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Run-Beyond-Cladding-Breach (RBCB) Test Results for the Integral Fast Reactor (IFR) Metallic Fuels Program

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## Introduction

In 1984 Argonne National Laboratory (ANL) began an aggressive program of research and development based on the concept of a closed system for fast-reactor power generation and on-site fuel reprocessing, exclusively designed around the use of metallic fuel. This is the Integral Fast Reactor (IFR).

Although the Experimental Breeder Reactor-II (EBR-II) has used metallic fuel since its creation 25 years ago, in 1985 ANL began a study of the characteristics and behavior of an advanced-design metallic fuel based on uranium-zirconium (U-Zr) and uranium-plutonium-zirconium (U-Pu-Zr) alloys. During the past five years several areas were addressed concerning the performance of this fuel system. In all instances of testing the metallic fuel has demonstrated its ability to perform reliably to high burnups under varying design conditions.

This paper will present one area of testing which concerns the fuel system's performance under breach conditions. It is the purpose of this paper to document the observed post-breach behavior of this advanced-design metallic fuel.

## Run-Beyond-Cladding-Breach (RBCB) Testing Program

The RBCB program, used to test the performance of metallic fuel under breach conditions, utilized an artificially-induced breach. This was accomplished by pre-thinning the clad of a test element and allowing it to breach under stress during irradiation.

Several tests were conducted using different fuel alloys of U-xPu-10Zr (x= 0-19 wt %) as well as D9 and Type-316 stainless steel cladding materials (future tests will examine

HT9 clad, see Table I). The initial scoping tests were designed around EBR-II driver fuel using 0.442 cm (0.174 in.) diameter fuel pins. Prototypical testing, upon completion of the scoping tests used the IFR fuel design of 0.584 cm (0.230 in.) fuel pin diameters. The test pins were previously irradiated to a range of burnups between 3 and 12 at.% burnup.

Steady-state irradiation and subsequent post-irradiation-examination (PIE) of the run-beyond-cladding-breach (RBCB) tests have resulted in a large data base that has produced strong support of the fuel's predicted benign behavior under breach conditions. Table I provides a description of the IFR RBCB program and its current status.

## Results and Discussion

Analysis of the fuel system under breach conditions addressed several important issues:

- Observe the RBCB characteristics of IFR metal fuel
- Observe characteristics of the fuel/clad interaction of D9 & HT9 cladding under RBCB conditions
- Characterize the "signature" of a fuel column breach in an open core position
- Characterize fission product release and fuel loss from elements during extended RBCB operation

As indicated in Table I, artificially-induced breaches in the fuel column region of RBCB tests have operated in reactor for periods in excess of 200 days without deterioration of the breach site. Figure 1 provides the basic release sequence of a breach in the fuel region.

In all the RBCB tests the same characteristic pattern was repeated in that only during the initial breach stage was any evidence of activity observed. After the sodium bond, cesium fission products, and accumulated fission gas expulsion, all activity ceased, with the exception of periodic small "burps" of gas.

Throughout the RBCB testing program, post-irradiation-examination (PIE) of breached elements revealed that no crack widening and negligible fuel loss had occurred during the RBCB residence time. Figure 2 shows a transverse metallographic section taken of the pre-thinned clad region of an IFR prototypical fuel element that underwent 170 days of irradiation after breach. Note that after the initial crack in the clad no further widening had occurred.

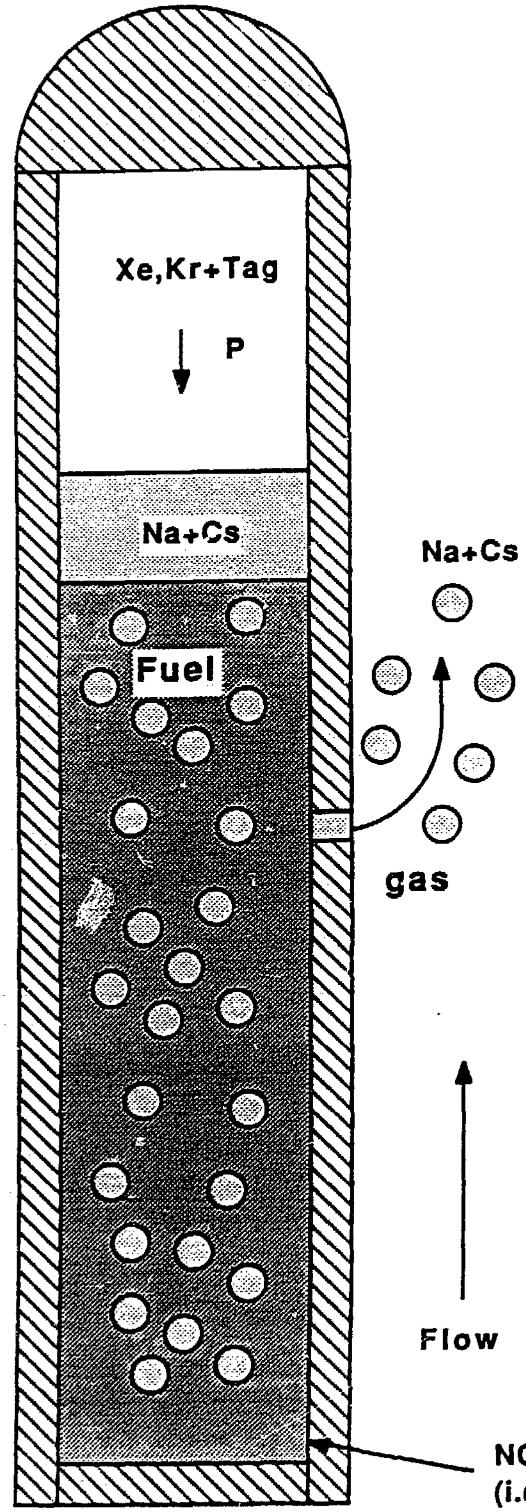
The performance to date of IFR metallic fuel clearly indicates that this fuel system is reliable to high burnups and also shows negligible performance deterioration after pin breach has occurred.

Table-I IFR RBCB Test Program

| | SCOPING TESTS | | | IFR PROTOTYPICAL | | |
|---|---|---|---|---|---|---|
| | XY-21/21A | XY-24 | XY-27 | X482 | X482A* | X---* |
| COMP. (WT%) | U-5 Fs | U-19 Pu-10 Zr | U-8 Pu-10 Zr | U-19 Pu-10 Zr | U-10 Zr | U-x Pu-10Zr |
| CLADDING | 316SS | 316SS | 316SS | D9 | D9 | HT9 |
| BURNUP | ~9.3 at.% | ~7.5 at.% | ~6.0 at.% | ~12.2 at.% | ~12.0 at.% | ~12.0 at.% |
| SIZE | MK-II(0.130") | MK-II(0.130") | MK-II(0.130") | MK-III(0.173") | MK-III(0.173") | MK-III(0.173") |
| RUN TIME: | | | | | | |
| BREACHED | 54 days | 233 days | 131 days | 168 days | Insert Runs 152-153 | Insert Runs 154-155 |
| MWD | 3348 | 18453 | 15234 | 9200 | --- | --- |
| RUNS | 136-139 | 143-146 | 144-146 | 149-150 | 152-153 | 154-155 |
| STATUS | RT95 breached | J507 breached | J432 breached | T139 breached | --- | --- |
| | | J516 no breach | J486 breached | | --- | --- |
| WT. LOSS(G) | ~2.0 g | 2.7 g | ~2.5g/element | 4.04 g | --- | --- |
| FACILITY | BFTF | FPTF | BFTF | Open Core | Open Core | Open Core |

*Future proposed tests

Figure 1- BREACH RELEASE CHARACTERISTICS




## Release Sequence

1. (Na-Cs)
   - Gas from fuel (short 1/2 life) DN precursors
   - DN signal depends on Na release rate.
2. Plenum, gas tag (if present)

## Result

1. Depressurized Element
   - Drop in cladding stress.
   - No crack propagation
2. Decrease in Fuel Thermal Conductivity.
3. No Fuel Extrusion
4. Steady Low Gas Release
5. Negligible DN Signal

Figure-2 Transverse of pre-thinned region showing small crack after breach. RBC3 test ran for 170 days after breach with no further clad deterioration