Hearing of the U.S. Senate Committee on Environment and Public Works

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"Hearing to explore the safety and associated benefits of licensing accident tolerant fuels for commercial light-water reactors and advanced nuclear reactors."

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The Electric Power Research Institute (EPRI) conducts research and development relating to the generation, delivery, and use of electricity for the benefit of the public. An independent, non-profit organization, EPRI brings its scientists and engineers, as well as experts from academia, government and the industry, to help address challenges in electricity, including reliability, efficiency, affordability, health, safety and the environment. EPRI's members represent approximately 90 percent of the electricity generated and delivered in the United States, and international participation extends to more than 35 countries.

The subject of today's testimony is EPRI's collaborative research efforts related to Accident Tolerant Fuels (ATF). ATF has the potential to offer significant safety, environmental, and economic benefits. Bringing ATF technologies from design concept to implementation is challenging and involves the collaboration of many governmental, public, and private stakeholders. This testimony provides an overview of EPRI's research activities related to the potential benefits from ATF as well as the support needed to accelerate further development and implementation.

In the wake of the 2011 Fukushima accident, the priority of accelerating the research and development of ATF technologies was recognized by Congress, the Department of Energy (DOE), and the nuclear industry. As a result, the DOE initiated a ten-year program with the goal of inserting test rods with enhanced accident tolerance into a commercial reactor by 2022. With the strong support of the nuclear industry, this goal was achieved in early 2018 at Southern Nuclear's Hatch Power Plant, located in Baxley, Georgia. Hatch loaded two different ATF concepts for testing into the reactor, a first for the U.S. industry. This was a significant achievement, but technical and regulatory hurdles still remain if the U.S. is to achieve full-core ATF deployment by the mid-2020s. Traditionally, licensing of new fuels designs can take 20 years. In order to realize the benefits of accident tolerant fuels in a meaningful time frame, collaborative and innovative approaches are being leveraged.

Overview of Accident Tolerant Fuel

The U.S. nuclear industry has been aggressively pursuing ATF concepts with the goal to improve performance during normal operations and accident conditions and to deploy these fuels by the early to mid-2020s.

Accident tolerant fuels are defined as fuels that can tolerate a loss of active cooling in the core for a longer time period than current fuel options, while maintaining and improving fuel, system, and plant performance during normal operation. The potential for ATF is to provide more resilient performance during hypothetical accident scenarios while providing more efficient performance during normal operation.

Key ATF targeted parameters under consideration and development include:

- Decreased corrosion rates
- Higher melting temperatures
- Reduced hydrogen generation during postulated accidents
- Improved strength, toughness, and high temperature behavior
- Enhanced behavior to ramp more quickly for flexible power operations
- Better confinement of radioactive materials during postulated accidents
- Improved resistance to wear and foreign material damage

The ATF concepts under active development can be divided into two categories: near-term and longer-term concepts, based on their anticipated timeline to full core deployment. Near-term concepts can use the current licensing structure with current regulations and regulatory guidance to allow for licensing of these ATF concepts. These near-term concepts are expected to be commercially viable for full-core deployment by the mid-2020s. Longer-term concepts have more gaps in data, regulatory acceptance criteria, limiting regulations and regulatory guidance. As a result, these concepts are expected to take a longer period of time to develop and license prior to full-core deployment in operating commercial reactors.

Whether ATF is adopted by commercial reactor operators will be a business decision. EPRI's research plays a role to inform key industry decision-makers on the potential ATF safety and economic benefits for their plants. A critical metric for the industry decision-makers is ATF deployment timeframes. The sooner these ATF concepts can be deployed, the sooner the safety and economic benefits will be realized. Historically, the licensing of new fuels and cladding within the current regulatory infrastructure has taken upwards of twenty years. An expedited approach to reduce licensing timeframes could lead to quicker deployment of these new fuels.

The research, development, licensing, and deployment of ATF represents a substantial investment and collaboration among fuel vendors, operating utilities, research institutions, regulatory authorities, and other governmental agencies. Substantial safety and economic benefits may be required to justify the adoption and wide-spread implementation of the new fuel technologies, e.g., increased safety margins, enhanced fuel reliability, improved economic benefits, optimized fuel cycle operational strategies, and reduced waste generation.

EPRI Research and Development

EPRI has been conducting research over the past 30 years on advanced fuels seeking greater reliability, safety, and performance. During that time, EPRI has collaborated with key domestic governmental and commercial stakeholders to conduct research and development activities to inform fuel reliability, performance, cost-savings, efficiencies and safety.

In the late 1990s, EPRI created its Robust Fuel Program to assess high burnup fuels under normal reactor operations and postulated accident scenarios. This work has also informed the dry storage and transportation of high burnup fuel. In the early 2000's, the focus of EPRI's research shifted to improved fuel reliability and operational issues to reduce fuel failures.

Recently, EPRI fuel programs have focused research efforts to inform further potential safety and economic benefits of ATF technologies, higher uranium enrichments and discharge burnups. While EPRI is not currently developing any ATF technology, it is informing public and private stakeholders with key safety, economic, and operational technical analyses to support strategic decision-making for potential ATF implementation.

The Potential Benefits of ATF Technologies

The early adoption of ATF by commercial reactor owners/operators is predicated on the need to assess the potential benefits from ATF and the associated implementation costs. In 2017, EPRI performed an initial assessment of expected ATF performance. This work was done to assess and quantify the various safety enhancements offered by various ATF concepts. For the initial ATF safety impacts assessment, the performance of each ATF concept was evaluated for a number of postulated accidents. These assessments consisted of performing safety analyses for key accident sequences and comparing the ATF results against those obtained for the same events calculated using current zirconium uranium oxide fuel designs.

At this stage of ATF development, there are significant uncertainties associated with the proposed ATF concepts. The analysis will need to be updated as additional test data become available. The key conclusions from EPRI's initial ATF study include:

- Safety benefits exist and vary among the different ATF concepts and plant characteristics
- Specific ATF concepts may have limited the Three Mile Island-2 core damage
- Other accident scenarios that were modeled showed that accident tolerant fuels have the potential to provide additional coping time

EPRI is conducting a second study to build on the initial results. The current work includes additional accident scenarios, fuel cycle optimization (increased enrichment and discharge burnups) assessments, and exploration of additional benefits not previously studied. These efforts have identified three major areas of potential economic benefits that can result from more resilient ATF fuels including:

- Increased fuel reliability

- More efficient fuel cycles that could also reduce the amount of generated waste
- More robust fuel performance leading to improved operational flexibility

These potential benefits could provide plant operational performance enhancements and/or substantial cost reductions and/or plant operational performance enhancements.

ATF concepts potentially include more durable materials that may provide better fuel reliability. These innovative designs and materials may provide enhanced reliability by reducing possible fuel failures and preventing the potential for plant shutdowns. Fuel cycle optimization through higher enrichments and discharge burnups would allow for improved fuel efficiencies.

Improved ATF material performance enables the potential for higher discharge burnups which provides the potential for higher enrichments and improved fuel cycle efficiencies. This may allow certain plants to go from 18 to 24-month fuel reloading which could reduce the amount of fuel needed, thereby, reducing the amount of waste generated.

Moreover, the enhanced ATF fuel performance could also lead to greater operational flexibilities which could improve integration of nuclear plants with other non-CO_2 emitting electricity generating sources. EPRI plans to evaluate enhanced flexible power operations in the near future. EPRI also plans to finalize a report in early 2019 documenting the safety benefits results that could lead to these economic benefits.

Innovations for Accelerated Implementation

Traditionally, qualification and licensing of new fuel designs has taken over twenty years. Innovative approaches can collect test data more rapidly and efficiently than the current paradigm of irradiation tests followed by destructive post-irradiation examinations at domestic and international hot cells. The time required to irradiate, cool down (for transportation), transport from irradiation facility to hot cell, and destructively test at the hot cell takes several years for each test. Several such tests have been carried out to demonstrate safety for new fuel licensing in the past, leading to the greater than twenty-year design-to-licensing timeframes for new fuels. Alternative advanced data collection methods could shorten this timeframe by collecting data in situ or without destructive examinations using sophisticated non-destructive techniques, which could reduce the transportation and destructive examination steps. EPRI is working to develop non-destructive examination techniques that could lead to quick data collection without the need for shipping and destructive examination.

Advanced modeling and simulation (M&S) along with new expedited experimental data collection methods through advanced sensors and non-destructive evaluation techniques could be used to provide sufficient technical information to support ATF implementation. The development of advanced M&S can facilitate ATF implementation with key support to utilities and vendors on design considerations, normal operation evaluations, ATF fuel performance assessments, and for licensing. Enhanced capabilities of advanced M&S, combined with targeted experimental data, can help provide confidence in the designs of ATF technologies.

The use of these new data collection and modeling tools can reduce the time and cost of introducing innovative technologies into operating nuclear plants by reducing the number of time-consuming and costly tests and demonstrations, potentially addressing one of the major hurdles in getting ATF to market sooner. A focused collaboration between the U.S. industry, EPRI, DOE, and NRC can help expedite the implementation of ATF concepts.

Current regulations are focused and fixed to the current fuel systems which are also applicable to the near-term ATF concepts. However, the lack of licensing acceptance criteria and regulatory expectations for longer-term ATF concepts limit vendors to develop experimental test plans and licensing strategies. The need for regulatory clarity and predictability can be alleviated through a collaborative process involving the key stakeholders to collectively identify and align on the gaps in regulatory acceptance criteria and data related to various fuel designs. This gap identification process involves working with technical regulatory specialists and subject matter experts to identify and define the key knowledge gaps in test data, modeling, licensing methodologies, regulations, and guidance. This effort can help prioritize the work to be done to fill the gaps, help all stakeholders align on a schedule and improve certainty in the process.

Irradiation Testing Facilities

Test reactor irradiations are traditionally and important step in the development of new fuels. In the past year, the nuclear industry lost a key asset in the Halden test reactor which had been operated since 1958 at the Norwegian Institute for Energy Technology (IFE) and funded by 19 countries under the Organisation for Economic Co-operation and Development Nuclear Energy Agency (OECD/NEA).

The DOE is in the process of defining the path forward without Halden. At this point, there does not seem to be a significant delay for the near-term ATF concepts. For the longer-term needs, EPRI is working with key domestic and international (OECD/NEA) stakeholders to identify a long-term solution to provide irradiation test facilities that can support longer-term ATF concepts.

Halden had unique capabilities for real-time monitoring and testing during irradiation while simulating the operating environments of existing U.S. reactors. All four vendors of ATF (Global Nuclear Fuels, Westinghouse, Framatome, and Lightbridge/Enfission) were current or prospective users of the Halden test reactor and hot cell facilities. Since Halden was scheduled to perform testing for all four U.S. ATF vendors, the unexpected loss of Halden will require some reconfiguration of the research and development plans in advance of commercial deployment of ATF.

Concluding Remarks

Accident Tolerant Fuels have the potential to provide increased safety margins over current nuclear fuels while also providing enhanced fuel reliability, improved economics through optimized fuel cycles, and reduced high-level waste generation. Accident Tolerant Fuels may enable utilities to realize additional economic and operational benefits from increased enrichments, higher

discharge burnups, and higher resiliency for more efficient operations and cost savings. EPRI will continue to conduct technical evaluation of accident tolerant fuels in order to provide information needed to establish criteria, provide safety analysis and identify economic benefits.