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I & E DEPLETED URANIUM FUEL ELEMENT RUPTURES EXPERIENCED UNDER PT-IP-132-AC

AUTHOR

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I & E DEPLETED URANIUM FUEL ELEMENT RUPTURES EXPERIENCED UNDER PT-IP-132-AC

by

W. A. Blanton

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INTRODUCTION

Beginning in February, 1958, a sufficient quantity of seven-inch dip canned I & E depleted uranium fuel elements was prepared for irradiation to produce eleven kilograms of plutonium, containing at least twenty per cent of the Pu-240 isotope, as authorized by the Atomic Energy Commission.[1] Subsequently, eighty-four columns in C reactor were partially charged with the finished depleted fuel under PT-IP-132-AC.[2] To date, ten depleted ruptures have been sustained, after being irradiated six to eight months toward a planned accumulated goal exposure of 210 MWD per column or a total irradiation time approximating 12-14 months. The mechanism and cause of these failures is being thoroughly investigated.

This document summarizes the fabrication history, irradiation experience to date, rupture examinations, and an investigation of process conditions which may have contributed to the high incidence of ruptures.

SUMMARY AND RECOMMENDATIONS

Insofar as can be determined through a review of the fabrication and canning history of the depleted uranium, the processing of this material did not deviate from process specifications for regular I & E production. Inherent problems in the fuel element preparation process, associated with cap wetting and braze porosity, are apparent factors contributing to the high incidence of ruptures during irradiation.

Three of ten depleted ruptures experienced to date are being examined in the Radiometallurgy Laboratory. Thus far, it appears that all three resulted from water entry through the cap closure or in close proximity thereof. Photographs of the rupture sustained in tube 3789 are shown in Figures 1 and 2. Examination of this rupture has progressed far enough to definitely establish that water entry was gained through a small pinhole in the cap weld and followed a channel of non-wet areas or braze porosity around the base of the cap to a point about one inch down the spire. Water-uranium reaction at this point created a mass of corrosion product of sufficient magnitude to crack the uranium and collapse the spire wall. Although metallography is incomplete on the other ruptures being examined, the failure mechanism appears to be the same.

A complete summary of the depleted ruptures is shown in Appendix III. As indicated, two ruptures occurred in ten tubes charged March 10, six in nineteen tubes charged March 17, and one each in eleven tubes charged on March 28 and April 11, 1958, respectively. Because of an apparent rupture proneness of the material charged on these dates, all tubes have been discharged except ten tubes charged March 28. Only 43 of the original 84 charges are being irradiated, plus eight replacement charges. Shipping and charging records (Appendix II) indicate most of the ruptures were from the first half of the production run on lot KP-001-A.

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1 HAN-67197, "Authorization for Production of High Pu-240 Plutonium," dated October 29, 1957, J. E. Travis to W. K. MacCready.

2 HW-54250, "PT-IP-132-AC, Production of High Pu-240 Plutonium at C Reactor," dated February 12, 1958, S. R. Stamp.

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Examination of unirradiated depleted fuel elements remaining in inventory from the virgin and recovered lots has confirmed a cap-wetting problem existed when this material was processed. Non-destructive and destructive tests to which these fuel elements were subjected included bond test, radiography, inspection of weld closures under magnification and with dy-check, autoclave cycling and cap removal. Under the autoclave cycling test 259 depleted and 161 normal I & E fuel elements were etched in caustic to remove 10-15 mils from the jackets prior to autoclave charging to approximate in-reactor corrosion conditions. After 61 cycles, ranging from a few minutes to one hour at operating steam pressure (100 psi) in a water autoclave, there were no failures. At this time the depleted fuel elements were removed for recanning to partially replace rupture prone material discharged from the reactor. Testing of the normal uranium I & E fuel elements was continued through 76 cycles without incident.

Based on available data it is postulated that the added thermal cycling the depleted fuel elements have received, as a result of extended residence time in the reactor, opened up pinholes or porosity in the weld beads which were too small to be detected under inspection and testing standards applied at the time the material was processed. Although the overall data appears inadequate to predict the performance of the remaining 43 tubes of I & E depleted fuel elements being irradiated or to make specific recommendations relative to the possibility of carrying the production test to completion, experience obtained from this test undoubtedly will benefit the quality of I & E fuel element production. Immediate steps have been taken to subject the caps on all I & E spires to a caustic (Aluminux) etch prior and in addition to the specified cleaning process to insure acceptable cap wetting. Preliminary evaluation of this etchant has been favorable. This treatment was given to the spires used recently to recan depleted uranium in inventory for partial replacement of rupture prone material discharged from the reactor. Other planned process changes include the following items, which should further improve the integrity of I & E fuel element cap and base closures:

a. Chloride heat treating of uranium in blank form to minimize braze porosity resulting from hydrogen outgassing during the canning assembly operation.

b. Improved mechanical vibration of can-sleeve assemblies to expel any entrapped gasses.

c. Revise spire preheat and submerge times for optimum cap wetting and minimum erosion losses.

d. Continue development of improved component cleaning processes and the application of ultrasonics.

e. Extend bond test to full length of fuel elements to detect porosity or non-wet areas in the cap and base closures.

f. Angle is being altered on radiograph trays to obtain better resolution of th weld closures.

g. Better visual aids and standards for weld inspection.

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DISCUSSION

I. Fabrication History

a. Uranium Fabrication

The depleted uranium was alpha rolled, beta heat treated in rod form and machined to core dimensions at Fernald in accordance with HAPO specifications.[3] Certified chemical and spectrographic analyses[4] of the depleted ingots showed an impurity range comparable to normal uranium. The U-235 isotopic content ranged from 0.147 to 0.154 per cent.

The cores were machined in accordance with DWG. No. H-3-8512 ("C" size normal uranium cores) except for length, which was reduced to 7.000 ± 0.010" for identification purposes during processing.

A total of 3,000 depleted uranium cores was received at HAPO in February, 1958. Statistical samples of this material indicated the cores met all surface and dimensional specifications. Metallographic analysis of six random core samples has confirmed that the grain size and orientation did nor vary from beta heat-treated normal uranium.

b. Fuel Element Preparation

Beginning February 25, 1958, a total of 2,977 depleted I & E cores (Lot KP-001-A) was dip-canned during three consecutive shifts (8-4, 4-12, and 8-4) on the No. 1 canning line. Thick wall (45 mil) 1245 aluminum alloy components were used to provide maximum residual jacket thickness for prolonged irradiation and corrosion resistance. A comparison of the I & E depleted process rejects in lot KP-001-A with ten I & E normal and enriched lots canned just prior to and following the depleted material is shown in Appendix I. These data do not indicate any significant differences in rejection rates, which might account for the high incidence of depleted ruptures. Process variables of short duration, of course, would not necessarily be revealed by reject data if they had existed. A thorough review of quality control records did not reveal any unusual conditions during the processing of the depleted fuel elements.

Because the depleted material was 7 inches in length, the assembled fuel elements were faced and welded on manually operated equipment to avoid special setups and interference with regular production. The end closures were welded with two full weld passes rather than a single weld pass, which was being adopted at that time.

Out of the original lot (KP-001-A) of depleted material, 1836 pieces were acceptable for irradiation. In addition 340 pieces rejected for internal penetration, following statistical destructive caustic etching to assure internal spire thickness was greater than 20 mils, were reprocessed as lot SP-001-A. All canning rejects were chemically recovered and recanned as lot CP-800-A.

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3 HW-37677, Rev. 2, "Specifications for Uranium Fuel Element Cores," dated September 10, 1957, K. V. Stave.

4 GEH 23786, "Certification of Analyses, FMPC Ingots-Shipping Order No. 6693, Shipping date 2/5/58," dated February 24, 1958, H. W. Weinke, National Lead Company of Ohio.

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A summary of the acceptable depleted I & E fuel elements by lot, including shipping dates and charging dates in C reactor, is shown in Appendix II. Since about half of lot KP-001-A was not finished for shipping until April 24, 1958, it is concluded that most of the ruptures involved pieces canned during the first part of run on this lot.

Major changes made in the processing and testing of I & E fuel elements since the depleted metal was processed are as follows:

1. Single pass welding was extended to all production.

2. Mechanical vibration of spires in Al-Si canning bath was increased from 4 to 11 seconds to improve cap wetting.

3. Cores are submerged deeper in the lead layer of the duplex bath during the preheat cycle, the temperature of the duplex bath has been raised and the silicon content of the Al-Si layer decreased to reduce brittle bonds.

4. Bond test standards have been gradually tightened from a 1 cm. circumferential standard to a long memory count rate standard.

5. A second weld inspection under magnification (~3X) was introduced prior to autoclave testing in July to implement the visual inspection after welding.

IRRADIATION EXPERIENCE

Eighty-four columns in C reactor were partially charged (5 I & E normal, 26 I & E depleted, 5 I & E normal per column) with I & E depleted fuel elements from March 10 through May 6, 1958, as indicated in Appendix II. The charges were loaded into three blocks of tubes on the far side of the reactor to make optimum use of the half rods to control anticipated local reactivity changes caused by the buildup of plutoniu in the depleted metal. Irradiation progressed satisfactorily until the first of ten ruptures was experienced on September 16, 1958.

A summary of the ruptures, including reactor data, is tabulated in Appendix III. It will be noted that two ruptures were sustained in ten tubes charged March 10, six in nineteen tubes charged March 17, and one each in eleven tubes charged on March 28 and April 11, 1958, respectively. Because of the apparent rupture proneness of the material charged on these dates, all but ten tubes charged March 28 have been discharged. Eight charges were replaced with recanned material on November 24, 1958, leaving a total of 51 tubes under irradiation.

During the rupture outage on November 9, 1958, three tubes of rupture prone material charged on March 17 required abnormal discharge pressure. Prior to reactor startup the remaining columns of depleted fuel elements were back seated to assure there was no further evidence of stuck charges. One additional column was discharged because excessive pressure (~3000 psi) was required to move the charge. Examination of the fuel elements from this column in C Basin revealed average and maximum warp of 25 and 70 mils, respectively. Maximum warp observed during measurement of the rupture c[illegible] was 43 mils, which is comparable to the maximum for irradiated normal uranium I & E production.

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Rupture Examination

Originally the first two depleted ruptures (2079C and 3789C) were classified as core splits because their external appearance was typical of cleavage type failures. Both of these ruptures and the fourth (1090C), which did not show any evidence of external splitting, were sent to Radiometallurgy Laboratory for sectioning to determine the rupture mechanism. Upon sectioning it was found that all three ruptures had resulted from water entry into the jacket. Sufficient progress has been made on the examination of the rupture from 3789C to definitely establish water entry was gained through a pinhole in the weld, and was channeled through a chain of non-wet and/or porous braze areas to a point along the spire about 1 inch below the cap. Water-uranium reaction occurred at this point to form a mass of corrosion product, which apparently caused the uranium to crack and collapsed the spire. Photographs of this rupture are shown in Figures 1 and 2. Although metallography is incomplete on the other ruptures, sections show that similar masses of corrosion product were formed along the spire, water channels have been traced along the spire to the cap end, and the failure mechanism appears to be the same as outlined above. Further, details of these examinations will be reported by Radiometallurgy when completed.

Examination of Non-Irradiated Depleted Fuel Elements

Destructive and non-destructive tests were conducted on the depleted I & E fuel elements remaining in inventory to determine if any correlation existed between the observed quality level and the in-reactor performance of this material. A total of 206 canned pieces from the virgin lot (KP-001-A) and 194 canned pieces from the recovered lot (CP-800-A) was available for these tests.

Cap and base welds were initially inspected under magnification (3X). Three defective welds were observed in material inspected from lot KP-001-A and one in lot CP-800-A as indicated below.

Lot No.	No. Pcs. Inspected	Description of Defective Welds
KP-001-A	161	Cap weld with less than 50 mils penetration. Extremely small pinhole in a cap weld. Extremely small pinhole in a base weld.
CP-800-A	194	Incomplete mixing and evidence of Al-Si stringers in a base weld.

Dy-Chek was applied to the welds on fifty pieces from each lot. No evidence of pinholes was observed other than those noted under magnified inspection. Two cap welds showed minor porosity in crater fill region. It is pointed out that weld soundness is largely dependent on the integrity of the underlying braze layer. Pinholes and porosity in welds are in most instances caused by either braze porosity or non-wet areas underneath the weld zone.

All of the available canned material was re-radiographed. No rejects were found in the material from lot KP-001-A. Two marginal rejects for voids in the cap braze layer were noted in material from lot CP-800-A.

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Caps broken off the fuel elements showed significant amounts of cap non-wetting. Following a cap wetting rating system used by Quality Control, the rating on caps removed from 20 canned pieces from each depleted lot was as follows:

Rating of Cap Wetting	KP-001-A (No. of Pieces)	CP-800-A (No. of Pieces)
1. Perfect wetting	0	2
2. Non-wet area on base or radius	4	13
3. Non-wet just past radius	12	5
4. Between 3 and 5	4	0
5. Non-wet path full length along side of cap	0	0
	20	20

Considering the above rating, cap wetting appeared to be significantly better on pieces examined from lot CP-800-A.

In addition to the aforementioned tests, 259 depleted I & E fuel elements (135 from lot KP-001-A and 124 from lot CP-800-A) and 161 normal uranium I & E fuel elements were cycled in a water autoclave at about 100 psi stream pressure and 175 C temperature to determine if failures could be induced by this technique. Ten to 15 mils of aluminum were removed from the surface of these pieces by caustic etching prior to autoclaving to approximate in-reactor corrosion conditions. Autoclave cycles were varied from an initial 14 short cycles to operating pressure, then 10 cycles holding material 15 minutes at pressure, and the remainder for one hour at pressure. The depleted fuel elements were subjected to 64 cycles without failure before it was necessary to recan them to replace rupture prone material discharged from the reactor. Testing of the I & E normal uranium fuel elements was continued through 76 cycles without incident.

Approximately mid-way through the autoclave cycling test two depleted I & E fuel jackets were perforated to the uranium with a 1/16" drill. One had four holes drilled through the cap and the other had 4 columns of three holes each equally spaced around the outer jacket. After 10 one hour cycles in the autoclave at pressure the piece drilled through the outer jacket had a blister around one hole about 1/8" by 1/2" in area. After 16 one hour cycles this piece showed definite blisters or swelling as a result of corrosion products forming in six holes and slight evidence of blisters around three other holes in the jacket. The piece that was perforated through the cap had a blister on the spire wall about 1/2" below the cap after 16 cycles.

From available data it is concluded cap wetting, combined with braze porosity, was the primary factor contributing to the high incidence of depleted ruptures. Insofar as can be determined the cap wetting problem was no worse on the depleted material than occasionally experienced on regular I & E fuel element production. It is postulated that prolonged irradiation and associated thermal cycling may have opened up pinholes in the welds that were too small to be rejected under inspection and testing standards in effect at the time the depleted material was processed. Experience obtained from the irradiation of the depleted fuel elements will undoubtedly benefit the quality of regular production. Immediate steps are being taken to etch the caps on all I & E spires in Aluminux (caustic etchant) prior and in addition to the standard component cleaning process to assure acceptable wetting. Preliminary tests using the etchant have been very favorable.

W. A. Blanton

W. A. Blanton, Engineer
Process Engineering
Engineering Operation
Fuels Preparation Department

WAB:rhm

COMPARISON OF PROCESS REJECTS IN I & E DEPLETED LOT KP-001-A WITH I & E PRODUCTION CANNED PRIOR TO AND FOLLOWING THIS LOT

Lot No.	No. of Pieces	Component Parts Prep.		Pcs. to Canning	Canning Date	Assembly Rejects	Braze Layer Integrity		Braze Layer Contamination	Thin Wall		Facing Rejects	Weld Rejects		Surface		M…
		Trans.	Pickle				Ext.	Int.		Ext.	Int.		Cap	Base	Inclusions	Other	Canning
KG813E	3000	—	4.9	2853	2/19/58	1.8	2.3	1.5	3.4	3.0	4.1	2.9	0.6	2.2	2.6	0.3	0.1
KG815E	1090	—	10.4	976	2/21/58	3.0	1.8	0.2	3.8	1.1	3.9	2.6	0.4	1.2	1.0	0.8	0.1
KG057E	458	—	2.8	445	2/21/58	2.0	1.8	0.7	2.7	0.4	1.1	0.4	—	1.6	—	0.4	0.4
KG816E	754	—	4.0	724	2/21/58	1.2	—	0.3	4.8	11.6	11.5	—	1.7	3.0	0.3	—	—
KG061E	458	—	—	458	2/21/58	2.0	3.5	0.6	2.4	1.5	10.2	—	1.3	11.4	33.6	1.3	—
KG817E	658	—	5.8	620	2/21/58	1.8	1.9	0.3	3.5	3.5	12.3	—	3.2	4.0	0.3	—	—
KG818E	568	—	2.5	554	2/21/58	1.4	3.6	12.1	2.2	6.0	—	—	1.8	14.6	—	0.2	—
CJ025E	1368	5.7	0.7	1280	2/21/58	3.9	2.6	1.6	1.8	0.4	14.0	0.8	0.5	3.8	0.2	0.5	0.2
CJ803A	7590	1.1	6.2	7035	2/24/58	5.5	0.2	0.1	2.1	1.7	11.1	0.6	2.5	1.6	2.4	3.9	—
KJ076A	5848	2.5	0.1	5692	2/25/58	4.7	0.9	3.0	4.5	2.6	11.5	1.3	1.3	2.8	2.1	0.2	—
*KP001A	2977	0.9	0.1	2946	2/25/58	5.4	0.9	0.2	1.7	1.8	11.5	1.7	1.7	—	6.5	1.1	0.2
CJ015A	1138	9.8	0.1	1025	2/28/58	2.2	0.6	3.7	1.5	0.8	7.0	0.5	0.7	1.5	0.9	—	0.1
CJ805A	2924	2.2	5.6	2696	2/28/58	1.8	1.2	1.0	0.4	2.6	8.6	0.4	0.4	—	1.4	—	—
KK003B	3427	0.4	0.3	3403	2/28/58	6.3	0.8	4.3	—	2.4	30.6	1.8	—	—	0.3	—	0.1
KK007B	3657	1.9	0.5	3570	3/3/58	5.0	0.9	0.4	—	1.8	37.3	0.7	0.4	—	0.2	0.2	—
CK008B	1598	3.7	1.4	1515	3/4/58	6.1	1.3	1.3	—	1.4	19.1	1.2	1.2	—	0.3	0.6	0.1
AK009B	1368	0.7	0.5	1351	3/4/58	6.2	2.2	3.0	—	6.6	16.4	6.2	0.1	—	0.3	0.2	—
AK010B	2737	1.8	0.1	2687	3/4/58	2.9	3.6	0.9	—	0.2	8.7	0.7	—	—	0.3	0.1	0.1
AK001B	1368	3.3	—	1323	3/5/58	2.5	3.2	—	3.0	2.6	20.6	1.1	0.2	0.5	0.2	—	—
CK013B	7252	14.1	0.5	6191	3/5/58	2.1	3.9	2.6	—	2.7	10.2	0.5	—	0.6	0.1	0.1	—
KK005B	5256	5.3	0.3	4957	3/6/58	1.7	1.5	1.2	—	1.1	10.2	1.6	—	—	0.2	—	—

*Depleted Lot

APPENDIX I

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COMPARISON OF PROCESS REJECTS IN I & E DEPLETED LOT KP-001-A WITH I & E PRODUCTION CANNED PRIOR TO AND FOLLOWING THIS LOT

nt ep. ckle	Pcs. to Canning	Canning Date	Assembly Rejects	Braze Layer Integrity Ext.	Braze Layer Integrity Int.	Braze Layer Contamination	Thin Wall Ext.	Thin Wall Int.	Facing Rejects	Weld Rejects Cap	Weld Rejects Base	Surface Inclusions	Surface Other	Marred Surface Canning	Marred Surface Finishing	Marred Surface Final
.9	2853	2/19/58	1.8	2.3	1.5	3.4	3.0	4.1	2.9	0.6	2.2	2.6	0.3	0.1	2.5	—
.4	976	2/21/58	3.0	1.8	0.2	3.8	1.1	3.9	2.6	0.4	1.2	1.0	0.8	0.1	4.0	0.2
.8	445	2/21/58	2.0	1.8	0.7	2.7	0.4	1.1	0.4	—	1.6	—	0.4	0.4	4.0	—
.0	724	2/21/58	1.2	—	0.3	4.8	11.6	11.5	—	1.7	3.0	0.3	—	—	3.0	0.3
[illegible]	458	2/21/58	2.0	3.5	0.6	2.4	1.5	10.2	—	1.3	11.4	33.6	1.3	—	4.4	—
[illegible]	620	2/21/58	1.8	1.9	0.3	3.5	3.5	12.3	—	3.2	4.0	0.3	—	—	2.7	0.2
[illegible]	554	2/21/58	1.4	3.6	12.1	2.2	6.0	—	—	1.8	14.6	—	0.2	—	2.2	0.2
[illegible]	1280	2/21/58	3.9	2.6	1.6	1.8	0.4	14.0	0.8	0.5	3.8	0.2	0.5	0.2	3.4	0.3
.2	7035	2/24/58	5.5	0.2	0.1	2.1	1.7	11.1	0.6	2.5	1.6	2.4	3.9	—	3.3	0.1
[illegible]	5692	2/25/58	4.7	0.9	3.0	4.5	2.6	11.5	1.3	1.3	2.8	2.1	0.2	—	2.6	0.1
[illegible]	2946	2/25/58	5.4	0.9	0.2	1.7	1.8	11.5	1.7	1.7	—	6.5	1.1	0.2	4.3	0.2
.1	1025	2/28/58	2.2	0.6	3.7	1.5	0.8	7.0	0.5	0.7	1.5	0.9	—	0.1	2.5	0.1
.6	2696	2/28/58	1.8	1.2	1.0	0.4	2.6	8.6	0.4	0.4	—	1.4	—	—	3.6	0.1
.3	3403	2/28/58	6.3	0.8	4.3	—	2.4	30.6	1.8	—	—	0.3	—	0.1	2.7	—
.5	3570	3/3/58	5.0	0.9	0.4	—	1.8	37.3	0.7	0.4	—	0.2	0.2	—	1.0	0.1
.4	1515	3/4/58	6.1	1.3	1.3	—	1.4	19.1	1.2	1.2	—	0.3	0.6	0.1	2.6	—
.5	1351	3/4/58	6.2	2.2	3.0	—	6.6	16.4	6.2	0.1	—	0.3	0.2	—	2.2	—
.1	2687	3/4/58	2.9	3.6	0.9	—	0.2	8.7	0.7	—	—	0.3	0.1	0.1	2.0	0.1
—	1323	3/5/58	2.5	3.2	—	3.0	2.6	20.6	1.1	0.2	0.5	0.2	—	—	1.4	—
.5	6191	3/5/58	2.1	3.9	2.6	—	2.7	10.2	0.5	—	0.6	0.1	0.1	—	1.6	—
.3	4957	3/6/58	1.7	1.5	1.2	—	1.1	10.2	1.6	—	—	0.2	—	—	1.7	0.1

APPENDIX I

[redacted]

DECLASSIFIED

HW-58281

SUMMARY OF DEPLETED I & E LOTS INCLUDING SHIPPING AND CHARGING DATES

Lot Number	Date Canned	Acceptable Pcs.	Date Shipped	No. of Pcs.	C Reactor Charging		
					Date	No. of Pcs.	No. of Tubes
KP-001-A	2/25/58	1836	3/6/58	224			
			3/7/58	788			
					3/10/58	260	10
					3/17/58	494	19
			3/24/58	824*			
					3/28/58	286	11
**SP-001-A	2/25/58	197	4/8/58	197			
					4/11/58	286	11
					5/1/58	182	7
***CP-800-A		562	5/6/58	357****			
					5/10/58	156	6
					5/23/58	520	20

*206 Pieces returned to 300 Area on November 5, 1958.
**Reprocess Lot
***Recovered Process Rejects
****Balance (200 pcs.) held in storage

APPENDIX II

DECLASSIFIED

[redacted]

SUMMARY OF DEPLETED I & E RUPTURES

Tube No.	Date Failed	Date Charged	Exposure MWD/T	Tube Power *KW	Outlet Temp. (°C)	Position in Tube (From rear)	Lot Number	Class
2079-C	9/16/58	3/17/58	567	605	68	11	KP-001-A	Inte[illegible]
3789-C	10/5/58	3/10/58	666	723	73	16	KP-001-A	Inte[illegible]
0984-C	10/11/58	3/17/58	743	692	72	9	KP-001-A	In[illegible]
1090-C	10/21/58	3/17/58	673	623	66	12	KP-001-A	In[illegible]
2777-C	10/31/58	3/17/58	733	721	73	13	KP-001-A	Inte[illegible]
0988-C	11/3/58	3/17/58	778	659	67	—	KP-001-A	Intern
1490-C	11/9/58	3/17/58	762	656	70	20	KP-001-A	Unclas
3590-C	11/17/58	3/10/58	826	655	68	17	KP-001-A	Unc[illegible]
2579-C	11/24/58	4/11/58	682	638	—	—	KP-001-A	[illegible]
1176-C	11/30/58	3/28/58	748	779	—	—	KP-001-A	Unc[illegible]

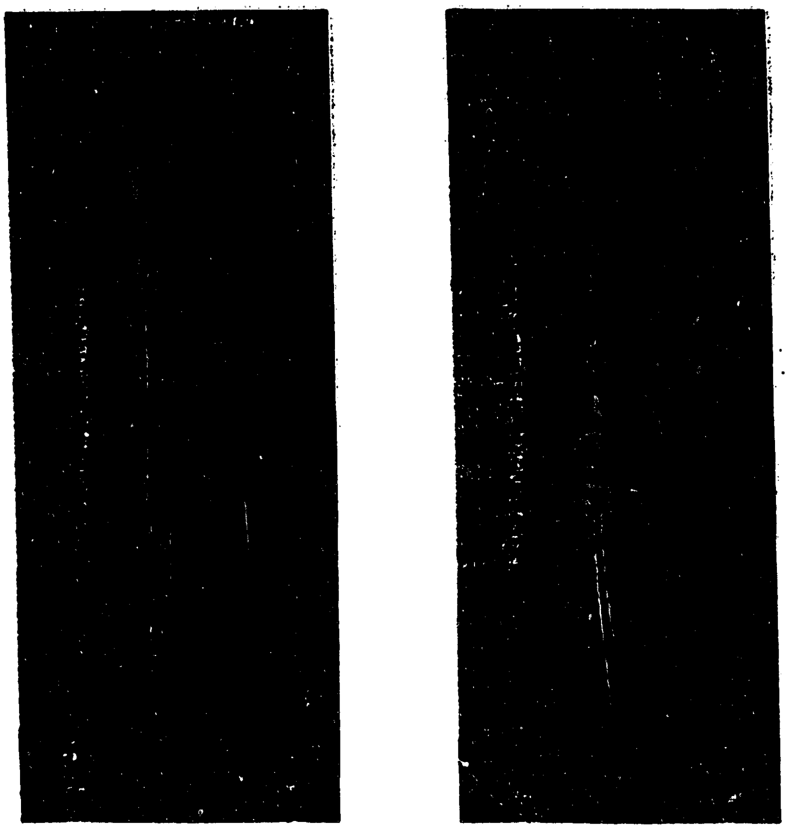
*Tube power at failure.

APPENDIX III

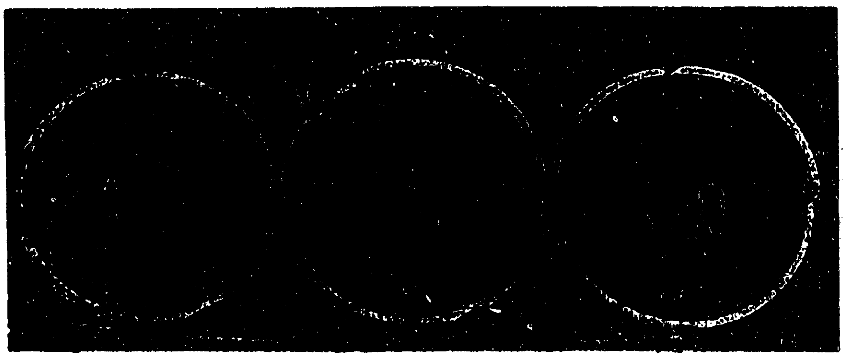
[redacted]

04/20/1994

I & E Depleted Rupture - 3789C

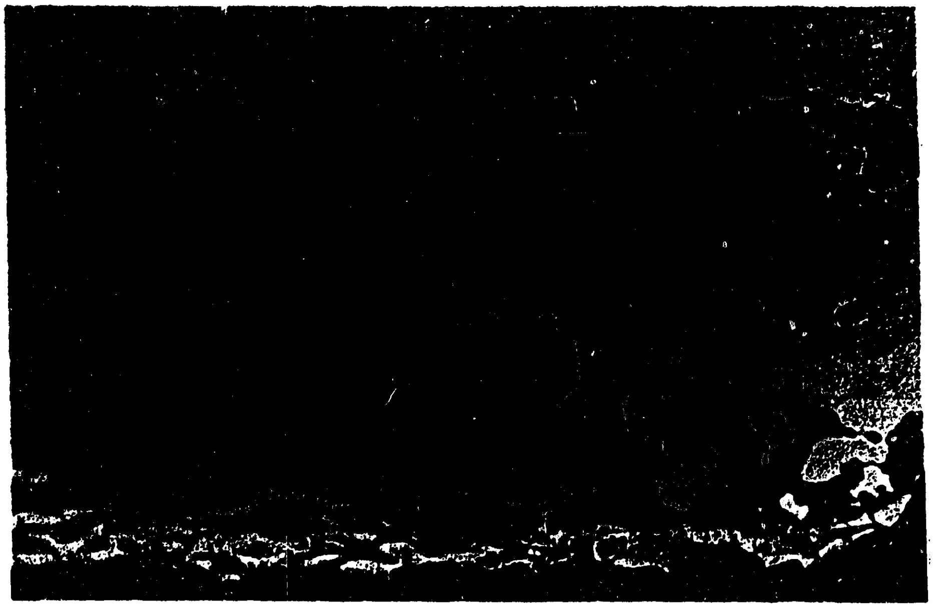


Photographs of Rupture as Received
by Radiometallurgy



Transverse Section about One-Inch Below Cap Showing
Mass of Corrosion Product Resulting from Water-Uranium Reaction

FIGURE 1



Section of Spire below Cap Base Showing Porous Channels in AlSi Braze Layer

View of Cap Base Showing Water Path Connecting with Porous Area in Cap-Can Braze Layer

Enlarged View of Porous Braze Area Under Cap

FIGURE 2

DATE
FILMED
7/8/94

END

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