# LWRS Newsletter

Light Water Reactor Sustainability

Issue 1 • August 2010


## Welcome to the LWRS Newsletter

**By Rich Reister**
Federal Program Director

Welcome to the first edition of the LWRS newsletter! I hope you find this information both interesting and informative. We plan to publish this newsletter on a quarterly basis to provide readers with updates on our research and development activities.

This program is really just getting started. However, we've made substantial progress over the last couple of years by completing a number of technical workshops, holding our first steering committee meeting, and developing a detailed program plan that defines the activities we believe will best support our industry in the long-term safety and economic operation of our fleet of nuclear power plants. Reports from these efforts along with more detailed technical information can be seen on the program's website at **http://www.inl.gov/lwrs**.

The Office of Nuclear Energy's Research and Development (R&D) Roadmap was submitted to Congress in April 2010. Objective number 1 is to develop technologies and other solutions that can improve the reliability, sustain the safety, and extend the life of current reactors. The Light Water Reactor Sustainability (LWRS) program is NE's principal means of achieving this objective. We have divided our work into five "R&D Pathways," which are: (1) Nuclear Materials Aging and Degradation; (2) Advanced LWR Nuclear Fuel Development; (3) Advanced Instrumentation, Information, and Control Systems Technologies; (4) Risk-Informed Safety Margin Characterization; and (5) Economics and Efficiency Improvements. In addition, we will be working closely with the Modeling and Simulation Hub, which was recently awarded to the Consortium for Advanced Simulation of Light Water Reactors (CASL).

We have assigned Idaho National Laboratory as our Technical Integration Office for the LWRS program. However, we have a broad and diverse group of participants from many different national laboratories, universities, industry partners and international participants and we seek to expand our group of collaborators further as the program grows.

In this newsletter, we have articles on the program in general, an update on Nuclear Materials Aging and Degradation and Advanced LWR Fuels Development technical pathways, and a look at our current partners. We plan to cover a wide range of topics from all five of our R&D pathways in future newsletters.

We welcome your feedback on this newsletter or any other aspect of the program. You can reach me by phone at 301-903-0234 or by e-mail at **richard.reister@nuclear.energy.gov**.

## What is the Light Water Reactor Sustainability Program?

A research and development program sponsored by the Department of Energy is providing the technical foundation for licensing and managing long-term, safe and economical operation of nuclear power plants by focusing on activities to extend their operating lifetime beyond 60 years.

That research and development program, performed in close collaboration with industry, is the LWRS Program. The focus is on longer-term and higher-risk/reward research that contributes to the national policy objectives of energy and environmental security.

According to the Nuclear Energy Institute, over the past two decades, nuclear power plants have achieved increasingly higher capacity factors with the same or greater levels of safety. The average capacity factor for U.S. plants in operation in 1980 was 56.3 percent; in 1990, 66 percent; and in 2009, 90.5 percent.

Nuclear energy provides 20 percent of the United States' electricity and is its No. 1 source of emission-free electricity.

But, if these nuclear power plants do not operate beyond

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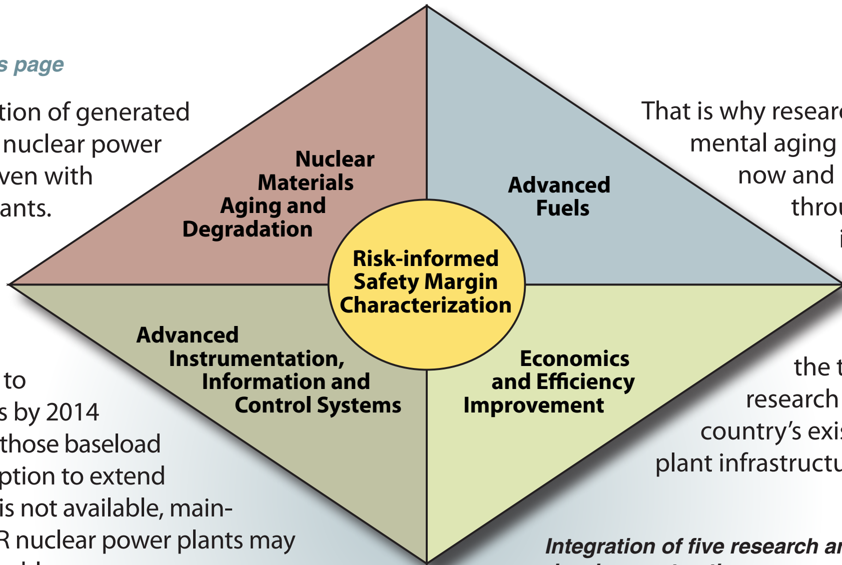
60 years, the total fraction of generated electrical energy from nuclear power will begin to decline even with the addition of new plants.

With the present 60-year licenses beginning to expire between 2029 and 2039, utilities are likely to start planning activities by 2014 or sooner for replacing those baseload power sources. If the option to extend current plant lifetimes is not available, maintaining the current LWR nuclear power plants may not happen in a sustainable manner.

That is why research to address fundamental aging questions must start now and is likely to extend through 2029, with higher intensity for the first 10 years. The LWRS program represents the beginning of the timely collaborative research needed to retain the country's existing nuclear power plant infrastructure.




*Integration of five research and development pathways.*

## Initial LWRS Partners (more to come)

- Electric Power Research Institute
- Energy Technology
- INL
- KNF Consulting
- Longenecker & Associates
- MIT
- North Carolina State
- Ohio State
- Oregon State
- ORNL
- Penn State
- PNNL
- SNL
- Texas A&M
- Texas Engineering Experiment
- University of California-Santa Barbara
- University of Idaho/ Idaho State University
- University of Michigan
- University of Tennessee

## From the TIO Director:

**By Ronaldo Szilard**
LWRS Program TIO Director

In 2007 a Strategic Plan for Light Water Reactor Research and Development was issued, which describes an Industry-Government Partnership to address climate change and energy security. With strong industry support workshops and meetings were held to identify R&D needs and define R&D pathways. Additional meetings were held to gain agreement in principle of the partners in a public-private partnership [proposed to be DOE-NE and Electric Power Research Institute (EPRI)] to the principle of governance, cost sharing, and management of the partnership program by April 2008. In agreement with DOE, the LWRS Program was formed and the program management structure was determined, which includes the LWRS Program Technical Integration Office.

INL and EPRI presented the plans for the DOE sponsored LWRS Program and the industry sponsored Long Term Operation (LTO) program to senior managers of U.S. utilities. The presentations were made to Nuclear Energy Institute's Nuclear Strategic Issues committee and to EPRI's Nuclear Power Council in August 2008. The presentations and discussions solidified strong industry support for the LWRS and LTO collaborative programs.

The budget for the LWRS Program under Gen IV was $2M in 2009 and $10M in 2010. With input from industry representatives, the R&D scope was identified and prioritized, and is further described in the LWRS Program Plan. The FY-11 budget request is $26M and is now part of the Reactor Concepts budget line. Industry is providing significant funding for collaborative activities either directly or through EPRI. The EPRI program is described in the EPRI LTO Technology Roadmap. Currently, DOE and EPRI are finalizing a Memorandum of Understanding to better define how DOE and EPRI will collaborate.

The LWRS Program is expected to have multiple national laboratory, governmental, industrial, international, and university partnerships. As appropriate, the LWRS Program technology development and execution activities will use facilities and staff from national laboratories, universities, industrial alliance partners, consulting organizations, and research groups from cooperating foreign countries.

For more information (i.e., program plan, newsletters, technical documents) please visit **http:/www.inl.gov/lwrs.**

# Nuclear Material Aging and Degradation

## *Identifying mechanisms and mitigation strategies for irradiation-assisted stress corrosion cracking of austenitic steels in LWR core components*

**By Jeremy Busby**
Nuclear Materials Aging and Degradation Pathway Lead

*(Nuclear Materials Aging and Degradation is one of the five principal Research and Development pathways identified to address the goals of the LWRS Program to better understand the challenges posed by the aging of nuclear power plants. Materials degradation in a nuclear power plant is extremely complex because of the many different materials, environmental conditions and stress states.)*

A comprehensive program consisting of crack growth rate and constant extension rate tensile tests is under way to identify metallurgical and environmental factors that have control irradiation assisted stress corrosion cracking susceptibility.

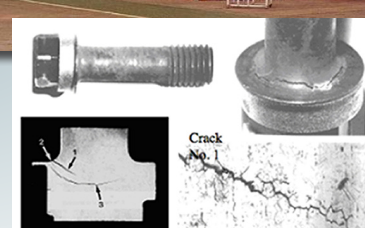
To achieve this goal, several key parameters have been identified, including specific metallurgical variables such as solute type, alloy purity, alloy type, presence of grain boundary carbides, localized deformation and cold work. Operational parameters such as irradiation dose, temperature and water chemistry also are being looked at.

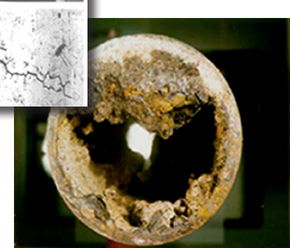
The program considers the capability of proton irradiation to emulate neutron irradiation in crack initiation susceptibility, the role of specific solutes in crack growth and crack initiation, and the effect of metallurgical structures and environmental parameters of cracking susceptibility.

The first year of the program was devoted to preparing for testing of irradiated samples. Three systems were used to perform tests (IM1, IM2 and IM3). The IM1 system (used to perform between 32 and 36 crack initiation tests) was equipped with specialized sample grips to allow for shoulder loading of irradiated samples and underwent preliminary checkout on unirradiated samples. The IM2 crack growth testing system was used to perform practice tests on unirradiated samples in air at room temperature and in normal water chemistry and hydrogen water chemistry environments. A third system, IM3, has been completed and is being benchmarked against results from IM2 to ensure that crack growth behavior is system-independent.

Preparations also have been made for receiving neutron-irradiated samples from Studsvik Nuclear AB. Sample descriptions (dimensions, dose, material parameters) were obtained, confirmed with Studsvik, and compared to results that have been obtained from similar materials tested (using similar test procedures and environments). A test program also has been established for both crack growth rate and constant extension rate experiments on irradiated samples.

***The Irradiated Materials Laboratory at the University of Michigan.***



***The IM2 crack growth testing system has been prepared for DCPD measurement and was used to perform practice tests on unirradiated samples.***

# Advanced LWR Nuclear Fuel Development

## *Advanced LWR Nuclear Fuel Cladding Utilizing Ceramic Matrix Composites*

**By George Griffith**
Advanced LWR Nuclear Fuel
Development Pathway Lead

Advanced, high-performance nuclear fuels are an essential part of the safe, economic operation of the current generation of reactors. Nuclear fuel performance is a significant driver of nuclear power plant operational performance, safety, operating economics and waste disposal requirements.

The Advanced Light Water Reactor Nuclear Fuel Development R&D pathway performs research on improving reactor safety margin, core power density, increasing fuel utilization, and developing enhanced computational models to better predict fuel performance. This research is further designed to demonstrate each of these technology advancements while satisfying all safety and regulatory limits through rigorous testing and analysis.

Three major tasks are designed to achieve the required performance in new fuel designs. The computational modeling includes the details of the individual uranium fuel crystals and scales up to full reactor cores. New advanced technology is being developed so that fuel can be designed and the data required for licensing are developed. The final task is the experimental demonstration of the new advanced fuel performance. Multiple reactors and multiple testing activities will demonstrate the understanding of the new advanced fuel performance.

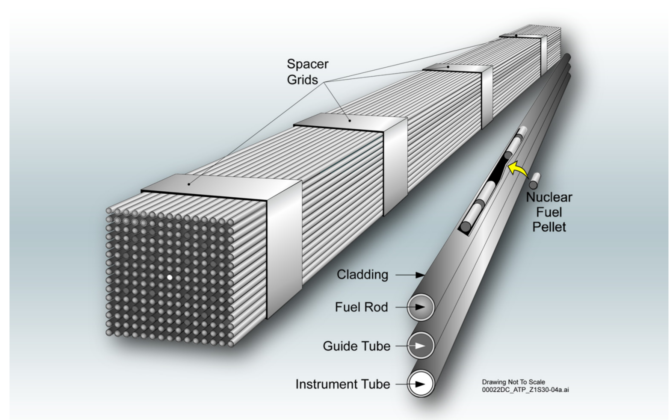
One of the flagship technologies being developed is advanced LWR nuclear fuel cladding made from ceramic matrix composites utilizing silicon carbide as the nuclear fuel cladding. Nuclear fuel cladding separates the reactor's cooling water from the uranium required to produce power in the current generation of reactors.

Silicon carbide is a very strong, high temperature ceramic material that is also nonreactive chemically. Very fine fibers of silicon can be woven into a tubular cladding form that will provide the structural strength of the advanced fuels. The fibers are bound into place by an additional bulk silicon carbide matrix that locks the fibers into place, preventing the designed weave from moving under stress. A very thin layer of material between the fibers and the matrix allows the ceramic materials to flex and twist enough to avoid brittle failure.

Silicon carbide ceramic matrix composite materials have been used extensively in the aerospace and defense industries because of their strength at very high temperatures and the ability to withstand high stresses. The primary nuclear application of silicon carbide is as a structural material in fusion reactor inner walls. Silicon carbide is also a proposed material for very high temperature reactor structures. The variety of current applications demonstrates performance required for advanced nuclear fuels.

The application of silicon carbide ceramic matrix composite as a nuclear fuel cladding material offers much greater strength at high temperatures that could occur during an accident than conventional zirconium alloys. The low chemical reactivity avoids high temperature reactions with the cooling water and corrosive materials naturally in the coolant. The very hard silicon carbide matrix will avoid the fretting action that can fail the current metallic fuel cladding.

Many technical issues need to be resolved to apply the great promise of ceramic cladding in a reactor. The fuel swells as it is used to generate power and eventually will press against the silicon carbide cladding. Predicting this interaction for the fuel's entire lifetime and during accidents is critical to the safe operation of the advanced nuclear fuel. The changing behavior of the silicon carbide cladding during its lifetime needs to be accurately predicted. The performance of the reactor during and after accidents needs to be understood to license the fuel. A new form of nuclear fuel may be required to generate the greatest benefit of the advanced nuclear fuel cladding.




***Silicon carbide ceramic matrix composite (SiC CMC) is being developed as a high-performance nuclear fuel cladding.***

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