ATR
National Scientific User Facility

The Energy of Collaboration

March 2013 Quarterly Report

Accomplishments and Look Ahead

February
- Dr. John Jackson visited the University of Wisconsin and presented on ATR NSUF and industry programs.
- Jeff Benson presented on the ATR NSUF Education Program during the Engineering Education technical session at the Conference on Nuclear Training & Education (CONTE) on February 5.

March
- Staff traveled to The Minerals, Metals and Materials Society (TMS) Annual Meeting & Exhibition to host an exhibit booth March 4-7.
- Anders Jenssen of Studsvik Nuclear AB led a colloquium on irradiation assisted stress corrosion cracking on March 7.
- Five of nine Rapid Turnaround Experiments (RTEs) submitted for the first quarter call for proposals were awarded on March 15.
- INEST Fuels and Materials CORE Workshop was held March 19 & 20.

April
- Registration for 2013 Users Week (June 10-14) is open until April 19th. To register or view the agenda, visit the ATR NSUF website or click here.
- Staff will travel to Student ANS April 4-6 to present a workshop, judge presentations, and present best paper awards.
- Frances Marshall will present a seminar at University of Massachusetts, Lowell on April 8.
- Frances Marshall will participate in and present an invited briefing on ATR NUSF to the IAEA Technical Working Group on Research Reactors in Vienna, Austria, April 17-19.

Open Proposal Calls
- Second quarter call for RTE proposals closes March 31.
- Call for irradiation, PIE and APS experiments closes June 27.
- Third quarter call for RTE proposals closes June 30th.
- 2014 FSRT call closes Dec. 2013.

Noteworthy News

ATR National Scientific User Facility program gives industry access to INL capabilities

Irradiation test designers Brandon Horkley and Ray Mitchell load and catalog EPRI IASCC specimen packages into a test train at INL's Test Train Assembly Facility.

Universities have many opportunities for access to research facilities, but private industry has fewer options when complex, high-end capabilities are needed to advance new technology. That is where public resources such as the U.S. Department of Energy's (DOE) national laboratory complex play a role.

Many of the national research capabilities that are unique to nuclear energy reside at Idaho National Laboratory, the nation's lead nuclear energy lab. DOE made these capabilities more accessible to university research teams by establishing a National Scientific User Facility around INL's Advanced Test Reactor.

Now, a new set of Advanced Test Reactor National Scientific User Facility (ATR NSUF) experiments is demonstrating how industry researchers also can access INL's distinctive capabilities. Two research projects with the Electric Power Research Institute (EPRI) — a non-profit research, development and demonstration organization for the electric utility industry — are directly supporting the nation's nuclear energy industry. Both experiments are cooperative research and development agreements (CRADAs) that allow ATR NSUF and EPRI to share knowledge and costs of the projects. One project will provide data that could help increase the robustness of cladding materials that surround and isolate nuclear fuel. Another supports relicensing efforts by boosting understanding of factors that can limit the lifetimes of reactor structural materials. The projects build on work the ATR NSUF has been doing to enhance relevance for industry.

"Collaborative research between universities and industry is absolutely invaluable to both sides," said Dr. John Jackson, ATR NSUF Industry Programs Lead and INL's principal investigator for the EPRI experiments.

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Industry program continued

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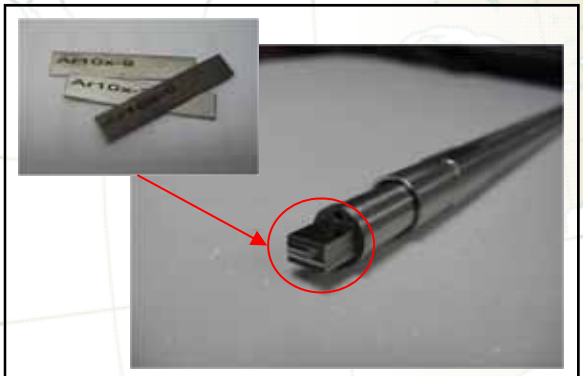
"The user facility concept represents a huge shift in the way research will be done for these companies. It is exciting for them and exciting for us."

To ensure the program offers capabilities needed to support industry experiments, the ATR NSUF Industry Advisory Committee (ANIAC) was created for regular interfacing with industry. Attendees at the most recent meeting held in May 2012 included representatives from EPRI, as well as:

- Électricité de France (EDF), the second largest electric utility company in the world
- U.S. Nuclear Regulatory Commission
- Materials Aging Institute, a French utility-run research center representing half the world's nuclear power station operators
- General Electric-Global Research Center, the research and development division of General Electric
- Duke Energy, the largest electric power holding company in the United States
- Rolls-Royce, a leading industry supplier of power systems and services
- Tohoku University, the third oldest Imperial University in Japan
- Westinghouse Electric Company, a nuclear power company providing nuclear products and services to utility companies worldwide
- Areva NP, a French public multinational nuclear services company
- Ironwood Consulting, a nuclear energy consulting firm.

The EPRI pilot experiments are paving the way for future industry use of the ATR NSUF. One of the projects ("EPRI Zr Growth") is irradiating 200 specimens of various Zirconium alloys to determine why reactor fuel channel cladding – the barrier between the fuel and reactor coolant – bows in service. Bowing could lead to cracks in the cladding and allow some fission products to escape into the coolant. Reactors are designed to deal with this using decontamination systems, which are expensive. Research and development on more robust cladding materials could save money and protect personnel by minimizing the escape of fission products.



EPRI Zirconium Growth experiment specimens in a partially assembled irradiation capsule prior to irradiation.

Another EPRI pilot project, focused on post-irradiation examination (PIE) of reactor structural materials ("EPRI IASCC"), is looking at how metal alloys behave under irradiation in reactor environments. Specifically, the project will explore the growth behavior of irradiation assisted stress corrosion cracks (IASCC) in two particular alloys, "X-750" (a nickel-based alloy) and "XM-19" (a nitrogen strengthened austenitic stainless steel) within a typical light water reactor environment. Engineers already use these alloys in hardware inside light water reactors in parts such as nuts and brackets. Stress corrosion cracking in reactor components tends to occur more frequently as a reactor ages.

The EPRI IASCC project experimenters fabricated three test capsules with specimens of X-750 and XM-19 alloys in each. Each capsule will be irradiated to different neutron fluence targets in ATR over the next year.

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Industry program continued

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Research and development on how these materials respond to irradiation contributes to the overall goal of extending the life of reactors and the components inside them. It also helps engineers optimize inspection intervals and predict component lifetimes.

EPRI IASCC experiment specimen packages prior to insertion into a test train.

The design, baseline characterization, irradiation, shipment, handling, and PIE for the EPRI IASCC experiment all will be performed at INL, marking the first time an IASCC experiment will undergo this type of full-scale characterization here. Instead of shipping the experiment to different laboratories to complete different stages of characterization, all aspects will be done here – a "one-stop shop."

The work is significant not only for the industry collaboration, but because this is the first time one of the ATR's coveted pressurized and chemistry-controlled experimental loops has been used by researchers outside the U.S. Navy. In the past, all five of the active loop test positions in ATR were reserved exclusively for Navy use, but the newly reactivated sixth loop, Loop 2A, is the first available for external user experimentation. Each pressurized water loop can be operated at the customer's desired pressure, temperature, flow, and water chemistry, independent of the conditions in the rest of the reactor. With a loop position, users nearly have their own customizable test reactor at their fingertips. Until now, capabilities like those offered with Loop 2A were not available to industry or universities in the United States.

Frances Marshall, ATR NSUF program manager, is looking forward to industry user program growth. "These tests (loop irradiation and IASCC characterization) are one of the highest priority research efforts for the light water reactor industry," Marshall said. "INL's ability to perform this work will increase our connection to the commercial nuclear power industry, as well as open up new opportunities for our ATR NSUF researchers to propose projects using these new capabilities."

The first of the three EPRI IASCC capsules will begin irradiation in March, the second in late April, and the third in early 2014. After irradiation, the user experiment will be part of another Laboratory first- the first to use the newly constructed IASCC test rig at INL's Materials and Fuels Complex (MFC). At MFC, capsules will undergo IASCC testing and fracture toughness testing using the brand new test rig.

The newly constructed irradiation assisted stress corrosion crack (IASCC) test rig at INL's Materials and Fuels Complex.

"Collaboration among industry, national laboratories, and universities can only enhance the ATR NSUF's ability to solve technically challenging problems in a way that benefits everyone," said Jackson. "We look forward to performing more work to support industry research needs."

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Researchers provide enhanced temperature, fluence sensor options for ATR NSUF experiments

Demands for high-temperature irradiation-resistant sensors with increased accuracy and resolution have led Idaho National Laboratory (INL) researchers to develop and deploy new sensor technologies that can better meet programmatic needs for advanced fuel and material irradiations conducted in the higher temperature/ higher flux conditions at US materials and test reactors (MTRs). At INL, in-pile instrumentation enhancement and development activities are primarily completed at the High-Temperature Test Laboratory (HTTL).

Encapsulation and evaluation processes performed in support of the EPRI tests have made new peak temperature and fluence sensor options available to all ATR NSUF experimenters.

Since the ATR NSUF program initiated this instrumentation development effort, HTTL researchers have made significant accomplishments in several instrumentation development and deployment areas. Specialized INL-developed sensors for real-time detection of temperature and thermal conductivity during high temperature irradiations are not only being provided to ATR NSUF reactors at INL and at the Massachusetts Institute of Technology, but also to Commissariat à l'Énergie Atomique et aux Energies Alternatives (CEA) in France and to the Institute for Energy Technology/Halden Reactor Project (IFE/HRP) in Norway. In return, these foreign research organizations are providing HTTL researchers with unique in-pile sensors for evaluating elongation and flux measurements. Although most HTTL research focuses on sensors capable of providing real-time data during an irradiation, they are also involved in expanding user options for peak temperature sensors, such as melt wires and silicon carbide temperature monitors, and integral fluence sensors, such as activation foils and flux wires. HTTL researchers are also evaluating 'advanced' technologies, such as fiber-optics based elongation sensors and ultrasonic thermometers. The higher accuracy and resolution data from these advanced technologies are desired by programs to enhance the understanding of reactor phenomena and for validating new multi-scale computational models.

Figure 1. EPRI flux monitor capsules 2A1, 2B3, 2B12, and 2C10 shown with a Lincoln cent for perspective.

To meet ATR NSUF experimenter needs for integral fluence and peak temperature sensors, HTTL researchers Benjamin Chase, Kurt Davis, and Darrell Knudson developed in-house encapsulation processes using vanadium capsules for iron flux wire monitors. Although a range of geometries are possible, the flux monitor capsules were constructed to fit within a 7.6 mm length and 1.7 mm diameter envelope for the EPRI 1, 2, and 3 Test Packages that were recently deployed in the ATR NSUF In-Pile Tube Test Train. These vanadium encapsulation processes may also be used to encapsulate melt wires that may be subjected to higher temperatures than our currently-used quartz capsules can withstand. The EPRI-2 flux monitor capsules are shown in Figure 1.

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Enhanced sensors continued

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A radiograph of a vanadium capsule with iron wire is shown in Figure 2. X-ray inspection was used during its development to optimize the laser welding parameters and to measure critical dimensions such as wall thickness, Fe wire placement, and laser weld penetration.

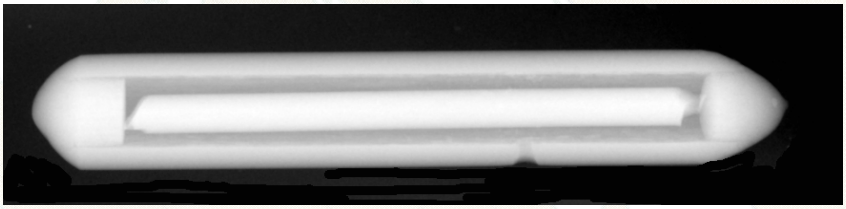


Figure 2. Radiograph of vanadium capsule with iron wire in the center.

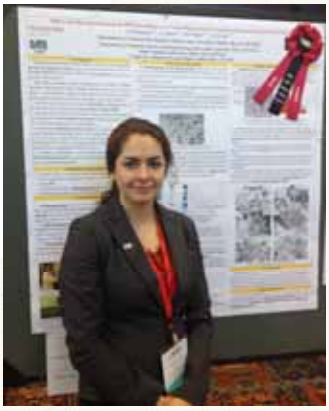
Chase, Davis, and Knudson also provided guidance related to melt wire selection for this EPRI test. In response to a request by the test design engineer, these researchers tested bismuth wire to assess its performance as a melt wire. Results from these evaluations led to bismuth wires being included as part of the set of melt wires used for the EPRI test. Pictures of the melt wires (see Figure 3) were taken by HTTL staff to provide a basis for evaluating whether melting occurred during the test irradiation.

Figure 3. Macrograph of quartz capsule with bismuth melt wire.

Encapsulation and evaluation processes performed in support of the EPRI tests have made new peak temperature and fluence sensor options available to all ATR NSUF experimenters. Nearly 30 melt wire materials, with temperatures ranging from 85-1455°C, are now available. Silicon carbide temperature monitors for temperature detection are also available. Vanadium encapsulation for flux wire materials such as, but not limited to, Fe, Ni, Co, Al, and Cu may be selected as needed. Based on user needs, additional melt wire and fluence materials will be evaluated to increase the options available to ATR NSUF experimenters. Although real-time sensor development and deployment remains an important aspect of HTTL instrumentation development activities, these peak and integral sensors are an important option that should be included in all ATR NSUF experiments.

Graduate researcher wins TMS award for ATR NSUF research project poster

Please join us in congratulating University of Idaho doctoral student Somayeh "Somi" Pasebani! At The Minerals, Metals & Materials Society (TMS) conference held the week of March 3-7 in San Antonio, Texas, more than 70 students entered the Technical Division Student Poster Contest. Of those students, twelve winners were selected – one undergraduate and one graduate student in each technical category. Each winner received a $500 award.



Somi Pasebani and of her winning project poster.

Somi was selected as the graduate student winner in the Structural Materials Division. Her poster titled, "Effect of Alloying Elements and Spark Plasma Sintering Parameters on Nano-dispersion Formation in Nanostructured Ferritic Steels," was based on the research she performed on an ATR NSUF rapid turnaround experiment.

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Faculty/Student Research Team project award winners announced

The ATR NSUF Faculty and Student Research Team (FSRT) program is an opportunity for faculty and students to spend part of the summer performing research in collaboration with an INL scientist or engineer. This ATR NSUF education program awards faculty-led team contracts to partner with an INL mentor and work on building capabilities needed in the user facility. In addition, teams gain an understanding of INL, build technical knowledge, and establish relationships with INL researchers.

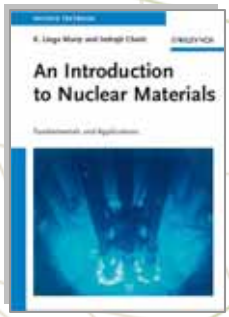
In January, two different FSRT projects were awarded from the most recent call for proposals. Oregon State University Assistant Professor Wade Marcum is the lead faculty on both projects and will bring two students with him to INL – one student for each project.

The first FSRT project will use advanced modeling and simulation capabilities, such as INL's Multiphysics Object-Oriented Simulation Environment, or MOOSE, and the Implicit Simulation Of Nuclear fuel, or BISON, to study transient fast reactors using computer simulation and modeling. MOOSE is a computer simulation framework that allows researchers who aren't computer scientists to utilize simulation and modeling capabilities and BISON is one of the several applications MOOSE can run. The simulation and modeling will be used to help predict behavior of advanced fuels, significantly improve fidelity of safety-based calculations, and reduce experimental design time toward future tests at the Transient Reactor Test Facility (TREAT). Dan Wachs in the INL Fuel Performance and Design department will be the INL mentor working with the FSRT.

The second FSRT project will look at thermodynamics and fuels by assessing current computational fluid-structure interaction software tools and developing a validation method. INL mentor Warren Jones of the Experiment Design Analysis department will be working with the FSRT this summer. Although computational fluid-structure interaction software tools have progressed in recent years, the effort to perform rigorous validation and verification (V&V) of multiphysics packages has fallen short due to a lack of resources and direction, problem complexities, and available experimental data. The FSRT project will assess the applicability of validation problem sets currently used by various software vendors and developers. The resulting method is planned to be exercised at INL to validate multi-physics computational analyses used by the Global Threat Reduction Initiative Fuels Development program and to supplement the design process of ATR NSUF experiments prior to qualification testing and irradiation.

The call for 2014 FSRT proposals is currently open and proposals are due by mid-December 2013. For more information on FSRT or to submit a proposal, contact Jeff Benson (jeff.benson@inl.gov, 208-526-3841) or visit http://atrnsuf.inl.gov/FacultyandStudents/FacultyStudentResearchTeams/tabid/76/Default.aspx.

ATR NSUF researchers collaborate, publish textbook



ATR NSUF researchers, Professors K.L. Murty (North Carolina State University) and Indrajit Charit (University of Idaho), recently published a textbook with publisher Wiley-VCH titled, *An Introduction to Nuclear Materials: Fundamentals and Applications.*

The idea behind the book began in 2006 when Murty and Charit saw a need for students studying nuclear science to have at least a basic understanding of nuclear materials. At the time, Charit was a post-doctoral fellow working under Murty.

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Nuclear textbook continued

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Dr. K.L. Murty, North Carolina State University

"This book is based on my teaching experiences over the last 32 years and on the needs Dr. Charit discovered teaching similar courses at University of Idaho," says Murty. "It fills in the gap on basic nuclear materials knowledge for those who have little background in materials science." According to Murty, over the course of his teaching career, he had been piecing together information from a variety of textbooks and some of his own notes to help students understand nuclear materials, but different nomenclatures used in those resources were an issue. Creating their own text gave Murty and Charit the opportunity to provide consistency, consolidate the knowledge both had been collecting over the years, and tailor information to students' learning needs.

"This textbook is not written for nuclear materials researchers or advanced graduate students," says Charit. "It is for senior undergraduates, beginning graduates and practicing professionals who are interested in the topic but not from nuclear materials backgrounds."

Dr. Indrajit Charit, University of Idaho

While the textbook is not directly tied to their ATR NSUF research project, their research at ATR NSUF did impact some content included. In its opening chapter, "Overview of Nuclear Reactor Systems," the book features a key ATR NSUF reactor capability, the Advanced Test Reactor.

K.L. Murty, Professor and Director of Graduate Programs in the Nuclear Engineering Department at North Carolina State University, was a principal investigator for one of the first ATR NSUF awarded irradiation experiments, and is University Lead for the Nuclear Fuels & Materials CORE of the Institute for Nuclear Energy Science and Technology (INEST) at INL. Indrajit Charit, an Assistant Professor of Materials Science and Engineering & Nuclear Engineering Programs at University of Idaho, has been an ATR NSUF principal investigator for two Rapid Turnaround Experiments. Copies of the textbook can be purchased directly from the publisher (Wiley-VCH) or on Amazon.com.

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