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Advanced Fuels Campaign

ADVANCED LWR FUELS

LWR Fuels

- **[LANL]** A milestone was submitted detailing an updated separate effects test plan for high uranium density fuels. The report updates the SET plan for high density fuels submitted in FY15 based upon the last 3 years of research in the area. The prioritization of efforts has been realigned to update the goals to the current mission within the Campaign and with Industry efforts in the area. This document retains the structure set forth by the original SET plan in FY10 for clarity and consistency. In the current plan, five base 'cornerstone' modules have been identified and expanded upon: thermal conductivity, thermochemistry, microstructural evolution, thermomechanical properties, and fission gas behavior. (J. White)
- **[LANL]** The Level 2 Milestone M2NT-18-LA020201021 titled, "Determination on the Feasibility to Waterproof UN for LWR Use," was completed. The report summarizes the progress on studying the ability to provide oxidation resistance to UN by incorporation into a UO2 matrix. Monolithic UN, monolithic UO2, and composites of varying amounts of UN have been synthesized, pressed into dense compacts, and exposed to steam in various atmospheres. The resulting O/U ratio of the material and the crystalline phase of the material were determined following exposure to the water vapor atmospheres. Results suggest UO2 provides oxidation resistance when the volume % of UN is sufficiently low, mitigating washout. If pellets with higher densities are achieved, then higher volume fractions of UN might also be protected by UO2. (N. Wozniak)
- **[LANL]** A paper titled, "In situ X-ray Characterization of Uranium Dioxide during Flash Sintering," was accepted in Materialia. In this work, the in-situ response of stoichiometric and non-stoichiometric UO2 is examined using high energy X-ray diffraction during flash sintering. Our results highlight that the onset of the flash event is driven by an increase in temperature and controlled by the applied field with no evidence of an accumulation of defects. (E. Kardoulaki)

LWR Core Materials

- **[LANL]** Tensile samples of ATF FeCrAl alloy, C26M were tested from two different tubes at room temperature, 300 and 600°C. Data was summarized and submitted in a report to meet a level 3 milestone. Data was consistent with previous testing performed on ATF FeCrAl tubing materials. (S. Maloy)
- **[ORNL]** To build upon previous irradiation work on oxide dispersion strengthened (ODS) FeCr and FeCrAl alloys, and to provide new and relevant data on the irradiation resistance of the low-Cr ODS FeCrAl alloys developed for nuclear applications, low-dose neutron irradiations were performed at the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL) on a 1st Gen. ODS FeCrAl alloy designated 125YF. The 125YF alloy, produced via mechanically alloying gas atomized Fe-12Cr-5.6Al powder with nanocrystalline FeO and Y2O3, has been previously investigated and the microstructure/mechanical properties can be found in a recent publication (S. Dryepondt, K. A.

Unocic, D. T. Hoelzer, C. P. Massey, and B. A. Pint, "Development of low-Cr ODS FeCrAl alloys for accident-tolerant fuel cladding," Journal of Nuclear Materials, 2018). Atom probe tomography (APT) was used to evaluate the stability of (Y,Al,O) nano-oxide precipitates to an irradiation dose of 1.8 dpa at temperatures 215°C, 357°C, and 557°C. In addition, investigations were performed at each irradiation temperature on this low-Cr ODS FeCrAl alloy to assess the alloy's susceptibility to the formation of the Cr-rich α' phase which precipitates out of solution within a specific temperature (300-450°C) range both after irradiation and/or thermal ageing based on the equilibrium Fe-Cr diagram.

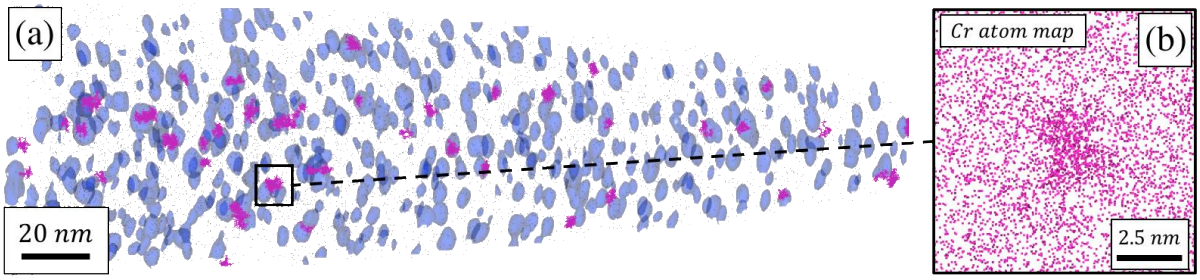

Figure 1 (a) APT reconstruction of 125YF neutron irradiated at 357°C to 1.8 dpa. Blue features represent 1.5 at. % (Y,YO,AlO) isoconcentration surfaces and magenta features represent Cr-rich clusters identified by cluster search algorithms. (b) A Cr atom map showing qualitative Cr-rich clustering at a site identified as a Cr-rich α'-precipitate.

After irradiation at all temperatures, the smallest (Y,Al,O) nanoprecipitates remain highly stable, with the average diameter and number density remaining unchanged at ~3 nm and 5x1023 m-3, respectively. Although no Cr-rich α'-precipitates were found in the specimens irradiated at low (215°C) and high (557°C) temperature, Cr-rich previpitates were identified in the intermediate temperature irradiation at 357°C. The composition of the Cr-rich precipitates (corrected for artifacts associated with the APT technique) was ~30Fe-61Cr-5Al (in at. %), which is consent with prior work on non-ODS FeCrAl previously irradiated with similar conditions. However, most notable is the difference in number density for the Cr-rich α'-precipitates identified in the ODS FeCrAl alloy 125YF. In this alloy, the number density of identified α'-precipitates was an order of magnitude lower (0.78x1023 m-3) than for the non-ODS FeCrAl variant with similar composition and neutron irradiation conditions (7x1023 m-3) [2]. This trend may indicate a sink-strength dependency on α'-precipitation, which would be beneficial for the suppression of deleterious irradiation-induced precipitation effects for ODS FeCrAl alloys. However, future work must be performed on higher dose (~7 dpa) samples of 125YF to gauge whether this trend is realized at even higher irradiation doses relevant to LWR operating conditions. All these results were summarized in a paper submitted to Scripta Materialia. (C. Massey, S. Dryepondt)

- **[ORNL]** To complete the M3FT-18OR020202061 milestone, a report titled, "Steam Oxidation and Burst Testing in the Severe Accident Test Station," was prepared and submitted. The report summarized recent work evaluating the steam oxidation behavior of FeCr and FeCrMo compositions including a study of the effect of steam on the growth of Cr-rich oxide scales. In addition, the report included the first set of 2nd generation FeCrAl C26M burst testing results. (B. Pint)
- **[ORNL]** A manuscript titled, "Impact toughness of commercial and model FeCrAl alloys," was accepted to be published in Materials Science and Engineering A in July 2018 (citation: Volume 734, 12 September 2018, Pages 93-101, https://doi.org/10.1016/j.msea.2018.07.074). It summarized the effect of microstructural factors on Charpy impact toughness in various FeCrAl alloys and suggested

an importance of microstructure control for thin-wall FeCrAl alloy tube production process. (Z. Sun, Y. Yamamoto)

LWR Irradiation Testing & PIE Techniques

- **[INL]** Preliminary basket loading calculations were completed for the next ATR operating cycle and the necessary Data Package revision was begun. (D. Dempsey)
- **[INL]** Continued irradiation of ATF-2 during Advanced Test Reactor cycle 164A reaching 36 effective full power days at the end of July. (G. Hoggard)
- **[INL]** Data from PIE is being compiled into the end of the year milestone report and manuscripts for publication in peer reviewed journals. (J. Harp)

LWR Fuel Safety Testing

- **[INL]** The secondary cans were delivered from the fabrication vendor on July 10th. This is a critical piece of the test vehicle and on time delivery was essential to the success of this year's milestone completion. (D. Dempsey)
- **[INL]** The primary containment pipes were welded and successfully test fit into the secondary cans. The first unit is dedicated as the Nuclear Equivalent Device (NED) and was delivered to the TREAT reactor building. The delivery is important because NED is required for the TREAT core reconfiguration process; without NED the reconfiguration would have been delayed which would have jeopardized the SETH irradiation timeline. (D. Dempsey)
- **[INL]** The first dry run SETH capsule assembly was completed successfully. Some assembly lessons were learned and as a result of the dry run, the assembly team has a high level of confidence that the actual capsule assembly will go well. Another dry run is scheduled to occur prior to the actual assembly to verify the lessons learned from the first dry run. (D. Dempsey)
- **[INL]** Electrical connections from the DAS and EIP panels to the ARCS system are complete. The acceptance plan completing SO testing making the system operational is complete. The DAS and EIP are ready for use with the ATF-3-0 SETH experiment campaign. (J. Schulthess/T. Pavey)
- **[ORNL]** The level 3 (L3) milestone report (ORNL/LTR-2018/521) titled, "Report on Design and Failure Limits of SiC/SiC and FeCrAl ATF Cladding Concepts under RIA," has been prepared and published. The report summarizes the mechanical test results of ATF cladding candidates of silicon carbide continuous fiber reinforced silicon carbide matrix composites (SiC/SiC) and the iron-chromium-aluminum (FeCrAl) alloys under loading conditions relevant to the postulated reactivity-initiated accidents (RIA). The mechanical tests were performed using the pulse-controlled modified-burst test equipment with an advanced optical measurement system design during FY16. Major conclusions are: (i) the present results have shown that the failure strain of the SiC/SiC exhibited a strain-rate sensitivity. With increasing strain-rate, the failure strain of the SiC/SiC has decreased, and (ii) The FeCrAl (Generation-I) alloys which have been subjected to long-term heating have retained a good amount of ductility at 250°C. (N. Cinbiz)
- **[INL]** Transient prescriptions support was completed. Instrumentation preparation was completed for the ATF SETH experiment. (T. Pavey)
- **[INL]** Low-level steady-state simulations have been completed for the transient prescription measurements, and preliminary transient simulations have been completed. The transient simulations demonstrate expected trends. Cross-section refinements are being applied within the MAMMOTH model to determine their effect on transient predictions. (T. Pavey)

LWR Computational Analysis & Fuel Modeling

- **[BNL]** Several options for coating fuel pellets to mitigate the fuel/coolant interactions for water-reactive high-density fuel phases, such as U3Si2, and UN have been proposed by LANL. Initial modeling of these options with the TRITON neutronic lattice physics code to provide an initial estimate of the impacts on reactor performance and safety characteristics is underway. Figure 2 shows K-infinity vs. burnup for 20 µm coatings of Zr-metal, ZrB2, Cr-10Al, and AlN on UN. The analyses assumed the standard Westinghouse 17x17 assembly geometry and fuel pellet OR and Zircaloy cladding IR/OR; therefore, the gap was reduced by the thickness of the coating. The nitrogen for all cases was 'natural'. If the nitrogen in the UN is enriched in N-15 cycle lengths will increase. (M. Todosow, A. Cuadra)

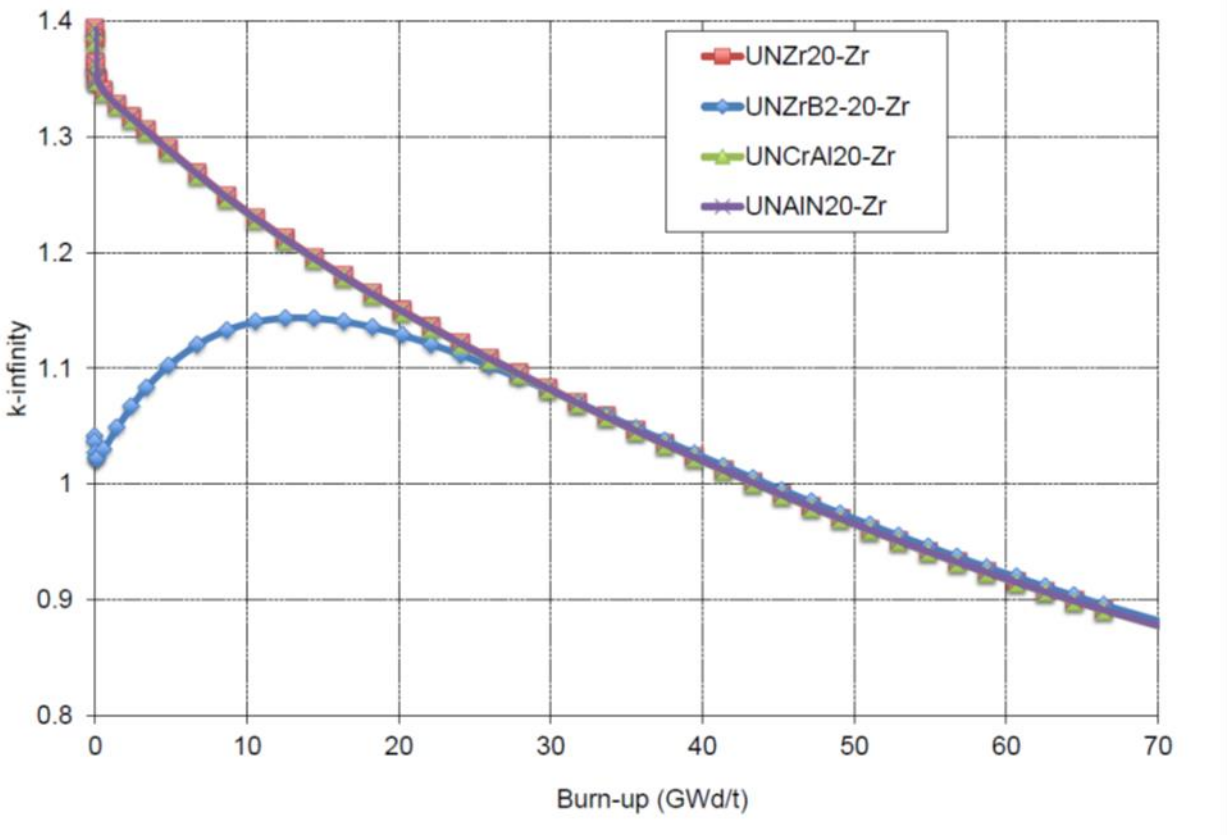

Figure 2. K-infinity vs. burnup for 20 µm coatings of Zr-metal, ZrB2, Cr-10Al, and AlN on UN.

- **[ORNL]** Additional models are being implemented to provide a comparison of SiC/SiC cladding under accident conditions, in order to facilitate a comparison against FeCrAl and Zircaloy cladding. The discussion and results of this work are currently being compiled into an upcoming milestone (M3NT-18OR020205032) on the behavior of alternative cladding materials under loss-of-coolant accident conditions. The SiC/SiC models used in this analysis are similar to those previously reported in earlier milestone reports and developed by Singh et al. (Singh et al., 2018), while the reactor conditions are representative of a BWR.

  Additional research is being performed to improve UO2 fuel models; this is needed to properly determine the onset of gap closure and the development of stresses in the cladding. Along with recent changes to the fuel irradiation and thermal creep model, further development of fuel fracture models and the investigation of a hot-pressing model are also pursued. (B. Wirth)

- **[ORNL]** Milestone M3NT-18OR020205041 was successfully completed and a report titled, "Design and analysis of oxidation tests to inform FeCrAl ATF severe accident models," was published on July 12th, 2018.

  The report is an extension of last year's work investigating the high temperature properties of FeCrAl to support both the upcoming QUENCH test and severe accident simulation efforts. Additional oxidation tests were conducted this FY to understand the repeatability of the oxidation rates observed. Also newly reported are material interaction tests in which two materials are put in contact and heated to high temperatures. The potential materials interactions (in contrast to just melting points) at high temperatures drives severe accident progression. Thus, these tests provide insight required to model the performance of the FeCrAl ATF concept during postulated accidents. (K. Robb, M. Howell, and L. Ott)

Industry FOA

- **[INL]** Fabrication of 163 U3Si2 low enriched fuel pellets was completed in preparation for laboratory analyses. PLN-5631, the U3Si2 Fuel Pellet Manufacturing and Quality Plan (MAQP) was issued. The Analytical Laboratory analysis of the project feedstock was completed. (S. Martinson)

ADVANCED REACTOR FUELS

AR Fuels

- **[INL]** Dimensional characterization of the segmented U-10Zr extruded 6 mm rod has begun. Table 1 shows the lengths and diameters of the rod. Compared to the last extrusion experiments which used worn dies, dimensional stability is much higher with this run. Also observed is a definite diameter reduction along the length of the rod. The diameter of the head of the extrusion is approximately 5.9 mm but this is reduced to 5.5 by the tail of the extrusion. The cause of this difference is not well known. Microstructural characterization will continue next month. Figure 3 shows a typical section of the extruded rod. (R. Fielding)

  Table 1- Section length and diameters of the U-10Zr extruded rod.

Section ID	Length (mm)	Center Diameter (mm- 0°)	Center Diameter (mm- 90°)
1	255.57	5.96	5.96
2	258.75	5.93	5.92
3	257.18	5.91	5.89
4	255.57	5.87	5.91
5	257.18	5.77	5.75
6	258.75	5.80	5.71
7	258.75	5.72	5.83
8	258.75	5.63	5.70
9	257.18	5.69	5.79
10	255.57	5.62	5.71
11	257.18	5.63	5.70
12	174.63	5.56	5.46

Figure 3. Typical section of the extruded rod.

- **[INL]** A vacuum assisted casting apparatus has been design and fabricated for glovebox use. This apparatus will be used to cast small diameter fuels slugs for use in high burnup fuel irradiation tests. This month the apparatus was tested with a low melting point non-reactive alloy. During testing, a pin of approximately 2.1mm diameter and 38 mm long was successfully cast showing the feasibility of the casting method. It was discovered that only a small amount of vacuum was needed to cast the pin. Too great of a vacuum pressure caused the material to flow too far into the copper hearth/mold. Based on the successful surrogate testing, the apparatus was installed in the arc melter in the glovebox. Several attempts were made to cast both uranium and uranium-10wt%zirconium (U-10Zr) and varying levels of vacuum pressure. It was found in general, for the small volume that is evacuated in the apparatus, approximately one atmosphere differential is needed. Some work will be needed to optimize the casting process, but initial results are very promising and show that casting fuel slugs of approximately 2.1 mm is feasible. Additional hardware will be fabricated to test feasibility of casting 1.4 mm diameter fuel slugs. Figure 4 and Figure 5 below show uranium and U-10Zr casting. (R. Fielding)

Figure 4. 2.1 mm diameter uranium slug.

Figure 5. 2.1 mm diameter U-10Zr slug.

- **[INL]** The 2018 draft of the Metallic Fuels Handbook for the level 2 milestone was completed and is currently undergoing review. Complete revisions of the sections on U-Zr and U-Pu-Zr thermal properties were included as well as a new section on mechanical properties of U-Pu-Zr. From these new sections, the program will develop scope for next year's characterization work to support the fuel qualification effort of U - 20 wt% Pu – 10 wt% Zr alloy. Figure 6 is an example figure from the mechanical properties section of the 2018 handbook. (C. Papesch)

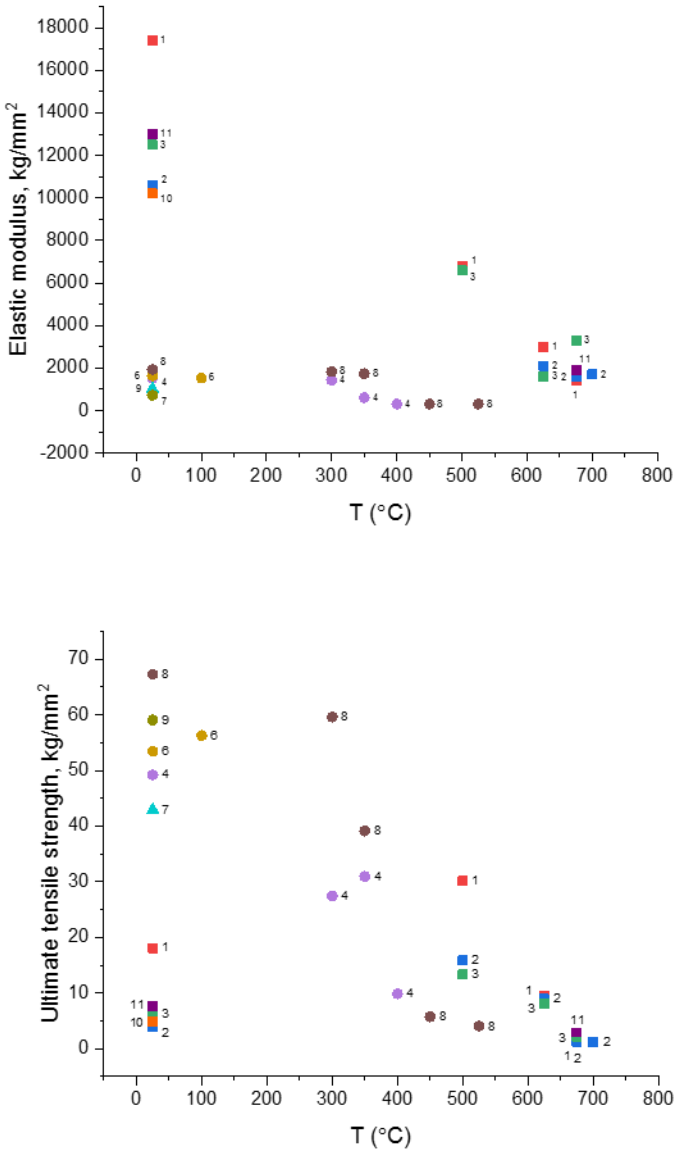

Figure 6. Mechanical properties of U-Pu-Zr alloys. Circles are ANL data from Kittel et al. (1971), squares are LANL data from extruded alloys, and the triangle is LANL data an as-cast alloy (Harbur et al. (1970)) Colors and numbers indicate individual samples and data values that are tabulated in the Handbook. All alloys had ~10-20 wt% Pu and ~5-15 wt% Zr.

- **[INL]** Optimized Fuel Additives Characterization: Two journal papers were submitted for review based upon the characterization work supported. (C. Papesch)
  - Rabi Khanal (University of Idaho); Nathan Jerred (University of Idaho); Michael T. Benson (Idaho National Laboratory); D. A. Andersson (Los Alamos National Laboratory); Robert D. Mariani (Idaho National Laboratory); Indrajit Charit (University of Idaho); Samrat Choudhury (University of Idaho), "A Novel Approach to Selection of dopant to Immobilize Neodymium in Uranium-Based Metallic Fuels", *Journal of Nuclear Materials.*

- Yi Xie (Virginia Tech); Jinsuo Zhang (Virginia Tech); Michael T. Benson (Idaho National Laboratory); Robert D. Mariani (Idaho National Laboratory), “Studies on the chemical interactions between lanthanide-additive compounds (Ce4Sb3, Ce2Sb, and CeTe) and cladding steel HT9”, *Journal of Nuclear Materials.*

- **[INL]** The level three milestone to complete one set of americium distillation runs due on July 31st was successfully met on July 18th. A new technique was used for this process whereby americium oxide is heated under a cover gas containing 10%, 25% or 50% hydrogen in argon. The idea behind this new approach is that at high temperatures the oxygen can be removed from the americium and carried away as a water molecule by the hydrogen in the cover gas. This is done at extremely high temperatures in the arc melter. If successful, this new method will provide a way to make both americium and neptunium as needed for characterization and fuel casting and eliminate the need for difficult storage of the material that is easily oxidized. The picture below shows the oxide material before the process and the material after the process. Samples of this material will be submitted to the analytical laboratory for extent of reduction analysis which allows the oxide and metal phases to be separated and analyzed individually to determine how much of the material was converted to metal and how much remains in oxide form. The information gained from this analysis will then be used to improve the process by adjusting the hydrogen concentration and heat times accordingly. (L. Squires)

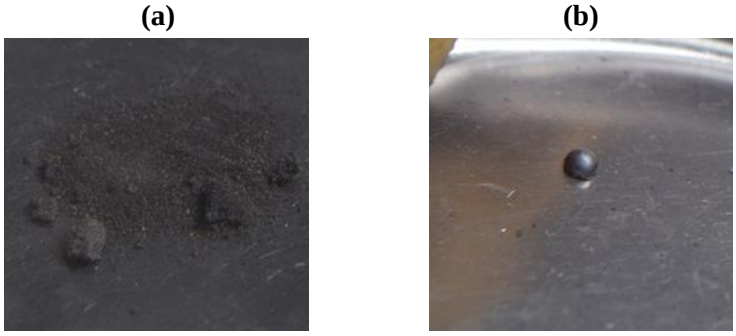

Figure 7 (a) Americium oxide starting material and (b) final americium product.

AR Core Materials

- **[LANL]** Significant tensile testing was completed on high dose irradiated samples from the ACO3 duct where samples were cut perpendicular to the long direction of the duct. This data will be a large contribution to the level 2 milestone due in September. (T. Saleh)

- **[PNNL]** The first draft of the report covering work for milestone, "M3NT-18PN020302024 - Analyze Fate of Injected Ions during Ion Irradiation and Write Report," has been completed. (M. Toloczko)

- **[PNNL]** Preparation for hardness tests and microstructural exams to support milestone, "M3NT-18PN020302026 - Report on and Perform Neutron Irradiated Material Microstructure Analysis and Barrier Hardening Coefficient Determination," are either being planned or are underway. (M. Toloczko)

- **[PNNL]** Preparation for microstructural exams and tensile tests to support milestone, "M3NT-18PN020302021 - Conduct Additional Mechanical Property Tests, Observe Microstructure of Neutron Irradiated MA957 and Write Report," are underway. (M. Toloczko)

- **[LANL]** A report was submitted summarizing high dose irradiations and microscopy performed on high and low nitrogen HT-9 alloys which were initially deformed up to 50%. This data is important in understanding the relationship between initial dislocation density and irradiation damage accumulation in ferritic/martensitic alloys and fulfills a level 3 milestone. (S. Maloy)

- **[ORNL]** A sample of the 1 mm thick 14YWT plate containing the friction stir weld (FSW) butt joint was prepared for SEM and electron backscattered diffraction (EBSD) analysis. The sample containing the stir zone cracked into two halves during cutting. This was partially expected due to the likelihood of residual stresses in the stir zone and 1 mm thick plate. Both halves were mounted in cross-section and polished to a final surface finish with colloidal silica. The SEM and EBSD results will be important for assessing the effects of the recent FSW parameters on the microstructure of 14YWT after joining. (D. Hoelzer)
- **[ORNL]** Three Zoz Simoloyer high-kinetic energy ball mills (two CM01 and the CM08) recently relocated to a new laboratory were inspected and modified for NRTL (Nationally Recognized Testing Laboratories) compliance. A new research safety summary (RSS) is currently being established for working in the new laboratory. Cooling water, vacuum and gas supply lines and power transformer were installed. The new location of the three Simoloyer ball mills will ensure that high quality research involving mechanical alloying of advanced oxide dispersion strengthened alloys will continue at ORNL. (D. Hoelzer)
- **[PNNL]** As part of the program to advance the technology associated with fabricating tubing from difficult-to-fabricate materials, the PNNL rolling mill is being modified so that it can perform pilgering of tubes. This will establish a unique R&D capability within the DOE complex. In order to modify the rolling mill so that it can perform pilgering, a set of rollers unique to the pilgering process and the rolling mill are required. These rollers are being machined by Precision Products. Machining of the rollers is nearing completion and Precision Products plans to ship the rollers to PNNL on Friday, August 10, 2018. The mandrels, which were machined by Precision Products, have already arrived at the Lab. Reduction schedules, feed and rotation rates for the first pilgering operation are being developed. (R. Omberg)
- **[PNNL]** The milestone report M3NT-18PN020302071 titled, "Mechanical properties of HT-9 steels after various thermomechanical treatments," was completed and submitted. This report is to summarize the results of systematic testing and evaluation after applying 16 new thermomechanical treatments (TMTs) and to suggest the best thermomechanical processing routes for the two HT-9 steels with and without nitrogen addition. The research aimed at a new processing route for each alloy that can yield exceedingly high strength and improved toughness in the SFR operation temperature range of 350–550°C. In order to produce quenched and tempered martensitic structures with ultrafine laths and precipitates, a series of TMTs combining a rapid quenching and nontraditional tempering treatments were designed and applied to the two HT-9 alloys. Both the strength and the ductility of HT-9 steels varied widely depending on processing route, particularly on the degree of tempering. Some tailored TMTs, i.e., combinations of rapid quenching and limited tempering, yielded excellent strength and outstanding fracture toughness in the high temperature range. (T.S. Byun)

AR Irradiation Testing & PIE Techniques

- **[ANL]** Multiple simulations of a postulated LOF-TOP accident in the ABTR core were performed with annular fuel using the new SAS4A models for the analysis of annular metal fuel behavior during severe accidents. These simulations used the SSCOMP-A, DEFORM-5A and PINACLE-M metal fuel modules and stopped at the time of cladding failure, as the post-failure fuel relocation model LEVITATE-M has not yet been extended to treat annular fuel pins. These simulations explored the evolution of the molten fuel cavity and the geometry of the central fuel hole for various low burnup conditions, ranging from 0.15 at% to 0.5 at%. The results indicate that the molten fuel region can reach the inner-hole boundary prior to the cladding failure, which can cause in-pin relocation of the molten fuel with significant reactivity effects. These results point to the need for the future development of a capability to model the ejection of the molten fuel into the inner-hole of the fuel

pin. Describing the molten fuel relocation and freezing in the inner-hole of the annular fuel will also be necessary. (T. Kim)

- **[INL]** Milestone INL NT-18IN02030302 titled, "Issue Report on the Evaluation of Alternate AFC Irradiation Capsule," was completed on time July 12, 2018. The output of this report is a new AFC capsule design effort aimed at increasing experiment throughput. Experiment throughput will be increased via an increase in the rate at which burnup is accrued. (D. Dempsey)
- **[INL]** Two new articles on metallic fuel PIE were accepted for publication in the Journal of Nuclear Materials and are now available online. (J. Harp)
  - Jason M. Harp, Luca Capriotti, Heather J.M. Chichester, Pavel G. Medvedev, Douglas L. Porter, Steven L. Hayes, "Postirradiation examination on metallic fuel in the AFC-2 irradiation test series," *Journal of Nuclear Materials*, Volume 509, 2018, https://doi.org/10.1016/j.jnucmat.2018.07.019.
  - Jason M. Harp, Heather J.M. Chichester, Luca Capriotti, "Postirradiation examination results of several metallic fuel alloys and forms from low burnup AFC irradiations," *Journal of Nuclear Materials*, Volume 509, 2018, https://doi.org/10.1016/j.jnucmat.2018.07.003.

AR Fuel Safety Testing

- **[INL]** Work continued on development of advanced reactor test plans for future testing (D. Wachs)

CAPABILITY DEVELOPMENT

CX Fuels

- **[INL]** The remote sputter coater was received at the warehouse on July 19 and delivered to our lab on July 25. The gold putter target was missing, but the vendor sent a replacement. The sputter coater has been set up and a functional test run. Standards will be coated and tested next week. We continue to work with the IMCL glove box installation team on feedthroughs and internal plumbing. (D. Hurley)

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

Material Recovery and Waste Forms Development

CAMPAIGN MANAGEMENT AND INTEGRATION

- **[ANL, INL, LANL, ORNL, PNNL, SNL, SRNL]** Campaign related meetings and management activities.

PROCESS CHEMISTRY AND INTEGRATION

- **[INL]** The level four milestone titled, "Prepare for test loop irradiation testing the ALSEP flowsheet with reconditioning," (M4NT-18IN030102015) has been completed. The reconditioning loop section of the INL radiolysis test loop was cleaned and repaired as necessary. The 'tankage' used in the reconditioning loop was also cleaned or replaced as required. The equipment required to operate the reconditioning loop (pumps, flowmeters, rotameters, etc.) were cleaned and calibrated. The reconditioning loop is currently in an 'operational' condition. (D. Peterman)
- **[INL]** The continuing structure-function relationship studies of aminopolycarboxylate holdback complexants aim at further increase of total ligand acidity and sustained efficient An3+/Ln3+ differentiation, via introduction of a sterically constrained nitrogen donor atom within the diethylenetriamine backbone of DTPA-type structure. A single acetate arm of ethylenediamine-N,N,N′,N′-tetraacetic acid, EDTA, was replaced by a picolinate moiety, building a –NCH2NCH2N– backbone. Specifically, 6-carboxypyridin-2-yl-methyl pendant arm, commonly known as N-methylpicolinate, replaced the N-acetate group of EDTA, yielding N-2-picolinatemethyl-ethylenediamine-N,N,N′,N′-tetraacetic acid, EDTA-PicM. This structural modification positioned a pre-organized nitrogen heterocycle at one of the terminals of diethylenetriamine backbone of such complexant. Such favorably oriented moiety impacts the thermodynamic stability of two chelate rings (one N-M-N, one N-M-O) formed upon metal ion complexation. Potentiometric, spectroscopic and liquid-liquid distribution studies have been completed to describe the thermodynamic impact of such structural modification on the protonation, trivalent f-element complexation equilibria, coordination environment, and An3+/Ln3+ separation in aqueous acidic mixtures. (P. Zalupski)
- **[ORNL]** Synthesis and characterization of larger cation exchanged membranes such as Cs and Rb was initiated. It is thought that the selectivity and separation factor of HTO/H2O could be substantially higher for ion-exchanged LTA zeolite membranes with larger cations. The compositions of as-synthesized NaA membrane and Cesium-exchanged LTA (CsA) membrane were confirmed using EDS analysis. After three repeated ion exchanges (3 h for each exchange), almost 70% of sodium ions were exchanged to cesium ions. After the ion exchange, the characteristic peaks associated with LTA structure are detected in the XRD pattern and it is confirmed that no other competing phases are formed during the synthesis and there was no loss of crystallinity loss after the ion exchange.

  Table 1 summarizes the pervaporation results obtained from NaA membrane and CsA membranes. The effective area of the membrane was ~ 8.7 cm2 and the average flux after the ion exchange was highly reduced compared to the flux before the ion exchange. This is attributed to reduction in the effective pore size of LTA zeolite due to large cesium cations. Although there is little information on cesium exchanged LTA zeolite materials, it is reported that the average pore size of CsA zeolite is about 0.25 nm, which is much smaller than the average pore size of NaA zeolite (0.40 nm). Therefore, water molecules with approximate molecular size of 0.27 nm do not easily permeate through the membrane because of diffusion limitations. Due to the pore size reduction of LTA zeolite, ethanol became impermeable through the membrane, which resulted in the increase of separation factor to > 10000. (B. Jubin)

Table 1. Pervaporation performances of synthesized zeolite NaA membrane and CsA membrane for dehydrating 90 wt% ethanol/ 10 wt% water mixture at 298 K

Membrane Type	Flux [kg/m2-h]	Separation factor
NaA	1.9	1160
CsA	0.4	>10000

- **[ORNL]** Previously prepared grout waste forms containing surrogate UNF are being leached using the ANSI/ANS 16.1 methodology. These waste forms were described in a previous milestone report (NTRD-MRWFD-2018-000143) and contain 0, 5, and 10% UNF surrogate. Leaching tests are being performed in triplicate for each loading condition. The leachate will be analyzed for uranium and cesium. (B. Jubin)
- **[PNNL]** A manuscript titled, "Micro-Raman technology to interrogate two phase extraction on a microfluidic device," was published in the journal Analytical Chemistry and was featured as the cover article for the month of July (Anal. Chem., 2018, (90), 8345–8353). The work summarizes a novel micro-Raman probe used to measure the active extraction of nitric acid into a TBP-dodecane organic phase. The concentrations of nitric acid in both aqueous and organic phases were measured in-situ within a microfluidic micro-channel, during the dynamic extraction. The kinetic parameters were determined and compared with a macro-scale extraction system. This work utilizes a probe developed jointly under DOE Office of Nuclear Energy (NTRD) and Office of Science (SBIR), and is a collaboration between Spectra Solutions Inc. (small business partner), College of Idaho, and PNNL. (S. Bryan, A. Lines)

SIGMA TEAM FOR ADVANCED ACTINIDE RECYCLE

- **[INL]** Studies have continued on the exact speciation of Am(V) to determine americium mass balance. We continue to probe the Am(V) systems first by oxidation in 0.1 M HNO3 then acidifying the systems to 3.0 M and 6.5 M HNO3 monitoring the change in speciation as the acid concentrations are changed. These experiments allow us to monitor the disproportionation of Am(V) to Am(VI) and Am(III) in an effort to keep track of the total americium in the systems. Work is underway on the next manuscript describing Am(VI) reduction rates under gamma irradiation. (T. Grimes)

WASTE FORM DEVELOPMENT AND PERFORMANCE

Electrochemical Waste Forms

- **[ANL]** Preparation of the report summarizing results and analyses of tests conducted with developmental iron phosphate glass waste forms made at PNNL is in progress. Activity leads discussed the status of activities at each lab and future efforts in a meeting at INL in early July and input for a journal paper is being prepared. (W. Ebert)

Zirconium Recycle

- **[ORNL]** Radiochemical analyses of the three effluent fractions from the initial purification test were received. The results show partial success in removing the major contaminants, Nb-94 and Sb-125. The pre-run fraction (12% of the mass effluents) was intended to contain the separated impurities and had 58% of the Nb-94 and 46% of the Sb-125, whereas the purified ZrCl4 (57% of the mass effluents) contained only 7% of the Nb-94 and 14% of the Sb-125. The third fraction (32% of the mass effluents) appeared to be unseparated feed. A new glassware, vapor-downflow purification

apparatus (Figure 8) has been fabricated and will be tested with non-radioactive ZrCl4, and then moved to the glove box facility for further purification tests. (B. Jubin)

Figure 8. Vapor downflow purification vessel for use in $ZrCl_4$ purification testing.

Advanced Waste Form Characterization

- **[ANL]** A final report summarizing tests conducted to assess the solution composition dependence of the ANL Stage 3 glass dissolution model is being finalized. For example, Figure 9 shows the dependence of glass dissolution on the pH, Al and Si concentrations in tests that degraded at the low residual rate and test that degraded at the Stage 3 rate. Figure 9a shows tests AFCI3-4, -8, and -12 degrade at the low residual rates during the first 50 days but at the higher Stage 3 rate thereafter. Other tests degraded at low residual rates throughout the 250-day test durations. Various tests were conducted to distinguish between causes and effects of Stage 3 dissolution behavior. Figure 9b, d, and f indicate the linear correlations between the residual rates on the pH, Al, and Si concentrations, respectively. Figure 9c and e show the Si concentration increases as the glass dissolves, but the Al concentration decreases. Discussions with collaborators at PNNL were held regarding coordination of testing and modeling efforts for future activities. (W. Ebert)

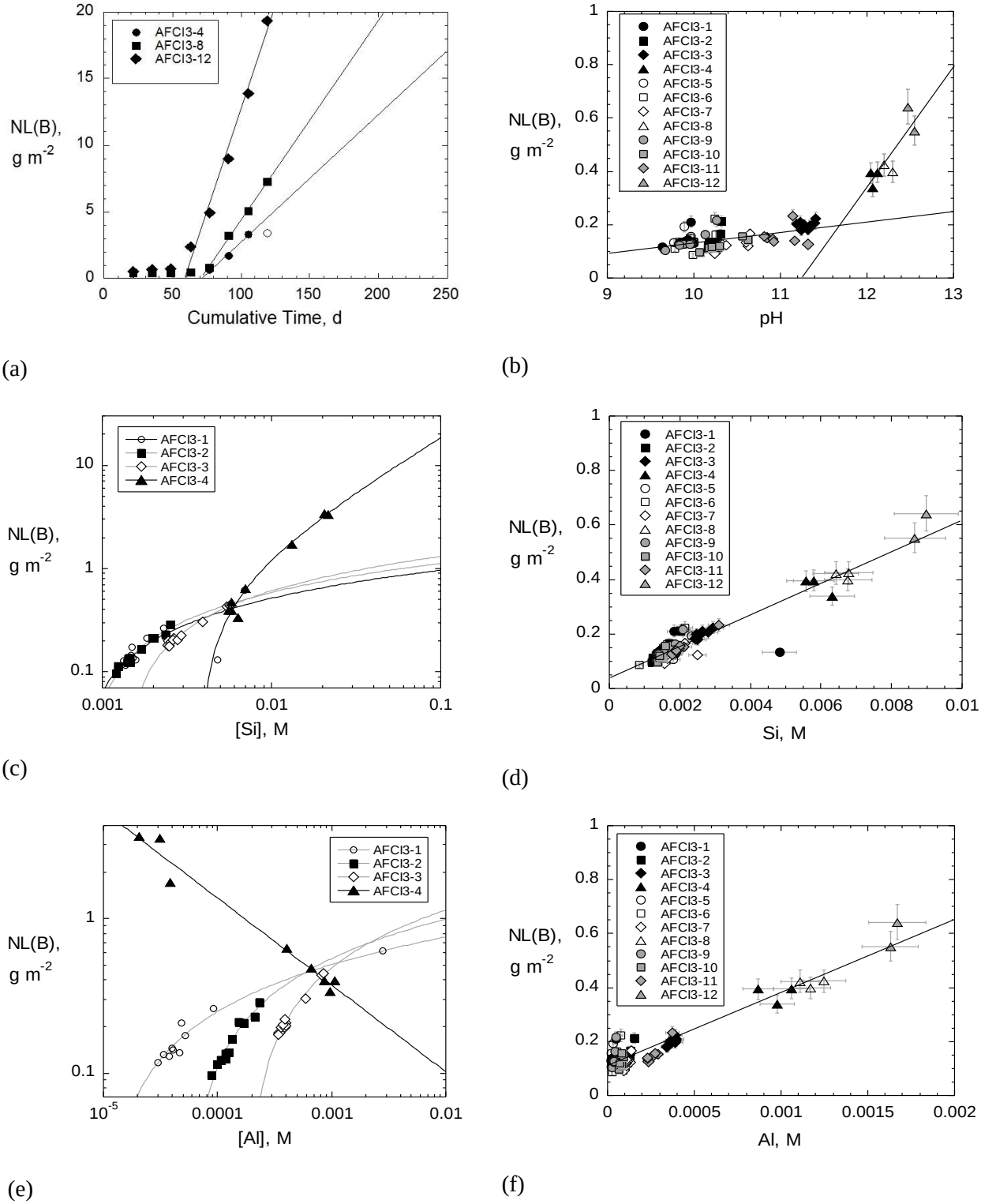

Figure 9. Analyses of results of tests with AFCI glass regarding dependence of degradation based on NL(B) on (a) time, (b) the pH, (c) and (d) the Si concentration, and (e) and (f) the Al concentration.

- **[PNNL]** A manuscript on molecular dynamics simulations of the structural changes that occur upon irradiation of alumino-borosilicate glasses by heavy ions has been drafted and will be submitted in August. The manuscript reports on modeling work performed by Ms. Jan, a PhD student visiting PNNL from CEA, France. The simulations show that ballistic effects in alumino-borosilicate glasses lead to a decrease in glass density, depolymerization of the borosilicate network, and an increase in the short- and intermediate-range disorder. Additionally, the magnitude of radiation damage was found to be dependent on the glass composition whereby borosilicate glasses were more damaged by irradiation than alumino-borosilicate glasses. (S. Kerisit)

DOMESTIC ELECTROCHEMICAL PROCESSING

- **[ANL]** The Civil Nuclear Energy Working Group project arrangement between Japan and the United States received governmental approval to begin pyroprocessing R&D activities in electroreduction of oxide fuel and waste form development. The status of on-going activities and initial discussions regarding new activities were held with collaborators at INL in early July. An informal internal workshop with ANL and INL staff addressing electrochemical measurements is being planned for September at ANL. (W. Ebert)

SIGMA TEAM FOR OFF-GAS

- **[INL]** Preparations are nearly complete for a new phase of deep-bed iodine adsorption testing for organic iodide species in simulated vessel off-gas. Work completed so far includes (a) modifications for higher gas flowrates by using purified and filtered building compressed air instead of compressed air cylinders, and (b) modifications to the sorbent bed columns to enable periodic sorbent sampling and analysis. Sorbent media, leak checks, test system blanks, and GC calibrations are in progress. Testing is expected to begin in August. (N. Soelberg)
- **[ORNL]** A 10-day integrated test was completed for the task titled, "Complete testing of integrated iodine scrubber and polishing bed system." This test was designed to evaluate the performance of an iodine scrubber preceding an AgZ polishing bed. A dry air stream containing 40 ppm I2 was passed through a 1M NaOH liquid scrubber, and the effluent from that scrubber was then passed through a 13 cm AgZ bed held at 150°C. The scrubber was held at ambient temperature and had a packing length of 0.6m. The liquid flow rate was 800 mL/min and the gas flow was 1.0 L/min, for an L/G ratio of 535. The scrubber bottoms were sampled daily and will be analyzed by ICP-MS to determine iodine content in the scrubber over the 10-day test duration. The AgZ bed was removed in discrete segments and will be analyzed by neutron activation analysis for total iodine content. The performance of this integrated system will be compared to the performance of an independent AgZ sorbent bed under similar conditions. (B. Jubin)
- **[ORNL]** Experimental testing has been completed and final analysis results are pending for the task titled, "Complete the initial series of Ru adsorption optimization studies and provide recommended changes to the assumptions used in the analysis of an integrated off-gas system." The technical report serving as the deliverable for this effort has been drafted. The final experimental test, in which the temperature of the sorbent was maintained at 250°C, demonstrated ruthenium deposited in a much shorter length of the bed than in previous experiments operated at 150°C. This indicates the rate of deposition increases with increased temperature. ICP-MS analysis of selected solutions used in the scrubbers downstream of the sorbent beds is complete. The data will help ascertain the effectiveness of the sorbent materials in abatement of ruthenium. Several images of the deposits on the wire mesh (screen) have been obtained by optical microscopy and SEM. (B. Jubin)
- **[ORNL]** Two thin bed TGA tests were completed examining the adsorption of CH3I by AgZ for the task titled, "Determine the impact of variations in NO, NO2 and water concentrations on iodine adsorption rates." The first test challenged the sorbent with a dry air stream containing 50 ppm CH3I

at 135°C. The second challenged the sorbent with a dry air stream containing 50 ppm CH3I and 1% NO at 165°C. Both tests were conducted at a superficial gas velocity of 10 m/min. The estimated iodine loading of the sorbent (according to weight measurements) will be confirmed by neutron activation analysis of the sorbent. A third test is underway. (B. Jubin)

- **[ORNL]** Work continued on the task to quantify the potential physisorption on silver-based sorbents that was potentially observed in FY-17 VOG testing. Preliminary results were received on a test that contacted a 200ppb CH3I stream with an AgZ sorbent bed. This data showed that 22% of the iodine delivered to the test bed was recovered on the sorbent bed, although the error in this preliminary number should be considered high. Further, no significant differences in iodine content were observed in samples that were removed by vacuum vs. by pouring. The full data set will now be set for analysis and a replicate test will be performed to validate the observed results. (B. Jubin)
- **[ORNL]** The task to design a test system and test plan for an alternate tritium capture method suitable for recycle of the reactive gas in the Zr recycle process is progressing. The method to capture tritium from Zr recycle off-gas depends greatly whether Cl2 or HCl is used in the zirconium volatilization step. Because the current baseline process uses Cl2, the focus has been on methods to separate 3HCl (or TCl) from Cl2. Aqueous scrubbing is used industrially to remove HCl from Cl2 because of the low solubility of Cl2 in water, but it introduces water vapor that must be removed before the Cl2 can be recycled to the Zr volatilization step. Solid sorbents including molecular sieves and a potential chemisorption reagent, which may be used in a dry system, have been identified for testing. Efforts are continuing with design of a test system. (B. Jubin)
- **[PNNL]** A series of experiments were conducted to improve the mechanical stability of MOFs with various binders including mesoporous alumina, sucrose, and polyacrylic acid (PAA) using wet granulation method (Figure 10). This method of granulation has been demonstrated to be extremely scalable, with manufacturers of pan-type granulators reporting tons of granules per hour in the fertilizer industry. Given the easy granulations, we are exploring this method to prepare MOF particles using the binders mentioned above. The particles obtained in this approach were vigorously shaken in a 20 mL vial. The attrition rates were measured by the amount of powdered MOF that resulted. With 15% Alumina we noticed <0.5% of powder sample. Further experiments are progressing to evaluate the optimal binder concentration with minimal loss of adsorption capacity. (P. Thallapally)

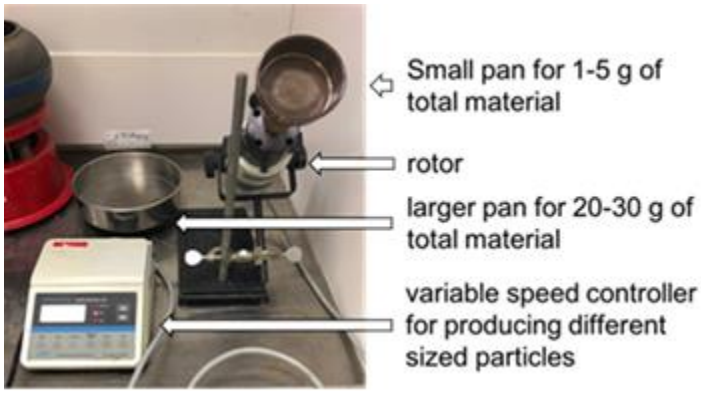

Figure 10. PNNL pan granulator for the wet granulation of MOFs.

FLOWSHEET DEMONSTRATIONS

- **[ANL]** ANL has started to develop a flowsheet for the next demo project with focus on control of Tc and Np behavior in the CoDCon flowsheet. Adding these species to the feed significantly complicates

design of the first segment relative to the flowsheet developed for the first two CoDCon demos. If the product composition can be made similar to that of the previous test, then the second segment should be similar to those run previously. (C. Pereira)

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

MPACT Campaign

MANAGEMENT AND INTEGRATION

NTD & Technical Support

- **[LANL]** Held MPACT Advanced Integration Meeting at LANL July 10-11, 2018. The goal of the meeting was to review activities that support the MPACT 2020 Milestone, discuss the integration of various support activities, decide next steps, and establish a schedule that meets the milestone. Had coordination calls with MRWFD and MSR campaigns to prepare for the NE-4 FY19 planning package meeting. Coordination with both campaigns' FY19 activities is complete.

SAFEGUARDS AND SECURITY BY DESIGN - ECHEM

Voltammetry

- **[ANL]** Long-duration tests of sensor performance continued. A third month of continuous testing of the electrochemical sensor was completed, further confirming the stability and repeatability of measurements.
- **[INL]** The voltammetry probe was installed in the Joint Fuel Cycle Studies (JFCS) Integrated Recycling Test (IRT) Oxide Reduction Furnace located in the hot cell of the Hot Fuel Examination Facility (HFEF). Three rounds of cyclic voltammetry (CV) have been performed to test connections and electrodes and troubleshoot the probe to address any need for modifications.

Sensor for Measuring Density and Depth of Molten Salt

- **[INL]** Presented at INMM Conference in Baltimore, MD. The Bubbler continued to operate in the Joint Fuel Cycle Studies (JFCS) Integrated Recycling Test (IRT) Electrorefiner (ER). Documentation requesting the calibration of the pressure transducers as well as a procedure to zero out the pressure transducers to avoid drifts have been put in place. In addition, the engineering required to modify a height gauge for in-cell use was completed. This height gauge will be used to reduce uncertainty in the calibration and the distance between the bubbler tube tips by making accurate independent depth measurements. Most of the required parts to complete the modifications have been purchased or are currently being manufactured.

Electrochemical Signatures Development

- **[LANL]** Radiation efforts regarding the MCNP6 moving objects analysis of moving radiation sources, including HDND analysis, and the theoretical fission chain model development concluded for the year. Two reports were produced: Calculation of Time-Dependent Radiation Signatures for Electrochemical Reprocessing Using MCNP6 Moving Objects FY18 Summary Report and Preliminary Efforts on Fission Chain Radiation Signatures for Pyroprocessing FY18 Summary Report (M3NT-18LA040104041).

Microfluidic Sampler

- **[ANL]** A mock-up of a molten salt droplet generator was designed and 3D printed from acrylic and high-density polyethylene. Now fabricated, the droplet generator may be tested with a surrogate solution. Ultimately, the droplet generator will be fabricated via direct metal laser sintering (DMLS) by a vendor. In addition, designing began on an AM fabricated centrifugal pump for molten salts. A completed design for a prototype is expected in early August and an acrylic mock-up is expected to be fabricated by the end of that month. After several discussions with TCS Micropumps regarding

the fabrication of a molten salt compatible micropump, a "no-bid" was received for the project. In-lieu of outsourcing the analytical-scale molten salt pump development, a molten salt centrifugal pump will be developed in-house by taking advantage of Argonne's expertise in rapid prototyping and centrifugal contactors for both aqueous and molten salt systems. A centrifugal pump design based on 3-D printed centrifugal contactors was developed and is being optimized for printing in acrylic. The prototype will be tested using water along with the rest of the sampling-loop droplet generator acrylic prototype. Pending successful testing, the components will be printed in stainless steel for molten salt testing.

Electrochemical Sensor

- **[INL]** Uranium sensor testing work was continued in MFC FASB glovebox. It was found that a micro crake, very difficult to be seen, might have formed in the sensor material, which can be seen as a challenge for fabrication of high quality uranium sensors. In order to deal with the challenge, experiments are underway by modifying the ion exchange process with lower temperature and longer annealing time.

ADVANCED INTEGRATION

Advanced Integration (Methods)

- **[LANL]** Data models have been acquired and are currently being used to perform sensitivity studies on the HDND, Microcal, and Voltammetry from ANL.

Advanced Integration (Facility Models)

- **[SNL]** The Molten Salt Reactor safeguards model has been updated to provide more consistent results. The measurement locations are being added to the model to prepare the model for more detailed analyses in the next fiscal year.

EXPLORATORY RESEARCH / FIELD TESTS

Microcalorimetry

- **[LANL]** Crosstalk characterization measurements have proven that relatively low microwave tone power can be used while still retaining good energy resolution. Median single-pixel energy resolution of approximately 60 eV FWHM at 100 keV is now routinely achieved. High-rate measurements have begun with encouraging preliminary results: 84 eV FWHM at 15 cps/pixel (~2300 cps total) and 102 eV FWHM at 30 cps/pixel (~4600 cps total). Achieved instrument stability and performance that meets requirements for measurement campaigns with the current system at LANL for the Advanced Integration and Distributed Testbed efforts. Katrina Koehler continues to make progress on her thesis work. Analysis of Pt-193 data is ongoing to search for low probability capture peaks from the states. Some of these peaks have been calculated and a comparison to experimental data will be an important result.

In situ Measurement of Pu Content in U/TRU Ingot

- **[INL]** Preliminary analytical chemistry results have been received and evaluated from the pre- and post-heating samples taken during testing with the fourth JFCS U/TRU product in March 2018 at the Hot Fuel Examination Facility (HFEF). The detected plutonium contents of these samples were within 10% of those predicted by the cooling curve analyses in HFEF.

High Dose Neutron Detector

- **[LANL]** Three HDND pods are currently at INL for continuing testing. PDT is investigating improved junction box designs.

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

Fuel Cycle Options Campaign

CAMPAIGN MANAGEMENT

- **[ANL, INL]** Participated in a Systems Analysis Coordination Meeting with DOE NE managers and national lab leads to discuss ongoing activities and future work on technical, economic/market, and policy analyses for the current fleet and advanced technologies. A future meeting is planned to discuss vision for integrating the activities including with other related programs both internal and external to NE.
- **[ANL, INL, BNL]** Solicited and collated ideas for the FY 2019 NEUP/CINR call for the area of nuclear energy systems analysis and integration. In concurrence with the Campaign Federal Manager, it was decided to invite proposals in the thematic areas of cost algorithms and interface tools for the transmutation data library.

EQUILIBRIUM SYSTEM PERFORMANCE (ESP)

Performance of Fuel Cycle Systems

- **[ANL, BNL, INL, ORNL]** Writing a level 2 milestone report on the fuel cycle performance of advanced nuclear energy systems. Completed the collection of the information on the planned advanced nuclear energy systems, which include advanced separation processes, micro-size reactors, marine reactors, and national fuel cycle concepts of foreign countries.
- **[ORNL]** Work has continued with Penn State University on improving the transmutation database. A draft report on transmutation database has been completed. In addition, a draft paper for a possible future conference has been produced to highlight the transmutation database and work of the Campaign. The data visualization tool has also been finalized and tested to make sure it can work on all platforms and it is ready to be released with the final report.
- **[INL]** The breakeven SFR core fueled with metallic TRU fuel was modeled utilizing the REBUS-3/MC2-3 code. This model can simulate cycle-by-cycle transition due to partial loading of LEU backup fuel in the equilibrium TRU fueled core. This model is utilized for studying the behavior of nuclide mass evolution during the batch-by-batch loading of high-assay LEU fuel and its impact on core characteristics, such as LEU fuel enrichment, cycle length, and (uncontrolled) reactivity swing during the transition.

Economic Analysis Capabilities and Assessments

- **[ANL]** The nuclear fuel cycle cost calculation website (https://cnpce.ne.anl.gov) was formally released for public access. All comments from SA&I teams have been accommodated and the website was approved for external release through the ANL's PANDA system. Now, the website is accessible without passcode, but the site is in a watch stage for a few weeks to check stability, security, and functionality. After this watch stage, the website will be officially advertised through various nuclear fuel cycle communities.
- **[ANL, INL]** Responded to an urgent request to support the VTR leadership with an "auditable" assessment of the expected cost of the VTR reactor using the ACCERT cost algorithm by mid-September of 2018. For this task, held a conference call to discuss the scope of work and as an initial step, developed an Excel spreadsheet with a full list of the technical parameters that need to be collected for the VTR cost estimate for performing the ACCERT calculations with the highest resolution possible with the current version of the algorithm.

- **[INL]** Completed the revision of Chapter 8 of the Cost Basis Report (CBR) to formalize the section on escalation. Clarified the distinction between escalation and inflation, then, updated the write-up with an illustrative example. Continued working on the CBR update with Kent Williams (ORNL, retired). Williams drafted an illustrative example of Echem processing and INL drafted the write up to accompany it in CBR Module F2/D2. Updated the text in F2/D2 to reflect the cost updating that INL and Williams performed on the studies cited in the module. Wrote up the findings of the based on the review of the studies published by KAERI on Echem reprocessing and included it in F2/D2.

Equilibrium System Performance (ESP) Tools Development

- **[BNL/PSU, ORNL]** A presentation was given at the 3rd Technical Workshop on Fuel Cycle Simulation on "Implementation of a Modernized Transmutation Library Database."
- **[SNL]** We continued to make progress on making improvements to our internal processes for data entry for the nuclear fuel cycle Catalog.
- **[BNL/PSU, ORNL]** Work on the Transmutation Data Library task continued. A draft version of the M3 deliverable is being finalized.

DEVELOPMENT, DEPLOYMENT AND IMPLEMENTATION ISSUES (DDII)

Technology and System Readiness Assessment (TSRA)

- **[ANL]** Responded to the comments on the level 2 milestone report of the Technology and System Readiness Assessment (TSRA) of a sodium-cooled fast reactor (SFR) in a U/TRU continuous recycle nuclear energy system. Rationales on the difference in technology readiness levels between the mature SFR with conventional technologies and a future SFR with advanced technologies were identified and the on-going R&Ds to support the future SFRs were provided to the SA&I campaign leadership.
- **[LLNL]** Input is being provided for updating the June INL report: "Technology and System Readiness Assessment of a Fast Reactor Recycle System".
- **[INL, BNL, ANL, LLNL]** Regularly scheduled telecons continued to finalize the M2 report ("Report on the Technology and System Readiness Assessment of a Fast Reactor Recycle System"), and plan follow-on activities.
- **[INL]** Started developing structure for maturation plan. Started addressing comments received on the "Technology and System Readiness Assessment of a Fast Reactor Recycle System" report.

Transition Analysis Studies

- **[ANL]** E. Hoffman attended the second meeting of the NEA Expert Group on Uranium Mining Economic Development (UMED). Discussed uranium mining in Wyoming, which will be the U.S. case study. Other case studies and presentations related to the task were provided by other participants. The outline of the report and responsible authors for each section were assigned. Hoffman will be the lead author for one section on business and capacity building. This relates to the physical, technical, and human infrastructure developed as a result of uranium mining and the potential for spinoffs of business outside of the uranium mining.
- **[ANL, ORNL]** Submitted a level 3 milestone report:
  - E. Hoffman (ANL), B. Feng (ANL), B. Betzler (ORNL), A. Worrall (ORNL) "Transitioning to an Advanced Nuclear Energy System: Sensitivities of Transition Results to Technology and

System Characteristics," NRRD-FCO-2018-0000444, Argonne National Laboratory, July 31, 2018.

- **[ANL, ORNL]** Attended the 3rd Technical workshop in fuel cycle simulation held in Paris, France, July 2018 and presented the following items:
  - B. Feng, E. Hoffman, and F. Heidet, "Modeling MSRs in DYMOND".
  - E. Hoffman, B. Feng, Ben Betzler, E. Davidson, and A Worrall "Impact of Technology Characteristics on Transition to a Fast Reactor Fleet".
- **[ANL]** For the fuel cycle code benchmark, simulated a small 300 MWt metallic SFR core using REBUS-3 and calculated the required input Pu content based on 4 different Pu vectors. Automatically searched for the equilibrium fuel composition based on the input burnup, cycle length, and number of batches. MCC-3 was used to generate the multigroup cross sections and the DIF3D flux solver was used. Results were referenced in the 3rd Fuel Cycle Workshop held in Paris, France, July 2018.
- **[ORNL]** Eva Davidson attended the 3rd Fuel Cycles Workshop in Paris and presented two talks on behalf of the Campaign: (1) Modeling a Fast Molten Salt Reactor with ORION by E. Davidson, B. Betzler, R. Gregg, and A. Worrall, and (2) Molten Salt Reactor Modeling and Simulation by B. Betzler, E. Davidson, and J. Powers. The overall attendance and participation was of great value and benefit to the attendee in terms of technical and professional development – support from the Campaign for such an opportunity is very much appreciated.
- **[ORNL]** The summer intern has continued the modeling of the fast spectrum MSRs for subsequent fuel cycle analyses. A modeling approach and subsequent models have been generated for four identified fast spectrum MSR designs available in the open literature. Input specifications and formats for new MSR tools recently implemented in SCALE have been generated and used to calculate accurate makeup feed rates, and generate relevant fuel cycle metrics. A poster on the work will be presented at the ORNL summer intern event in August.
- **[INL]** Drafted an outline for the econ transition study. .

Regional and Global Analysis

- **[PNNL]** Investigated the impact of ongoing transportation electrification on the demand for electricity and nuclear energy using the long-term GCAM model. Currently in the process of preparing technical report on renewable portfolio standards (RPS) and transport electrification impact on nuclear energy for milestone delivery.
- **[ANL]** Work continued on the EDGAR code (Economic Dispatch Genetic AlgoRithms), to enable its use for energy market analysis within the SA&I Campaign. The Genetic Algorithm was completely re-written in order to fix some bugs, improve the computational and optimization performance. The new version of the EDGAR code currently provides capability to optimize the unit commitment and economic dispatch (UC/ED) problem based on parallel calculations.

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

Joint Fuel Cycle Study Activities

- The oxide reduction system was operated with two separate batches of depleted uranium oxide to prepare the system. Processing of interim spent LWR fuel is expected to begin in August.
- A waste form expert's meeting was held at INL July 10 – 12 with participants from INL, ANL, PNNL, SNL, and KAERI.
- Initial surrogate testing of the LiCl melt crystallization hardware was completed successfully. This system concentrates fission products into order to minimize waste volumes, and will be tested in the hot cell with real materials.
- Analytical results were received for a number of prior ER Salt and U/TRU material sampling points.

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

AFCI-HQ Program Support

UNIVERSITY PROGRAMS

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

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

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

INNOVATIONS IN NUCLEAR TECHNOLOGY R&D AWARDS

Summary Report

2018 Innovations in Nuclear Technology R&D Awards

- University Research Alliance completed press releases on behalf of the 2018 Innovations Awards winners. Winners' university department heads, advisors, and newspapers are among those who are formally notified of their achievement.
- University Research Alliance completed posting the 2018 Innovations Awards announcement on the nucleartechinnovations.org website with the winners' information.

2018 Innovators' Forum

- University Research Alliance processed travel reimbursements for the Innovations Awards winners who attended the 2018 Innovators' Forum, a meeting designed to train students in techniques that encourage innovative thinking, which took place May 21-23 at the Sheraton Nashville Downtown Hotel.
- University Research Alliance completed compiling student evaluations from the 2018 Innovators' Forum and will be using them to improve future events.

Other Activities

- University Research Alliance continued to update the Innovations Awards announcement distribution list in anticipation of the 2019 Innovations Awards.

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