THE *NUCLEAR NEWS* INTERVIEW

Kurt Edsinger: EPRI and the zero fuel failures program

In any given year, only 15 to 20 nuclear fuel rods fail out of about 5 million fuel rods in U.S. reactors.

Kurt Edsinger is the senior program manager of the Nuclear Fuel Program at the Electric Power Research Institute, the independent, nonprofit organization that performs research, development, and demonstration in the electric power sector.

Fuel reliability is critical to the safe and economic operation of nuclear power plants. Fuel failure, or a breach in the cladding, can lead to the leakage of radioactive material, lost energy generation, increased inspection and repair activities, premature removal of fuel assemblies, and increased radiation exposure. According to EPRI, recent nuclear fuel failures in the United States have cost individual utilities as much as $80 million.

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In 2006, the Institute of Nuclear Power Operations (INPO) set a goal to achieve zero fuel failures by 2010, a target backed by the U.S. nuclear industry. As a first step in moving toward zero fuel failures, EPRI led the development of guidance documents to assist utilities in improving fuel integrity and performance. These technical guidelines address 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.

Edsinger, who has been with EPRI since 2001, previously worked in General Electric's fuel business, Global Nuclear Fuel. He talked with Rick Michal, *NN* senior editor, about the success of the initiative to achieve zero fuel failures by 2010.

What exactly constitutes a fuel failure?

A fuel failure is basically any defect in a fuel rod that allows water or steam inside the rod. Typically, nuclear plant personnel will do a cursory inspection of new fuel rods when they are delivered by the fuel vendor, but first the rods are very carefully inspected by the vendor. In fact, all fuel components are inspected, assembled, and then inspected as a whole at the vendor's location before they're shipped out.

Is there a problem that is most common regarding fuel defects?

Yes, there is one, called grid-to-rod fretting, that happens only in pressurized water reactors. The fuel rods are assembled in spacer grids, which are square matrices that hold the rods at just the right separation inside the reactor. The grids have springs that maintain grid-to-rod contact. Over time, the contact pressure can relax, allowing the fuel rod to wear against the spring. If conditions are severe enough, the grid can rub through the fuel rod. Nearly 70 percent of all PWR fuel failures in the United States are due to that mechanism, and it tends to occur toward the end of fuel life, because it takes time to wear through the fuel rod.

What is the number one problem for BWR fuel?

It's a mechanism known as debris fretting, which results when a foreign material, such as a small piece of wire or a metal scrap, becomes trapped—typically between the grid and the fuel rod—and vibrates in the coolant flow against the fuel rod surface until it wears a hole in the rod. Preventing debris fretting is pursued from two directions. First, it's important to prevent foreign material from entering the coolant, either from maintenance or other plant activities. Second, debris filters, which are traps installed where the coolant enters the fuel assembly, are now standard and continue to be improved.

With respect to INPO's zero fuel defects 2010 initiative, how practical is a goal of zero fuel failures?

The goal is incredibly challenging, and everybody recognizes that, but it's achievable. Fuel performance statistics and improvements implemented by the U.S. nu-

clear industry over the past few years give us even more confidence. Is it possible that we'll never have another fuel failure in the history of the industry? Not very likely, but I'm confident that there will be years where there won't be a single failure in any plant in the United States. Other countries have accomplished zero failures over sustained stretches. It's just harder to do in the United States because we have so many different combinations of reactor designs and fuel designs. So, it's theoretically and technically possible, but also challenging.

What do the numbers reveal about fuel failures in the United States?

Roughly speaking, in any given year now, there may be 15 to 20 fuel rods that fail out of something like 5 million fuel rods in U.S. reactors. (A reactor has on the order of 50 000 fuel rods, and there are 104 operating reactors in the United States.) Current statistics suggest that 90 percent of U.S. reactors won't report a single failure in 2010, and that percentage is expected to continue to increase with continued efforts on fuel reliability.

Would the widespread use of mixed-oxide (MOX) fuel in U.S. power reactors present operational issues?

There are certainly things to consider, and there are some differences between MOX fuel and fresh fuel. EPRI did a study on the experience that the United States has had with MOX fuel, dating back to the 1970s and 1980s, and identified about a half-dozen considerations. For example, the reactivity of the fuels is different, so the core design is going to be different. There are also some licensing differences, since some of the ways that the industry would have to show compliance with safety regulations are different. Duke Power operated with some MOX fuel test assemblies a couple of years ago, and that was largely successful. Other utilities have also expressed interest to the Department of Energy about operating with MOX fuel.

Do you have a comment on the recent study from the Massachusetts Institute of Technology that indicates that uranium resources are sufficient for the foreseeable future?

The MIT report actually reinforces what other experts have said and what EPRI has also said previously. They're all looking at the same data, and over the next 50 to 100 years, uranium availability isn't expected to be a constraint. Once we get beyond that time frame, it will depend on the details of the fuel cycle scenario chosen. [Editor's note: The MIT study, *The Future of the Nuclear Fuel Cycle,* is available online at <http://web.mit.edu/mitei/docs/spotlights/nuclear-fuel-cycle.pdf>.]

How does EPRI view the current relationships between fuel vendors and nuclear utilities, which some have described as adversarial?

I don't think that's a totally fair characterization. I think that certainly they sometimes have different commercial interests, so they're not going to agree on everything. For the most part, however, the vendor and the utility have the same priority, and that is to make sure that the fuel operates successfully in the reactor.

Does EPRI think that utilities and vendors are more or less open, compared with a decade ago, to post-irradiation examination of failed and unfailed fuel in order to extend the industry database?

I would say that it's about the same, but with a comment. The U.S. industry right now is inspecting a lot more fuel than it has in the past. The only way to understand what failures are out there and what failures might be coming is to take a hard look at the fuel, see how it's performing, and really understand the margins. Right now, a lot of measurements are being taken, which can be time consuming and expensive, but also enlightening.

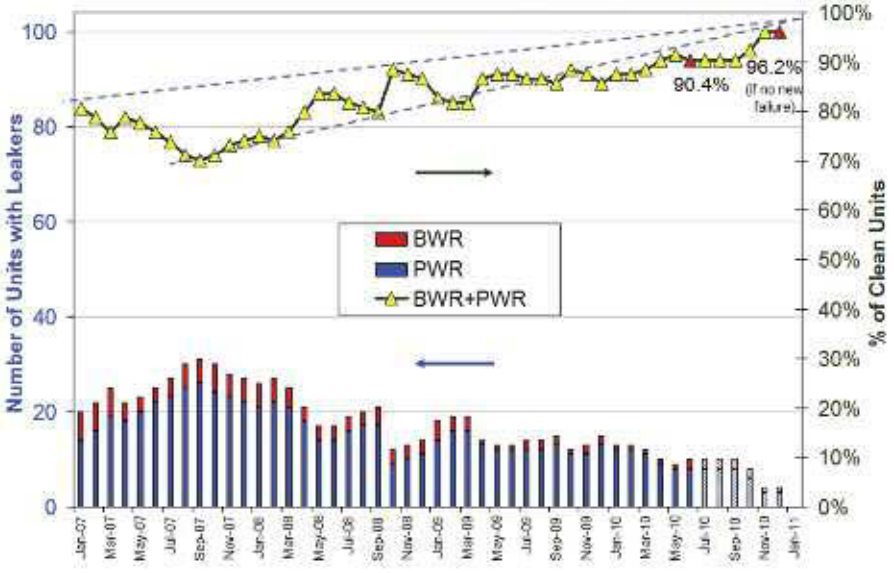
What kind of measurements are done?

Many measurements can be performed nondestructively in the spent fuel pool, where the equipment is brought to the site and the measurements are taken locally. This is generally the least costly option and provides the fastest results. These measurements are generally performed by a fuel vendor, although utilities can often perform some of them. The measurements include a visual inspection to characterize the appearance of the fuel assembly, dimensional measurements such as rod length or diameter, and eddy current to measure the corrosion thickness. Corrosion product samples from the fuel rod surface are also commonly collected for subsequent chemistry or microstructural analysis.

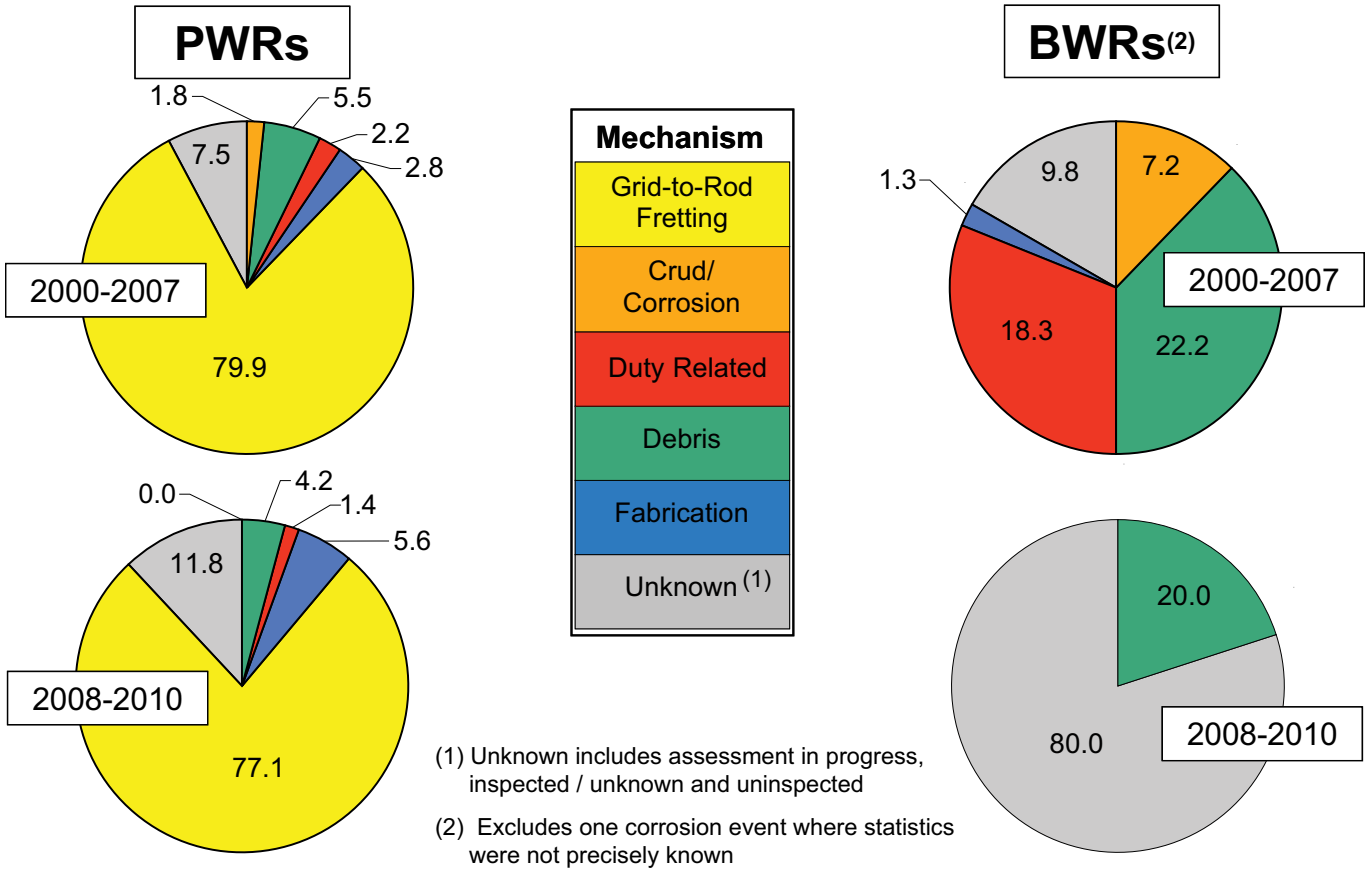
When nondestructive techniques are not sufficient to answer the questions at hand, fuel rods or fuel assembly components can be sent to a hot cell for more detailed investigation. This is a more expensive option, since it requires that the fuel rod or component be shipped off site. In some cases though, the more sophisticated capabilities available in a hot cell laboratory are the only way to get the information of interest. When there is a fuel failure, for example, the parties involved in the examination will first use all available nondestructive poolside techniques in attempting to identify the cause of the failure. If the cause cannot be satisfactorily determined poolside, the fuel must be shipped to a hot cell. Hot cell examinations can sometimes take several years to arrive at an answer. EPRI supports both approaches and is involved in most of the fuel failure investigations in the United States, and a few outside of the United States. It's also worth noting that because of the substantial investment required to conduct a hot cell examination, we're typically looking at issues with wide industry interest.

What does EPRI see as the next evolution in light-water reactor fuel design with respect to burnup and fuel utilization, critical heat flux performance, reactivity-initiated events, and those sorts of things?

I see small, incremental improvements being made. The fuel vendors and the utilities continue to figure out ways to increase the amount of energy from uranium by coming up with better fuel designs and core designs. In terms of regulatory change, I would say loss-of-coolant accidents (LOCA) will have a bit of an impact. The new rules that are coming from the Nuclear Regulatory Commission's LOCA research will ulti-



The U.S. nuclear industry has been trending toward 100 percent no leakers. As of July 2010, slightly more than 90 percent of the units in the United States were failure free. (Graphics: EPRI)



The percentages of nuclear fuel failure mechanisms in U.S. reactors

mately put limits on the amount of hydrogen that can be in the cladding, which is related to how much corrosion is on the cladding. That type of rule change will put a little more emphasis on designing fuel to have lower hydrogen pickup.

In terms of critical heat flux limits, we essentially have the same fundamental limits that we have always had, so the fuel designs have generally increased margins by increasing the amount of surface area to conduct the heat or by improving mixing of the coolant. Those types of improvements continue today. Another factor that touches on this area is crud, since certain types of crud can impede heat transfer. When you add the implications of crud on operations and plant dose, it's easy to see why the industry is putting so much effort into understanding the impact of crud, how to control it, and what the implications are in terms of fuel performance and reliability.

Just as for LOCA, new regulations are being developed for reactivity insertion accidents. To date, only interim criteria have been published, so it's not yet clear what the impact will be on the current fleet, but it appears that the latest analytical methods will gain as much margin as the new criteria might take away, so the net results won't be any real change.

What is the exact definition of crud?

It's anything in the water that precipitates out on a surface inside the reactor. When the original acronym was coined, it stood for Chalk River Unidentified Deposits, a reference to some deposits found in a Canadian reactor. Today, it's basically synonymous with the slang version of crud, which means anything in the water that could end up plating out on the fuel.

How does the industry continue to gather data on fuel performance in a cost-effective and reliable manner?

There is a big emphasis on nondestructive examination techniques. I've talked about the difference in time and cost between a pool examination and a hot cell examination. Right now, I think that is where most of our emphasis is—to either improve the tools we have to do it better and faster, or to look at new, untried technologies that can give us an answer in the fuel pool rather than in a hot cell.

What about the "healthy" fuel exams in the aftermath of fuel reliability guidelines? Is that related to gathering data on fuel performance?

It definitely is. One of the biggest pushes from the zero fuel failures by 2010 initiative was to measure typical fuel to understand what the margins are relative to various failure mechanisms so that the margins could be increased where needed and failures could be eliminated. The term "healthy" fuel inspections was coined because we were looking at fuel that had not failed. We have been closely involved with a lot of those inspections over the past couple of years.

Where is EPRI's testing done?

The EPRI model is always to find what we think is the best place to do work to answer a particular question. We'll go anywhere that we think has the right capability. If we take something that requires a hot cell, as an example, to investigate a fuel rod failure, the number of options quickly decreases to a handful. Not everybody has a license to handle radioactive fuel. In the United States, we have General Electric's Vallecitos Nuclear Center in California and the DOE's national laboratories. We also go out of the country. There is a hot cell in Canada that can do this kind of work, and one in Sweden. And there are some others.

What tests are done?

Everything imaginable is tested in nuclear fuel, because the performance expectations are high and the cycle time is slow. (It typically takes 4.5 to 8 years to operate a fuel rod to the end of its life.) The tests range from laboratory-scale to full-scale, and from simplified conditions to fully prototypic conditions at high temperature with the correct hydraulic conditions, coolant chemistry, and neutron flux. If we look at the facilities used to test resistance to grid-to-rod fretting, for

example, the fuel vendors have full-scale test loops to check fuel assembly performance under the relevant flow conditions. They also have smaller loops in which they check the dynamics of the individual components that make up the spacer grid. They want to make sure that there are no resonant frequencies in the operating regime on the individual component level or on the assembly level. They also need to check the behavior under a range of spring-to-rod contact conditions representative of the conditions throughout the life of the actual fuel assembly.

How does EPRI view the current state of the nuclear renaissance and what are your members saying?

I'm not sure that EPRI has any better insight than the general public does, but the current times are exciting, and there's value in that. When you're in growth mode it's healthy, it's dynamic. It's probably resulting in better long-term strategies, because the industry is thinking longer term. Another more obvious and tangible benefit is that the renaissance is drawing in new talent. The industry is hiring new people. Young people are actually going to nuclear engineering classes again. We're starting to see a whole new set of bright people out there working in this area.

We look at the renaissance as a global movement rather than just a U.S. movement. While some of the anticipated new-build activity has temporarily slowed in the United States because of issues with loan guarantees and construction costs, nuclear development activity has certainly not slowed down globally. EPRI's collaborative research reflects this global perspective. We're getting close to 40 percent research funding from non-U.S. utilities. A lot of what we're doing in our advanced nuclear technology program—for example, benchmarks for new-build activities in countries such as South Korea, where they're building multiple reactors and where they're learning lessons in terms of construction techniques and modular design principles—can be shared around the industry.

Is EPRI's membership growing?

We have full participation from the U.S. nuclear utilities. Our growth sector is outside of the United States. It's identifying those opportunities where we can show the collaborative value of working with EPRI and with all of the other utility members around the world. In recent years, Korea Hydro & Nuclear Power Company Limited and Nucleoeléctrica Argentina S.A. have become members. For nuclear utilities willing to commit to EPRI's collaborative research model, we're very interested in spreading out to where nuclear already exists, where programs are growing, and where they're thinking about starting new programs. NN