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INTERIM REPORT: SOME TEMPERATURE AND SWELLING DATA ON ZIRCALOY-2 CLAD COEXTRUDED FUEL ELEMENTS

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R. L. Call and G. T. Geering

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INTERIM REPORT: SOME TEMPERATURE AND SWELLING DATA ON
ZIRCALOY-2 CLAD COEXTRUDED FUEL ELEMENTS

By:

R. L. Call and G. T. Geering

January 25, 1961

The attached table lists some temperature and swelling data on Zircaloy-2 clad, coextruded fuel elements irradiated in the KER loops and in the GEH-3X3P7 loop at the ETR. Data on both rod cluster fuel elements and tubular fuel elements are included. Density changes, where density measurements were made, have also been included. These data are preliminary and are subject to change.

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TABL

Test No.	RM No.	Description of Fuel	Exposure MWD/T	Uranium Temperature °C		Diameter Change Inches	
				Surface	Center	Mean	Maximum
PT-IP-146-A	277	7 RCFE with 0.030" thick Zircaloy-2 clad and 0.630" diameter rods. Uranium cores coextruded by NMI.	1250 1155	325	410	+0.0005	+0.008
PT-IP-172-A	254	Four 1.6% enriched 4-rod clusters tested. Rod diameter - 0.631". Cladding thickness - 30 mils. Four rods measured.	2200 220	270	510	+0.008	+0.012
PT-IP-205A	BMI Con-DDR-78	2-1.002" diameter rods .020" Zircaloy-2 clad 36" long	1570 at center 1195	300 C	650-680	+0.008	+0.013
PT-IP-205A	BMI Con-DDR-78	2-1.785x1.450" .030" clad tubes, one tract integrally end closed.	1700 at center 121	295	350	Diameter measurements - very erratic.	
PT-IP-214-A	295	Four 1.6% enriched 7-rod clusters tested. Rod diameter - 0.591". Cladding thickness - 30 mils. One cluster measured.	1500 1185	296	437	+0.001	+0.004
PT-IP-226-A	279	Seven 1.6% enriched 7-rod clusters tested, four with 20-mil thick cladding. Pre-irradiation rod diameter 0.592". One cluster of each cladding thickness measured.	1200 1215	294 296	435 420	-0.0005 -0.0018	+0.005 +0.005
PT-IP-226-A (Suppl. A.)	555	Seven 1.6% enriched 7-rod clusters tested, six with 20-mil thick cladding and one with 30-mil thick cladding. Pre-irrad. rod diameter 0.590 in. One cluster of each cladding thickness measured.	2240 128	311 310	456 476	+0.0018 +0.0002	+0.005 +0.003

Volume Change %		Density Change %	Remarks
Mean	Maximum		
+0.47%	+1.2%	-0.43	The data is taken from the seven rods of one element. The ΔV calculation includes the expansion of uranium into the end cap relief space. No swelling pores appeared in electron micrographs. Salt bath beta heat-treated and air-cooled.
--	+6.5	--	This test was performed in pH 4.5 water. A heavy film (probably iron oxide) was deposited on the fuel rods. Because of this film, the calculated temperatures are probably much lower than actual temperatures. There is some evidence that the rod center temperatures were above 660 C. The high temperatures made it possible for the large amount of swelling to occur without splitting the cladding. Salt bath beta heat-treated and air-cooled.
8.5 +1.66%	+3.6%	-1.0%	The center of one rod was beta transformed. The other appears to have operated in the high alpha. No bumping could be seen, even though one rod was slow-cooled during beta heat treat. The other was air-cooled.
--	--	-1.1%	One tube was extensively cracked. The cracks were radial and many were full fuel width. Both tubes were badly out of round after exposure. One tube was air-cooled, and one slow-cooled after beta heat treatment.
10 +0.35	+0.77	-0.5	Meaningful length change data were not available. Therefore the volume changes were calculated by assuming that the rods had swelled so that the 25-mil gap at the end of each rod was half filled. The maximum volume change was calculated by using the mean diameter of the rod which had the largest increase in mean diameter. Salt bath beta heat-treated and air-cooled.
+0.03	+0.83	-0.48	Where two lines of figures exist, the upper line of figures is for the 30-mil clad clusters and the lower for the 20-mil clad clusters. The volume changes were calculated by assuming that the 25-mil gap left under each end cap had been half filled with uranium. The maximum volume change was calculated using the mean diameter of the rod which had the largest increase in mean diameter. Salt bath beta heat-treated and air-cooled.
-0.06	+0.70	-0.74	
+0.67	+1.35	--	Where two lines of figures exist, the upper line is for the 30-mil clad cluster and the lower for the 20-mil clad cluster. The volume changes were calculated by assuming that the space under the end cap (a spherical segment) had been completely filled. The maximum volume change was calculated using the mean diameter of the rod which had the largest increase in mean diameter. Salt bath heat-treated and air-cooled. One rod of one of the 20-mil clad clusters failed. The cladding split longitudinally.
+0.13	+0.74	--	

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TABLE I (C)

Test No.	RM No.	Description of Fuel	Exposure MWD/T	Uranium Temperature °C		Diameter Change Inches	
				Surface	Center	Mean	Maximum
PT-IP-226-A (Suppl. B)	562	Six 1.6% enriched 7-rod clusters tested - four with 20-mil thick cladding and two with 30-mil thick cladding. Pre-irradiation rod diameter 0.590". One rod from each cladding thickness measured.	2520	300 306	443 453	+0.0029 +0.0005	+0.006 +0.006
PT-IP-250A	550	Tube/tube element 36" long KER size 0.020, clad uranium core.	250	310	380	--	--
PT-IP-250A (Suppl. C)	553	KER tube/tube element 36" long, 0.020" clad enriched uranium.	400	315	415	--	--
PT-IP-250A (Suppl. C)	568	Tube/tube element 36" long KER size 0.020" clad enriched uranium core, uranium-2% zirconium	1100	315	415	+0.010 +0.009 +0.007	+0.027 +0.011 +0.017
PT-IP-292A	569	KER tube/tube element 18" long enriched uranium with uranium and uranium-2% zirconium cores.	3250	310	410	+0.020 +0.000 +0.010 +0.008	+0.029 -0.003 +0.011 +0.011
PT-IP-292-A	572	Two KER-size tube/tube elements, one 1.6% enriched U-2% Zr alloy, one 1.47% enriched unalloyed. Cladding thickness - 20 mils. The inner tubes only were examined. Pre-irradiated. O.D. - 1.050; I.D. - 0.520	1000			+0.0043 +0.0027	+0.007 +0.006
GEH-10-2	281	Three natural uranium 7-rod clusters tested. Pre-irradiation rod diameter - 0.592". Cladding thickness - 30 mils. Only one rod measured.	950	377	516	+0.0033	+0.007

Volume Change %		Density Change %	Remarks
Mean	Maximum		
+1.03	+1.44	--	Same as last item on 2. The reason for the large discrepancy between the increase in volume and decrease in density is not known. Salt bath beta heat-treated and air-cooled. One rod of the four 20-mil clad clusters failed. The cladding split longitudinally and a necked area in the cladding was observed extending from one end of the split for more than an inch along the cladding surface.
+0.22	+1.06	-3.55	
--	--	--	No good dimensional data. Inner tube warped and bumped. Salt bath beta heat-treated and very slow-cooled.
--	--	--	This element ran with pH 4.5 coolant. A heavy crud layer caused the element to overheat. The Zircaloy-2 clad suffered pitting corrosion and failed on the inside of the inner tube. Salt bath beta heat-treated and air-cooled.
--	--	--	Inner tube O.D. The inner tube developed a severe "S"
--	--	--	Inner tube I.D. warp in the reactor, causing a hot spot
--	--	--	Outer tube O.D. failure. One end of the element had anisotropic growth. The length had decreased 3/16". Salt bath beta heat-treated and air-cooled.
--	--	--	Inner Tube O.D. uranium. The inner tube of one element
--	--	--	Outer Tube O.D. uranium. failed by clad splitting. Sur-
--	--	--	Inner Tube O.D. alloy. face bumped on uranium pieces,
--	--	--	Outer Tube O.D. alloy. very smooth on alloy pieces. Salt bath beta heat-treated and air-cooled.
--	--	--	The diameter measurements are O.D. measurements only.
--	--	--	No I. D. measurements have been made. Therefore, it is not yet possible to calculate any volume changes. The upper line is for the U-2% Zr alloy, the lower for the unalloyed uranium. Salt bath beta heat-treated and air-cooled.
+1.73	--	-0.37	The large disagreement between the density decrease and the volume increase may be because of the inaccuracies of the post-irradiation density measuring method in use at the time the density measurement was made. The method in use at that time was subject to rather large errors. Salt bath beta heat-treated and air-cooled.

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