport 165 Metric Tons of Heavy Metal (MTHM) in 1,940 planned shipments of SNF (including 575 Navy shipments) to the INL Site through the year 2035 [60 Federal Register (FR) 28680, June 1, 1995].

DOE issued an amended ROD in June 1996 for the 1995 PEIS, which lowered the number of planned shipments of SNF to the INL Site to 1,133 (575 shipments for the Navy and 558 planned shipments for DOE) (61 FR 9441, March 8, 1996).

At present, INL cannot accept irradiated fuel subject to the Idaho Settlement Agreement. In November 2019, DOE and the State of Idaho signed the *Supplemental Agreement Concerning Conditional Waiver of Section D.2.e and K.1 of 1995 Settlement Agreement* wherein the parties agree that DOE may resume the receipt of and plan for additional research quantities of commercial SNF at INL pursuant to the 2011 Memorandum of Agreement, the terms and conditions of which govern such additional shipments, upon successful production of at least 100 canisters of treated sodium- bearing high-level waste (HLW) located at INL and so long as:

i. DOE is not in breach of any terms and conditions of the 1995 Agreement, or the 2008 Agreement other than those described in the Supplemental Agreement and

ii. The Integrated Waste Treatment Unit (IWTU) is continuing sustained operations to treat the remaining Sodium Bearing HLW located at INL.

INL anticipates it will be able to accept the irradiated lead test rods by 2022. If INL cannot accept the irradiated lead test rods, another facility will complete PIE and other activities.

The amount of irradiated fuel INL can receive remains subject to the limits established in the 1995 Agreement, —55 metric tons heavy metal (MTHM)—, and the INL Site has received 81 shipments of spent nuclear fuel that contained 27.8646 MTHM since 1995. DOE anticipates it will not reach the total number of shipments or MTHM limits identified in the MOA and amended ROD before 2035. Based on current planning, DOE anticipates the INL Site will receive less than 21 MTHM of additional SNF before 2035. Therefore, DOE would not exceed the 55 MTHM limit imposed through the Settlement Agreement by receiving the additional LFR or LTAs. However, prior to planning to receive or ship commercially irradiated materials to INL, this EC will be revised to verify material quantities and transportation routes have been evaluated in compliance with the National Environmental Policy Act (NEPA).

<u>ATF-4 Test Series: Transient Testing of LTR/LTA Rods in TREAT</u>
The ATF-4 test series assumes that the irradiation of ATF concept(s) in a commercial LWR as part of an LTR/LTA program begins in FY22. The logical final phase of the irradiation test program is to subject a subset of these Lead Test Rods to transient testing in TREAT. Since LTRs will be much longer than can be accommodated in TREAT, either shorter, segmented rods will need to be included in the LTR/LTA program or a sectioning/remanufacturing capability will be needed in the PIE facility in order to prepare appropriate test rods for TREAT. As in the ATF-3 test series, it is anticipated that this phase of testing would begin with fresh (unirradiated) fuel rods, fabricated by the same vendor and process as used for the LTRs, and progress to irradiated LTR segments of multiple burnup levels.

INL is evaluating capabilities to refabricate rods and conduct a full suite of transient testing at both TREAT and ATR. INL may need to refabricate irradiated rods coming from either ATR or commercial LTR/LTA programs for re-insertion into INL test reactors (ATR or TREAT). The purpose of these re-irradiation programs may be to extend the burnup of the rods or to conduct transient irradiations mimicking operational transients, anticipated operational occurrences (AOOs) or design basis accidents (DBAs). Prior to deciding to implement facility modifications or other actions needed to section or remanufacture LTRs or LTAs, this capability will be evaluated in compliance with NEPA and this EC will be revised.

As noted, INL performs irradiation experiments at both the ATR and TREAT. INL develops a variety of experiment test trains at both reactors to meet the data needs of industry partners. INL also customizes irradiation tests to meet specific data needs as they arise. INL is currently irradiating ATF concepts in both drop-in capsule irradiations and in the ATR pressurized water loop. These irradiations use small rodlets having LWR fuel radial dimensions but are typically shorter in their axial dimensions. The Following discussion summarizes the status of ATF R&D efforts performed in cooperation with industry led teams from Framatome, GE, and Westinghouse:

Framatome
Table 3 summarizes the status of Framatome ATR irradiations at INL.

Table 3. Status of Framatome ATF Irradiations at INL.

Rodlet / Capsule ID	Fuel system	Status	Baseline PIE non-destructive	Baseline PIE destructive
Drop-in-Capsule Irradiations				
ATF-00/A01	UO_2 / Zr-4		Completed	Completed
ATF-01/A02	UO_2 / Zr-4	In irradiation		
ATF-02/A03	UO_2+SiC / Zr-4	In irradiation		
ATF-03/A04	UO_2+SiC / Zr-4		Completed	Completed
ATF-04/A05	UO_2+Diamond / Zr-4		Completed	Completed
ATF-05/A06	UO_2+Diamond / Zr-4	In irradiation		

Pressurized Water Loop Irradiations		
AR-01	UO_2 / M5	In irradiation
AR-02	UO_2 / M5	In irradiation
AR-03	UO_2 / M5	In irradiation
AR-04	UO_2 / M5	In irradiation
AR-11	$UO_2+Cr_2O_3$ / Cr Coated M5	In irradiation
AR-12	$UO_2+Cr_2O_3$ / Cr Coated M5	In irradiation
AR-13	$UO_2+Cr_2O_3$ / Cr Coated M5	In irradiation
AR-14	$UO_2+Cr_2O_3$ / Cr Coated M5	In irradiation
AR-15	$UO_2+Cr_2O_3$ / Cr Coated M5	In irradiation
AR-16	$UO_2+Cr_2O_3$ / Cr Coated M5	In irradiation
AR-17	$UO_2+Cr_2O_3$ / Cr Coated M5	In irradiation

In FY20 INL has planned three steady state irradiation cycles (166B, 168A, and 168B) at the ATR, each lasting about 60 days. In FY21 INL only plans one steady state cycle (169A) prior to the ATR core-internal-changeout (CIC). ATR will resume irradiations in FY22. After test rodlets reach target burn-up, INL removes them from the reactor, allows the experiments to cool, then ships the materials to INL's hot cell facilities for Post Irradiation Evaluation (PIE) or to the Transient Reactor Test (TREAT) facility for transient irradiations. In addition, rods coming from Framatome LTR or LTA programs may be sent to INL for PIE or transient irradiations at TREAT. Post irradiation examination at INL's MFC is divided into three general categories: 1) Non-Destructive Examinations (NDE), 2) Baseline Destructive Examinations, and 3) Advanced PIE.

INL supports the following Framatome ATF efforts:

Steady State Irradiation Experiments
INL supports inserting new steady state irradiation experiments which support Framatome ATF development. This task has three subtasks as described below.

Inspection, Insertion, and Irradiation of Chrome Coated Pins in ATF-2
Following cycle 166B when INL removes Framatome rodlets AR-01, AR-02, AR-11 and AR-14 from the pressurized water loop, INL will replace the rodlets with like-for-like replacements having rodlet designations AR-05, AR-06, AR-18, and AR-19. INL will insert these rodlets into ATR cycle 168A. Rodlets AR-05 and AR-06 will be UO2 / M5 rodlets, and rodlets AR-18, and AR-19 will be UO2+Cr2O3 / Cr Coated M5 rodlets. Framatome has also discussed with INL the possibility of inserting SiC-SiC clad rods into cycle 169A. INL will evaluate this possibility with Framatome and make plans for their insertion pending further discussions.

Design and Analyze Drop-in-Capsule Experiment with High Thermal Conductivity Pellets
In cycle 170A (the cycle following 168B), Framatome plans to insert nine new drop-in-capsule rodlets, which test a new fuel design that includes a chrome additive to the UO_2 matrix. Framatome aims to improve the thermal conductivity of the fuel with this design. The text matrix involves two chrome additive levels and baseline UO_2. INL will irradiate rodlets at similar linear heat generation rates (LHGRs) with target fuel temperatures of less than 1600°C. Rodlets are planned to reach 10, 30, and 50 GWD/MTU burnup. INL will not irradiate these rodlets until FY21, but INL plans experiment design, analysis, and assembly activities to take place in FY20.

Fabricate and Insert Capsules with High Thermal Conductivity Rodlets
In FY20, INL will receive Framatome rodlets proposed for high thermal conductivity experiments in cycle 169A in FY21. INL will inspect and green tag the rodlets for insertion in cycle 169A. INL will also fabricate drop-in-capsules based on as-built dimensions of the received rodlets and load the rodlets into capsules for insertion in cycle 169A.

General Electric Global Research (GE)
General Electric Global Research (GE) proposes continuing development efforts for the ATF Program. GE plans to expand and continue research and development related to ATF related concepts at INL in ATR, TREAT, and in out of pile tests and commercial reactors with prototypic segments and rods. The project also proposes to develop a licensing plan for future Nuclear Regulatory Commission (NRC) approval for initial commercial partial core loading in the mid-2020s. INL support to GE includes the following tasks:

1. Fundamental research, characterization and testing
2. Irradiation studies
3. Fabrication of tubing and rods
4. Modeling and simulation
5. Interface with utilities
6. Regulatory activities.

GE efforts under the ATF program include collaborations with GE Global Research, Global Nuclear Fuels (GNF), and several national laboratories such as Oak Ridge National Laboratory (ORNL), INL, and Los Alamos National Laboratory (LANL). The GE ATF concept focuses mainly on developing ironchromium-aluminum (FeCrAl) cladding for urania fuel. GE FeCrAl cladding has been trade named IronClad. The project has been expanding to include coatings for zirconium alloys, trade-named ARMOR (initially developed for fretting resistance), and silicon carbide (SiC) ceramics for fuel channels.

GE and GNF aim to install a second LTA into a commercial power reactor (Clinton Unit 1 plant) in the fall of 2019 and to obtain neutron irradiation data for FeCrAl material to advance manufacturing processes for ferritic alloys. GE plans to expand the scope of the project to coating Zircaloy tubes to increase fretting and corrosion resistance and to developing silicon carbide compatible with 300 °C water to be used for the fuel channels. The national laboratories (Idaho, Los Alamos, and Oak Ridge) offer academic insight on nuclear materials behavior including manufacturing, resistance in reaction with superheated steam, and neutron irradiation damage. The national laboratories also perform modeling and simulation to predict changes in the reactor core from using IronClad in place of a zirconium alloy.

Table 6 summarizes the main tasks of this revision.

Table 6. Main Tasks for GE ATF.

Tasks	Responsibility
1—Fundamental Research, Characterization and Testing	
1.1 Nuclear grade closed metal confinements (CMCs) for channels	GE Global Research
1.2 Isothermal corrosion of CMCs, IronClad, welds and tubes	GE Global Research
1.3 Zircaloy channel coating development	GE Global Research
1.4 Crud Deposition on rods	GE Global Research
1.5 Material properties and deformation and tube fabrication studies	GE Global Research
1.6 Method optimization for weld inspection	GE Global Research
1.7 Project management and technical support to commercial sector	GE Global Research
1.8 Development of a UO_2 -cermet fuel	LANL
1.9 Corrosion/oxidation investigations	ORNL
1.10 Normal operation cladding performance	ORNL
2—Irradiation Studies	
2.1 ATF-1 and Post Irradiation Examination (PIE) of early rodlets	INL
2.2 ATF-2 testing at ATR and TREAT	INL, GNF
2.3 ATF-3 TREAT testing	INL, GNF
3—Fabrication of tubing and rods	
3.1 Additive manufacturing of caps and other components	GE Global Research
3.2 Laser welding method development	GE Global Research
3.3 Tubing production development	GNF
3.4 Fuel rod fabrication development	GNF
3.5 NDT Inspection Development	GNF
4—Modeling and Simulation	
4.1 Conceptual fuel assembly design	GNF
4.2 Prototype mechanical design	GNF
4.3 Plant safety and performance analysis	GNF
4.4 Properties for fuel modeling	ORNL
4.5 Thermal mechanical methods and advanced modeling	GNF
4.6 Computational materials modeling	GNF
4.7 Thermal-hydraulic testing	GNF
5—Interface with Utilities	
5.1 Insertion of a fueled LTA in Cycle 20 at Clinton	GNF & Exelon
5.2 IronClad poolside irradiated fuel inspections	GNF & Southern Nuclear
5.3 PIE of IronClad Tube	GNF
5.4 Transportation	GNF
6—Regulatory Activities	
6.1 LTA licensing	GNF

6.2 Licensing plan	GNF

INL support to GE for ATF includes:

1. Rodlet design and experiment reconsiderations (FY19).
2. Receive, from GNF, and pre-irradiation test 6 ATF-2 UO_2 fueled GE rodlets (FY19).
3. Transport 4 pins batch (ATF-1) from ATR to HFEF (FY19).
4. Transport 4 pins (ATF-1) from ATR to HFEF (FY20 and FY21) for PIE analysis or TREAT for transient studies.
5. Baseline PIE testing of ATF-1 rodlets (FY19).
6. Dry capsule test, in a Separate Effects Test Holder (SETH) capsule, 3 cladding types (Zircaloy Clad, FeCrAL Clad, and ARMOR Clad) in FY19. Each test is five separate transients to determine the enthalpy needed to cause cladding breach. Tests will be followed by PIE to determine the radiation effect from each transient (FY18 & 19).
7. Wet capsule test, in Minimal Activation Retrievable Capsule Holder (MARCH)-Static Environment Rodlet Transient Test Apparatus (SERTTA) capsules, 3 cladding types (Zircaloy Clad, FeCrAL Clad, and ARMOR Clad) with DOE-owned fresh fuel. Each test will be 5 transients and simulate reactivity insertion accidents (RIA) for different cladding to determine the enthalpy needed for cladding breach. Tests will be followed by PIE to determine radiation effect from each transient (FY20 and FY21).
8. Natural circulation flow test, in Super-SERTTA capsules, 1 of three cladding types (Zircaloy Clad, FeCrAL Clad, and ARMOR Clad) with DOE-owned fresh fuel in FY21. Each test will be 2 transients. These tests simulate Loss of Coolant Accidents (LOCA) and will be followed by PIE to determine the radiation effect from each transient (FY21).
9. Redesign, analyze, and fabricate new ATF-2 tier and pin holders for switching from the baselined .374 size pins to .404 pins (FY19)

Westinghouse

INL supports Westinghouse by conducting irradiation experiments on Westinghouse's ATF concepts and examining irradiated ATF materials to develop data sets supporting Westinghouse ATF concept design and licensing. INL is currently irradiating Westinghouse ATF concepts in both drop-in-capsule irradiations and the pressurized water loop of the ATR. These irradiations use small rodlets typical of LWR fuel in their radial dimensions but are typically shorter in their axial dimensions. Table 7 shows a status summary of Westinghouse ATF irradiations at INL.

Table 7. Status of Westinghouse ATF Irradiations at INL.

Rodlet / Capsule ID	Fuel System	Status	Baseline PIE non-destructive	Baseline PIE destructive
Drop in Capsule Irradiations (ATF-1)				
ATF-10/W01	U_3Si_2 / **ZIRLO®**		On-going	
ATF-11/W02	U_3Si_2 / **ZIRLO**	In irradiation		
ATF-12/W03	U_3Si_2 / **ZIRLO**	In irradiation		
ATF-13/W04	U_3Si_2 / **ZIRLO**		Completed	Completed
ATF-14/W05	U_3Si_2 / **ZIRLO**	In irradiation		
ATF-15/W06	U_3Si_2 / **ZIRLO**		Completed	Completed
ATF-29/WB1	UN-30%wt U_3Si_2 / **ZIRLO**	In irradiation		
ATF-30/WB2	UN-30%wt U_3Si_2 / **ZIRLO**		On-going	
ATF-31/WB3	UN-30%wt U_3Si_2 / **ZIRLO**	In irradiation		
ATF-32/WB4	UN-30%wt U_3Si_2 / **ZIRLO**	In irradiation		
ATF-33/WB5	UN-30%wt U_3Si_2 / **ZIRLO**	In irradiation		
ATF-34/WB6	UN-30%wt U_3Si_2 / **ZIRLO**		On-going	
Pressurized Water Loop Irradiations (ATF-2)				
W-01	UO_2/Cr-coated **Optimized ZIRLO™**	Shipment to MFC Pending		
W-02	UO_2/Cr-coated **Optimized ZIRLO**	Shipment to MFC Pending		
W-03	UO_2/Cr-coated **Optimized ZIRLO**	Shipment to MFC Pending		
IW-01	Cr-coated **Optimized ZIRLO**	In ATR Canal		
IW-02	Cr-coated **Optimized ZIRLO**	In irradiation		
IW-03	Cr-coated **Optimized ZIRLO**	In irradiation		
IW-04	Cr-coated **Optimized ZIRLO**	In irradiation		
W2-01	Cr-coated **Optimized ZIRLO**	Awaiting Initial Insertion		
W2-02	Cr-coated **Optimized ZIRLO**	Awaiting Initial Insertion		

W2-03	Cr-coated **Optimized ZIRLO**	Awaiting Initial Insertion

Westinghouse plans three steady state irradiation cycles (166B, 168A, and 168B) in FY20 in the ATR, each lasting approximately 60 days and one in FY21. (169A) prior to the ATR CIC. After test rodlets reach their specified burn-up target, INL discharges them from the reactor and allows them to cool before being shipped to INL hot cell facilities for PIE.

INL will refabricate irradiated rods from ATR or commercial LTR and LTA programs for re-insertion into ATR or TREAT. The purpose of these re-irradiation programs may be to extend the burnup of the rod, or to mimic operational transients, anticipated operational occurrences (AOOs) or design basis accidents (DBAs).

INL supports the following Westinghouse ATF efforts:

Irradiation Experiments
INL supports reactor insertion of new steady state irradiation experiments for Westinghouse ATF development. The following tasks describe Westinghouse irradiation experiments at INL:

Fabrication, Insertion, and Irradiation of Chrome Coated Pins in ATF-2
In cycle 168A, INL will insert three new Westinghouse rodlets into the ATR pressurized water loop. The rodlets will be about 12 in. long, one rodlet will be uranium dioxide (UO_2)/Cr-coated Optimized **ZIRLO** ATF concept, and two rodlets will be **ADOPT™**-UO_2/Cr-coated optimized **ZIRLO** ATF concept. Westinghouse will supply INL with the Cr-coated optimized **ZIRLO** cladding, UO_2 fuel, and end cap material necessary to fabricate the rodlets prior to the 168A cycle. Westinghouse subrecipient General Atomics plans to insert SiC-SiC rods into ATR cycle 168B. If this insertion is unsuccessful, Westinghouse rods IW-02, IW03, and IW04 will remain in the reactor for additional irradiation.

New ATF-2 Test Train Design with Wireless Sensors
In future irradiations, Westinghouse plans to use in-pin sensors to accelerate information acquisition on fuel pins. These sensors use transceivers outside the pins to wirelessly send and receive signals.

Post Irradiation Examination
PIE is an essential component of the fuel development effort in that it provides data on material irradiation performance that feeds back to fabrication variables and provides data to help qualify the down-selected fuel system that meets performance requirements. INL perofrms the following types of PIE in HFEF:

Blister Anneal Testing
This test requires that the fuel component be heated to the point where the first failure threshold has been reached as indicated by raised areas (blisters) on the surface of the component. This is required for fuel qualification since blistering is conservatively presented as a precursor to a breach of the fuel cladding, the primary containment of the fuel and fission products. Blister anneal testing can be performed in simple furnaces provided the temperatures can reach a maximum of 550°C. This is a destructive examination.

Burn-up and Scanning Electron Microscope (SEM)/Transmission Electron Microscope (TEM) Sample Preparation
Sample preparation involves sectioning of irradiated components, packaging and transferring materials to appropriate facility. This is a destructive examination.

Disassembly
Disassembly of the capsules is done only to remove the fuel rodlets from the external capsules. Every effort is made to do so without damaging the internal fuel rodlets. A lathe would be used to cut the endcaps off the capsules. The rodlets are then pushed out of the capsule tube using an appropriately sized drill rod. This is non-destructive (to the rodlet) process.

Eddy Current (Oxide)
Eddy current measurements are taken to estimate the oxide thickness that has grown on the fuel components. This is a non-destructive examination.

Fission Product Release
Data obtained from fission gas release may be used in the fuel qualification report. The purpose is to identify the failure thresholds and measure fission product release to define the allowable safety margins for monolithic and dispersion fuel utilization. Specifically source term data is determined based on the type and movement of various fission product inventories. These examinations can be performed in a furnace that can accommodate the sample size and that is capable of reaching at least 2000°C. This is a destructive examination.

Gamma Scanning
All irradiated experimental components are scanned using the precision gamma scanner (PGS). Gamma scan results are used to determine the relative 2-D fission density gradient over a surface. This is a non-destructive examination.

Immersion Density

Immersion density data provides fuel swelling values for the material. This information is used in the fuel qualification report as a fundamental fuel behavior property. This is a non-destructive examination.

Metallography
Metallography is both a qualitative and quantitative measure. This is a destructive examination of irradiated materials requiring sectioning and mounting small pieces of the irradiated fuel for examination in the microscope.

Microhardness
Microhardness testing is done on the system installed in the HFEF met box. This is a destructive examination of irradiated materials requiring sectioning and mounting small pieces of the irradiated fuel.

NRAD
Neutron radiography is performed to identify any cracking in the fuel foil prior to sectioning. This is a non-destructive examination.

Profilometry
Profilometry data is used to determine local fuel swelling and is vital to the fuel qualification report. This is a non-destructive examination.

Visual Examination
The visual examinations of materials at HFEF would be performed to identify any anomalies, changes or defects that may have occurred during irradiation or shipping. The examination is performed using a telephoto lens and camera, taking photos through the HFEF hot cell window. Photographs are taken of the front, back, and end of all capsules. This is a non-destructive examination.

Some samples may be sent to the Analytical Laboratory, Electron Microscopy Laboratory (EML), Irradiated Materials Characterization Laboratory (IMCL), Radiochemistry Laboratory, or the Sample Preparation Laboratory (when available) at MFC for additional analysis.

After PIE, irradiated test pin segments and PIE remnants will be stored with other similar DOE-owned irradiated materials and experiments at MFC, most likely in the HFEF or the Radioactive Scrap and Waste Facility (RSWF) in accordance with DOE's Programmatic SNF Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement (FEIS) and ROD (DOE/EIS-0203, 1995) and supplemental analyses (DOE/EIS-0203-SA-01 and DOE/EIS-0203-SA-02) and the Amended Record of Decision (February 1996). Ultimate disposal of the irradiated test pin segments and PIE remnants will be along with similar DOE-owned irradiated materials and experiments currently at MFC. Categorizing this material as waste is supported under Department of Energy Order (DOE O) 435.1, Att. 1, Item 44, which states "…Test specimens of fissionable material irradiated for research and development purposes only…may be classified as waste and managed in accordance with this Order...".

In addition, to complete proposed work activities, it is necessary for the project to use the HFEF hot cell which contains both defense and nondefense related materials and contamination. Project materials will come into contact with defense related materials. It is impractical to clean out defense related contamination, and therefore, waste associated with project activities is eligible for disposal at the Waste Isolation Pilot Plant (WIPP). National Environmental Policy Act (NEPA) coverage for the transportation and disposal of waste to WIPP are found in Final Waste Management Programmatic Environmental Impact Statement [WM PEIS] (DOE/EIS-0200-F, May 1997) and Waste Isolation Plant Disposal Phase Supplemental EIS (SEIS-II) (DOE/EIS-0026-S-2, Sept. 1997), respectively. The 1990 ROD also stated that a more detailed analysis of the impacts of processing and handling transuranic (TRU) waste at the generator-storage facilities would be conducted. The Department has analyzed transuranic (TRU) waste management activities in the Final Waste Management Programmatic Environmental Impact Statement (WM PEIS) (DOE/EIS-200-F, May 1997). The WM PEIS analyzes environmental impacts at the potential locations of treatment and storage sites for TRU waste; SEIS-II addresses impacts associated with alternative treatment methods, the disposal of TRU waste at WIPP and alternatives to that disposal, and the transportation to WIPP

Packaging, repackaging, transportation, receiving, and storing used nuclear fuel and R&D for used nuclear fuel management is covered by DOE's Programmatic Spent Nuclear Fuel (SNF) Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement (EIS) and Record of Decision (DOE/EIS-0203, 1995) and supplemental analyses (DOE/EIS-0203-SA-01 and DOE/EIS-0203-SA-02) and the Amended Record of Decision (February 1996). The analyses include those impacts related to transportation to, storage of, and research and development related to used nuclear fuel at the INL (see Tables 3.1 of the SNF Record of Decision (May 30, 1995) and Table 1.1 of the Amended Record of Decision [February 1996].

The environmental impacts of transferring LLW from the INL Site to the Nevada National Security Site were analyzed in the 2014 *Final Site-Wide Environmental Impact Statement for the Continued Operation of the Department of Energy/National Nuclear Security Administration Nevada National Security Site and Off-Site Locations in the State of Nevada* (DOE/EIS-0426) and DOE's *Waste Management Programmatic EIS* (DOE/EIS-200). The fourth Record of Decision (ROD) (65 FR 10061, February 25, 2000) for DOE's *Waste Management Programmatic EIS* established the Nevada National Security Site as one of two regional LLW and MLLW disposal sites.

The potential for transportation accidents was analyzed in the SNF EIS (Section 5.1.5 and Appendix I-5 through I-10).

In addition to disposal of the irradiated fuel that will be generated as described above, industrial, mixed, and low level waste will be generated throughout the R&D process. This waste will be classified and disposed in accordance with INL procedures and DOE regulations/requirements.

SECTION C. Environmental Aspects or Potential Sources of Impact:

Air Emissions
The proposed action has the potential to generate radiological and chemical emissions from irradiation in ATR and TREAT and PIE at MFC. Air emissions are anticipated to be minor, and concentrations would not exceed the current monitored air emissions from these facilities. An Air Permit Applicability Determination (APAD) may be required.

The TREAT irradiation activities are not modifications in accordance with Idaho Administrative Procedures Act (IDAPA) 58.01.01.201 and 40 Code of Federal Regulation (CFR) 61 Subpart H. TREAT radionuclide emissions are sampled and reported in accordance with Laboratory Wide Procedure (LWP)-8000 and 40 CFR 61 Subpart H. All experiments will be evaluated by Environmental Support and Services staff. All radionuclide release data (isotope specific in curies) directly associated with this proposal will be calculated and provided to the Environmental Support organization.

The irradiated specimens will be delivered to the MFC HFEF for disassembly and then undergo routine PIE. All radionuclide release data at HFEF will be recorded as part of the HFEF continuous stack monitor. The PIE examination in HFEF is not a modification in accordance with Idaho Administrative Procedures Act (IDAPA) 58.01.01.201 and 40 Code of Federal Regulation (CFR) 61 Subpart H.

In 2018, the effective dose equivalent to the offsite maximally exposed individual (MEI) from all operations at the INL Site was calculated as 1.02 E-02 mrem/yr, which is 0.10% of the 10-mrem/yr federal standard and was calculated using all sources that emitted radionuclides to the environment from the INL site. The emissions are bounded by the analysis in the 1995 EIS, which estimated the annual cumulative doses to the maximally exposed worker, offsite maximally exposed individual (MEI), and the collective population from DOE's decision to implement the preferred alternative (DOE/EIS-0203). The potential air emissions and human health impacts associated with the proposed action would be smaller than and are bounded by the impacts presented in the 1995 EIS.

Disturbing Cultural or Biological Resources

The facilities at MFC have not been reviewed for eligibility to NRHP. Therefore, a cultural resource review is required.

Generating and Managing Waste

Irradiated sample debris and PIE waste are expected to generate research and development-related TRU waste and mixed TRU waste. TRU waste generated for the ATF experiments will be less than 1 m^3. Categorizing this material as waste is supported under DOE O 435.1, Att. 1, Item 44, which states "…Test specimens of fissionable material irradiated for research and development purposes only…may be classified as waste and managed in accordance with this Order...".

The proposed action has the potential to generate small amounts of hazardous waste from cleaning solvents, solders, metals; scrap metal (held for recycle whenever appropriate). Waste Generator Services (WGS) will evaluate, characterize, and manage hazardous waste. In addition, WGS may establish satellite accumulation areas to manage hazardous waste.

Small amounts of low-level waste would be generated in the form of personal protective equipment (PPE) and towels used for cleaning and polishing.

Project activities would also result in the generation of small amounts of industrial waste.

Project personnel would work with WGS to properly package and transport regulated, hazardous or radioactive material or waste according to laboratory procedures.

Releasing Contaminants

Chemicals will be used and will be submitted to chemical inventory lists with associated Safety Data Sheets (SDSs) for approval prior to use. The Facility Chemical Coordinator will enter these chemicals into the INL Chemical Management Database. All chemicals will be managed in accordance with laboratory procedures. When dispositioning surplus chemicals, project personnel must contact the facility Chemical Coordinator for disposition instructions.

Although not anticipated, there is a potential for spills when using chemicals or fueling equipment. In the event of a spill, notify facility environmental staff. If environmental staff cannot be contacted, report the release to the Spill Notification Team (208-241-6400). Clean up the spill and turn over spill cleanup materials to WGS.

Using, Reusing, and Conserving Natural Resources

All applicable waste will be diverted from disposal in the landfill when possible. Project personnel will use every opportunity to recycle, reuse, and recover materials and divert waste from the landfill when possible. The project will practice sustainable acquisition, as appropriate and practicable, by procuring construction materials that are energy efficient, water efficient, are bio-based in content, environmentally preferable, non-ozone depleting. have recycled content and are non-toxic or less-toxic alternatives. New equipment will meet either the Energy Star or SNAP requirements as appropriate (see http://www.sftool.gov/GreenProcurement/ProductCategory/14).

SECTION D. Determine Recommended Level of Environmental Review, Identify Reference(s), and State Justification: Identify the applicable categorical exclusion from 10 Code of Federal Regulation (CFR) 1021, Appendix B, give the appropriate justification, and the approval date.

For Categorical Exclusions (CXs), the proposed action must not: (1) threaten a violation of applicable statutory, regulatory, or permit requirements for environmental, safety, and health, or similar requirements of Department of Energy (DOE) or Executive Orders; (2) require siting and construction or major expansion of waste storage, disposal, recovery, or treatment or facilities; (3) disturb hazardous substances, pollutants, contaminants, or Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)-excluded petroleum and natural gas products that pre-exist in the environment such that there would be uncontrolled or unpermitted releases; (4) have the potential to cause significant impacts on environmentally sensitive resources (see 10 CFR 1021). In addition, no extraordinary circumstances related to the proposal exist that would affect the significance of the action. In addition, the action is not “connected” to other action actions (40 CFR 1508.25(a)(1) and is not related to other actions with individually insignificant but cumulatively significant impacts (40 CFR 1608.27(b)(7)).

References: 10 CFR 1021, Appendix B to subpart D, items B3.6, "Small-scale research and development, laboratory operations, and pilot projects"

Final Environmental Assessment (EA) and Finding of No Significant Impact (FONSI) for the Resumption of Transient Testing of Nuclear Fuels and Materials (DOE/EA-1954, February 2014).

Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement and Record of Decision (DOE/EIS-0203, 1995) and supplemental analyses (DOE/EIS-0203-SA-01 and DOE/EIS-0203-SA-02) and the Amended Record of Decision (1996)

Final Environmental Impact Statement for the Waste Isolation Pilot Plant (DOE/EIS-0026, October 1980) and *Final Supplement Environmental Impact Statement for the Waste Isolation Pilot Plant* (SEIS-I) (DOE/EIS-0026-FS, January 1990)

Final Waste Management Programmatic Environmental Impact Statement [WM PEIS] (DOE/EIS-0200-F, May 1997) and *Waste Isolation Plant Disposal Phase Supplemental EIS* (SEIS-II) (DOE/EIS-0026-S-2, September 1997)

Final Site-Wide Environmental Impact Statement for the Continued Operation of the Department of Energy/National Nuclear Security Administration Nevada National Security Site and Off-Site Locations in the State of Nevada (DOE/EIS-0426, December 2014).

Justification: The proposed R&D activities are consistent with CX B3.6 "Siting, construction, modification, operation, and decommissioning of facilities for small-scale research and development projects; conventional laboratory operations (such as preparation of chemical standards and sample analysis); small-scale pilot projects (generally less than 2 years) frequently conducted to verify a concept before demonstration actions, provided that construction or modification would be within or contiguous to a previously disturbed area (where active utilities and currently used roads are readily accessible). Not included in this category are demonstration actions, meaning actions that are undertaken at a scale to show whether a technology would be viable on a larger scale and suitable for commercial deployment."

DOE evaluated the environmental impacts of transient irradiations in the TREAT reactor, including 1) transporting experiment materials between MFC and TREAT, 2) pre- and post-irradiation radiography, 3) PIE of test components at HFEF or other MFC facilities, and 4) waste generation and disposal in the *Environmental Assessment (EA) and Finding of No Significant Impact (FONSI) for the Resumption of Transient Testing of Nuclear Fuels and Materials* (DOE/EA-1954, February 2014).
After PIE, irradiated test pin segments and PIE remnants will be stored with other similar DOE-owned irradiated materials and experiments at MFC, most likely in the HFEF or the Radioactive Scrap and Waste Facility (RSWF) in accordance with DOE’s *Programmatic SNF Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement (FEIS) and ROD* (DOE/EIS-0203, 1995) and supplemental analyses (DOE/EIS-0203-SA-01 and DOE/EIS-0203-SA-02) and the Amended Record of Decision (February 1996). Ultimate disposal of the irradiated test pin segments and PIE remnants will be along with similar DOE-owned irradiated materials and experiments currently at MFC. Irradiated sample debris and secondary waste could total as much as 20-30 Kg. Categorizing this material as waste is supported under Department of Energy Order (DOE O) 435.1, Att. 1, Item 44, which states “…Test specimens of fissionable material irradiated for research and development purposes only…may be classified as waste and managed in accordance with this Order...”.

NEPA coverage for the transportation and disposal of waste to WIPP are found in the *Final Waste Management Programmatic Environmental Impact Statement* [WM PEIS] (DOE/EIS-0200-F, May 1997) *and Waste Isolation Plant Disposal Phase Supplemental EIS* (SEIS-II) (DOE/EIS-0026-S-2, Sept. 1997), respectively. The 1990 ROD also stated that a more detailed analysis of the impacts of processing and handling TRU waste at the generator-storage

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facilities would be conducted. The Department has analyzed TRU waste management activities in the *Final Waste Management Programmatic Environmental Impact Statement* (WM PEIS) (DOE /EIS-200-F, May 1997). The WM PEIS analyzes environmental impacts at the potential locations of treatment and storage sites for TRU waste; SEIS-II addresses impacts associated with alternative treatment methods, the disposal of TRU waste at WIPP and alternatives to that disposal, and the transportation to WIPP.

The environmental impacts of transferring LLW from the INL Site to the Nevada National Security Site were analyzed in the 2014 *Final Site-Wide Environmental Impact Statement for the Continued Operation of the Department of Energy/National Nuclear Security Administration Nevada National Security Site and Off-Site Locations in the State of Nevada* (DOE/EIS-0426) and DOE's *Waste Management Programmatic EIS* (DOE/EIS-200). The fourth Record of Decision (ROD) (65 FR 10061, February 25, 2000) for DOE's *Waste Management Programmatic EIS* established the Nevada National Security Site as one of two regional LLW and MLLW disposal sites.

Is the project funded by the American Recovery and Reinvestment Act of 2009 (Recovery Act) ☐ Yes ☒ No

Approved by Jason Sturm, DOE-ID NEPA Compliance Officer on: April 6, 2020