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ADVANCED FUELS CAMPAIGN

ADVANCED LWR FUELS

LWR Fuels

- **[LANL]** Neutron time-of-flight powder diffraction was conducted on three U-Si samples with nominal compositions of $USi_{1.70}$, $U_3Si_{2.00}$, and $U_3Si_{2.01}$ between room temperature and 1100°C. The data will provide information on the crystal structure evolution over this temperature range, thus covering operation as well as accident temperatures. The main phase, U_3Si_5 ($USi_{1.67}$), has a hexagonal crystal structure and the diffraction analysis will provide the thermal expansion coefficients for the *a* and *c* crystal axes separately, which have not been determined in the literature to date. Furthermore, atomic positions and anisotropic thermal motion parameters will be determined, from which parameters such as bond lengths can be derived as a function of temperature. This experimental data will be used to verify the U-Si phase diagram for phase stability, and can be used to model anisotropic thermal stresses that may develop in the microstructure during the lifetime of the fuel in a reactor setting. This type of data is only available by diffraction techniques, e.g. dilatometry or calorimetry methods are not sensitive to details of crystal structure changes or the differences between expansion along the crystallographic *a* and *c* axes. The neutron data, with its vastly different elemental contrast between uranium and silicon atoms compared to X-ray diffraction, will also provide additional information for the identification of minority phases that were thus far elusive to identification by X-ray diffraction. Once identified, the crystal structure of the minority phases will be evaluated simultaneously. A total of 150 datasets were collected on the HIPPO neutron diffractometer for the three samples and the data analysis has started. (S. Vogel).
- **[LANL]** The level 3 milestone, M3NT-18LA02020101018 titled, "Complete manuscript on growth of uranium silicide crystals," was completed and describes the growth and characterization of a series of U_3Si_2 single crystals to determine a set of growth parameters suitable to grow quality crystals that can be used for property measurements and basic studies. The manuscript describes the process of evaluating the key parameters necessary when growing single crystals of U_3Si_2 using the Czochralski method within a tri-arc unit. A series of parameters were evaluated to determine their effect on the quality and stoichiometry of the crystals that were grown. Good quality crystals that could be harvested for test samples were grown with a diameter of 5.5 mm x 35 mm in length. As expected for this intermetallic compound, some cracking can be present, but overall crystal quality is good in terms of residual strain, orientation stability, phase purity and stoichiometry. (D. Byler).

LWR Core Materials

- **[LANL]** One L3 milestone report was met this month. Nanohardness testing was performed on rods of two FeCrAl alloys (B136Y3 and C35M4) after ion irradiation to does up to 70 dpa. Data showed similar hardening in both alloys in agreement with the TEM analysis submitted last month. (S. Maloy)

- **[LANL]** Microstructure was characterized in FeCrAl tubing (C26M) using EBSD and nanohardness testing. Results were summarized in a L3 report and show uniform properties along the radial and longitudinal directions of the tubing. (S. Maloy)
- **[ORNL]** New ring specimens were designed to allow for the determination of the mechanical properties of the new 500um thick ODS Fe-10Cr-6Al-0.3Zr+0.3Y_2O_3 (CrAZY) tube, and specimen machining will take place in January 2018. ~12mm tall tube coupons were also ramped up in steam at temperature up to 1450ºC. The ODS CrAZY tube exhibited good oxidation resistance up to 1400ºC, but was completely oxidized at 1450ºC. These results are consistent with similar tests conducted on previous ODS Fe-10Cr-6Al thick coupons. (S. Dryepondt)
- **[ORNL]** A paper titled, "Development of Low-Cr ODS FeCrAl alloys for accident tolerant fuel cladding," was accepted for publication in the *Journal of Nuclear Materials*. (S. Dryepondt)
- **[ORNL]** In order to provide relevant data for accident models, steam oxidation testing is being conducted on the new 2nd generation FeCrAl tubing, C26M, the same material that will go into Plant Hatch in 2018. Experiments with temperature ramp schedules defined by the modeling team are being conducted to compare to earlier results on 1st generation FeCrAl and commercial APM and APMT tubing at temperatures up to 1700°C. Fittings and components are being assembled for LOCA burst testing. (B. Pint)
- **[ORNL]** Communication continued with Century Tubes, Inc. to produce Gen. II wrought C26M FeCrAl alloy tubes (Fe-12Cr-6Al-2Mo base) for PWR fuel cladding design. The target tube size for a half amount of the final tubes was modified to meet with BWR fuel cladding design. The drawing process details including cleaning procedure for the tube inner surface were discussed. The tube drawing process were initiated in late December 2017. There is no change in the expected delivery date (March 2018). (Y. Yamamoto)
- **[ORNL]** Discussions were held with General Atomics to coordinate properties data compilation and analysis for the prototypical SiC/SiC cladding tubes and end-plug elements. The General Atomics silicon carbide cladding materials property manual was shared with the ORNL team and future data exchanges were agreed upon. (Y. Katoh)

LWR Irradiation Testing & PIE Techniques

- **[INL]** Irradiation of the Accident Tolerant Fuels 2 (ATF-2) Sensor Qualification Test (SQT) experiment for Advanced Test Reactor (ATR) cycle 162A was completed on December 7, 2017. Design, analysis, and fabrication of "low risk" ATF-2 (Fuel Test) components are in progress. ATF-2 fuel pin components are being machined and weld development is in progress. (G. Hoggard)
- **[INL]** Samples from ATF-1W (U_3Si_2 – Zirlo) were examined by optical microscopy. Overall, the performance of the fuel appears very good and was in-line with previous PIE results. Very little evidence of swelling was observed in the fuel. The gap between the pellets and the fuel largely appears to have been maintained. There is cracking in the fuel that is very similar to, but perhaps less severe, than the cracking observed in UO2. It was possible to observe some secondary phases that are likely due to fabrication in the fuel. There was some very small intra granular porosity that is likely the initial formation of fission gas voids. This significantly, is the first optical microscopy on neutron irradiated U3Si2 irradiated under light water reactor conditions. A cross section is shown in Figure 1 below. It should be noted that there are significant improvements to be made in sample preparation and the majority of the dark areas in the cross section are due to pull-out in sample preparation. A higher magnification image is included in Figure 2 to better illustrate the true state of the microstructure. (J. Harp)

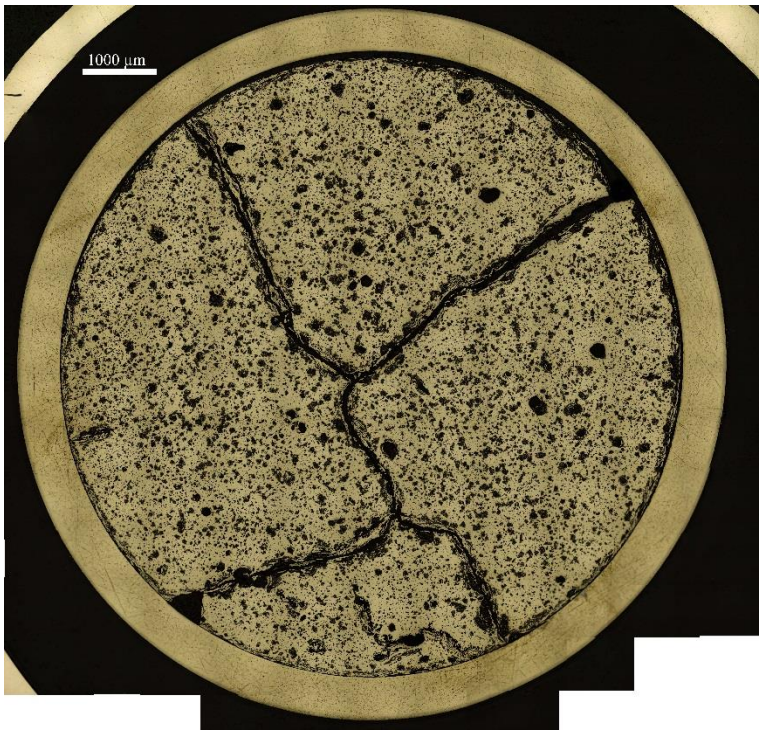


Figure 1. Composite image showing the optical microscopy from ATF-1W R6 (U3SI2-Zirlo). Note that the majority of the dark areas in the fuel are from pull-out. The cracking observed is consistent with ceramic fuels behavior.

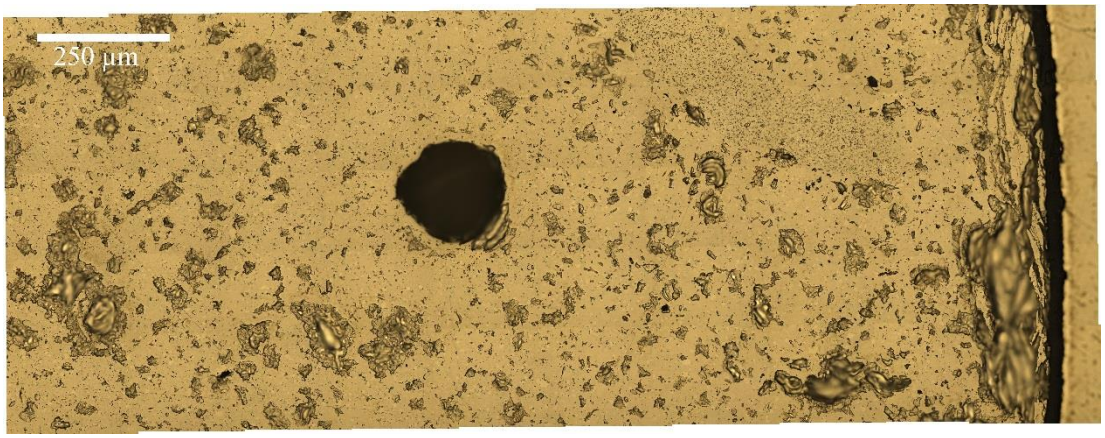


Figure 2. Higher magnification image from ATF-1W R6 (U3Si2-Zirlo), illustrating the as irradiated microstructure, which is very similar to the as-fabricated microstructure, and a large void from fabrication. There is also an area of secondary phase material in the upper right side of the fuel also likely from fabrication.

LWR Fuel Safety Testing

- **[INL]** Capsule and confinement design activities continued in December. Additionally, instrument design and weld development continues in earnest. Instrument attachment to the experiment clad is a critical need to support data collection during the experiment. (D. Dempsey)

- **[INL]** The original safety analysis was conducted for dosimeter wires using what was considered the maximum enrichment of U-235 in depleted Uranium. The actual wire material obtained has a higher enrichment specification. Analysis was done to see how power coupling changes with the higher enrichment in multi-SERTTA CAL. This was done to determine the limiting case in TREAT testing when a comparison is made to analysis of the same wire material placed in the M8CAL test vehicle. Updates to the multi-SERTTA CAL ECAR will be done once lab testing results reveal the true composition of the material and analysis can be done. (J. Schulthess)
- **[INL]** Comments on the Thermal Safety and Programmatic Analysis ECAR for the –CAL vehicle were completed and the document finalized, but is pending any additional changes based on the above potential changes to the Neutronics evaluation. (J. Schulthess)
- **[INL]** Exercising/testing of components of the data acquisition system were performed. These tests involved heating a small graphite block sample (approximately 1/2" cubed) with an embedded TC. The TC was connected to the TREAT DAS system and logged data every 1ms (Figure 3). Data was collected for 31 seconds, 1 second pre-trigger, and 30 seconds post trigger. The DAS was triggered manually with a switch, then the furnace was switched on for approximately 2 seconds. Heat up rates were in the 200-300 °C per second range. These tests show the DAS is progressing in the correct direction for measuring experiment temperatures. (J. Schulthess)

Figure 3. Test of TREAT DAS by heating a small graphite block with an embedded TC.

LWR Computational Analysis & Fuel Modeling

- **[BNL]** M. Todosow attended the AFC Annual Program Integration Meeting at the University of New Mexico, Albuquerque, NM, and provided an overview and status of the "LWR Computational Analysis and Fuel Modeling" activities in FY17 and plans for FY18. (M.Todosow)
- **[BNL]** Manual cycle-by-cycle depletion with PARCS is close to completion for ¼ core model with cross-sections from SCALE6.2.2. (A. Cuadra, L.-Y. Cheng)
- **[BNL]** A proposal is being developed to install and run VERA and/or BISON on BNL's new institutional clusters. The clusters have sufficient number of computing nodes to allow high-definition simulations of ¼ core with depletion / detailed fuel performance models (A. Cuadra, L.-Y. Cheng, M. Todosow)
- **[INL]** An effort to define suitable BISON simulations supporting ATF development is ongoing in collaboration with AFC program elements. (P. Medvedev)

Industry FOA

- **[INL]** Procurement of the V Blender was completed. The Davis Bacon determination was obtained. EJ-2432 for the EFF facility modifications was issued. Work Order MD253718 for EFF facility modifications was issued. The demo was conducted for existing equipment and piping in EFF in

preparation for facility modifications. The factory acceptance testing was initiated for the sintering furnace. The initial risk register for the project was developed. (P. Wells)

ADVANCED REACTOR FUELS

AR Fuels

- **[INL]** Microstructural characterization of the extruded U-10Zr and U-6Zr samples have continued, including scanning electron microscopy. Initial characterization focused on the center section of the U-10Zr rod. Both longitudinal and radial metallographic samples were inspected. Both samples showed a typical U-10Zr microstructure, although the longitudinal also shows a heavily deformed structure which is expected from the extrusion. Figure 4 and Figure 5 below show both the radial and longitudinal samples. (R. Fielding)

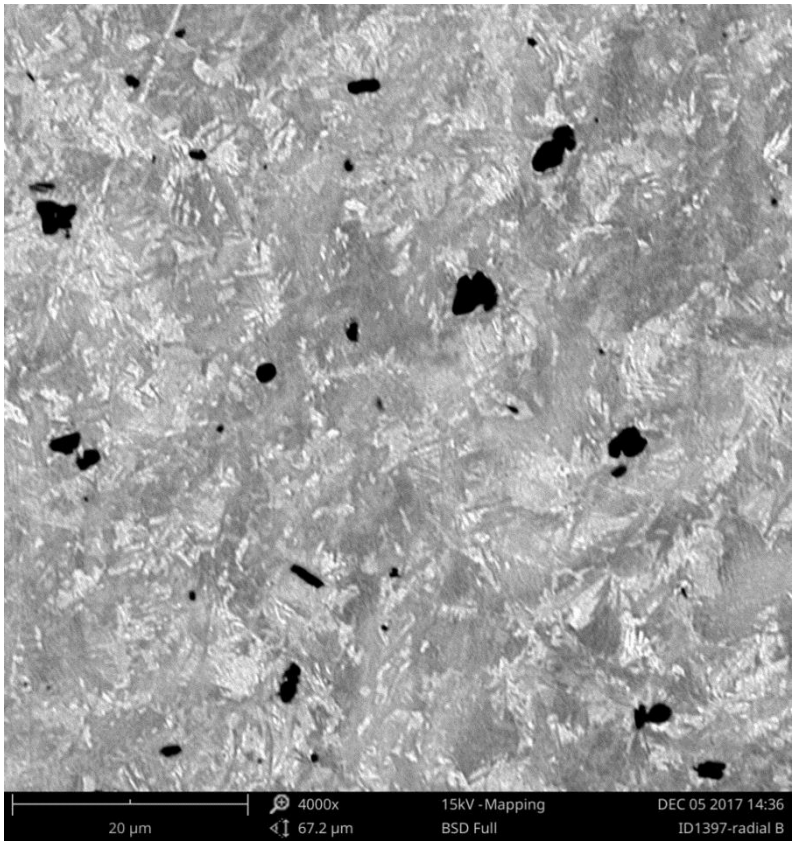


Figure 4. Radial view of U-10Zr extruded rod.

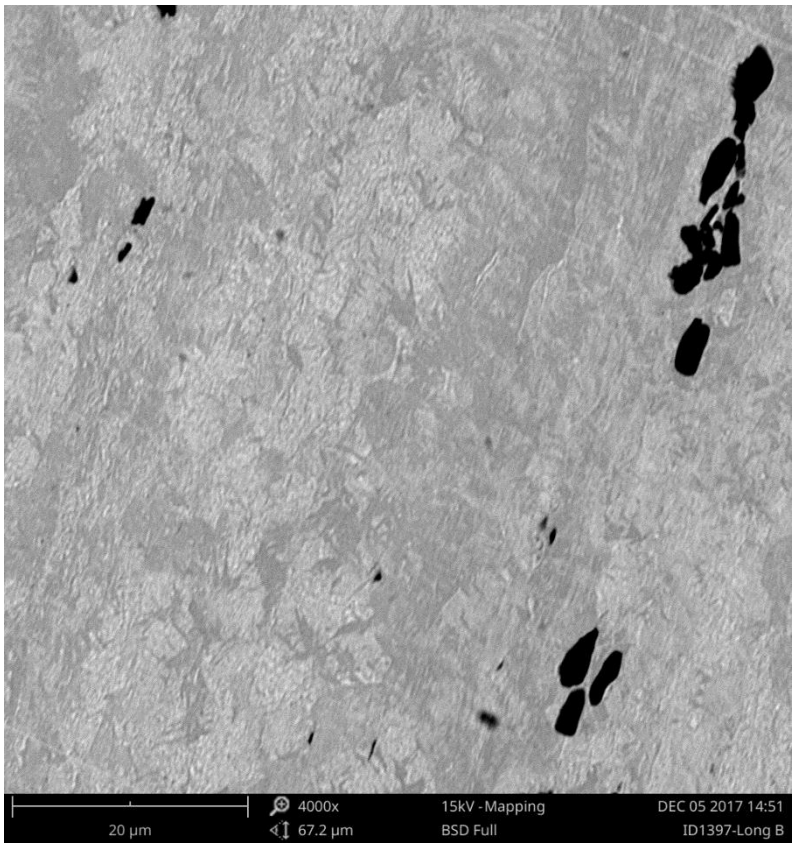


Figure 5. Longitudinal view of extruded U-10Zr rod.

- **[INL]** Initial planning was continued for future casting and sample recovery. An archival slug from the X521 experiment which contained a U-Pu-Zr-Ga fuel alloy. Optimized fuel composition has continued with alloy production, diffusion couple assembly, and manuscript preparation. (R. Fielding)
- **[INL]** Work continued on the 2018 update of the Metallic Fuels Handbook, which is a Level 2 milestone at the end of August, 2018. The handbook will feature a thorough review of the properties of several alloys of specific interest for fuels including U-10Zr. (C. Papesch)
- **[INL]** More than 14000 U-10Zr fuel pins were irradiated in EBR-II and FFTF, with maximum burnup over 18 at%. Although a great deal of information can be obtained from examination of the irradiated fuel, very little data is available about properties of un-irradiated U-10Zr alloys. The data that exists is scattered among a number of publications and reports, many of which are old or obscure. (C. Papesch)
- **[INL]** Figure 6 (from previous revisions of the Handbook) compares all of the available numerical data on thermal conductivity of U-Zr alloys. Although there is some scatter, the data show that thermal conductivity decreases with increasing proportions of Zr. For many alloys, the conductivity is below that of a-Zr, which phase diagrams indicate should not be present in significant quantities in most of these alloys.

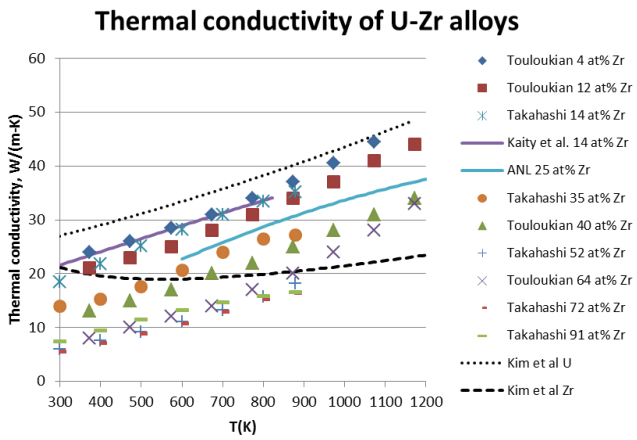


Figure 6. Comparison of all available numerical data on thermal conductivity of U-Zr alloys.

- **[INL]** Figure 7 (which will appear in the next revision of the Handbook) compares all of the available data (including graphical presentations) from U-Zr alloys with ~10 wt% (~22.5 at%) Zr. It shows generally good agreement at temperatures between ~600 and 1100 K, and good consistency with the single set of measurements at lower temperatures. Almost all of the data is from a single publication that quoted otherwise unpublished data from other researchers. (Matsui et al.) (C. Papesch)

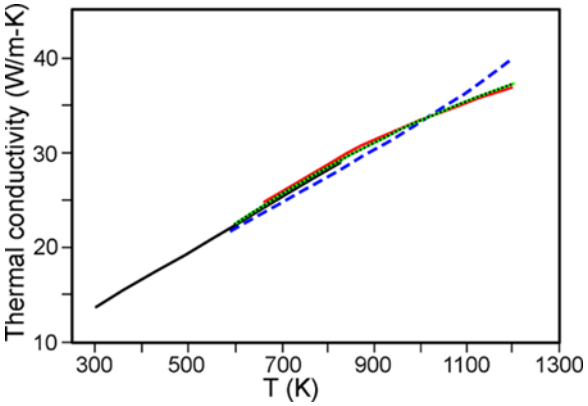


Figure 7. Comparison of available data from U-Zr alloys with ~10 wt% (`22.t at%) Zr.

- **[INL]** Differential scanning calorimetry (DSC) measurements on un-irradiated U-Pu-Mo-Ti-Zr, U-Pu-Pd-Zr and U-Pu-Pd-Zr-Ln (Ln = La,Pr,Nd,Ce alloy) fuel samples (AFC 3A and 3B compositions with Pu) were collected to determine melting points and phase transitions (Figure 8). (C. Papesch)

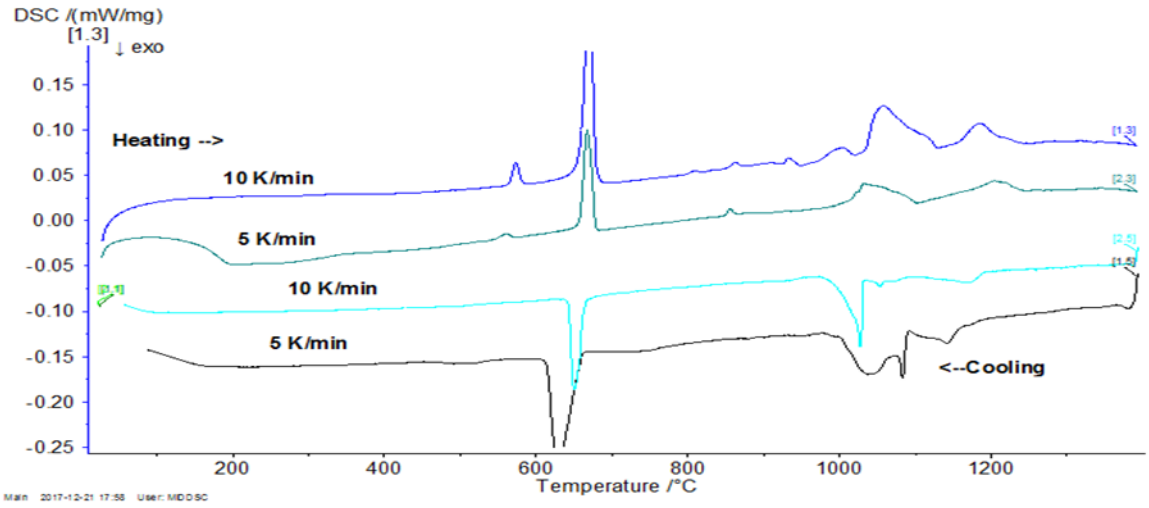


Figure 8. DSC traces of U-Pu-Pd-Zr. Tests were conducted at heating and cooling rates of both 5 C/min and 10 C/min

- **[INL]** A new method to reduce neptunium oxide to neptunium metal is being investigated. The first run shows great promise as arc melting the material under argon creates a thin metal shell around the oxide core. Work control updates and facility approvals are underway to allow for arc melting the oxide material under safe gas (3% hydrogen) in the AFCI glovebox. The addition of hydrogen to the gas mix should produce reduced metal material throughout the sphere. If this method is successful it will significantly reduce the time and cost for neptunium oxide reduction/ neptunium metal production. Figure 9 shows a ball with a neptunium metal shell surrounding a neptunium oxide core. (L. Squires)

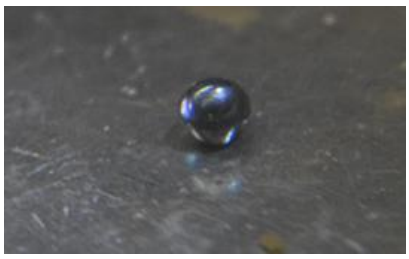


Figure 9. Ball with a neptunium metal shell surrounding a neptunium oxide core.

- **[INL]** A manuscript titled, "Isolation of high purity americium metal via distillation," L.N. Squires, J. A. King, R.S. Fielding, P. Lessing, was accepted for publication in *J. Nuc Mat*. 500 (2018), pp. 26-32. (L. Squires)

AR Core Materials

- **[PNNL]** The milestone titled, "Report on and Perform High Dose Ion Irradiation Studies of Candidate FR Clad and Duct Materials (FY17)," was completed and the report submitted on time. The focus of this work was understanding internal carbon contamination issues during heavy ion irradiation of iron based alloys. The microstructure and mechanical properties of iron base alloys are very sensitive to carbon levels, and added carbon can affect both of these aspects of the alloy as well as perturb the high dose irradiation response of the material compared to when no carbon is added. It was found that up to 4x of the as-fabricated carbon level could be readily injected into the material in

an accelerator not specially prepared to prevent carbon contamination. Since carbon is a light element, it can be difficult to measure its concentration using traditional TEM and SEM methods. This report also shows and discusses methods for accurately characterizing carbon contamination. (M. Toloczko)

- **[LANL]** Rods of 14YWT produced at ORNL from the FCRD-NFA1 powder were pilger processed successfully at CEA into tubes with a final wall thickness of 0.5 mm, 1.0 cm diameter and length of 95 cm. This is part of the DOE-CEA bilateral. Tubes will be sent back to LANL for characterization. (S. Maloy)
- **[ORNL]** The 1 mm thick plate of 14YWT was cut into two sections and were then joined along a butt joint by friction stir welding (FSW). The FSW process went well except that the weld was not fully penetrated by the pin tool, but was very close to penetrating. Some flashing occurred due possibly to excess heat input, but sufficient stir zone exists for conducting residual stress measurements at HB-2B beam line at HFIR in January 2018. Although further development in FSW parameters is required, these results are nevertheless significant due to the many challenges associated with attempting to produce a butt joint by FSW on thin sections such as plates or tubes of the advanced ODS 14YWT ferritic alloy. (D. Hoelzer)
- **[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. Two thick-wall hollow tubes of 14YWT have been extruded and are staged for pilgering. To facilitate the pilgering process, it was decided that the two tubes should be straightened prior to pilgering. A tool was purchased and the two tubes were successfully straightened at room temperature without using a load frame. The tubes and are now ready for pilgering. (R. Omberg)
- **[PNNL]** The PNNL rolling mill is being modified so that it can perform pilgering of tubes. The design of the rollers needed to perform pilgering has been initiated. Material for the rollers has been procured. A Solid Works drawing of the rollers is being developed and this drawing will be used to set the dimensions for the pilgering grooves. (R. Omberg)
- **[PNNL]** The recently developed method to evaluate strain-hardening behavior during unstable deformation was applied to analyze the tensile test data of HT-9 steels after various quenching and tempering treatments. Deformation mode maps, in which elastic, uniform, and unstable deformation areas are defined by the yield stress (YS), plastic instability stress (PIS) and true fracture stress (FS) versus temperature curves, were produced for the HT-9 steels in various tempering conditions. Comparison of those maps indicates that relatively high fracture toughness can be obtained from the as-quenched HT-9 steels when both the uniform deformation area and the unstable deformation area are enlarged with increased strength. This analysis method will be used to evaluate the HT-9 steels currently being tested. (T.S. Byun)

AR Irradiation Testing & PIE Techniques

- **[ANL]** Analysis of the annular fuel performance in steady and transient states continued. For steady state fuel performance analysis, the gas swelling model and the corresponding thermal conductivity degradation model for fuel temperature prediction and Zr redistribution model were improved. The agreement for the BISON license for ANL is being finalized. If the BISON code is available, the improved models are to be implemented for analysis of annular fuel performance. For transient analysis, the Unprotected Loss of Flow (ULOF) transient of ABTR with solid metallic fuel were successfully run with the new SAS4A models in the last month, and the annular fuel model for ULOF transient analysis will be developed. Due to the advanced fuels for lead-cooled fast reactors discussed in the AFC integrated program review meeting held in Albuquerque, NM, a LFR core model is under

development to support a potential LFR fuel development in the AFC campaign. In addition, the impact of Sn additive to a metallic fuel is also under investigation. (T. Kim)

- **[INL]** Investigation into an alternate material (Hastalloy-N) to be used in the AFC-OA experiment design was begun. Material was ordered to support feasibility of fabrication. If fabrication appears to be viable, design efforts may be pursued. (D. Dempsey)
- **[INL]** Microhardness testing was performed on AFC-4A samples. This revealed evidence of fuel-cladding interaction that is not readily visible in optical microscopy (Figure 10). (J. Harp)

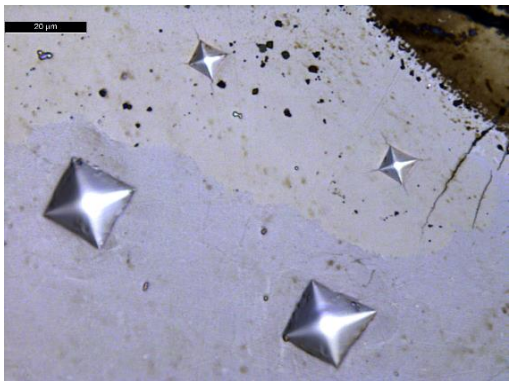


Figure 10. Microhardness results revealing interaction layers in the cladding of AFC-4A R3 (U-MTZ with HT-9).

- **[INL]** AFC-3D rodlets were examined by gamma spectrometry. This reveals the distribution of fission products in the fuel and can be used to infer local changes in fission density. Optical microscopy was completed on the samples from X-501 U-Pu-MA-10Zr. Select samples will be evaluated for future electron microscopy exams. (J. Harp)
- **[ORNL]** Specimens from HFIR irradiation capsules previously transferred to LAMDA have been opened and cleaned. Most of the sample holders are stuck together, trapping the TEM disks inside. Laboratory technicians in LAMDA are attempting to pry apart the sample holders, but cutting may be necessary to remove the samples. (G. Helmreich)

AR Computational Analysis & Fuel Modeling

- **[INL]** The newly developed model for void migration in fast reactor MOX fuel was found to be in a good agreement with experimental trends. BISON correctly predicted experimentally observed effect of LHGR on central void diameter (Figure 11). (P. Medvedev)

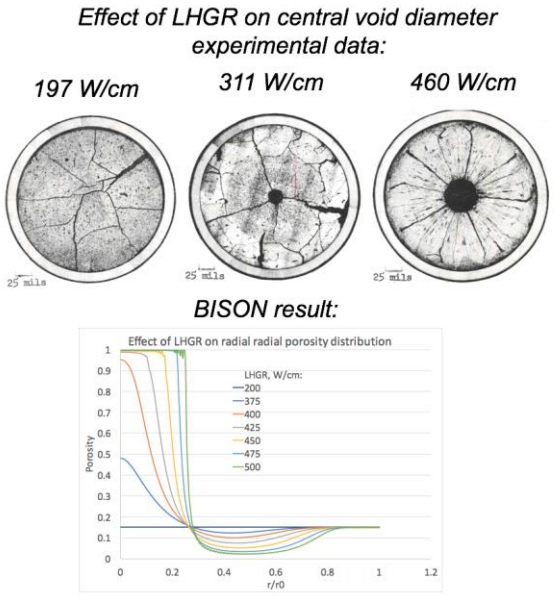


Figure 11. BISON prediction of experimentally observed effect of LHGR on central void diameter.

CAPABILITY DEVELOPMENT

CX Fuels

- **[INL]** Alternate sputter coaters for use with the TCM have been identified, but complications with making them compatible with remote operation may drive the use of the more expensive coater. Compatibility testing of a stage motor in an argon environment was completed by Dean Burt in a glove box at MFC 789. The motor ran for continuously for 54.5 hours without signs of degradation. Results are reported in INL/INT-17-44259. These positive results will eliminate the need to disassemble and modify the stages. Multimode fibers for delivery of the 488 nm light to the thickness monitor have been ordered and received. The new multimode feed through was ordered from Fiberguide and delivery is expected by the end of January. Two 10 meter stage control cables have been procured and two gender adapters for the stage motor electrical feedthroughs have been fabricated. Testing of the stages with full length cable runs incorporating the feedthroughs can now be conducted. (D. Hurley)

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

MATERIAL RECOVERY AND WASTE FORMS DEVELOPMENT

PROCESS CHEMISTRY AND INTEGRATION

- **[INL]** INL is studying the impacts of gamma radiolysis on the ALSEP minor actinide extraction process. Several test loop radiolysis experiments were performed in the INL Test Loop during FY-2017 to examine the impacts of gamma degradation processes upon the extraction and scrub sections of the ALSEP flowsheet. Recent efforts have focused on analysis of the aqueous and organic samples generated during the FY-2017 test loop campaign. Gas chromatography and liquid chromatography are being used to determine the composition of the ALSEP solvent as a function of absorbed dose for the various irradiation experiments performed. The dose constants for the radiolytic degradation of the HEH[EHP] in ALSEP solvent irradiated in contact with 3.0 M nitric acid determined for the FY-2016 and FY-2017 experiments agree to within the experimental error of the analysis (d = 1.300 x 10-4 kGy-1). Analyses of the remaining FY-2017 test loop samples are ongoing. (D. Peterman)

- **[INL]** A manuscript titled, "Synthesis and Characterization of a Novel Aminopolycarboxylate Complexant for Efficient Trivalent f-element Differentiation: N-butyl-2-acetamide-diethylenetriamine-N,N',N",N"-tetraacetic Acid," was published in *Dalton Transactions*. The article delivers a thermodynamic and kinetic study of monoamide-functionalized DTPA aqueous holdback reagent. The characterized reagent offers significant advantages over conventional DTPA in the stripping stage of the ALSEP process. This work was performed in collaboration with ORNL. (P. Zalupski)

  Full article citation:

  > Heathman, C.R.; Grimes, T.S.; Jansone-Popova, S.; Ivanov, A.S.; Bryantsev, V.S.; Zalupski, P.R. "Synthesis and Characterization of a Novel Aminopolycarboxylate Complexant for Efficient Trivalent f-element Differentiation: N-butyl-2-acetamide-diethylenetriamine-N,N',N",N"-tetraacetic Acid." *Dalton Trans*., 2018, DOI: 10.1039/C7DT04104G

- **[INL]** A manuscript titled, "Influence of Heterocyclic N-Donor Group on the Coordination of Trivalent Actinides and Lanthanides by Aminopolycarboxylate Complexants," was published in *Inorganic Chemistry*. The article elaborates on the inclusion of additional nitrogen donor group into the structure of DTPA. The novel reagent allows for the inclusion of extra six-membered N-M-N chelate within the coordination sphere formed upon the complexation of trivalent f-element. Such structural modification nearly doubles the separation factor between americium and lanthanides for the Talspeak-type liquid-liquid distribution platform. This work was performed in collaboration with ORNL. (P. Zalupski)

  Full article citation:

  > Grimes, T.S.; Heathman, C.R.; Jansone-Popova, S.; Ivanov, A.S.; Santanu Roy; Bryantsev, V.S.; Zalupski, P.R. "Influence of Heterocyclic N-Donor Group on the Coordination of Trivalent Actinides and Lanthanides by Aminopolycarboxylate Complexants," Inorg. Chem., 2018, DOI: 10.1021/acs.inorgchem.7b02792.

- **[INL]** A meeting was held in Long Beach with the INL and the Cal State University collaborator, Steve Mezyk. Several important items were discussed at this meeting that contribute to the goals of the Fundamental Radiation Chemistry program. A draft manuscript was completed that details the results of the investigation into the radiation chemistry of the hydrophilic DGAs. This manuscript was also written in collaboration with Forschungszentrum Juelich. Their comments are now being incorporated and the paper will soon be submitted. Regarding monoamide radiolysis studies, sample analysis is still underway for the most recent irradiation campaign. Irradiated material is also being used to repeat U/Pu solvent extraction experiments currently in progress. (B, Mincher)

- **[ORNL]** In the month of December, the membrane cascade design was reanalyzed for the concentration of tritiated water with LTA zeolite membranes. The details on the material balances, and the changes in flow rate of feed and permeate streams as a function of separation stages were added for the case of tritiated water concentration with LTA membranes. The energy cost for the membrane process was recalculated which was higher than previously thought due to additional separation stages on the permeate side, but it is still substantially lower than that estimated for the CECE process. (B. Jubin)
- **[ORNL]** Several improved LTA tubular zeolite membranes were synthesized and characterized for water vapor permeance with ethanol-water separation factor to determine the quality of the membranes. The results indicated very high selectivity for ethanol-water separation with separation factor in the range of 1000 to 10,000. These values are consistent with the separation performance of LTA membranes for ethanol dehydration application. These will be evaluated for tritiated water concentration in January 2018. (B. Jubin)
- **[ORNL]** Two pellets were pressed using copper powder from Sigma-Aldrich with a particle size under 45µm and WO3 powder also from Sigma Aldrich with a particle size under 25µm. The mixing ratio was 40v% WO3 and 60v% Cu. The first pellet was pressed at 5,000 psi and held for 2 minutes. The second pellet pressed at 20,000 psi and held for 3 minutes achieving a green density of 5.17 (63% of theoretical). The lower pressure pellet was unsatisfactory as it easily crumbled. However, the pellet pressed at 20000 PSI, as shown in Figure 1, looked solid and it was easily handled without losing material.

  The green pellet was then heated in an oven at 900oC under argon for six hours and then allowed to cool down to room temperature also under argon (see Figure 2). The initial and final weights were nearly identical (37.78g) but there was a significant shrinking in volume. The final density after sintering was 7.66 g/mL equivalent to 93% of the theoretical density (8.24g/mL). The sintered specimen was cut in half (Figure 3) and the cutting surfaces will be polished to allow for a microscopic examination. To the naked eye, the composite materials appear uniform. (B. Jubin)

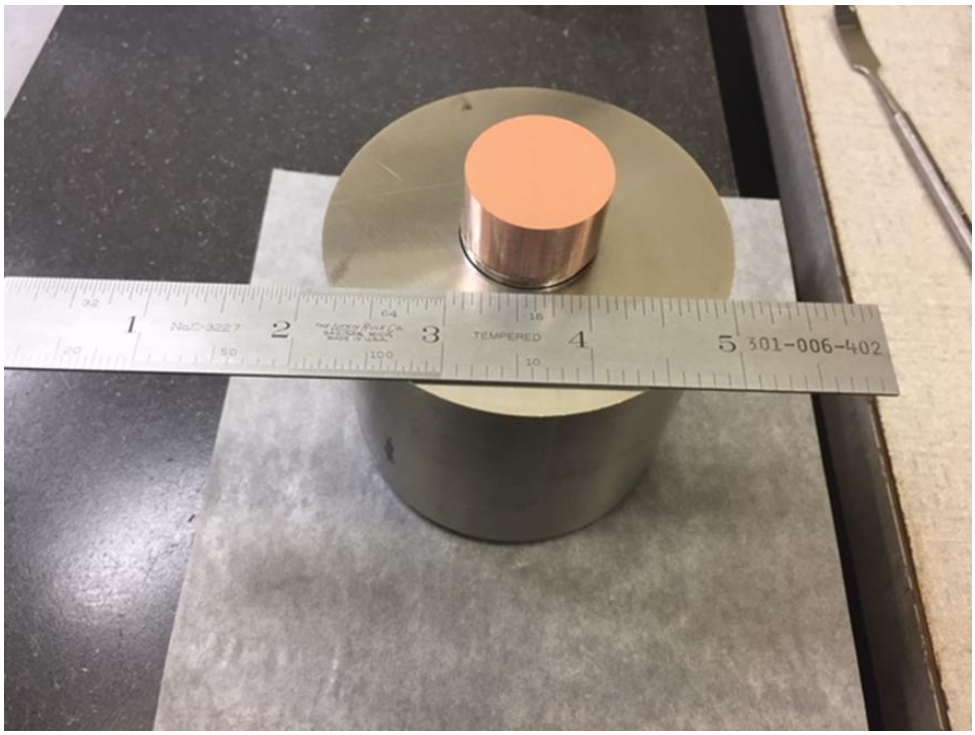


Figure 12. Green pellet 40-60 20,000 PSI, 63%.

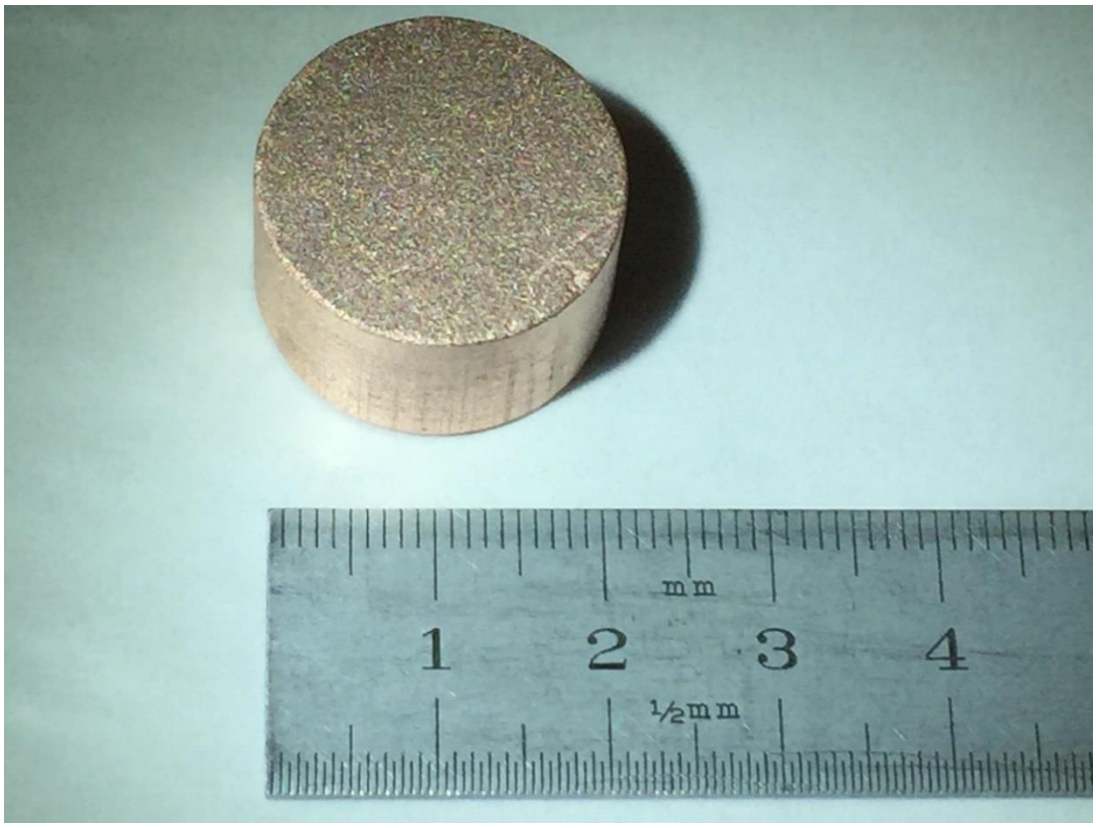


Figure 13. Sintered Pellet 900C, 6 hr.

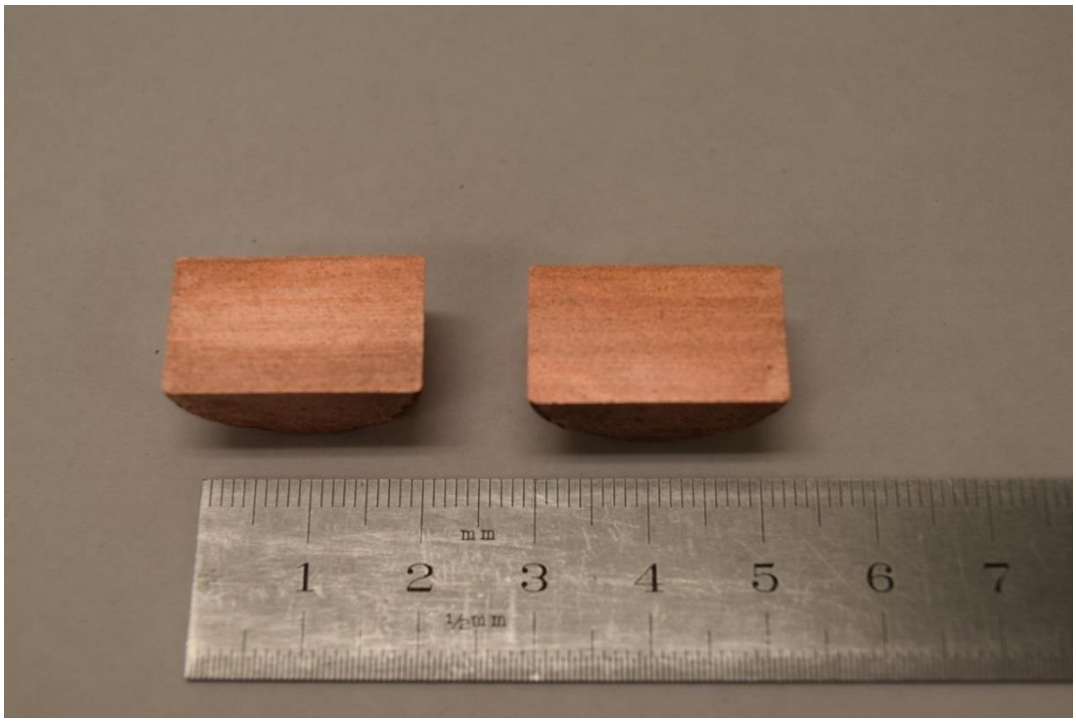


Figure 14. Cut Pellet 900C, 6 hr.

SIGMA TEAM FOR ADVANCED ACTINIDE RECYCLE

- **[INL]** Kinetic runs were completed for non-irradiated AmV in various acid concentrations. In a significant development, a discrepancy in mass balance between AmIII + AmV and total Am has been measured. This cannot be due to choice of molar extinction coefficients for the Am absorbance peaks as these were previously determined for AmVI reduction experiments. This implies that AmIV may be present. If so, it is the first time evidence for AmIV in nitric acid solution has ever been seen. Experiments are underway to confirm this exciting possibility. (Mincher)
- **[INL]** A meeting was held at Texas A&M between researchers from INL and Texas A&M to plan collaborations in the area of co-crystallization of AmVI. Goals of the collaboration and experimental details were discussed (T. Grimes, K. Lyon, D. Burns).

WASTE FORM DEVELOPMENT AND PERFORMANCE

Electrochemical Waste Forms

- **[ANL]** Long-term electrochemical tests initiated in FY 2017 with an RAW-6 alloy made with U and Tc were completed. These tests show that material is very durable in aggressive acidic and alkaline solutions containing 10 mM NaCl and over a wide range of solution redox (Eh) values, with corrosion current densities decreasing to values on the order of nanoamps as passivating layers form within a few days. A final summary report is being prepared that shows how small modifications in trim metals added to RAW-6 materials made with Re, with U, and with U and Tc improve the corrosion resistance. (W. Ebert)
- **[ANL]** Modifications to the procedure used to dehalogenate salt waste and immobilize the residue in an iron phosphate glass waste form were discussed with colleagues at PNNL and INL and a path forward was determined. A new material will be generated at PNNL and provided to ANL for analysis in early January. (W. Ebert)

Ceramic Waste Forms

- **[LANL]** The investigation on radiation-induced microcrack in multiphase crystalline ceramic and glass ceramic waste form samples, single phase oxyapatite, powellite, and hollandite, and glass (based on reminder glass in the glass ceramics with the crystals removed after slow cooling) has been summarized (Table 1). The formation of microcrack would affect chemical durability of nuclear waste forms in storage.

  Radiation damage was performed using ion irradiations including He (alpha) ion beam to simulate helium accumulation and alpha radiation in nuclear wastes and Kr ion beam to simulate alpha decay in nuclear wastes. Scanning electron microscope (SEM) was used to characterize microcracks in irradiated samples. Our results show that microcracks are observed in He irradiated multiphase crystalline ceramic samples and glass ceramic sample GC-4, remainder glass, but not in most Kr irradiated samples. It suggests that microcracks are induced by He accumulation and alpha radiation. Further, microcracks in multiphase samples are only observed in hollandite and celsian phases, not in other crystalline phases. Since there are cracks in pristine samples of single phase oxyapatite, powellite and hollandite, we do not know if radiation damage could induce cracks in these materials. (M. Tang)

Table 1. Radiation-induced microcrack in nuclear waste form materials. "N" represents no cracks found, "Y" represents obvious microcracks - "small" means small cracks.

condition / sample	pristine	He irradiated	Kr irradiated
CAF-11113(ANSTO)	N	Y, hollandite phase	N
CAF-44413(ANSTO)	N	Y, hollandite phase	N
SW-1727(SRNL)	N	Y, hollandite phase	small
GC-4(PNNL)	N	Y, celsian phase	small
Glass(PNNL)	N	Y	N
GC-Mo-5.85(PNNL)	N	N	N
Oxyapatite(PNNL)	Y	Y	Y

- **[SRNL]** SRNL completed thermal modeling of CIM to assess temperature control from proposed modifications (cut-off the drain tube above the crack) to the CIM. (J. Amoroso, P. Smith)

Glass Ceramics Waste Forms

- **[SRNL]** Cesium (Cs) analyses via inductively coupled plasma mass spectrometry (ICPMS) for leachates from long term PCT were completed in December. The final report has been drafted and is expected to be complete January 2018. (P. Smith)

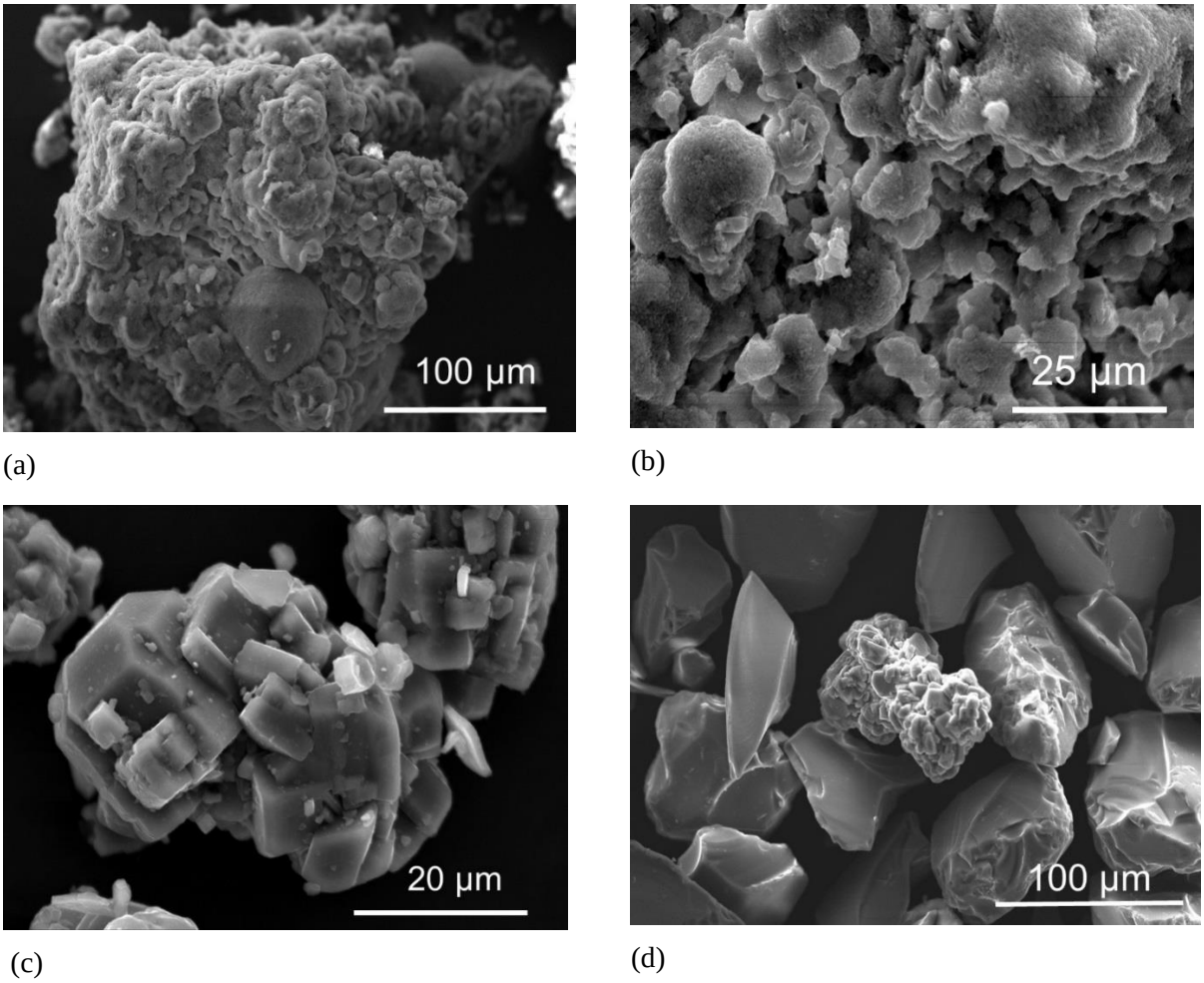
Zirconium Recycle

- **[ORNL]** Bill Del Cul and Emory Collins attended the 3rd year review of the NEUP project at UTK on December 7. The review included presentations on accomplishments in Year 2 for developing a protocol in analyses of gas phase reactions and modeling by density functional theory, experimental equipment and test results on $ZrCl_4$ purification protocols, development of non-rad methods for cesium analyses in cold tests, and a potentially new method for $ZrCl_4$ purification by crystallization. (B. Jubin)
- **[ORNL]** Design of the glassware equipment for the $ZrCl_4$ purification tests at ORNL has been completed and a custom procurement from a commercial fabricator is in progress. Arrangements for time and location of the purification tests have continued. Because of the tight schedule for use of Cave B, the use of a new glovebox at Building 3525 (where the chlorination tests were made) with added shadow shielding as necessary, is now being considered. (B. Jubin)

Advanced Waste Form Characterization

- **[ANL]** The available analytical results for solutions collected in ASTM C1308 tests with AFCI and LRM glass were documented in a status report (NTRD-MWFD-2017-00197) and are being evaluated to derive parameter values for the ANL Stage 3 model for waste glass degradation. A key objective of tests initiated in FY 2016 was to evaluate the relationship between the solution composition and the

on-set of Stage 3. To impose a range of Al and Si concentrations when tests were initiated, different amounts of $Al(OH)_3$ and K_4SiO_4 glass were added to different tests. Figure 15a and 4b show a particle of K_4SiO_4 glass and Figure 15c and 4d show an isolated aggregate of $Al(OH)_3$ and an aggregate among several grains of AFCI glass. The AFCI and LRM particles are visually distinguishable from the $Al(OH)_3$ and K_4SiO_4 glass particles.

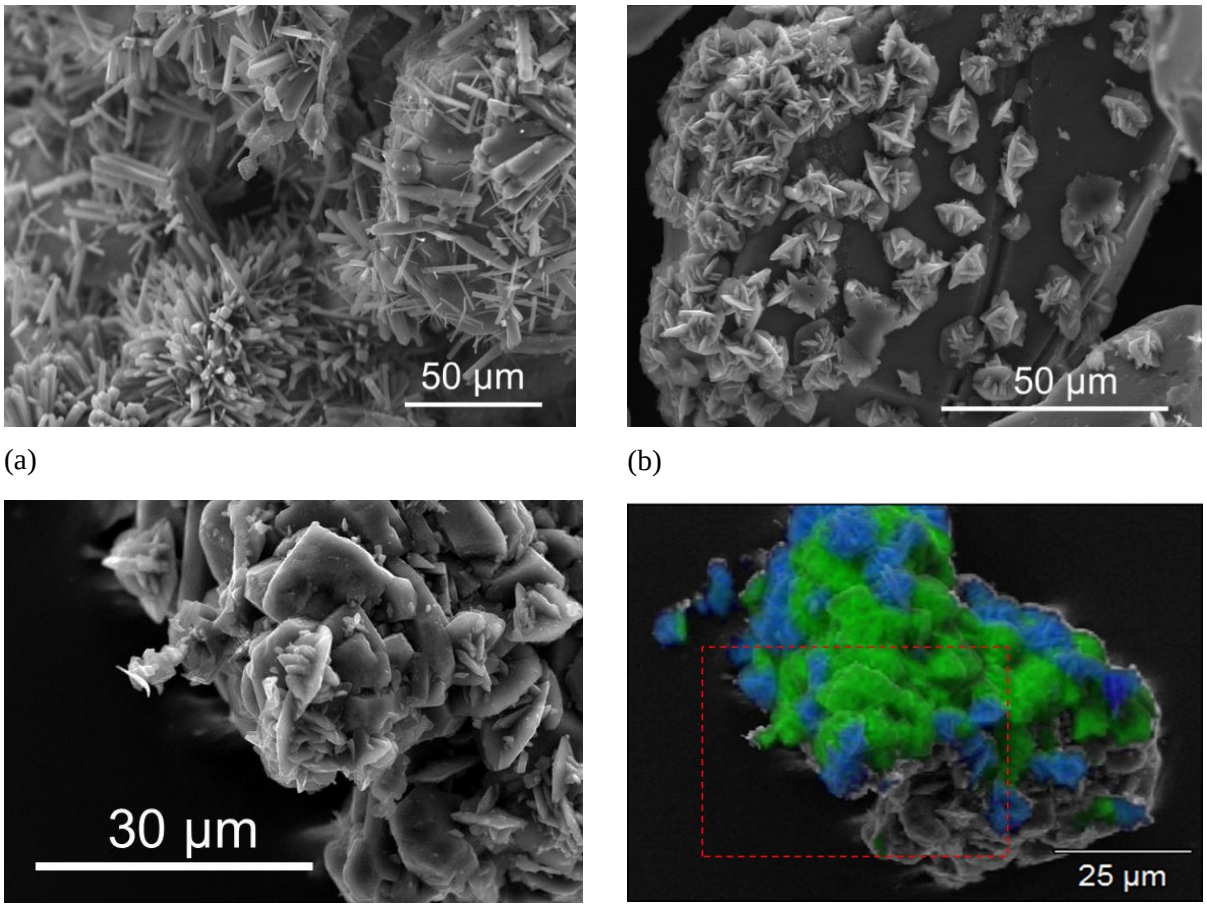


(a) (b)

(c) (d)

Figure 15. SEM images of (a) and (b) particle of K_4SiO_4 glass and aggregates of reagent $Al(OH)_3$ (c) in isolation and (d) mixed with AFCI glass particles.

Figure 16a and 5b show particles of AFCI and LRM glass, respectively, covered with different secondary phases that formed during Stage 3 corrosion. Phillipsite $[(K_2Na_2Ca)_3(Al_6Si_{10}O_{32})\bullet 12H_2O]$ is the dominant secondary phase formed in tests with AFCI glass and the dominant secondary phase formed in tests with LRM glass is chabazite $[(K_2Na_2Ca)(Al_2Si_4O_{12})\bullet 6\ H_2O]$. This is likely due to the high potassium concentrations generated by the K_4SiO_4 glass. Figure 16c shows an $Al(OH)_3$ particle recovered from the same test as the LRM particles shown in Figure 16b (namely, L3-16) that is covered with the same secondary phases that formed on the glass particles. Figure 16d shows EDS x-ray maps of Al (blue) and Si (green) overlain on the SEM photomicrograph of that $Al(OH)_3$ aggregate. The secondary phase also contains similar amounts of Na and K. No particles of K_4SiO_4 glass were detected with the reacted solids and appear to have completely dissolved during the tests, but many $Al(OH)_3$ aggregates remained in most tests and did not completely dissolve. Aggregates were not detected in tests with extensively corroded AFCI glass, although they may be coated with secondary phases and not distinguishable. (W. Ebert)



(a) (b)

(c) (d)

Figure 16. SEM images of (a) AFCI glass particles, (b) LRM glass particles, and (c) $Al(OH)_3$ aggregate covered with secondary phases and (d) EDS x-ray maps for Al (green) and Si (blue) overlaying $Al(OH)_3$ aggregate shown in (c).

- **[PNNL]** Milestone report M3NT-18PN030105132 titled, "Stage III Modeling," was completed this month for the WFDP Modeling & Simulation work package. This report provides a detailed description of the implementation of a model of mineral nucleation and growth into the Glass Corrosion Modeling Tool (GCMT) and its application to the study of Stage III dissolution of simple borosilicate glasses. Classical nucleation theory and an Aagaard-Helgeson-type crystal growth model were implemented in the GCMT to perform a preliminary examination of how these processes influence glass alteration rates. Coupling to the GRAALP model of glass dissolution allowed for modeling corrosion data from the CJn borosilicate glass series. In particular, the potential effects of the precipitation of a simple sodium silicate phase on the dissolution of CJ4 and of that of a calcium silicate on the dissolution of CJ8 were explored and the results of each test case were contrasted with the observed experimental data. This latest modification of the GCMT allows a qualitative account of all three stages of glass alteration. (S. Kerisit)

DOMESTIC ELECTROCHEMICAL PROCESSING

- **[ANL]** Work continued on final reports on the Echem process data gap study and the development of a co-deposition cathode. A draft project arrangement proposing expanded collaboration between the

US and Japan in molten salt chemistry and waste form development was submitted to DOE-NE for review. The proposed activities would complement existing activities conducted by the US and Japan under the Civil Nuclear Energy Working group bi-lateral agreement. (W. Ebert)

SIGMA TEAM FOR OFF-GAS

- **[INL]** A second long-term iodobutane adsorption test was started in early December. This test was placed on hold during the Christmas curtailment, and was re-started in January. This test may be complete near the end of January. (N. Soelberg, A. Welty)
- **[ORNL]** Testing associated with the milestone to complete testing of integrated iodine scrubber and polishing bed system has required system upgrades of the NO_2 delivery system. This upgrade is expected to be completed in January. The scrubber system was received in late December and will be assembled in January. (B. Jubin)
- **[ORNL]** The milestone report for the task, "Performance of Ru removal systems in prototypical TOG streams," has been written and is undergoing internal review. The report will be issued in January. (B. Jubin)
- **[ORNL]** Work continues on testing of an iodine and tritium removal system for advanced tritium pretreatment. Corroded fittings from the test system were sent for iodine and tritium analysis. The analyses indicated both tritium and iodine present in the corrosion products, which prevents closure of the mass balance of those components for completed testing. The report for this milestone has been drafted and is undergoing internal technical review. (B. Jubin)
- **[PNNL]** The Level 5 milestone (NTRD-MRWFD-2018-000216) titled, "Scale up of CaSDB MOF for INL deep bed measurements," was completed on time. Work progresses on production of a large batch of the CaSDB MOF for upcoming milestone. (P. Thallapally)

FLOWSHEET DEMONSTRATIONS

- **[ORNL]** A presentation was made to a group of JAEA visitors on December 1, comparing the co-decontamination flowsheet tests made in the two CETE campaigns at ORNL in 2008-2009 with planned tests in the current CoDCon project at PNNL. (B. Jubin)

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

MPACT Campaign

MANAGEMENT AND INTEGRATION

Management and Integration

- **[INL]** Jeff Sanders attended the JFCS SSWG meeting in Vienna, Dec. 11-13, with participation by ROK and IAEA. Several MPACT funded process monitoring technologies were presented, and their importance to safeguarding pyroprocessing facilities highlighted. Dan Vega provided input from MPACT to the NEAC meeting. Jeff Sanders and Mike Miller hosted Howard Menlove and Daniela Henzlova from LANL to visit potential locations for testing the High Dose Neutron detector at INL.

SAFEGUARDS AND SECURITY BY DESIGN - ECHEM

Voltammetry

- **[ANL]** Work on constructing the multielectrode sensor is proceeding according to plan. The final parts have been fabricated, and the sensor is to be assembled in the next two weeks.
- **[INL]** Two different reference electrodes (Ag/AgCl and Ni/NiO) were tested in a surrogate system. The goal is to determine which of the two electrodes will provide the most stable and reproducible measurements under the conditions found in the IRT-OR. Counter electrodes were assembled in preparation of upcoming experiments. The original probe used for tests in the mock-up IRT-OR was disassembled to study the degradation of the probe components. Based on these observations a new mock-up probe is in the process of being fabricated to be tested with surrogates, before the fabrication of the probe that will be used in the IRT-OR.

Sensor for Measuring Density and Depth of Molten Salt

- **[INL]** Experiments were performed using a transparent furnace to study thermal expansion of the triple bubbler system. Preliminary analysis showed that the observed thermal expansion was within 6% of the expected growth (determined from the temperature profile of the thermocouple).

Electrochemical Signatures Development

- **[LANL]** A 137Cs source used by the High Dose Neutron Detector (HDND) Team for experimental purposes was modeled with motion using the experimental MCNP6 moving-objects code. Mesh tally results were obtained. PHL detector tally results are pending. If available in the future, measured data will be of use for benchmarking MCNP6 simulations. The moving-object neutron model with the HDND detector plus the Westinghouse oxide fuel and the ANL PEER (WFA/PEER) was executed using greater numbers of source-particle histories so as to assess improvements in the PHL detector tally statistics. This type of analysis is germane to concept of using MCNP6 radiation modeling to assist with the development and deployment of radiation detectors. MCNP6 is limited to providing static mesh-tally plots of radiation fields within a prescribed geometry. While useful, it is of interest to have capability to examine radiation evolution using a dynamic format. Initial animated mesh-tally capability was developed per the following. Survey - MCNPX contains a set of subroutines developed in the late 1990's to provide mesh-tally data in a format suitable for auxiliary plot routines. The subroutines reside in a package named gridconv, which is created during MCNPX compilation as a standalone executable. This package is not part of MCNP6. Gnuplot is a portable command-line driven graphing utility for Linux, OS/2, MS Windows, OSX, VMS, and many other platforms, and it is freely distributed. Gnuplot has the capability to plot heatmaps. The MCNP6 mesh tallies can be interpreted as constituting heatmaps. GIMP (GNU Image Manipulation Program) can be used to

create movies using a set of jpeg or png files. Animated movies can be created by taking multiple gnuplot jpeg or png files and linking them using the GIMP package to create a gif files. The gif files can be included in various documents (e.g., Word, Powerpoint) and executed without gnuplot. Development - After preliminary assessment, three relevant MCNPX gridconv subroutines were modified to provide the desired data for gnuplot mesh-tally plots. The existing capability required user interaction. Additional modifications were implemented to facilitate automated execution within the context of Perl script initiation inclusive of parameter variations. A gnuplot routine was written to plot heatmap equivalents of the MCNP mesh tallies. The gnuplot code was used to display sets of images. The gnuplot presentation improves as the number of mesh-tally datasets increases. It was estimated that 100 images would provide adequate coverage of the evolving radiation field to create a suitable movie. MCNP6 execution tests were conducted to determine an approximate upper bound on the number of time-segmented mesh tallies that could be obtained per job. It was found that MCNP6 can accommodate approximately five time-segmented mesh tallies per job for the models of interest. Thus, for initial tests, 20 MCNP6 jobs with five mesh tallies per job were executed using dt=tmax/(ntal*nset). Processing of the MCNP6 input file creation, execution, and data processing was automated by writing and executing Perl scripts and Fortran codes to perform repetitive tasks for file creation, job execution, file naming and collection, and data extraction with gnuplot datafile creation. Once the aforementioned tasks were completed, movies were developed for the 252Cf and 137Cs sources. These movies provide an appreciable visual enhancement (vs the MCNP6 static mesh tallies) of the evolving radiation field as these sources move past the HDND, inclusive of vivid radiation scattering and streaming behavior.

ADVANCED INTEGRATION

Advanced Integration (Methods)

- **[LANL]** Continuing to work with Mark Croce with the microcalorimetry sensor to develop spectrum for the notional ER data. While microcal was producing data in Dec., we developed notional diversion scenario data to begin the process of understanding how to statistically analyze the data given noise. Charts were produced for detecting diversions using isotope ratios including Cm/Pu, Am/Pu, U/Pu, Np/Pu for a microcal detector.

Advanced Integration (Facility Models)

- **[SNL]** The preliminary Molten Salt Reactor Model has been developed, and will be used to generate initial results for review. More design information will be needed to expand the model in the future.

EXPLORATORY RESEARCH / FIELD TESTS

Microcalorimetry

- **[LANL]** Improved temperature stability enough to finish a series of measurements of plutonium at high count rates (up to 60 counts per second per pixel). We found that energy resolution did not significantly degrade with count rates below 20 counts per second per pixel, which corresponds to 10 million counts per hour for the whole array. This is a very important result that illustrates the capabilities of the microwave readout architecture. We also completed measurements of different gamma sources to measure the efficiency of the array, which will be important for quantitative analysis. Katrina Koehler has calculated theoretical calorimetric electron capture spectra for both 1-hole and 2-hole excitations, where the 2-hole excitations have been calculated up to second order in orbital overlaps with unmatched quantum numbers. The 1-hole theoretical spectra have been calculated for 4 different isotopes—Ho-163, Pt-193, Fe-55, and I-125—and compared to experimental data in the cases of Pt-193. This is still to be done for Ho-163 and Fe-55. The 2-hole

theoretical spectra have been calculated for 2 different isotopes—Ho-163 and Pt-193. The next step is to collect more experimental data on Pt-193 to enable a better comparison to the theory.

In situ Measurement of Pu Content in U/TRU Ingot

- **[INL]** A test plan was developed and issued for characterization of the furnace with surrogate metals and measuring the melting point of U/TRU products in the Hot Fuel Examination Facility from which facility procedures will be initiated. Due to the smaller than expected recoveries of U/TRU products to date during the JFCS liquid cadmium cathode operations, the fourth U/TRU product will be utilized for melting point studies which are currently scheduled for February 2018.

High Dose Neutron Detector

- [LANL] Repaired HDND detectors were tested and found fully functional. Daniela Henzlova and Howard Menlove participated in scoping trip to INL on December 20. The discussions focused on materials and locations available for field test of HDND. Initial plan was discussed for possible times of measurements, HDND detector shipment to INL and set-up. INL is currently finalizing list of items that will be available for measurements.

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

Fuel Cycle Options Campaign

CAMPAIGN MANAGEMENT

- **[ANL, INL]** Completed the FY 2017 Achievement Report for the Fuel Cycle Options 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, INL]** With federal manager/director, developed a short paper on the key contributions and services that the Campaign provides the DOE NE-4 program office.

EQUILIBRIUM SYSTEM PERFORMANCE (ESP)

Performance of Fuel Cycle Systems

- **[ANL]** Collected information on the Micro Modular Reactor (MMR) that is under development by Ultra Safe Nuclear Corporation (USNC). The MMR is a small-size gas-cooled modular reactor that integrates the reactor power module, power conversion module, and power generation modules. The proposed fuel cycle is once-through with low enriched uranium (LEU) fuel (evaluation group EG01 or EG02), but the use of plutonium and thorium has also been proposed.
- **[ORNL]** A meeting with the BNL sub-contractor, Penn State, was held to determine final scope on the transmutation library task. The work will initially focus on the data generate for the evaluation groups, and will make sure the importer captures all of the needed data. A table containing definitions for all of the inputs will be produced, and then these definitions shared with the Campaign to ensure agreement. Cross-sections will then be added to the database, again based on pre-generated cases from the Campaign.
- **[INL]** The decay heat from full fresh/irradiated driver assemblies for the equilibrium EG24 SFR, including that from structural materials (HT-9, Na), was evaluated for the possible use in TSRA analyses. The data for this evaluation were taken from the EG24 transmutation library and ANL-AFCI-177 report.
- **[INL]** Continued to work on the review of nuclear energy and fuel-cycle concepts for FY18.

Economic Analysis Capabilities and Assessments

- **[ANL]** For the algorithm for advanced reactor costs, work continued in identifying the cost models of equipment based on typical chemical engineering costs. Additionally, an analysis was started on metallurgy and component fabrications in order to improve the understanding of the cost drivers for large metal components of nuclear reactors, such as pressure vessels, steam generators etc. Also interacted with Dr. Claudio Filippone of Holosgen, who has developed cost data for several representative components and may be willing to share some of that knowledge.
- **[INL]** Met with ANL to plan out how the front end modules in the CBR should be updated going forward. Based on a prioritization to overall life cycle costs, INL will begin with detailed time-series analysis of SWU prices to support updating the module on enrichment. This will include identifying the impact of technology transition from gaseous diffusion facilities to centrifuge. Then we will revisit the module on uranium prices to forecast the impact of Fukushima and the depletion of weapons grade fuel for reprocessing on uranium prices. INL will finish the front-end updates by updating the conversion module with the latest market prices and factors expected to impact conversion prices in the long run.

Equilibrium System Performance (ESP) Tools Development

- **[ANL]** The possibility of remote login by non-ANL personnel was successfully demonstrated for the NE-COST website using a "cyber gate pass". Work still needs to be done on the text and explanations, before official reviews can begin for the website.
- **[SNL]** We resolved a problem with the database that was preventing us from entering the fuel parameters for one particular option; the data for this option has now been entered and the interactive flow diagram is being prepared. We also made further progress on the on-line fuel cycle option data entry system, deciding on a path forward for resolving a parameter input issue.
- **[BNL/PSU, ORNL]** A plan was developed for importing data from the Evaluation and Screening study data files into the new transmutation data library. The planning included meetings to clarify and explain some of the initial findings in the effort to convert the Transmutation Library Database. The overall conversion process has been clarified to better document references for each recipe entry in the importer template. Data and calculation descriptions in the importer template may be altered on an ad hoc basis. These descriptions and calculations will be better defined in an effort to create a "user's manual" for the new transmutation library. The project will now focus on implementing importer templates for the evaluation group cases, starting with EG01, EG04, EG29, EG30, and EG39. These cases were selected because they span the range of possible fuel cycles. This information can be readily found or calculated, whereas some of the legacy transmutation library data has missing data or is not fully documented.
- **[BNL/PSU]** Preliminary work has been completed to implement the action plan for the new transmutation data library. There are currently two rough drafts of importer templates which include informal references. The rough drafts are for EG01 and EG29. EG01's importer is closer to completion while more information must be determined for EG29's importer. Additionally, terms that are prevalent in the importer templates have been listed in a document so that a glossary can be built. Only a few terms have been defined at this time. Similarly, a list of acronyms has been developed for those that appear frequently in the importer templates. Further, initial versions of scripts have been developed for shifting isotopic data into the importer templates from the legacy transmutation data library. Immediate action items include finalizing importer templates for EG01 and EG29 with formal references, building importer templates for EG04, EG30, and EG39, continuing to add terms and definitions into glossary, and developing additional scripts to expedite building importer templates.

DEVELOPMENT, DEPLOYMENT AND IMPLEMENTATION ISSUES (DDII)

Technology and System Readiness Assessment (TSRA)

- **[ANL]** Participated in conference call and discussion on the TSRA for a fast reactor recycling option, and provided information on the subsystems of a sodium-cooled fast reactor.
- **[LLNL]** Participated in TSRA working telecons to define the analysis example and refine the readiness questionnaire.
- **[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. have been reviewed for incorporation in updates to the questionnaires for the Technology Readiness Levels (TRLs) and/or the Systems readiness levels (SRLs) contained in "Technology and System Readiness Assessment Process for R&D Evaluation, FCRD-FCO-2016-000110, June 30, 2016.

- **[BNL, INL, ANL]** INL and ANL have developed an alternative approach to ordering the TRLs via "Tasks" (e.g., "requirements and Assumptions", "Safety, Environmental Compliance"). As part of this "ordering" some additional questions have been proposed, as well as modifications to the wording of some of the initial TRL questions. The "base/reference" questionnaires are being updated to include inputs from this approach.
- **[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 "promising" fuel cycle.
- **[INL]** Continued to refine technology readiness level (TRL) questions to ensure that starting an analysis at a TRL other than 1 does not result in aspects of the readiness evaluation not being addressed. This will facilitate the analysis of technologies which enter the evaluation process in a partially mature state by eliminating the need to start the evaluation at level 1. Continue refinement of tracks of TRL questions to facilitate focus on specific aspects of readiness. Started developing a stepwise guide for performing a TSRA to help with TRL tool development and orient the team that will be performing the TSRA of a fast reactor fuel cycle in FY18. Developed a draft of the upper level functional elements for the EG24 fast reactor fuel cycle.

Transition Analysis Studies

- **[ANL]** Using Argonne's MSR physics tools, developed fast spectrum chloride molten salt reactor core that fits into EG24 (fast spectrum, continuous recycle of U/TRU, NU feed only). From this model, fuel cycle mass flow rates and first core startup requirements were calculated and can be directly used in fuel cycle systems code such as DYMOND for technology-specific transition analysis. Some additional refinements to the model will be made (limited fission products removal, lower Cl-37 content, lower initial enrichment of LEU, etc.) but the final mass flows are expected to be similar and sufficient for comparison with those for SFRs.
- **[ORNL]** All analysis has been completed on the cross section vs. recipes assessment report, "Report Identifying the Value Added by Fuel Cycle Dynamics Tools Directly Using Cross Section Data". Work is progressing well on the report writing and assessment of the findings of the analysis. The report is on schedule for delivery on February 9th, 2018.
- **[INL]** Started the economic modeling for the study on transition economics. Used output data which is generated using the VISION model for alternative scenarios under consideration. For the cases of EG23 and EG30, the study quantifies the change in costs that result from phasing in separations and fuel fabrication facilities based on full capacity demand as opposed to building facilities at initial demand.

Regional and Global Analysis

- **[PNNL]** Prepared presentation material for upcoming OECD/NEA Expert Group meeting on Advanced Reactor Systems and Future Energy Market Needs.
- **[PNNL]** Updated GCAM model for FY18 US regional scenario analysis.

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

- **[INL]** Work continued on scoping and evaluating potential upgrades to the VISION model to support upcoming analyses. These include improvements to the recovered uranium management algorithm, rearranging of input and output files to improve workflow, reduce maintenance burden, and efficiently allow for runs of varying duration.

- **[ORNL]** Further investigation into the single stage MSR model in ORION revealed the differences between the reactor physics and fuel cycle models due to the lack of accounting of various effects seen in MSRs. Specifically, the heavy metal loading, fuel enrichment, specific power and fuel density are all increasing or decreasing over time for various MSR types. Current fuel cycles codes are unable to account for these varying parameters and as a result, there are noticeable differences seen between the mass flows calculated by the reactor physics and fuel cycles models. In addition to these varying parameters, the isotopics within the MSR fuel salt are continuously evolving over time and using cross sections instead of recipes allows the fuel cycles analyst the flexibility of running a fuel cycles model using any time step without having to generate recipes for each time step being used in the fuel cycles model. Generating recipes at each time step, especially if the time steps are kept small, can get cumbersome.
- **[ORNL]** Related to the above work and report on the assessment, a narrative on the generic fast spectrum molten salt reactor model used for the ORION fuel cycle analyses has been written. This narrative detailed the assumptions, material removals, and fueling scheme, and was folded into the larger paper that is being compiled on the ORION results. This work will also lay the foundation of the SFR vs. fast MSR assessments to be completed later in the FY, where the underlying cause of any fuel cycle differences in these two fast spectrum technologies will be evaluated.

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

Joint Fuel Cycle Study Activities

- The first and second U/TRU products were consolidated by melting in the casting/sampling furnace. Samples of the cast slug and residual metal heel were sent to the analytical laboratory at MFC for analysis. This completed the level 2 milestone "Prepare U/TRU Material for Casting of Recycled Fuel Slugs."
- Process experiments for the third U/TRU recovery were completed in December. This experiment used Li-Cd alloy to recover a mixed U/TRU product from the electrorefiner salt. This product will be sampled in January.
- Readiness reviews for operation of the electrorefiner scalability testbed glovebox were completed.

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
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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 completed reimbursements for the 2017 Innovations Award winners' travel expenses to the American Nuclear Society Winter Meeting in November.
- University Research Alliance continued preparing materials for the 2018 Innovations Awards.
- 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.