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FISSION PRODUCT RELEASE FROM HIGH GAP-INVENTORY LWR FUEL UNDER LOCA CONDITIONS*

R. A. Lorenz
J. L. Collins
M. F. Osborne
A. P. Malinauskas

Chemical Technology Division
Oak Ridge National Laboratory
P. O. Box X
Oak Ridge, Tennessee 37830

To be presented at the 1980 Annual Meeting of the Americal Nuclear Society; Las Vegas, Nevada; June 8-13, 1980.

*Research sponsored by Office of Nuclear Regulatory Research, U. S. Nuclear Regulatory Commission under Interagency Agreements 40-551-75 and 40-552-75 with the U. S. Department of Energy under contract W-7405-eng-26 with the Union Carbide Corporation.

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Fission product release tests were performed with light water reactor (LWR) fuel rod segments containing large amounts of cesium and iodine in the pellet-to-cladding gap space in order to check the validity of the previously published Source Term Model[1] for this type of fuel. The model describes the release of fission product cesium and iodine from LWR fuel rods for controlled loss-of-coolant accident (LOCA) transients in the temperature range 500 to 1200°C. The basis for the model was test data obtained with simulated fuel rods[2] and commercial fuel irradiated to high burnup[3] but containing relatively small amounts of cesium and iodine in the pellet-to-cladding gap space.

In order to broaden the data base, tests were performed with commercial fuel irradiated to 13,000 MWD/MT (metric ton) in the Peach Bottom-2 BWR at higher heat ratings and temperatures. The amounts of krypton, cesium, and iodine released in-reactor to the plenum and gap space of the Peach Bottom-2 fuel are compared in Table 1 with the amounts in the previously tested H. B. Robinson-2 fuel. The concentrations of cesium and iodine in the gap space were 36 times greater in the Peach Bottom-2 fuel rods. Most commercial fuel rods should have concentrations within this range. These "gap inventories" were measured by purging the pellet-to-cladding gap space with purified helium while the test segments were heated in the temperature range 700 to 1100°C. This method was devised as a means of

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Table 1. Amounts of fission products in the pellet-to-cladding gap space

Fuel type	Burnup (MWd/MT)	Fission products in the gap space				
		Krypton	Cesium		Iodine	
		(%)[a]	(%)[a]	($\mu g/cm^2$)[b]	(%)[a]	($\mu g/cm^2$)[b]
H. B. Robinson-2	30,000	0.25[c]	0.30	13	0.30	1.2
Peach Bottom-2	12,400	11.4[d]	12.5	470	12.1	42

[a]Percent of total produced.

[b]μg of total element per cm^2 of cladding surface.

[c]Measured in room temperature fuel rod puncture.

[d]From room temperature fuel rod puncture measurement adjusted for local burnup and heat rating.

measuring the total quantity of fission products potentially releasable from a ruptured fuel rod in a controlled LOCA.

Results of the fission product release and gap purge tests with 30.5 cm lengths of high gap-inventory fuel are summarized in Table 2. The burst tests were performed by inductively heating 15.2 cm of the test segment prepressurized with purified argon so that the Zircaloy cladding expanded and ruptured into flowing steam at the temperatures shown. The pressure required to rupture the cladding at 850°C was 2.8 times that required at 960°C. The larger volume of gas vented in the 850°C test caused the release of cesium and iodine to be almost the same as that which occurred at 960°C. The Source Term Model predicts this behavior.

The 1200°C diffusion test was performed using the same fuel rod segment previously ruptured at 850°C. The entire length of the test segment was heated uniformly with a resistance furnace in a flowing steam atmosphere for an effective time of 25 minutes. Fission product release occurred by diffusion from the previously generated rupture opening. The gap purge test was performed with a new test segment uniformly heated and arranged so that purified helium flowed axially through the gap space to carry out readily vaporizable material. The amounts of cesium and iodine released in this test originated in the pellet-to-cladding gap space; release from the pellet matrix is believed to have been negligible during the time period involved. The quantities of cesium and iodine eluted during this test are referred to as the "gap inventory" and are required as input to the Source Term Model.

Table 2 also includes releases of cesium and iodine predicted by this model. Measured and predicted values agree quite well considering that the model was based on tests with low gap-inventory fuel and with simulated fuel rods. The mass of cesium (sum of all isotopes) released in each of the three tests with

Table 2. Amounts of fission products released

Test No.	Test type	Amounts released (%)[a]				
		^{85}Kr	Cesium		Iodine	
		Measured[b]	Measured	Calculated by source term model	Measured	Calculated by source term model
BWR-1	960°C burst	1.7	1.71	1.26	1.18	1.67
BWR-2	850°C burst	1.0	1.70	1.81	2.54	3.18
BWR-3	1200°C diffusion	1.1	1.85	1.07	2.99	2.70
BWR-4	700-1100°C gap purge	1.2	12.2	——	12.1	——

[a]Percent of total produced in-reactor in heated length of test fuel rod segment.

[b]These amounts are in addition to the 11 to 15% released in reactor.

Peach Bottom-2 fuel ranged from 7150 to 7950 μg. The releases of cesium during similar tests with H. B. Robinson-2 fuel were much smaller - 130 to 280 μg.

The results of these tests permit us to use the LOCA Source Term Model with greater confidence. However, aspects such as definition of the gap inventory and effect of hole size, fuel rod length, rate of plenum gas blowdown, and external pressure have not been clarified.

REFERENCES

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