Irradiation Testing of Accident Tolerant Fuels for LWRs

Photograph of the Advanced Test Reactor showing the serpentine of fuel elements and piping from different pressurized water test loops.

The safe, reliable, and economic operation of the nation's nuclear power reactor fleet has always been a top priority for the U.S. 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 is to develop nuclear fuels and claddings with enhanced accident tolerance for use in the current fleet of commercial light water reactors (LWRs) or in advanced reactor concepts (GEN-III+). A companion information sheet, Enhanced Accident Tolerant Fuels for Light Water Reactors, provides additional detail on the overall goals for Accident Tolerant Fuel (ATF) development for LWRs.

The ATF program supports the investigation of a number of technologies to improve fuel system response and behavior under 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.

The overall ATF development goal is to demonstrate performance by inserting a lead fuel rod (LFR) or lead fuel assembly (LFA) into a commercial power reactor by 2020 with deployment in the U.S. fleet to follow. As a step toward this goal, a series of irradiation tests has been defined to assess the performance of proposed ATF concepts. The test plan progresses from feasibility experiments under normal operating conditions to demonstrations under accident conditions to support the insertion of lead fuel rods and assemblies and the eventual qualification of an ATF concept for full core use. Data generated by this test program will be used to establish the feasibility of certain aspects of proposed ATF concepts, as well as provide information to support screening among concepts.

ATF-1 Test Series: Drop-In Capsules

Designated as the ATF-1 Test Series, irradiation of ATF concepts are being performed in a series of drop-in capsule tests in the Advanced Test Reactor (ATR), operated by Idaho National Laboratory (INL). These experiments investigate the performance the proposed ATF concepts under normal LWR operating conditions.

The ATF-1 capsules are filled with an inert gas and are designed to isolate fuel rodlets from the ATR primary coolant during irradiation. Hence, the test rodlet cladding is not in contact with water coolant during irradiation. This test series is intended to investigate the irradiation behavior of new fuels and their and their interaction with the cladding. Data obtained on fuel behavior and fuel-cladding interaction is being used to inform down-selection to one or more promising concepts prior to subsequent irradiation tests.

ATF-1 began with the insertion of several ATF concepts supported by development teams that are led by Westinghouse, Areva, General Electric, Oak Ridge National Laboratory, and Los Alamos National Laboratory. ATF capsules will be removed from ATR for post-irradiation examination at burnup levels ranging from 10 to 80 GWD/MTU (240 to 1300 effective full power days) to build a performance database.

ATF-2 Test Series: ATR Pressurized Water Loop

The ATF-2 series will test the most promising concepts from ATF-1 in the INL pressurized water loop. In an ATR loop, experimental fuel rods will be in direct contact with high-pressure water coolant with active chemistry control

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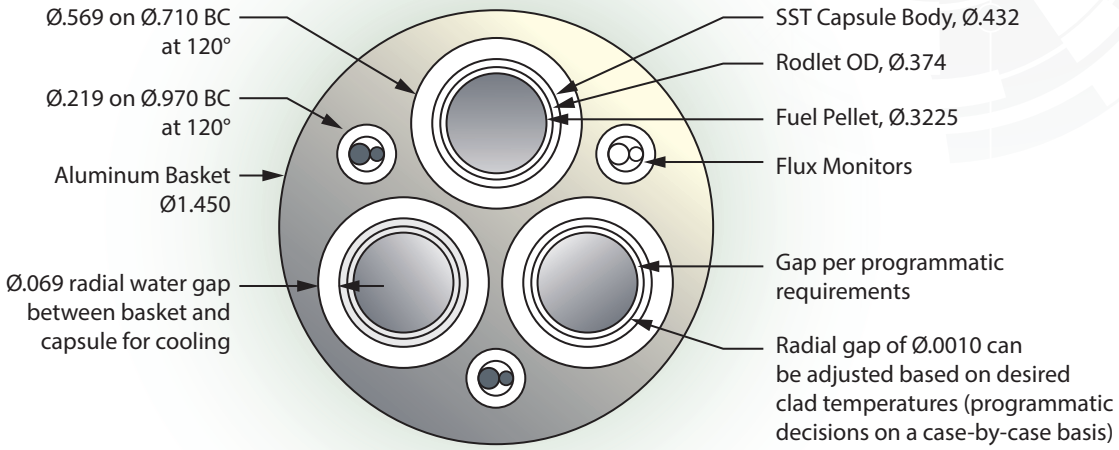
to mimic the conditions of pressurized water reactor (PWR) primary coolant. In addition to continuing the investigation of fuel behavior and fuel-cladding interaction begun in ATF-1, ATF-2 will include cladding-coolant interaction. ATF-2 will be the most prototypic irradiation test possible in the ATR to assess the performance of ATF concepts under normal PWR operating conditions. Insertion of ATF-2 test rodlets is expected to begin in the spring of 2018.

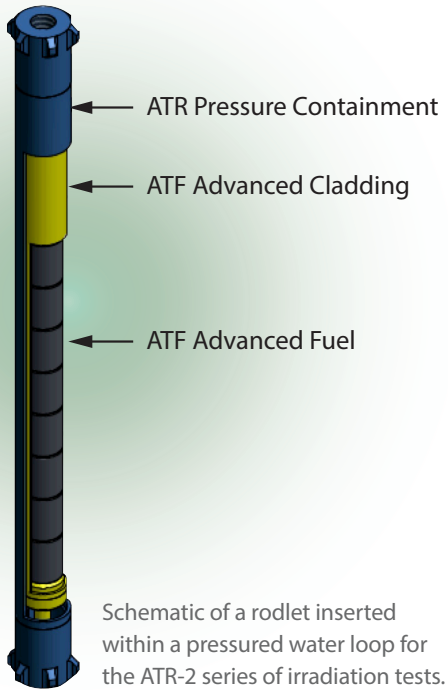
ATF-3 and -4: Transient Testing

Promising concepts will proceed to transient testing at the INL Transient Reactor Test (TREAT) facility for the ATF-3 series of tests. In TREAT, ATF rodlets will be subjected to simulated reactivity-insertion accidents to investigate their performance under severe conditions. This phase of testing will begin with fresh (unirradiated) fuel rodlets to assess performance at beginning-of-life and progress to testing of irradiated fuel rods at multiple burnup levels obtained from the ATF-1 and ATF-2 test series.

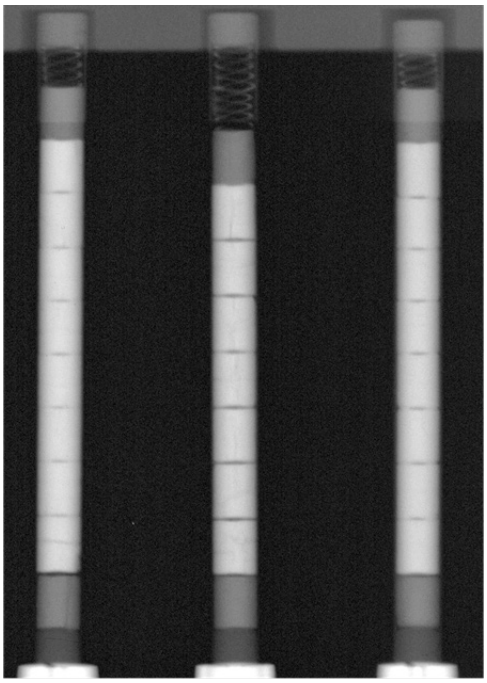
The final phase of the irradiation test program is to subject LFRs from commercial reactor irradiation to transient testing in TREAT. As in the ATF-3 test series, this phase of testing will begin with fresh fuel rods, followed by testing of LFRs that have been irradiated to various burnup levels.



Cross-section of an existing ATR basket assembly adapted for the ATR-1 series of irradiation tests. Multiple capsules can be stacked within each radial position.



Schematic of a rodlet inserted within a pressured water loop for the ATR-2 series of irradiation tests.



Neutron radiography of different Accident Tolerant Fuel concepts taken as part of the ATF-1 series of irradiation tests.

For additional information contact:

Dr. Gary L. Povrik
AFC Irradiate and PIE Technical Lead
gary.povrik@inl.gov
208.526.0805

Dr. Jon Carmack
National Technical Director
Advanced Fuels Campaign
jon.carmack@inl.gov
208.526.5424

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