Taking the Long View of Nuclear Plants
The increasing demand for energy independence, coupled with the necessity of reducing greenhouse gas emissions, positions nuclear energy to meet current needs and to respond to future needs, such as charging the millions of electric cars expected to fill the streets. But given the many barriers to building and licensing new nuclear plants, existing facilities may be required to run far beyond their initial life expectancies.

“While there is no doubt that the industry aspires to build a new generation of nuclear plants, given the significant regulatory uncertainty, the high cost of new construction, and the status of the credit markets, the first priority must be maintaining existing fleet capacity,” said Mano Nazar, chief nuclear officer at Florida Power & Light Company and chair of EPRI’s Nuclear Power Council. “Like a classic car from the 1970s, our plants have shown that if they’re maintained properly, they become an increasingly valuable asset for the long term. This is not a trend that I expect will change.”

Indeed, extending the operating lives of existing plants provides clear advantages. High capacity factors and low operating costs make U.S. nuclear plants some of the most economical power generators in the country. And even when major plant components must be upgraded to extend operating life, these plants represent a cost-effective, carbon-free asset that is critical to the nation’s energy future.

In light of this value, power companies have put special emphasis on efforts to preserve and even upgrade their nuclear facilities for the long term. “A separate group in our company focuses on renewing the licenses for our plants,” said Amir Shahkarami, senior vice president for engineering and technical services at Exelon Nuclear, the largest U.S. operator, with 17 reactors of different vintages. “A good number of our plants are already licensed for 20 additional years, and we’ll be licensing the rest of our fleet for extended life to 60 years.”

In the United States, nearly all of the 104 operating nuclear power plants are expected to receive license extensions to 60 years; around the world, many other countries are considering life extension to 50 or 60 years as well. Many experts believe, however, that these plants can operate safely well beyond their initial or extended operating periods—possibly to 80 or 100 years. To provide the technical data and rationale supporting continued operation, EPRI has established the Long-Term Operations (LTO) Project. “The objective of this program is to provide technology for the continued operation of the existing fleet,” said Shahkarami. “Our company strongly supports this effort.”

Research Requirements

EPRI’s LTO Project supplements existing EPRI, Department of Energy (DOE), and international nuclear research projects and is very specific in its scope and purpose. “We have an objective process based on five key criteria for picking our projects,” said John Gaertner, the EPRI technical executive who is leading the effort. “Otherwise, we could end up with science projects that are interesting but don’t meet the needs of the industry or the public.”

The first criterion is that the project either has to advance high performance within the lifetime that plants are currently allowed to operate or has to remove uncertainties that could jeopardize further life extension. Items to be addressed for the 60-year period, for example, include major components inside the containment vessel that might degrade. When it comes to 80-year research, the focus is on the non-moving infrastructure. “Studies show that most or all vessels will last 60 years, but we haven’t looked at them for 80 years,” said Gaertner. “We believe they will remain physically sound, but we can’t make the technical case today without that research.”

The second criterion is that results must be available within a 5- to 10-year time frame; if projects could not be completed within 10 years, the results would show up too late for use in life extension planning. Third, the research must be truly new or be an important extension of existing work. Fourth, the project must provide a solution to a recognized problem, confirm that a potential concern is not in fact a real problem, or improve the capacity factor, reliability, cost, or safety of a plant. Finally, it is desirable, but not required, that activities align collaboratively with DOE’s Light Water Reactor (LWR) Sustainability Program, which opens up the opportunity to leverage more expertise and other resources.

Using these criteria, and with guidance from industry advisors, EPRI selected nine projects for funding in 2009 that fall into five categories: managing the aging of pas-
Concrete Aging
Concrete structures age and can degrade when exposed to water, chemicals, radiation, and high temperatures. Whether such exposure weakens the concrete to the point that it prevents plant operation beyond 80 years, however, is not well known. “If aging-related degradation is allowed to continue ad infinitum, at some point these structures will be unable to perform their functions,” said EPRI project manager Joe Wall.

In a collaborative project with DOE, EPRI is working with the Materials Aging Institute and Oak Ridge National Laboratory (ORNL) to identify critical issues, characterize materials properties, and develop computational materials science on concrete aging. The project will analyze the performance of concrete in LWRs and prioritize the locations where degradation is likely to occur. In the process, it will investigate new nondestructive evaluation and forensic concrete examination methods, prognostic modeling for determining remaining useful life, and potential mitigation measures to help extend life.

Cracking in Component Metals
Crack growth in primary system metals is a known problem for nuclear plants and a major target of EPRI research. Two projects being pursued with ORNL, the Pacific Northwest National Laboratory, and the University of Michigan are developing a more fundamental understanding of the mechanisms behind stress corrosion cracking. “As plants age, they accumulate more and more neutron irradiation, which changes the mechanical and corrosion properties of the materials,” said Raj Pathania, EPRI program manager. “The goal of this program is to understand the changes that are going on in this material so we can do a better job of predicting degradation and develop methods to mitigate the damage in the long term.”
shipped to ORNL and the University of Michigan for analysis. The research will apply advanced inspection and characterization methods, including the use of atomic probe tomography to create three-dimensional images of the metal interior at a microscopic level.

“Examining this material with very powerful microscopes—almost at the nanometer scale—we can start seeing what the grain boundaries look like,” said Pathania. “We are finding that irradiation causes displacement of atoms, and as a result, the composition of the grain boundary is significantly different from the normal composition of the alloy. This enables a crack to grow more easily into the material.” The project is examining both how cracks are initiated and how they then propagate. The analysis will correlate crack initiation and growth with the radiation dose, the stress the metal was subject to in shipping and welding, and the alloy composition.

“With this information, we will be able to find ways to minimize long-term damage,” Pathania said. “This may mean you have to change the water chemistry, replace a material with an improved alloy, or do something to protect the material.”

**Building Confidence**

Major capital refurbishment and modernization projects are linked to the expected remaining life of the plant. That is why some nuclear plant owners expect to seek approval for extended operation as early as 2013. The research must start now, as it will take years to gather the data necessary to justify life extension out to 80 or 100 years. The technical basis for extended operation must not only inform the business decision but also satisfy regulatory agencies and the public.

“Public confidence doesn’t come overnight,” said Shahkarami. “The sooner we start and the sooner we invest the right resources on the right topic, the sooner we build confidence on the part of the public and everyone else that the technology and tools can provide for safe operation beyond 60 years.” Mano Nazar agreed wholeheartedly; “The LTO project couldn’t come at a better time, as our industry grapples with ways to meet increasing demand for electricity while simultaneously achieving our national goal of reducing greenhouse gas emissions. The technical merit and collaborative structure of the LTO Project will enable the industry to learn and implement best practices and creative solutions that will help extend the life of our plants without compromising safety or the environment.”

This article was written by Drew Robb. Background information was provided by John Gaertner (jgaertne@epri.com).

---

**Ceramic Cladding for Fuel Rods**

Nuclear fuel rods are exposed to challenging temperature and radiation environments. The conventional zirconium cladding that surrounds the pellets, first introduced about 40 years ago, has undergone continuous improvement and has generally been quite successful. But to increase operational flexibility, ensure high reliability, and maintain safe operation, the LTO Project is investigating new fuel designs. These designs have the potential to increase fuel lifetime by a factor of 2 or more and to completely avoid fuel damage under postulated accident conditions.

One possibility being examined is replacing the zirconium cladding with a ceramic such as silicon carbide (SiC). With zirconium, in the event of an accident, fuel damage and melting might begin at a temperature of 2300°F. The fuel interacts with the cladding, creating exothermic chemical reactions that can lead to melting. Ceramics, however, do not interact with the fuel at those low temperatures. “That would offer a lot of operational flexibility for the plant,” said EPRI’s John Gaertner. “Cladding that’s able to tolerate higher temperatures offers a greater safety margin and could provide more opportunity for power uprates as well.”

The research effort consists of irradiating SiC-clad tubing at the Massachusetts Institute of Technology’s Nuclear Research Reactor under PWR conditions and then testing the tubing samples to characterize their behavior and mechanical properties. Early tests will focus on the performance of the end caps of the SiC tubes, which are the equivalent of the end plugs and welds for zirconium-based fuel rods.

The goals for the next five years are to test the material under real reactor conditions and to analyze the operational and accident performance of SiC fuel using EPRI’s FALCON fuel analysis software code.

John Gaertner is technical executive in nuclear plant technology at EPRI. Gaertner joined EPRI in 1983 as a project manager in the area of risk assessment and management. He left the Institute in 1990 and served as vice president and then senior vice president of ERIN Engineering until returning to EPRI in 1998. He was subsequently program manager for risk and safety and manager of Nuclear Sector operations. Gaertner has a B.S. degree in physics from Indiana University of Pennsylvania and an M.S. degree in atmospheric science from the Massachusetts Institute of Technology.