DOE-ID NEPA CX DETERMINATION
Idaho National Laboratory

CX Posting No.: DOE-ID-INL-21-184

SECTION A. Project Title: Development of Advanced Fuel Materials for the BWXT Advanced Nuclear Reactor (BANR)

SECTION B. Project Description and Purpose:

The Office of Nuclear Energy, Reactor Fleet and Advanced Reactor Deployment program is intended to facilitate the development of U.S. private industry advanced nuclear reactor demonstrations. It will provide funding for several advanced reactors that are reliable, cost effective, licensable, and commercially viable. These designs are expected to enable a market environment in which commercial reactor services are available that are safe and affordable to both construct and operate when compared to competing, alternative sources of energy in the near- and mid-term. These designs are expected to provide significant improvements in safety, security, economics, and environmental impacts over current nuclear power plant designs.

BWXT Advanced Technologies, LLC is a wholely owned subsidiary of BWX Technologies (BWXT), a leading supplier of nuclear components and fuel to the U.S. government; BWXT provides technical, management and site services to support governments in the operation of complex facilities and environmental remediation activities; and supplies precision manufactured components, services and CANDU® fuel for the commercial nuclear power industry.

BWXT is currently engaged in a number of activities to support development of the BWXT Advanced Nuclear Reactor (BANR) microreactor. BWXT is seeking to pair with INL to leverage expertise in reactor design, coated particle fuel development and sensor development; including, irradiation in the Advanced Test Reactor (ATR) and post irradiation examination (PIE) of fuel compacts to be fabricated by BWXT.

The BWXT has a long history of working with INL on the above topics. Most recently, the Department of Energy Office of Nuclear Energy's (DOE-NE's) Advanced Gas Reactor (AGR) program worked on coated particle fuel performance testing; including, irradiation and PIE at the INL's site of fuel particles and compacts fabricated at BWXT's production scale facilities. The AGR program proceeded using a methodology highly similar to those proposed for the current project: fuel test specimen fabricated at the BWXT's site will be irradiated and PIE performed at the INL's site, in coordination with BWXT's efforts with Oak Ridge National Laboratory (ORNL) for design and fuel performance safety testing. Both INL and ORNL will be working with BWXT under separate CRADAs. The same progression and basic fuel development strategy is proposed for the BANR fuel. This project aims to use different fuel materials and fabrication methods than used by AGR and will operate under different conditions. The core coated particle characterization and post irradiation facilities located at the INL's site are unique in the world and specifically suited to this purpose. Furthermore, the BWXT will leverage reactor sensor technology developed and tested by INL to enhance reactor semi-autonomous capabilities for commercialization. The current DOE-NE mission centers on working with industry to transition the outcomes of research investments to the private sector, making the current project highly supportive of these goals.

This project supports activities aimed at addressing the most significant technological risks towards deployment of a 50 megawatts thermal (MWth) high temperature gas-cooled reactor (HTGR) led by the BWXT in response to an FY20 DOE-NE ARDP call (DE-FOA-0002271). This project will leverage and expand upon advanced fuel, design, and manufacturing technologies currently under development under the U.S. DOE Tranformational Change Reactor program, as well as, core tri-structural isotropic (TRISO) fuel characterization and PIE capabilities developed under the U.S. DOE AGR program. INL will specifically support the following thrust areas:

- Generation of fuel performance data for UN TRISO
- Reactor design support using advanced modeling and simulation techniques
- Research and Development leading to qualification of Instrumentation and Control (I&C) sensors necessary for advanced gas cooled reactors

These activities are focused on simultaneously maturing and de-risking the BANR design while informing the long-lead licensing data for this reactor.

Additionally, INL will be available for discussion on high level form and function of the BANR and subsystems throughout the performance period.

Tasks:

Task 1: Irradiation Testing over a range of temperature and burnup

Description:

This task is to perform irradiation of UN TRISO fuel at INL's Advanced Test Reactor (ATR). This task aims to leverage and benefit from U.S. DOE's Advanced Gas Reactor (AGR) program facilities and capabilities at ATR.

The basic requirements for the irradiation experiment are listed below:

- The task will involve a single irradiation campaign
- The irradiation will involve continuous measurement of fission gas released from the fuel
- The experiment should irradiate the fuel under a range of conditions. Specifically:
    - o The target burnup range is 5 – 10% FIMA
    - o Target fuel temperature is 1000 – 14000°C
- The experiment will include fuel specimens with UN TRISO in a SiC matrix, and a smaller number of specimens with UN TRISO in a conventional graphitic matrix
- The experiment will include advanced sensors and instrumentation, with the main goal of performing in-pile testing of the instrumentation (Section 3.7 for additional details)

Task 2: Post Irradiation-Examination

Description:

This task will involve sizing and shipping the experiment to the INL Materials and Fuels Complex (MFC) to start post-irradiation examination after the required cooldown period.

This task includes receipt of the experiment test train in the Hot Fuel Examination Facility, non-destructive examination of the intact test train, disassembly of the capsules and removal of all interior components, non-destructive metrology and gamma scanning of the holder and compacts, destructive analysis of the capsule internals, and destructive examination of selected compacts by cross sectioning and microscopy. Also included is shipment of selected fuel specimens to Oak Ridge National Laboratory (ORNL). The current estimate is based on the assumption of 36 fuel specimens from INL to ORNL in 9 separate shipments (4 fuel specimens per shipment).

Task 3: High-temperature post-irradiation safety testing in oxidizing conditions

Description:

This task would involve heating fuel specimens in INL Air/Moisture Ingress Experiment (AMIX) system at the desired temperature and gas composition for the desired time while assessing fission product release. Specific conditions will be defined through discussion with BWXT. The system is capable of temperatures as high as 16500°C and can use gas mixtures consisting of air or moisture impurities. It may be advisable to include more than one fuel specimen per test to increase the overall statistics. A total of four heating tests are assumed.

Task 4: Integrated Modeling and Simulation

Description:

This task is for INL to support modeling and simulation that informs architectural design of UN TRISO for BWXT's reactor and to predict in-pile performance. This task will include performing analysis, as requested, using advanced modeling and simulation tools such as BISON. This task includes on-call consultations regarding fuel modeling and predicted results, as well as participation in regular calls and meetings. Two peak periods of activity are expected – one at the beginning of the program prior to irradiation when the team is developing analysis models and performing predictive calculations, then again as PIE and safety testing results become available and results are being used to update and/or validate models. During irradiation, there may be a low level of effort to support evaluation of gas release data as it becomes available.

Task 5: Coupled Neutronic and Thermal Hydraulic Design and Analysis

Description:

This task is a level of effort activity for on-call consultation, analysis reviews by INL subject matter experts, and INL subject matter expert participation in core design reviews. As budget permits, the task may also include performing independent calculations using INL computational tools.

Task 6: High Temperature Sensor Identification and Testing

Description:

This task includes two major activities:

1) Level of effort activity for an INL instrumentation engineer to integrate with the core design team. The selection and demonstration of sensor technologies will develop in parallel with design requirements, project objectives, and operational plans.

2) Development and fabrication of instrumentation that will be demonstrated and performance tested in ATR along with the planned irradiation test for fuel qualification. (This may include, but is not limited to, sensors such as those for He gas pressure, thermocouples, and Self-Powered Neutron Detector (SPNDs).) The purpose of this task is to fill gaps in sensor qualification data that will not be addressed in other DOE programs, such as Advanced Sensor and Instrumentation (ASI), in a way that minimizes cost and schedule impact for fuel irradiation. This task includes evaluation of test results.

Task 7: Program Management

Weekly coordination meetings will be held throughout the duration of the project. Specific INL personnel will be determined by the focus of the calls and the phase of the project. For example, modeling and test planning participation will be higher early in the project, while post irradiation examination will dominate later years of the work.

Reporting

In addition to the minimum deliverables detailed above, INL will provide the following reporting:

1) Written quarterly status updates to activities accomplished, planned work, schedule performance, project and technical issues, and project performance risks.

2) Research Performance Progress Report input for submittion to the DOE; due every 6 months during performance of the ARD FOA. INL will provide BWXT with written input summarizing progress and outcomes of all Tasks above in support of this bi-annual reporting requirement. This reporting requirement may be fulfilled by INL by inclusion in the quarterly reporting noted below.

3) INL and BWXT will also complete a final report due at the conclusion of the project summarizing activities and outcomes of all tasks.

Associated SOW Section	BWXT Role	INL Role
Task 1: Irradiation Testing over a range of temperature and burnup Irradiation Preparation Receipt of fuel specimen from BWXT Irradiation in ATR with Cooldown, size, and ship to MFC	Fuel data package (as built QA built) Fuel Test Specimen Specification Preparation and delivery of irradiation test requirements Fabrication and delivery of fuel compact test specimen Review and sign-off of fuel test plan QA evaluation of INL to support fuel qualification	Analysis and preparation of fuel test plan in ATR Test Specification/Functional and Operational Requirements Design and fabrication of ATR test capsule(s), test train and ATR handling/testing equipment including sensors, and final disposition of waste generated at INL during test train fabrication and handling. Installation and verification of fission gas monitoring equipment Performance of test plan in ATR
Task 2: Post-Irradiation Examination	Coordination with ORNL for receipt of fuel specimen shipments Preparation and delivery of PIE requirements Review and sign-off of PIE plan and PIE plan revisions	Analysis and preparation of INL PIE plan(s) INL is responsible for all INL activities in the PIE plan(s) Documentation of PIE performed and results Disposition of fuel specimens received Shipment of selected fuel specimens to ORNL, including containers and transport. Final disposition of waste generated at INL during the post-irradiation examination. Final disposition of fuel specimen remnants and other waste generated at INL during fuel specimen heating in the AMIX system
Task 3: High-temperature post-irradiation safety testing in oxidizing conditions	Preparation and delivery of post-irradiation safety test requirements Review and sign-off of fuel test plan	Analysis and preparation of fuel safety test plan in AMIX AMIX tooling, handling and testing equipment Performance and data collection of AMIX test plan
Task 4: Integrated Modeling and Simulation Predictive modeling (peak period) Analysis of gas release Model validation and updates (peak period)	Provide requirements and specifications for modeling and simulation activities to be performed by INL	Provide modeling and simulation support as detailed in task description; including: • Consultation and training (online with in-person as necessary) • Collaborative design and analysis • Verification, validation and design review activities • Documentation of analysis performed
Task 5: Coupled Neutronic and Thermal Hydraulic Design and Analysis	Provide requirements and specifications for design and analysis activities to be performed/supported by INL; BWXT to provide quarterly look-ahead for anticipated support.	Provide subject matter expert support as detailed in task description.
Task 6: High Temperature Sensor Identification and Testing Instrumentation engineer level of effort support Instrument fabrication and test preparation	Provide sensor / instrumentation selection criteria Provide instrument demonstration test requirements Review and sign-off of ATR instrument test plan	Analysis of existing and needed sensors for BANR and preparation of instrument test plan in ATR Fabrication or procurement of advanced sensor(s) and instrumentation for in-pile testing of the sensor(s)/instrumentation. Performance and data collection of ATR instrument test plan and post irradiation evaluation

Test result evaluation	Review and sign-off instrument post irradiation evaluation plan	Performance to Quality Assurance standards supporting instrument qualification; including support of supplier QA evaluation by BWXT Final disposition of waste generated at INL following instrument irradiation Subject matter expert support and consultation

Fabrication may take place at the MFC Machine Shop , North Holmes Laboratory or at an off-site fabrication facility.

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/EIS0203, 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...". 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), 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) and in the FRR EIS (Sections 4.2.1 and 4.2.2). In addition to disposal of the irradiated fuel that will be generated as described above, industrial, mixed, and low-level waste will be generated and will include grinding and polishing consumables, other plastics, sleeves, and swipes needed for radiological and contamination control, construction waste for facility modifications and equipment installation, molds, and sample residue from analytical chemistry. 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 the destructive and non-destructive PIE at HFEF. 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) is required for any work or project causing radiological emissions that are not covered under an existing APAD.

The ATR 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. ATR 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 associated with the PIE portion of this experiment 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 2019, the effective dose equivalent to the offsite maximally exposed individual (MEI) from all operations at the INL Site was calculated as 5.59 E-02 mrem/yr, which is 0.56% of the 10-mrem/yr federal standard and was calculated using all sources that emitted radionuclides to the environment from the

INL site. The additional increment in emissions from the proposed action would not significantly change the total site-wide MEI dose. Therefore, 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.

Discharging to Surface-, Storm-, or Ground Water

N/A

Disturbing Cultural or Biological Resources

The ATR Reactor Building (TRA-670) and HFEF (MFC-785) are eligible for nomination to the National Register of Historic Places. No structural or aesthetic changes will be made to the buildings.

Generating and Managing Waste

Some industrial waste will be generated. Hazardous/mixed waste will be generated that includes irradiated cadmium-bearing experiment baskets from ATR, analytical laboratory waste and small amounts of electronic waste.

Radioactive waste will be generated from PIE and irradiated structural metals and includes PPE and wipes.

It is estimated industrial waste could be as much as 100 kg (~75 m3), mixed waste as much as 1 m3 (<1 kg) and low level waste as much as 25 m3 (15 kg).

Project personnel will work with Waste Generator Services (WGS) to characterize, properly package and transport and dispose of all regulated, hazardous or radioactive material or waste according to laboratory procedures.

TRU Waste: Irradiated sample debris and PIE waste may generate TRU waste and mixed TRU waste. Irradiated sample debris and secondary waste could total as much as 4.2 kg. Project personnel would work with WGS to characterize and properly dispose of all waste.

Releasing Contaminants

When chemicals are used during the project there is the potential for spills that could impact the environment (air, water, soil).

Using, Reusing, and Conserving Natural Resources

Project description indicates materials will need to be purchased or used that require sourcing materials from the environment. Being conscientious about the types of materials used could reduce the impact to our natural resources.

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"

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 Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada (DOE/EIS-0243) and supplemental analysis (SA) (DOE/EIS-0243-SA-01).

Final Environmental Assessment and Finding of No Significant Impact for the Replacement Capability for Disposal of Remote-Handled Low-Level Radioactive Waste Generated at the Department of Energy's Idaho Site (DOE/EA-1793, December 2011)

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."

Transportation, receiving, and storing used nuclear fuel, as well as, research and development 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 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 analysis includes 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 EIS limits the number of shipments to the INL, and the proposed activities would fall within the limits of the EIS.

The potential for transportation accidents has already been analyzed in the SNF EIS (Section 5.1.5 and Appendix I-5 through I-10). 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 TRU waste at the generator-storage 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 low level waste from the INL to the Nevada National Security Site were analyzed in the 1996 Nevada Test Site EIS (DOE/EIS-0243) and supplemental analysis (SA) (DOE/EIS-0243-SA-01) 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 SA considers additional waste streams, beyond those considered in the 1996 NTS EIS, that may be generated at or sent to the Nevada National Security Site for management.

Onsite disposal of RH-LLW was analyzed in the Final Environmental Assessment for the Replacement Capability for Disposal of Remote-Handled Low-Level Radioactive Waste Generated at the Department of Energy's Idaho Site (DOE/EA-1793, 2011).

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

Approved by Jason L. Anderson, DOE-ID NEPA Compliance Officer on: 03/04/2022