Innovation

Accident-Tolerant Fuels: A Global Collaboration

EPRI, DOE, Vendors, Utilities, and Other Stakeholders Advance Several Concepts

By Brent Barker

"Imagine Fukushima without zirconium." That was the thought experiment EPRI Nuclear Sector Vice President Neil Wilmshurst handed his staff and the nuclear industry in 2012. Zirconium-alloy cladding for fuel rods has been the industry standard for nearly 50 years. With proven performance, it has been the ideal material under normal operating conditions but does not hold up under severe accident conditions. At temperatures approaching 700°C, the cladding loses its physical integrity, begins to buckle, and rapidly oxidizes in the presence of water or steam, generating heat and releasing flammable hydrogen.

Shortly after the Fukushima accident, the U.S. Department of Energy (DOE) and materials research institutions around the world turned their attention to accident-tolerant nuclear fuels. Some concepts can potentially maintain structural integrity at 1200–1500°C for up to several hours, while also eliminating or reducing hydrogen generation from cladding oxidation. This increases the safety margin and "coping time" for operators to restore cooling. Other potential benefits include enhanced performance under normal operating conditions, increased power levels (power uprates), and extended plant life.

To pursue alternatives for accident-tolerant fuels, DOE is funding separate teams headed by three major vendors—GE, Westinghouse, and AREVA.

"Congressional authorization for funding came with a hard deadline," said EPRI Principal Technical Leader Andrew Sowder. "At least one concept has to be loaded into a commercial reactor by 2022 as a lead test rod or assembly."

One concept being pursued in the United States and internationally involves applying coatings to protect the zirconium-alloy cladding from oxidation. Because of their similarity to existing rods, such fuels could potentially be loaded into reactors in the near future. Ceramic claddings made of silicon carbide represent a significant departure from metallic claddings but offer potentially substantial improvements in high-temperature performance with minimal neutron absorption penalties. In contrast, cladding with advanced steels such as iron-chromium-aluminum alloys offers resistance to oxidation and modest improvements in temperature ranges—but with significant neutron absorption penalties. EPRI has developed and is testing a thin-walled coated molybdenum cladding, which maintains its strength at very high temperatures.

It will take time to move these fuel concepts from testing to commercial availability. "Developing accident-tolerant fuels is a complicated, expensive, high-risk proposition. It requires years of testing alternative materials and designs," said Sowder. "No company or country can do it alone. It demands collaboration on a global scale. We are trying to bring together all the global stakeholders: DOE, developers, vendors, utilities, and regulators."

The Organisation for Economic Co-operation and Development's Nuclear Energy Agency in Paris, a global center for nuclear collaboration, has established the Expert Group on Accident-Tolerant Fuels to provide information and coordinate research. The International Atomic Energy Agency has also set up a program to coordinate research.

“Interest among U.S. utilities has increased markedly in the last year as they begin to see the long-term value and benefit,” said Sowder.

The Nuclear Energy Institute, a U.S.-based industry group, has recently set up a working group, with EPRI serving as the technical collaboration hub. “We have global reach, and collaboration is part of our mission,” said Sowder.

Key EPRI Technical Experts

Andrew Sowder