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IRRADIATION EFFECTS ON ZIRCONIUM-CLAD
URANIUM-ZIRCONIUM FUEL PLATES

by

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R. E. Bailey

I. INTRODUCTION

This report summarizes the series of irradiations conducted in a Hanford reactor on specimens of zirconium-clad, uranium-zirconium fuel plates containing 3, 6, and 14 wt-% highly (93.4%) enriched uranium. More than thirty fuel plates were exposed during the test program, which extended over a period of several years.

II. SAMPLE DESCRIPTION

A. Fabrication

The specimen plates were of the "picture frame" type, approximately 1 x 0.09 x 2 in. and 1 x 0.09 x 6 in. The fuel plates were fabricated at Battelle Memorial Institute. The picture frames and clad covers were extruded from non-homogenized, crystal bar zirconium at ANL.

The sandwich components were cleansed in nine rinses of acetone and one rinse of ether, assembled, welded in steel jackets, and rolled to size in three passes at 1650F. The rolled specimen was straightened by applying a 100-ton load at 1500F for one-half minute. The jacket was removed and the plate cold pressed under a 100-115-ton load, then machined to size. Seven plates were not cold pressed before machining.

Two clad thicknesses were used: 20 mils and 30 mils. The average over-all side thickness was 140 mils, and the average end thickness 200 mils.

B. Pre-Irradiation Conditioning

All samples were annealed for one-half hour in a vacuum at 760 C. They were then corrosion tested for 48 hr in steam at 100 psi, and for 120 hr in static water at 350F. The seven elements which were not cold pressed before machining were exposed for 387.5 hr in the latter test.

III. IRRADIATION

The plates were irradiated in open aluminum capsules in a water channel at 70-140F. The exposures ranged from 0.69×10^{20} to 16.4×10^{20} nvt thermal. The per cent burnup of total core atoms varied from 0.03 to 3.3%.

IV. RESULTS

The results are summarized in Table I.

Table I

SUMMARY OF IRRADIATION TESTS ON ZIRCONIUM-CLAD,
URANIUM-ZIRCONIUM FUEL PLATES

<u>Plate No.</u>						<u>Enrichment, %</u>					
17-29						3					
30-39						6					
41-52						14					
Minimum Zr Thickness, mil						Minimum Zr Thickness, mil					
BMI			<u>Change, %</u>			BMI			<u>Change, %</u>		
Plate No.	Plate Side	Plate End	Burnup, %	Density (-)	Thickness (+)	Plate No.	Plate Side	Plate End	Burnup, %	Density (-)	Thickness (+)
<u>Top Clad Thickness: 20 mil</u>						<u>Top Clad Thickness: 30 mil</u>					
18*	120	110	0.350	0.527	1.06	23	150	230	0.480	0.441	0.84
17*	120	80	0.374	0.076	0.841	28	130	310	0.480	0.349	1.06
20	150	200	0.374	0.709	0.839	27	130	140	0.590	0.501	-
33	150	320	0.40	0.662	2.22	24	140	300	0.650	0.318	1.46
22	150	210	0.590	0.605	0.0	26	130	160	0.715	0.091	0.83
19*	120	80	0.650	0.360	1.00	25	130	310	0.715	0.076	0.52
31	150	140	0.720	1.02	1.79	39	140	150	0.92	0.604	1.27
32	150	250	0.720	1.44	1.68	36	150	280	0.92	0.831	1.90
29*	140	150	1.10	1.39	1.38	47	150	200	0.96	0.984	1.68
34	150	250	1.10	1.18	1.05	35	140	320	1.20	0.663	1.80
30	150	150	1.20	1.09	1.31	38	140	130	1.37	0.44	1.47
41*	120	150	1.60	0.211	5.32	37	150	230	1.37	0.32	1.68
45	140	210	1.73	2.77	5.23	51	120	160	1.73	1.70	3.91
42*	130	150	2.70	3.19	7.55	52	130	130	2.2	1.79	5.47
43*	140	100	3.0	2.88	8.60	48	140	220	2.2	1.94	3.88
46	140	200	3.0	3.10	8.08	49	140	240	2.7	2.08	2.76
44	150	250	3.3	2.79	8.29	50	140	120	3.3	1.79	4.89

ENRICHMENT: 3% BURNUP: 0.48

ENRICHMENT: 6% BURNUP: 0.92

ENRICHMENT: 14% BURNUP: 0.96

ENRICHMENT:	14%	6%	3%
BURNUP:	2.2	0.92	0.35

FIG. 1
ZIRCONIUM-CLAD, URANIUM-ZIRCONIUM FUEL PLATES
IRRADIATED IN WATER AT 70-140 F

There were insignificant positive changes in length, width, and weight; the maximums were 0.12%, 0.15%, and 0.04%, respectively.

The hardness increased five points to a constant value of 85 after an accumulated exposure of 13.8×10^{20} nvt thermal (Fig. 2).

There was a definite increase in the average thickness (+8.6% max.) and a corresponding decrease in density (-3.1% max.) with burnup of total core atoms (Fig. 3). For a given burnup, the per cent change in density is inversely proportional to the clad thickness. The ratio of per cent density change for the 20-mil clad to the 30-mil clad is 3:2 for all burnups studied.

The following theory is suggested in connection with the breaks in the curves at 1.5% burnup. When an unrestrained uranium alloy fissions, the resultant fission products promote changes in the physical structure, with consequent expansion, of the alloy. Since the test specimens were enclosed within a relatively heavy zirconium frame and a thin zirconium clad, the expanding alloy would tend to deform the cladding. The rate of increase in volume of the fuel plate is expected to be linear with the per cent burnup until the yield point of the cladding is attained. At this point there would be a deviation from a linear increase in proportion to the ductility of the cladding.

The scatter in the data may be attributed to: (1) the different equipment used by the respective operators during the conduct of the test program; and (2) the fact that the neutron flux along any row of samples is not constant.

FIG. 2
HARDNESS OF ZIRCONIUM-CLAD URANIUM-ZIRCONIUM FUEL
PLATES AS A FUNCTION OF NEUTRON IRRADIATION

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FIG. 3
CHANGE IN DENSITY AND PLATE THICKNESS AS A
FUNCTION OF BURNUP OF TOTAL CORE ATOMS

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