Enhanced Accident Tolerant Fuels for Light Water Reactors

Development Goal: Demonstrate performance by inserting accident tolerant fuel technology into a commercial power reactor by 2022 followed by commercialization.

The safe, reliable, and economic operation of the nation's nuclear power reactor fleet has always been a top priority for the United States' nuclear industry. Continual improvement of technology, including advanced materials and nuclear fuels, remains central to the industry's success. Decades of research combined with continual operation have produced steady advancements in technology and have yielded an extensive base of data, experience, and knowledge on light water reactor (LWR) fuel performance under both normal and accident conditions. Thanks to efforts by both the U.S. government and private companies, nuclear technologies have advanced over time to optimize economic operations in nuclear utilities while ensuring safety.

One of the missions of the U.S. Department of Energy's (DOE) Office of Nuclear Energy (NE) is to develop nuclear fuels and claddings with enhanced accident tolerance for use in the current fleet of commercial LWRs or in reactor concepts with design certifications (GEN-III+). In 2011, following the Great East Japan Earthquake, resulting tsunami, and subsequent damage to the Fukushima Daiichi nuclear power plant complex, enhancing the accident tolerance of LWRs became a topic of serious discussion. As a result of direction from Congress, DOE-NE initiated the Enhanced Accident Tolerant Fuel (ATF) Development program.

Current LWR Fuel

Today's U.S. commercial LWR fleet uses uranium dioxide (UO_2)-zirconium alloy fuel system to provide 70 percent of the nation's clean energy. Decades of industry research and operational experience have produced an extensive database supporting the performance of LWR fuel during normal power operations and during postulated accident conditions. The nuclear power industry is focused on continuous improvement and reliable operation, deploying design enhancements to the fuel system (typically small, incremental improvements) as they become available.

ATF Program Goals

The overall goal of ATF development is to identify alternative fuel system technologies to enhance the safety, competitiveness, and economics of commercial nuclear power. The development of an enhanced fuel system supports the sustainability of nuclear power, allowing it to continue to generate clean, electrical power in the United States.

Enhanced accident tolerant fuels would endure loss of active cooling in the reactor core for a considerably longer period of time than the current fuel system –

(Continued)

Improved Reaction Kinetics with Steam
- Decreased heat of oxidation
- Lower oxidation rate
- Reduced hydrogen production (or other combustible gases)
- Reduced hydrogen embrittlement of cladding

Improved Fuel Properties
- Lower fuel operating temperatures
- Minimized cladding internal oxidation
- Minimized fuel relocation/dispersion
- Higher fuel melt temperature

Enhanced Tolerance to Loss of Active Core Cooling

Improved Cladding Properties
- Resilience to clad fracture
- Robust geometric stability
- Thermal shock resistance
- Higher cladding melt temperature
- Minimized fuel - cladding interactions

Enhanced Retention of Fission Products
- Gaseous fission products
- Solid/liquid fission products

Key considerations in establishing accident-tolerant fuel attributes depending on the LWR system and accident scenario – while maintaining or improving fuel performance during normal operations. Key requirements for advanced fuels relate to nuclear fuel performance, cladding performance, and adherence to overall system constraints.

DOE is sponsoring multiple teams to develop ATF concepts within national laboratories, universities, and the nuclear industry. These concepts offer both evolutionary and revolutionary changes to the current nuclear fuel system.

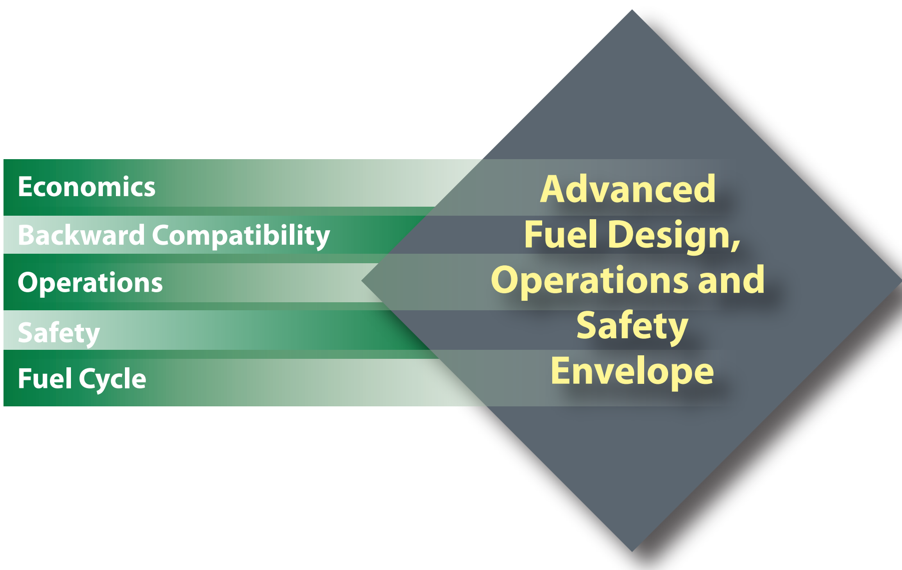
These important ATF attributes include:

- Reduced hydrogen generation (resulting from cladding oxidation)
- Enhanced fission product retention under severe accident conditions
- Reduced cladding reaction with high-temperature steam
- Improved fuel-cladding interaction under extreme conditions

Constraints

Any new fuel concept proposed for enhanced accident tolerance must also be compliant with and evaluated against current design, operational, economic, and safety requirements. The constraints associated with commercial nuclear fuel development and deployment include:

- *Backward Compatibility*— Compatible with existing fuel handling equipment, fuel rod or assembly geometry, and co-resident fuel in existing LWRs.
- *Operations*— Maintains or extends plant operating cycles, reactor power output, and reactor control.
- *Safety*— Meets or exceeds current fuel system performance under normal, operational transient, design-basis accident (DBA) and beyond design-basis accident (BDBA) conditions.
- *Front end of the nuclear fuel cycle*— Adheres to regulations and policies, for both the fuel fabrication facility and the operating plant, with respect to technical, regulatory, equipment, and fuel performance considerations.
- *Back end of the nuclear fuel cycle*— Cannot degrade the storage (wet and dry) and repository performance of the fuel (assuming a once-through fuel cycle); should give consideration to possible future transition to a closed fuel cycle.
- *Economics*— Maintains economic viability with respect to additional costs (e.g., fabrication) and potential cost reductions realized through improved performance (higher burnup for extended cycles and power upgrades) or increased safety margin.



The ATF program is in the development and qualification phase of research and development, supporting the investigation of a number of technologies that may improve fuel system response and behavior in accident conditions. DOE is sponsoring multiple teams to develop ATF concepts within national laboratories, universities, and the nuclear industry. These concepts offer both evolutionary and revolutionary changes to the current nuclear fuel system. Mature concepts will be tested in the Advanced Test Reactor at Idaho National Laboratory. The research team is simultaneously developing a set of technical evaluation metrics to support downselection of ATF concepts.

References

Idaho National Laboratory, *Light Water Reactor Accident Tolerant Fuel Performance Metrics*, INL/EXT-13-29957, February 2014.

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