3-2003

AFCI Quarterly Input – UNLV January through March, 2003

Harry Reid Center for Environmental Studies. Nuclear Science and Technology Division

AFCI Quarterly Input – UNLV
January through March, 2003

1.0 University of Nevada, Las Vegas

1.1 Infrastructure Augmentation

1.1.1 Objective and Scope

The infrastructure augmentation component of the UNLV Transmutation Research Program enhances UNLV's research staff and facilities to increase the ability of the university to perform AFCI research.

1.1.2 Highlights

Chemistry Professorship. UNLV is near conclusion of a search for a Materials Chemist tenure-track associate professor. Selection and offer will be made next quarter.

Facilities Progress Update. Three facilities are in the laboratory remodel stage. Architectural and engineering drawings have been completed for the remodeling. The bidding process for construction will be completed by next quarter for the Transmission Electron Microscope user facility and the Interim Lead Bismuth Eutectic loop facility. The third facility is an ICP Atomic Emission Spectrometer user facility that requires minimal improvements to the existing laboratory space. The ICP AES has been ordered and is expected to arrive and be installed next quarter.

1.2 International Collaboration

1.2.1 Objective and Scope

The international collaboration component of the UNLV Transmutation Research Program enhances UNLV's breadth of scientific and scholastic experience. University collaboration is also an efficient conduit for international collaboration that benefits the national AFCI program. UNLV has ongoing relationships with the Khlopin Radium Institute (KRI) in St. Petersburg, Russia; the Institute for Physics and Power Engineering (IPPE) in Obninsk, Russia; and members of the International Molten Metal Advisory Group (from Sweden, Germany, Belgium, and Italy).

1.2.2 Highlights

International Science and Technology Center. UNLV became an approved Partner Organization with the ISTC. The UNLV program directors reviewed and approved a new scope of work with the Institute for Physics and Power Engineering in Obninsk, Russia, to prolong the LANL contract to develop and conduct research on the ISTC Target Complex 1 located at UNLV.

Khlopin Radium Institute. KRI completed construction and testing of a He-3 neutron detector. It will be shipped to UNLV next week for use in a graduate student research project investigating neutron multiplicity. UNLV has also finalized two new contracts with KRI that support two other graduate student projects: Iodine Sequestration and Fluorapatite Waste Forms.

1.3 Student Research

The Student Research component is the core of the UNLV Transmutation Research Program with steadily increasing funds as the program evolves and capability expands. The milestones, schedules, and deliverables of the student research projects are detailed in the individual research proposals. UNLV currently has 16 student research tasks that include 37 graduate students and involve 33 faculty members. The tasks are divided below in terms of their research area: fuels, separations, and transmutation sciences.

1.3.1 Fuels Technology

<u>Metallic Fuel Pins (Task 1)</u>. An important aspect of the AFCI is the development of a casting process by which volatile actinide element (i.e., americium) can be incorporated into metallic alloy fuel pins. The traditional metal fuel casting process uses an inductively heated crucible. The process involves evacuation of the furnace. The evacuation of the furnace also evacuates quartz rods used as fuel pin molds. Once evacuated the open ends of the molds are lowered into the melt; the casting furnace is then rapidly pressurized, forcing the molten metal up into the evacuated molds where solidification occurs.

This process works well for the fabrication of metal fuel pins traditionally composed of alloys of uranium and plutonium, but does not work well when highly volatile actinides are included in the melt. The problem occurs both during the extended time period required to superheat the alloy melt as well as when the chamber must be evacuated. The low vapor-pressure actinides, particularly americium, are susceptible to rapid vaporization and transport throughout the casting furnace, resulting in only a fraction of the charge being incorporated into the fuel pins as desired. This is undesirable both from a materials accountability standpoint as well as from the failure to achieve the objective of including these actinides in the fuel for transmutation.

Candidate design concepts are being evaluated for their potential to successfully cast alloys containing volatile actinides. The selection of design concepts has been conducted in close cooperation with ANL staff. The research centers on the development of advanced numerical models to assess conditions that significantly impact the transport of volatile actinides during the melt casting process. The work includes the collection and documentation of volatile actinide properties, development of several conceptual designs for melt casting furnaces, modeling and analysis of these concepts, development of sophisticated numerical models to assess furnace operations, and analysis of these operations to determine which furnace concept has the greatest potential of success. Research efforts focus on the development of complex heat transfer, mass transfer, and inductive heating models.

<u>Task 1 Highlights</u>.

- The computational meshes for the metallic fuel pins model were refined to get the better numerical results.
- A few different mold materials associated with the different initial and boundary conditions such as filling velocities and mold and melt temperatures have been used for the solidification process.

- Modeling results for constant pressure casting, which is more realistic, have been obtained and produce physically realistic results for flow that starts, flows, and then eventually stops as it enters the mold.
- Potential mass transfer modeling features (Lammuir's law for example) are being studied to enhance the capabilities of a mass transfer in a detailed system model.
- Different parameters are being varied as part of a parametric study to evaluate factors that impact the flow of the melt into the molds.
- The ability to include the induction heating governing equations as part of an overall system model is being studied and preliminary efforts to include this complex phenomenon as part of a more detailed model are underway.

Remote Fuel Fabrication (Task 9). The objective of this project is the design and evaluation of manufacturing processes for AFCI fuel fabrication. The large-scale deployment of remote fabrication and refabrication processes will be required for all transmutation scenarios. The evaluation of the fabrication processes will create a decision support data base to document design, operations, and costs. Fabrication processes required for different fuel types differ in terms of equipment types, throughput, and cost. Differential cost Implications of various fuel choices will be assessed. Another aspect is the assessment of robotic technology and robot supervision and control, and the simulation of material handling operations using 3D simulation tools with view towards the development of a fully automated and reliable, autonomous manufacturing process. Such development has the potential to decrease the cost of remote fuel fabrication and to make transmutation a more economically viable process. An added benefit would be the potential for large reductions in dose to workers. This project is being conducted in close cooperation with the fabrication development group at Argonne National Lab.

Manufacturing processes will be simulated as robotic operations supervised by remote operators. Both normal operations as well as failure scenarios will be investigated, analyzed, and simulated. The results of the simulations will be used by AFCI program personnel to perform sensitivity studies on the impact of different fuel types on system operation. Conceptual designs for plant designs and the accompanying supervision and control systems will be developed. Impacts on transmutation system capital cost, economics of operation, estimates of process loss, and environmental and safety issues will be estimated.

Task 9 Highlights.

- Development continued on a 3-D process simulation model with a Waelischmiller hot cell robot.
- Continued work on concepts and methods for vision-based hot cell supervision and control.

1.3.2 Separations Technology

Systems Engineering Model (Task 8). The objectives of this task are the development of a systems engineering model and the refinement of the Argonne code AMUSE (Argonne Model for Universal Solvent Extraction). The detailed systems engineering model is the start of an integrated approach to the analysis of the materials separations associated with the AFCI Program. A second portion of the project is to streamline and improve an integral part of the overall systems model, which is the software package AMUSE. AMUSE analyzes the UREX process and other related solvent extraction processes and defines many of the process streams that are integral to the systems engineering model.

Combining these two tasks is important in ensuring that calculations made in AMUSE are accurately transferred to the overall systems model. Additional modules will be developed to model pyrochemical process operations not treated by AMUSE. These modules will be refined as experiments are conducted and as more knowledge is gained in process steps.

Integrating all aspects of the proposed separations processes will allow for detailed process analyses, trade-off studies or the evaluation of proposed process steps, complete material balances that include all potential waste streams, the impact of changes in feed streams, studies detailing the importance of process control and instrumentation, and the ultimate optimization of the process.

Task 8 Highlights.

- Development of the Visual Basic (VB) Interface for AMUSE code was completed.
- Trade-off techniques for optimizing the system model were examined. Development of the design matrix was initiated.
- A successful meeting was held March 6 and 7 with Argonne National Laboratory (ANL) researchers to discuss project details and provide feedback and support.
- Five specific objects are being implemented for the graphical user interface as a result of the meetings with ANL researchers: Flow sheet, Section, Streams, Stages and Concentrations.
- Work continues on the development of flow sheet objects that allows the user to select flow sheet name, reports location, type of process and other required input.
- A Separations area called "Tools" is being developed to allow the user to develop process blocks within the software environment to build a specific process flow sheet, which includes the ability to generate process streams, sections, stages and input data for each of them.
- Development of an overall process model continues using MATLAB with SIMULINK that will eventually allow the top five most influential factors to the process to be automatically selected those factors will be used for the design variables for the optimization.

Criticality and Heat Transfer Analyses of Separations Processes (Task 11). The success of the AFCI program will rely upon the ability of radiochemists to separate spent nuclear fuel. The Chemical Technology Division at Argonne National Laboratory is actively involved in the development of pyrochemical separation technology that minimizes the usage of strong acids with the subsequent problems involved in disposing of the acidic residue.

Small scale experiments are being validated at ANL to separate spent nuclear fuel, but they must be scaled up to accommodate the large amount of commercial spent fuel that must be treated. As the volume of waste to be treated is increased, there is a higher probability that fissionable isotopes of plutonium, americium, and curium can accumulate and form a critical mass. Criticality events can be avoided by ensuring that the effective neutron multiplication factor, k_{eff}, remains below a safe level. NRC regulations normally allow an upper value of 0.95 for k_{eff}. This parameter can be computed for any combination of fuel and geometry using Monte Carlo neutron transport codes. Scale 4.4a from the Oak Ridge National Laboratory and MCNP4C2 from the Los Alamos National Laboratory are two codes that are regularly used to assess criticality.

Task 11 Highlights.

- Completion of plutonium and americium mixture criticality and heat transfer analysis.
- Research begun on criteria for use of commercial dry casks for the storage of strontium and cesium.

Immobilization of Fission Iodine (Task 15). The recovery of iodine released during the processing of used nuclear fuel poses a significant challenge to the transmutation of radioactive iodine. This task will develop and examine the use of Fullerene Containing Carbon (FCC) compounds as potential sorbents for iodine release from the reprocessing of nuclear fuel. This work will also include the development of bench-scale testing capabilities at UNLV to allow the testing of the FCC material in a simulated process off-gas environment. This experimental capability will also be used to test other potential sorbtion materials and processes, such as natural organic matter (NOM) and other promising alternatives. This work also examines the development of a process to convert the sorbed iodine into a ceramic material with the potential for use as either a transmutation target or as a waste form in a partitioning and sequestration strategy.

Bench scale experimental apparatus and methodologies to simulate iodine entrainment in the vapor phase released from the head end of the PUREX process (the 4M nitric acid dissolution of spent nuclear fuel) will be developed, along with procedures to test the sequestration of Iodine from the vapor mixture. Long term performance/suitability of FCC and NOM will be tested for sequestration of iodine released by nuclear fuel reprocessing. FCC-bearing materials will be prepared and evaluated under laboratory conditions by collaborators at the Khlopin Radium Institute (KRI-KIRSI). Simulated process evaluations will be done on the FCC-bearing materials, NOM, and other matrices suggested by the collaborators at UNLV. Conversion of the sequestered iodine to a ceramic-like material will be examined by the KRI-KIRSI team. Recovery of the Iodine from the sequestering matrices will also be examined by both teams.

Task 15 Highlights.

- The Iodine vapor generator assembly was completed.
- Several tests of iodine sequestration/adsorption were conducted with a commercial peat moss (Natural Organic Matter, NOM),. The results indicated extremely low breakthrough at iodine vapor concentrations close to saturation.

- We have tested and used the ion selective electrode to monitor iodine vapor breakthrough (after bisulfite reduction) in the iodine generator experiments. Also, the ion chromatography method for separation of various iodine species was tested.
- We have examined the kinetics of iodine oxidation by chlorine sulfonamide resins. These resins may be used with NOM to promote iodine binding.
- We have begun assembling an apparatus for simulating nuclear fuel dissolution. Several additional glass items were ordered and we are awaiting delivery.
- The ion chromatography method for separation of various iodine species was tested with NOM samples. Serious interference was discovered and a new column ordered.
- The transfer of iodide to organic matter as facilitated by the by the chlorine sulfonamide resins was examined. Using NOM analogs iodine was shown to become associated with organic matter in the presence of the active chlorine resins.

Fluorapatite Waste Forms (Task 16). Fluorapatite, fluorinated calcium phosphate, has been identified as a potential matrix for the entombment of the zirconium fluoride fission product waste stream from the proposed FLEX process. If the efficacy of fluorapatite-based waste-storage can be demonstrated, then new and potentially more-efficient options for handling and separating high-level wastes, based on fluoride-salt extraction, will become feasible. This task is a dual-path research project to develop a process to fabricate a synthetic fluorapatite waste form for the ZrF_4, FP waste stream, characterize the waste form, examine its performance under environmental conditions, and correlate the behavior of the waste form with natural analogs. Characterization of the material will be accomplished through probing the molecular-scale electronic and geometric structure of the materials in order to relate them to macroscopic properties, with the goal of developing techniques to evaluate and predict the performance of different waste-form materials. Time and funding permitting, other waste forms for the zirconium fluoride, fission product salt waste stream will be examined and benchmarked against the fluorapatite matrix baseline.

- Baseline Raman spectra have been obtained for hydroxyapatite and fluorapatite.
- Natural fluorapatite crystals have been obtained commercially, and will be examined spectroscopically to determine what contaminants naturally occur.
- Plans were developed for chemically preparing samples in which some of the calcium in apatite materials is substituted by nonradioactive actinide surrogates or elements produced by decay of actinides.

1.3.3 Transmutation Sciences

Niobium Cavity Fabrication Optimization (Task 2). Multipacting is one of the major loss mechanisms in rf superconductivity cavities for accelerators. This loss mechanism limits the maximum amount of energy/power supported by the cavities. Optimal designs have been identified in others' studies. In practice, these designs are not easily manufactured. Chemical etching processes used to polish the cavity walls result in a nonuniform surface etch. A nonuniform surface etch will leave some unclean areas with contaminants and micron size particles. These significantly affect mutipacting. Further, a nonuniform etch will leave areas with damaged grain structure, which is not good for superconducting properties. Typically, the depth of chemical polishing etch ranges between 10 to 150 microns.

It is the purpose of this study to experimentally model the fluid flow resulting in the chemical etching of niobium cavities with the aid of a baffle. The current etching process with baffles does not uniformly etch the cavity surface. Multiple cavity cell geometries are being investigated. Optimization techniques will be applied in search of the chemical etching processes that will lead to cavity walls with near ideal properties.

The optimization procedure is intended to be fully automated among a variety of existing codes. Codes are to be modified to provide a statistical study of impacting in the multicavity geometry. Optimization techniques to be developed based on the desired resonant frequency of the geometry and/or on the multipacting condition. An existing vacuum system is, in part, to be modified for multipacting experiments to be conducted in this effort.

Task 2 Highlights.

- Niobium cavities design optimization code appears to be working but is converging to undesired geometries having same constraints. Modified niobium cavity optimization code and created a random seed cavity generator.
- Flow visualization system modified with new back-lighting system and camera deployment. Flow visualization system has completed testing phase and is ready for experimental use. Tuning camera for fluid flow studies.
- Two new optimized geometries based on resonant frequency and mode found.

LBE Corrosion of Steel (Task 3). The goal of this task is to achieve a basic understanding of corrosion of steels by Lead Bismuth Eutectic (LBE). There have been previous studies of LBE, especially by the Russians, who have over 80 reactor-years experience with LBE coolant in their Alpha-class submarine reactors. The Russians found that the presence of small amounts (ppm) of oxygen in the LBE significantly reduced corrosion. However, a fundamental understanding and verification of its role in the corrosion of steels is still very incomplete. We are carrying out a program of post-experiment testing and analysis on steel samples that have been in intimate contact with LBE. We have employed surface analysis techniques, including Scanning Electron Microscopy (SEM), Energy Dispersive X-Ray (EDAX) spectroscopy, and X-ray Photoelectron Spectrometry (XPS), and laser Raman. These techniques, applied to the steel surface, have probed the surface morphology, elemental analysis and oxidation states as a function of position. The measurements were made using the facilities at UNLV. Chemical alterations and resulting chemical species are studied at the steel surface. We plan to use powder X-ray diffraction in the near future. In addition to these well-established laboratory-based instrumentation approaches at UNLV, we have begun to use a state-of-the-art synchrotron-based spectroscopy and microscopy technique, the X-ray fluorescence microprobe at the Advanced Light Source, at Lawrence Berkeley National Laboratory. We are characterizing spectroscopically the stainless steel before and after interaction with LBE to determine their composition, including minor components such as chromium and nickel. The research moves toward establishing a rigorous experimental database of experimental measurements of LBE and its reactions with steels. Such a database can be used by DOE scientists and engineers in engineering efforts to control, avoid, and/or minimize the effect of corrosion of steels by LBE.

Task 3 Highlights.

- Maintenance of the X-ray Photoelectron Spectroscopy (XPS) system was completed.
- Experimental design for benchtop LBE corrosion experiments at UNLV completed.
- Completed characterization of steel samples of HT9 using XPS.
- Enlarged the bibliography of LBE-related and associated publications.

Environment-induced Degradation of Materials (Task 4). During the past two years of this project, the primary effort was focused on evaluating the effect of hydrogen on the cracking behavior of candidate target materials namely, Alloys EP-823, HT-9 and 422 in aqueous environments of different pH values at ambient and elevated temperatures. More recently, emphasis is being placed to evaluate the cracking behavior of these materials in molten lead-bismuth eutectic (LBE) environment at much higher testing temperatures so as to compare the cracking susceptibility in environments containing molten metals and aqueous solutions, respectively. The most recent tests to evaluate the cracking susceptibility were primarily based on two state-of-the-art techniques known as constant-load and slow-strain-rate (SSR) methods. Simultaneously, efforts were made to determine the localized corrosion (pitting and crevice corrosion) behavior in similar aqueous environments at ambient and elevated temperatures using electrochemical polarization techniques. However, these techniques cannot be applied to LBE environment. Therefore, the work scope described in the original proposal has been modified to include additional testing methods to suit the high-temperature LBE environment. Although, testing still will be continued to complete the original matrix involving all three alloys in aqueous environments using constant-load, SSR, and polarization techniques, future testing will be performed in both aqueous and LBE environments using self-loaded specimens such as C-Ring and U-Bend stress-corrosion-cracking (SCC) test specimens. In addition to this corrosion testing, significant efforts will be made to evaluate the crack-growth behavior of radiation-hardened target materials using sub-size compact tension (CT) specimens. The test materials will undergo appropriate thermal treatments prior to their testing. All tested specimens will be examined metallographically. Further, the scanning electron microscope (SEM) will be used to determine the extent and nature of cracking in the tested specimens. The thrust of this overall testing program is to evaluate the environmental and radiation effects on the cracking behavior of candidate target materials.

Task 4 Highlights.

- Stress corrosion cracking (SCC) tests using constant-load and slow-strain-rate (SSR) techniques are ongoing in aqueous solutions at ambient and elevated temperatures.

- SCC tests under controlled cathodic potentials (with respect to the corrosion potential) are ongoing to evaluate the effect of hydrogen charging on cracking.
- Localized corrosion (pitting and crevice) behavior of all three alloys is being evaluated by cyclic potentiodynamic polarization (CPP) method.
- Smooth and notched tensile specimens of Alloys EP-823, HT-9 and 422 are being used for SCC testing.
- Metallographic evaluations of failed samples by optical microscopy are ongoing.
- Fractographic evaluations of failed samples by scanning electron microscopy are in progress.

LBE Corrosion Modeling (Task 5). This project combines chemical kinetics and hydrodynamics in target and test-loop lead-bismuth eutectic (LBE) systems to model system corrosion effects. The goal is to produce a predicative tool that can be validated with corrosion test data, used to systematically design tests and interpret the results, and provide guidance for optimization in LBE system designs. The task includes two subtasks. The first subtask is to try to develop the necessary predictive tools to be able to predict the levels of oxygen and corrosion products close to the boundary layer through the use of Computational Fluid Dynamics (CFD) modeling. The second subtask is to predict the kinetics in the corrosion process between the LBE and structural materials by incorporating pertinent information from the first subtask.

In many cases a component fails because of the combined effect of mechanical or hydraulic factors and corrosion. Such cases are of three types: stress corrosion, corrosion fatigue, and liquid-velocity effects (corrosion erosion and cavitations). The compatibility issues arising from the interaction of liquid metals, corrosion/dissolution, with structural materials at temperatures of interest are important while lead alloy as a coolant for a fast breeder type nuclear reactor is used. The second subtask focuses on the kinetics of the dissolution/deposition process as a function of temperatures, flow velocities, dissolved metal concentrations and the oxygen potentials of the system, the kinetics of film formations in the presence of oxygen, and the kinetics of transports of metal through the oxidized surface film. Both mass transfer controlled and the diffusion coefficient of dissolved species will be parametrically studied for the corrosion process.

Task 5 Highlights.

- Modeling and simulation of the DELTA Loop geometry is being benchmarked against observations at LANL.
- Modeling of sudden expansion geometry work simulation is proceeding and is now able to predict some already existing 3-D experimental work.
- Computer simulation results for Task 5 have been obtained for several geometries, i.e., 2-D sudden expansion flow, torroidal loop with momentum source simulation, straight pipe flow simulation. Wall temperature and concentrations were prescribed. Objectives are to estimate concentration wall mass flux to predict the areas on the wall which depict corrosion rates and those that predict precipitation rates; and, to locate maxima for each corrosion sites and precipitation sites.

Neutron Multiplicity (Task 6). The goals of this task are to measure the neutron leakage from 15, 20 and 40-cm diameter Pb-Bi / Pb targets and to compare these empirical measurements with MCNPX results. These measurements are essential in validating and benchmarking MCNPX modeling results of target materials. The neutron leakage measurements should provide a systematic set of precision data that will enable direct comparison with code calculations. Two detector systems, which employ independent technologies, are in fabrication. Comparisons of results obtained from both should remove many uncertainties and permit the derivation of relative measurements in the few percent range at the 95% Confidence Level (CL). A 60 detector element ^{3}He tube based system and a prototype neutron sensitive glass fiber-based system were designed during Yr-1 of this study. The glass fiber detector prototype is complete and ready to test in upcoming target experiments at LANCSE. The 60 element ^{3}He based, target monitoring system is in final design and initial fabrication stages. MCNPX models of the ^{3}He system have been developed and will be integrated with target models. Models of the glass fiber detectors have been developed and used for developing July 2002 LANSCE target experiments.

Task 6 Highlights.

- Nuclear Transport Code Models (MCNP 4B, MCNPX) needed to finalize the ^{6}Li glass fiber neutron multiplicity detector prototype design were completed. Detector design was finalized subsequent to completion and analysis of modeling results.
- Production of detector material (^{6}Li glass fiber) for the prototype sensor was begun and is nearing completion. Neutron Multiplicity detector prototype (^{6}Li glass fiber detector) is ~70% complete for all hardware and electronic card production (for optoelectronic interfaces, light guides, signal train, firmware). Communication output hardware and software is about 80% completed. Prompt signal circuitry needed for the detector to communicate with the cyclotron signals is ~60% completed.
- ^{3}He Neutron Multiplicity detector prototype (64 element) is nearing 90% completion and will be shipped to UNLV from Russia in April or May.
- Testing of the ^{6}Li glass fiber detector system prototype scheduled at the Crocker Nuclear Laboratory, University of California, Davis for May.

Dose Conversion Coefficients (Task 7). A research consortium comprised of representatives from several universities and national laboratories has been established as part of this task to generate internal and external dose conversion coefficients (DCC) for radionuclides produced in spallation neutron sources. Information obtained from this study will be used to support the siting and licensing of future accelerator-driven nuclear initiatives within the U.S. Department of Energy complex, including the Spallation Neutron Source (SNS) project. Determination of these coefficients will also fill data gaps for several hundred radionuclides that exist in Federal Guide Report No. 11 and in Publications 68 and 72 of the International Commission on Radiological Protection (ICRP).

Task 7 Highlights.

- International DCC consortium met at UNLV to:
    - Provide updates from consortium members on progress
    - Develop a new timeline for completion of dose coefficient calculations
    - Compare and contrasted results of DCs from different institutions
    - Finalize the methodology for the calculation of the DCs
- Modifications to the computer codes used to calculated dose were completed with the assistance of Dr. K. Eckerman, ORNL.
- Completed the dose coefficients calculations for the QA radionuclides.
- Implemented the new EDISTR computer code.

Properties of Alloy EP-823 (Task 10). The purpose of this project is to evaluate the elevated temperature tensile properties of Alloy EP-823, a leading candidate material for transmutation applications. This alloy has been proven to be an excellent structural material to contain the lead-bismuth-eutectic (LBE) nuclear coolant needed for fast spectrum operations. However, very little data exist in the open literature on the tensile properties of this alloy. The selection of Alloy EP-823 as the test material in the proposed task is based on the recommendation of our collaborator at the Los Alamos National Laboratory (LANL). The test material will be thermally treated prior to the evaluation of its tensile properties at temperatures relevant to the transmutation applications. The deformation characteristics of tensile specimens, upon completion of testing, will be evaluated by surface analytical techniques using scanning electron microscopy (SEM) and transmission electron microscopy (TEM). The overall results will lead to the development of a mechanistic understanding of the elevated-temperature deformation processes in this alloy as a function of thermal treatment. Understanding deformation mechanisms of Alloy EP-823 may also help the development of suitable target materials possessing enhanced LBE corrosion resistance and acceptable radiation damage in the United States

Task 10 Highlights.

- High-temperature tensile testing using new specimen grips on the Materials Testing System has been initiated.
- The ambient temperature tensile testing of Alloy EP-823 is ongoing.
- Additional tensile specimens of Alloy EP-823 are being machined from the heat-treated bars.

Oxygen Sensing in LBE (Task 13). Although liquid lead-bismuth eutectic (LBE) is a good candidate as a coolant in fast nuclear systems, it is known to be very corrosive to stainless steel, the material of the carrying tubes and containers. Such a corrosion problem can be prevented by producing and maintaining a protective oxide layer on the exposed surface of stainless steel. The proper formation of this oxide layer critically depends on the accurate measurement and control of the oxygen concentration in liquid LBE. YSZ (Yttria Stabilized Zirconia) oxygen sensors, using molten bismuth saturated with oxygen as the reference, have been utilized to accurately measure the concentration of oxygen dissolved in LBE.

A new experimental apparatus with several important improvements to an older version at LANL is under development at UNLV. The proposed specific aims of the task are: (1) To complete and fully test the new oxygen control and measurement apparatus; (2) To continue the sensor calibration by using our new set-up in UNLV at higher temperature ranges (350 ^{0}C to 700 ^{0}C); (3) To employ a more precise and easier H_2/H_2O steam injection strategy for oxygen control instead of previous method of direct injection of O_2; (4) To simulate the dissolved oxygen concentration distribution in the liquid LBE of our system by using FEMLAB or other software (ABAQUS/FLUENT). The results obtained from the simulations will be used to cross-check and cross-validate with the experimental data; (5) To determine oxygen dissolving rates under various conditions including changing temperatures and inlet O_2 supply; and, (6) To determine the diffusion coefficient of O_2 in liquid LBE under different temperatures through theoretical modeling and experimental measurement.

Task 13 Highlights.

- A 2-dimensional model of the oxygen-sensor/LBE experimental set-up was completed using FEMLAB. After a few simulations, it was recognized that FEMLAB is not suitable for the simulation of the oxygen concentration and dissolving rate in LBE..
- Most of the parts for the Task 13 apparatus have been received and moved into TBE B310.
- LabView module for the control of our apparatus has been designed and is under testing and improvement.

Positron Annihilation Spectroscopy (Task 14). The purpose of this collaborative research project involving UNLV and the Idaho State University (ISU) is to evaluate the feasibility of determining residual stresses of welded, bent (three-point-bend), and cold-worked engineering materials using a new nondestructive technique based on positron annihilation spectroscopy. The technique uses x-rays from a small MeV electron Linac to generate positrons inside the sample via pair production. This method can be used for materials characterization and investigation of defects in thick samples that could not be accomplished by conventional positron technique or other nondestructive methods. The data generated will be compared to those obtained by other nondestructive methods such as neutron diffraction and x-ray diffraction, and a destructive method known as ring-core technique. Materials to be tested in the initial phase will be unirradiated austenitic (Type 304L) and martensitic (EP-823) stainless steels that will be welded, bent and cold-worked prior to the evaluation of their residual stresses. Metallurgical microstructures will also be evaluated. In addition, deformation characteristics in terms of dislocations and their movements resulting from welding and plastic deformation will be analyzed by transmission electron microscope (TEM). Later, irradiated Alloy EP-823, HT-9, and austenitic materials (Type 316L stainless steel and Alloy 718) will be included in this program.

Task 14 Highlights.

- Cold-worked, bent and welded specimens of heat-treated Alloy EP-823 and Type 304L stainless steel are being evaluated for residual stress measurements using positron annihilation spectroscopy at the Idaho State University and X-ray and Ring-Core methods at the Lambda Research Laboratory.

- All three types of specimens are being evaluated for residual stress measurements by positron annihilation spectroscopy at ISU.
- Residual stress measurements in bent and welded specimens are in progress at the Lambda Research Laboratory (LRL) using X-ray and Ring-Core methods.