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A REVIEW OF EXPERIMENTS AND RESULTS FROM THE TRANSIENT REACTOR TEST (TREAT) FACILITY*

L. W. Deitrich, C. E. Dickerman, A. E. Klickman, and A. E. Wright

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A Review of Experiments and Results from the Transient Reactor Test (TREAT) Facility

L.W. Deitrich, C. E. Dickerman, A. E. Klickman, and A. E. Wright

Argonne National Laboratory
9700 S. Cass Avenue
Argonne, IL 60439 USA

The TREAT Facility was designed and built in the late 1950s at Argonne National Laboratory to provide a transient reactor for safety experiments on samples of reactor fuels. It first operated in 1959. Throughout its history, experiments conducted in TREAT have been important in establishing the behavior of a wide variety of reactor fuel elements under conditions predicted to occur in reactor accidents ranging from mild off normal transients to hypothetical core disruptive accidents. For much of its history, TREAT was used primarily to test liquid-metal reactor fuel elements, initially for the Experimental Breeder Reactor-II (EBR-II), then for the Fast Flux Test Facility (FFTF), the Clinch River Breeder Reactor Plant (CRBRP), the British Prototype Fast Reactor (PFR), and finally, for the Integral Fast Reactor (IFR). Both oxide and metal elements were tested in dry capsules and in flowing sodium loops. The data obtained were instrumental in establishing the behavior of the fuel under off-normal and accident conditions, a necessary part of the safety analysis of the various reactors. In addition, TREAT was used to test light-water reactor (LWR) elements in a steam environment to obtain fission-product release data under meltdown conditions. Studies are now under way on applications of TREAT to testing of the behavior of high-burnup LWR elements under reactivity-initiated accident (RIA) conditions using a high-pressure water loop.

During the first few years of operation, a large number of fuel-rod meltdown experiments (85 during the first two years) were performed on unirradiated and irradiated fuel, most of them in dry capsules. These were largely phenomenological experiments in that they were used to identify and study the basic physical processes occurring during rapid overheating of the fuel-rod samples, rather than simulating specific accident conditions. Although sodium-bonded uranium-alloy fuel was the predominant type tested, various fuel and cladding materials, were also studied. By the mid-1960s, integral experiments in flowing-coolant loops were being conducted.

In the late 1960s, the major emphasis shifted to testing of oxide fuel for application in the FFTF, and eventually, in later commercial fast reactors. The Mark-III sodium loop was designed for use in these tests. The original Mark-III loops could accommodate up to seven fuel pins of the FFTF design of 5.84 mm diameter. These loops utilized a "package" concept, in which the whole experiment was assembled outside the reactor, inserted into an appropriate location in the core for transient irradiation, and then removed for disassembly and post-test examination. Supporting facilities were established at both Argonne sites to assemble test trains using both fresh and preirradiated pins, insert the test trains into the loops, disassemble the loops after the tests, and perform post-test macroscopic and microscopic examinations. This basic concept of TREAT testing has been followed to the present day.

Also in the late 1960s, the fast neutron hodoscope was developed under the leadership of A. DeVolpi. This instrument enables real time tracking of the location of fissile material within an experiment by counting collimated fission neutrons emitted from the fuel. Since fuel relocation in an accident sequence is crucial to the reactivity feedbacks and therefore the power history and energy release, experimental information to validate fuel motion models used in such codes as SAS is of great importance in safety analysis. TREAT experiments done with the fast neutron hodoscope are the primary source of such data.

Through the decade of the 1970s, the primary emphasis in TREAT experiments was support of FFTF and CRBRP safety analysis and licensing. For FFTF, the primary emphasis was on simulations of transient overpower (TOP) and unprotected loss of flow (LOF) accidents. The primary interest was in determining the time and location of fuel pin failure, and the nature of the subsequent fuel motion. The principal finding was that there was no strongly compactive fuel motion that would lead to a reactivity excursion that would exacerbate the assumed input ramp. The LOF experiments, conducted at essentially constant power with decaying flow, also showed an absence of strongly compactive fuel motion implying an energetically benign transition into a core melt.

Early analysis of similar accident sequences for the CRBR showed that, because of the positive sodium void worth of that reactor, the so-called "transient undercooling driven overpower (TUCOP), required experimental simulation. TREAT experiment results were used to help establish a licensing position that the energy release in a TUCOP sequence would not cause loss of structural integrity of the reactor system and that containment integrity would be maintained.

The PFR/TREAT collaborative program included thirteen experiments conducted using UK designed bottom-plenum fuel pins between late 1980 and the end of 1983. Six of them were single pin capsule tests; seven were seven-pin bundle tests in flowing sodium. Two used fresh fuel; all of the others used irradiated fuel. In every test, there was an axial redistribution of fuel into a less reactive configuration. The results tended to validate predictions of time and location of failure, and showed that cladding meltthrough is an important failure mechanism. The results emphasized the need for comprehensive modeling in all stages of the experiment and in application of the results.

In 1984, the CRBRP project was terminated, and attention shifted to the Integral Fast Reactor (IFR) program. The IFR concept used sodium-bonded metal fuel, rather than on gas-bonded oxide, and emphasized the inherent properties of metal fuel and passive safety features in design. The emphasis in TREAT experiments shifted to investigation of the pre-failure fuel axial expansion and cladding failure threshold under transient overpower conditions, to verify that the inherent fuel behavior characteristics would lead to reactivity decrease and reactor shutdown. Six loop experiments were performed in the mid-1980s on metal-fuel elements of various combinations of fuel and cladding material. In general, the metal fuel exhibited a large margin to cladding breach, significant prefailure fuel axial expansion (with strong dependence upon fuel alloy), and apparent very-dispersive postfailure fuel motion with high probability of coolability. The IFR program was terminated in October, 1994. No TREAT experiments have been conducted since then.

Although most of the work that has been conducted with the TREAT Facility has been directed at safety of fast reactors, a major program was conducted in the early 1980s to investigate fission product release from LWR fuel elements during meltdown in a steam environment. The Source Term Experiments Project (STEP), which was sponsored by the Electric Power Research Institute (EPRI), core melt accidents.

Consideration is now being given to utilization of TREAT for testing of high burnup LWR fuels in simulations of reactivity-initiated accidents (RIA). Preliminary studies indicate that TREAT has excellent capabilities for producing prototypic power transients and can produce sufficient energy in highly irradiated samples to simulate predicted RIA conditions. The capabilities of TREAT and its supporting facilities are the subject of a companion paper.