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NUCLEAR TECHNOLOGY RESEARCH AND DEVELOPMENT TECHNICAL MONTHLY DECEMBER FY19

Advanced Fuels Campaign

ADVANCED LWR FUELS

LWR Fuels

- **[LANL]** High temperature neutron diffraction data was collected on CaF2 to a maximum temperature of 1150°C at the LANSCE HIPPO beamline. This work was initiated to study the Bredig transition of a low temperature, non-toxic substance prior to studies on UO2 and MOX surrogate system. Bredig transition and Frenkel disorder, which can be observed at high temperature, is a major feature of fluorite structures including actinide oxides such as UO2 and MOX. Both are expected to give rise to an anomalous specific heat capacity at temperatures above 2100 K. Neutron scattering measurements provide an informative approach to investigate what temperature Bredig transition and Frenkel disorder will start, since it gives configuration information of light ion, i.e. F in the fluorite structure, which is relevant to each phenomenon. Work conducted under this study is part of the Civilian Nuclear Working Group between JAEA and DOE-NE and is part of the research of Dr. Taku Matsumoto, a visiting scientist at LANL from JAEA. (S. Vogel)
- **[LANL]** A manuscript titled, "Experimental and Computational Assessment of U-Si-N Ternary Phases," was accepted in the Journal of Nuclear Materials. This work details investigations into the understanding of ternary phases that form in the UN-U3Si2 composite high uranium density fuels through a combination DFT+U calculations and experimental studies verifying the formations of a thermodynamically stable U20Si16N3 phase in this liquid phase sintered system. Outcomes of this study are relevant to understanding existing UN-U3Si2 fuels that are part of ATF-1 test irradiations in ATR. This study was conducted as a collaborative effort between USC and LANL as part of a NEUP led by Dr. Besmann. (J. White)
- **[ORNL]** A paper titled, "Production of more ideal uranium trioxide microspheres for the sol-gel microsphere pelletization process without the use of carbon," has been published in the Journal of Nuclear Materials. The paper evaluates four highly suitable synthesis conditions for the fabrication of UO3 microspheres via an internal gelation reaction for the fabrication of advanced fuels. The goal was to identify experimental conditions that lead without the use of carbon as a pore former to highly porous UO3 microspheres. The low density UO3 micro spherical feedstock has a great potential to be utilized directly via cold pressing and sintering into highly dense UO2 fuel pellets. It was also confirmed that an aging step of the spheres after gelation is necessary to produce an ideal feedstock. These findings will allow to fabricate highly dense advanced fuel pellets without dust formation or multiple processing steps which is of particular interest for the fabrication of transuranic fuel candidates as well as advanced fuel candidates. (R. Hunt, J. Collins, M. Lloyd, S. Finkeldei)

LWR Core Materials

- **[ORNL]** Preparation of master rod/plate C26M2 samples (heat #17025001, Fe-12Cr-6Al-2Mo base, ATF wrought FeCrAl alloy) for hydrogen diffusivity measurement was completed. Two different, fully annealed samples (a rod sample with average grain size of ~300 μm and flattened tubes with average grain size of ~40μm) were delivered to the corresponding PI. These samples are to be

machined into a disk shape and then subjected to the hydrogen permeation testing at ORNL, specifically focusing on the grain size effect at the beginning. (Y. Yamamoto)

- **[ORNL]** ORNL permeation testing system has been successfully upgraded to enable the hydrogen thermal diffusivity measurement through time-lag technique. FeCrAl Gen III C26M2 samples with two different grain sizes, 40μm and 300μm, are being machined to fit the permeation testing sample fixture. Dependence of hydrogen permeability, diffusivity, and solubility of FeCrAl on microstructure will be investigated. (X. Hu)
- **[ORNL]** Micro-tensile specimens of Generation II FeCrAl alloys irradiated near 7.5 dpa at 236, 282, & 460°C have been for shipped to ORNL's LAMDA facility for in-situ testing. Micro-tensile testing will enable more robust structure-property relationships to be developed for irradiated FeCrAl alloys. (K. Field)
- **[ORNL]** Advanced microchemical mapping of FeCrAl alloys after irradiation and then deformation have been completed. Results show removal of the deleterious alpha prime phase from deformation channels formed under in-situ straining techniques. Results provide new insight into the deformation and embrittlement mechanisms in irradiated FeCrAl alloys. (D. Zhang)
- **[ORNL]** Chemical vapor deposition (CVD) and chemical vapor infiltration (CVI) are versatile and scalable technologies that enable advanced ATF cladding concepts through manufacturing of ceramic matrix composite and/or depositing over-coatings. Development of coating technologies are imminent needs for SiC composite-based claddings to ensure environmental protection in oxidizing water chemistry and hermeticity against gaseous fission products release. Seal-coating technology for end-plugging is another pressing need for the ceramic claddings. Longer term, development of improved fiber-matrix interphases that are more oxidation-resistant in both water and steam environments than the current pyrolytic carbon technology is desired for future SiC composite-based LWR claddings and core components. With these future objectives, the current effort focuses on establishing a CVD/CVI capability that offers adequate configurational versatility and flexibility for precursor species and deposition conditions.

  Power for the CVD/CVI furnace has been installed in L107, and the furnace and quartz process tube have been tested to 1100°C (Figure 1) which is the maximum anticipated deposition temperature. The furnace maintained 1100°C at ~70% power output demonstrating more than adequate capacity for the additional thermal load associated with the intended gas flow rates during the deposition process. (B. Jolly, Y. Katoh)

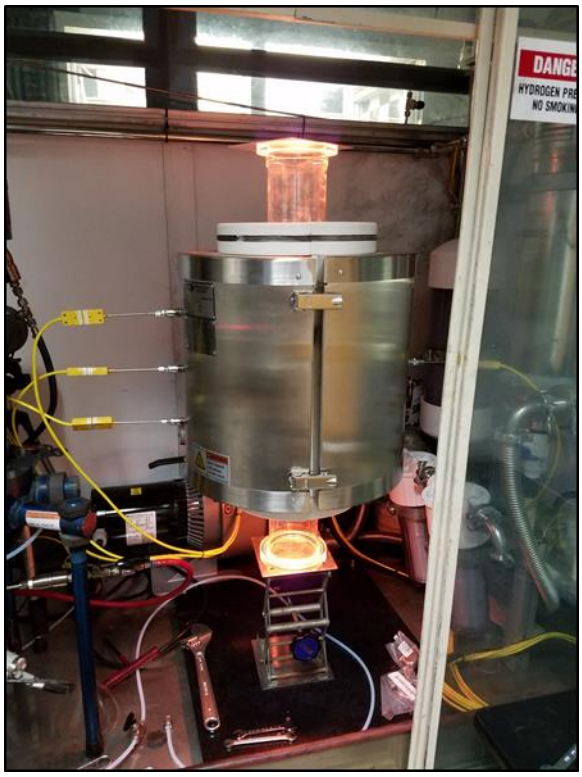

Figure 1. ATS 3 zone tube furnace being tested with quartz process tube at 1100° C.

- **[INL]** Several cladding materials with various dimension were identified at INL, ORNL and LANL for this project. A special pressure resistance weld (PRW) system at INL was examined for use in this project. The PRW vendor was contacted for fabrication of several sets of customer designed electrodes to fit the ODS cladding dimension. (J. Gan)

LWR Irradiation Testing & PIE Techniques

- **[INL]** ATR continued repairs and replacement of the north (1D) in-pile tube during the unplanned outage that began November 4, 2018. Activities continued associated with the ATF-2 design change for ATR cycle outages 166B (addition of 6-pin holders with BWR-diameter pins at Tiers 3 and 4) and 168A (addition of a 9-pin holder with wireless instrumentation at Tier 5/6). (G. Hoggard)
- **[INL]** Nineteen ATF-1 capsules remain in irradiations in the ATR (of the original thirty-one capsules representing seven unique design concepts). Three of these will reach designed burnup at the end of the current cycle (164B). Preparations for the next planned shipment of five irradiated capsules are now underway. Additional flux-wire monitor holders are also in fabrication. (C. Murdock)
- **[INL]** Four ATF-1 rodlets were removed from their capsules. The rodlets were from ATF-06 (UO2, Alloy-33 FeCrAl), ATF-08 (UO2, APMT FeCrAl), ATF-45 (U3Si5, Kanthal-AF FeCrAl), and ATF-73 (UO2, various FeCrAl alloys). Visual exams were performed on these 4 rodlets (Figure 2). Neutron radiography was also performed on these four rodlets (Figure 3). Shots were performed at every 30 degrees to capture any asymmetries. Damage of some of the UO2 in ATF-08 from capsule disassembly was observed. (J. Harp)

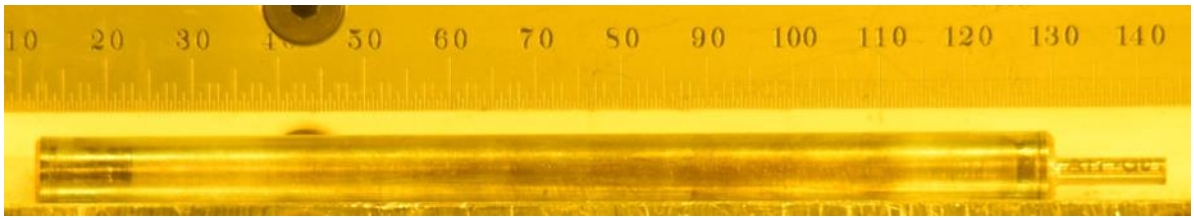

Figure 2. Visual examination of the rodlet from ATF-06.

Figure 3. Thermal neutron radiography of the four ATF-1 rodlets from (left to right) ATF-73, ATF-45, ATF-08, and ATF-06.

LWR Fuel Safety Testing

- **[INL]** Conceptual design efforts are on-going for Super SERTTA. TWERL conceptual design efforts are on-going. (H. Guymon)
- **[INL]** Work for the first high burnup fuel sample was completed. An environmental checklist for the high burnup work was initiated and approved. The initial attempts for using a sealed partial pressure method for pre-hydriding zirconium samples showed positive indications with hydrides precipitating uniformly across the thickness of the cladding and oriented in the circumferential direction as expected. (L. Emerson)
- **[INL]** Initial setup was completed and studies began for evaluation of water effects on infrared pyrometer measurement of temperature to support ATF testing in MARCH-SERTTA later this year. Instrument support and data evaluation continued for SETH tests with successful measurement of neutron flux and cladding temperature to greater than 1000°C. (K. Bowman)
- **[INL]** The level 3 milestone titled, “All ATF-1 and ATF-2 as built characteristics are stored in NDMAS,” was completed. This is the first step toward the goal of providing a database of all

relevant ATF data that allows one point access for industry partners and researchers while maintaining proper access restrictions (e.g., proprietary information). (D. Dempsey)

- **[INL]** A meeting was held with key personnel from MFC, TREAT, RadCon, Experiment Management, and Transportation to develop experiment transportation processes including communication protocol between facilities in support of the continued development of the TREAT shipping strategic plan. Efforts are on-going to establish PIE capabilities at MFC in support of future TREAT experiments. (H. Guymon)
- **[ORNL]** A journal paper titled, "An advanced experimental design for modified-burst testing of the nuclear fuel cladding materials during transient loading" has been published in the Annals of Nuclear Energy. The paper investigates the modified-burst test (MBT) in detail using a novel optical set-up and the digital image correlation (DIC) approach. The optical set-up is capable of observing the 360°-view of the tube specimens. This can enable us to track the failure location and to calculate the strains with a high-accuracy. The paper also examines the applicability of the conventional two-dimensional DIC approaches by evaluating the strains on virtually 360°-wrapped surfaces as a function of locations, noise, and the loading paths. (M. Nedim Cinbiz, M. Gussev, K. Linton, K. Terrani)
- **[ORNL]** A journal paper titled, "Failure Behavior of SiC/SiC Composite Tubes under Strain Rates Similar to Those in the Pellet-Cladding Mechanical Interaction Phase of Reactivity-Initiated Accidents," has been published in the Journal of Nuclear Materials. This paper investigates the mechanical response of a nuclear-grade silicon carbide fiber-reinforced silicon carbide matrix composite (SiC/SiC) under conditions simulating the pellet-cladding mechanical interaction (PCMI) period of the reactivity initiated-accident (RIA). MBT and an advanced experimental set-up with DIC have been used for this purpose. The mechanical response of the SiC/SiC composite samples have been investigated for the RIA pulse width from 12 to 100 ms, including representative quasi-static expansion-due-to compression (EDC) tests. Results shows that a loading-rate effect, which can be translated to the event-time for the RIA, on the SiC/SiC composites. As the loading-rate exceeds a specific value, the failure strain decreases from ~1.2% to ~0.6% as shown in Figure 4. Importantly, the expected RIA pulse characteristics for SiC/SiC composites have been utilized to understand the implications of the results, and a preliminary failure strain limit of SiC/SiC cladding for RIA has been suggested. (M. Nedim Cinbiz, T. Koyanagi, G. Singh, Y. Katoh, K. Terrani, N. Brown)

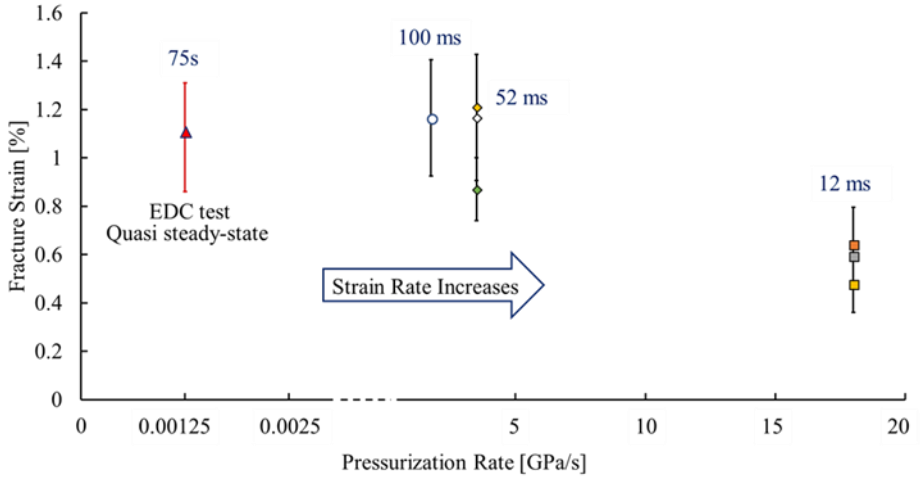

Figure 4. Dependence of the fracture strain of SiC/SiC composites have been tested with MBT and EDC (quasi-static) on the pressurization rate. Fracture strains are calculated using DIC methods from speckle-painted surfaces of the tube samples.

- **[ORNL]** The development of the Plane-Strain Tension (PST) Test has been started, and PST test fixtures have been designed compatible to the future hotcell testing. PST has been developed to assess the mechanical response of the zircaloy claddings for the RIA-like conditions. The schematic of the PST test is shown in Figure 5a. To induce a strain-driven loading, the specimen's gauge section is oriented perpendicular to the loading direction. The sample has a double edge notched geometry to impose a near plane-strain loading conditions (see Figure 5b). This loading condition is also close the loading path imposed by the MBT. Figure 6 depicts the failure strain of the hydrogen-charged Zr-alloy cladding tubes as a function of hydrogen content for various tests. Ring tensile test and EDC have similar loading path of uniaxial tension, and the failure strains of both tests are found to be similar. On the other hand, MBT and PST have near plane-strain tension loading path, and the resultant failure strains are similar. Because the implementation of the PST test in a hotcell is relatively easier than the implementation of MBT, we have designed modular PST fixtures (see Figure 7) for the separate-effects testing capability at ORNL's irradiated fuels examination laboratory (IFEL). A metal part for the preparation of double-edge notched specimen from the tube samples has been designed and manufactured, as shown in Figure 8. (M. Nedim Cinbiz, B. Garrison, R. Sitterson, K. Linton)

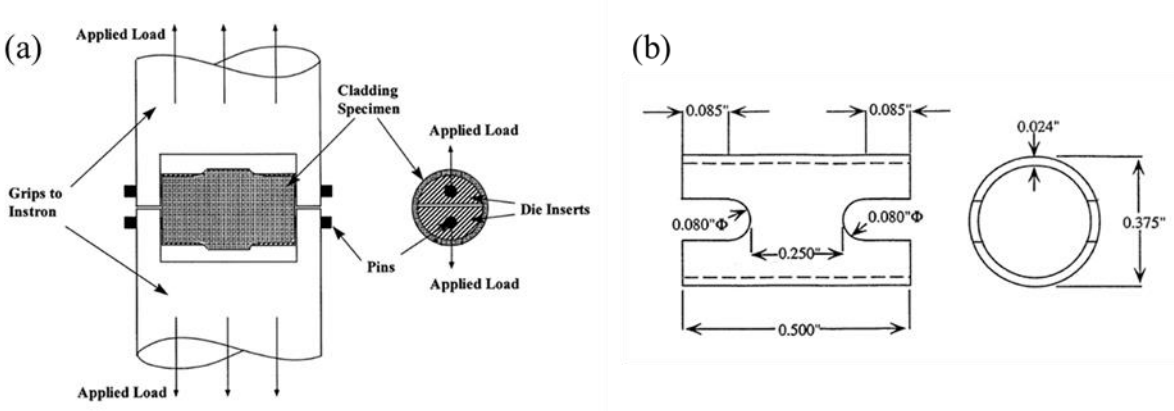

Figure 5 (a) Schematics of the PST test and (b) the specimen geometry. Note the gauge section is on the top of the mandrel where the loading direction is perpendicular to the gauge section.

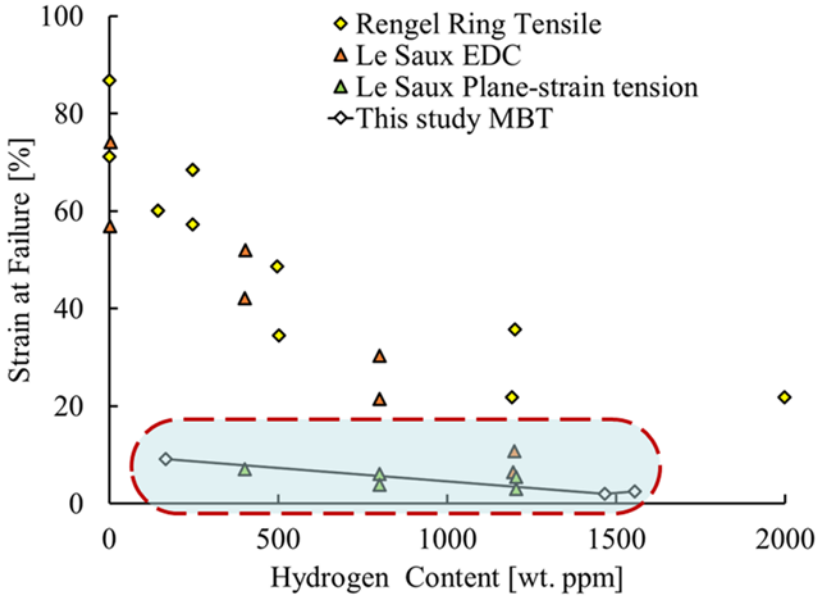

Figure 6. Comparison of failure strains of various tube tests. Ring tensile and expansion-due-to-compression (EDC) have same loading paths. On the other hand, the loading paths of PST and MBT are similar.

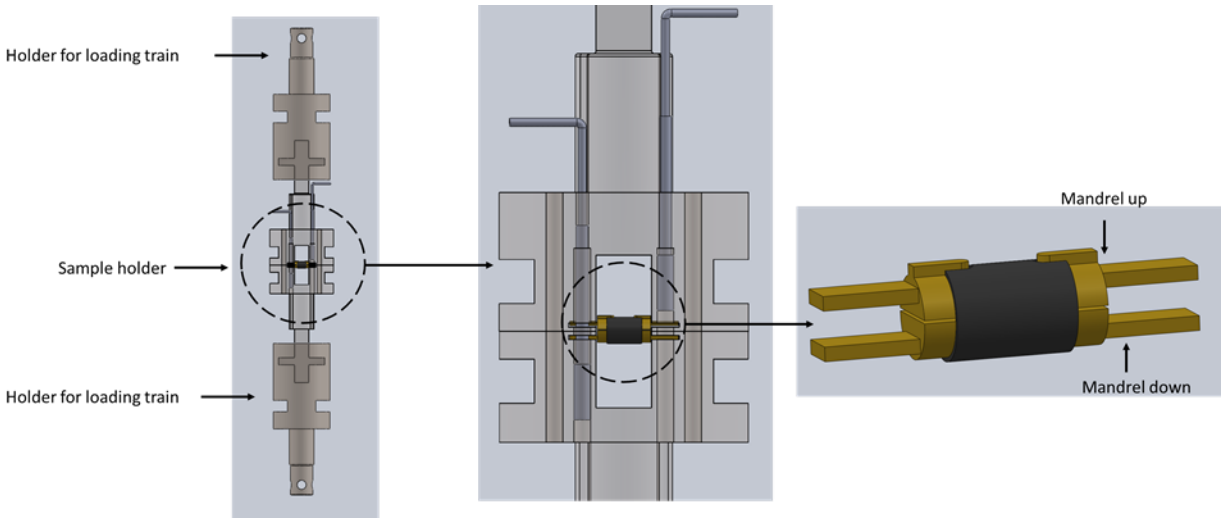

Figure 7. Schematics of the fixtures for the PST test.

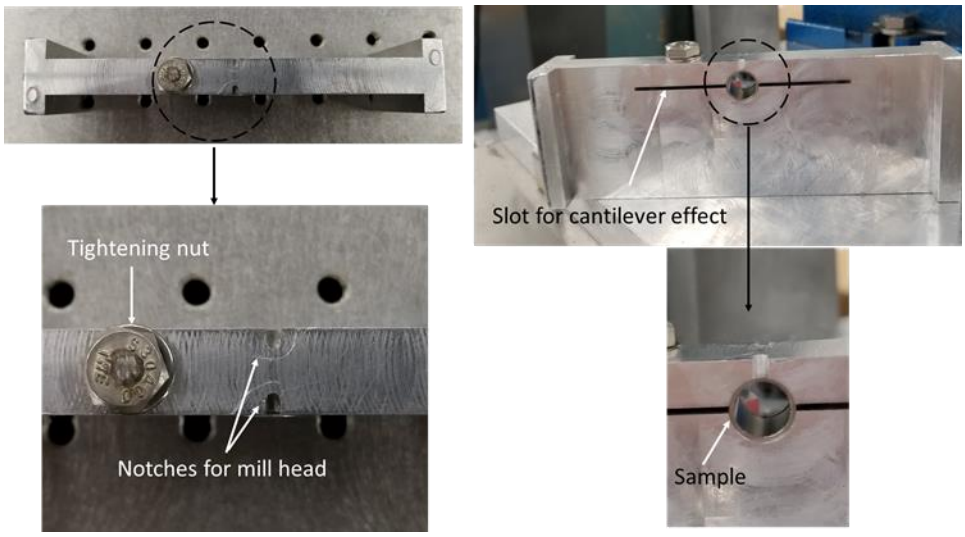

Figure 8. Part for milling a double-edge notched specimen for PST tests.

- **[INL]** Hodoscope activities in support of the TREAT experiment program for SETH-C transient testing are on-going, including transient operations with the Nuclear Equivalent Device (NED). Development efforts of a Fuel Motion Monitoring System (FMMS) process flow and data package template to support experiments are on-going. (H. Guymon)

LWR Computational Analysis & Fuel Modeling

- **[BNL]** Several options for coating fuel pellets/individual particles to mitigate the fuel/coolant interactions for water-reactive high-density fuel phases, such as U3Si2, and UN have been proposed by LANL. Initial modeling of these options with the TRITON neutronic lattice physics code to provide an initial estimate of the impacts on reactor performance and safety characteristics continued. Two options have been evaluated U3Si2: 1) coating of the fuel pellet; and 2) coating of individual fuel particles. Analyses have been completed for 20 and 70 μm coatings of Zr-metal, Y2SiO5, Cr-10Al, and 20 μm coatings of ZrB2, on the fuel pellet, and 5-v/o of Zr-metal, Y2SiO5, Cr-40Al on individual particles. The analyses all assumed an explicit model of the standard Westinghouse 17x17 assembly geometry, fuel pellet OR and Zircaloy cladding IR/OR and constant enrichment of 4.9-w/o; therefore, the gap was reduced by the thickness of the coating. Burnups and cycle lengths were estimated via the linear-reactivity model assuming 3-batch fuel management. The burnups for all cases are essentially the same, and close to those for the "reference" UO2-Zr case. Cycle lengths were also very similar for all cases and ~15% longer than for the reference UO2-Zr case, reflecting the higher density of U3Si2, relative to UO2. The reactivity and control coefficients (fuel and moderator temperature coefficients, and soluble boron and control rod worths) are effectively the same for all the coatings and for the 5-v/o additions. (M. Todosow, A. Cuadra)

Industry FOA

- **[LANL]** A report was issued to Westinghouse detailing efforts to mitigate waterside corrosion through the use of corrosion resistant coatings on the surface of pellets. In this report, Cr coatings are applied to the surfaces of U3Si2 pellets using a high temperature plasma spray coating procedure. Microstructural characterization of the coatings and associated defects that form during the coating process is described. Preliminary steam testing on a coated pellet showed similar degradation behavior to an uncoated monolithic U3Si2 pellet which is associated with large defects in the coating associated with the coating procedure. Routes to minimize these defects through the plasma spray

coating procedure are discussed as well as alternative approaches to coatings to properly investigate if this is a viable route to mitigate waterside corrosion in high uranium density fuels. (J. White)

ADVANCED REACTOR FUELS

AR Fuels

- **[INL]** Several samples of the annular extrusion were taken which included areas in which the mandrel was present. These samples will be prepared using standard metallographic preparation techniques. Of particular interest will be the tool steel (mandrel) and uranium alloy interface, to determine if any chemical took place or if deformation of the tool steel led to mechanical bonding of the uranium alloy and billet material. Tooling design and fabrication for annular fuel extrusion has continued.

  In addition, work has continued on FAST test fabrication and assembly development. The technical specification has been sent to the preferred vendor for cladding tubing fabrication. Also, recent work on casting of the reduced diameter pins has shown to be more difficult than originally thought due to the operator dependence of the arc casting method. Work has continued on this task, including coating of the copper mold with a ZrO2 thermal barrier. With the application of this material, the molten material appears to flow over a much longer distance showing that casting is feasible. The right combination of thermal barrier, power applied to the melt, and vacuum pressure in the vacuum accumulator will be determined and casting studies will continue. (R. Fielding)

  [INL] Fabrication of both the ½ and 1/3 diameter modified endplug has taken place. The modified endplugs were easier to machine and leaves less material in the upper endplug region that has to be melted during the welding process. An initial welding trial of these endplugs using a micro-TIG torch was performed by a welding system vendor. Initial results show that welding of both sizes using a standard micro-TIG torch is feasible, although additional testing will be required. Initial fixturing design has been initiated with some fabrication. Figure 9 shows the initial simplified hardware concept in which multiple pins can be loaded in a single fixture, and translated past the endplug press and welding torch. (R. Fielding)

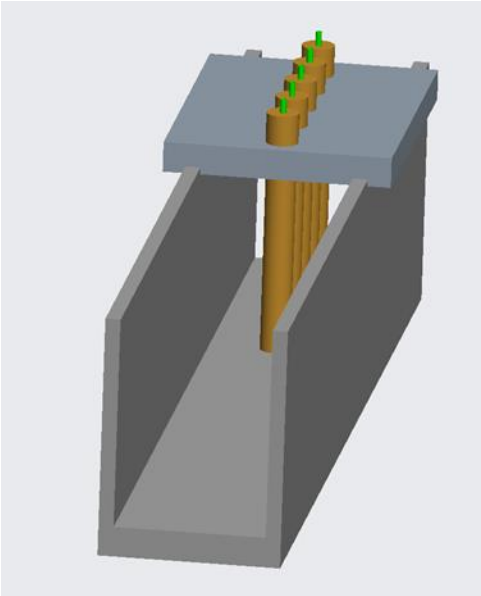

Figure 9.Initial simplified hardware concept.

- **[INL]** Dr. Michael Benson submitted a journal article titled, "Microstructural characterization of annealed U-20Pu-10Zr-3.86Pd and U-20Pu-10Zr-3.86Pd-4.3Ln." The authors are M.T. Benson, Y. Xie, L He, K.R. Tolman, J.A. King, J.M. Harp, R.D. Mariani, B.J. Hernandez, D.J. Murray, and B.D. Miller. (J. Giglio)

AR Core Materials

- **[PNNL]** The report for milestone "M3FT-19PN020302025 titled, "Report on and Perform Neutron Irradiated Material Microstructure Analysis and Barrier Hardening Coefficient Determination (FY17)," was completed on time. This report uses tensile, hardness, and microstructure data to examine the relative contributions of a wide range of irradiation-induced strengthening mechanisms in neutron irradiated oxide dispersion strengthened (ODS) ferritic and tempered martensitic steel (TMS) alloys. For the ODS ferritic alloys, it appears that grain size refinement, solid solution strengthening, and YTiO oxide population changes all contribute significantly to the strength increase during irradiation. For the TMS alloys, strengthening was due primarily to grain size refinement and the formation of G-phase. Some microstructure data are still being obtained and when it is available, the contributions will be estimated again, but little change to the overall conclusion is expected. These results provide understanding of how irradiation affects the strength of these materials and also provides guidance on designing improved alloys that are more resistant to irradiation-induced hardening that also typically causes reductions in alloy ductility. (M. Toloczko)
- **[PNNL]** Application of six new thermomechanical treatments to three Fe-9Cr alloys was completed as a part of the development effort to improve the mechanical properties of 9Cr steels for fuel cladding application. Selection of the new thermomechanical processing routes applied to the Fe-9Cr alloys was based on those developed for high strength and high toughness HT-9 steels (Fe-12Cr steels), among which the tempering at 500°C or 600°C yielded the best combination of mechanical properties. Eighteen thermomechanically treated coupons were produced for the three Fe-9Cr alloys, and evaluation of high temperature mechanical properties and examination of tempered martensite structures are to be followed. Machining of three-point bend fracture and tensile specimens is underway. (T.S. Byun)
- **[PNNL]** Last fiscal year, as part of the program to advance the technology associated with fabricating tubing from difficult-to-fabricate materials, the PNNL rolling mill was modified so that it can perform pilgering of thick-wall tubes. This capability to pilger thick-wall tubes into finished tubing establishes a unique R&D capability within the DOE complex. (R. Omberg)
- **[PNNL]** Funding for FY-19 did not arrive in PNNL until 14 December 2018, and work was initiated immediately. Prior to this, with carry-over funds depleted, work was in a stand-down. With the return from the stand-down, the first order of business was to incorporate a geometric arrangement on the pilger/rolling mill so that longer tubes could be pilgered. This rearrangement will now allow tubing with a 240 mil outer diameter and a 20 mill wall to be pilgered, which is reasonably close to the desired end dimensions. (R. Omberg)
- **[PNNL]** The initial pilgering run for this fiscal year has been scheduled in the next few weeks and the rate at which work then progresses will determine if subsequent milestones may be in jeopardy. This run to check out the geometric rearrangement will be performed with stainless steel so as not to risk the more limited supply of MA956 for 14YWT unduly. After this testing with stainless steel is complete, MA956 and 14YWT will be pilgered. (R. Omberg)

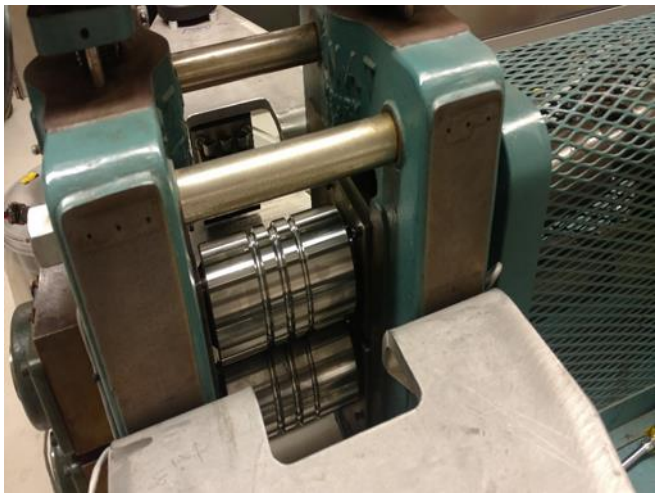

Figure 10. Rolling mill with pilger dies installed.

- **[ORNL]** Five 4-in. diameter cans fabricated from 4140 steel containing ball milled OFRAC powder are being prepared for hot extrusion. After filling each can with ~2 kg of ball milled powder, a 0.25-in. diameter stainless steel tube welded to the end cap, which was then welded to the can. The cans are being degassed at 300ºC under vacuum for 24 h. Three of the five cans have been degassed. Once degassed, the cans are scheduled to be extruded at 850ºC through a 1.75 inch diameter die to form the master rods. The goal of this task is to produce five master rods that will be shipped to NFD (Nippon Nuclear Fuel Development) for fabricating tubing with final dimensions of 6 mm outer diameter and 0.5 mm wall thickness. (D. Hoelzer)
- **[ORNL]** Transmission electron microscopy was performed on the Y01 and Y23 specimens of 14YWT (SM13) that were neutron irradiated at BOR60 to 16.6 dpa at ~386ºC and ~412ºC, respectively. Both specimens were lifted from neutron irradiated TEM disks and thinned by focus ion beam (FIB) using the FEI Versa 3D Dual Beam FIB-SEM located in the LAMDA facility. Multiple bright-field through-focus image series obtained from both specimens did not reveal the presence of dislocation loops or cavities. The Y23 specimen had a very nice thin region that was beneficial for doing Fe-M, Cr-M and Ti-M jump ratio maps. The Y01 specimen was slightly thicker that degraded the quality of the jump ratio maps. However, the EFTEM results confirmed the presence of Cr-rich alpha prime particles in both specimens, which agreed with the APT results. It was difficult to image the Ti-Y-O nano-size oxides in the Fe-M jump ratio maps of Y23 due to local depletion of Fe. However, the Fe-M jump ratio maps showed Fe depletion due to the alpha prime particles that were then confirmed with Cr-M jump ratio maps. It is not clear why the Ti-Y-O nanoclusters were difficult to observe since some of the regions in Y23 possessed thicknesses that were ideal for resolving 2-4 nm dia. particles. Support for the specimen preparation and TEM analysis was provided by the NSUF Rapid Turnaround Experiment: 18-1130 (P.I.'s: Dr. M. Auger, Oxford University and D.T. Hoelzer, ORNL). These results highlight the effects of neutron irradiation on the microstructural stability of 14YWT and the capabilities of advanced instruments in LAMDA for obtaining high impact PIE results. (D. Hoelzer)
- **[ORNL]** New code was developed to correctly measure defect sizes using the machine learning defect detection frame work. The new algorithms will provide the framework outputs that are in similar formats to datasets typically acquired using electron microscopy and further enable the framework to replace hand counting techniques for defect detection in irradiated alloys. (D. Morgan/K. Field)

AR Irradiation Testing & PIE Techniques

- **[INL]** Irradiations are on-going for the AFC-IRT1, 4C, 3F, and 4B/D experiments. IRT1 is planned for two more cycles of irradiations beyond the current cycle (164B) and will ship to PIE early in FY2020. The 4D capsules are anticipated to be removed and replaced by a new group of experiments called Fission Accelerated Steady-State Test (FAST) in early FY2020. The remainder of experiments will continue into Mid-FY2020 or beyond. The latest group of experiments called FAST is in the preliminary design phase. FAST preliminary design analyses and fabrication development activities are making progress and the preliminary design review is anticipated to be held at the end of January. (C. Murdock)
- **[INL]** Fission gas analysis was initiated on X430-T653 and X521-G594. These pins were irradiated in EBR-II at 10 at% (X430) and 1.5 at% (X521) burnup. Pin plenum volume and pressure were measured and they are consisted with EBR-II literature. Fission gas sampling were collected and sent to PNNL for chemical analysis. (J. Harp)
- **[INL]** A slice of minor actinide bearing U-19Pu-1.2Am-1.3Np-10Zr fuel from X501-G591 was sent to the Electron Microscopy Laboratory for Scanning Electron Microscopy Analysis (Figure 11). The performance of this fuel is generally similar to ternary U-19Pu-10Zr fuel. However, Am was observed in an interaction layer between the fuel and the cladding, and incorporated into lanthanide phases. This is similar to Am behavior observed in the FUTURIX-FTA DOE1 pin. Much more data analysis is required to fully process all the data collected in this short exam. Further electron microscopy will also be identified for this sample. (J. Harp)

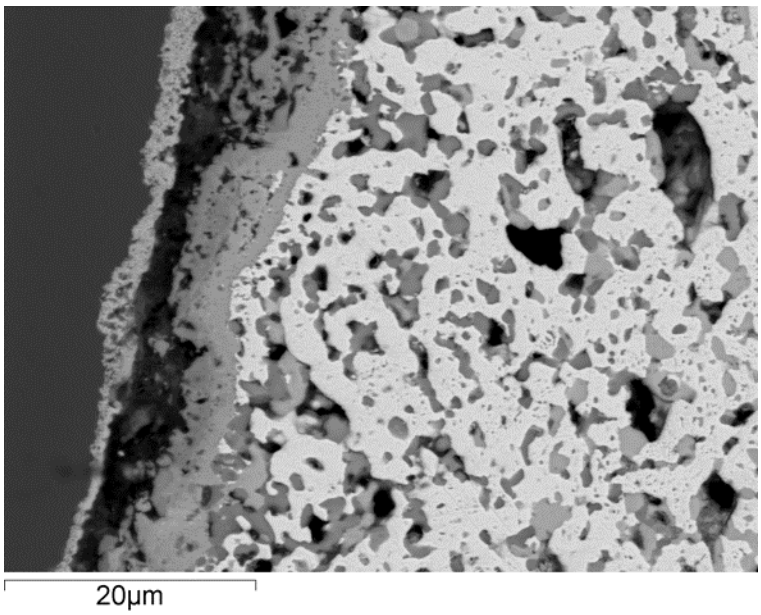

Figure 11. Backscatter Electron Microscopy image from sample of X501-G591 showing the Am bearing interaction layer at the fuel cladding interface (left of image).

- **[INL]** Electron microscopy samples were prepared from the AFC-3D R1 (U-10Zr, annular, 55% smear density, ~4.5% burnup) rodlet. Optical microscopy was performed on the sample and these samples will be examined in the near future.
- **[INL]** A conceptual design for the furnace testing apparatus has been completed. Parts for this design are being identified. (J. Harp)

- **[ANL]** A paper titled, "Fuel Performance Evaluation of Annular Metallic Fuels for an Advanced Fast Reactor Concept," was submitted by Y. Miao, et al., to the journal, Nuclear Engineering and Design. The annular fuel performance in a high-burnup sodium cooled fast reactor is summarized in this paper. (T. Kim)

AR Fuel Safety Testing

- **[INL]** Work was initiated on a heat sink module design for the MARCH system with the creation of conceptual sketches and the draft of a test plan. A scope of work statement for sodium loop work was drafted. (L. Emerson)
- **[INL]** Design activities are on-going to support the final design of the TREAT Characterization-scale Instrumented Neutron Dose Irradiation (CINDI) experiment schedule for irradiation in early 2019. The CINDI final design kick-off meeting is scheduled in January of 2019. A draft Focus Area Test plan in support of the fuel safety research milestone is being prepared. (H. Guymon)
- **[INL]** Project meetings were established. Individual performing modelling was brought up to speed on the project scope. (L. Emerson)

AR Computational Analysis & Fuel Modeling

CAPABILITY DEVELOPMENT

CX Fuels

- **[INL]** The TCM was delivered to the IMCL thermal properties cell on Dec 10. Ancillary equipment was delivered the week of Dec 10. Training for facility access and initial operation of the TCM on a work bench in the TPC have been completed. An installation and test plan is being drafted and training requirements for final installation testing are being determined. (S. Martinson)
- **[INL]** Investigations continue on the effects of diffraction on the PTR measurement. The laser used for sample excitation was returned to the manufacturer for warranty repair work. We expect it to be returned in early to mid-January. (D. Hurley)

TREAT Testing Infrastructure

- **[INL]** Design efforts in support of a shielded cell in building MFC-723 in support of TREAT experiments is on-going. Design and equipment identification to establish TREAT experiment handling capabilities at MFC are on-going. (H. Guymon)

For more information on Fuels contact Steven Hayes (208) 526-7255.

Material Recovery and Waste Forms Development

PROCESS CHEMISTRY AND INTEGRATION

- **[ONRL]** DFT calculations were performed to elucidate the difference in the inner-sphere coordination and Am3+/Eu3+ selectivity for several polyaminocarboxylic acids. The predicted trend in the Am3+/Eu3+ selectivity increasing in the order of DTTA-PzM < DTTA-PyM < DTTA-BuA is in agreement with the results of complexation studies. The employed theoretical approach, however, points to some challenges in describing the Am3+/Eu3+ separation quantitatively with conventional non-hybrid and hybrid general gradient approximation density functionals. Analysis of the canonical orbitals shows larger extend of orbital mixing with Am 5f orbitals than with Eu 4f orbitals. This is further confirmed via calculation of natural orbital occupancies, indicating larger participation of the Am 5f orbitals than Eu 4f orbitals in the metal−ligand dative bonds. The results of the NBO second-order perturbation analysis also point to the importance of metal-to-ligand back donation interactions, which are becoming more noticeable for the Am3+ complexes with more extended basis sets. Synthesis of two new aminopolycarboxylate ligands has been initiated. (S. Jansone-Popova)
- **[ANL]** Waste from laboratory activities has been packaged and submitted for pick-up. (W. Ebert)

WASTE FORM DEVELOPMENT AND PERFORMANCE

Electrochemical Waste Forms

- **[ANL]** An abstract was prepared for submittal to the American Ceramic Society meeting to be held in Boston in June, 2019, summarizing the testing of developmental iron phosphate waste forms for EChem salt waste. Improved materials being prepared at PNNL will be evaluated when they become available. (W. Ebert)

Glass Ceramics Waste Forms

- **[ANL]** Six glasses provided by SRNL are being prepared for testing by crushing and sieving. Tests will be conducted to measure the pH dependence of the dissolution rates before and after Stage 3 is triggered to derive rates to be used in the Stage 3 dissolution model. (W. Ebert)
- **[PNNL]** A letter report was submitted on December 31 in fulfillment of milestone M5FT-19PN030105096. The letter details the role of mass transport in the various mechanisms that control the long-term aqueous chemical durability of nuclear waste glasses. Despite the wide variety of mechanisms in play (including the dissolution-based destruction of the glass network, silicate transformation into alteration layers, solid-state ion exchange/interdiffusion inside the glass, the evolution of silicate alteration layers, chemical transport through the alteration layers, precipitation of secondary minerals, and aqueous diffusion), most of them are impacted in large part by mass transport at the buried interface between the glass and the porous alteration layers. The concentration, chemistry, and solid-state mobility are all changed by the fact that the solution is confined into nanoscale porosity. Ongoing efforts from both the US programs on glass corrosion research and international colleagues are probing into these differences more deeply than at any other time in previous years. These insights are expected to lead to the next generation of glass corrosion models, which will include a coupled series of mechanistic models that take the impacts of constricted geometries into account. (J. Ryan)

Iodine Waste Forms

- **[ANL]** The level 2 report recommending a test method for use in process development of HIPed mordenite and spark plasma sintered silica aerogel waste form was written and provided to co-

workers for review and comment prior to issuance at the end of January. The recommended method is based on results of tests conducted to-date at ANL and PNNL with prototype materials. Microscopic analyses of some of the HIPed mordenite waste forms made by ORNL in 2017 were examined and will be subjected to the recommended test in January to demonstrate application of the method and assess the degradation behavior. (W. Ebert)

- **[PNNL]** Two milestones were completed in December. A level 4 milestone, M4FT-19PN030105111 titled "Experimental Suite for AgI Waste Forms- Submit Short Report to ANL," was completed. A level 3 milestone M3FT-19PN030105114 titled "Investigating the Durability of Iodine Waste Forms in Dilute conditions," was submitted to a special issue of Materials. (M. Asmussen)

DOMESTIC ELECTROCHEMICAL PROCESSING

- **[ANL]** Analyses of Li2O-bearing salts from experiments measuring the degradation of zirconium indicated the amount of dissolved Zr remained constant over the approximately 7-day test durations. The Zr concentration was higher in salts with higher Li2O contents, but highest in the salt without added Li2O. The Zr specimens are being examined with SEM/EDS and will be evaluated by using XRD. A system is being constructed to evaluate corrosion in molten salt by using electrochemical methods similar to those developed for metal waste forms.

  The system being used to conduct the parametric tests with solid cathodes is being prepared. Tests will be conducted to measure the effects of anode basket placement and cathode cup designs on operating parameters and product quality. A newly designed probe will be used to perform electrochemical measurements during operation to improve process control. A meeting will be held in Washington DC to discuss status of electroprocessing and waste forms with Japanese colleagues and discuss work scope for FY2019 and beyond. (W. Ebert)

SIGMA TEAM FOR OFF-GAS

- **[INL]** A long-term deep-bed adsorption test was temporarily halted on December 14, 2018 in order to (a) collect sorbent bed samples for analysis, (b) shut down for the INL Christmas curtailment, and (c) enable calibration as needed per the calibration schedule for mass flow meters used in the gas blending system. At the time of the temporary shutdown, this test had continued for 2,889 hours since it started in August 2018. This test has shown that for at least this duration, the silver Aerogel sorbent remains active at capturing iodine from iodobutane, a moderate-long-chain organic iodide, in a simulated vessel off-gas (VOG) from aqueous used fuel reprocessing.

  Figures 1 and 2 provide the updated chemisorbed iodine concentrations and Ag utilizations in the sorbent bed at different bed depths. These measurements were made by collecting and analyzing small samples of sorbent from different bed segments. The total cumulative bed depth started at about 7.5 inches, and has decreased to 5.8 inches due to the periodic removal of sorbent samples. The chemisorbed iodine concentrations and sorbent behavior have continued as expected. The iodine concentrations and silver utilizations have increased in the first ~1.5 in. each time that the sorbent has been sampled up to hour 2,889; reaching about 21 wt% and 66%, respectively.

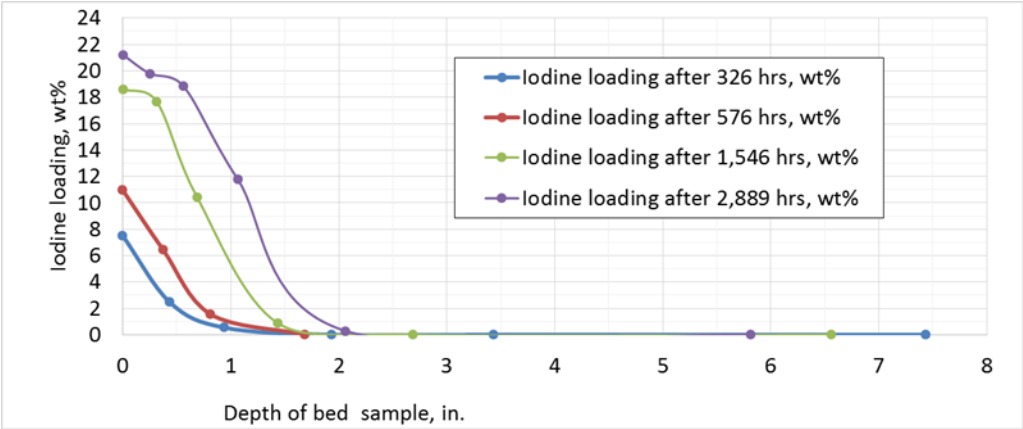

Figure 12. Iodine loading on Ag Aerogel sorbent during simulated VOG testing with a target 1 ppm iodobutane concentration in the inlet simulated VOG.

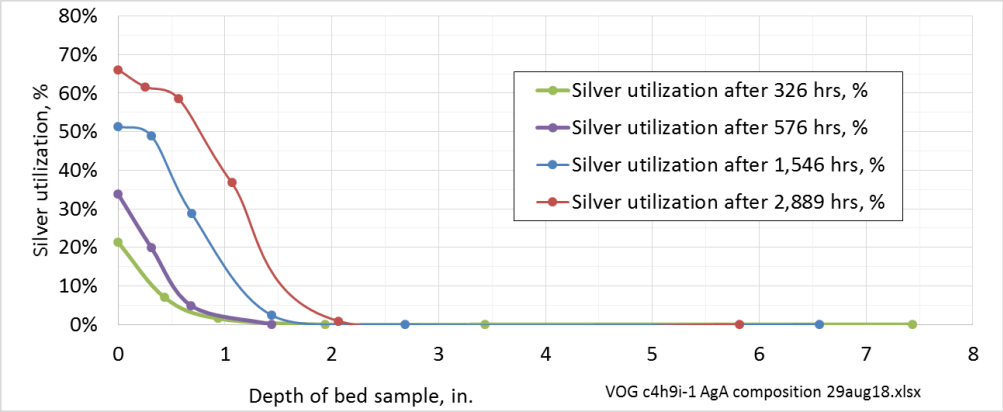

Figure 13. Silver utilization in Ag Aerogel sorbent during simulated VOG testing with a target 1 ppm iodobutane concentration in the inlet simulated VOG.

No adsorbed iodine has yet been detected beyond about 2.5 inches deep in the bed, indicating that even after this many operating hours, the mass transfer zone for iodine adsorption at these VOG test conditions is about 2.5 inches or less.

Figure 14 shows that, as expected, the increase in iodine concentration in the first two bed segments (up to 0.25 in. deep in the bed) is less at hour 2,889 compared to hour 1,546. This means that the iodine concentration and the silver utilization are beginning to approach asymptotic limits.

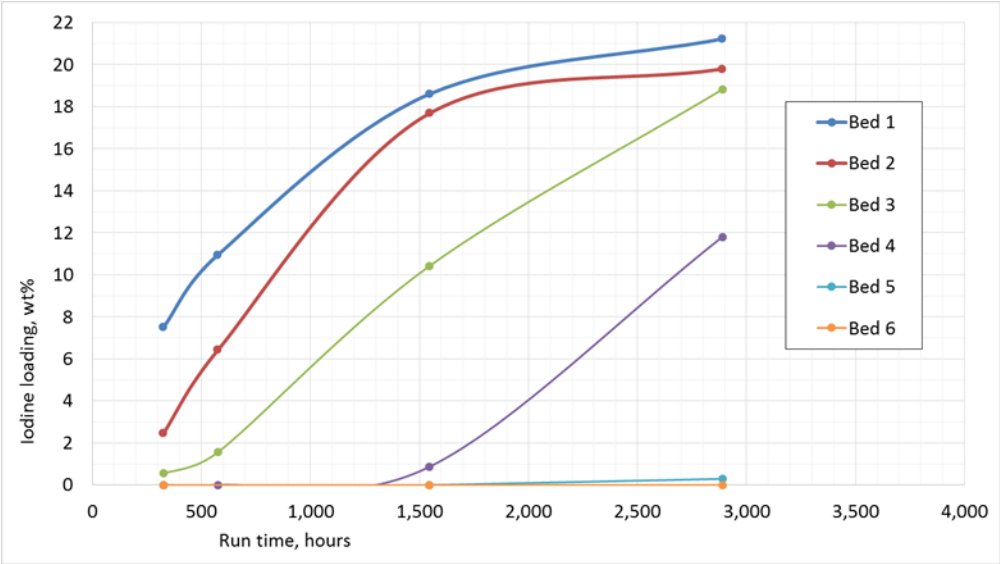

Figure 14. Silver utilization versus test run time in Ag Aerogel sorbent during simulated VOG testing with a target 1 ppm iodobutane concentration in the inlet simulated VOG.

This test will be re-started in early January and is planned to continue through February, when this test may be shut down to provide time in the second half of this fiscal year for a second VOG iodine adsorption test. (J. Law)

- **[ORNL]** Components to assemble the Off-Gas Capture System for Advanced Tritium Pretreatment described in the test plan have been identified and orders have been placed. The surge tank and mounting fixtures are being designed and built in-house. The construction of this test system has been the primary effort focus area this month. (B. Jubin)
- **[ORNL]** A report summarizing production of four large-format HIPed I–AgZ samples has been issued. These samples are 1.5 in. diameter and 2 in. length and contain 49 g of I–AgZ. Two samples were prepared at an iodine loading of 64 mg I/g I-AgZ, and two samples were prepared at an iodine loading of 135 mg I/g I–AgZ. These two sets of duplicate samples will be made available upon request in support of iodine waste form durability method development efforts. This is a FY18 carry-over task. (B. Jubin)
- **[ORNL]** In FY18 the effects of NO and NO2 on methyl iodide and iodine adsorption onto AgZ were studied using a statistically designed test matrix. Efforts in FY19 will complete this work to determine the effects of NO and NO2 on I2 and CH3I adsorption onto silver-functionalized aerogel. The first tests conducted using aerogel as the CH3I sorbent did not show any CH3I loading onto the sorbent. As part of the troubleshooting process, the CH3I system has been modified to eliminate unnecessary carrier gas and has removed several check valves that were inhibiting flow to TGA manifold, and the gas pressures of the various streams were rebalanced. Work in this area continues. (B. Jubin)
- **[PNNL]** A level 5 milestone, M5FT-19PN0301070314 titled “Growing Metal Organic Frameworks on Porous Supports,” was completed. (P. Thallapally)
- **[PNNL]** A level 3 milestone, M3FT-19PN0301070311 titled, “Production of Mechanically Robust Ag0-functionalized Silica Aerogel,” was completed ahead of schedule. The main purpose of this study was to investigate possible improvements in the synthesis protocol to further improve the mechanical stability of Ag0-aerogel. Granules of temperature-strengthened silica aerogel were used to study the effect of hydration/thiolation, concentration of silver nitrate solution used for anchoring

of Ag+ on thiol-modified surfaces, and temperature of silver ion reduction on mechanical stability of Ag0-aerogel. The results were compared with attrition data for Ag0-aerogel that closely, but not completely, mimicked material that was tested in the past at Idaho National Laboratory and Oak Ridge National Laboratory. The mechanical response to attrition was evaluated with a vibratory sieve shaker and a rotating platform. The selected samples were analyzed for macro- and microstructural changes with N2(g) adsorption/desorption isotherms using the Brunauer–Emmett–Teller (BET) method.

The results indicated that the length of hydration had only a negligible effect on mechanically stability. A clear benefit of silver deposition at higher AgNO3 concentrations was demonstrated. The higher concentration of silver led to more mechanically robust sorbent. The silver reduction temperature did not play significant role in improving mechanical properties of the sorbent at low concentrations of silver. However, at higher concentrations of silver, a notable improvement in mechanical stability was observed. In the next phase, the synthesis protocol for production of Ag0-aerogel will be further optimized. In addition, mechanical stability of Ag0-aerogel will be tested after exposure to different off-gas streams to evaluate the effect of off-gas chemistry on mechanical strength. (J. Matyas)

FLOWSHEET DEMONSTRATIONS

- **[ORNL]** The University of Tennessee Knoxville (UTK) report authored by Dr. Craig Barnes titled, "Purification of Zirconium Tetrachloride from UNF Cladding," was reviewed and found to be an excellent summary of the work done at UTK to develop a purification protocol and perform a quantum chemistry modeling study of the gas phase reactions of zirconium tetrachloride with other metal chlorides. A few minor comments were sent to PNNL and INL for relay to UTK. (R. Jubin)
- **[ANL]** We are working to develop a preliminary design basis for a UREX process and associated balance of plant systems. The design basis report for the Engineering-scale Demonstration (ESD) of the UREX+1a process that was developed in 2005 for the AFCI is serving as the basis for equipment and process requirements. Though UREX+1a is more complicated because of inclusion of three additional extraction processes, since UREX is the front-end process in the ESD many of the upfront systems are similar, and many of the same back-end operations will be required. The design basis will include equipment requirements (unit operations, tankage, waste treatment) for the process based on the expected feeds, products, and wastes. (P. Candido)
- **[INL]** ZIRCEX Demonstration Project, FT-19IN03010805, Collection of data continued for the analysis of alternative locations for the hybrid uranium recovery demonstration (based on ZIRCEX, solvent extraction and high-level-waste vitrification). Scoring and selection of a recommended alternative is anticipated in January. (M. Patterson)
- **[PNNL]** Spectral training set collection was completed in December 2018. The training set matrices were collected on NIR, Raman, and UV-Vis instruments simultaneously for a variety of nitric acid (HNO3) concentrations, actinide species concentrations, and oxidation states. Spectra of actinide species collected included sets from: U(IV), U(VI), Pu(III), Pu(IV), Pu(VI), Np(IV), Np(V), and Np(VI). Concentrations of HNO3 ranged from 0.5 M to 4 M, with variable actinide species concentrations spiked into the HNO3 phase. Select aliquots of the aqueous phase were titrated to confirm the concentration of HNO3 throughout the training set collection.

  The spectral training sets included collections in the aqueous phase, and, for select species, collection of spectra post-contact with an organic phase. For contacts that involved an organic phase, solutions of aqueous phase, spiked with actinide species, were contacted with an equal volume of 30% TBP in n-dodecane and mixed vigorously. Following separation of the organic and aqueous phase, spectra were collected on each of the individual phases, illustrating the transfer of species post-contact. This

combination of variable actinide species in the aqueous and organic phase, and variable HNO3 concentrations, covers the range of concentrations and speciation that is anticipated in the fourth CoDCon experiment (planned for April 2019). (G. Lumetta)

For more information on Material Recovery and Waste Forms Development contact Terry Todd (208) 526-3365

MPACT Campaign

MANAGEMENT AND INTEGRATION

NTD & Technical Support

- **[LANL]** MPACT CAM, Federal Program Manager, and NTD worked through funding issues related to new start FY19 activities. Partial funding release requested to enable new starts (MSR Safeguards and Advanced Fuel Cycle Scoping Review Panel) to initiate activities. Both activities have commenced, but full funding release will be required to meet deliverables. MPACT CAM, Federal Program Manager, and NTD began planning for MPACT annual spring meeting. Meeting will coordinate MPACT projects with related NEUP activities. Related Nuclear Material Accountancy (NMA), safeguards, and nuclear security offices will be invited from across the DOE and U.S. Government complex. The meeting is planned to be held at ANL in the April, 2019. MPACT CAM, Federal Program Manager, and NTD began high-level FY19 objectives for the MPACT program including the internal MPACT program sizing review and Milestone 2020 messaging plan.

ADVANCED FUEL CYCLE SCOPING

Advanced Process Modeling and Simulation (Process Tests)

- **[PNNL]** Continued internal conversations identifying source material for LANL's MicroCal analysis efforts. No commitments have been made for PNNL material, however, we are poised to support as needed for MPACT's missions. A varied inventory of unique radioactive materials have been identified and could be loaned and/or committed to LANL as per their receiving requirements. ATM-109 spent fuel and dissolved HEU samples are examples of materials that could be rapidly prepared for analysis.

Advanced Fuel Cycle Scoping – Review Panel

- **[ANL]** Participated in discussions regarding molten salt reactor safeguards needs.

SAFEGUARDS AND SECURITY BY DESIGN – ECHEM

Microfluidic Sampler

- **[ANL]** Designs were completed for the custom analytical-scale molten salt pump, continuously circulating molten salt sampling loop, and custom two-chamber oven to house the system. The molten salt pump design was finalized based on results from testing the acrylic prototypes and will be fabricated by Argonne's Central Shops. Several motors were investigated for use as the new pump driver due to the need for higher speeds. The motor will be procured and the pump fabrication will begin when FY19 funds become available. Fabrication of the molten salt gravity flow cell was started, and the full system will be fabricated and tested with chloride salts when FY19 funds become available.

Actinide Sensor

- **[INL]** SEM analysis of the Uranium-beta" alumina membranes that were tested in a LiCl-KCl-UCl3 salt system for an extended period of time has been performed. The planning and preparation of the experimental setup for the uranium sensor work in nuclear facility (Fuel Conditioning Facility) is still underway.

Bubbler for Measuring Density and Depth of Molten Salt

- **[INL]** Work was performed to gain insight on the systematic errors and corrections that can be made to improve the bubbler data. Areas explored prior to installing the cleaned bubbler were, 1) the differential pressure transducer (DPT) zero setpoint and drift and 2) the line losses through the system. Most of the month was spent understanding the pressure drop. In addition, work was performed towards getting a height gage ready to go into Hot Fuel Examination Facility (HFEF) hot cell. A gage was purchased and modifications were made so it could be used in HFEF. The final touches of the gage are currently being placed.

ER Voltammetry

- **[ANL]** Initial electrorefiner operations with the sensor immersed in the salt have begun. Optimizations and modifications of the voltammetry procedures to achieve the safeguards and process monitoring requirements are being worked out. Design costing for sensor installation into the IRT ER has been nearly completed.

OR Voltammetry

- **[INL]** A series of cycle voltammograms (CVs) were performed over a period of several days in the Joint Fuel Cycle Studies Integrated Recycling Test (JFCS-IRT) oxide reduction furnace (OR) before the furnace was cooled down. The focus of these CVs was on how the Ir electrode responded at different initial open circuit potentials (OCPs). The CVs obtained were consistent with previous results.

MODELING ADVANCED INTEGRATION AND MILESTONE 2020:

Advanced Integration (Methods)

- **[LANL]** Working on voltammetry integration. Initial paper has been written and going through a review.

Advanced Integration (Security Facility Models)

- **[SNL]** The physical security model for the conceptual Echem processing building is complete, and the site layout is nearing completion. Scoping of the scenarios that will be examined has been completed.

Modeling and Simulation for Analysis of Safeguards Performance

- **[SNL]** Carryover funding has been used to support minimal activities exploring integration of process monitoring with traditional safeguards measurements for Echem.

EXPLORATORY RESEARCH / FIELD TESTS

Microcalorimetry

- **[LANL]** In the past, one obstacle to practical large-array microcalorimeter spectrometers has been the challenge of combining spectral data from hundreds of pixels. Each pixel has a slightly different response, and previous methods of co-adding data required significant user input or were only robust for certain categories of radioactive materials. We have now developed a software module ("Micro Matcher") to co-add data from individual pixels in a completely automated way without using any nuclide-specific information. It works by automatically choosing a template single-pixel spectrum,

then finding and matching patterns of peaks in the spectra from other pixels. In our testing so far, the automated algorithm is better at aligning the individual pixel data than the standard method and results in a higher-resolution combined spectrum. This software tool will be an important component of a successful user assessment. Testing of the internal radiation shielding has shown that it increases the dose threshold before the superconducting resonators shift in frequency. We are now measuring more LANL Pu items and using the data to improve our analysis methods. The pulse tube refrigerator for the field testing instrument has been ordered. This item has a very long lead time and delivery is expected around early May. This should allow sufficient time to meet our M3 milestone, provided that we test other sub-systems on the instrument in advance.

High Does Neutron Detector

- **[LANL]** LANL received a 3D model of the junction box section of miniature HDND. PDT will supply the remaining part of the miniature HDND (detector housing) during the January time-frame (pending updated schedule due to incurred delays in material delivery). As soon as available, the full model will be shipped to INL for testing.

For more information on MPACT contact Mike Browne at (505) 665-5056.

Systems Analysis and Integration (SA&I) Campaign

CAMPAIGN MANAGEMENT

- **[ANL, INL]** Completed the FY 2018 Achievement Report for the Systems Analysis and Integration (SA&I) Campaign. The report discussed the Campaign Mission and Objectives and Key Deliverables, and provided representative highlights of the Campaign's work completed during the fiscal year.
- **[ANL, Colorado School of Mines]** Completed hosting of webinar to NE-1 and NE-4 titled, "Visualization Tool for Comparing Energy Options" presented by Prof. Mark Deinert (Colorado School of Mines). Feedback was very positive.

EQUILIBRIUM SYSTEM PERFORMANCE (ESP)

Performance of Fuel Cycle Systems

- **[ANL]** Continued the collection of information on advanced nuclear energy systems, which include the breed-and-burn concept with Molten-Salt Reactor.
- **[ORNL]** Work has continued on the generation of the isotopics and data for the "most promising" international fuel cycles and reactor systems. A SCALE AFCR model was created to generate cross sections using ORIGEN. These cross sections were used to generate the spent fuel isotopics (assuming a burnup of ~10 GWd/MTU) for further analyses of the Chinese nuclear fuel cycle. Work was finalized for the fuel cycle analysis for generating the discharge isotopic composition of a 43-element CANDU fuel element with burnable absorbers.

Economic Analysis Capabilities and Assessments

- **[ANL]** The campaign's 2014 report entitled "Identification and Analyses of Fuel Cycle Economics Issues", by F. Ganda et al., was released for public access, per request from DOE earlier in 2018.
- **[ANL]** Ganda accepted an invitation to attend and present at an EPRI, NEI, GAIN workshop on Construction Economics on January 17-18 in Washington DC.
- **[ANL]** Initiated the paperwork to attend and present also at a meeting at the OECD/NEA headquarters in Paris on February 12 and 13, 2019 on an upcoming report on the economics aspects of new nuclear power plants construction. Participating in both of these meetings will provide an opportunity to showcase the SA&I Campaign's work to a relevant audience, and to increase the visibility and relevance of the SA&I Campaign in this space.
- **[ANL]** The activity on the cost of Public versus Private construction costs continued. Reports from the late 1990s on best practices in large project management were found and analyzed. Additionally, it was possible to have a meeting with Ed Temple, as suggested by Dr. Dave Moncton (MIT, previous ALD of ANL) in November. Ed Temple was project director for several successful DOE mega-projects, including APS, SNS and others. In preparation of the meeting, a list of relevant questions was developed. Afterwards, a draft write-up was developed with notes from the meeting. The meeting was attended by Ms. K. Biegel, Dr. T. Taiwo and F. Ganda. The engagement with Ed Temple has a high potential value for this ESP project, by providing an opportunity to learn about the management of mega-projects within the DOE framework, and it also has a high potential value by providing a connection that can be instrumental for the VTR project.
- **[ANL]** For the ACCERT cost algorithm project, the material obtained from Lee Nelson (INL) in November was studied. This work was performed by Dominion Engineering under INL sponsorship, as containing useful information on the fabrication cost of large mechanical components. However,

only high-level data was found in the files received, insufficiently detailed to be useful for the ACCERT algorithm. Separately, a careful revision of the complete set of code of account costs was initiated from the EEDB dataset.

- **[PNNL]** Investigating alternative representations of electric power systems in energy models. No significant progress due to late arrival of funding and holidays.
- **[INL]** Continuing work on the literature review for cost overruns in public and private nuclear construction, reviewed several papers discussing the role of management and failures thereof. Drafted key insights from this review and sent it to collaborators at ANL (F. Ganda and K. Biegel) for the purpose of beginning to outline the shape of the report on this topic.

Daily Market Studies of Advanced Nuclear Energy Systems

- **[ANL, BNL, INL, PNNL, ORNL]** Held multi-lab monthly videoconference to discuss progress in the ESP "Energy Market Analysis" activity.
- **[ANL]** Additional work was conducted on the EDGAR code. The development done on nuclear load following in FY18 was generalized in order to allow modeling more than one nuclear unit with EDGAR, each being on a different load schedule. This was required as the focus is switching to analyze very different regions as initially used for EDGAR development and validation.
- **[ANL]** A meeting was held between the EDGAR developers (N. Stauff, R. Maronati) and nuclear economists (F. Ganda, G. Ponciroli) to discuss how to quantify electricity prices in the most defensible way with the EDGAR code. The issue of marginal cost versus the standard use of derivatives for the determination of electricity prices was discussed extensively and there were suggestions to address this issue: (a) review literature on this topic and (b) check how markets really function from on-line materials on the various markets' websites. Additionally, for coupling of EDGAR with DAKOTA, there was discussion on how to arrive at a fully functional capacity expansion model by adding Capital and O&M fixed costs in the objective function and a new approach to arrive at the price for ancillary services possibly without re-performing the full Monte Carlo optimization both in the nominal and perturbed states.
- **[ANL]** A journal paper entitled "An Improved Genetic Algorithm approach to the Unit Commitment/Economic Dispatch problem" was reviewed and submitted to IEEE.
- **[SNL]** We are making progress towards finding a way to automate the process of creating interactive flow diagrams. Currently, the process for creating these diagrams is very labor intensive; finding a way to automate this process would reduce the time it takes to make fuel cycle options available on the public Nuclear Fuel Cycle Options Catalog.

Enhancements to the Cost Basis Report (CBR) Tool

- **[ANL]** The work on the improvements of the Cost Basis Report continued. The integration and re-writing of module D1-1 on fabrication cost of LWR fuel is proceeding, and the calculations for the cost of fabrication of contact and glove-box handled metallic fuel for module D1-6, from the NASAP study, were completed. These results, together with previous cost for metallic fuel fabrication based on EBR-II pilot studies, can be utilized to develop a writeup that fills a current gap in the cost basis for module D1-6.
- **[INL]** Continuing on the integration of NASAP studies into the D Module of the Cost Basis Report, coordinated with F. Ganda, K. Williams and E. Hoffman on planned updates. This entails comparing the results of the NASSAP analysis with bases already in the CBR, and updating as necessary.

Analysis of NES to Augment Information in Fuel Cycle Catalog

- **[ANL, ORNL]** Collected mass flow data from Advanced Fuel CANDU Reactor (AFCR) for development of FCDP of a Chinese fuel cycle concept which is the continuous recycle of U/Pu with LEU feed in fast and thermal reactors (EG31).

Campaign Special Sessions at International Topical Conference

- **[ANL]** Participated in a telecon of the GLOBAL 2019 Technical Program Committee to discuss a panel session to be hosted by the SA&I campaign, entitled "Challenges and Opportunities for Nuclear Energy Systems in a Future Energy Market".

Quick Turn-Around Studies

- **[LLNL]** Explore issues of technology maturity for one of a kind research facilities.

DEVELOPMENT, DEPLOYMENT AND IMPLEMENTATION ISSUES (DDII)

Technology Development Roadmap for a Continuous Recycle System Using Fast Reactors

- **[ANL]** Continued collection of information for the critical technology elements (CTEs) of sodium cooled fast reactor, in support of the development of technology maturation plans (TMPs). The CTEs included advanced materials, electro-magnetic pump, SCO2 power conversion system, etc. In December, the TMP outline of the SCO2 power conversion system was developed and shared with the TSRA national team.
- **[INL]** Completed the Critical Technology Element and Technology Readiness Level analysis for the separations portion of the near-term fuel cycle example. Developing structure for maturation plan and roadmap. Assisting with extension of Technology and System Readiness Level questions to level 7.
- **[LLNL]** Continued evolution of the TSRA framework address more mature systems and application to the VTR.

Transition Analysis Studies

- **[ANL, INL, ORNL]** Committed to participating in organizing committee for next international Technical Workshop on Fuel Cycle Simulations (TWoFCS) hosted by UIUC (Prof. Huff) in June 2019.
- **[ANL, INL, ORNL]** Participated in kick-off call for Functionality Isolation Test (FIT) Benchmarks with international fuel cycle modeling collaborators to coordinate joint FY19 activities.
- **[INL, ANL]** Held first call discussing topic and outline of M2 deliverable, journal paper manuscript on key lesson from transition analyses – benefits of starting fast reactor fleet on HALEU
- **[INL]** Worked to finalize analyses for NEA TRU Management Benchmarking Cases. Began planning out partial transition analysis framework for testing relative costs and benefits as a function of the extent of transition completion.

Regional and Global Impacts

- **[PNNL]** Investigating the long-term scale, timing and value of nuclear energy within the context of a comprehensive U.S. and global energy system. No significant progress due to late arrival of funding and holidays.

Implications of Deploying Multiple Advanced Nuclear Energy Systems

- **[ANL]** Laid out where key interactions will exist when multiple technologies are deployed. These occur over the entire life cycle from initial R&D to disposal of the waste. The focus of the report will be on those that relate to past transition analyses. These interactions will have implications for the government sector. The large number of systems being studied are being group into categories based on how they will interact with other systems. Variants of the same technology/fuel cycles are not of interest, so like systems, in terms of deployment, will be grouped together. This will focus on key aspects that effect deploying multiple different technologies.

Adaptation of OR-SAGE for NES Analysis

- **[ORNL]** Work continued to review NRC guidelines related to fuel cycle facility siting. Specifically, the following NRC sources for review guidelines related to siting: RG 4.9, Preparation of Environmental Reports for Commercial Uranium Enrichment Facilities; RG 4.17, Standard Format and Content of Site Characterization Plans for High-Level Waste Geologic Repositories; RG 4.19, Guidance for Selecting Sites for Near-Surface Disposal of Radioactive Waste. From the review and assessment, a draft note has been produced that highlights the data that is likely needed to complete a GIS assessment based on the above siting criteria, and from which a series of parameters will be determined for siting limitations/needs.

For more information on Systems Analysis and Integration contact Temitope Taiwo (630) 252-1387.

Joint Fuel Cycle Study Activities

- Held the JFCS Technical Coordinating Committee and Steering Committee Meetings in Seoul, Korea.
- Supported the U.S.-ROK Joint Standing Committee for Nuclear Energy Cooperation (JSNEC) held in Seoul, Korea.
- Performed system inspection on the OR system prior to processing IFSF-stored LWR fuel.
- Ordered long lead items necessary for transporting and processing IFSF-stored LWR fuel.
- Received analytical results for a number of prior samples including ER Salt and U/TRU materials.

For more information on Joint Fuel Cycle Studies Activities contact Ken Marsden (208) 533-7864.

AFCI-HQ Program Support

UNIVERSITY PROGRAMS

Site: University Research Alliance at West Texas A&M University in Canyon TX, and the following universities: University of Michigan, University of Tennessee, University of California at Berkeley, Texas A&M University, Vanderbilt University, University of Idaho, Oregon State University, Kansas State University, Northwestern University, University of Nevada at Las Vegas, Clemson University, Rensselaer Polytechnic Institute, Purdue University, Georgetown University, Virginia Commonwealth University, Florida International University, and other universities.

Universities engaged in Nuclear Technology research via URA programs since 2001:

Boise State University
Boston College
Clemson University
Colorado School of Mines
Georgia Institute of Technology
Georgetown University
Idaho State University
Florida International University
Florida State University
Kansas State University
Massachusetts Institute of Technology
Missouri University of Science and Technology
North Carolina State University
Northern Illinois University
Northwestern University
Ohio State University
Oregon State University
Pennsylvania State University
Purdue University
Rensselaer Polytechnic Institute
Rutgers University
Texas A&M University
University of Arkansas
University of California at Berkeley
University of California at Santa Barbara
University of Chicago
University of Cincinnati
University of Florida
University of Idaho
University of Illinois at Urbana-Champaign
University of Michigan
University of Missouri
University of Nevada at Las Vegas
University of New Mexico
University of North Texas
University of Notre Dame
University of Ohio
University of South Carolina
University of Tennessee at Knoxville
University of Texas at Austin
University of Virginia
University of Wisconsin
Vanderbilt University
Virginia Commonwealth University
Washington State University

INNOVATIONS IN NUCLEAR TECHNOLOGY R&D AWARDS

Summary Report

- University Research Alliance continued processing reimbursements for the 2018 Innovations Awards winners' travel expenses for the ANS meeting.
- University Research Alliance mailed desktop awards to the 2018 Innovations Awards winners who did not attend the ANS Meeting.
- University Research Alliance continued to prepare materials for the 2019 Innovations Awards.
- University Research Alliance continued to improve the email distribution list in preparation for the 2019 Innovations Awards.

For more information on the University Research Alliance contact Cathy Dixon (806) 651-3401.