Enhanced Accident Tolerant Fuels for LWRs: Industry Teams

Research teams began irradiation of Accident Tolerant Fuel concepts in Idaho National Laboratory's Advanced Test Reactor in 2014.

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. 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+). A companion Fact Sheet Enhanced Accident-Tolerant Fuels for Light Water Reactors provides additional detail on the overall goals for Accident Tolerant Fuel (ATF) Development for light water reactors (LWRs).

ATF Development Activities

With the assistance of the nuclear energy community, the DOE Nuclear Technology Research and Development (NTRD) Advanced Fuels Campaign has embarked on an aggressive schedule for the development of enhanced accident-tolerant LWR fuel system candidates. The program is currently supporting the development of a number of technologies that may improve the fuel system. The overall ATF development goal is to demonstrate performance by inserting a lead test rod (LTR) or lead test assembly (LTA) into a commercial power reactor by 2022, followed by commercial deployment.

ATF development utilizes a three-phase approach to commercialization.

Phase 1: Feasibility Assessment and Down-Selection— Fuel concepts are developed, tested, and evaluated. Feasibility assessments are performed to identify promising concepts including lab-scale experiments, such as fabrication, preliminary irradiation, and material property measurements; fuel performance code updates; and analytical assessments of economic, operational, safety, fuel cycle, and environmental impacts. (FY 2012–FY 2016)

Phase 2: Development and Qualification— Prototypic fuel rodlets are irradiated in a test reactor at LWR conditions to provide the data required for the LTRs/LTAs. The fabrication process expands to industrial scale for LTRs/LTAs. (FY 2016–FY 2022)

Phase 3: Commercialization— Partial-core (region-sized) reloads are tested to verify the performance observed for the LTRs and LTAs and to provide additional data for final licensing of the product. Commercial fabrication capabilities are established. (FY 2022 and beyond)

Each development phase roughly corresponds to the technology readiness levels (TRL) defined for nuclear fuel development, where TRL 1–3 corresponds to the "proof-of-concept" stage (Phase 1), TRL 4–6 to "proof-of-principle" (Phase 2), and TRL 7–9 to "proof-of-performance" (Phase 3).

Industry-Led ATF Teams

Early in Phase I, the DOE contracted directly with three LWR nuclear fuel vendors, AREVA Inc., General Electric, and Westinghouse Co. to develop advanced accident tolerant nuclear fuel technologies. In cooperation with multiple institutions from across the United States each of the teams have executed Phase I of research and development and selected specific accident tolerant nuclear fuel technologies to develop in Phase II. The teams are now developing industrial fabrication processes, generating data through LTR and LTA irradiations. Phase II will culiminate with introduction of accident tolerant fuels into batch and reloads of United States commercial nuclear reactors.

AREVA

The AREVA R&D team is designing both fuel and cladding concepts to improve performance under both normal and beyond design-basis accident conditions while ensuring that the ATF cost remains competitive with the current fuel design. AREVA provides team leadership and technical guidance related to fuel manufacture and fuel requirements. Additional team members include the University of Florida, developing fuel pellets; the University of Wisconsin and Savannah River National Laboratory, providing cladding coatings; and Duke Energy and the Tennessee Valley Authority, providing utility consultation.

Concepts being considered by the AREVA team include:

Enhanced UO_2 Fuel:

- Chromia doping to reduce fission gas generation, improve load-following characteristics, increase uranium density, improve wash-out characteristics in rod failure, and lock up cesium into the fuel matrix.

(Continued)

Modified Zr-alloy Cladding:

- Coatings on existing Zr-alloy cladding to reduce hydrogen pickup, mitigate hydride reorientation in the cladding, and increase coping time during accident conditions.

General Electric Global Research

The objective of the General Electric Global Research and Global Nuclear Fuels team, which includes the University of Michigan and Oak Ridge National Laboratory (ORNL), is to investigate the replacement of Zr-alloy cladding with advanced steels, such as FeCrAl alloys, which offer a number of benefits in beyond design-basis accident conditions. Improved properties under normal conditions may provide sufficient benefit to mitigate the increased neutron absorption characteristics of these materials.

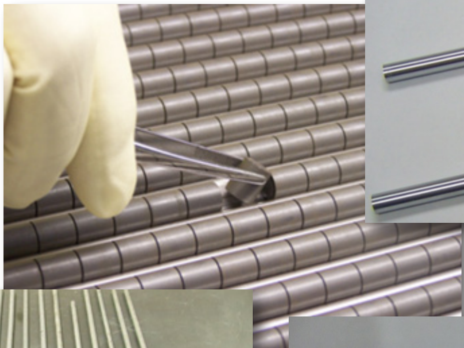
Samples of commercial and experimental alloys have been successfully tested over different lengths of time in 100% superheated steam from 600 °C to 1475 °C. Results to date indicate that the best candidate new alloys—including APMT and Alloy 33—have several orders of magnitude improvement over the current Zr-based alloys in reaction kinetics with steam. Similarly, these advanced steels have been tested to demonstrate superior mechanical properties under both normal operating conditions and accident conditions. Ferritic steels are also highly resistant to irradiation damage and environmentally assisted cracking under normal operating conditions.

Westinghouse

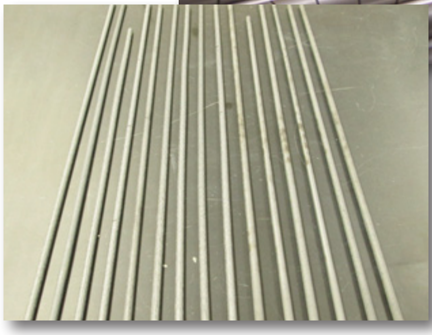
The objective of the Westinghouse Electric Company LLC team is to develop an ATF having improved economics during normal operation and providing containment of all fission products within the fuel during a beyond design-basis accident. The partners in this consortium include: Westinghouse, developing fuel concepts, determining research needs, licensing approach and cost, and evaluating the overall economics of ATF; General Atomics, developing SiC cladding; the Edison Welding Institute, developing hot-spray coatings on Zr-alloy cladding; the University of Wisconsin, developing cold-spray coatings on Zr-alloy cladding; Los Alamos, manufacturing UN fuel; INL, studying options for uranium silicide processing uranium silicide (U_3Si_2) fuel; the Massachusetts Institute of Technology, providing steam oxidation, quenching, and preliminary reactor testing of ATF cladding candidates; and Southern Company, providing insight to ATF licensing and economics from the customer's perspective.

U_3Si_2 has been successfully manufactured into pellets of ~94% of theoretical density. U_3Si_2 would offer a 17% increase in 235U loading (at equivalent enrichment) and a five-fold increase in thermal conductivity relative to standard UO2 fuel.

AREVA: Tubes Coated with Chromium

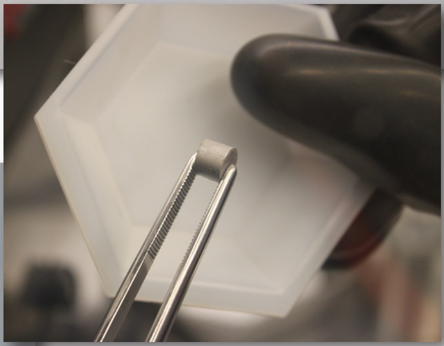


AREVA: Chromia Doped Pellet



Westinghouse: Meter Long SiC Tubes

GE: Sandvik Technology APMT Tubes



Westinghouse: U_3Si_2 Pellet Sintered at INL Using Finely Ground Powder

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