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TITLE
ANALYSIS OF DATA FROM IP-56-A-86MT: EVALUATION OF DIMENSIONAL STABILITY CHARACTERISTICS OF LOW HYDROGEN URANIUM-I AND E FUEL ELEMENTS

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April 9, 1959

ANALYSIS OF DATA FROM IP-56-A-86MT: EVALUATION OF DIMENSIONAL STABILITY CHARACTERISTICS OF LOW HYDROGEN URANIUM I AND E FUEL ELEMENTS

1.0 Introduction

This production test was designed to evaluate the suitability of low hydrogen dingot uranium as routine process material. Nine tubes of I and E fuel elements (6 dingot, 3 ingot) with 32 fuel elements in each tube, have recently been discharged at the C Reactor and this document contains the results of analyses made on the dimensional stability properties of this material.

2.0 Summary

The dingot I and E fuel elements irradiated under this test show significantly higher TFC[1] values than the ingot I and E fuel elements. The distribution of TFC values is of considerable importance and in this regard the dingot fuel elements show not only a higher over-all average value but a wider dispersion of TFC values for individual fuel elements. This indicates that the dingot fuel elements have a higher probability of having TFC values in the higher ranges (50 mils or greater say).

The results for warp values follow the results for TFC values very closely. That is,that dingot material shows a higher average warp, a greater dispersion of warp values and more warp values in the higher ranges of values.

MASTER

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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The dingot fuel elements also show on the average a significantly larger swelling at the center of the fuel element than the ingot I and E fuel elements.

3.0 Results

For purposes of statistical analysis fuel elements 1-4 are considered to be in position 1, fuel elements 5-8 in position 2, and so on.

3.1

The following table gives the exposure (MWD/ton) and power (KW) for the different tubes.

TABLE I

Ingot			Dingot		
Tube	Exposure	Power	Tube	Exposure	Power
2158-C	720	1000	2157-C	720	1000
2270-C	830	1100	2167-C	730	1020
2170-C	830	1030	2269-C	825	1010
			2168-C	825	1070
			3763-C	860	940
			2183-C	890	770

3.2 Tube-Filling Capacity (TFC)

The average TFC for the different tubes and positions are given in Table II.

TABLE II

Positions	Tube: Ingot			Dingot					
	2158	2270	2170	2157	2167	2269	2168	3763	2183
1	1.2	6.2	4.0	2.8	10.2	10.0	9.2	18.5	12.2
2	3.2	9.5	5.8	15.8	11.8	23.2	20.2	18.5	32.5
3	7.8	9.0	4.5	23.8	24.8	22.8	20.0	24.2	26.2
4	11.2	14.0	10.0	30.0	27.8	28.8	22.5	12.8	20.5
5	20.5	15.5	10.5	20.5	24.0	26.5	14.5	24.8	17.2
6	25.8	11.2	15.2	37.2	25.5	32.8	25.2	37.0	24.5
7	15.0	19.0	6.2	21.8	18.8	24.2	21.8	29.8	25.8
8	13.2	4.8	0.0	9.5	3.5	4.5	8.8	33.5	10.5
Average	12.2	11.1	7.0	20.2	18.3	21.6	17.8	24.9	21.2

Average Ingot TFC Value = 10.1 mils.
Average Dingot TFC Value = 20.6 mils.

[redacted]

As the above table readily indicates the dingot I and E fuel elements have significantly higher TFC values than ingot I and E fuel elements.

The position effect is highly significant for both ingot and dingot fuel elements, where the higher TFC values occur in the central portion of the tubes. (See Figure 1 for a graphic portrayal of this.) Note that the position effect is stronger for the dingot material.

In most instances the TFC value is equal to the concave warp plus the Δ diameter at the fuel element center. Since the dingot material shows a greater swelling at mid-point and greater average warp values (see sections 3.3 and 3.4) the larger TFC values are to be expected.

The tube-to-tube differences are somewhat higher than would be expected from chance variation alone.

3.3 Average Warp

The average warp is defined as the average of the concave and convex warps for a fuel element. The following table shows the average warp value for the four fuel elements in each position.

TABLE III

	Tube								
Positions	Ingot			Dingot					
	2158	2270	2170	2157	2167	2269	2168	3763	2183
1	3.8	8.0	7.2	4.8	8.8	11.0	7.8	19.2	12.5
2	4.0	10.8	5.5	13.0	9.2	23.8	16.0	15.0	32.8
3	3.5	10.2	3.5	22.0	21.0	19.8	21.2	29.8	32.5
4	13.8	15.8	9.2	27.5	24.2	26.0	19.5	11.2	41.0
5	22.0	15.0	9.2	17.2	21.5	21.2	13.0	23.5	17.5
6	26.5	9.0	11.2	35.8	24.5	27.0	20.2	36.2	25.7
7	14.2	18.0	4.8	17.0	23.0	23.0	16.7	27.5	22.2
8	12.8	7.8	4.5	9.5	6.8	6.8	9.0	33.8	12.5
Average	12.6	11.8	6.9	18.3	16.0	19.8	15.4	24.0	22.1

Ingot Average = 10.4 mils.
Dingot Average = 19.3 mils.

The estimated difference of 9 mils between the average dingot and ingot warp values is highly significant. The position effect is significant for both ingot and dingot fuel elements, where the position effect is stronger for dingot material.

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The tube-to-tube differences are statistically significant for both ingot and dingot material. In essence the average warp values behave very much like the TFC values for the fuel elements irradiated under this test.

3.4 Δ Diameter at Mid-Point

The Δ diameter at the mid-point of a fuel element is equal to the post - minus the pre-irradiation diameter and measures the swelling. The average Δ diameters at mid-point are 5.2 mils for dingot material and 1.4 mils for ingot material and the difference of 4 mils is highly significant statistically.

The position effect is significant for both types of material; the position effect is more pronounced for the dingot material. Higher Δ diameters tends to be found near the central portion of the tube.

AVERAGE Δ DIAMETER AT MID-POINT

TABLE IV

By Position

Position	Ingot	Dingot
1	-1.2	1.1
2	0.3	3.9
3	2.2	3.2
4	2.0	8.0
5	3.2	8.6
6	3.2	8.6
7	2.6	6.7
8	-0.7	1.2
Average	1.4	5.2

TABLE V

By Tube

Tube	Ingot	Tube	Dingot
2158	1.2	2157	5.6
2270	2.0	2167	6.5
2170	1.1	2269	5.4
		2168	4.6
		3763	6.1
		2183	3.0
	1.4		5.2

3.5 Δ Diameter at the Ends

The Δ diameter at the end of a fuel element is equal to the post - minus the pre-irradiated diameter. The data used in the analysis is the average of the Δ diameters at both ends of the fuel element.

The difference between the two fuel element types is small and is not statistically significant.

[redacted]

TABLE VI

By Position

Position	Ingot	Dingot
1	-2.4	-0.7
2	-0.3	+0.7
3	-1.5	-1.2
4	-1.2	-1.4
5	-2.3	-1.4
6	-0.2	-0.5
7	-0.8	+0.2
8	-3.3	-2.0

Average Ingot Value = -1.5
Average Dingot Value = -0.8

TABLE VII

By Tube

Tube	Ingot	Tube	Dingot
2158	-2.5	2157	-1.2
2270	-2.7	2167	-1.3
2170	0.7	2269	0.0
		2168	2.6
		3763	-2.1
		2183	-2.6

3.6 Distribution of Warp Values

As has been mentioned before, the dingot I and E fuel elements show higher average warp values. The distribution of the warp values for the individual fuel elements may be of greater concern however. The following estimates give the percentage of warp values larger than x.

x	Ingot	Dingot
60 mils.	-----	0.9%
50 mils.	-----	2.7%
40 mils.	0.5%	7.5%
30 mils.	2.5%	18%
20 mils.	12%	-----

The following frequency distribution shows how these are distributed for ingot and dingot material.

FREQUENCY DISTRIBUTIONS OF THE WARP VALUES FOR INGOT AND DINGOT I AND E FUEL ELEMENTS

Class Interval	Ingot	Dingot
65-72		I
57-64		II
50-56		II
43-49		III
37-42	III	~~IIII~~ III

[redacted]

FREQUENCY DISTRIBUTIONS....Cont-

Class Interval	Ingot	Dingot
31-36		~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ III
26-30	I	~~IIII~~ ~~IIII~~ ~~IIII~~ II
21-25	~~IIII~~	~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~
17-20	~~IIII~~ IIII	~~IIII~~ ~~IIII~~ ~~IIII~~ IIII
13-16	~~IIII~~ ~~IIII~~ ~~IIII~~	~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ IIII
10-12	~~IIII~~ ~~IIII~~ III	~~IIII~~ ~~IIII~~ ~~IIII~~ II
7-9	~~IIII~~ IIII	~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ II
5-6	~~IIII~~ ~~IIII~~ ~~IIII~~	~~IIII~~ ~~IIII~~ II
3-4	~~IIII~~ ~~IIII~~ ~~IIII~~ III	~~IIII~~ II
2	~~IIII~~	~~IIII~~ IIII
1	I	I
0	III	

4. Discussion

An ingot fuel element, which had the average dimensional stability characteristics found in this test, would warp 10 mils, have a TFC value of 10 mils and have Δ diameters of +1.5 mils and -1.5 mils respectively at the center and ends of the fuel element.

In the same manner an "average" dingot fuel element would warp 19 mils, have a TFC value of 21 mils and have Δ diameters of +5 mils and -1 mil respectively at the center and ends of the fuel element.

The distribution of the individual average warp and TFC values may well be the most important consideration, however, rather than the average. The results of section 3.6 indicate that dingot I and E fuel elements have more warp and TFC values in the higher ranges. The strong position effect for dingot material indicates that these high warp and TFC values tend to be found in the central portion of the tubes.

In all the tables the tubes have been ordered according to exposure. There is no pattern of increasing average warp or TFC values with increasing tube exposure. Similar results are true for the tube powers.

The results in this test are straightforward; there isn't much doubt that dingot I and E fuel elements have the poorer dimensional stability properties. In many tests, however, the results may not be as apparent as this. Using alternate ~~ingot~~ dingot and I and E fuel elements will increase the sensitivity of the test because it will eliminate the tube effect in assessing whether there is a significant difference in the dimensional stability characteristics of different types of fuel elements.

K. B. Stewart

K. B. Stewart
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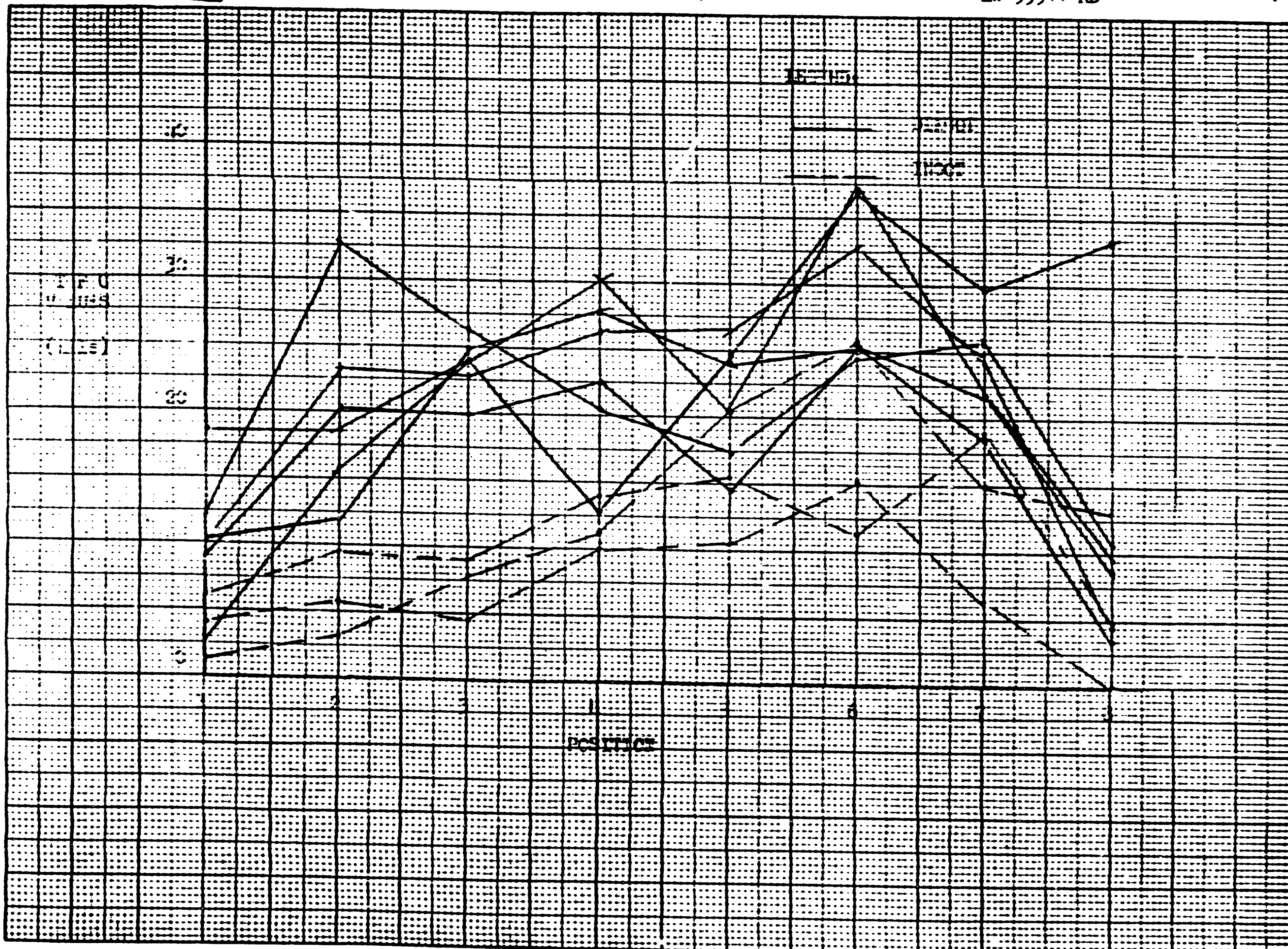

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