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This document consists of 5 pages.
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November 5, 1958

ANALYSIS OF PRODUCTION TEST IP-120-A-94FP COMPARISON OF PERFORMANCE OF INGOT AND LOW HYDROGEN DINGOT URANIUM FUEL ELEMENTS

Reference: HW-57379 RD "Analysis of Partial Data from Production Test IP-120-A-94FP. Comparison of Performance of Ingot and Low Hydrogen Dingot Uranium Fuels Elements." J. L. Jaech, 9/9/58

Introduction

Twenty charges of low hydrogen dingot and twenty charges of "standard" ingot fuel elements were irradiated at DR-reactor under this production test primarily in order to compare the materials with respect to rupture performance. Short charges consisting of 25 fuel elements per tube were utilized in order to decrease the probability of sustaining corrosion type ruptures. Dimensional distortion data were taken on all of the fuel elements. An analysis of the distortion data from 22 tubes is given in the reference document and this report which includes these results plus the results from an additional 16 tubes completes the analysis.

Conclusions

The results of the data from the additional 16 tubes (9 ingot, 7 dingot) agree quite closely with those in the earlier report. That is that the dingot fuel elements show a proneness to a greater tube filling capacity[1] (TFC) and to greater diameter growths at both the center and the ends of the fuel elements. In general the diameter growths at the center of the fuel elements are larger than at the ends.

The difference between average warp values for the two types of fuel elements is not statistically significant which indicates that the greater TFC values shown by the dingot fuel elements are due to their larger diameter growths at the slug center rather than to larger warp values.

[1] HW-56490, "Basis for Use of Tube Filling Capacity Statistic in Analysis of Dimensional Distortion Data," J. L. Jaech, 6/23/58.

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Operating Data

Data from the following tubes are considered in this analysis:

Ingot			Dingot		
Tube #	Exposure*	Power**	Tube #	Exposure*	Power**
2978	750	800	2874	760	820
2977	760	810	2876	780	830
2980	780	810	2774	790	850
2877	780	840	1879	800	850
2881	800	850	2880	800	850
2077	810	830	1882	810	860
2775	820	880	1883	810	880
2983	820	860	2883	820	860
2175	320	880	2882	820	870
1982	840	890	1981	840	890
2284	850	910	2683	870	920
1975	790	850	2875	770	830
2075	790	860	1880	790	850
1976	800	850	1978	800	860
1977	800	860	1881	800	850
1979	810	860	1980	810	860
2177	810	890	2783	870	920
2076	820	870	2281	870	920
2181	840	900			
2081	850	900			

*From RW Bown's Status of Special Loadings Reports (Rounded Off)

**Personal communication, RR Bloomstrand

△Diameter - Slug Center

The △ diameter is defined as the post-irradiation diameter minus the pre-irradiation diameter. Table I gives the average △ diameters measured at the fuel element centers for the individual tubes.

Table I (△ diameters at slug centers)

Ingot		Dingot	
Tube #	Average △ Diameter	Tube #	Average △ Diameter
2978	4.7	2874	7.6
2977	6.0	2876	9.6
2980	4.2	2774	12.0
2877	4.2	1879	12.2
2881	3.9	2880	11.1
2077	4.7	1882	10.0
2775	3.4	1883	12.7
2983	3.2	2883	9.1
2175	2.4	2882	10.0
1982	4.7	1981	11.4
2284	3.6	2683	13.4
1975	4.6	2875	12.0
2075	4.2	1880	11.6
1976	5.0	1978	12.3
1977	4.0	1881	10.4
1979	3.8	1980	11.7

Table I Continued

Tube #	Average Diameter	Tube #	Average Diameter
2177	4.3	2783	12.3
2076	4.8	2281	11.8
2181	5.5		
2081	2.6		
Average	4.2		11.2

The dingot fuel elements grew on the average about 7 mils more than the ingot fuel elements at the slug centers and this difference is highly significant statistically. As indicated in the reference document the difference is greater than 7 mils from a practical standpoint because the position effect is stronger for dingot fuel elements. That is the average difference of 7 mils is made up of a difference of 3-4 mils at the ends of the tube and 10 mils at the more important central portion of the tube.

△Diameters - Slug Ends

Table II contains average△ diameters measured at the slug ends.

Table II (△ diameters at slug ends)

Ingot Tube #	Average △ Diameter	Dingot Tube #	Average △ Diameter
2978	-3.4	2874	2.6
2977	-2.5	2876	-0.5
2980	-4.0	2774	0.8
2877	-3.5	1879	-0.5
2881	-1.2	2880	4.1
2077	-3.4	1882	5.4
2775	0.1	1883	-0.2
2983	-4.9	2883	3.1
2175	-0.8	2882	3.7
1982	-4.1	1981	-0.1
2284	-0.2	2683	-1.1
1975	-4.2	2875	1.8
2075	-3.8	1880	0.7
1976	-3.2	1978	-0.2
1977	-3.6	1881	0.1
1979	-5.1	1980	1.1
2177	-2.7	2783	0.8
2076	-4.2	2281	-1.4
2181	-3.1		
2081	-1.4		
Average	-3.3		1.1

The average difference of 4.4 mils is statistically significant. The position within the tube effect is not significant however, and this means that diameter growth at the slug ends as measured by the△ diameters is independent of the fuel element position within the tube, a result which is consistent with those found in previous studies.

Average Warp

Average warp is defined as the average of the warps measured for the convex and concave profiles. The individual tube averages are given in Table III.

Table III (Average Warp)

Ingot Tube #	Average Warp	Dingot Tube #	Average Warp
2978	14.0	2874	13.9
2977	10.9	2876	12.2
2980	13.9	2774	11.1
2877	18.4	1879	15.5
2881	13.1	2880	8.5
2077	11.0	1882	12.5
2775	10.0	1883	15.4
2983	12.4	2883	10.5
2175	14.1	2882	13.7
1982	11.5	1981	8.6
2284	8.1	2683	13.0
1975	14.6	2875	12.8
2075	14.1	1880	12.8
1976	17.0	1978	12.7
1977	16.5	1881	16.2
1979	10.6	1980	13.2
2177	12.2	2783	16.4
2076	9.0	2281	17.0
2181	12.6		
2081	13.1		
Average	12.9		13.1

The difference of 0.2 mils in the average warp is not statistically significant but the interaction between slug type and position within the tube is significant. For purposes of analysis slugs 1-5 were considered to be in position 1, slugs 6-10 in position 2 and so on. For ingot slugs no significant differences exist between slug positions within the tube but for dingot fuel elements the slug position within the tube is highly significant, statistically. In this regard the dingot fuel elements in section 2 are high and the dingot fuel elements in section 4 have low warp values. There are 950 warp values in the analysis however, and small but true differences show up to be highly significant statistically. For all practical purposes the larger TFC values of the dingot fuel elements are due to larger Δ diameters at the slug centers rather than to greater warp values.

TFC

Of greatest practical interest is the TFC value associated with a fuel element. Individual tube averages are given in Table IV.

TABLE IV (TFC)

Ingot Tube #	TFC	Dingot Tube #	TFC
2978	14.4	2874	18.9
2977	13.6	2876	16.2
2980	17.9	2774	17.5

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Table IV Continued

Ingot		Dingot	
Tube #	TFC	Tube #	TFC
2877	12.0	1879	21.4
2881	14.4	2880	18.6
2077	12.0	1882	19.0
2775	10.6	1883	20.6
2983	12.4	2883	17.0
2175	14.4	2882	21.0
1982	11.6	1981	16.1
2284	9.5	2683	20.5
1975	15.1	2875	21.0
2075	14.4	1880	20.1
1976	18.2	1978	18.8
1977	16.5	1881	21.8
1979	15.1	1980	19.0
2177	13.6	2783	22.8
2076	9.8	2281	21.9
2181	13.9		
2081	14.1		
Average	13.7		19.6

As one would expect from the definition of the TFC (tube filling capacity) statistic, the difference between the over-all averages is roughly equal to the difference between the average Δ diameters at the slug centers, and of course it is highly significant statistically. The larger average TFC value exhibited by the dingot fuel elements represents a result which is significant from both a practical and statistical point of view. The position effect is also statistically significant where the smaller TFC values are found in positions 1 and 5, and the larger TFC values in positions 2, 3 and 4.

A graphic presentation of the results from the first 22 tubes analyzed is given in the reference document. As would be expected these results agree quite closely with the results found in an analysis of all the tubes.

In interpreting results of this production test, one must keep in mind that short charges were used. For this reason, one cannot compare results of this test with full charge irradiations used in other production tests.

K. B. Stewart

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