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ADVANCED FUELS CAMPAIGN

ADVANCED LWR FUELS

Metrics Development for ATF

- **[INL]** S. Bragg-Sitton and B. Merrill held a teleconference with researchers from General Atomics (GA) to discuss the possible use of the modified version of MELCOR for analysis of ATF. GA is interested in having INL extend the MELCOR work led by B. Merrill to update the SiC failure modes per their current data/understanding and to add U3Si2 fuel to the materials options. GA may also want to link FRAPTRAN with MELCOR. The discussion focused on feasibility, given GA provides the fuel data and SiC failure models. A follow-on discussion has been scheduled with GA management on Friday, September 8 to address timeline and funding for the proposed work. (S. Bragg-Sitton)

Analyses

- **[BNL]** The TRACE PWR plant model has been modified to enable the simulation of accident scenarios that assumed no mitigating actions. This is an effort to support the evaluation of the coping time of candidate ATF concepts. The first scenario analyzed was a station blackout (SBO), a high pressure event. The SBO transient was initiated by a reactor trip and primary pump trip at time zero. Active components that have the potential to influence the outcome of the SBO were disabled by modifying their trip or controller settings. Disabled components included makeup/letdown flow, pressurizer heater, pressurizer spray, pressurizer safety relief valve (SRV) and power operated relief valve (PORV). In addition, the primary loop was isolated from the secondary loop at the start of the transient. This was achieved by replacing the convective boundary condition on the outside wall of the steam generator U-tubes with an insulated boundary condition at time zero. The net result of the model represents a 'bottled' up reactor. The SBO with no mitigation is not expected to have any short term (minutes) effect on the fuel/cladding temperatures because the core is covered by coolant. Preliminary results indicate that it took about 150 s for the reactor pressure to increase by 45% (see Figure 1). In the longer term (hours) either the reactor vessel or primary loop components would start to leak or rupture due to high pressure or temperature. Subsequent to the loss of coolant the fuel would start to heat up, leading to potential fuel/cladding failure. Figure 2 shows the relatively slow heat up of the coolant. With the reactor at decay power level and the core fully covered, the fuel temperature is observed to follow the coolant temperature. It is of interest to simulate other variants of the SBO scenario that might lead to an earlier and more realistic time of core uncover. Future simulation will include a case of allowing the pressurizer SRV to actuate or a case of stuck open PORV. (L-Y Cheng)

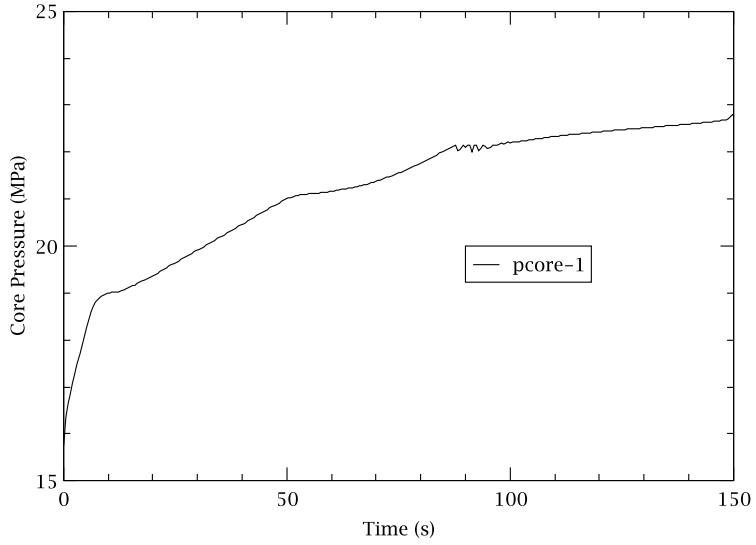


Figure 1. Core pressure.

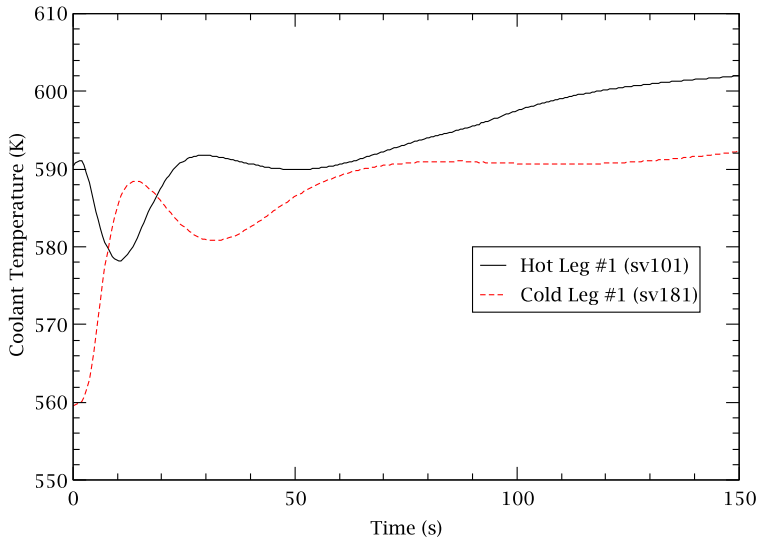


Figure 2. Coolant temperature.

- **[ORNL]** The Level 3 milestone (M3FT-17OR020205041) "Parametric and Experimentally Informed BWR Severe Accident Analysis Using FeCrAl," was completed. The oxidation kinetics of the 13 Cr-6 Al FeCrAl alloy were found to be higher than that of the commercial APMT FeCrAl alloy (~5x higher rate constant). These tests informed severe accident simulations in which the oxidation kinetics were parametrically varied over the observed range. Since FeCrAl's oxidation kinetics are a couple of

orders of magnitude lower than that of zirconium based alloys, the variations in FeCrAl kinetics had a secondary influence on the accident progression. Thus, the gains afforded by the FeCrAl ATF concept with respect to accident sequence timing and combustible gas generation were found to be consistent with previous efforts. In addition, the 13 Cr – 6 Al alloy will be used in the upcoming QUENCH test at KIT. This study has aided in the pre-test planning and future post-test analysis of the planned QUENCH test. (K. Robb)

LWR FUELS

- **[LANL]** Milestone NTRD-M3FT-17LA0202010311, titled "Property-Structure Relationships of U-Si-X Fuel Forms," was completed. The report summarizes structure-property relationships determined for the U-Si-Al system. The effect of aluminum additions have been previously demonstrated to improve the oxidation resistance of U3Si2 and are therefore of interest to overcome this key vulnerability. Synthesis and analysis of U2AlSi2, U3Al1.76Si3.24, UAlSi, and UAl2 was performed to assess basic phase stability in this system. Despite prevalence of U3Al1.76Si3.24 throughout all the samples, other phases were identified. Annealing provided no further homogenization of a single phase. UAl2 was successfully arc-melted and the coefficient of thermal expansion, heat capacity and thermal diffusivity were determined from room temperature to 1273K. This binary was included to provide a terminal comparison point for performance of these ternaries. A thermal expansion value of 1.49x10-5 K-1 was determined over the entire range. Thermal diffusivity increased linearly with temperature and the thermal conductivity was calculated as 8-18W m-1 K-1 over the investigated range. This work largely concludes AFC work in the area of U-Si-Al studies to improve the corrosion behavior of U-Si compounds. (C. Grote)
- **[LANL]** Synthesis of a series of high density U3Si2 monolithic samples containing controlled levels of oxygen was completed. The effect of oxygen on the properties of U3Si2 is known to be of importance to the industrial fabrication of U3Si2 given that the conditions used in the laboratory are unlikely to be retained at scale. Six different composition sets of U3Si2 containing oxygen levels ranging between 500 and 20,000 weight parts per million were fabricated at a range of sizes but at densities between 90 and 95 percent theoretical. Microstructural characterization is ongoing. These samples will provide the basis for a series of property measurements to be presented in a September milestone. (J. Dunwoody).
- **[ORNL]** The successful completion of Level 2 milestone (M2FT-17OR020201071) is described in a report titled, "Post-Fabrication Characterization of High Density Uranium Bearing Ceramics." The report highlights a fruitful example of inter-laboratory collaboration where high density fuel specimens prepared at LANL underwent detailed characterization at ORNL. High density U ceramics are of great interest to AFC but remain far less understood with respect to their basic structure and chemistry compared with more established fuels. This report provides a summary of advanced characterization studies performed on uranium mononitride (UN), and two uranium silicide (U3Si2 and U3Si5) ceramic fuels. Specifically, modern electron microscopy tools and techniques were utilized to characterize the microstructure and chemistry of these high density U-bearing ceramics. Unprecedented detail on chemistry and structure of the native oxide of these materials on the nanometer scale was provided by this work. This information is key for interpretation of degradation mechanisms relevant to light water reactor deployment of these materials. Further, electron backscatter diffraction maps were collected for the first time on these materials (Figure 3). These results demonstrate the potential for future studies to provide representations of authentic fuel microstructures to members of the modeling and simulation community who are presently exercising BISON and other tools to explore in-pile evolution of these fuel concepts. (K. Terrani)

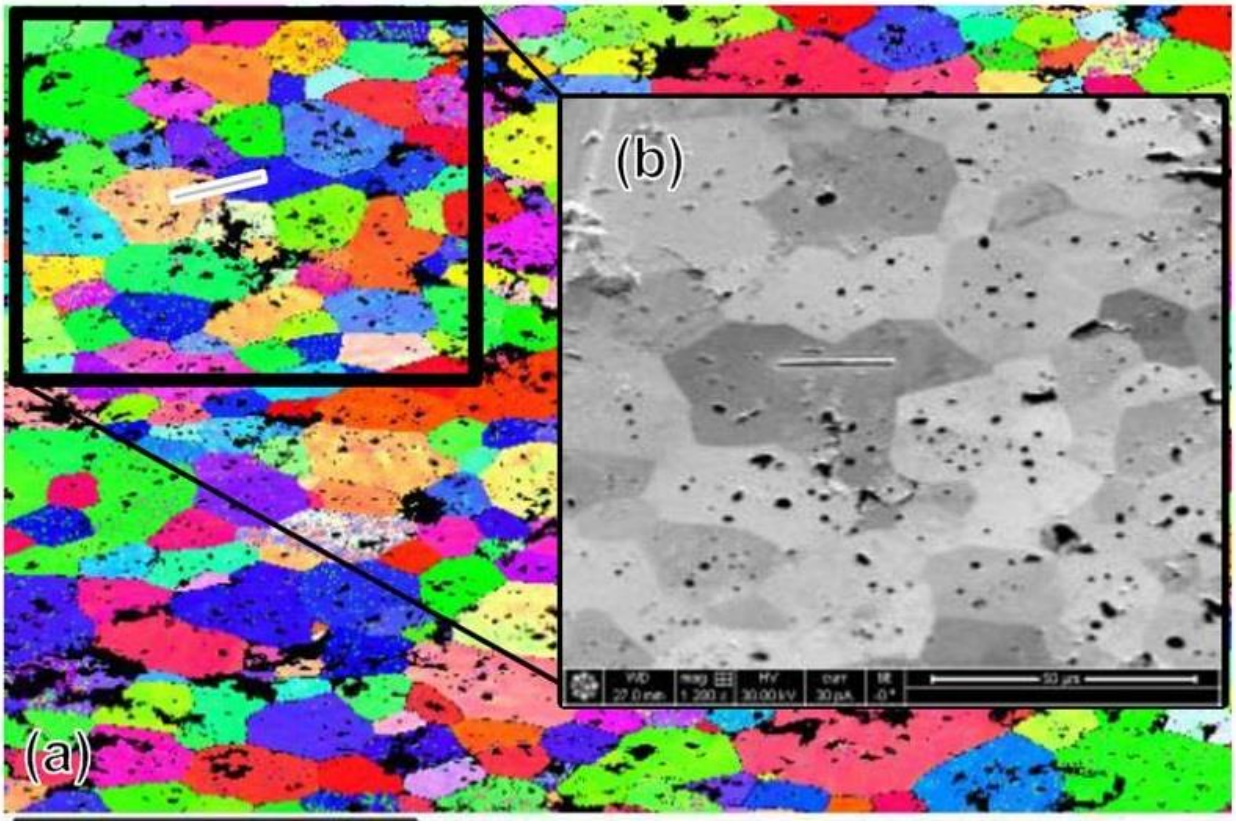


Figure 3. a) EBSD grain orientation map of polished UN pellet (35P-358, M107050803), and b) magnified ion beam image of selected grains for TEM.

- **[LANL]** Milestone report M3FT-17LA020201023, titled "Assessment of preferred field assisted sintering techniques for ATF composites," was completed. In this report, the fabrication of high density UB_2, UB_4, UO_2-UB_2 and UO_2-UB_4 pellets via spark plasma sintering (SPS) is reported. An initial assessment of the thermophysical properties of the UO_2-UB_2 composites, with 5, 15 and 30%wt UB_2 was carried out. A significant increase in the thermal diffusivity of the UO_2-30%wt UB_2 composite was observed, compared to UO_2. Calculated thermal conductivities for these composites also follow this trend, with the 30%wt UB_2 composite showing a 50% increase compared to UO_2, as shown in Figure 4.

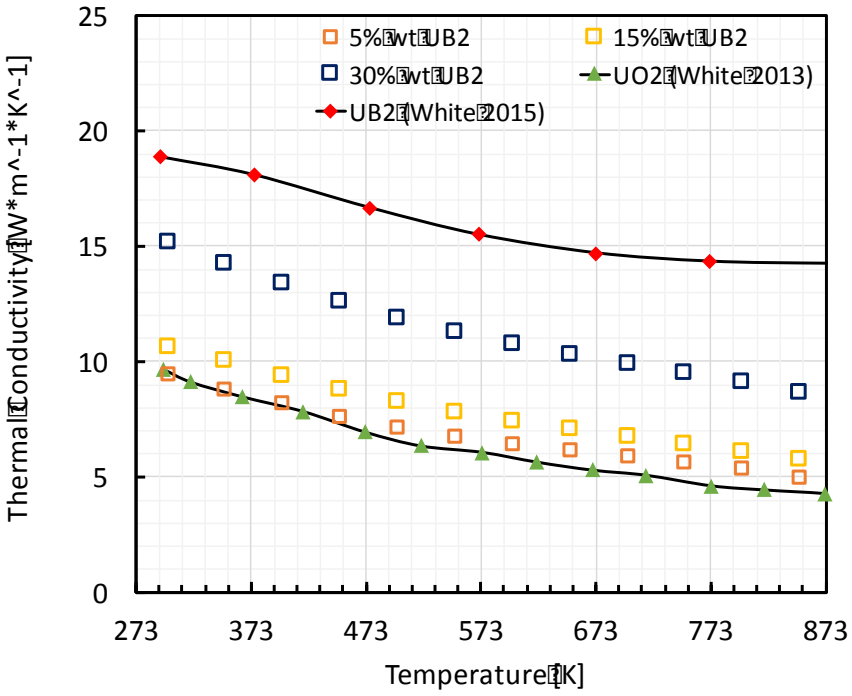


Figure 4. Calculated thermal conductivity values as a function of temperature for UO_2-UB_2 composites (squares) together with reference thermal conductivity data on UO_2 and UB_2.

Furthermore, an assessment as to the preferred field assisted sintering technique for fabrication of proposed ATFs was carried out based on the reported SPS data and previous data on the flash sintering (FS) of UO_2-UB_2 composites. Based on our current understanding, UO_2 composites with metallic phases are not expected to work well with FS, we believe due to inhomogeneous current density associated with the distribution of the highly conductive secondary phases (i.e. UB_2 or UB_4). Also, we don't expect FS to work well on pure metallic fuels due to the negative feedback relationship between current and temperature, preventing a current runaway. As things stand, SPS is proposed as the preferred method for sintering metallic composites as the heating profile during sintering is defined by the user and is not controlled by the material resistivity as it is in FS. (E. Kardoulaki, LANL)

- **[LANL]** A workshop on laser-driven neutron sources was held at the Los Alamos Neutron Science Center (LANSCE) on August 16th, 2017. Based upon a Level 3 milestone report, "Assessment of Laser-Driven Pulsed Neutron Sources for Poolside Neutron-based Advanced NDE – A Pathway to LANSCE-like Characterization at INL," submitted April 14, 2017 (NTRD-FUEL-2017-000064), it was determined that this workshop sought technology that was relevant to the NE mission. The workshop brought together experts in plasma physics, high intensity lasers, laser target fabrication, spallation physics, and applications for intense pulsed neutron sources. In essence, the workshop established that laser-driven neutron sources may provide LANSCE-like characterization capabilities with pulsed neutron in the not too distant future for advanced, nondestructive examination (imaging and diffraction) at NE testing facilities. The outcome of the workshop was presented to Ken Kellar at LANL on August 21, 2016. (K. McClellan)

- **[INL]** U3Si2 fuel fabrication to support the ATF-2 test and General Atomics' Silicon Carbide cladding concept has been restarted in the Fuels and Applied Sciences Building (FASB) after a short delay to reconfirm correct enrichment. (G. Core)
- **[INL]** Many of the 5 w/o U-235 enriched U3Si2 fuel pellets have been successfully centerless ground to the as-required outside diameter (Figure 5 and Figure 6). (G. Core)

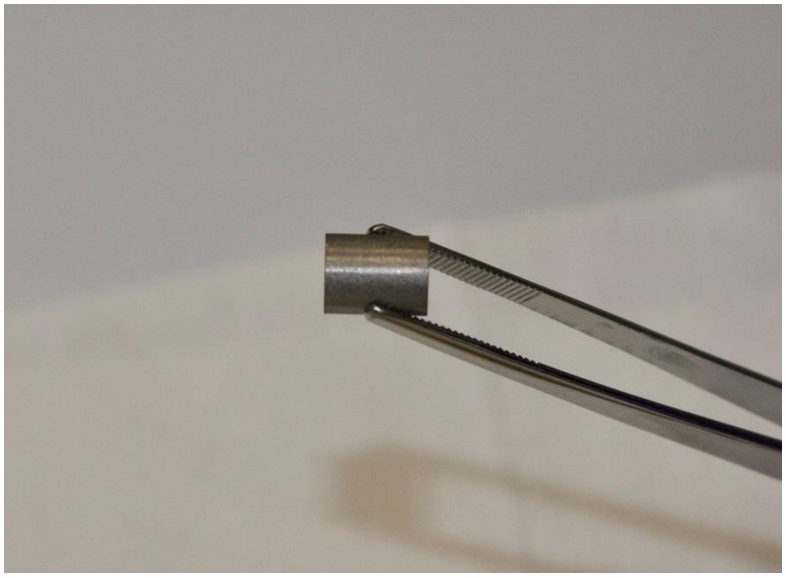


Figure 5. As-ground finished U3Si2 fuel pellet.

Figure 6. As-ground finished U3Si2 fuel pellets.

- **[INL]** The team received the final analytical laboratory results including XRD, chemical analyses, and isotopic analysis for a majority of the 5 w/o U-235 enriched U3Si2 fuel pellets. All results confirm that the fabricated fuel meets the approved specification. (G. Core)

- **[INL]** GE Fuel Fabrication Milestone M3FT-17IN02020110 was completed on 8/1/17. The completion of this milestone allows the INL to make an informed decision about the risk of using APMT in the as-received condition in the ATF-2 test. Further testing is planned to evaluate the effect of heat treating prior to and after performing a weld with 300-series stainless steel. (G. Core)

LWR CORE MATERIALS

Thin Walled Tube Development

- **[INL]** Samples 38-13 – 38-16 were welded using the PRW system. Samples 38-13 and 38-14 utilized the revision-10 endplug design and samples 38-15 and 38-16 utilized the r11 endplug design. Based on the tensile results of samples 38-5 and 38-6, which used the revision-10 endplug design, samples 38-13 and 38-14 were bonded at increased currents. Again, due to the tensile results of samples 38-9 and 38-10, which used the revision-11 endplug design, samples 38-15 and 38-16 were also joined with increasing current. As can be seen in Figure 7 below, all the samples show increased joining current and subsequent joining energy. Samples were bonded to explore the bond strength when welded using increased current. Samples have been passed off for X-ray CT analysis. *NOTE: joining force & joining time were maintained at 1100 lbs, & 2 cycles, respectively.* (J. Gan)

Sample 38-13
R10 endplug design
Time: 2 cycles
Current: 12.53 kA
Energy: 1202 J
Force: 1100 lbs_f

Sample 38-14
R10 endplug design
Time: 2 cycles
Current: 13.58 kA
Energy: 1343 J
Force: 1100 lbs_f

Sample 38-15
R11 endplug design
Time: 2 cycles
Current: 14.36 kA
Energy: 1365 J
Force: 1100 lbs_f

Sample 38-16
R11 endplug design
Time: 2 cycles
Current: 15.08 kA
Energy: 1606 J
Force: 1100 lbs_f

Figure 7. Samples 38-13 through 38-16.

- **[INL]** LBW samples 37-3 – 37-6 were prepared for elevated temperature testing. First, all four samples underwent a post-weld heat treatment process of 700°C for 2hrs under an argon atmosphere. (Figure 8). To get more accurate sample surface temperature data, type K thermocouple wires were

bonded to the upper section of each weldment endplug. The thermocouple wires used were 24 gauge (0.020" dia.) and were bonded to the external surface using a discharge welding system (Figure 9).

A dummy sample using an attached type k thermocouple was loaded into the Instron furnace and taken to 300°C to evaluate the variation between the sample surface and furnace temperatures. It was found that after several hours, the temperatures stabilize to where the sample surface temperature is ~5°C cooler than that of the furnace. Thus, the furnace temperature will be operated at 305°C. With all the checks on the Instron furnace complete and with confidence in the new fixtures (see next section), testing of samples 37-3, 37-4 & 37-5 at elevated temperature will be completed early next month. (J. Gan)

Figure 8. Samples 37-3-37-6 after heat treatment.

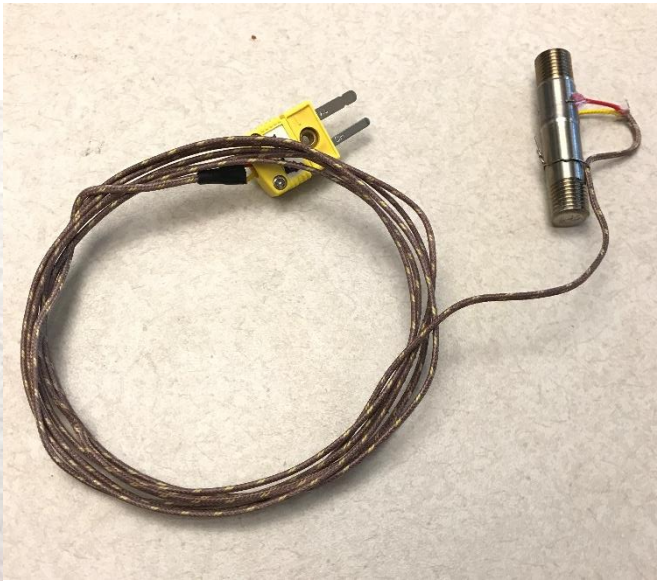


Figure 9. Sample 37-4 with t/c attachment for elevated temperature testing.

- **[INL**] In preparation for elevated temperature testing of samples 37-3 – 37-6, it was determined testing one of the samples at room temperature using the fixturing to be used for elevated temperature testing would give confidence in the fixturing setup – the sample would act as a 'control sample.' Sample 37-6 was thus tested at room temperature using the elevated temperature testing fixturing. (Figures 10 through 12). Sample 37-6 mechanically performed as previous LBW samples performed that were welded using the same welding parameters. Through testing, sample 37-6 underwent significant deformation in the tube section followed by failure in the tube. No issues were experienced using the new fixturing. The measured tensile and yield strengths are in agreement with previously tested laser welded samples and with that of Kanthal D as a material.

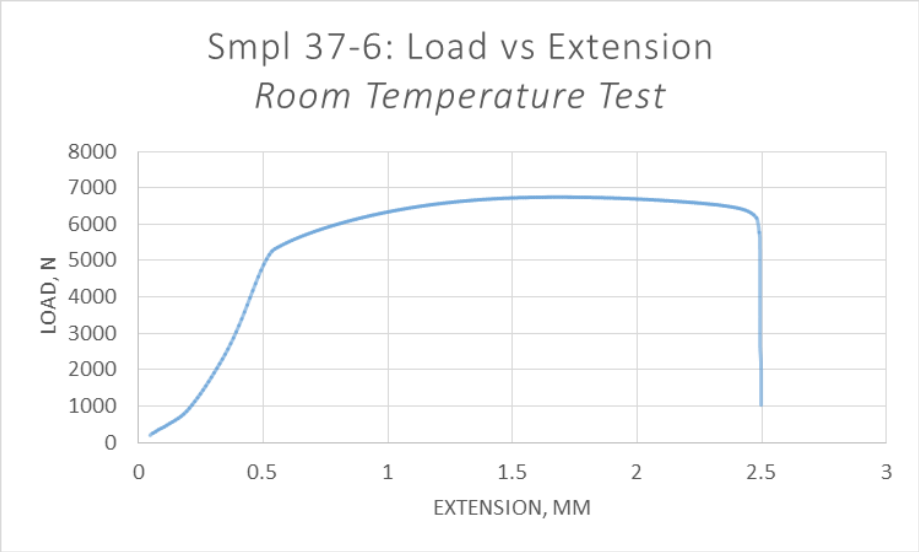


Figure 10. Sample 37-6 load vs. extension room temperature test.

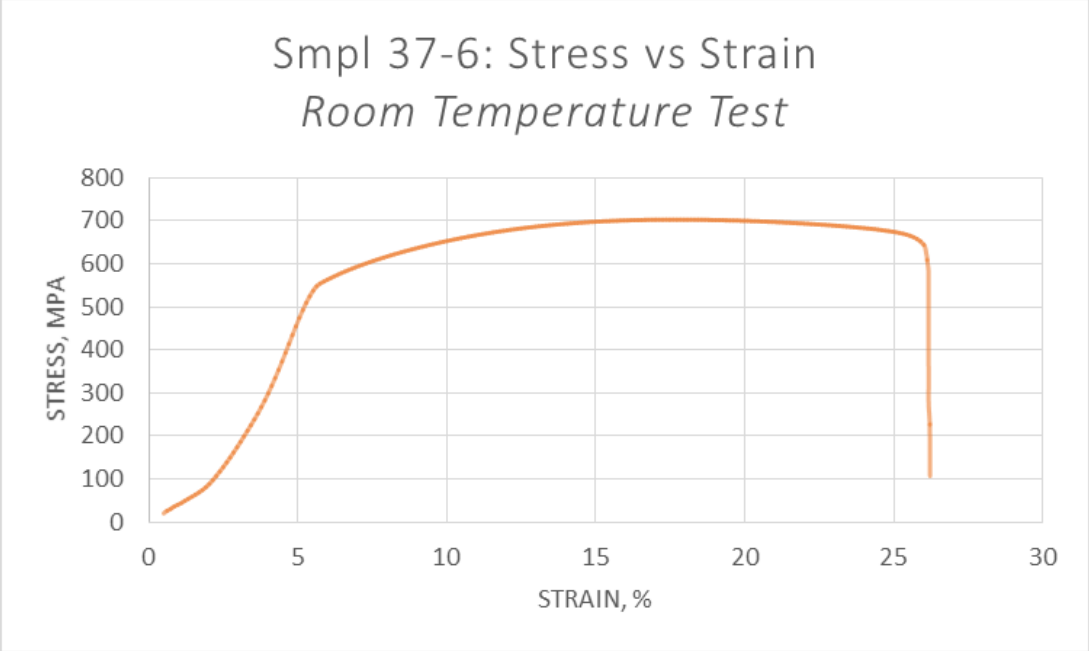


Figure 11. Sample 37-6 stress vs. strain room temperature test.

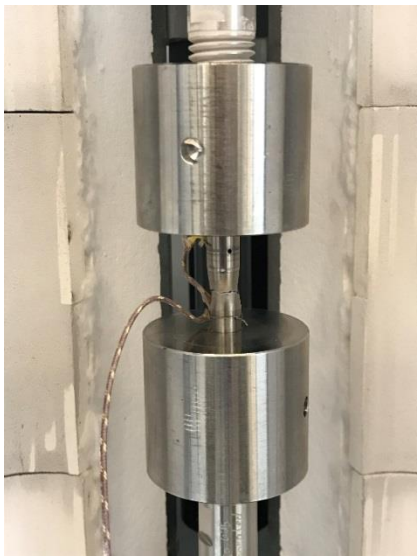


Figure 12. Sample 37-6 after tensile testing using the elevated temperature testing fixtures, within the Instron furnace.

- **[LANL]** A tube of Gen II FeCrAl alloy was received from ORNL which will be characterized through EBSD analysis and nanohardness testing to meet a L3 milestone. (S. Maloy)

Advanced LWR Materials Development and Testing

- **[LANL]** Initial testing of HFIR irradiated FeCrAl alloys is underway to meet the L2 milestone due in September. (T. Saleh)
- **[ORNL]** Procurement of seamless Gen II. C26M alloy tubes (Fe-12Cr-6Al-2Mo-Si-Y, wt.%) with 9.5 mm outer diameter is in progress. The master bar production of Fe-12Cr-6Al-2Mo base alloy (C26M2, heat #17025001) with 1.000" +/- 0.001" diameter was completed, and the surface inspection through dye penetration technique was conducted at ORNL. It was found that only one bar exhibited a shallow scratch on the surface. The master bars were shipped to Century Tubes, Inc., with the inspection results, and the gun-drilling process was initiated. The expected delivery date is November/December 2017. (Y. Yamamoto)
- **[ORNL]** Size inspection of C26M tubes and C26M2 wires, to be delivered to GE/GNF, was completed. All products met the size specifications. The inspection certificates were issued by the meteorology department at ORNL. (Y. Yamamoto)
- **[ORNL]** Room-temperature tensile properties of powder metallurgy APMT alloys and newly-developed wrought FeCrAl alloys have been evaluated and correlated with the Charpy test results. Residual strain observed in the as-received APMT alloys with fine grain structure, as well as 10% warm-rolling applied to the wrought FeCrAl alloys, increased the yield strength significantly compared to the same alloys with less/no residual strain. On the other hand, considerable deformability with ~0.1-0.15 uniform plastic strain was observed in the alloys with reasonably fine grain structure, no matter whether the residual strain existed or not. Since the deformability is more important in FeCrAl alloys for the tube production process, and the impact toughness would be improved by minimizing/eliminating the residual stress, the property improvement of the FeCrAl alloys could be expected by balancing the grain refinement and reduction of the residual strain. Lowering the ductile-brittle transition temperature (DBTT) is another concern in improvement of

FeCrAl alloy properties, and additional Charpy tests have been performed to accurately determine DBTT and the upper shelf energy of tests alloys. (Z. Sun, Y. Yamamoto)

- **[LANL]** Ion irradiation was completed on two FeCrAl alloys (B136Y3 and C35M4). Irradiation was performed with Fe ions to doses up to 70 dpa. Characterization of these samples is underway which will include nanohardness testing and TEM analysis. (S. Maloy)
- **[LANL]** Tube ring pull testing is underway on two Generation I FeCrAl alloys in preparation to meet the L3 milestone in September. (S. Maloy)
- **[ORNL]** Two ODS Fe-10Cr-6Al-0.3Zr+Y2O3 sheets, 3mm in thickness, were cold rolled with thickness reduction of 40%, 10% per pass. The procedure was repeated four times to obtain ~0.6mm thick foils. Tensile testing of the foil revealed a significant increase of the alloy strength but decrease of the ductility, with ultimate tensile strength values of ~1500 MPa but elongation at ruptures below 6%. These results confirm the need of intermediate heat treatment to fabricate tubes by cold pilgering. (S. Dryepondt)
- **[ORNL]** The Level 3 milestone (M3FT-17OR020202104) titled, "SiC/SiC Cladding Materials Properties Handbook," has been completed. Properties of SiC composites were summarized for better multi-physics modeling of ATF SiC cladding. The report presents various properties, including mechanical properties, thermal properties, chemical stability under normal and off-normal operation conditions, hermeticity, and irradiation resistance. (T. Koyanagi, Y. Katoh)
- **[ORNL]** A level 3 milestone report titled "Interlaboratory Round Robin Study on Axial Tensile Properties of Tubular SiC/SiC Specimens," was submitted. The milestone report presents the statistics on the mechanical properties of nuclear grade SiC/SiC composite and the precision statement for the ASTM standard C1773 which is employed for testing ceramic fiber reinforced ceramic matrix composite tubes. Based on the same work, a manuscript for journal publication was submitted to the *International Journal of Applied Ceramics Technology*. (G. Singh, Y. Katoh)
- **[ORNL]** A manuscript ("Evaluating the Irradiation Effects on the Elastic Properties of Miniature Monolithic SiC Tubular Specimen", G. Singh, T. Koyanagi, C. Petrie, K. Terrani and Y. Katoh) was submitted for publication to the *Journal of Nuclear Materials*. The initial results of the post-irradiation examination study conducted on CVD SiC tubular specimens irradiated under a high radial heat flux are presented in the paper. The elastic moduli were found to decrease more than that estimated based on previous studies. The microscopy examination revealed cracks in the specimens and the significant decrease in moduli was attributed to these cracks. (G. Singh, T. Koyanagi, Y. Katoh)
- **[ORNL]** A report titled, "Steam Oxidation Testing in the Severe Accident Test Station," was submitted to complete milestone M3FT-17OR020202111. A paper titled, "Steam Oxidation Behavior of FeCrAl Cladding," was presented at the 18th International Conference on Environmental Degradation of Materials in Nuclear Power Systems in Portland, OR. To provide integral data for accident models, materials interaction tests continued this month in the high temperature furnace examining interactions between FeCrAl and core materials such as structural alloys and B4C in steam at ≥1300°C. Unlike Zr-based alloys, less interaction was observed. (B. Pint)

LWR IRRADIATION TESTING & PIE TECHNIQUES

- **[INL]** All optical microscopy was completed on ATF-1A (see Figure 13). These exams allow for the first true examination of the microstructure of these different transmutation fuel forms. Features in these micrographs will be studied extensively to understand the evolution of this fuel under irradiation, as this fuel is UO_2 based. The results of this exam appear to be highly useful for validating UO_2 models. (J. Harp)

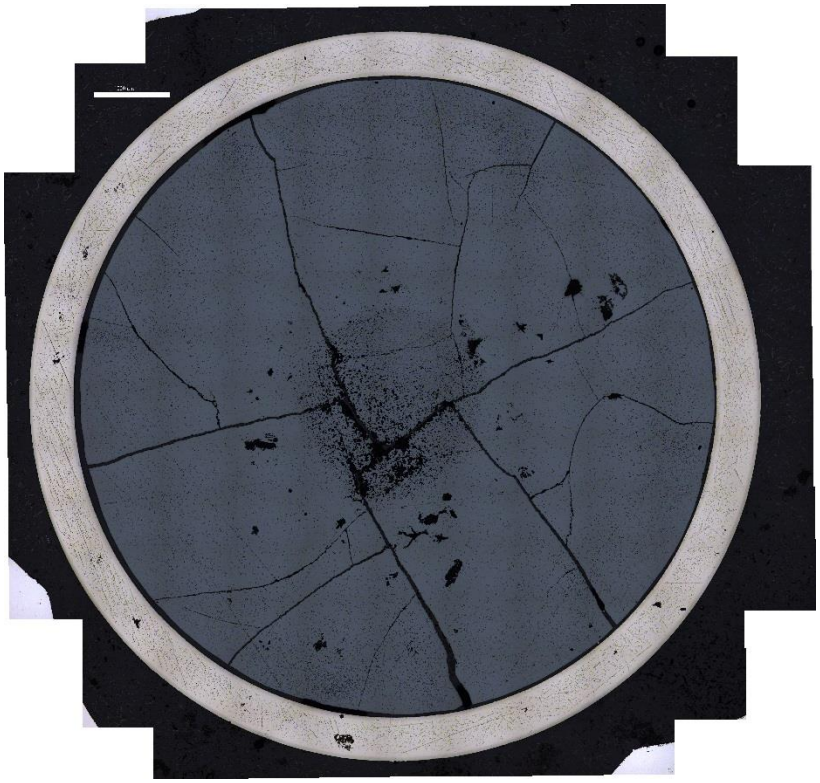


Figure 13. Optical microscopy imaging of the ATF-1A R01 (SPS fabricated UO2 clad in Zircaloy-4) irradiated fuel.

- **[INL]** Gamma tomography was performed on the ORNL concept ATF-1 pin (UO2 FeCrAl) to identify the radial distribution of fission products in this fuel. (J. Harp)
- **[INL]** The Accident Tolerant Fuels 2 (ATF-2) Sensor Qualification Test (SQT) experiment assembly was completed on August 3, 2017. The level 3 milestone, M3FT-17IN020203043, "Complete ATR Safety Documentation (ESA) to Support SQT," was completed on August 7, 2017. The Experiment Safety Analysis (ESA) documents the SQT compliance with the Advanced Test Reactor (ATR) safety basis and is required for insertion and irradiation. Installation of SQT support equipment (electrical and gas panel systems) was completed and support equipment testing is in progress. 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)
- **[ORNL]** The deformed structure of C35M after tensile testing was investigated using advanced electron microscopy studies. In the highly deformed region, only dislocation pile-ups and dislocation entanglements were observed, no localized deformation was observed. Results suggest vastly different deformation modes in FeCrAl alloys compared to austenitic stainless steels. (D. Zhang/K. Field).

- **[ORNL]** Milestone M3FT-17OR020203031, "ATF FeCrAl Cladding Handbook of Properties," was successfully completed on August 4th. The milestone report establishes a consolidated database on materials properties in varying FeCrAl alloys for nuclear power applications. (K. Field)
- **[INL]** The Transmutation Fuels Handbook Level 2 milestone was met with the final release of the Metals Fuels Handbook Parts 1 and 2. (C. Papesch)
- **[INL]** The year-end final report for the NEAMS model verification is being drafted and will be sent out for review. (C. Papesch)
- **[INL]** The phase diagram development final report is being drafted and will be sent for review. (C. Papesch)

LWR TRANSIENT TESTING

- **[INL]** Comment resolution on comments received during the –CAL vehicle design review has begun. Resolving the design comments is the critical step to beginning fabrication of a –CAL vehicle to be used at TREAT. Additionally, quality level determinations have been updated and are now being used to begin the purchase of long lead items which are needed to support the fabrication of –CAL in FY18. (J. Schulthess)
- **[INL]** Transient prescription data package development began this month. The transient prescription will describe experiment objectives, requirements, and parameters for the primary purpose of providing TREAT personnel the necessary information to prepare for and run the desired transient. (A. Beasley)
- **[ORNL]** The Level 2 Milestone, "In-Cell Installation and Demonstration of the Severe Accident Test Station," was completed. A Severe Accident Test Station (SATS) capable of examining the oxidation kinetics and accident response of irradiated fuel and cladding materials for design basis accident (DBA) and beyond design basis accident (BDBA) scenarios has been successfully installed and demonstrated in the Irradiated Fuels Examination Laboratory, a hot cell facility at Oak Ridge National Laboratory. Two test station modules provide various temperature profiles, steam, and the thermal shock conditions necessary for integral loss-of-coolant accident (LOCA) testing, defueled oxidation quench testing, and high-temperature BDBA testing. Installation of the SATS system restores the domestic capability to examine postulated and extended LOCA conditions on spent fuel and cladding and provides a platform for evaluating advanced fuel and accident-tolerant fuel cladding concepts. The LOCA demonstration test (Figure 14) was performed with an unirradiated Zircaloy-4 tube. Figure 15 shows the temperature and pressure profile for integral LOCA demonstration test Zr4-26, performed on the in cell SATS. (K. Linton, Y. Yan)

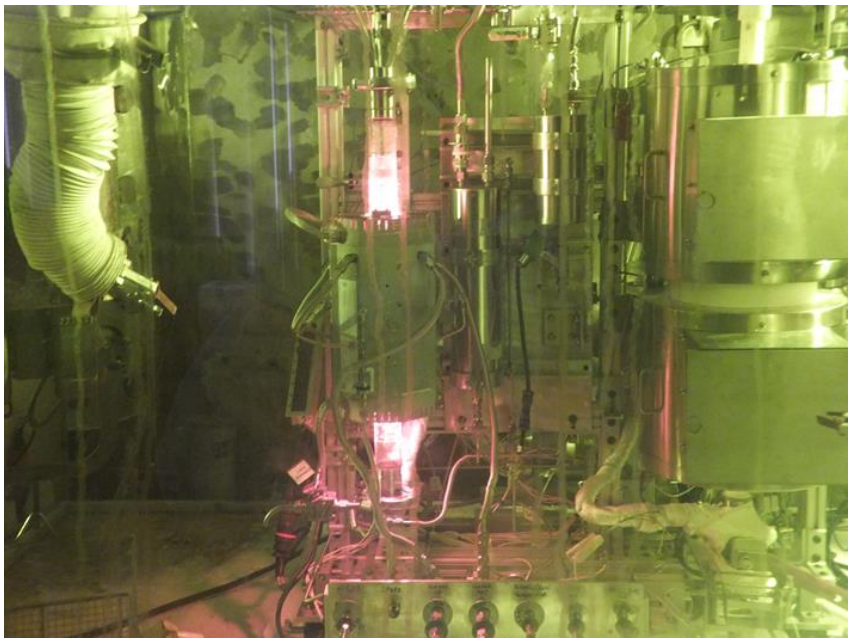


Figure 14. A full LOCA sequence was performed in Building 3525, the Irradiated Fuels Examination Laboratory (IFEL) at ORNL. The orange glow from the infrared furnace occurs during the LOCA simulated heating ramp as it approaches the peak temperature of 1200°C.

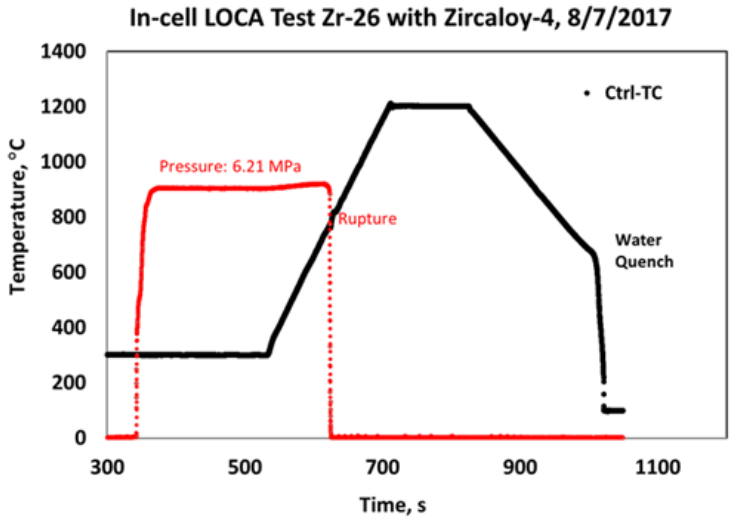


Figure 15. Pressure and temperature histories for in-cell LOCA integral test Zr4-26.

- **[ORNL]** A deliverable report titled, "RIA simulation tests using driver tube for ATF cladding," was released. The report depicts the progress in the transient test development for ATF cladding which involves the capability of the test rig with mechanical pulse control, employment of a mirror system to the mechanical frame for 360°-view of the sample (see Figure 16 and Figure 17), and the selected experiments of ATF candidates of FeCrAl and SiC composites. Six mirrors were used to obtain the image of the sample on the camera from the object's reflections as depicted by the schematics of the mirror set up in Figure 16. A label shown in Figure 17(a) was attached to the driver tube's outer

surface for the verification of the 360°-view of the sample as shown in Figures 17(b) and (c). (M. N. Cinbiz, N. R. Brown (PSU), R.R. Lowden, K. A. Terrani, K. Linton)

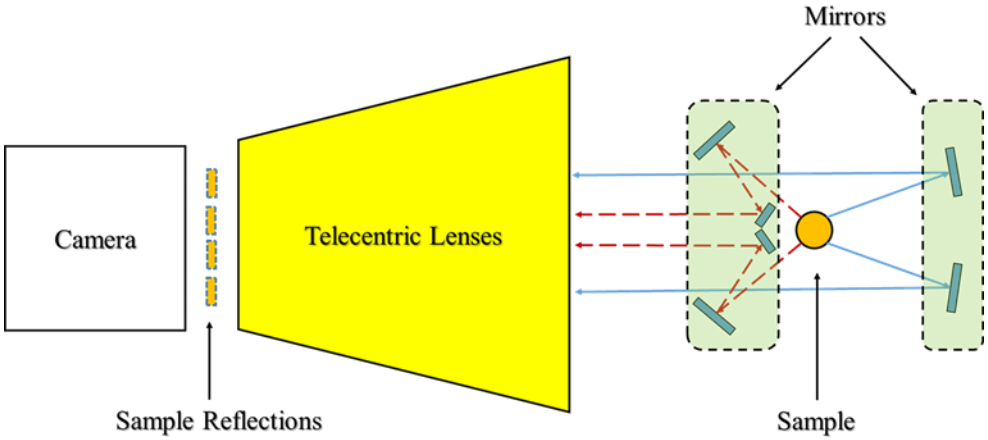


Figure 16. Schematic of the 360°-view concept for tube samples

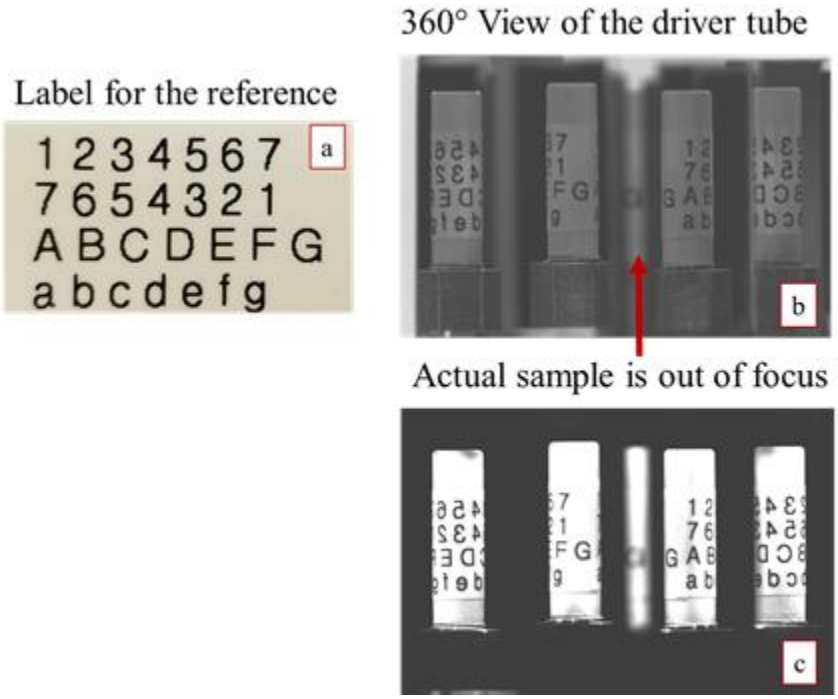


Figure 17. (a) Label attached on the tube surface, 360° view of the outer surface of the tube with label under low light (b) and lighting conditions for tests (c)

ADVANCED REACTOR FUELS

AR Computational Analysis

- **[INL]** The Bison code repository has been updated with new and modified code kernels for MOX pore migration and actinide redistribution with documentation and regression tests. Work is underway to try to resolve the differences between CEPTAR and Bison. Now that the latest MOX capability is available on the repo, we hope a resolution will quickly follow. We are also planning for Dr. Ozawa from JAEA to visit the INL to help with MOX capability development (CNWG activity). (P. Medvedev)
- **[INL]** An example problem that uses the new tensor mechanics material version of several metallic fuel models has been pushed to the Bison repository. Work on implementing anisotropic swelling for metal fuel, based on models found in literature, has continued and is progressing. (P. Medvedev)

AR Fuels Development

- **[ANL]** In order to reduce temperature gradient in an Americium-bearing blanket (AmBB) assembly and increase the Am transmutation rate, a small addition of fissile has been proposed by the CEA. The performance with 5% Pu-239 in each AmBB pin was evaluated and compared with the original AmBB concept that does not have fissile. The addition of fissile increases the average flux and power, which decreases the flux gradient between the hottest and coldest pins in the AmBB assembly (see July monthly). However, there was no noticeable change of Am transmutation rate with fissile addition, which is inconsistent with the claimed performance by CEA. The reason for this inconsistency was investigated and it was concluded that the addition of Pu reduced low energy neutrons (i.e., hardened neutron spectrum) where Am has high capture cross section (<3kEV). Thus, to achieve both goals of flat temperature distribution and high Am transmutation rate, addition of moderators was recommended (see performance Table below) (Aliberti)

Case	Reference (no fissile added)	5 at% Pu239 added	5 at% Pu239 added with ZrH
Total power in target AmBB at BOC, MW	0.37	1.20	1.20
Fraction of low energy (<3keV), %	6.2	4.8	26.9
Am241 transmutation rate (1-BOC/EOC)	33.2	35.9	86.4

- **[INL]** The level three milestone to fabricate and analyze actinide standards for the EPMA was completed. Completion of this task was an important stepping stone in the process to set up the EPMA to run radiological samples in IMCL. (L. Squires)
- **[INL]** Acceptance testing of the stoichiometry control system was initiated in August. During testing, all gas flows, furnace operation, oxygen monitor operation, and user configurable control software were verified. During verification, it was discovered that the mass flow controller and the newly installed rotameter do not correlate as well as the argon and nitrogen systems. The source of the error, whether due to the mass flow controller drifting out of calibration or due to the rotameter being inaccurate is not well understood at this point. During further testing, trends will be verified and further investigated. Only low temperature testing, up to 1000°C was performed on the sintering furnace. Although some control issues were seen, it is expected that through furnace tuning these can be remedied, especially at higher temperatures. A few minor modifications were made to the oxygen monitoring and control software. Originally the software was designed to be controlled based on moisture level of the cover gas. This was changed to monitor moisture level, but control the oxygen partial pressure of the gas flowing into and out of the furnace. System testing has gone well overall with a few minor modifications. (R. Fielding)
- **[INL]** Traditionally, transmutation fuel has been produced through casting, however, other fabrication methods may also have benefits. A possible method of fuel fabrication currently being investigated is extrusion. Although extrusion will be difficult to implement remotely, it carries the

advantage of possibly being able to produce long annular fuel slugs, in much the same way as tubing is currently extruded in other metal industries. To investigate the extrusion of U-10Zr and U-6Zr alloys, two extrusion billets of that composition have been cast. The billets are approximately 2-2.5 kg in mass, and 3.8 cm in diameter. Although it is possible to extrude bare uranium alloys, these billets will be canned in a zirconium can. When extruded, the can will form an integral fuel cladding chemical interaction barrier on the outside surface of the fuel. The zirconium cans have been machined per the sketch shown in Figure 18. Overall length of the zirconium can is 9.59 cm, outside diameter is 3.43 cm, and wall thickness is .28 cm. The uranium alloy billets will be machined to slip into the cans and seal welded in preparation for extrusion. A third can was also fabricated approximately 15.2 cm in length. This will be used to investigate casting directly into the can. If the zirconium can is successfully cast into and a bond formed between the fuel and the can, the billet machining and can seal welding steps can be avoided and the assembly extruded directly after casting. (R. Fielding)

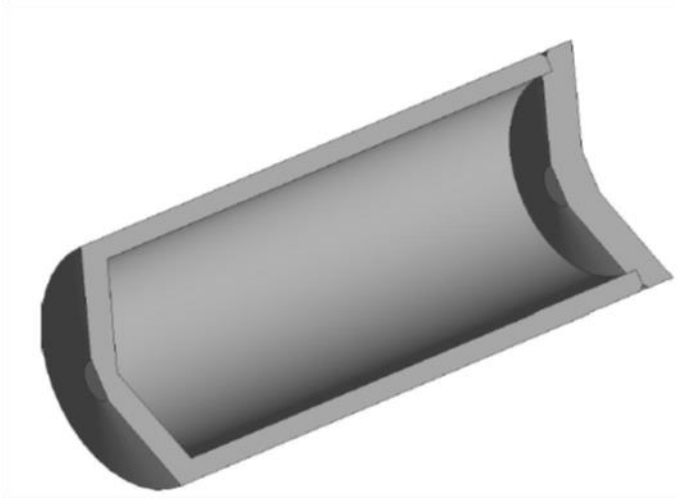


Figure 18. Schematic model of the zirconium can to be used for zirconium/U-Zr co-extrusion.

AR Core Materials

- **[LANL]** Final ring pull testing is underway on the BOR-60 irradiated 14YWT tube. This data will be added to the L2 milestone report by the end of September. (T. Saleh)
- **[PNNL]** Edits to the draft version of Milestone report, "M3FT-17PN020302043-Issue Report on Microstructural Studies on Neutron Irradiated MA957 (FY15)," had to be delayed due to other program priorities. The projected completion date is now late September. (M. Toloczko)
- **[PNNL]** Atom probe investigations of 500 dpa ion irradiated 14YWT continued. At least 3 APT specimens (in most cases 4 or 5) have now been examined for all KIPT ion irradiated specimens irradiated to 100 dpa and 500 dpa. Unirradiated material has also been examined. Preliminary analysis is showing no obvious effect on the YTiO oxide particle population after 100 dpa, while at 500 dpa, the data show evidence of ballistic dissolution for irradiation at 400°C and possible refinement (reduction in size and increase in number density) of the oxide particle population at 500°C. The ballistic dissolution after 500 dpa at 400°C matches the response of MA957 ion irradiated at the same conditions, but the response after 500 dpa at 500°C does not make sense and is different than what was observed for MA957. Additional exams are planned for the 500°C/500 dpa specimen. (M. Toloczko)
- **[PNNL]** A manuscript on the topic of identification of carbon contamination in ion irradiated materials was submitted and accepted for review by *Scientific Reports*. A manuscript is being

prepared that introduces a new and improved way to identify and measure the size of precipitates observed in APT studies. This method is based on an open source algorithm called OPTICS that is designed to characterize spatial variations in density of populations of items such as atoms. It is felt that this method will become the standard for automated identification and quantification of precipitates in APT studies due to its more accurate algorithm for identification of clusters and its ease of use. (M. Toloczko)

- **[PNNL]** Hardness testing has been started on several neutron irradiated materials in support of the milestone M3FT-17PN020302042. Three alloys are currently being tested. (M. Toloczko)
- **[LANL]** In an effort to determine the effect of nitrogen on irradiation resistance of HT-9, two HT-9 alloys with high and low nitrogen content are being strained in the TEM after ion irradiation. Initial results on the high nitrogen alloy show localized deformation and very low ductility. Testing of the low nitrogen alloy is underway. (S. Maloy)
- **[PNNL]** The second set of new thermomechanical processing (TMP) routes was designed for HT9 steels applied to the alloys with and without nitrogen addition (LANL alloys). This is part of the effort to improve the high-temperature performance of HT9 steels for fast reactor application. The newly proposed final processing steps include single-step tempering at low temperatures (300–600°C) and two-step tempering (i.e., the low-temperature tempering plus 650°C tempering). These treatments are expected to produce various tempered martensitic structures in HT9 steels but with lower degrees of tempering when compared to the typical tempering at ~750°C for 0.5–1 hour. Preliminary mechanical characterization will follow to select appropriate TMPs for further analyses. (T.S. Byun)
- **[PNNL]** As part of the program to fabricate tubing from difficult-to-fabricate materials, MA956, 9YWT, and 14YWT are being extruded and pilgered to final dimensions. Plans are being developed to modify an existing rolling mill for use as a pilger mill. The chuck with gearing which will be used to rotate the tubing being pilgered is shown in Figure 19 below. The next activity in this modification is to design and then fabricate the rollers which will be used for pilgering. It is anticipated that the rollers will be designed and fabricated next fiscal year. Subsequent activities for next fiscal year will be to take extruded thick wall MA956 and 14YWT tubes and pilger them, developing the characteristic process parameters for this pilger mill along the way. (R. Omberg)

Figure 19. Chuck and gearing used in Roller Mill modification to a Pilger Mill.

AR Irradiation Testing & PIE Techniques

- **[INL]** The milestone M3 – "Revise the Advanced Reactor Fuels Irradiation Experiment Design Objectives Report," was completed on 8-15-2017. This report looks at irradiation testing history and post irradiation examination results in order to develop the rationale for the activities needed to support the development of advanced metallic fast reactor fuel systems. (D. Dempsey)
- **[INL]** All optical microscopy was completed on AFC-4A (Figure 20). These exams allow for the first true examination of the microstructure of these different transmutation fuel forms. Features in these micrographs will be studied extensively to understand the evolution of this fuel under irradiation. (J. Harp)

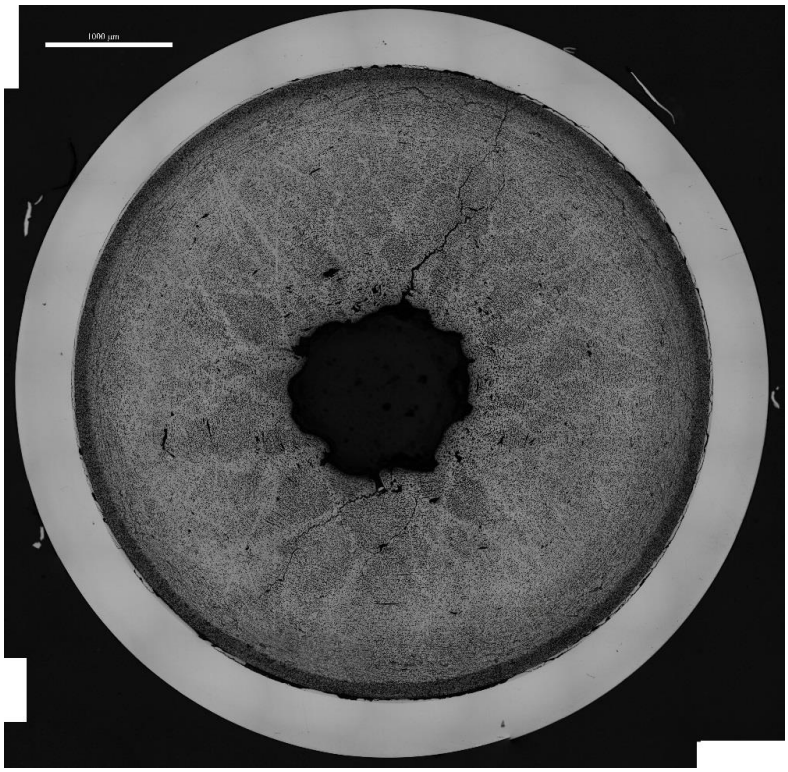


Figure 20. Optical microscopy imaging of the AFC 4AR1 (annular U-10Mo) irradiated fuel.

- **[INL]** Neutron radiography was completed on AFC-3C and AFC-3D. This exam provides information on the axial swelling of the fuel and the general state of the fuel after irradiation (J. Harp)

CAPABILITY DEVELOPMENT

Fuels

- **[INL]** The TCM and associated equipment were entered into stage one mockup at MFC on 9/6/2017. This included the TCM, the equipment rack, and all ancillary equipment, as well as the film thickness monitor. Mockup testing is underway and includes manipulator compatibility and performance verification testing using thermal conductivity standards. (D. Hurley)

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

MATERIAL RECOVERY AND WASTE FORMS DEVELOPMENT

REFERENCE TECHNOLOGIES AND ALTERNATIVES

- **[INL]** Tests performed earlier this fiscal year at INL indicated that gamma radiolysis should have little impact upon the separation of the minor actinides from the lanthanides using the ALSEP process. Additional experiments were performed in order to examine the importance of the hydrolytic degradation of AHA on the efficacy of the ALSEP scrub section. Distribution ratio analysis of the ALSEP solvent and aqueous scrub solutions suggest that hydrolytic degradation of the AHA added to the ALSEP scrub feed should have only a minimal impact of the separation of the minor actinides from the lanthanides. (D. Peterman)
- **[ORNL]** The ORNL "Nuclear review panel" reviewed the plans for a hot demonstration for FY2018 and identified some high level issues to be resolved by senior level managers. The Nuclear Security and Isotope Technology Division Director has briefed DOE NE23 on the concerns that the ORNL "Nuclear review panel" raised. These include the waste disposal pathway, the potential for Cs release impacting TRISO work, and space availability partially due to the "sister rod" work for NE. Dr. Parks suggested putting a hold on the hot-cell demo and, instead, focus on a research task on providing a disposal waste form for the fuel powder that had already been generated previously as part of the NE-Coupled End To End project, the notion being that this would thereby address the open waste disposal pathway issue. He also mentioned the Cs issue could be addressed and that efforts were moving forward to improve the space situation. (B. Jubin)
- **[ORNL]** During the month of August, a number of experiments were performed on K-LTA tubular membranes to determine the separation performance and to verify data reproducibility. The type and quality of the support has a large impact on the resulting membrane quality. LTA membrane synthesized on CoorsTek porous disk supports showed some reactant gel penetration issues resulting in a thicker membrane layer. It is also thought that the larger pores (>0.5 micron) in the symmetric (approximately 1 mm thick) support can result in the formation of inter-crystalline defects. This could be the reason for the observed poor performance of Na and K exchanged LTA zeolite membrane fabricated on disk. To overcome these difficulties, an engineered asymmetric tubular alumina support with a thin smooth top layer of about 100 nm pore size was used to prevent gel penetration resulting in a thinner LTA layer. This approach enabled the preparation of high permeance LTA membranes with higher HTO/H_2O separation factor. (R. Bhave, B. Jubin)
- **[ORNL]** The results of different HTO/H_2O separation experiments carried out using K-LTA zeolite membrane fabricated on tubular alumina support showed a significant improvement in the HTO/H_2O separation factor and ideal selectivity. It was interesting to note that the K-LTA membranes selectively permeated the H_2O instead of HTO resulting in higher concentration of HTO in retentate compared to the permeate. While the separation factor (α_F) varied in the range of 1.28-2.79, ideal selectivity ranged between 1.07 and 2.33. However, the experiment carried out at lower pH (pH 4.5) showed significantly poorer performance compared to the evaluations at higher pH. This could be attributed to the fact that LTA membranes with lower Si/Al rations are susceptible to the irreversible leaching under acidic conditions. It was also observed that, although, the HTO concentration in permeate was significantly lower than the feed, the retentate HTO concentration did not show the expected increase. In order to understand the underlying reason, a complete material balance was done for each experiment. The ΔD indicates total unaccounted amount of HTO which varied between 0.57 to 15.14% of HTO in feed. It is anticipated that there will be about ±2-3% error in volumetric (experimental) and 1-2% error in LSA (analytical) measurements. Thus, based on the preliminary evaluations at this stage, it can be believed that most of the unaccounted HTO could be adsorbed in the K-LTA membrane layer and support structure. (R. Bhave, B. Jubin)

SIGMA TEAM FOR ADVANCED ACTINIDE RECYCLE

- **[ANL]** A paper titled, "Speciation of select *f*-elements with lipophilic phosphorus acids and diglycol amides in ALSEP backward-extraction regime," has been accepted for publication in *ACS Industrial & Engineering Chemistry Research*. The complexation of HDEHP, HEH[EHP], T2EHDGA, TODGA and mixtures thereof in n-dodecane with Nd(III), Pm(III), and Am(III), extracted from pH 3 aqueous media, were analysed by distribution analysis, IR, UV-Vis, and x-ray spectroscopies. Appreciable ternary complex formation is seen among HDEHP with DGA components and to a lesser extent with HEH[EHP]. Ternary complex formation constants were determined by absorption spectroscopy and slope analysis. The effect of the adduct formation on the process performance and on the Ln/An selectivity is discussed. It has been shown that the ternary complexes have a tendency to extract larger trivalent cations as Am and Nd over Eu, thus diminishing the overall Ln/Am selectivity of the process. Also, previously unreported extraction constants were derived for HEH[EHP] with Am and Pm as well as coordination information for Nd-HEH[EHP] and Nd-T2EHDGA complexes. (A. Gelis)

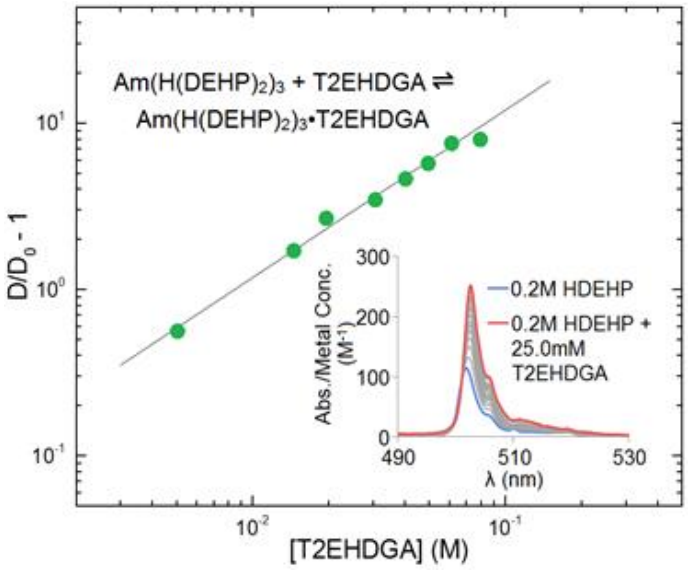


Figure 21. Formation of ternary Am(III) complexes in the HDEHP-T2EHDGA solvent extraction system.

- **[INL]** The Level 2 Milestone, "Am(VI) Extraction Tests in Centrifugal Contactors," due 8/31/17 has been completed and an external report issued. A series of five hot tests were performed using 2-cm 3D printed centrifugal contactors. With the most recent test, a D value of 2.51 ± 0.21 (72 % extracted) was obtained for Am in the single contactor stage demonstrating Am(VI) separation using a DEHBA extractant. Multiple recycle of organic solutions has also been demonstrated. Selective stripping of Am and Ce remains problematic, as does re-oxidation of Am and Ru removal from the feed stream prior to oxidation. (B. Mincher)
- **[ORNL]** The manuscript, "Trivalent Americium, Curium and Lanthanide Complexation by N-Butyl-2-acetamide-diethylenetriamine-N,N',N'',N''-tetraacetic Acid," by Heathman, C. R.; Grimes, T. S.; Jansone-Popova, S.; Ivanov, A. S.; Bryantsev, V. S.; Zalupski, P. R., has been submitted to the journal, *Inorganic Chemistry*. Among the new five diethylenetriaminetetraacetic acid (DTPA) complexant analogues synthesized at ORNL and tested at INL, the title compound (L = DTTA-BuA), has been shown to efficiently separate An(III) and Ln(III) below pH 2. Computational analysis

revealed that back-donation from singly occupied f-orbitals to the unoccupied ligand orbitals is primarily responsible for larger stabilization and thus weaker basicity of the Am(III) complex compared with the Eu(III) complex. (B. Moyer)

- **[PNNL]** Two papers on the subject of the Advanced TALSPEAK method for separating actinides from lanthanides were published in the peer-reviewed journal, *Solvent Extraction and Ion Exchange*.
  - G.J. Lumetta, T.G. Levitskaia, A. Wilden, A.J. Casella, G.B. Hall, L. Lin, S.I. Sinkov, J.D. Law, G. Modolo, An Advanced TALSPEAK Concept for Separating Minor Actinides. Part 1. Process Optimization and Flowsheet Development, DOI: 10.1080/07366299.2017.1368901.
  - Wilden, G.J. Lumetta, F. Sadowski, H. Schmidt, D. Schneider, M. Gerdes, J. Law, A. Geist, D. Bosbach, G. Modolo, An Advanced TALSPEAK Concept for Separating Minor Actinides. Part 2. Flowsheet Test with Actinide-Spiked Simulant, DOI: 10.1080/07366299.2017.1368945.

  These papers represent the culmination of 5 years of research regarding the Advanced TALSPEAK extraction system, resulting in a successful counter-current flow test of separation method. They also represent the successful collaboration between the DOE Materials Recovery and Waste Form Development Campaign and the European SACSESS program. (G. Lumetta)

- **[PNNL]** The M3FT-17PN030103047 milestone report, "Sigma Team for Advanced Actinide Recycle," PNNL FY 2017 Summary Report (NTRD-MRWFD-2017-000174), was completed. This report summarized investigations into the fundamental aspects of the extraction chemistry of the ALSEP system, focusing on the neutral N,N,N',N'-tetra(2-ethylhexyl)diglycolamide (T2EHDGA) extractant. Studies of the extraction of water, HNO_3, and Eu into *n*-dodecane solutions of T2EHDGA were described. Modeling of distribution data with the SXLSQI program suggested the formation of the following species in the organic phase: HNO_3•T2EHDGA, $(HNO_3)_2$•T2EHDGA, $[Eu(NO_3)_3(T2EHDGA)_3]$, $[Eu(NO_3)_3(T2EHDGA)_3(HNO_3)]$, and $[Eu(NO_3)_3(T2EHDGA)_3(HNO_3)_2]$. A batch ALSEP test using a solution generated from dissolving irradiated nuclear fuel in HNO_3 was also described. Preliminary results determined by gamma spectroscopy indicate the ALSEP system performed as expected, with good extraction of Eu and Am from HNO_3 solution, retention of these elements in the organic phase during scrubbing, and selective stripping of Am from the ALSEP solvent with either N-(2-hydroxyethyl)ethylenediamine-N,N',N'-triacetic acid or diethylenetriaminepentaacetic acid. Europium was quantitatively stripped from the solvent with N,N,N',N'-tetraethyldiglycolamide. (G. Lumetta)

- **[PNNL]** Two presentations describing work performed under the Sigma Team for Advanced Actinide Recycle were given at the 254th American Chemical Society National Meeting in Washington, DC. Gregg Lumetta presented a paper titled, "Diluent effect on distribution and speciation behavior of T2EHDGA and HEH[EHP] as individual extractants and in the combined ALSEP solvent," and Vanessa Holfeltz presented a paper titled "Supramolecular aggregation in the ALSEP system: Effect of diluent." Both of these papers describe various aspects of the fundamental chemistry underlying the ALSEP minor actinide separation system. (G. Lumetta)

SIGMA TEAM FOR OFF-GAS CAPTURE AND IMMOBILIZATION

- **[INL]** Iodine adsorption testing was initiated using 1-iodobutane as a surrogate for organic iodides, and silver Aerogel for the sorbent. This test will continue into September or until off-gas measurements indicate that the adsorption capacity is being approached at least for the first one or two sorbent beds. Periodic GC/MS analysis has so far not identified any gaseous organic byproducts of organic adsorption, although several unknown peaks have been detected using the more sensitive GC-FID analysis. This is generally consistent with the prior results of the methyl iodide adsorption tests. (N. Soelberg, A. Welty)

- **[ORNL]** The milestone, "Effect of iodine concentration on the removal of iodine from VOG streams by AgZ," was completed as part of the Level 2 milestone report, M2FT-17OR030107021 issued on 8/21/2017. (S. Bruffey. B. Jubin)
- **[ORNL]** To conserve funds for FY18, the activity to determine the impact of variations in NO, NO_2 and water concentrations on iodine adsorption rates will receive lower priority. The associated milestone, M3FT-17OR0301070217, due 3/31/17 will be completed by 12/30/17. No impact to M2. (S. Bruffey, B. Jubin)
- **[ORNL]** To conserve funds for FY18, Phase 1B Ch_3U tests will receive lower priority. The associated milestone, M3FT-17OR0301070218, will be completed by 2/28/18. No impact to M2. (S. Bruffey, B. Jubin)
- **[ORNL]** Sixteen samples were HIPed and returned from the vendor in two separate batches for the hot isostatic pressing of engineered forms of I-AgZ task. The first batch, comprised of 10 samples, have been assessed for sample density and have been cross-sectioned and sent for XRD analysis. The cross-sections are shown in Figures 2-11. Samples 26, 27, and 28 are scaled up samples, with 10x total sample volume. These are not shown to scale. The samples are currently under examination by XRD. The remaining 6 samples will be analyzed in a similar fashion. Due to the time required to prepare the samples, section each one and complete the XRD, the expected completion of the initial analysis phase of these samples is now 9/30/2017. (S. Bruffey, B. Jubin)

Figure 22. Sample HIP17-7

Figure 23. Sample HIP17-8

Figure 24. Sample HIP17-9

Figure 25. Sample HIP17-20

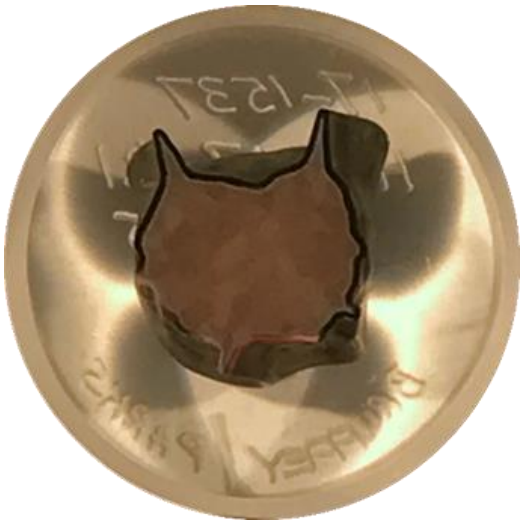


Figure 26. Sample HIP17-21

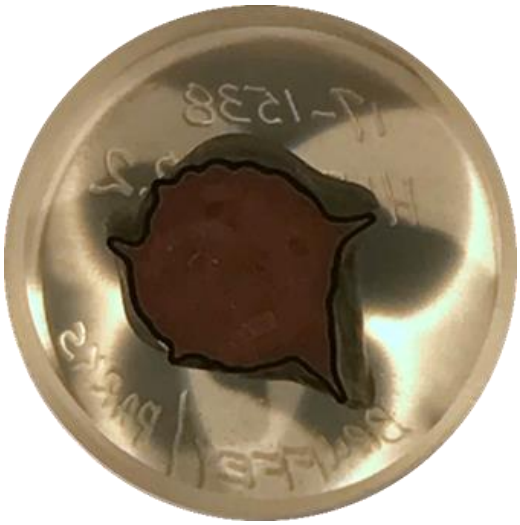


Figure 27. Sample HIP17-22.

Figure 28. Sample HIP17-23.

Figure 29. Sample HIP17-26 (not to same scale as Figure 1-7).

Figure 30. Sample HIP17-27 (not to same scale as Figure 1-7).

Figure 31. Sample HIP17-28 (not to same scale as Figure 1-7).

- **[ORNL]** The report that described Comparison of AgZ and AgAerogel performance under VOG conditions with penetrating forms of iodine was issued on August 21 completing the Level 2 milestone, M2FT-17OR030107021 on time. This report also completed the Level 3 milestone, M3FT-17OR0301070213, on the effect of iodine concentration on the removal of iodine from VOG streams by AgZ. (S. Bruffey, B. Jubin)
- **[ONRL]** Both I_2 and CH_3I adsorption tests have been conducted with Ag^0Z and AgAerogel at a range of concentrations up to 1000 ppb. These experiments were performed with two specific aims: (1) to assess the effect of iodine concentration on its adsorption by the sorbent, and (2) to compare the performance of Ag^0Z and AgAerogel in removal of iodine from a prototypical VOG stream.

Results show that the concentration of CH_3I within the range studied (40-1000 ppb CH_3I) does not affect either the maximum observed iodine loading for the sorbent, or the penetration of CH_3I into the Ag^0Z sorbent bed. Similar testing performed on the adsorption of CH_3I by AgAerogel showed the same lack of dependence on CH_3I feed concentration. The lack of dependence on feed concentration can also provide a technical basis for the type of accelerated testing that was conducted in this effort. Early testing on the adsorption of iodine under VOG conditions was performed through extended duration testing using very low iodine feed concentrations (7-40 ppb). The tests were required to run for 3 to 4 months to obtain an iodine adsorption profile through the sorbent deep bed. (S. Bruffey, B. Jubin)

- **[ORNL]** The second aim of this work was to compare the performance of Ag^0Z and AgAerogel in VOG conditions. Ag^0Z and AgAerogel iodine adsorption performance was examined for two I_2 concentrations (7 and 500 ppb) and three CH_3I concentrations (40, 400, and 1000). The most notable difference between the two sorbents is that in all cases for both sorbates, the maximum observed iodine loadings are higher for AgAerogel. This has also been observed in thin bed testing performed at higher concentrations. However, if the iodine loading data is normalized to account for the higher silver content in the AgAerogel, then no clearly discernable differences exist between the two sorbents. (S. Bruffey, B. Jubin)
- **[ORNL]** The glass components for the Ru volatilization and sorption tests were installed in the tube furnaces to verify fit. The gas supply systems and mass flow meter to deliver oxygen to the system were connected. Ru metal powder was sieved to obtain a size fraction that was judged to provide sufficient surface to volume ratio to enhance volatilization, while not being so small that it would be transported out of the reaction boat by the flowing gas. Minor modifications to the liquid scrubber, used for recovery of Ru that might pass the solid sorbent, were identified and the glass shop is making the changes. Experimental work is continuing. This milestone is expected on schedule for 9/29/2017. (S. Bruffey, B. Jubin)
- **[ORNL]** The material for the hot isostatically pressed AgZ waste form samples has been prepared and the filled capsules are ready to be sealed by electron beam welding. This task is on schedule for completion on the 9/29/2017 due date. (S. Bruffey, B. Jubin)
- **[ORNL]** Components of the iodine and tritium removal system were assembled and the system was leak checked. Iodine and tritium are charged batch wise to the system through air-locks built from ball valves. These reagents evaporate into the recirculating gas of the closed system, allowing the gas to pass multiple times over the silver nitrate impregnated alumina trap. Each test requires 8 to 14h each to complete. Four tests are planned, with one of those already complete with the remaining to be completed in early September. Analysis of the samples is expected to be completed by the end of September. (S. Bruffey, B. Jubin)
- **[PNNL]** A level 4 milestone, M4FT-17PN030107037, for DOE-NE project, "Development of Ag0-functionalized silica aerogel (Ag0-aerogel) for capturing and immobilization of radioiodine from reprocessing off-gas," was completed. The main purpose of the study was to investigate thermal stability of Ag0-aerogel with and without iodine in air and helium with themogravimetry-mass spectrometry (TG-MS) and thermogravimetry and differential scanning calorimetry (TG-DSC).

  Developed Ag0-aerogel is stable at operating plant temperatures of 150°C in air or helium atmosphere. The organic moiety with anchored silver nanoparticles starts to decompose at around 200°C in an air, and at around 310°C in helium. Interestingly, SEM-EDS analysis showed that some organic moiety from functionalization was preserved inside of the complex porous structure of silica aerogel even after heating at 1100°C in helium. This observation was confirmed by mass spectrometry, detecting release of ion fragments m/z 34 (H2S) and 64 (SO2) at this temperature. As for iodine-loaded Ag0-aerogel, the decomposition of the organic moiety started earlier, at around

175°C, and was also observed between 700°C and 1100°C. Sorption of iodine with Ag0-aerogel in iodine-saturated environment produced some physisorbed iodine which was released upon heating between 100°C to 420°C. In addition, the decomposition of AgI was detected to start at 915°C. Compared to Ag0-aerogel, ramp heating of iodine-loaded Ag0-aerogel to 1100°C produced significantly more micrometer-sized inclusions of silver at the grain boundaries. These inclusions can be explained by a low melting temperature of silver iodide (558°C) which would promote expelling of molten AgI from silica grains. In contrast, silver metal melts at 962°C. (J. Matyas)

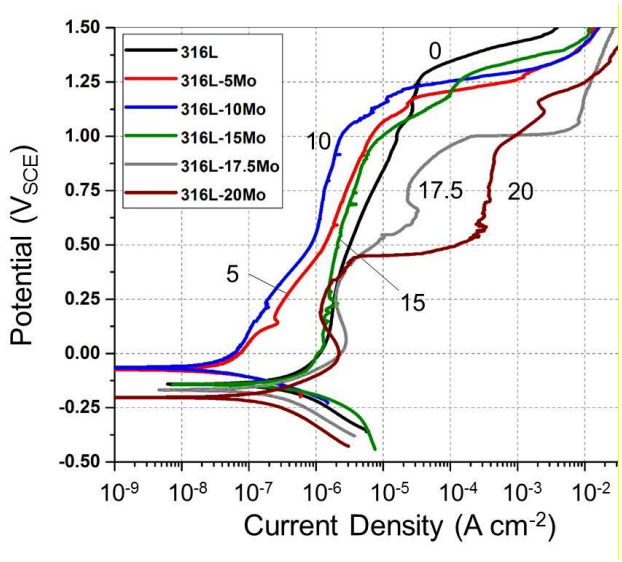
FUNDAMENTAL SEPARATION DATA/METHODS

- **[INL]** The library of structurally modified aminopolycarboxylate aqueous holdback complexants, utilized for enhanced An3+/Ln3+ differentiation, has been expanded through full experimental characterization of N-butyl-2-acetamide-N,N′,N″,N″-diethylenetriaminetetraacetic acid (DTTA-BA) and N-methyl-2-pyridyl-N,N′,N″,N″-diethylenetriaminetetraacetic acid (DTTA-MPy). The manuscript titled "Trivalent Americium, Curium and Lanthanide Complexation by N-butyl-2-acetamide-diethylenetriamine-N,N',N",N"-tetraacetic Acid," describing the thermodynamic and kinetic studies of DTTA-BA, has been submitted for publication. The manuscript discussing the f-element coordination features of DTTA-MPy is currently in preparation. (P. Zalupski)

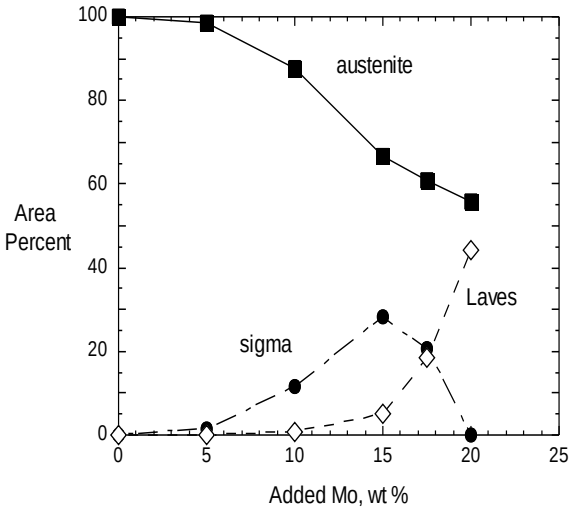
WASTE FORM DEVELOPMENT AND PERFORMANCE

Electrochemical Waste Forms

- **[ANL]** A series of electrochemical tests was completed with alloys made with various amounts of Mo added to 316L stainless steel. These provided a simple system representing the effects of waste loading on the generation of FeCrMo intermetallics known to form in metallic waste forms and host Tc. Figure 12a shows a compilation of potentiodynamic scans conducted with alloys made with 0, 5, 10, 15, 17.5, and 20 mass % added Mo in a pH 4 dilute brine solution. This shows the addition of 5% and 10% Mo is beneficial but the additions of greater amounts are detrimental. Figure 12b shows the relative amounts of sigma and Laves inclusion phases formed in the different alloy and Figure 12c and 12d show SEM images of the corroded electrode surfaces of the 316L-10Mo and 316L-15Mo alloys after the PD scans. These show the Laves phases are corroded preferentially and their formation is detrimental to the alloy durability. The Mo and Ni contents of the austenite increase when 5 and 10% Mo is added, but remains essentially constant as even more Mo is added. The sigma and Laves phases form to accommodate the added Mo, but are less corrosion resistant that the austenite. The measured corrosion currents in the PD scans are the sums of contributions from corrosion of Laves, sigma, and austenite phases weighted by their area fractions. This data set is being used to establish the approach used for modeling more complex multi-phase alloy waste forms. (W. Ebert)



(a)



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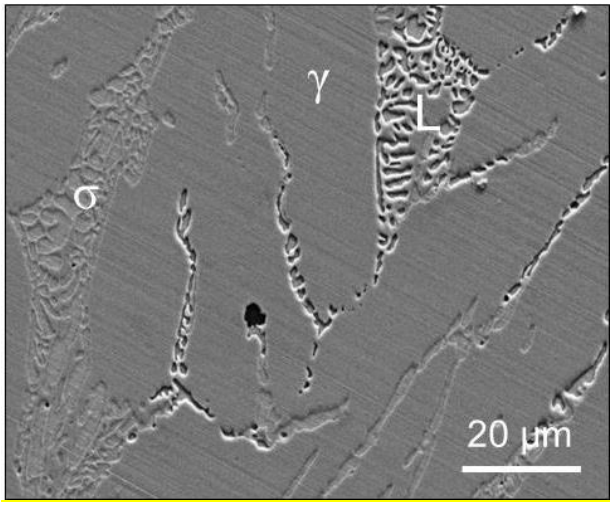

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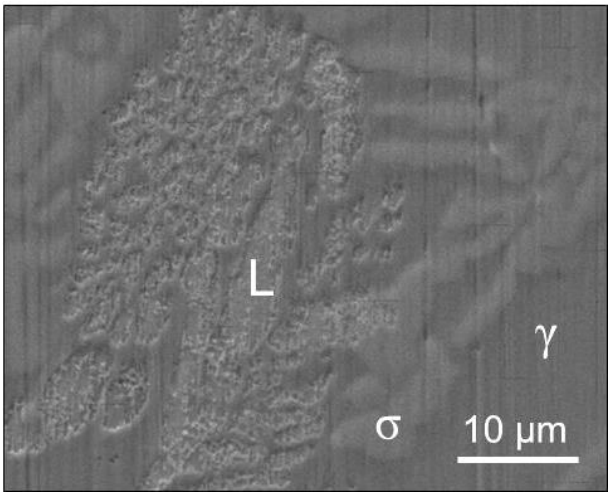


(d)

Figure 32 (a) PD scans for alloys made with 316L and added Mo, (b) area fractions of austenite (γ), sigma (σ), and Laves (L) phases for different alloys, and corroded surfaces of (c) 316L-10Mo and (d) 316L-15Mo alloys

- **[ANL]** The test plan for demonstrating a dehalogenation process for echem waste salt (Test Plan for Salt Treatment and Waste Form Development, NTRD-MRWFD-2017-000191) was issued to meet a M3 milestone. This is based on the results of a recent literature review and forms the basis for collaborative work at PNNL, INL, and ANL planned for FY2018 to implement the process demonstration. (W. Ebert)
- **[SRNL]** Final transmission of electronic data to ANL was completed. Data transmitted summarized RAW characterization for PA model. Electrochemical testing of surrogate metal alloy waste forms was performed on alloy composition RAW-6(Ni1). Multiple electrodes from this surrogate alloy waste form were fabricated, then polished and the polished surfaces characterized via SEM and light microscopy. Two of these electrodes were held at 300 mV at pH 3 and pH 8. Post corrosion

electrode surface conditions were analyzed via SEM. Solution aliquots from electrochemical testing were analyzed by ICP-MS. Potentiostatic EIS characterized corrosion behavior and oxide film formation on waste forms after exposure to simulated characteristic ground water conditions. **(**L. Olson, P. Smith)

Ceramic Waste Forms

- **[LANL]** During nuclear waste storage, He atoms will accumulate as a result of the capture of two electrons by alpha-particles, and the He concentration will increase with cumulative dose from alpha-decay events. At increased concentrations, it may form bubbles, which can cause swelling and affect many of the physical properties of the nuclear waste materials. To understand the potential effects of He accumulation and radiation damage, He ion beam irradiation was performed on several multiphase ceramic waste form samples (from ANSTO and SRNL). Focus is on the bubble formation, radiation-induced volume swelling, microcrack, and microstructural evolution. Characterizations are in progress. (M. Tang)
- **[SRNL]** Researchers at the Savannah River National Laboratory (SRNL) performed a melt-pour operation on a SYNROC crystalline composition using a cylindrical induction melter. In this initial test, 1kg of calcined feed was heated to a nominal melting temperature of ~1550C followed by a complete drain of the contents of the melt at temperature. This test is believed to be the first test of its kind in the world and demonstrates the feasibility of melt-processing ceramic nuclear waste forms.

  A second pour of material was attempted. The CIM got to temperature but material did not flow. Lab testing confirmed the material should drain. Discussions are ongoing to resolve the problem. (J. Amoroso, P. Smith)

Glass Ceramics Waste Forms

- **[LANL]** As noted earlier, He accumulation in nuclear waste forms is an important issue for long time storage. To explore the potential effects of He accumulation, radiation damage, and chemical durability, He ion beam irradiation was performed on several multiphase glass ceramic waste form samples, single phase oxyapatite and powellite which are major crystalline phases in our multiphase glass ceramics, and centroid remainder glass. The further characterization will focus on the bubble formation, volume swelling, microcrack, and microstructural evolution. Monolithic leaching test will be performed on He irradiated samples and non-irradiated pristine samples to study He accumulation and radiation damage effects on chemical durability. (M. Tang)

Zirconium Recycle

- **[ORNL]** Preparation of the hot cell for the third chlorination continued and the test was begun during the last week of August. The goals of this test, which is being made on 250 g of the high-burnup North Anna PWR UNF cladding, are (1) to test a tritium trap in the chlorination condenser off-gas and (2) to modify the chlorination heating process to include taking a pre-cut of the product containing a small amount of the zirconium with most of the impurities, followed by the main cut that would contain the bulk of the zirconium with fewer impurities. Since the reactor and condenser had not been used since the February 2017 chlorination test, a preliminary chlorination of the system (without cladding feed) was made to remove any stainless steel corrosion products that may have accumulated. During this preliminary operation, 39 g of white particles were collected in the product collection bottle. This material will be analyzed later to determine its composition. The reactor was then cooled, opened, and the 250 g of cladding tubes were loaded. The reactor was then heated to an intermediate temperature to see if any volatile impurities could be removed. None were observed in the product collection bottle, so the reactor was heated further to begin the evolution of $ZrCl_4$. During this period, pressurization of the system occurred even though gas flow bubbles through the tritium

trap water absorber continued. An incubation period of about 2 hours occurred before $ZrCl_4$ accumulation began in the product collection period (no incubation period occurred during the February 2017 chlorination of 250 g of the North Anna PWR UNF cladding). The argon flow rate was decreased and Cl_2 flow rate increased during the incubation period and the reactor temperature was again increased. The $ZrCl_4$ product collected was a white powder. The Cl_2 flow was then stopped and the reactor temperature was lowered to <100 °C. Investigation of the cause of pressurization will be made prior to continuing the chlorination test. (E. Collins, 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 with solutions sampled every 14 days. Figure 33 shows key results through about 115 days for tests with AFCI and LRM glasses. Tests were conducted at different initially imposed pH values of pH 12.5 (red), pH 11.5 (blue), pH 10.5 (green) and pH 9.5 (yellow), three different amounts of added Al(OH)3, and three different amounts of added K4SiO4. Figures 13a and 13d show the fractional releases of B based on the amounts measured in the solution and estimated to be present in the glasses added to the test. Figures 13b and 13e and Figures 13c and 13f show the solution concentrations of Al and Si measured in test conducted with AFCI and LRM glasses .Whereas the initial results of tests with AFCI glass indicate the importance of the pH and Al concentration consistent with previous findings, continued sampling has indicated Stage 3 behavior has not been triggered in other tests. Although previous tests showed Stage 3 to be triggered for LRM glass, Stage 3 behavior was not triggered in LRM glass in these tests in solution compositions that triggered Stage 3 behavior in AFCI glass. This may indicate the solution composition is not sufficient to trigger Stage 3 behavior and that the glass surface plays an important role. Although the test results are not providing information needed to determine the trigger for Stage 3, they are providing information being used to determine the solution compositional dependencies of the Stage 2 rate. (W. Ebert)

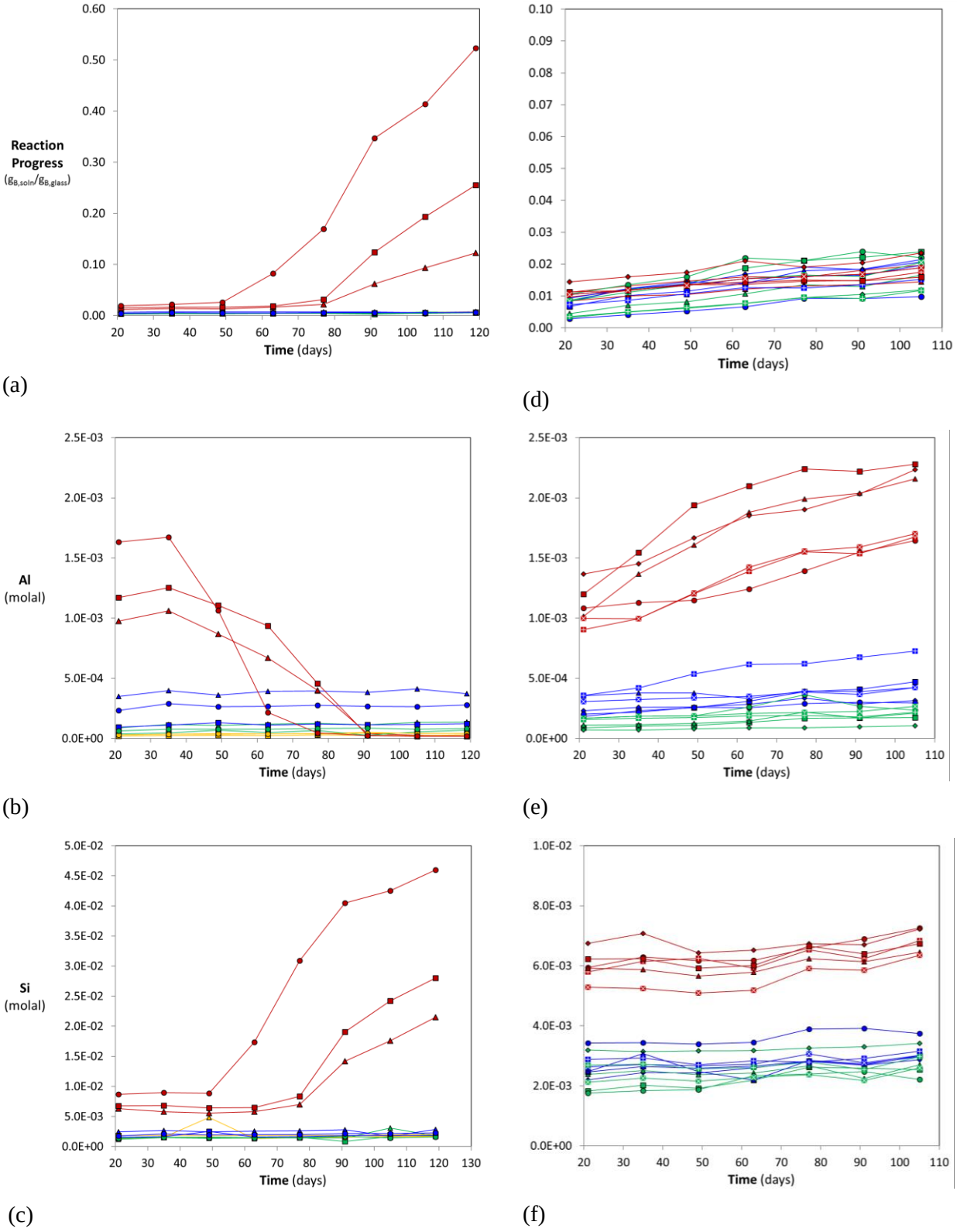


Figure 33. Results of modified PCT (a) and (d) reaction progress based on fraction of B dissolved, (b) and (e) measured Al concentration, and (c) O and (f) measured Si concentration with AFCI and LRM glass, respectively.

- **[ANL]** Electrochemical tests with AgI electrodes were completed to measure the corrosion currents (which are proportional to the mass dissolution rates) in pH 10, pH 11, and pH 12 solutions at potentials spanning the stability field for the reductive dissolution reaction. Work is in progress to use various $FeSO_4$ solution concentrations to chemically-control the solution Eh. (W. Ebert)

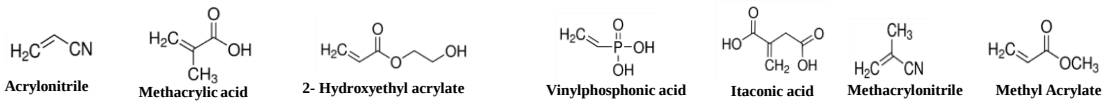
FUEL RESOURCES

- **[ORNL]** ORNL Fuel Resources PIs participated in the 2017 Summer PI Meeting of the Fuel Resources Program at Sequim, WA, on August 2-3, and gave the following presentations:
  - Janke, C.; Das, S.; Mayes, R.; Dai, S.; Gill, G.; Kuo, L.-J.; Wood, J.; Strivens, J., "Recent Developments on ORNL'S RIGP Adsorbents." A summary of seawater capacity results on selected ORNL RIGP (Radiation-Induced Graft Polymerization) adsorbents is given in the Figure 34. This listing is a compilation of ORNL's best RIGP adsorbents that were developed during the project from 2010 to 2017. (Chris Janke)

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

Summary of Seawater Capacity Results from PNNL on Selected ORNL RIGP Adsorbents (35 psu; 20 ± 1.5 °C)

Adsorbent ID	Composition	21d cap. (g-U/kg-ads.	56d cap. (g-U/kg-ads.)	K_d Half sat. (d)	B_{max} Sat. cap. (g-U/kg-ads.)	V/U mass ratio (56d)	Cost ($/kg U)
38H/AO-Regular	AN/MAA	2.30	3.30 ± 0.18	16.9 ± 2.8	4.29 ± 0.24	2.0	450-810
AI8/AO-Regular	AN/VPA	2.38	3.54 ± 0.12	25.8 ± 2.1	5.17 ± 0.18	4.6	1300-3300
AF1/AO-Regular	AN/ITA	2.62	3.86 ± 0.18	20.3 ± 1.8	5.39 ± 0.20	3.6	560-1000
AF1/AO-DMSO	AN/ITA	3.38	5.04 ± 0.15	22.9 ± 1.7	7.05 ± 0.21	4.0	460-850
MAN1/AO-DMSO	MAN/ITA	3.56	5.04 ± 0.16	18.5 ± 1.6	6.70 ± 0.22	4.0	470-840
MAN8/AO-DMSO	MAN/ITA	3.27	5.09 ± 0.24	29.2 ± 3.0	7.75 ± 0.37	3.6	470-970
AN/MA 42 KGY-a1/AO-DMSO	AN/MA	2.96	5.13 ± 0.44	36 ± 6.1	8.43 ± 0.72	1.9	450-930
AN/MA 42 KGY-A1/AO-DMSO	AN/MA	4.26 (4.13,4.38)				1.6	
AN/MA 42 KGY-A1/AO-DMSO	AN/MA	3.55	4.89 ± 0.24	18.5 ± 2.5	6.50 ± 0.32	2.0	460-790
AN/MA 84 KGY-A1/AO-DMSO	AN/MA		5.02				450-780
AN/MA 200 KGY-A2/AO-DMSO	AN/MA		5.02				450-780
HEAEC/Air/AO-DMSO	AN/HEA(EC)		5.39			1.7	450-830
HEAEC/F18/80/12/PB-a2/AO-DMSO (mod. fiber)	AN/HEA(EC)		6.65			1.1	380-700
HEAEC/F18/80/12/PB-a1/AO-DMSO (mod. Fiber)	AN/HEA(EC)		7.91 (7.94,7.88)			1.2	320-580



AO/Regular: 50/50 water-methanol, 80 °C/72h; AO/DMSO: DMSO, 70 °C/3h; *Base cond.: 0.44M KOH, 80 °C/1h*

20

Figure 34. Summary of seawater capacity results on selected ORNL IRGP adsorbents.

  - Vyacheslav S. Bryantsev, Alexander S. Ivanov, Ilja Popovs, "Towards in silico Design of Selective Functional Groups for Enhanced Uranium Capture." In this presentation, the roles of the open chain amidoxime and cyclic imide dioxime in binding uranium and vanadium have been clarified via thermodynamic quantum chemical calculations. The cyclic form is responsible for high uptake of uranium, but it is problematic because it is also responsible for high uptake of vanadium. These thermodynamic predictions are broadly consistent with U

and V uptake of various polymer formulations from simulant and seawater. The computational protocol for simulating IR spectra of polymer materials has been developed. This is helpful in assigning or ruling out certain functional groups within the polymer chain. The molecular design of new adsorbents with "modified" amidoxime functionalities should be highly encouraged. Further progress in adsorption properties by incorporating ligands that show high binding affinity and selectivity for U and moderate pKa values are expected. (Vyacheslav Bryantsev)

- Mayes, R.T.; Popovs, I.; Abney, C.; Earl, L.; Ivanov, A.; Tipker, R., "Understanding Amidoxime Adsorbents: Methylated Amidoxime." (Richard Mayes)
- Abney, C.W.; Bryantsev, V.; Ivanov, A.; Earl. L., "Multi-scale Investigations of Metal Binding by Polyamidoxime Ligands." This presentation disclosed the binding mode of Ni by the polyamidoxime adsorbents known as AF-1 and AI-8. X-ray absorption fine structure (XAFS) and density functional theory (DFT) calculations were combined to positively identify the adsorbent-bound Ni coordination environment following contact with environmental seawater. DFT calculations proposed four potential Ni binding environments, contingent upon the metal spin state and whether Ni is bound to the cyclic imidedioxime group or the open chain amidoxime group. Comparison of the theoretical scattering paths generated by these computational models with the experimental XAFS data indicated the presence of a significant quantity of another species, identified as Ni(0) nanoparticles and comprising approximately 25% of all adsorbent-bound Ni. The final fitted model suggests the predominant form of bound Ni (75%) is Ni(II) bound to two cyclic imidedioxime ligands. This result is consistent with the computational effort and previously reported small molecule titrations, as well as with XAFS work pertaining to uranium and vanadium binding environments. Both vanadium and nickel bind strongly at cyclic imidedioximes, while uranium XAFS shows no indication of this binding mode. Elimination of cyclic imidedioximes should improve the selectivity of the adsorbent for uranium over other metals in seawater. (Carter Abney)
- Ladshaw, A.P.; Yiacoumi, S.; Tsouris, C., "Progress in Modeling Uranium Adsorption." This presentation included latest results on the development of aqueous adsorption models based on the protonation/charging of the ligand itself when exposed to seawater. This new charging mechanism provided improved results at predicting uranium uptake in laboratory experiments. (Costas Tsouris)
- Tsouris, C.; Ladshaw, A.P.; Wiechert, A.I.; Yiacoumi, S.; Saito, T.; Liao, W.-P.; Hong, E.; Das, S.; Mayes, R.T.; Janke, C.J.; Gill, G.A.; Kuo, L.-J., "Influence of Environmental Variables on Uranium Adsorption." This presentation included work performed to model the Raceway adsorption system at the PNNL Marine Sciences Laboratory. (Costas Tsouris)

- In addition, a presentation titled, "Selective Recognition of Metal Ions in Seawater by Amidoxime-Functionalized Polymers," was given by Alexander Ivanov at the 254th ACS National Meeting in Washington, DC, August 20-24, 2017. Amidoxime-functionalized polymer fibers are currently the state-of-the-art in adsorbent materials for extracting uranium from seawater. Despite significant advancements made over the past decade toward increasing the uranium adsorption capacity, there is still little understanding of how these adsorbents function. For instance, it is not clear what factors determine their affinity and selectivity for particular metal ions in seawater. This research seeks to provide a rationalization of the impact that representative molecular functionalities and their interactions with different metal ions have on the performance of complex polyamidoxime systems. Results of combined quantum chemical simulations and spectroscopic studies both for conventional adsorbents reported in the literature and newly designed systems synthesized at Oak Ridge National Laboratory were discussed in the presentation. An emphasis was placed on demonstrating the

molecular level understanding of selective metal ion recognition by amidoxime-based sorbents. (A. Ivanov)

- **[PNNL]** The Marine Science Laboratory at PNNL hosted the bi-annual project meeting of the Seawater Uranium Recovery Program, a part of the DOE-NE Fuel Resources Program on August 2-3, 2017 in Sequim Washington. The meeting was chaired by Dr. Stephen Kung of DOE-NE and included 28 participants from several national laboratories (PNNL, ORNL, LBNL, and BNL) as well as university partners (University of Maryland, Woods Hole Oceanographic Institute, University of California at Riverside, Massachusetts Institute of Technology, Georgia Institute of Technology, University of Idaho, University of Texas at Austin, and the University of South Florida). Each institution gave a brief update on progress to date. (G. Gill)
- **[PNNL]** A manuscript titled, "Temperature Dependence of Uranium and Vanadium Adsorption on Amidoxime-Based Adsorbents in Natural Seawater," was submitted to the journal *Chemistry - A European Journal* on August 15, 2017. The manuscript is currently under review. The authors of the manuscript are: Li-Jung Kuo, Gary A. Gill, Costas Tsouris, Linfeng Rao, Horng-Bin Pan, Chien M. Wai, Christopher J. Janke, Jonathan E. Strivens, Jordana R. Wood, Nicholas Schlafer and Evan K. D'Alessandro. (G. Gill)
- **[Stanford]** Sea water selectivity tests are ongoing based on a new type of sorbent material using electrochemical method. Performance optimization is still being investigated by exploring the parameter space. Also, a long term test based on new sorbent material is being investigated. (C. Liu)

CoDCon Demonstration

- **[PNNL]** The following paper was published in the peer-reviewed journal *Analytical Chemistry*:
  - A.M. Lines, S.R. Adami, S.I. Sinkov, G.J. Lumetta, and S.A. Bryan, "Multivariate analysis for quantification of Plutonium (IV) in nitric acid based on absorption spectra," *Anal. Chem.*, published online July 20, 2017, DOI: 10.1021/acs.analchem.7b02161.

  This paper describes a chemometric method for determining plutonium(IV) concentrations in nitric acid media. Identification and quantification of Pu(IV) species by traditional single variate analysis of spectrophotometric data is hindered by changes in speciation with changing nitric acid concentration. The chemometric analysis allows for the accurate quantification of Pu(IV) without a priori knowledge of nitric acid concentration. This method is to be used in monitoring process solutions during the CoDCon flowsheet testing effort. (G. Lumetta)
- **[PNNL]** A preliminary CoDCon flowsheet test was performed using the full 16-stage bank of 2-cm centrifugal contactors and a uranyl nitrate feed spiked with plutonium. In this test, four different flow rates for the fresh TBP solvent entering the "U re-extraction" stages were examined to determine approximately what rate this flow should be set at for the next planned preliminary flowsheet test. The CoDCon flowsheet uses U(IV) to strip Pu from the TBP solvent. This was verified to be effective since no Pu was detected in the TBP solvent exiting the process. Interpretation of the uranium behavior was complicated by the fact that steady state was not reached for most of the flow conditions examined. Nevertheless, the test provided enough information to set the initial flow conditions for the next preliminary test, which is scheduled for early September. The next test will use the full amount of U and Pu that is planned for the actual CoDCon flowsheet tests. The various process streams will be monitored in real time using spectrophotometry and Raman spectroscopy. This will allow for refinement of the flowsheet conditions so that the target uranium/plutonium mass ratio is obtained in the product stream from the solvent extraction. Successful completion of this upcoming preliminary test will set the stage for the actual CoDCon flowsheet tests to be conducted in FY 2018. (G. Lumetta)

- **[PNNL]** The M3FT-17PN030108047 milestone report, "CoDCon Project: FY 2017 Status Report," (NTRD-MRWFD-2017-000222) was completed. This report describes the progress made through July 2017 including:
    1. Establishing a method to prepare uranium in the +4 oxidation state [U(IV)] to be used as the Pu reductant in the CoDCon flowsheet testing
    2. Establishing a method to destroy hydrazine prior to the modified direct denitration (MDD) step
    3. Demonstrating the batch MDD method for converting the U/Pu nitrate solution from the solvent extraction portion of the CoDCon flowsheet testing to the mixed oxide product
    4. Collecting spectral training sets and developing the chemometric models for monitoring key species [U(IV), U(VI), Pu(III), Pu(IV), and HNO3] in the process solutions
    5. Developing the CoDCon flowsheet to be tested. (G. Lumetta)

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]** The MPACT Working Group Meeting was held August 3-4 at the Washington DC, INL office. The meeting focused on review of key projects and FY17 deliverables as well as planning for FY18. Attendance was limited to national laboratory participants. On August 17-18, a subset of the group met at DOE-Germantown for a final workshop on the MPACT Implementation Plan level 2 milestone, due at the end of the month. The group continued to refine the R&D needed for achieving a new level of integration as applied to the safeguards and security system to support the MPACT 2020 milestone.

CAM & Technical Support

- **[LANL]** Planned and attended the MPACT Working Group Meeting, held in Washington, DC, Aug. 3-4, 2017. Compiled input to the Advanced Integration Roadmap Update. Provided input to the MPACT Implementation Plan.

SAFEGUARDS AND SECURITY BY DESIGN - ECHEM

Microfluidic Sampler

- [ANL] Fabrication of the flow cell version of the molten salt droplet generator was completed. Water testing was completed and the system is now being installed in an argon atmosphere glovebox for testing with molten salt. A presentation on the micropfluidic sampler work was made at the MPACT Working Group meeting; the molten salt microfluidic work was also included in a summary presentation of MPACT research at Argonne for the Advanced Implementation meeting.

Modeling and Simulation for Analysis of Safeguards Performance

- **[ANL]** Recent work has focused on improving the electrolysis portion of the DyER code. There are several papers in the literature covering electrolysis which can be used for code validation. Several cases were run looking specifcally at diffusion layer effects. The models were refined yielding an improved match to the experimental data, though the absence of experimental detail is a hindrance. A presentation on the modeling work that has been completed in 2017 was made at the MPACT Working Group Meeting; the modeling work was also included in a summary presentation of MPACT research at Argonne for the Advanced Implementation meeting. Modeling is a significant segment of the virtual test bed.

Electrochemical Sensor

- **[INL]** Completed one test of online monitoring of UCl3 in LiCl-KCl-xUCl3 system by incremental additions of LiCl-KCl-41.6% UCl3 salt into the LiCl-KCl-xUCl3 system. A U-beta" alumina sensor was made by ion exchange of a K-beta" alumina in a LiCl-KCl-41.6% UCl3 salt at 500C. The U-beta" alumina sensor responded to the UCl3 concentration changes and the results show that the U-beta" alumina sensor is promising for monitoring UCl3 concentration. A U-beta" alumina material was fabricated by ion exchange of Na- and K- beta" alumina in pure UCl3 at 795C for 120 hours. There are some interactions between UCl3 and beta" alumina materials, particularly for K-beta" alumina material. A U-beta" alumina sensor was successfully made by ion exchange of a Na-beta"

alumina in pure UCl3. A final draft of the end of year report was completed and submitted for technical review.

Sensor for Measuring Density and Depth of Molten Salt

- **[INL]** All the aqueous (room temperature) tests were completed. The data was analyzed and used for calibration of the bubbler. The bubbler was then moved to the Center for Advanced Energy Studies (CAES) to perform two series of high temperature tests in two different furnaces. These tests have been designed to study the effects of thermal expansion of the bubbler tubes and fine tune the calibration for high temperature molten salts. All the components for the tests have been fabricated and safety walks with facility personnel have been completed. Dry runs were conducted at temperature and data collected. Data is currently being analyzed.

Voltammetry

- **[ANL]** The objective of this activity is to evaluate the performance of an electrochemical sensor through a series of targeted tests to examine issues such as cross-talk, etc. Use of the sensor for transient concentration measurements in multicomponent molten salts was conducted. Measurements of the concentrations of U3+ and Gd3+ in the salt along with the evolution of the salt depth were captured during U drawdown with Gd metal. Further modeling improvements (e.g., the inclusion of underpotential deposition/monolayer formation on the electrode surface) have also been developed allowing for better predictions of salt species concentrations at low actinide loadings.

Electrochemical Signatures Development

- **[LANL]** The Working Group Meeting in Washington, D.C. on August 3, 4 was attended. Conversations with attendees were held, including Mark Croce and Howard Menlove regarding their detector work and prospects for measured data with which to benchmark the MCNP6 Echem radiation signatures capability. Preparation of the FY18 work package commenced.

ADVANCED INTEGRATION

Advanced Integration (Methods)

- **[LANL]** Completed the Advanced Integration Roadmap and contributed to the Advanced Integration Implementation Plan. Presented at the MPACT Working Group Meeting that was held in Washington, DC, Aug. 3-4 and attended a meeting on Advanced Integration at DOE HQ in Germantown on Aug. 17-18. Planned scope for FY18 efforts.

Advanced Integration (Facility Models)

- **[SNL]** The M3 deliverable on the Integration of the SSPM and STAGE with the Virtual Facility Distributed Test Bed was completed. Key results include expanding the SSPM capabilities to allow for easier integration with other lab capabilities in the future. The improved capabilities include: updating the source term, adding a GUI, adding isotopic tracking, and standardizing the data output. The Fall MPACT meetings were attended.

MIP Monitor and CoDCon

- **[PNNL]** Staff traveled to SRNL to close out the MIP monitor deployment effort at H-Canyon nuclear separations facility. PNNL indicated that efforts involving rapid and targeted experiments may be required at a future date. H-Canyon teams indicated that deployment efforts that are mobile can easily be accommodated in the future. Work at UTK continued their effort on evaluating the current

data sets. Current data crunching efforts are focusing on the sampling boxes with replicate data runs. The teams are working to understand the impact of the amount of cycling time needed for the boxes to obtain a homogenous signal. H-Canyon operational management is quite interested in any and all data associated with leveraging this data to support their operational efforts.

EXPLORATORY RESEARCH / FIELD TESTS

Microcalorimetry

- **[LANL]** The primary technical objectives of our M3 milestone, the high-bandwidth array readout demonstration, have been completed. Functionality of all components of a readout architecture based on microwave frequency-division multiplexing was demonstrated together. The cryostat system has 8 GHz of total bandwidth. Readout of 128 resonators (channels), of which approximately 32 were connected to microcalorimeters, was demonstrated in 500 MHz of bandwidth. This translates to a potential capacity of 2048 pixels in the cryostat system. Katrina Koehler completed the remaining FY17 M4 milestone for her thesis work, the literature review and background. This section of her thesis consists of a literature review of prior work on calorimetric electron capture spectroscopy and the background of neutrino science research that motivates development of the calorimetric technique. Mark Croce participated in the MPACT working group meeting (8/3-4) and planning meeting (8/17-18) in Washington, DC.

In situ Measurement of Pu Content in U/TRU Ingot

- **[INL]** Remote handling features were installed on the furnace to allow consistent placement of thermocouples inside the furnace with respect to the crucible and molten metal. The furnace will be transferred into the Hot Fuel Examination Facility for the second JFCS liquid cadmium cathode product, currently scheduled for November 2017. A PI gave a progress presentation at the MPACT Working Group Meeting in Washington, D.C.

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

Fuel Cycle Options Campaign

CAMPAIGN MANAGEMENT

- [ANL, INL] Completed the Planning Packages for the FCO Campaign and had all of them approved by the campaign Federal manager and director.
- [ANL, INL] Coordinated with lab leads to begin preparation of FY-18 work packages.

EQUILIBRIUM SYSTEM PERFORMANCE (ESP)

Equilibrium System Analyses

- **[ANL, INL]** Submitted the level 3 milestone report entitled "Compatibility of Nuclear Technologies with Variable Grid Demand" by N. Stauff, et al. This report is a deliverable under the Work Package "FT–17AN12010201 – Equilibrium System Performance (ESP) - ANL." The objective of the work is to provide potential future nuclear load following requirements based on different grid markets in the U.S., and to compare them with the capabilities of advanced reactor concepts. Information on U.S. electricity grids, associated markets, and future maneuverability needs was summarized in the report. The load-following capability of nuclear reactors and the benefits of load following operation per variable renewable energy production rates are discussed, including the future work to derive cost-effective and reliable load following operations of nuclear power plants.
- **[ANL, BNL, INL, ORNL]** Developed a draft report entitled "Fuel Cycle Concepts – FY 2017" to support a level 3 milestone due in mid-September. Information on fifteen fuel cycle concepts has been collected in FY 2017, and the concepts have been placed into appropriate Evaluation Groups (EGs). A check of consistency of claimed performance characteristics with the results of the E&S study was also conducted.
- **[ORNL]** The final presentation for Global 2017 on "Fuel Cycle Analysis of Thermal and Fast Spectrum Molten Salt Reactors" has been completed. The paper compares the relative fuel cycle performance of MSRs, and the sub-classes of fast and thermal spectrum systems.
- **[INL]** An alternative EG30 equilibrium scenario was analyzed using high-breeding SFR core models. Several SFR core models were examined in order to analyze several aspects, such as the impact of Pu contents in SFR fuels on core designs and SFR-LWR support ratios.
- **[INL]** As a part of assignment for the ANL deliverable report, completed analyses of Japanese fuel cycle concepts using fast reactors and Accelerator Driven Systems.

Economics and Financial Risk Assessment

- **[ANL]** Progress was made towards the preparation of the report on cost breakdown of reactors due in September. Two example reactors designs were identified in order to test the algorithm for the cost differentials, and example evaluations were performed. The resulting analyses will be incorporated in the report. Separately, work continued in the drafting of the report in order to meet the deliverable's due date.
- **[INL, ANL]** Significant progress was made on the 2017 edition of the Cost Basis Report, due next month. A number of modules have been edited to escalate to current year dollars, while adding information on the estimate basis, change history, and new cost information. Several modules have undergone major updates. A new chapter is also being added to the main report to provide an example application of the cost basis.

- **[ANL]** Completed a draft of a revised module F2/D2 (on pyro-processing and remote fabrication), F1 (on aqueous reprocessing), D1-2 (on the cost of pelletized LWR MOX fabrication) for the Cost Basis Report milestone due at the end of September. The revised module includes newly revised unit costs for both remote fabrication and pyroprocessing of nuclear fuel, the adjustment of the cost of the Engineering Alternative Studies reference UREX+1a 3000 MT/y facility that was developed in FY16, and the cost of pelletized LWR MOX fabrication.
- **[INL]** Drafted the write up to document the forecast analysis which will be included in the Cost Basis Report update. Based on historical data, the analysis generates price forecasts for uranium, enrichment, and conversion. Coupled with the causal forecasts in the CBR, the two methods provide a solid basis for price expectations in economic analysis of the nuclear fuel cycle.

Maintenance of Fuel Cycle Catalog

- **[SNL]** In preparation for Sandia upgrading the platform for the Public Nuclear Fuel Cycle Options Catalog from SharePoint 2010 to SharePoint 2013, we examined a version of the catalog that has SharePoint 2013 as the platform instead of SharePoint 2010 and evaluated the changes that will need to be made. We estimate that it will take about a week's worth of work to make the changes necessary to restore the public website site to its current format.

DEVELOPMENT, DEPLOYMENT AND IMPLEMENTATION ISSUES (DDII)

Technology and System Readiness

- **[BNL, INL, ANL]** The Technology and System Readiness Assessment (TSRA) process has been used to evaluate the status of metallic fuel for the sodium-cooled Versatile Test Reactor (VTR) as an example of the implementation of the approach to a specific technology. The fuel assembly was considered as the "system" to be assessed, and six (6) constituent "technologies" were defined: 1) fuel; 2) cladding; and 3-6) structural components of the assembly. The Advanced Fuels Campaign (AFC) Focus Area Lead for Advanced Reactor Fuels provided responses to the "reference" questionnaires for TRL1 – TRL6 for metallic U-10Zr fuel and HT9 and SS316 cladding. ANL is involved in the over-all design of the Versatile Test Reactor and provided responses to the questionnaires for TRL-1 through TRL-6 for the structural components of the assembly.
- **[BNL, INL]** Work was initiated on the Level-3 deliverable due 9/29/2017: Report On Revised Version Of The TSRA Process Based On Lessons Learned To Date. In addition to the trial applications of the process, significant discussions have also occurred on the role of TSRA within a broader strategic planning and R&D program and on the development of technology maturation roadmaps.
- **[INL]** Continuing work on the technology and system readiness assessment of the aqueous recycle portion of the fuel cycle for the Materials Recovery and Waste Form Development campaign. Continued developing the Technology Readiness Level (TRL) evaluations for the U/Pu/Np Separations subsystem. Addressing comments received on the Fuel Chopping and Leaching Subsystem from two technical reviewers.

Transition to Alternative Fuel Cycle

- **[LLNL]** Draft FY-2018 work packages have been drafted for review.
- **[INL]** Developed the approach for the transition analysis summary report, including the story line and initial outlining.

- **[ANL]** Supporting INL with writing the M3 report due on Sept. 29 titled, "Report Providing the Summary of Fuel Cycle Transition to the Most Promising Options".
- **[ANL]** Updated the fuel cycle systems code DYMOND to be used on the latest system dynamics platform, STELLA Architect, and performed tests to ensure consistency of results with those from previous platform. Several modifications and improvements have been made to enable more accurate modeling of cycle lengths, reprocessing as needed, first core loading differentiation, improved user interface, etc. Development/scripting to couple DYMOND with ORIGEN are also underway to enable depletion, decay, and modeling of isotopes
- **[ORNL]** A formal evaluation framework has been developed under which the impact of using recipes or cross-sections can be evaluated. This is readiness for work in FY18. The approach has developed a range of fuel cycle input parameters, and impact on resulting metrics to be evaluated. Base cases for simplified once-through, and LWR-MOX recycle have been identified ready for the start of work in FY18.
- **[LLNL]** Informal review of several year-end deliverables at other labs, as requested.

Transition Economics

- **[INL]** Developed a model to evaluate alternative build profiles for the deployment of separations facilities and fuel fabrication. The analysis supports economic comparison of alternative transition possibilities.
- **[INL]** Worked with INL collaborators to set up alternative EG-23/24 scenarios in VISION for examining economics impacts of delaying facility builds to increase utilization.

Regional and Global Impacts

- **[INL, BNL, PNNL]** Delivered the level 2 milestone report, "Market Penetration of Nuclear Power under Various Technology and Climate Change Policy Scenarios" by Sonny Kim, Arantxa Cuadra-Gascon, and Brent Dixon. This report completed the Level 2 milestone, M2FT-17IN120103033 in work package FT-17IN12010303, "Development, Deployment and Implementation Issues (DDII) – INL", due September 1st, 2017. The report summarized the body of work to date conducted to investigate the current and future role of nuclear energy in the context of the evolving US regional and global energy system, including examining the regional and global impact to nuclear energy of clean energy scenarios and availability of CCS, renewable and energy storage technologies. Focus on nuclear energy issues include sensitivity assessments of nuclear capital costs, lifetime extensions and nuclear energy deployment and availability, traditional and non-traditional role of nuclear energy, lifecycle analysis of the nuclear energy systems, and assessment of alternative nuclear fuel cycle and reactor technologies.
- **[PNNL]** Completed and delivered milestone report on the market penetration of nuclear power under various technology & climate change policy scenarios in conjunction with Brent Dixon at INL and Arantxa Cuadra Gascon at BNL. The report synthesizes recent analyses on a range of issues affecting nuclear energy deployment and its potential response to climate change mitigation.
- **[BNL]** Provided additional input to INL for their L2 Deliverable "Market Penetration of Nuclear Power for Various Climate Change Policy Scenarios" with a focus on MARKAL capabilities and selected results assessing the potential role of nuclear technologies in the mix of energy options in the US under various scenarios.

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

Joint Fuel Cycle Study Activities

JFCS OVERSIGHT

- Research of critical technology aspects to support the Integrated Recycling Test (IRT) continues. Campaign personnel continue to operate and test equipment with irradiated fuel to acquire data to support assessments of technical and economic feasibility and nonproliferation acceptability of electrochemical recycling.
- Processing of the second batch of FFTF MOX in the IRT electrorefiner began in mid-August and nearly reached completion.
- Members of the Korean Ministry of Science and Information Technology (MSIT) and the Korean National Research Foundation visited MFC as a part of a JFCS program review.
- A level 2 milestone "Complete initial system operability tests for the electrorefiner scalability testbed" was completed. This milestone refers to systems operation in a new glovebox in the Fuels Conditioning Facility of MFC.
- A level 2 milestone "Determine and document electrochemical kinetic parameters for Np and select rare earth elements via AC electrochemical methods" was completed at ANL. This milestone marks the completion of fundamental studies of neptunium electrochemistry.

ELECTROCHEMICAL RECYCLING ACTIVITIES

Head-End

- In August, head-end equipment was moved to window 10M to refurbish and update the equipment for use with light water reactor fuel.

Oxide Reduction System

- The oxide reduction system was held in hot standby during August pending additional process experiments. The second of two electro-reduction experiments was previously completed in June.

Electrorefiner System

- Analytical data from salt samples taken during electrorefining experiments with the first FFTF MOX batch were received from the MFC Analytical Laboratory in early August. This allowed processing of the MOX2 batch in the Electrorefiner to begin in mid-August and nearly reach completion. Phase II qualification of the liquid cadmium cathode equipment (for U/TRU recovery) began in August and is expected to be completed in September after the arrival of fabricated parts.

Remote Distillation Systems

- The remote distillation system was used to separate salt from the second MOX batch from the electrorefiner system in August.

JFCS CRITICAL GAP RESEARCH AND DEVELOPMENT

- **[ANL]** Completed the level 2 milestone "Determine and document electrochemical kinetic parameters for Np and select rare earth elements via AC electrochemical methods." Experimental work for remaining milestones is complete and final reports are in preparation and review.

- **[INL]** Method development for cadmium and salt distillation process continued in the prototype distillation apparatus at the Engineering Development Laboratory. Experiments with alternative crucible materials are ongoing. Efforts in this area are focused on alternatives to BeO crucibles destined for use in electrorefining, distillation, and casting systems.
- **[PNNL]** In August, additional experiments were performed to finalize work on aerogel sorbents. Work summarizing the experiments conducted to make glass-bonded sodalite using the advanced CWF process with OR salt simulants is ongoing.

JFCS FUELS

Fuels – IRT

- In August, the casting/sampling furnace management self-assessment was initiated and is nearly complete.

Fuels – Critical Gap

- Several casting runs were performed using the Glovebox Advanced Casting System furnace in the casting laboratory. These runs have focused on suction casting of U-10Zr-3RE using a solid yttria crucible liner. Results were positive and showed minimal dross formation. FCCI diffusion couple testing continued in August. Samples were prepared and awaiting analysis via electron microscopy.

For more information on Joint Fuel Cycle Studies Activities contact Mike Goff (208) 526-1999 or Ken Marsden (208) 533-7864.

Program Assessment & Coordination

PROGRAM MANAGEMENT

- Working with GAIN voucher recipient process.
- Working with OSTI acknowledgement process.
- Completed NTRD logo.
- Coordinated, hosted, and facilitated NE customer meetings.
- Created PICS Work Package shells in preparation for WPM input.
- Reconciled the identified PP M2 milestones seeded to WP's.

QUALITY SUPPORT

- **[ANL]** Finalized FY 2018 Work Package and submitted it.
- **[BNL]** Participated in POC conference calls and submitted FY18 work package for approval.
- **[INL]** Comprehensive report draft report sent to NTRD DOE QA Manager.
- **[LANL]** continuation of editing on rev. 3 of QAPP interface document to ensure no conflicts with rev. 4 of the QAPD effective 7/5/17, entered FY18 work package information, starting on LANL WP reviews.
- **[LBNL]** Finalized QA Interface document. Reviewed and submitted two technical milestone reports.
- **[LLNL]** Nothing reported.
- **[ORNL]** Continued to provide QA expertise to ORNL FC Work Package managers concerning quality rigor levels for FY18 work packages and deliverables.
- **[PNNL]** The PNNL NTRD Interface document has been updated and approved, incorporating Revision 4 of the NTRD QARD requirements.
- **[SNL]** 2 Staff certified as NQA-1 auditors in training provided at SNL
- **[SRNL]** The Interface document is routing for approval, but was pulled back to be in compliance with the QAPD latest revision.

COMMUNICATIONS

- Provided final copy of GLOBAL2019/Top Fuel2019 teaser video for GLOBAL2017 showing.

INFORMATION MANAGEMENT

- The Document Management System (DMS) upgrade to the Production environment is set to begin Thursday, September 14, 2017. The upgrade is estimated to take approximately three days, and is scheduled to be completed Sunday, September 17, 2017.

REACTOR DIGITIZATION

- The draft report is being reviewed. The model files are being loaded into the INL engineering data storage system.

For more information on Program Assessment and Coordination contact Bonnie Hong (208) 526-0629.

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 (FORMERLY INNOVATIONS IN FUEL CYCLE RESEARCH AWARDS)

Summary Report

- University Research Alliance provided information to the First Place Innovations Awards winners and worked with the award winners and the American Nuclear Society on the Innovations in Nuclear Technology R&D Awards special session to be held at the ANS Winter Meeting in November.
- University Research Alliance completed sending award checks for the 2017 winners, along with the letters of congratulations from the DOE..
- University Research Alliance distributed press releases on behalf of the 2017 winners to the winners' department heads, advisors, school newspapers, and other media outlets
- University Research Alliance posted the 2017 winners on the nucleartechinnovations.org website.

- 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.