Advancing the cause of fuel reliability

BY BETSY TOMPKINS

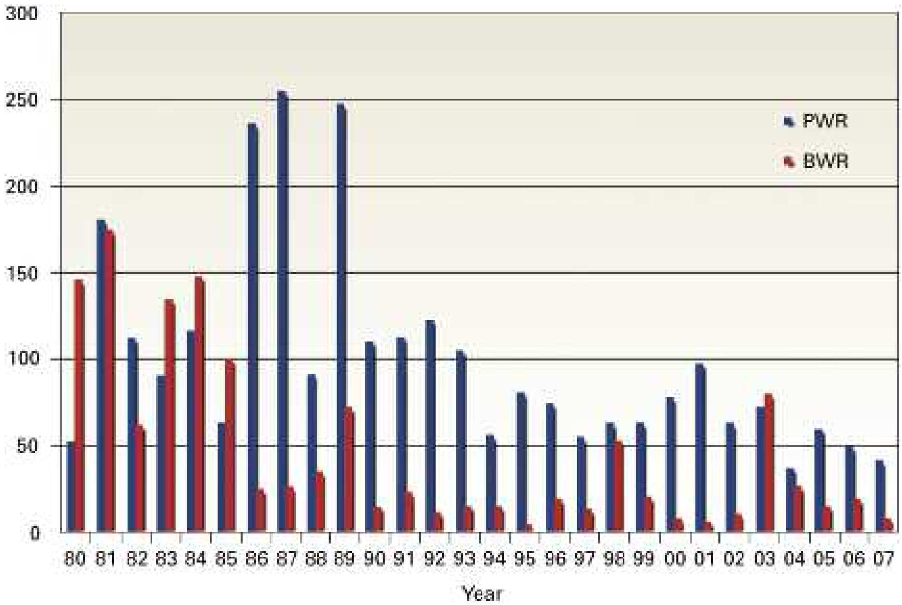
In collaboration with utilities, industry organizations, and fuel vendors, EPRI has developed a series of guidelines to help utilities achieve the goal of zero fuel failures by 2010.

THE ATTENTION TO detail required to operate a nuclear power plant safely is almost incomparable—if not incomparable—in the industrial world. The nuclear industry has focused on improving the overall operation of its plants over the past couple of decades and has successfully used industry guidelines to improve performance in various areas of nuclear power. In the area of fuel, however, guidelines have not been widely used. According to Kurt Edsinger, senior program manager of the Electric Power Research Institute's (EPRI) Fuel Reliability Program, "This can be attributed mainly to the challenge of balancing industry best practices against the flexibility needed for effective, plant-specific fuel design and operations."

Over the past 15 or so years, the industry has made a concerted effort to understand the causes of fuel failures and to eliminate those causes. As a result, fuel failures have decreased significantly in comparison with earlier decades in both pressurized water and boiling water reactors (see accompanying graph). Since about 1990, however, the number of failures has not moved much closer to zero.

In 2004, EPRI overhauled its Fuel Reliability Database, providing an extensive upgrade that has improved the sharing of fuel performance and reliability information among utilities. Included are data from all 104 U.S. nuclear power plants and most Fuel Reliability Program international members. The database provides information on fuel failures, operational experience, core design, control rod type and experience, and water chemistry.

In November 2005, the Institute of Nuclear Power Operations (INPO) set a goal for the industry: zero fuel failures in all U.S. plants by 2010. The industry response came in the form of an initiative to "take high-impact actions to significantly improve fuel cladding performance in support of industry 2010 goals," with the ultimate goal of zero fuel failures. The Fuel Integrity Initiative, which emphasizes the development of fuel reliability guidelines, was drafted, finalized, and backed by utility management by mid-2006. The initiative outlines steps for operators to take to reduce fuel failures, including transitioning to the most robust fuel assembly designs as soon as possible and improving foreign material exclusion (FME) practices (that is, eliminating debris from all plant systems upstream of the reactor vessel), along with the development of reliability guidelines.



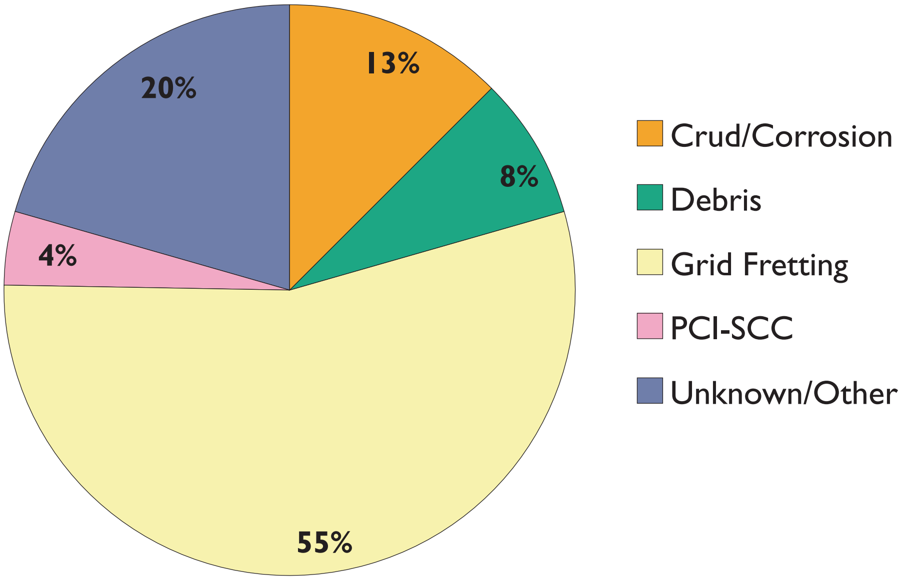
Fuel failures in U.S. PWRs and BWRs, 1980–2007 (Graphics: EPRI)

To initiate the process of developing the guidelines, INPO gathered and summarized fuel performance–related information in a series of underlying documents. These results were then summarized in INPO Guideline 07-004, *Guidelines for Achieving Excellence in Nuclear Fuel Performance,* published on June 28, 2007. This guideline establishes the top-level expectations of the Fuel Integrity Initiative and includes relevant content from existing technical guides, as well as a section on expectations for upper management support.

To support greater awareness of FME best practices, EPRI developed a DVD on foreign material exclusion that was released on July 30, 2007. The DVD, which addresses FME in general but emphasizes fuel reliability, presents examples and consequences of inadequate FME practices and provides good practices for preventing foreign material from entering plant systems. The DVD can be incorporated into utilities' training materials for plant workers, including management, staff, contractors, and supplemental workers. In addition, EPRI is in the process of revising its Foreign Material Exclusion Guidelines, which are intended to provide a framework for developing an effective overall plant FME program, with an increased focus on preventing the foreign materials of most consequence to fuel reliability from entering the reactor vessel. This report will be available from EPRI in July.

Building on the information collected by INPO, EPRI has led the development of the new technical guidelines, titled to cover five specific areas: Fuel Surveillance and Inspection, Pressurized Water Reactor Fuel Cladding Corrosion and Crud, Boiling Water Reactor Fuel Cladding Corrosion and Crud, Pellet Cladding Interaction, and Grid-to-Rod Fretting.

"The first three of these documents have been completed and were issued on April



Percentage of fuel failures by mechanism for PWRs and BWRs, 2000–2007

1, 2008, and the last two will be final later in 2008," Edsinger said. "The documents capture industry state-of-the-art knowledge, providing specific guidance and good practices to help utilities avoid fuel failures associated with specific failure mechanisms." More than 70 utility experts and 26 vendor experts participated in the development of the guidelines, along with personnel from EPRI, INPO, and the Nuclear Energy Institute and industry consultants. "All U.S. nuclear utilities and five international nuclear utilities have been involved in the review process via EPRI working groups and the Zero by 2010 industry group," Edsinger said.

The guidelines

Recommendations for each of the guideline documents are presented in tiers, consistent with industry practice, as follows:

■ *Mandatory:* Implemented at all plants where applicable.

■ *Needed:* Implemented wherever possible, but alternative approaches are acceptable.

■ *Good Practice:* Expected to provide significant operational and reliability benefits, but implementation is left to the discretion of each utility.

Fuel Surveillance and Inspection

"Fuel is the only component in our primary system that doesn't come with an inspection and maintenance plan," Edsinger noted. "'Run-to-failure' is not an acceptable strategy." And so, this guideline sets out to help utilities establish a successful fuel surveillance and inspection program that will ensure acceptable fuel performance and prevent fuel failures. More specifically, these inspection programs will help plant operators identify margins in key fuel performance characteristics for currently operating fuel designs; assess margins in key fuel performance characteristics following changes in fuel design, manufacture, and operation; and provide guidance on failed fuel action planning.

Three mandatory recommendations are set out in this guideline document, which applies to both PWRs and BWRs:

■ Establish a unit-specific surveillance and inspection program for nonfailed fuel.

■ Establish a program to prevent the reinsertion of failed fuel.

■ Perform causal analysis to establish apparent cause of failure.

Three needed recommendations are as follows:

■ Perform baseline, "healthy fuel" inspections (for PWRs, visual, oxide, and grid-to-rod fretting measurements, and for BWRs, visual and oxide measurements).

■ Evaluate the need for inspections following significant changes or events, such as changes in fuel design, water chemistry, core design, and operation strategy.

■ Enter the baseline inspection scope into the EPRI Fuel Reliability Database.

PWR Fuel Cladding Corrosion and Crud

The recommendations in this guideline are based on analyses of the four crud-induced corrosion failures that have occurred in the United States since 1990. The guideline encompasses state-of-the-art information on how changes in core design, assembly mechanical design, and chemistry can affect corrosion product deposition on fuel.

One mandatory recommendation is stated:

■ Include a crud-induced corrosion risk assessment as part of the core design process for each cycle.

Five needed recommendations are as follows:

■ Assess the effect of core and fuel design changes on critical factors controlling crud deposition, and take action to reduce crudding risk.

■ Minimize locally high steaming rates on small fuel rod surface areas.

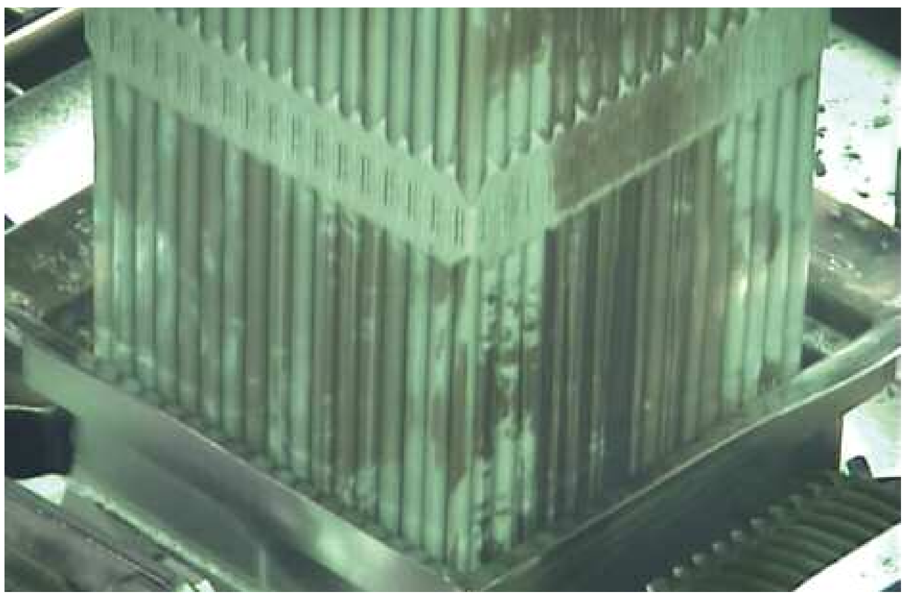
■ Maintain reactor coolant total pH (pHT) at ≥7 while at full-power xenon-equilibrium conditions. Beginning-of-cycle pHT should be as high as achievable within industry experience and vendor-specified lithium restrictions.

■ Analyze reactor coolant during shutdown and startup at a frequency allowing reasonable estimates of nickel, iron, and cobalt-58 releases and removal.

■ Optimize plant operating parameters that can affect sub-cooled nucleate boiling at all times during the operating cycle.

BWR Fuel Cladding Corrosion and Crud

The recommendations in this guideline are based on BWR fuel operational experience over the past 30-plus years. They define approaches utilities can take to ensure



Visual inspection of a fuel assembly to assess crud loading that cladding materials provided by fuel suppliers meet corrosion-resistance quality requirements and provide recommendations on how to control water chemistry impurities and additives to minimize crud and cladding corrosion.

One mandatory recommendation is set forth:

■ Incorporate a crud-induced corrosion risk assessment as part of the core design process for each cycle.

Seven needed recommendations are presented, as follows:

■ Provide the fuel vendor with anticipated fuel operating and environmental conditions for the reload.

■ Review the vendor's fuel fabrication quality assurance program and planned quality control checks.

■ Implement fuel handling procedures that provide for protection from mechanical damage and surface contamination until stored underwater.

■ Review vendor-proposed changes in cladding alloy chemistry or material processing specifications.

■ Ensure that new zirconium alloys will meet the corrosion, hydriding, and mechanical property requirements of fuel designed for high-exposure applications.

■ Maintain feedwater oxygen within BWR chemistry guideline limits to minimize flow-assisted corrosion of carbon and low-alloy steels.

■ Assess risk of adverse fuel impacts before increasing quarterly average feedwater zinc concentration >0.5 parts per billion or the cycle average feedwater zinc concentration >0.4 ppb.

According to Edsinger, "It should be noted that the two corrosion and crud guidelines are to be applied in combination with existing industry guidance on water chemistry, including EPRI's PWR and BWR water chemistry guidelines."

The other two guideline documents will provide details on two of the leading causes of fuel failures. The Pellet Cladding Interaction guidelines will help utilities assess their operating margins for pellet cladding interaction relative to current fuel vendor recommendations and plant-specific demands. The Grid-to-Rod Fretting guidelines will address the failure mechanism that Edsinger said is responsible for more than 70 percent of all fuel failures, with recommendations covering fuel design, core design, and plant-specific flow conditions.

The fast-approaching deadline

Considering that 2008 is already halfway over, utilities have much to do by December 31, 2010. "Incorporation of the individual guidelines into utilities' fuel reliability programs is to be completed by six months after the issuance of each," Edsinger said, but actual implementation of the mandatory, needed, and good practices recommendations—especially those requiring changes in fuel design—will take longer.

Because there is not enough time for all plants to perform healthy fuel inspections prior to 2011, the industry is performing inspections at specific "bounding" plants—that is, Edsinger explained, "a selection of U.S. nuclear plants operated under the most challenging conditions, based on industry judgment."

Bringing the nuclear industry a useful, quality Fuel Reliability Program is truly a collaborative effort among utilities, fuel suppliers, and the various industry organizations involved. In the end, all of the hard work will be well worth it, with a vital aspect of nuclear power plant operation—the fuel—brought into the industry's fold of excellence. NN

ENRICHMENT

GLE, Areva select sites for new facilities

Two companies with separate plans to build new uranium enrichment plants have announced their prospective construction sites. Global Laser Enrichment (GLE), a subsidiary of GE-Hitachi Nuclear Energy, said on April 30 that it has selected a site in Wilmington, N.C., where GE-Hitachi headquarters is located. Then, on May 6, Areva said it has chosen a location in Bonneville County, Idaho.

GE-Hitachi, under a 2006 agreement with the Australian company Silex Systems Ltd., has exclusive rights to develop, commercialize, and launch on a global basis a third-generation uranium enrichment technology developed by Silex. In the Silex process, uranium hexafluoride is vaporized into a gaseous form and exposed to a laser beam that preferentially excites the U-235, which enables the separation of relatively enriched product from relatively depleted "tails" material.

"With the selection of the Wilmington site for a potential commercial facility, we can now move forward with the Nuclear Regulatory Commission's licensing process," said Tammy Orr, GLE president and chief executive officer.

Before proceeding with full-scale production plans, however, GLE will first evaluate the results of a demonstration test loop, which is currently under construction in Wilmington, and obtain an NRC license to build and operate the commercial plant. Licensing activities are under way to support a projected startup date of 2012.

The company said it intends to make a final decision on construction by as early as the beginning of 2009. If the plan goes forward, the new plant, which would have a target capacity of between 3.5 million and 6 million separative work units (SWU), will result in the creation of hundreds of new technical, operational, and support jobs at the site between now and 2012. No new types of hazardous materials would be added to the GE-Hitachi plant site, the company said. The new plant would take up about 200 acres of the approximately 1600-acre site.

Wilmington-based Global Nuclear Fuel Americas, a joint venture of GE, Hitachi, and Toshiba, receives low-enriched uranium (LEU) that is used to fabricate fuel bundles for commercial nuclear power plants. The new GLE enrichment facility could potentially become an LEU supplier to the fuel fabrication facility.

Areva's choice

Areva's potential enrichment plant site is located 18 miles west of Idaho Falls, close to the Department of Energy's Idaho National Laboratory. Areva had also considered sites in New Mexico, Ohio, Texas, and Washington.

The Idaho site was selected after an extensive technical, environmental, and socioeconomical analysis of potential sites throughout the United States, Areva said. The company will move forward to seek all necessary approvals from federal, state, and local agencies, including an NRC license to construct and operate the facility. A license application could be filed with the NRC by the end of this year or early next year.

Areva's enrichment plant will represent a $2-billion investment that is expected to create hundreds of jobs during the construction and operation phases, according to the company. It will provide enrichment services to the United States using an advanced and proven centrifuge technology developed by Enrichment Technology Company, an Areva subsidiary. This technology has been successfully deployed in Europe for more than 30 years and uses 50 times less electricity than the gaseous diffusion process, Areva said. The plant's planned capacity will be about 3 million SWU per year once full operation is achieved, which is projected for no later than 2019. Areva is expecting the plant's first module to be operational by early 2014.

Areva owns and operates the Georges Besse enrichment plant in France, which has operated safely for nearly three decades. The company is currently constructing a new gas centrifuge enrichment facility in France—Georges Besse II—with first deliveries expected in 2009. NN