CONF-871101--16

CONF-871101--16

DE87 011373

FIRST TREAT TRANSIENT OVERPOWER TESTS ON U-PU-ZR FUEL: M5 AND M6*

W. R. Robinson, T. H. Bauer, A. E. Wright, E. A. Rhodes
G. S. Stanford, and A. E. Klickman

Argonne National Laboratory
9700 South Cass Avenue
Argonne, Illinois

* Work performed under the auspices of the U. S. Department of Energy.

Work supported by the U. S. Department of Energy "Technology Support Program" under contract W-31-109-Eng-38.

FIRST TREAT TRANSIENT OVERPOWER TESTS ON U-PU-ZR FUEL: M5 AND M6

W. R. Robinson, T. H. Bauer, A. E. Wright, E. A. Rhodes
G. S. Stanford, and A. E. Klickman

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

Transient Reactor Test Facility (TREAT) tests M5 and M6 were the first transient overpower (TOP) tests of the margin to cladding breach and prefailure elongation of metallic U-Pu-Zr ternary fuel, the reference fuel of the Integral Fast Reactor concept. Similar tests on U-Fs fueled EBR-II driver pins were previously performed and reported [1,2]. Results from these earlier tests indicated a margin to failure of about 4 times nominal power and significant axial elongation prior to failure, a feature that was very pronounced at low burnups. While these two fuel types are similar in many respects, the ternary alloy exhibits a much more complex physical structure and is typically irradiated at much higher temperatures. Thus, a prime motivation for performing M5 and M6 was to compare the safety related fuel performance characteristics of U-Fs and U-Pu-Zr.

Baseline thermal conditions in the test fuel were referenced to nominal fast reactor conditions that include a peak linear power rating of 39.4 kW/m, an inlet temperature of 630 K and a 150 K coolant temperature rise. However, to compensate for radial depression of the TREAT reactor's thermal flux within the test fuel pins, baseline power and flow were both increased by 38%, and the inlet temperature was reduced by 50 K. Thus, at the reported overpower levels, the fuel and cladding temperatures closely approximate fast reactor conditions.

Each of the two tests included two U-19 w/o Pu-10 w/o Zr fuel pins which had been preirradiated in EBR-II, and each included the highest burnup pins then available. M5 tested pins of 0.8 and 1.9 at.% burnup in August 1986, and M6 tested pins of 1.9 at.% and 5.3 at.% in February 1987. The same TREAT Mark-III flowing sodium loop and test train were used in both tests. Each fuel pin occupied a separate flow tube in the test train. Power was increased exponentially on an 8-s period (Fig. 1b). Pre-failure coolant boiling was precluded by high loop pressure. The pins of M5 were heated short of cladding breach and one pin of M6 was heated to failure. During the power rise the thermal performance of the fuel was monitored, and axial elongation was measured by the TREAT fast neutron hodoscope. After the cladding failure event in M6 was detected by an inlet flowmeter, the power transient was shut down very rapidly (Figs. 1 a and b).

During M5 the 0.8 and 1.9 at.% burnup pins survived overpower levels of approximately 4.2 to 4.4 respectively. In M6 the 5.3 at.% burnup pin failed at about 4.1 times nominal power, and the 1.9 at.% burnup pin survived an overpower level of about 4.2. The following axial elongations were measured with the hodoscope (all prefailure): 2% and 3% in the 0.8 at.% and 1.9 at.% burnup pins of M5, respectively and 4% in the 1.9 at.% and 5.3 at.% pins of M6. Purely thermal elongations would contribute only about 1% to these elongations. At the lower burnups these elongations were much smaller than had been measured in U-Fs fuel, but for medium burnup the magnitudes were similar [2,3].

Behavior of the breached 5.3 at.% burnup U-Pu-Zr pin in M6 was similar to that of a breached 4.4 at% burnup U-Fs pin [2,3]. Posttest radiographs indicated that the failed pin in M6 breached at the top of the fuel column. As much as two-thirds of the fuel from the pin was expelled into the coolant channel and swept upward. The 0.5-mm-thick stainless steel flowtube was not breached or blocked by the expelled fuel.

Preliminary analyses of M5 and M6 have been performed using modeling concepts developed from tests on U-Fs fuel [2,3]. The measured and calculated temperature rises along individual flow tubes show reasonable agreement at the top of the fuel column. Figure 1c shows one example from M6. The ternary pin failure observed in M6 was consistent with the same failure mechanisms deduced for U-Fs fuel: rapid eutectic penetration into the cladding when the temperature at the fuel-cladding interface exceeds 1350 K coupled with high internal pressure. The mechanism for prefailure extrusion developed for U-Fs fuel is expansion of dissolved fission gas trapped in molten fuel. However, when fission gas concentrations appropriate to the U-Fs analysis were assumed for ternary fuel, calculations significantly overestimated prefailure elongation in M5 and M6, despite much fuel melting in these tests (Fig. 1d for illustration). One explanation may be that the higher operating temperatures in ternary fuel leads to much lower concentrations of retained fission gas [4].

In summary, tests M5 and M6 indicate that, under the TOP conditions used in the tests, ternary fuel displayed about the same margin to failure as U-Fs fuel. At low burnups ternary fuel showed less prefailure axial elongation than observed in U-Fs pins, but elongations of 3-5 % might turn out to be typical. Finally, fuel from the breached ternary pin in M6 showed, qualitatively, the same benignly dispersive behavior as U-Fs.

REFERENCES:

1. W. R. Robinson et al., "Integral Fast Reactor Safety Tests M2 and M3 in TREAT", Trans. Am. Nucl. Soc., 50, 352 (Nov. 1985).

2. T. H. Bauer et al., "Behavior of Metallic Uranium-Fissium Fuel in TREAT Transient Overpower Tests", Trans. Am. Nucl. Soc., 53, 306 (Nov. 1986).

3. A. E. Wright et al., "Recent Metal Fuel Safety Tests in TREAT", Proceedings of the International Conference on the Science and Technology of Fast Reactor Safety, Guernsey, UK, May 1986, BNES.

4. E. E. Gruber and J. M. Kramer, unpublished information, Feb. 1987.

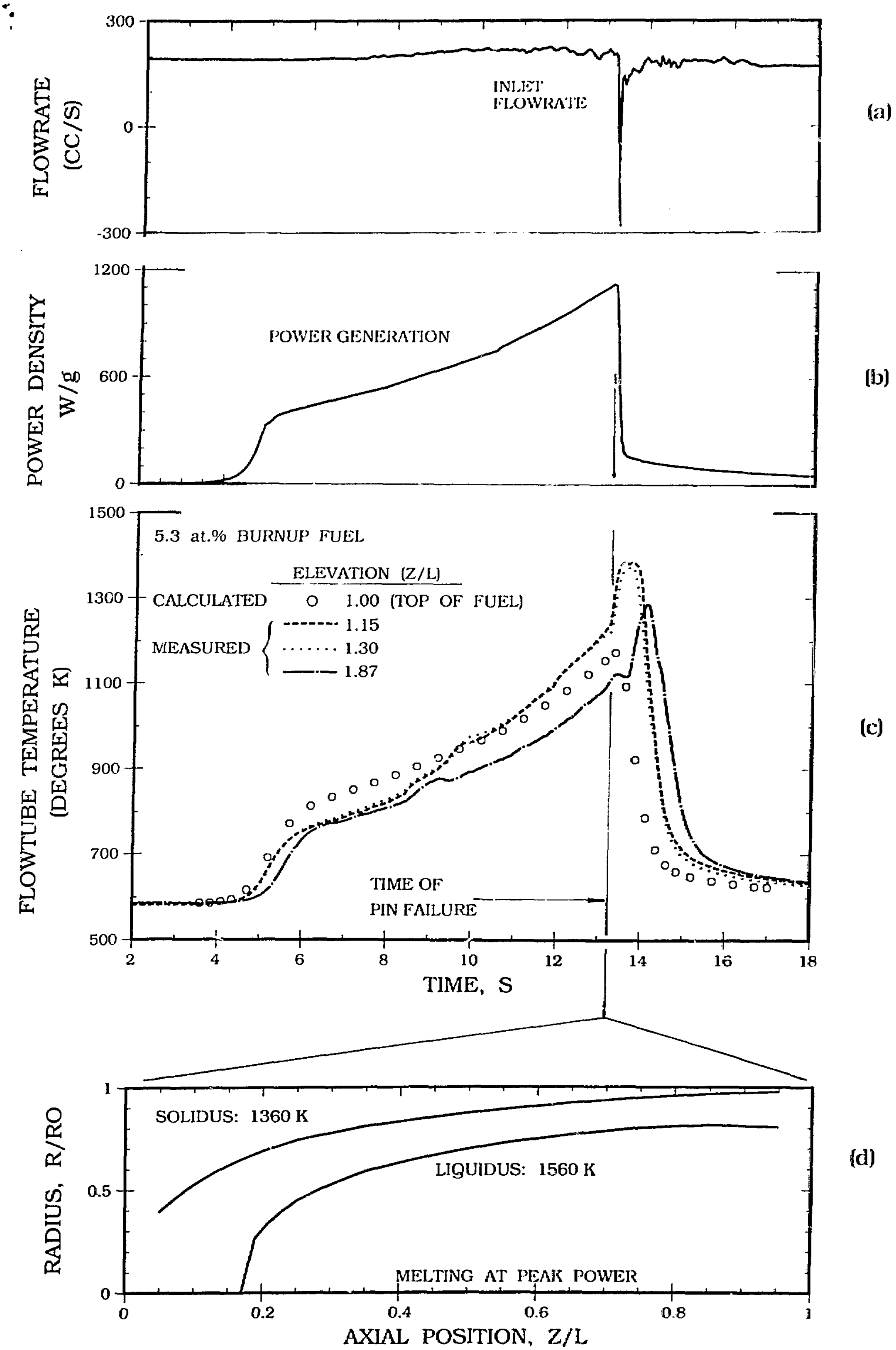

Fig. 1. Calculated and Measured Results from Test M6