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ADVANCED FUELS CAMPAIGN

CAMPAIGN MANAGEMENT AND INTEGRATION

- **[ANL]** The R&D roadmaps of two liquid metal cooled fast reactors (SFR and LFR) were developed targeting a commercial or engineering demonstration by the early 2030s (T. K. Kim, et al, "Research and Development Roadmaps for Liquid Metal Cooled Fast Reactors – Draft for Public Comment," ANL/ART-88 Rev. 01). The SFR technology is mature enough for commercial demonstration by the early 2030s, and the remaining key activities and R&D needs are generally related to the completion of qualification of fuel and structural materials, validation of reactor design codes and methods, and support of the licensing frameworks. The LFR's technology is less-mature compared to the SFR's, and will be at the engineering demonstration stage by the early 2030s. Key LFR technology development activities will focus on resolving remaining design challenges and demonstrating the viability of systems and components in the integral system, which will be done in parallel with addressing the gaps shared with SFR technology. (T. K. Kim)

ADVANCED LWR FUELS

LWR Fuels

- **[LANL]** Center-of-Mass pixel-centroiding was deployed for the first time on nuclear-fuel samples at Flight-Path-05 at the Lujan Neutron Scattering Center to increase the spatial resolution provided with the current Time-of-Flight neuron detector system. This method makes use of the activated pixels for each neutron that is detected. In order to determine a more precise location of the originating event, the center of the multiple pixels that were activated for each event is computed. The pixel size of the detector is $55\times55\mu m^2$. Initial results show significant improvement on image resolution. Features down to 20 μm were successfully resolved using this method. For comparison, non-centroided images only provided up to ~100μm resolution. The improved resolution can be observed in Figure 1 below, showing a centroided image in A) and a non-centroided image in B) of a dUN/dUSi fuel rod, together with a resolution grading. Tomographic data-analysis using this method is ongoing. The improved spatial resolution will greatly benefit the determination of the cladding to fuel gap in encapsulated fuel rods. (Adrian S. Losko, Nicholas P. Borges).

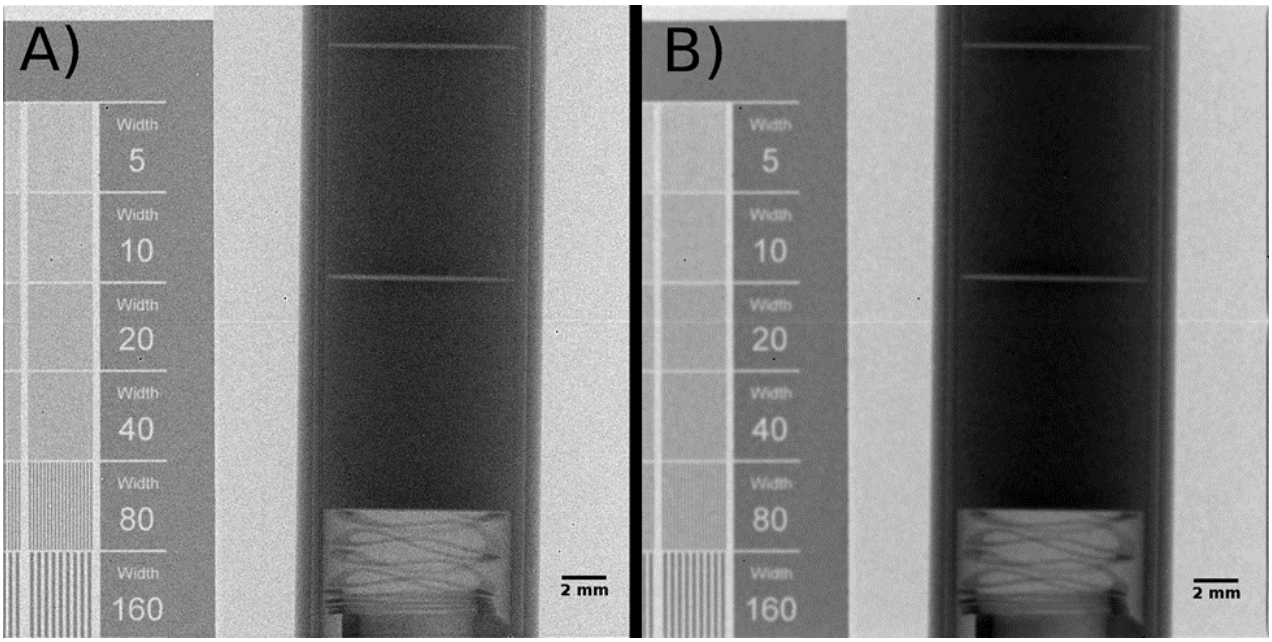


Figure 1. Neutron radiograph of resolution grading and UN/USi fuel rod with post-acquisition pixel center-of-mass centroided radiograph in A) and non-centroided radiograph in B).

- **[LANL]** A manuscript titled, "Exploiting the reactivity of actinide fluoride bonds for the synthesis and characterization of a new class of monometallic bis(azide) uranium complexes," K.A. Erickson, A.G. Lichtsheidl, M.J. Monreal, A.T. Nelson, B.L. Scott, D.E. Morris, and J.L. Kiplinger, was accepted for publication in the *Journal of Organometallic Chemistry*. The publication presents synthesis routes demonstrated for a new class of monometallic uranium complexes. A range of spectral methods are used to characterize the synthesis of thorium and uranium terminal fluoride complexes with an emphasis on coordination environments and the nature of the wedge ligand bonding in the demonstrated systems. This work is important to advancement of the fundamental understanding of fluoride synthesis routes for non-oxide fuels, specifically uranium nitride but also applicable to uranium silicides and other compounds presently under investigation as advanced LWR fuel concepts. (A. Nelson)

LWR Core Materials

- **[LANL]** Ion irradiation was completed on two FeCrAl alloys (B136Y3 and C35M4). Irradiation was performed with Fe ions to doses up to 70 dpa. Final TEM analysis is being completed on these samples at 15 dpa. FIB liftouts are being performed to analyze the defect density in this high dose location. (S. Maloy)
- **[ORNL]** A thin ODS Fe-10Cr-6Al-0.3Zr+0.3Y2O3 tube, 8.5mm OD and .5mm thick, was fabricated by a Japanese industrial partner from an 18mm OD, 3mm thick master tube by cold pilgering. Four cold pilgering steps were necessary with intermediate heat treatment at 850-950ºC between each step. Characterization of the alloy microstructure revealed the presence of very fine grains, ~100nm in size, elongated along the pilgering direction. Recrystallization of the tube was observed after heat treatment at 850-1100ºC, with an increase of the recrystallized grain number with increasing temperature. Partial recrystallization will most likely be required to improve the tube ductility, and the optimized heat treatment will be determined based on the mechanical properties of similar ODS FeCrAl foils cold rolled and annealed. These results were presented in October 2017 at MS&T 2017 in the session on accident tolerant fuels. (S. Dryepondt)

- **[ORNL]** The impact energy of a series of Gen. II wrought FeCrAl alloys was comprehensively evaluated as a function of test temperature. All alloys exhibited the typical transition behavior from the low shelf energy to upper shelf energy. The brittle ductile transition temperature (DBTT) and the upper shelf energy were determined by a curve fitting. The impact toughness was correlated with the room-temperature tensile properties to evaluate the processability of FeCrAl alloys for tube fabrication. Based on the impact toughness results, it was found that the cracks formed and prorogated during tube reduction process were attributed to improper processing conditions. A warm reduction process in the range of ~200-300 °C would effectively suppress the cracking susceptibility of FeCrAl alloys during tube fabrication. A manuscript summarizing the "effect of the Nb addition on recrystallization and recovery behavior of FeCrAl alloys" was submitted to *Acta Materialia*, and the review is currently in progress. Two additional journal articles related to the recrystallization texture and impact toughness of FeCrAl alloys are being prepared. (Z. Sun, Y. Yamamoto)
- **[ORNL]** A manuscript titled, "Thermo-mechanical assessment of full SiC/SiC composite cladding for LWR applications with sensitivity analysis," G. Singh, K. Terrani and Y. Katoh, was accepted for publication in the *Journal of Nuclear Materials*. In the work presented in this article, the foundation for 3D thermo-mechanical analysis of SiC/SiC cladding was laid out and a set of analyses were performed to evaluate the distribution and variation of the stresses and temperature in the cladding with time under in-reactor conditions. The work also involved systematically evaluating the relative influence of material properties of SiC/SiC composite on the stresses and temperature distribution in the cladding. (G.Singh, Y.Katoh)
- **[LANL]** E-beam welds were completed on FeCrAl tubing in preparation for finishing the deuterium diffusion testing on these alloys at temperature up to 600C. (S. Maloy)

LWR Irradiation Testing & PIE Techniques

- **[INL]** A major Engineering Calculation and Analysis Report (ECAR) which provides the basis for combining all past and future ATF-1 irradiation history data was approved. With the approval of this report, the team is now able to use a more streamlined method of reporting as-run results for all ATF-1 tests. (G. Core)
- **[INL]** Development on the ATF Nuclear Data Management and Analysis System (NDMAS) continued with the generation of plots for the on-line instrumentation in the ATF Sensor Qualification test currently in the ATR. These data are being combined and sorted into downloadable .csv files for use by experiment designers and engineers. Additionally, the NDMAS team is finalizing the features of the SharePoint site which will be used for document collaboration and obtaining experiment data. (G. Core)
- **[INL]** The Accident Tolerant Fuels 2 (ATF-2) Sensor Qualification Test (SQT) experiment began irradiation on October 6, 2017 during Advanced Test Reactor (ATR) cycle 162A and is scheduled to finish on December 7, 2017. Fabrication of "low risk" ATF-2 (Fuel Test) components is in progress. ATF-2 fuel pin components are being machined and weld development is in progress. (G. Hoggard)
- **[INL]** Dimensional inspections were completed on two rodlets from ATF-1W (U3Si2-Zirlo). Gamma spectrometry was also performed on these rodlets including the first ever gamma tomography on U3Si2. This showed the radial distribution of fission density in the fuel where fission was higher at the periphery as expected and some migration of Cs from the center of the fuel towards the cooler periphery of the fuel (Figure 2). (J. Harp)

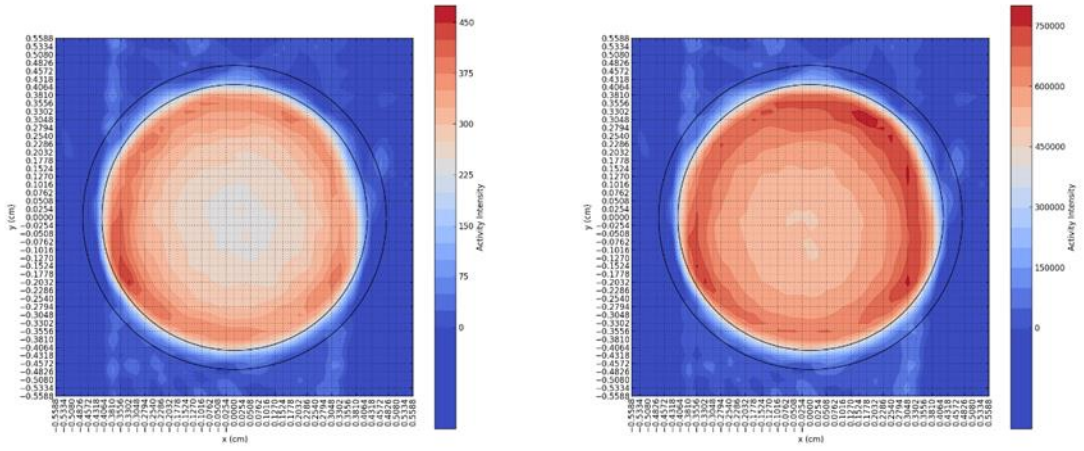


Figure 2. Relative distribution of Cs-137 in ATF-1W R6 (left) and relative distribution of Nb-95 (right) in ATF-1W R6, which scales with local fission density.

LWR Fuel Safety Testing

- **[INL]** Design review comments have now been fully resolved and incorporated for the calculation reports supporting Multi-SERTTA-CAL. These reports are now being routed for final approval in INL's document control system. (J. Schulthess)
- **[INL]** While a few outstanding design review comments remain for the mechanical design, with particular regard to the ease of fabrication for some features, good progress has been made toward identifying workable design options that will likely facilitate assembly and welding of some key features in the dosimeter holder structure. Mockup items are on order and will be used for trial welds in the coming weeks in order to finalize these design features (J. Schulthess)
- **[ORNL]** Aging of FeCrAl cladding tube samples (at 479 °C for 200 days) was completed. Aging of FeCrAl causes α′ precipitation in FeCrAl alloys, similar to that experienced under irradiation conditions. Furthermore, the failure of the FeCrAl is expected to be governed by irradiation-assisted α′ precipitation. We aim to simulate the irradiated cladding mechanical behavior by using aged unirradiated FeCrAl samples for screening tests of reactivity initiated accident-like mechanical loadings. (M. Cinbiz, N. Brown (PSU), K. Terrani, K. Linton)
- **[ORNL]** A heating system with a controller has been built to perform modified-burst test (MBT) on cladding tube samples, including a previously developed mirror system for digital image correlation at hot-zero power reactor temperatures, such as 300 °C. (M. Cinbiz, N. Brown (PSU), K. Terrani, K. Linton)
- **[ORNL]** A draft journal article intended for submission to the Springer *Engineering Mechanics* journal has been prepared. The paper will depict the newly developed digital image correlation system and mirror system to observe the outer surface of the tube samples. Also, the strain evaluation using digital image correlation is a key component of the article. (M. Cinbiz, M. Gussev, K. Terrani, K. Linton)

LWR Computational Analysis & Fuel Modeling

- **[INL]** An effort to define suitable BISON simulations supporting ATF development has been initiated in collaboration with AFC program elements. (P. Medvedev)

- **[ORNL]** A manuscript titled, "Parametric Evaluation of SiC/SiC Composite Cladding with UO2 Fuel for LWR Applications: Fuel Rod Interactions and Impact of Nonuniform Power Profile in Fuel Rod," G. Singh, R. Sweet, N. R. Brown, B. D. Wirth, Y. Katoh and K. Terrani, was accepted for publication in the *Journal of Nuclear Materials*. In this work, the effect of non-uniform dimensional changes in SiC/SiC composite caused by neutron irradiation with spatially varying temperatures, along with the closing of the fuel–cladding gap, on the stress development in the cladding over the course of irradiation were evaluated. This work also showed the potential issue of significant lateral bending of SiC/SiC cladding that will arise due to non-uniform circumferential power profile in the fuel rod. (G. Singh)
- **[ORNL]** The temperature dependent swelling of SiC/SiC under irradiation may cause lateral bending in the channel box, as has been shown for SiC/SiC cladding (Singh et al., 2017). This potential issue with the SiC/SiC channel box will be analyzed through finite element (FE) calculations focused on determining the deformation of SiC/SiC channel box under the BWR conditions. A FE model was set up and temperature boundary conditions obtained through thermal-hydraulic calculations, were implemented into the model. The next step of this work will involve incorporating the neutronic calculations-based neutron flux boundary conditions into the model and perform scoping analysis on the channel box deformation. (G. Singh)

Industry FOA

- **[INL]** The project schedule and cost estimate for the Fuel Fabrication for Westinghouse LFRs are being finalized and development of the Project Execution Plan has been initiated. Development of the Functional and Operational Requirements for the Sintering Furnace and Tri-Arc Melting Furnace have been completed. Procurement of the Sintering Furnace and Tri-Arc Melting Furnace have been initiated. (P. Wells)
- **[ORNL]** Communication has continued with GE/GNF for delivery of tube and wire products made of Gen. II wrought FeCrAl alloy (C26M, Fe-12Cr-6Al-2Mo base). All documentation requested from GE was prepared and provided, including the records of all purchase orders related to all production processes (the heat production and hot-isostatic pressing at Sophisticated Alloys, Inc., hot-extrusion and machining for master bar production process at ORNL, and tube reduction process at Century Tubes, Inc.), the ORNL Nuclear R&D QA plan, a part of the size inspection results conducted at ORNL, the material certificate of C26M heats, the materials safety data sheet (MSDS) of C26M alloys issued by ORNL, and the Statement of Conformity. A memorandum was also exchanged under agreement between ORNL and GE which described several exemptions in the GE's purchase order, including the detailed material chemistry, mechanical test results, the roughness inspection results, visual inspection results, cleaning, and so on. (Y. Yamamoto)
- **[INL]** Work continued on the Weld Under Pressure System (WUPS) to support all ATF-2 fuel pin pressurization efforts. (G. Core)
- **[INL]** Through many conversations with General Electric and program representatives at the INL, the initial ATF-2 test train loading has been altered to remove GE's six Billet APMT-clad pins. Pins of a completely separate design are expected to be fabricated and assembled to support a test train insertion in late CY 18. In light of this scope change, the team will cease all effort on the fabrication of Billet APMT-clad pins aside from the final mechanical property testing. (G. Core)
- **[INL]** The team made preparations to finalize the mechanical property testing of Billet APMT in order to fully characterize the as-received material's room temperature mechanical properties. (G. Core)
- **[INL]** Drawings for fuel pins continue to be worked with finalization expected early in November. Annular pellets were created by drilling U3Si2 pellets in support of instrumented pins for the ATF-2

fueled test. Thermocouples would be placed in the annulus of these pellets to attempt to accurately model the exact fuel centerline temperature during the test. Pre-irradiation characterization of the U3Si2 fuel pellets continued. (G. Core)

- **[INL]** The team supported a visit from General Atomics representatives to discuss the state of the U3Si2 fuel as well as acceptance of their SiC/SiC cladding concept for use in the ATF-2 fuel test. (G. Core)

ADVANCED REACTOR FUELS

AR Fuels

- **[INL]** Previously, zirconium lined U-6Zr and U-10Zr alloy billets were successfully extruded showing no obvious signs of failure. This proved feasibility of extruding a zirconium lined fuel, producing a fuel form with an integral zirconium FCCI barrier. The extruded rods were cut into approximately 10in. (250 mm sections) for ease of handling during metallographic sectioning and radiography activities. After cutting into approximate length, the total length of each rod was measured. The U-6Zr rod total length was measured to be 126.69 in. (321.8 cm) while the U-10Zr rod measured to be 118.69 in. (301.5 cm). It should be noted that these total lengths include some copper footer or header material. The diameter of each section was measured at the approximate center of each section, with two measurement taken approximately 90° apart from each other. Table 1 shows the average diameter and standard deviation for each extruded rod. Some deviation can be seen between the two rods. It should also be noted several grooves were visible on each rod, as shown in Figure 3. The grooves were at least in part caused by die wear, although bare uranium extrusions done prior to these extrusions using the same die did not show as significant grooving. Along with measurements, the rod sections were radiographed as well. Based on radiographic images the outer zirconium barrier is approximately 0.020 in. (0.5mm) and appears to be consistent over the length of the rod after the initial transition periods were completed. Figure 4 and **Error! Reference source not found.** show the radiographic images. From the images it can be seen that some copper material still adhered to the rods from either the header or footer. These areas are shown as darker regions in the radiographs. Also shown in the radiographs is a void region at the fuel/footer interface of the U-6Zr rod. Radiography as well as sectioning also showed a region where the copper was extruded into the fuel section at the footer region of the extrusion. This was caused because on this rod the initial billet was installed backwards (footer first), by mistake. (R. Fielding)

  Table 1. Average Diameter and Standard Deviation for each Extruded Rod

	O° Diameter (mm)	Std. Dev.	90° Diameter (mm)	Std. Dev.
U-6Zr	6.21	0.28	6.03	0.32
U-10Zr	5.79	0.27	5.82	0.25

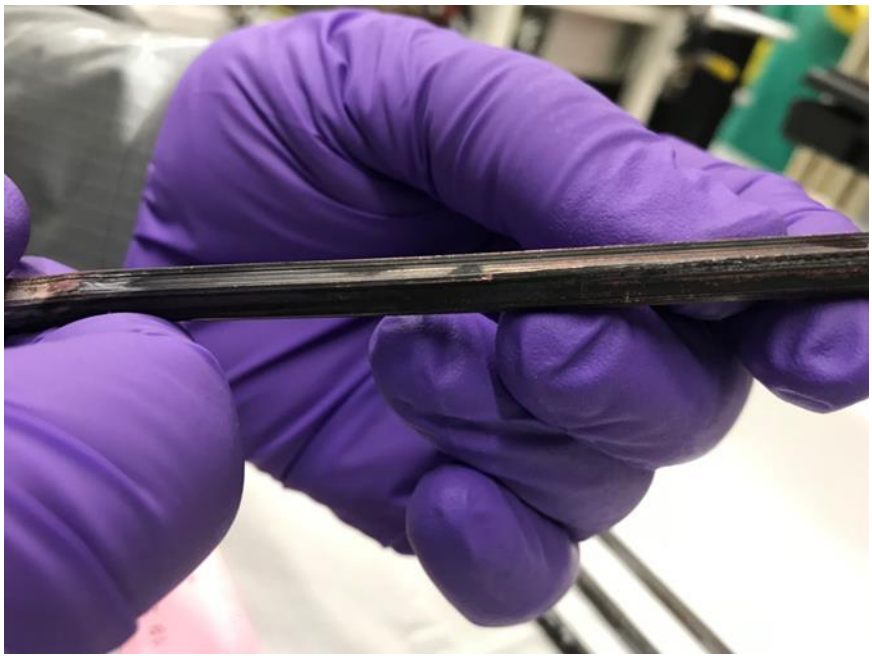


Figure 3. Deepest groove found on the U-6Zr rod.

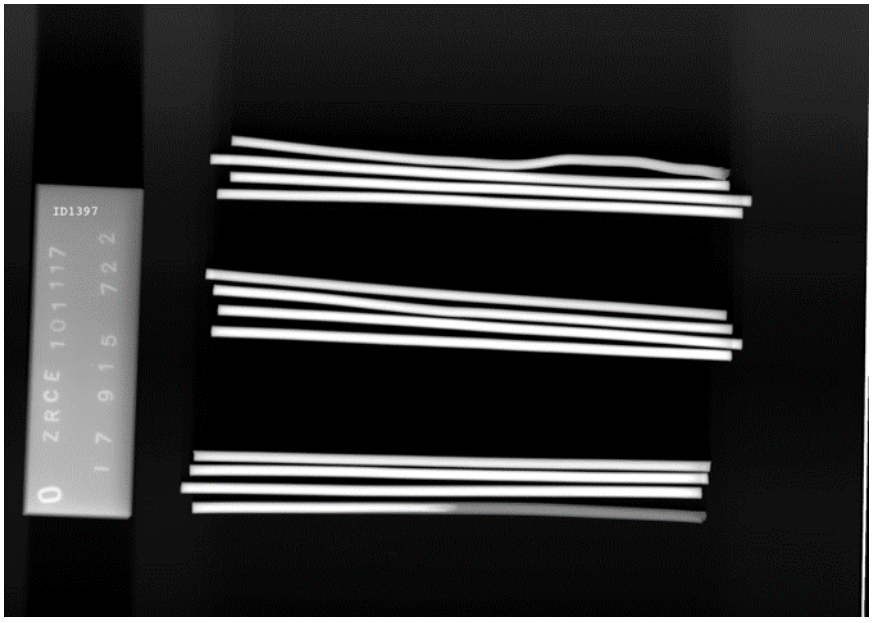


Figure 4. U-10Zr radiographic image. Darker sections shows copper header material.

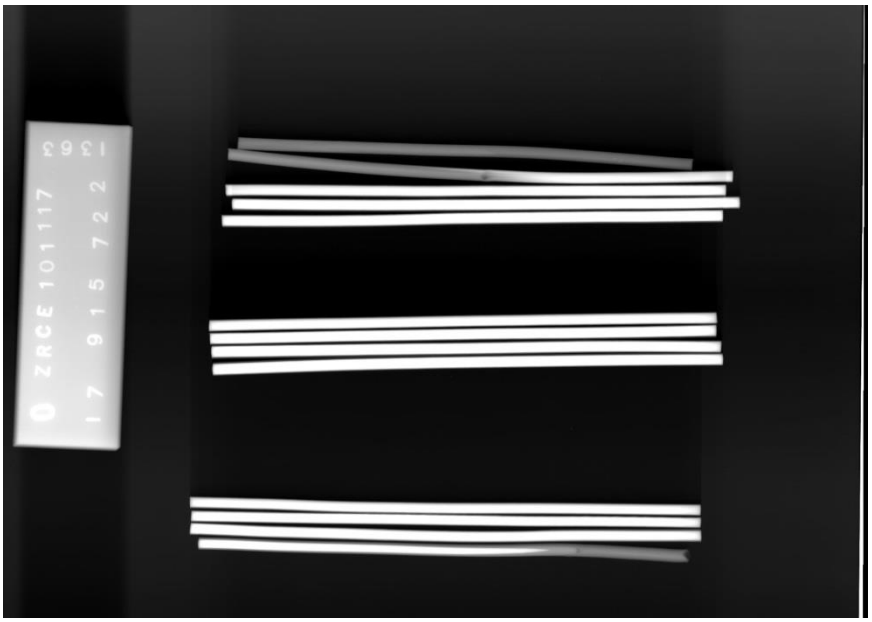


Figure 5. Figure 3. U-6Zr radiographic image. Darker sections show copper header and footer material.

- **[INL]** During the month of October, work focused on preparing for further MOX work in the form of ordering supplies, literature reviews, and experiment planning. Some optimized fuel work has also been ongoing with long term heat treatments of diffusion couples. (R. Fielding)
- **[INL]** A fresh assessment of the U-Zr phase diagram is being conducted for the next handbook using the most current data. Attempts to determine which phase diagram is correct using more recent data are inconclusive, as neither of the two phase diagrams that has been proposed matches all of the data. Further high-quality measurements would be useful, but are complicated by the demonstrated sensitivity of phase boundaries in U-Zr alloys to concentrations of dissolved oxygen as low as ~160 ppm, sluggish phase-transition kinetics, and likely involvement of two metastable phases. Comparing the two phase diagrams to newer data from U-10Zr: The Sheldon and Peterson phase diagram (Figure 6) is generally accepted, but has a phase transition at ~660 °C that doesn't match the experimental data; the alternative proposed by Rough and Bauer (Figure 7) has too few transitions between ~685 and 740 °C. Neither phase diagram explains the transitions at temperatures below ~610 °C. (C. Papesch)

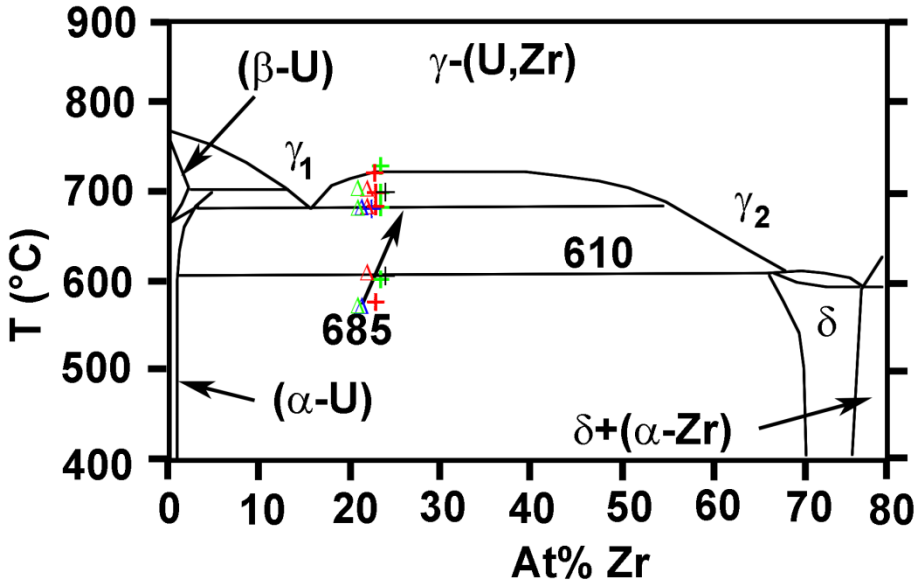


Figure 6. Sheldon and Peterson phase diagram.

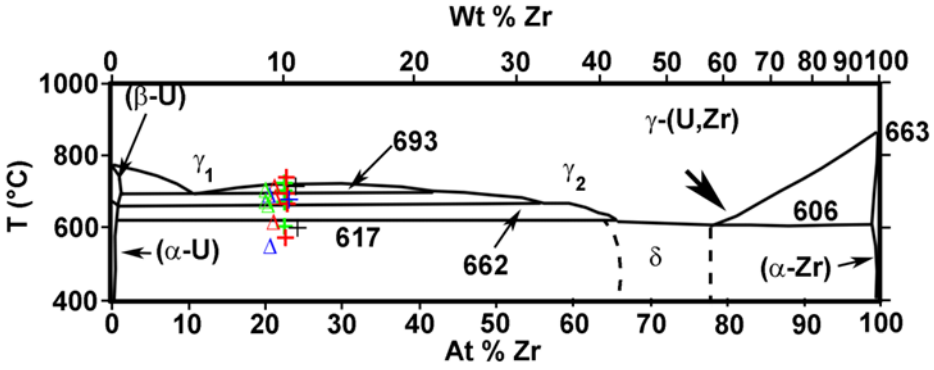


Figure 7. Rough and Bauer phase diagram.

- **[INL]** Two INL staff members attended vendor training of the laser flash system at Netzsch in Boston, MA. (C. Papesch)
- **[INL]** C. Papesch attended the Thermodynamic of Actinide Fuels – International Database (TAF-ID) meeting and the Materials Modeling and Simulation of Nuclear Fuels workshop in Ottawa, Ontario Canada hosted by the Canadian Nuclear Laboratory. These meetings allowed for the INL to continue to be a programmatic member of the TAF-ID committee and will give us a vehicle by which to add to the database from our knowledge and data collected on metallic fuel. (C. Papesch)
- **[INL]** C. Papesch attended the 2017 Winter meeting of the American Nuclear Society and participated in the Material Science and Technology Division executive committee meeting. (C. Papesch)

AR Core Materials

- **[LANL]** Initial testing is underway on a hardness tester to be installed in the hot cells in the next couple of months. Excellent results were obtained from initial testing outside of the hot cells. (T. Saleh)
- **[PNNL]** Activities analyzing the fate of injected ions began this month. Data has already been produced that will rapidly lead to a first publication. (M. Toloczko)
- **[PNNL]** Preparation of 14YWT has begun in support of looking at accelerator-to-accelerator differences in ion irradiation response. (M. Toloczko)
- **[PNNL]** A manuscript on the topic of identification of carbon contamination in ion irradiated materials has been accepted by *Scientific Reports* for publication and will be published in November.
- **[PNNL]** Hardness testing was completed on several neutron irradiated materials in support of the milestone M3FT-17PN020302042. (M. Toloczko)
- **[LANL]** Two invited presentations were given at MS&T17 by S.A. Maloy. One presentation covered an update on the development of ferritic steels for high dose fast reactor applications and the other discussed processing studies for producing tubing of 14YWT. (S. Maloy)
- **[PNNL]** As part of the program to fabricate tubing from difficult-to-fabricate materials, MA956 and 14YWT are being extruded and pilgered to final dimensions. An existing PNNL rolling mill has been modified so that pilgering can be conducted. An initial set of runs to check out the pilgering modifications have been completed and were successful. The initial checkout runs consisted of pilgering flat plates with three different materials. The next activity is to design the tooling, particularly the mandrels and rollers. As part of the design and fabrication of the rollers for pilgering tube shapes, stock is being procured from which the rollers will be fabricated. (R. Omberg)
- **[PNNL]** The Level 3 milestone, M3FT-17PN020302053, was completed on 25 September 2017. The report, PNNL-26852, "FY-17 Status Report for Advanced Reactor Tube Pilgering for Process Development," was completed and transferred to the Technical Area Lead at LANL on the same date. (R. Omberg)
- **[PNNL]** As part of the effort to improve the fracture resistance of HT9 steels, estimation of plane-strain fracture toughness (K_{IC}) was performed for the two HT9 steels (i.e., those with original composition and with nitrogen addition) in water-quenched condition and two-step tempered conditions. The Hahn and Rosenfield's model for fracture toughness calculation from tensile test data was modified to apply to the HT9 steels. The estimation results confirm the general temperature dependence of fracture toughness in ferritic steels, in which the fracture toughness slowly decreases with test temperature and the decreasing becomes steeper above about 400°C, primarily because of decrease in strength at high temperatures. The results indicate that the nitrogen addition in HT9 steels may not improve fracture toughness although it will increase ductility. Relatively higher fracture toughness was calculated for the water quenched samples, which indicates that an incomplete tempering condition can result in improved fracture toughness along with increased strength. (T. S. Byun)

AR Irradiation Testing & PIE Techniques

- **[ANL]** A full paper titled, "Assessment of AmBB Performances in Fast Reactors," by G. Aliberti, et al., was developed and submitted to the PHYSOR 2018 conference, Cancun, Mexico, April 22-26, 2018. The paper summarizes the transmutation performance of the Americium Bearing Blanket (AmBB) fuel in the 1500 MWth ASTRID reactor. (G. Aliberti)

- **[INL]** The Functional and Operational Requirements for the AFC-IRT experiment was completed and issued. This document provides the design inputs for the experiment. Preparations were completed for the AFC-IRT Conceptual Design review to be held in early November. (D. Dempsey)
- **[INL]** Dimensional inspections were completed on AFC-3C rodlets and initiated AFC-3D rodlets. Gamma spectrometry was initiated on AFC-3C. (J. Harp)
- **[INL]** Staff attended an OECD NEA Expert Group on Innovative Fuels Meeting and discussed modeling and simulation benchmark activities for minor actinide bearing fast reactor fuels. A new activity to create a recommended set of data for fuel performance modeling of fast reactor driver fuel was also initiated. (J. Harp)

AR Computational Analysis & Fuel Modeling

- **[INL]** A presentation titled "AR Computational Analysis," was made at the AFC leads meeting. It included updates on BISON development for fast reactor metallic and MOX fuel. (P. Medvedev)

CAPABILITY DEVELOPMENT

CX Fuels

- **[INL]** The vendor for a sputter coater that is currently being used for remote sputter coating at INL has been contacted and it is being determined if the specifications meet the requirements for the TCM. Use of this sputter coater would simplify qualification since it has already been tested using remote manipulators. A statement of work has been received and a subcontract is being established for bug fixes and enhancements of the TCM software. An INL engineer has also been engaged to perform argon/motor compatibility testing. (D. Hurley)

For more information on Fuels contact Jon Carmack (208) 533-7255.

MATERIAL RECOVERY AND WASTE FORMS DEVELOPMENT

PROCESS CHEMISTRY AND INTEGRATION

- **[ORNL]** In the month of October, the analysis and assessment of operating cost for the membrane-based and CECE process for tritium separation and concentration was continued. A draft of the report was prepared and submitted for review. The technical review pointed out some areas that need more careful analysis of the available published reports on the CECE process for the concentration of tritiated water. Additional literature was located and reviewed to determine the operating and capital cost for the CECE process. Most of the literature references are related to the CANDU reactor process for the recovery and concentration of deuterated water. The available data can be used to determine the energy requirements for the concentration of deuterated and tritiated water. We will use this approach to determine the energy cost for the CECE process and compare with the membrane-based concentration of tritiated water for an aqueous stream flow rate of 10 L/min. It was observed that the cost associated with the electrolysis of water is relatively high compared to the membrane-based process for the concentration of tritiated water. There is a wide variation in the calculated energy consumption using the data reported in the literature and we are working to determine which of the several cases analyzed is more representative for the concentration of tritiated water. This work is on-going and will be completed in the next few weeks. A more detailed cost estimate for the membrane-based process is also being developed. The delayed milestone report is due by the end of December 2017. (B. Jubin)
- **[ORNL]** Technical progress was limited due to the forced relocation of the laboratories from Wing 1 to Wing 2 of 4500N. In preparation for the powder solidification work to be conducted, efforts have been undertaken to locate the necessary equipment. Most of the equipment for making cermets that were examined in a recent LDRD effort have not been relocated. One of the key investigators for grout waste form is out briefly for on medical leave but will be contacted shortly about the availability of their equipment. (B. Jubin)

WASTE FORM DEVELOPMENT AND PERFORMANCE

Electrochemical Waste Forms

- **[ANL]** Electrochemical tests with RAW-6(UTc) are being completed to measure the dependence of the corrosion rate of passivated surfaces on the Eh and pH. Figure *8*a shows the effect of pH on the corrosion of the bare surface measured in a 10 mmolal NaCl solution using a potentiodynamic scan and Figure *8*b shows the 20-fold decrease in the corrosion current density due to passivation in the same solution as represented by the diagonal line. Additional tests will be conducted to better quantify the relationship, but the line that is shown is parallel to the current in the passive region of the potentiodynamic scan. Note that the vertical line extends to potentials below Ecorr (where the anodic and cathodic currents are equal and the current density is zero) and can be used to estimate anodic corrosion rates that cannot be measured directly. The corrosion current density is proportional to the mass corrosion rate through Faraday's law. Similar stabilization was measured in acidic brine solutions. These tests are being used to determine the Eh and pH dependence in the alloy waste form degradation model. (W. Ebert)

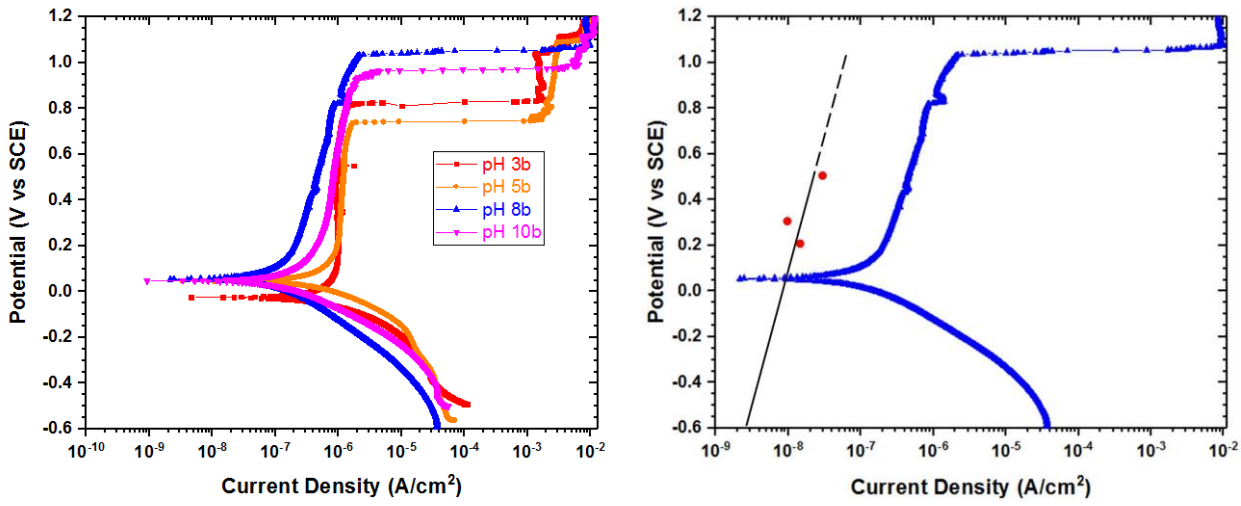


Figure 8. Results of (a) potentiodynamic tests with RAW-6 (UTc) in various brine solutions and (b) comparison of currents measured for passivated surfaces at different imposed potentials (symbols) with potentiodynamic scan in pH 8 brine solution.

Ceramic Waste Forms

- **[LANL]** Radiation-induced volume change in multiphase ceramic waste form samples (HIPed by ANSTO and melter processed by SRNL) was investigated using ion irradiation and atomic force microscopy (AFM) techniques. Ion irradiation was performed using 390 keV Kr ion at room temperature to simulate alpha radiation damage. In this study, part of the surface regions for each sample was covered by aluminum foil to block from ion beam irradiation to allow the characterization of irradiation-induced volume change. The surface morphology and the interface between the unirradiated and irradiated regions were characterized by AFM. Figure 9 shows 2D and 3D AFM images of the irradiated and unirradiated region of one HIPed sample, and the measured step heights corresponding to the line scans in image. Figure 10 shows AFM results of one melter processed sample. Swelling or compaction percentage is calculated using height change compared with ion irradiation range. Based on the observation of these two samples, the preliminary results reveal different swelling & compaction in different crystalline phases of irradiated multi-phase ceramics. Further characterizations on more samples are in progress in order to interpret radiation-induced volume change in ceramic waste form samples. (M. Tang)

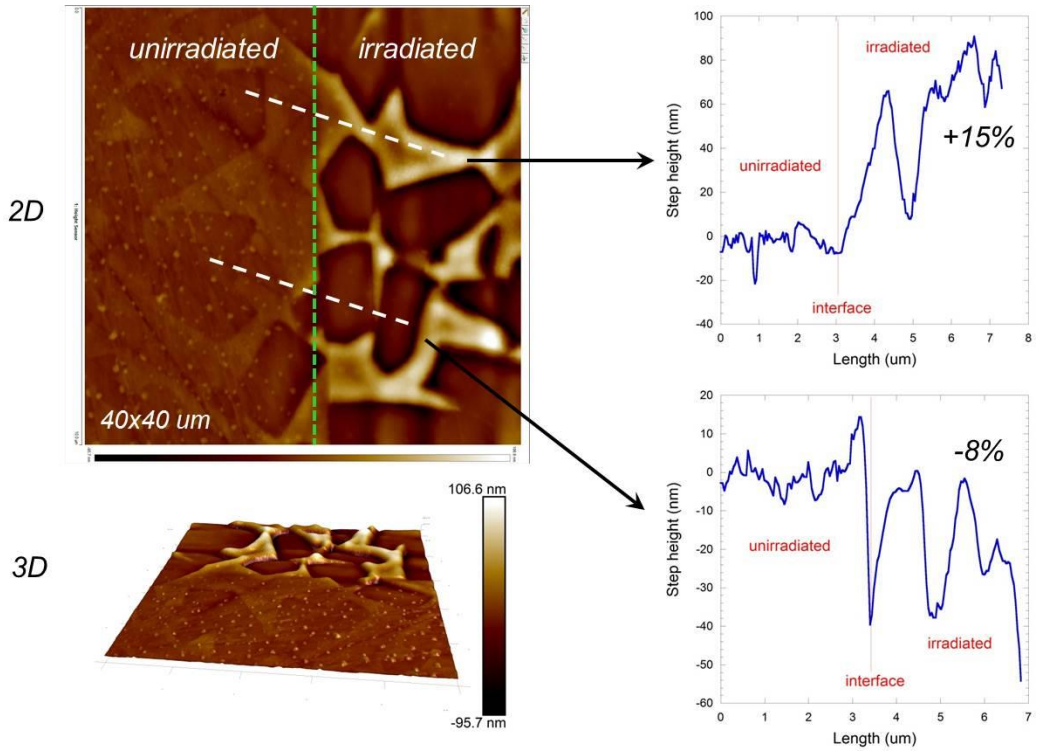


Figure 9. 2D and 3D AFM images (left) of the irradiated and unirradiated region of one HIPed sample, and the measured step heights (right) corresponding to the line scans in the image.

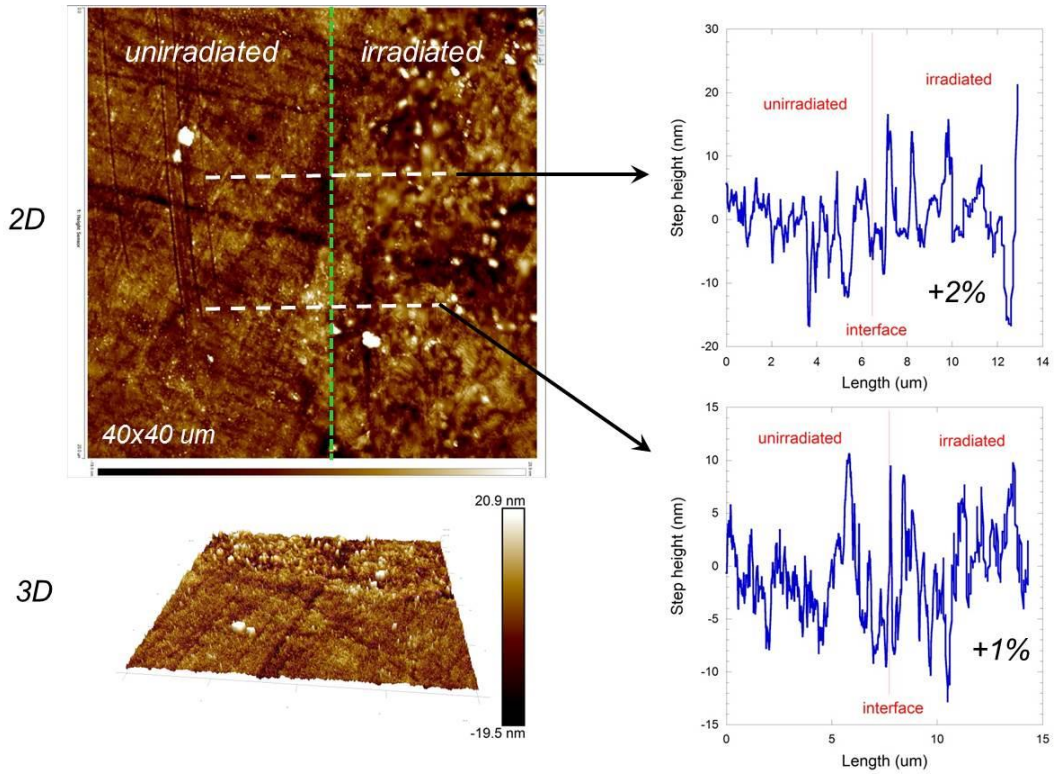


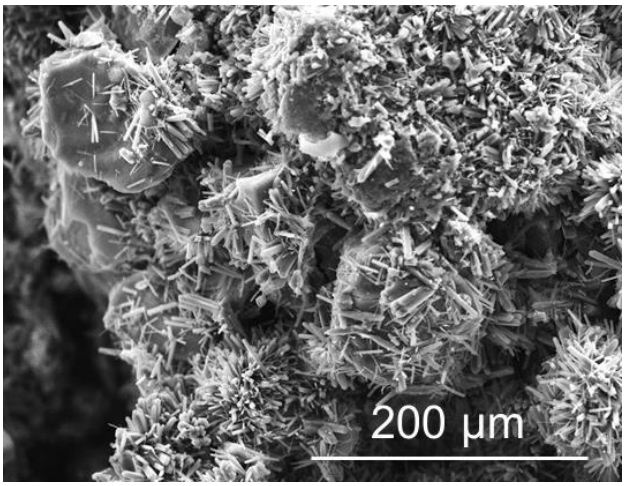
Figure 10. 2D and 3D AFM images (left) of the irradiated and unirradiated region of one melter processed sample, and the measured step heights (right) corresponding to the line scans in the image.

Zirconium Recycle

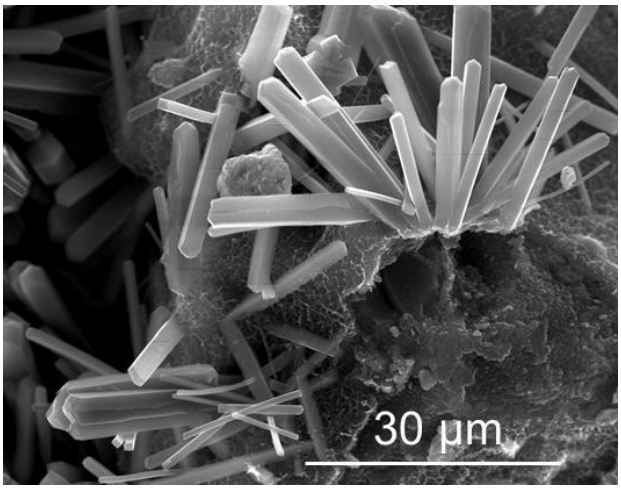
- **[ORNL]** The investigation of the pressurization problem in the stainless steel chlorination reactor and $ZrCl_4$ product salt condenser was continued. The entire internal components of the reactor, including the remaining cladding, boat, and filter/absorber unit were removed from the reactor and visual inspection of the neck tube between the reactor was determined to be free of blockage. The pressure gauge was replaced. Even with this open structure, pressurization of the reactor was still present under argon flow. Therefore, a decision was made to replace the metal unit with a glass system to complete the third chlorination test. Design of the glass system was begun. (B. Jubin)
- **[ORNL]** Design of the glass reactor-condenser for purification tests on $ZrCl_4$ produced from the second chlorination test using high burnup PWR UNF cladding continued. This cladding, which is a Zr-Nb alloy and contains an excessive amount of Nb-94 and Sb-125 will be used for the purification tests which will be made in shielded Cave B at the REDC 7920 hot cell facility. (B. Jubin)

Advanced Waste Form Characterization

- **[ANL]** Tests to measure the solution conditions triggering the increased Stage 3 glass dissolution rate and that rate remain in progress. The solution sampling interval has been increased to 28 days and tests are being terminated selectively to examine the solids. For example, Figure 11a and 4b show secondary phases form in test A3-12 with AFCI glass in a solution with added Al and Si adjusted to pH 12.5 after 133 days. Figure 11c shows an SEM image of glass recovered from test A3-10 after 147 days. That test was conducted with added Al and Si that was adjusted to pH 10.5. No secondary phases were detected in the solids recovered from test A3-10. The solution results indicate test A3-12 was triggered to Stage 3 after about days, but test A3-10 was not triggered to Stage 3. Figure 11d shows the measured XRD pattern for the solids from test A3-12 and a reference pattern for phillipsite. (W. Ebert)



(a)



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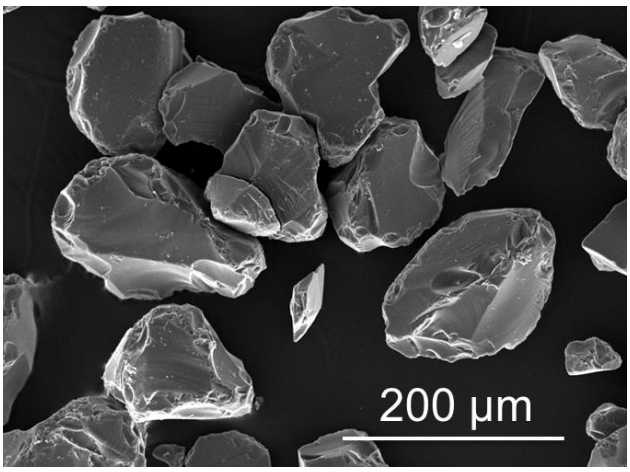
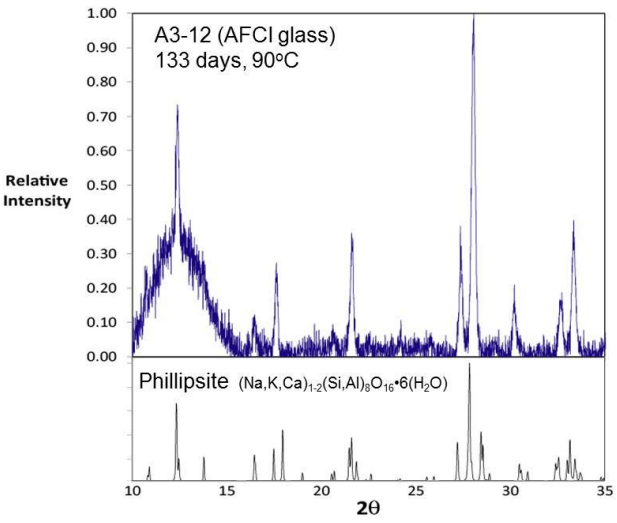


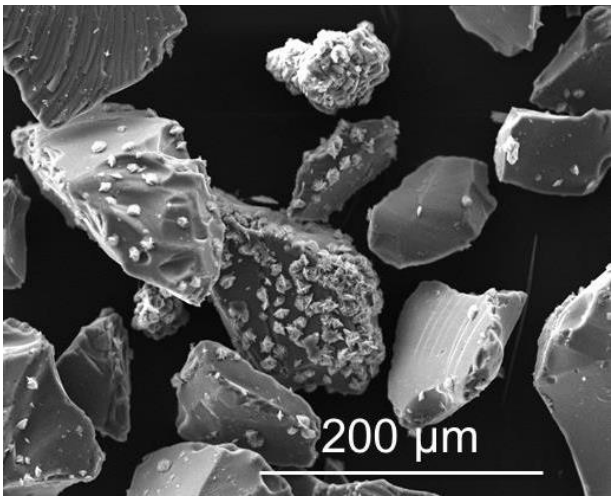
(c)



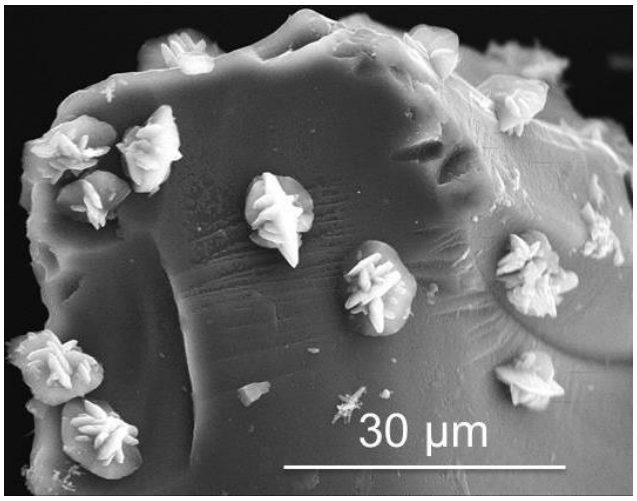
(d)

Figure 11. SEM analysis of corroded AFCI glass from (a) and (b) test A3-12 and (c) test A3-XX, and (d) XRD pattern of solids from A3-12.

- Although the solution results did not indicate Stage 3 was triggered in tests with LRM glass, SEM examination shows secondary phases have been generated. For example, Figure *12*a and Figure *12*b show an abundance of phases with plate-like morphology formed in test L3-16. This suggests Stage 3 had been triggered before the initial solution sample was collected after 21 days, and that the all samplings occurred as the glass corroded at the Stage 3 rate. Figure *12*c shows the results of an initial XRD analysis of the corrosion products that is dominated by the residual glass. A sample of the corrosion products is being crushed and sieved to remove large glass grains in an effort to improve the XRD response. For comparison, Figure *12*d shows the surface of LRM glass reacted in demineralized water at 150 °C in previous test that appears to be covered with a similar plate-like secondary phase. New tests will be conducted with LRM glass under the same conditions and same solutions, but will be sampled after shorter test durations to determine when Stage 3 was triggered. (W. Ebert)



(a)



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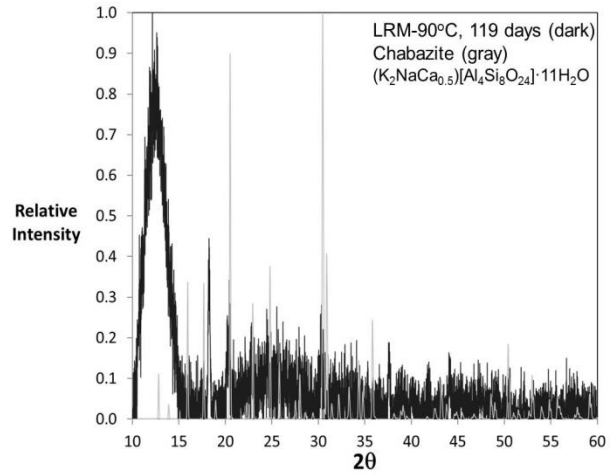

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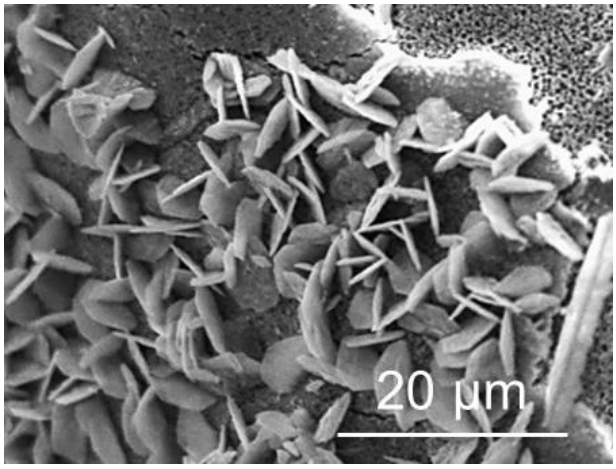

(d)

Figure 12. SEM analyses of corrode3d LRM glass from (a) and (b) test L3-16 and (c) initial XRD pattern of solids from L3-16, and (d) secondary phases formed in previous test with LRM glass at 150ºC.

- **[PNNL]** A paper titled, "A method for the in-situ measurement of pH and alteration extent for aluminoborosilicate glasses using Raman spectroscopy," was submitted to *Geochemica et Cosmochemica Acta*. Static dissolution tests are commonly used to assess durability and the durability mechanisms of waste glasses, but the obtained results and related errors are impacted by the frequency and protocol of samplings performed to determine release via solution analysis. A non-invasive method was developed to continuously monitor glass alteration based on in situ Raman spectrometry of the solution contained in the alteration vessel. The alteration of a benchmark glass, the environment assessment (EA) glass, for 7 days at 90°C showed the pH and B concentration results obtained from pH measurement in solution and ICP-OES quantification were similar to the results obtained from chemometric modeling of the Raman spectra and within error of previously published results in similar conditions. The errors on altered amounts of glass based on B release were similar for both in-situ Raman and ICP-OES. This new method provides a more detailed picture of an ongoing alteration experiment, with intervals between monitor times as short as dozens of

seconds. The method also helps to reduce perturbation to experiments caused by the physical sampling of aliquots (including temperature excursions, re-equilibration with atmosphere, volume variation, and potential chemical contamination) by limiting their number and frequency. (J. Ryan)

DOMESTIC ELECTROCHEMICAL PROCESSING

- **[ANL]** Data from previous experiments are being incorporated into a database to both refine existing electrorefining models and support the development of new processes in which zirconium chemistry must be addressed. This activity is continued from FY2017 and a final report is scheduled for the end of December. Continued technical support will be provided for further developments of the electrochemical process. (W. Ebert)

SIGMA TEAM FOR OFF-GAS

- **[INL]** Analyses of Ag Aerogel sorbent used in the first iodobutane adsorption test were analyzed for Ag and I content. Preliminary results show that the Ag concentration in the Ag Aerogel was about 25 wt%, and the maximum iodine concentration was about 11-12%. As a practical iodine chemisorption capacity limit, this concentration reflects about 40% Ag utilization. This is consistent with and even higher than capacity measurements in Ag Aerogel for adsorption of iodine from methyl iodide using the deep-bed adsorption system. (N. Soelberg)
- **[ORNL]** Issues on the completion of Phase 1B CH_3I tests were identified during completion of other milestones, in particular the Level 2 VOG effort, which also used the CH_3I feed streams. The compact Stirling Shuttle freezer unit has been ordered. This will allow the direct introduction of controlled quantities of CH_3I via a bubbler operated at -20 to -40°C or low if desired. (B. Jubin)
- **[ORNL]** A report documenting the "Hot Isostatic Pressing of Engineered Forms of I-AgZ," was issued. This completed milestone M3NT-18OR0301070220. This was a FY17 carryover milestone (M3FT-17OR0301070220) and was completed on time per the revised schedule. Hot isostatic pressing (HIP) has been considered for direct conversion of iodine-loaded silver mordenite (I-AgZ) to a waste form suitable for long term storage. Use of HIP may result in a low volume waste form with minimal additional waste formers. This document describes the preparation of twenty-seven samples that are distinct from previous efforts in that they are prepared exclusively with an engineered form of AgZ that is manufactured using a binder. Iodine was incorporated solely by chemisorption. This base material is expected to be more representative of an operational system than were samples prepared previously with pure minerals. This sample set is intended for storage at ORNL and to be made available for collaborators upon the development of performance test methods. This document also serves as a repository of the preliminary characterization efforts of these samples. The densities, mineral phases, and visual appearances of each sample are provided. (B. Jubin)
- **[ORNL]** A literature review of iodine scrubbing methods has been initiated. The scope of this was limited to fairly conventional methods such as caustic or acid scrubbing. The more exotic methods such as Iodox or mercuric-nitrate-nitric-acid scrubbers that have been studied in some detail in the 1970's and 1980's were excluded from consideration due to their complexity and process chemistry. A commercially available laboratory scrubber has been identified and an outline of the test plan has been developed. (B. Jubin)
- **[ORNL]** Five additional experiments were completed for the performance of Ru removal systems in prototypical TOG streams task. Ruthenium was volatilized as before by oxidizing Ru with O_2 at 700°C. In one of the experiments, silica gel was tested again but with the test proceeding for 3 five-hour periods in an attempt to saturate the silica gel at the leading edge of the bed. Color change in the silica gel indicated a smooth sorption profile. After cooling, the silica gel was removed in 5 segments and placed in plastic bottles. Overnight, the inside of the bottles were blackened, with the blackening

decreasing from the segment at the leading edge of the bed to the segment at the end of the bed. These visual observations indicate that the silica gel does not hold the RuO_4, that it is evidently released and, presumably, decomposes to RuO_2 on the surface of the plastic. As for the scrubber solutions used to capture RuO_4 passing through the blank columns and the packed columns, the solution was initially a yellow-orange, but on standing the solution became clear and a fine black precipitate was observed in the container. A reducing agent was added to the samples to ensure that the Ru would fully precipitate, and centrifugation followed by decantation is being attempted to obtain the precipitate for weighing and further chemical analysis. A few silica gel samples were prepared for analysis by neutron activation. The steel wool adsorbent seems very effective, with no evidence of releasing Ru. Options for analyzing the steel wool are being evaluated and may include leaching or total dissolution of the Ru loaded steel wool followed by ICP-MS. Sample analysis is continuing. (B. Jubin)

- **[ORNL]** A total of five runs have now been completed to examine the effectiveness of silica gel and 3A MS as tritium sorbents and silver-nitrate-impregnated alumina as an iodine sorbent for application in the off-gas treatment for an advanced tritium pretreatment system. Analysis of the iodine in the scrubber solutions is still pending. The analysis of solids for iodine is complete and results processing is underway; preliminary analysis suggests low iodine recovery on the silver nitrate impregnated alumina. A series of additional follow-on tests have been planned to examine the potential reasons for the low recovery of both iodine and tritium and should be completed early in November. (B. Jubin)

FLOWSHEET DEMONSTRATIONS

- **[INL]** The CPP-653 GENERAL LABORATORY WORK Instructions LI-814 was issued on 10/24/17. This LI will allow INL personnel to perform general laboratory work to support the installation, functional testing and upkeep of the MRPP. Also, a change has been made to the subcontract with DR construction to allow for the modifications to the sprinkler system in CPP-653. This work will lower the fire sprinkler heads down into the Perma-Con structure and ensure that CPP-653 is compliant with the fire suppression building codes. (M. Warner)
- **[ANL]** A model for the distribution coefficient of U(IV) between aqueous and organic solution was incorporated into AMUSE. The chemistry of U(IV) in aqueous nitrate solutions, organic TBP solutions and emulsions of both solutions was reviewed and kinetic data on U(IV) oxidation and reaction with Pu(IV) were extracted from the literature for incorporation into AMUSE. A report on this work was completed. (C. Pereira)

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

MPACT Campaign

SAFEGUARDS AND SECURITY BY DESIGN - ECHEM

Modeling and Simulation for Analysis of Safeguards Performance

- **[ANL]** The AMPYRE user interface was modified and tested for use with parameters required for independent timing of individual unit operations. Simulations with the dynamic drawdown subunit model were conducted with a theoretical salt composition, as code verification for both constant current and constant voltage operating modes. Results indicate that the model performs as expected and can predict the composition of the drawdown product and treated salt. The length of time necessary to recover a specified fraction of material from the salt is also indicated by these results.

Sensor for Measuring Density and Depth of Molten Salt

- **[INL]** A manuscript summarizing results of measurements performed in aqueous solutions in the Engineering Development Laboratory (EDL) was written. This manuscript will be submitted to the Journal of Industrial and Engineering Chemistry. Temperature measurements were made in the Joint Fuel Cycle Studies Integrated Recycling Test (JFCS-IRT) electrorefiner (ER) at the Hot Fuel Examination Facility (HFEF) this month using a 12 point thermocouple (TC). The TC was positioned at four different depths in the salt resulting in 48 measurements. The temperature profile obtained was used to adjust the two zone furnace at Center for Advance Energy Studies (CAES). It was found that the temperature profiles could be matched well up to the first 15 inches (from the bottom), after which the profiles were slightly different due to differences in the baffle region. Thermal expansion analysis will be performed to assess the potential impact. In addition, a number of at temperature dry runs were performed using the transparent furnace at CAES, in which photographs were taken of the bubbler at different temperatures to observe thermal expansion. The difference between the observed and predicted thermal expansion is under investigation.

Electrochemical Signatures Development

- **[LANL]** The MCNP6 model developed and used for the High Neutron Dose Detector (HDND) development was adapted for source motion. This model uses a 252Cf neutron source (inside of a cylindrical 304 SS case) for detector-response studies inside of a room with concrete walls. The reference model has the static source positioned 50 cm in front of the detector, at coordinates (0, -60, 0). To test detector response to a moving source, the source was located at coordinates (-200, -60, 0) and moved in the +x direction 400 cm to (200, -60, 0) at a constant speed of 3.048 cm/s (1 foot/10 s) for form model hdndmoi. Two problems were identified and fixed. After the corrections were made, simulations were executed to develop (1) mesh tallies of the radiation distribution within the experimental facility and (2) time-dependent pulse-height tallies for the HDND detectors. Per email exchanges with other MPACT project PIs, there is interest in the use of the Westinghouse oxide fuel, the ANL PEER, and the simplified AFCF pyroprocessing facility as a common model for the Advanced Integration work leading to the MPACT 2020 capability demonstration milestone.

ADVANCED INTEGRATION

Advanced Integration (Methods)

- **[LANL]** Worked with Mark Croce with the Microcalorimetry sensor to integrate his data with a pyroprocessing flowsheet. Developed normal and off-normal data for a notional pyro facility by leveraging the Advanced Fuel Cycle Facility Electrochemical Separations Cell design as a basis. This

approach can allow for fleshing out of the size and location of the "blocks" within the facility—basically gross physical sizing and movement necessary to understand normal and off-normal data.

Advanced Integration (Facility Models)

- **[SNL]** Additional modeling capabilities for the SSPM are being explored, as well as the integration within the MPACT program.

EXPLORATORY RESEARCH / FIELD TESTS

Microcalorimetry

- **[LANL]** The 256-pixel SLEDGEHAMMER detector module was brought to LANL in October for testing and gamma ray spectroscopy measurements. Joel Ullom and others from the University of Colorado were at LANL for periods from Oct. 2-20. The 256-pixel detector module was installed in the LANL microcalorimeter system. We were able to acquire the first plutonium spectrum measured with a large microwave-multiplexed microcalorimeter array. We demonstrated simultaneous operation of a large fraction of the total pixels, using two ROACH2 FPGA systems. However, the October measurements also demonstrated that several key components of the system (FPGA firmware, resonator response, temperature regulation) are not yet stable enough for sustained data acquisition. There is still sufficient time to do the development work required to meet our M2 milestone of preparing an instrument for field testing.

In situ Measurement of Pu Content in U/TRU Ingot

- **[INL]** The out-of-cell functional testing for the furnace was completed in mock-up thereby enabling the furnace to be transferred into the Hot Fuel Examination Facility for the second JFCS liquid cadmium cathode product, currently scheduled for November 2017.

High Dose Neutron Detector

- **[LANL]** HDND development and evaluation was presented at ANS meeting in Washington, D.C. and was awarded DOE Nuclear Energy Fuel Cycle R&D Excellence Award.

For more information on MPACT contact Mike Miller at (208) 526-2813.

Fuel Cycle Options Campaign

CAMPAIGN MANAGEMENT

- **[ANL, BNL, INL, LLNL, PNNL, ORNL, SNL]** The FCO Campaign Working Group Meeting was held at the DOE-NV Offices, Las Vegas, October 17 – 18, 2017. The accomplishments of FY 2017 and planned activities for FY 2018 were discussed, including the status of the NEUP projects related to the FCO campaign. In addition, a discussion was held on the top-down analysis of the DOE NE-4 program portfolio, engaging the NTDs of the Advanced Fuels, Fast Reactors, and Material Recovery and Waste Form Development campaigns, and the FCO Federal manager and director.
- **[ANL, INL, LLNL]** Developed a draft strategy document for NE-4 R&D and distributed for comment. This document will be provided to DOE as a starting point for the NE-4 top-down analysis.
- **[INL]** Continued population of the internal reports section of the FCO SharePoint site with milestone reports from prior years.
- **[ORNL]** At the request of Campaign Federal managers, a write up of ideas and suggestions raised during the FCO meeting by Andrew Worrall was distributed.

EQUILIBRIUM SYSTEM PERFORMANCE (ESP)

Performance of Fuel Cycle Systems

- **[ANL]** Reviewed detailed FY18 work plans for the fuel cycle analysis area and solicited information from campaign personnel on the advanced and innovative nuclear energy systems that are being developed by industry, university, and national labs.

Economic Analysis Capabilities and Assessments

- **[ANL]** Initiated data gathering on technical and economic information on heavy forgings, in order to improve the understanding of the cost drivers for reactor vessels. The reactor vessel and associated components of the 1000 MWth Advanced Burner Sodium cooled Fast Reactor (ABR-1000) were identified in the FY17 example application of the cost algorithm.
- **[ANL]** Ed Hoffman attended the meeting of OECD/NEA Expert Group on Uranium Mining and Economic Development (UMED), which was held at the OECD/NEA headquarters, France, October 10-11, 2017. The expert group consists of experts on nuclear fuel cycle and economics analysis from Australia, Canada, Demark, EU, and the United States. The primary purpose of this Expert Group is to analyze the potential local regional and global economic and social benefits of uranium mining.
- **[INL]** Held initial discussions on the daily market assessment work scope, including the technical approach and the necessary analysis capabilities and data.

Equilibrium System Performance (ESP) Tools Development

- **[SNL]** Made plans for updating the development site for the Nuclear Fuel Cycle Options Catalog (which is not available to the public) to meet the requirements of SharePoint 2013. Also started looking into auto-generating the interactive flow diagrams. Currently, the process for turning the flow diagrams that we receive in the Fuel Cycle Data Packages into interactive flow diagrams is a time-consuming process, so we are looking into ways of generating those diagrams automatically.
- **[ANL]** Incorporated recently discussed modifications to the NE-COST website's text and appearance, and resolved a technical issue associated with the sliding bars for cost inputs. Additionally, arranged

with information technology support to have a certificate for the NE-COST website purchased, in order to have encrypted communications for externally-facing websites, as per DOE guidelines.

- **[INL]** Determined the primary analysis tool for the daily market analysis effort will be Raven with modifications developed by the Hybrid Energy Program (within NE-5), while a tool developed at ANL via LDRD funds will initially be used for confirmatory analyses.
- **[INL]** Began developing a list of recent physics analyses in preparation for updating the content of the Transmutation Data Library when it has been converted from Excel to database form. When the input template is finalized, the analysts for these analyses will be asked to populate their data into the template.

DEVELOPMENT, DEPLOYMENT AND IMPLEMENTATION ISSUES (DDII)

Technology and System Readiness Assessment (TSRA)

- **[INL, ANL, BNL]** Regularly scheduled telecons have been initiated to discuss and plan the TSRA activities for FY18, including the application of the TSRA process to a complete fast reactor recycle nuclear energy system. The initial calls are focused on reviewing the lessons learned from the FY 2017 Technology and System Readiness Level Assessment (TSRA) process and finalizing plans for FY 18 activities.
- **[BNL, INL, ANL]** Suggestions for potential modifications to the TSRA process resulting from the trial implementation described in the FY17 level 3 milestone report entitled "Lessons Learned from Trial Application of the TSRA Process to Example Metallic Fuel and Aqueous Reprocessing Systems" by M. Todosow, et al. are being reviewed for possible incorporation in updates to the questionnaires for the Technology Readiness Levels (TRLs) and/or the Systems readiness levels (SRLs).
- **[INL]** Developing some additional system readiness questions to strength that portion of the TSRA process. Developing a draft sequencing and grouping of TRL questions and associated activities to create an example of how the road mapping portion of the TSRA process might be structured.
- **[LLNL]** Contributed to a draft paper quantifying the benefits of government R&D in nuclear energy.

Transition Analysis Studies

- **[ORNL]** A joint ORNL-NNL paper "A US-UK Collaboration on Fuel Cycle Assessment" was presented at the ANS Winter Meeting. The paper was part of a special session on US-UK collaborations.
- **[ORNL]** Work has continued on the assessment of recipes vs. cross sections. The recent activities evaluate the value added for cross sections as compared to recipes for an SFR coupled to a MOX LWR at equilibrium which included generated scenario specific recipes for the inner and outer blanket, driver, and the LWR.
- **[ORNL]** An ORION model has been set up for a fast-spectrum MSR and is currently being tested with the unique MSR option in ORION. Since recipes will not accurately simulate the evolving isotopics within an MSR during operation, the current ORION MSR model has been set up to run with cross sections. Initial mass flow trends show time-dependent evolution in isotopics during the reactor's operations. However, this model is undergoing further testing to confirm its accuracy. This work has required the development of a range of recipes and cross-sections for testing, and subsequent analysis.

- **[ANL]** Reviewed detailed FY18 work plans for the transition analysis activity which focuses on analyzing transition to technology-specific fuel cycles (continuous recycling with MSR versus SFR, etc.) and developed a work plan.
- **[INL]** Reviewed transition economics analysis plans to reduce the number of analysis cases needed to address the planned scope. The analyses will focus on trade-offs between storage, material costs, fissile availability and capacity factors of fuel cycle facilities to better understand the cost relationships.
- **[INL, ANL]** Brent Dixon chaired and Bo Feng contributed to a meeting of the OECD/NEA Expert Group on Advanced Fuel Cycle Scenarios (AFCS), which was held at the OECD/NEA headquarters, France, October 5-6, 2017. Representatives from Belgium, Finland, France, Hungary, Italy, Japan, Spain, the U.S., IAEA and NEA were in attendance (18 people total). The primary focus of the meeting was presentations and discussion on preliminary results for the Benchmark study on TRU management and presentations on updated (near final) results for the Benchmark on dose rate calculations for an irradiated bare fuel assembly.

Development, Deployment, and Implementation Issues (DDII) Tools Development

- **[INL]** Began scoping and preparatory work for upgrades to the VISION model to support future analyses and enhance capabilities.

For more information on Fuel Cycle Options contact Temitope Taiwo (630) 252-1387.

Joint Fuel Cycle Study Activities

- Phase III qualification of the liquid cadmium cathode hardware was completed in HFEF. Process experiments were initiated for the first U/TRU recovery into liquid cadmium using a galvanic mode of operation.
- Completed casting/sampling furnace management self-assessment (MSA) to perform castings with recovered U/TRU material.
- Eight KAERI visitors were hosted at INL for a week to discuss collaborations on remote process automation.

For more information on Joint Fuel Cycle Studies Activities contact Mike Goff (208) 526-1999 or 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, Massachusetts Institute of Technology, University of Utah, Rensselaer Polytechnic Institute, Washington State University, Colorado School of Mines, University of Nevada at Las Vegas, Clemson University, University of South Carolina, Purdue 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
Idaho State 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
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 provided information to the 2017 First Place winners of the Open Competition and worked with the American Nuclear Society on the Innovations in Nuclear Technology R&D Awards student session, to be held Thursday November 2 at the American Nuclear Society Winter Meeting in Washington DC.
- University Research Alliance received desktop awards for the 2017 award winning students, which will be presented at the ANS meeting to those attending, and mailed to the remaining winners.
- University Research Alliance continued to improve the email distribution list in preparation for the 2018 Innovations Awards.

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