TOPICAL MEETING

Nuclear fuels and structural materials

NFSM 2014 brought together nuclear materials experts from industry, academia, and national laboratories to discuss current R&D in the field.

The biennial Nuclear Fuels and Structural Materials (NFSM) topical meeting, sponsored by the ANS Materials Science and Technology Division, was first held in 2008 and has since become, in the words of Idaho National Laboratory's Todd Allen, a "must-do" conference for scientists and engineers researching advanced fuels and materials. "It provides a venue more focused on engineering application than is available at many of the materials science conferences," he said.

Allen

NFSM 2014 was held June 17–19 in Reno, Nev., in conjunction with the ANS Annual Meeting, and was cochaired by Allen and Lance Snead, of Oak Ridge National Laboratory. The meeting featured 12 sessions on topics such as light-water reactor accident tolerant fuels, LWR sustainability and used fuel disposition, fuel behavior and performance, salt and gas reactor fuels and materials, core structural components, fast reactor fuels and materials, and radiation effects, in addition to a poster session and a two-part special session in honor of Donald Olander, a professor in the Nuclear Engineering Department at the University of California at Berkeley.

The meeting kicked off with a plenary session featuring presentations by Peter Lyons, the Department of Energy's assistant secretary for nuclear energy, and Marius Stan, the national technical director for advanced modeling and simulation in the DOE's Office of Nuclear Energy (NE) and a senior computational energy scientist at Argonne National Laboratory.

In his presentation, "Advanced Fuels and Materials R&D at DOE Office of Nuclear Energy," Lyons stated that President Obama has made it clear that nuclear energy plays a key role in current U.S. energy policy. "The appointment of Ernest Moniz as secretary of energy further illustrates the importance the administration places on nuclear energy as part of our nation's carbon-free energy supply, as he has been a long-standing voice of leadership on topics of nuclear technology and policy," he said.

The mission of NE, Lyons said, is to support nuclear power as a sustainable and innovative source of energy—a mission it accomplishes in part through its research, development, and demonstration (RD&D) programs, the objectives of which include fostering effective used fuel management and international and industry collaboration, improving economics, and reducing technical, financial, regulatory, and proliferation risks.

Lyons

NE's nuclear fuels–related programs, Lyons noted, include the development of advanced nuclear fuels for LWRs, fast reactors, and high-temperature gas reactors, with improved experimental capabilities that are integrated with high-performance computing and advanced modeling and simulation. This research, he said, embraces NE's science-based, engineering-driven approach that combines cutting-edge examination capabilities with the computational power of high-performance computing.

In response to the events at Fukushima Daiichi, Lyons said, NE's Advanced Fuels Campaign has begun an effort to develop new concepts of nuclear fuel with enhanced accident tolerance for application in LWRs. "While existing uranium-Zircaloy fuel has been optimized through decades of evolutionary improvements and safe operation," he said, "the question has been raised, 'Can this fuel be improved for the expected decades of future LWR operation?' The concepts under consideration are being developed to improve cladding and fuel integrity, retain fission products, improve reaction kinetics with steam, and slow the generation of hydrogen in extreme, beyond-design-basis events, as well as improve economics and performance under normal operating conditions."

According to Lyons, the initial evaluation of these concepts has highlighted interest in materials with lower oxidation rates when exposed to steam, including advanced steels, such as iron-chromium-aluminum alloys; refractory metals, such as molybdenum; ceramic cladding; innovative alloys with dopants; and Zircaloy with a coating or sleeve. "Each concept has some pros and cons across the spectrum of operating and transient conditions of interest," Lyons said. "A systematic analytical and experimental evaluation is being performed during the feasibility studies."

Partnerships have been formed to address this key area of research, Lyons noted, including collaborations with all three U.S. fuel vendors—AREVA, General Electric Company, and Westinghouse Electric Company—and with universities, which also play important roles in the development of these innovative concepts. "A goal of the enhanced accident-tolerant fuel pro-

gram is to prioritize the most promising concepts for further development in 2016 and have a lead test assembly or lead test rod ready for demonstration in a commercial reactor by 2022," Lyons said.

Other research in NE's advanced nuclear fuel program includes work on transmutation fuel for managing the minor actinide waste from the back end of the nuclear fuel cycle in a sustainable way with fast reactors, Lyons said, adding that among the notable efforts in this area are advanced fabrication techniques, characterization of material properties of minor actinide–bearing fuels, better understanding of irradiation behavior of actinide-bearing fuel compositions, and development of advanced claddings with high burnup capability.

Regarding the development of uranium carbide tristructural-isotropic (TRISO) coated fuel for high-temperature gas reactors, Lyons said that progress is being made on an industrial scale at Babcock & Wilcox on a high-quality, low-defect level. "This performance is further demonstrated by high-temperature furnace testing, demonstrating safe performance of high burnup TRISO fuel up to 1,800 degrees Celsius," he said.

Lyons also said that national laboratories play a vital role in NE's fuel R&D with their unique capabilities and highly trained scientists, engineers, and technicians. He pointed to the resumption of transient testing of fuel at INL's Transient Test Reactor, or TREAT, as an example. "The environmental assessment is complete, and a finding of no significant impact was issued in February 2014, which identified TREAT at INL as the selected alternative," Lyons said. "Preliminary assessments of the reactor fuel, the filtration/cooling system, and the electrical distribution system have all been positive. Current efforts are focused on updating safety documentation and procedures to allow fuel handling and movement of the control rod drives. The goal is to resume transient testing operations by FY 2018, which supports the future testing needs of the office's advanced fuels programs."

Lyons concluded his talk on a positive note. "These are exciting times for DOE's advanced nuclear fuel program," he said. "From the innovation of groundbreaking methods of science-based, engineering-driven RD&D to the opportunity to shape the future of LWR fuels with enhanced accident tolerance, transmutation fuel for fast reactors, and TRISO fuel for HTGRs, the Office of Nuclear Energy and its partners are addressing the needs of our nation."

Stan followed his DOE colleague with "Modeling and Simulation Coordination at DOE Office of Nuclear Energy," which focused on the coordination among three DOE programs—the Consortium for Advanced Simulation of Light Water Reactors (CASL), Nuclear Energy Advanced Modeling and Simulation (NEAMS), and Nuclear Energy University Programs (NEUP)—with an emphasis on their partnership in developing advanced computational methods to address nuclear energy challenges and solve high-impact problems.


Stan

According to Stan, advanced modeling and high-performance computer simulation, coupled with experimental validation, contribute to improving the understanding of the complex phenomena that occur in the nuclear reactor and help in the design and optimization of new fuels, materials, and reactor concepts.

"CASL, a DOE Energy Innovation Hub, provides simulation technology that has been deployed and applied to enhance the safety, reliability, and economics of LWRs," he said. "CASL has developed the Virtual Environment for Reactor Applications core simulator, or VERA-CS, and successfully used it to analyze the startup conditions of the AP1000 plant design. The NEAMS program develops and validates computational tools for the analysis and design of current and future reactor and fuel cycle systems, providing insights into complex phenomena such as fission gas accumulation, microstructure evolution, and thermal transport. CASL and NEAMS complement each other in providing insights and computational tools for current and next-generation reactors."

National laboratories play a vital role in the Office of Nuclear Energy's fuel R&D with their unique capabilities and highly trained scientists, engineers, and technicians.

The experimental validation necessary to create confidence in simulation predictions, Stan said, is provided by national laboratories and universities via NEUP, an Office of Nuclear Energy program established in 2009 to consolidate its university support under one program.—*Michael McQueen* NN