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FABRICATION AND PREIRRADIATION DATA FOR HIGH FLUX ISOTOPE REACTOR PROTOTYPE TARGET RODS

J. D. Sease
D. M. Hewette II

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J. D. Sease and D. M. Hewette II

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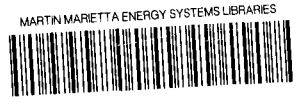

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ABSTRACT

To assist in an evaluation of the adequacy of the High Flux Isotope Reactor target element design, four prototype irradiation samples are being irradiated in the Engineering Test Reactor. The 3/8-in.-diam aluminum-clad elements, which are slightly shorter than the proposed HFIR target elements, are 24 1/2 in. long and contain 14 1/4 in. of fueled length, which is composed of aluminum-jacketed $Pu^{239}O_2$-Al dispersion pellets (approximately 14 vol % PuO_2). The fabrication of the four irradiation prototype elements along with two control elements consisted of (1) pressing of aluminum-jacketed PuO_2-Al dispersion pellets, (2) loading of pellets into fuel rod, (3) welding of end cap, (4) hydrostatic collapse of clad onto pellets, and (5) attachment of spacing can to finned clad tubing. A description of the fabrication procedures and complete preirradiation data and photographs are presented.

INTRODUCTION

An irradiation experiment is now under way at the Engineering Test Reactor to evaluate the irradiation behavior of the proposed High Flux Isotope Reactor target element. Although the operating conditions in the ETR will not be as severe as those in the HFIR, answers to the more controversial features of the target element design should be gained. Some specific questions that are to be answered include (1) adequacy of heat transfer across the pellet-to-cladding gap, (2) effect of cyclic thermal strains across the fins, (3) the transmutations of X-8001 aluminum to silicon, (4) pressure buildup from gaseous fission products, and (5) swelling from solid fission products.

The irradiation prototype target elements differ from the actual HFIR target elements in length and amount of fissionable loading. The prototype is 24.5 in. long containing an active fuel length of 14.272 in., while the reference HFIR target element is 35 in. long and contains a fuel column 20 in. long. The active fuel length is made up of dispersion pellets composed of PuO_2-Al (about 14 vol % PuO_2) fabricated by powder metallurgy

techniques. In the prototype target rods, Pu^{239} was substituted for Pu^{242} and the other actinide elements to simulate the fissioning that will occur in the actual target.[1]

For the irradiation experiment, six prototype elements (five containing 90% theoretically dense pellets, one containing 97% theoretically dense pellets) were fabricated. Four of these elements (three containing 90% theoretically dense pellets, one containing 97% theoretically dense pellets) are currently being fabricated; two elements are being retained as controls for the experiment. The fabrication of these prototype elements provided an excellent demonstration of the proposed HFIR target fabrication procedure and equipment, which is entirely a glove-box operation. This report describes the fabrication of the prototype elements and presents pertinent preirradiation data.

TARGET ROD DESIGN

The configuration of the prototype irradiation target element is shown in Fig. 1. A detailed engineering drawing of this element is included in Appendix A. As indicated, the aluminum-clad fuel rod contains a 14.275-in. fueled column composed of 25 aluminum-jacketed PuO_2-Al dispersion pellets, having nominal dimensions of 0.249-in. OD × 0.571 in. long. The pellet jacket consists of an open-end aluminum tube having a nominal thickness of 0.027 in. with 0.050-in.-thick compacted powder caps on each end. Five of the rods for the irradiation experiment contained pellets having a theoretical density of 90%; the sixth rod contained pellets having a theoretical density of 97%. The reference HFIR target pellet density is 90% of theoretical.

The plenums on each end of the fuel column, provided for the collection of fission gases, are lined with age-hardened 7075-T6 aluminum alloy sleeves to support the fuel tube during the collapse step. The fins on the tube provide centering spacers to which the hex can is attached. End closures were made by fusion welding a step-type end plug onto the fuel tube.

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[1] Chem. Tech. Div. Ann. Prog. Rep. May 31, 1963, ORNL-3452, p 133.

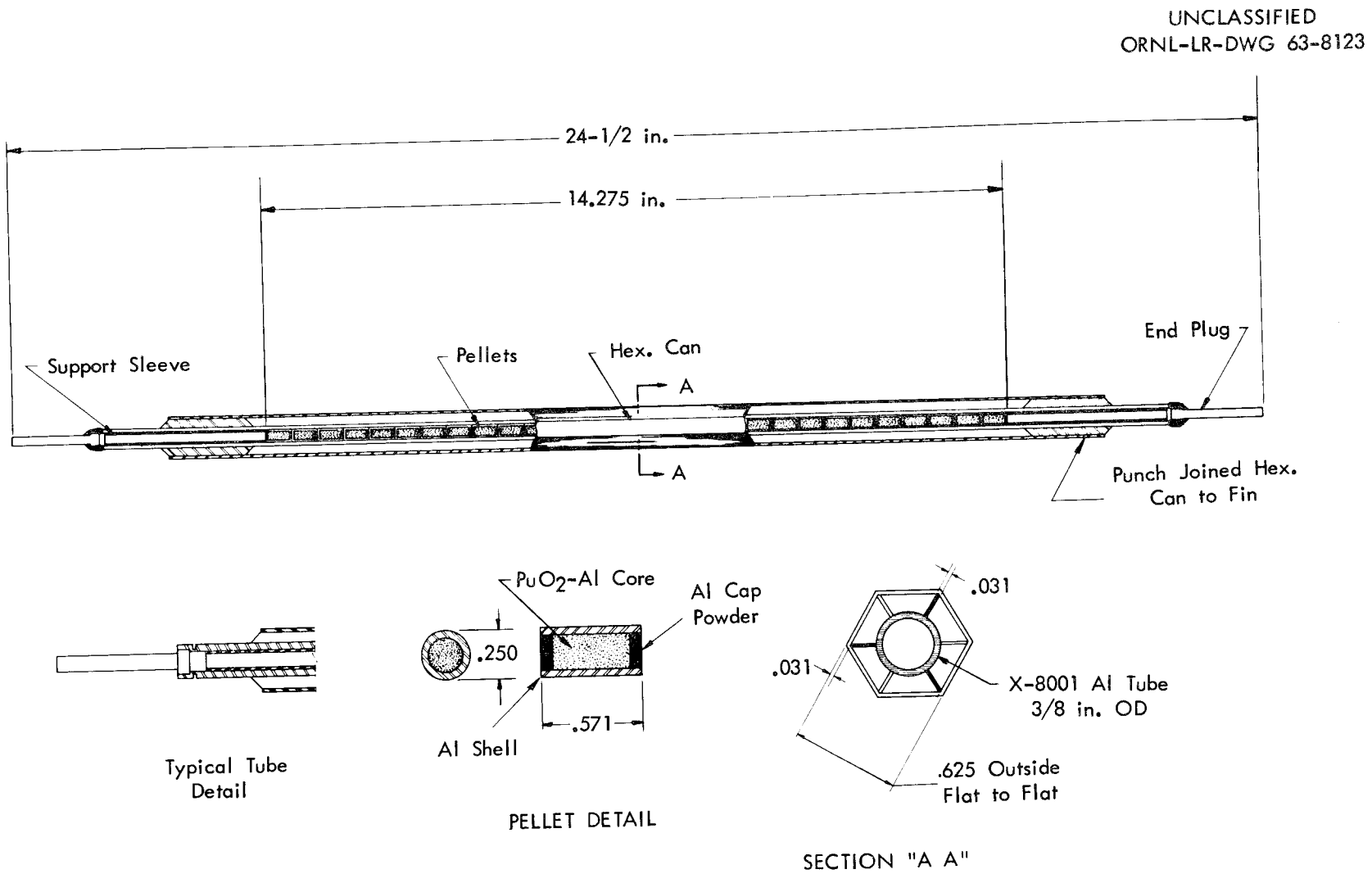


Fig. 1. Configuration of HFIR Target Radiation Prototype.

FABRICATION PROCEDURE

The procedure (Fig. 2) employed to fabricate the plutonium target irradiation prototype elements includes (1) pressing of the aluminum-jacketed PuO_2-Al dispersion pellets, (2) loading of the pellets into the fuel rod, (3) welding of the end caps, (4) hydrostatic collapse, and (5) attachment of hex can. Details of each of the fabrication steps follow.

Pellet Fabrication

Materials

The coarse, high-density PuO_2 particles were prepared in accordance with the procedures outlined in Appendix B. The particle-size distribution of the PuO_2 used for the target rods is shown in Table 1.

Table 1. Plutonium Oxide Screen Analysis

Screen Size (mesh)		Size (μ)	Weight Percent
−70	+140	210–105	48.1
−140	+170	105–88	15.8
−170	+200	88–73	9.7
−200	+325	73–44	26.4

The aluminum powder used in the core of the pellet was type 1100 semi-spheroidal (Alcoa grade 101) having a particle size of −100 mesh. The end-cap powder (also Alcoa grade 101) had a particle size of −270 +325 mesh.

The pellet jacket was prepared from type 1100 aluminum tube stock which had been vacuum annealed at 500°C for 1 hr.

Weighing and Blending

Aluminum and PuO_2 powders were weighed in batch quantities to produce 28 pellets of the desired density, thus allowing three reject or control pellets per batch. The quantities of powder weighed for each batch and each pellet are indicated in Table 2. All weights were performed on a

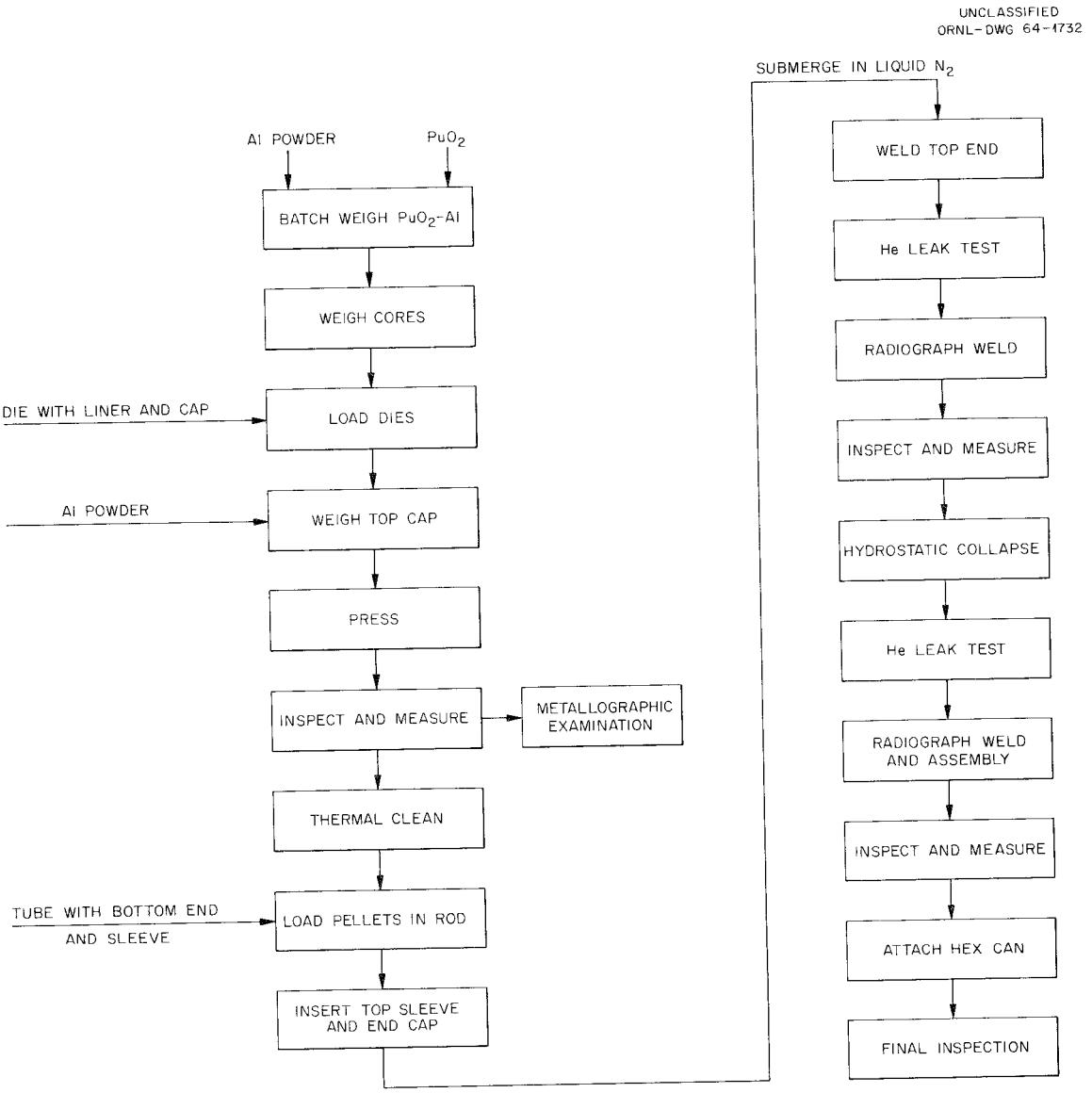


Fig. 2. Flow Diagram for Fabricating Plutonium Target Prototype Elements.

torsion balance to an accuracy of 0.005 g. The core powders were blended in a 2-oz oblique blender for 2 hr.

Table 2. Pellet Batch Compositions[a]

Batch Number	PuO_2 in Core/Batch (g)	Aluminum in Core/Batch (g)	Aluminum End Cap Two/Pellet (g)	Al-PuO_2 Core/Pellet (g)
1–5	10.58	13.27	0.060	0.852
6	10.58	17.94	0.060	1.019

[a]Calculated to make 28 pellets/batch.

Following batch blending, the quantity of the core material for one pellet was loaded into a preassembled die containing the bottom punch, the bottom cap powder which had to be slightly prepressed, and the pellet tube liner. The dimensions of the pellet liner used were 0.250-in.-OD × 0.220-in.-ID × 1.0 in. long. The top cap powder was then added and the pellet pressed. During fabrication, all 28 pellets from one batch were weighed and pressed before weighing any of the pellets in the next batch to prevent mixing pellets of different batches.

Pressing

The pellets were pressed on a hydraulic-actuated 5-ton press at a constant pressure. An electrically driven hydraulic pump, which allowed continuous and rapid application of pressure during pressing, was used. A die lubricant composed of stearic acid and CCl_4 was applied to the die before assembly to reduce die friction during pressing. The pressing pressures were 20 tsi for the 90% theoretically dense pellets and 41 tsi for the 97% theoretically dense pellets. The 25 pellets to be used in the fuel rods were selected from the 28 pellets produced. The pellet-rejection criterion was based on both surface quality and density. Rejected pellets were used as controls and as metallographic samples.

Cleaning

After pressing, the pellets were cleaned in CCl_4 to remove die lubricant. The pellets were then heated in a vacuum (0.010 torr) to

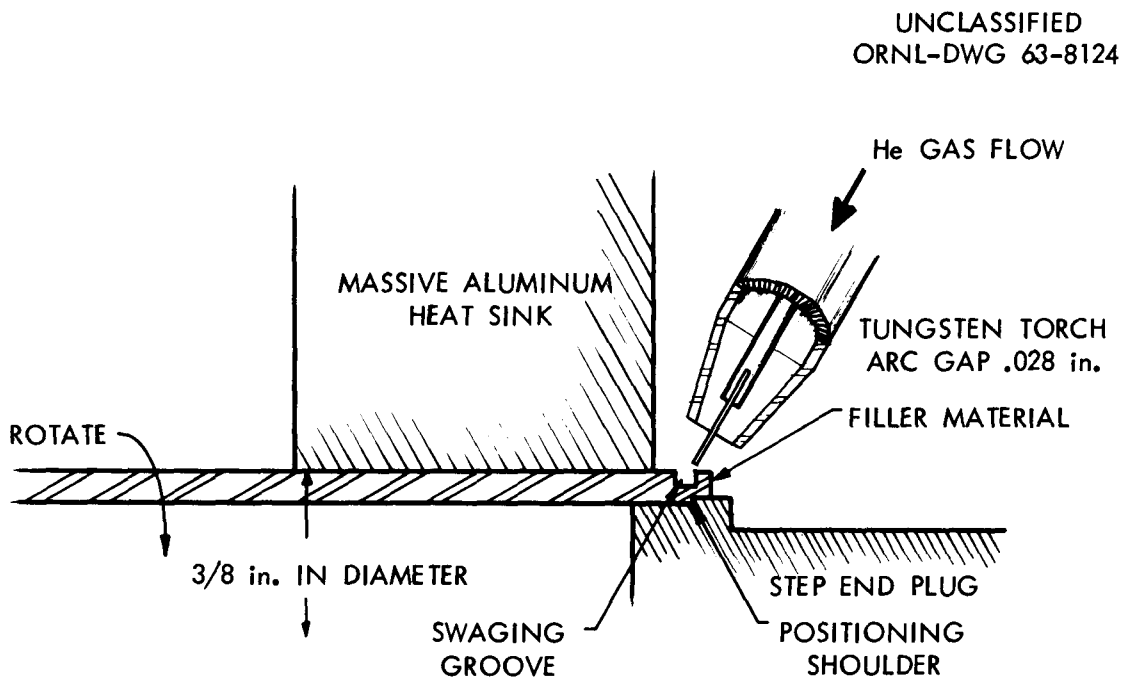
600°C and held at this temperature for 3 hr to eliminate any complex chloride which may have been formed during cleaning.

Fuel Rod Loading

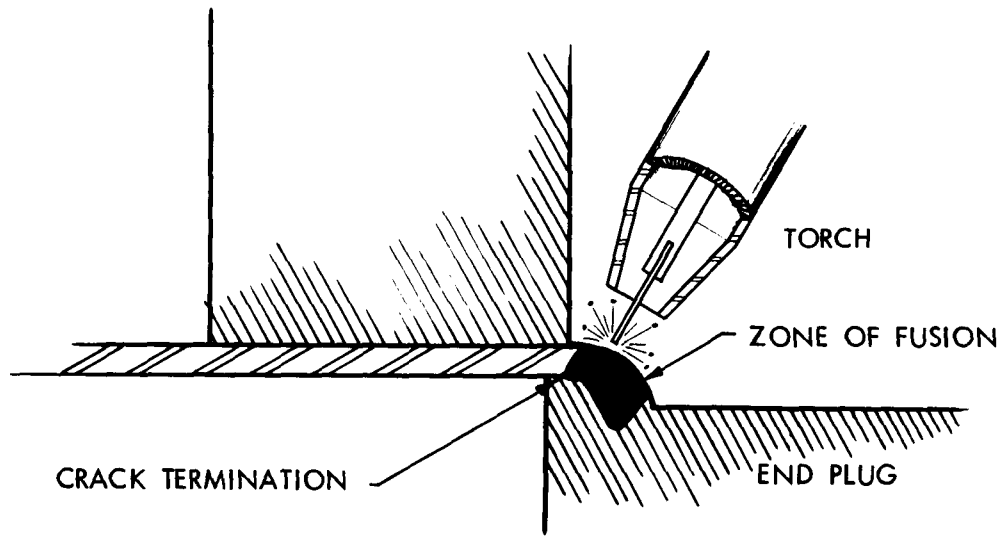
Twenty-five pellets per fuel rod were loaded one at a time into prefabricated tubes. The prefabricated tubes contained one welded and fully inspected end closure (see next section) and the bottom support sleeve. To minimize the contamination of the outside surfaces of the fuel rod during loading, only the open end of the prefabricated rod was exposed to a contaminated atmosphere. To accomplish this task of exposing only the open end to the contaminated atmosphere, 1/4 of the fuel rod adjacent to the open end was covered with aluminum foil and sealed to the rod; the portion of the fuel rod covered with foil was then sealed inside a plastic bag, leaving the majority of the fuel rod outside the bag. The sealed bag containing the unloaded tube was then placed on the bag ring of the loading glove box and the pellets were placed in the rod. After loading, the pellets were seated with a ramrod before measuring the length of top support liner required. The top support liner was then cut to length and placed into the tube before heat sealing the plastic bag from the loading glove box. The loaded fuel rods were then transferred to the welding glove box. There, the aluminum foil and the plastic bag were removed, the weld area cleaned preparatory to welding, the tube flushed and backfilled with helium, and the top-end plug inserted.

End-Cap Welding

The closure welding procedure that was developed for the target rods involves fusion of a step-type end cap onto the 3/8-in.-diam aluminum tube by the tungsten-arc inert-gas process. The step-type end-weld design and weld setup used are shown in Fig. 3. Before welding, the end plug and mating parts were thoroughly degreased with acetone and wire brushed. Then, the end plug was inserted into the tube and a mechanical joint was made between the end plug and tube by deforming the tube in the swaging groove. A massive aluminum heat-sink which was clamped directly on the tube during welding was used to extract heat away from the weld zone. The



(a) CROSS SECTION BEFORE WELDING



(b) CROSS SECTION AFTER WELDING

Fig. 3. Weld Design and Setup for Welding Step-Type End Cap.

unique feature of this weld design is the use of the machined lip as weld filler material. The welding cycle was programmed as shown in Fig. 4 in order to obtain reproducible welds. A Miller Model ESR-150 constant current type power supply was used.

Following welding, the rods were cleaned with acetone and checked for transferable contamination. The fuel tubes were then removed from the welding glove box, monitored for radiation, and checked for leaktightness. In leak checking, the entire rod was placed in the vacuum chamber connected to a helium mass spectrometer leak detector having a calibrated sensitivity of 5×10^{-10} std cm^3/sec. Any detectable leak in the chamber was grounds for rejection. After leak testing, the weld areas were radiographed using soft x-ray techniques. Following these steps, post-collapse data and photographs were taken.

Collapse

Collapse of the cladding onto the fuel pellets was done at a hydrostatic pressure of 20,000 psi held for 5 min. With this procedure, a 0.0005-in. radial gap can be expected. After collapsing, the welds were leak tested, the weld areas (as well as the entire rod assemblies) radiographed, and dimensional data and photographs taken.

Hex-Can Attachment

The hex can was attached to the fuel tube by deforming the can into the fins thus effecting a mechanical joint. To preclude excessive warping of the hex can during the deforming operation, the hex can was supported in a "V" block and clamped with a "C" clamp. The indentation in the can was produced by a chisel point driven by a spring-loaded punch. Attachment was made on each fin with three indentations on each end fin and one indentation on each of the middle fins. Following hex-can attachment, the hex can-to-tube spacing was measured with a "Dermatron" eddy-current probe.[2]

[2]C. V. Dodd, Design and Construction of Eddy-Current Coolant-Channel Spacing Probes, ORNL-3580 (April 1964).

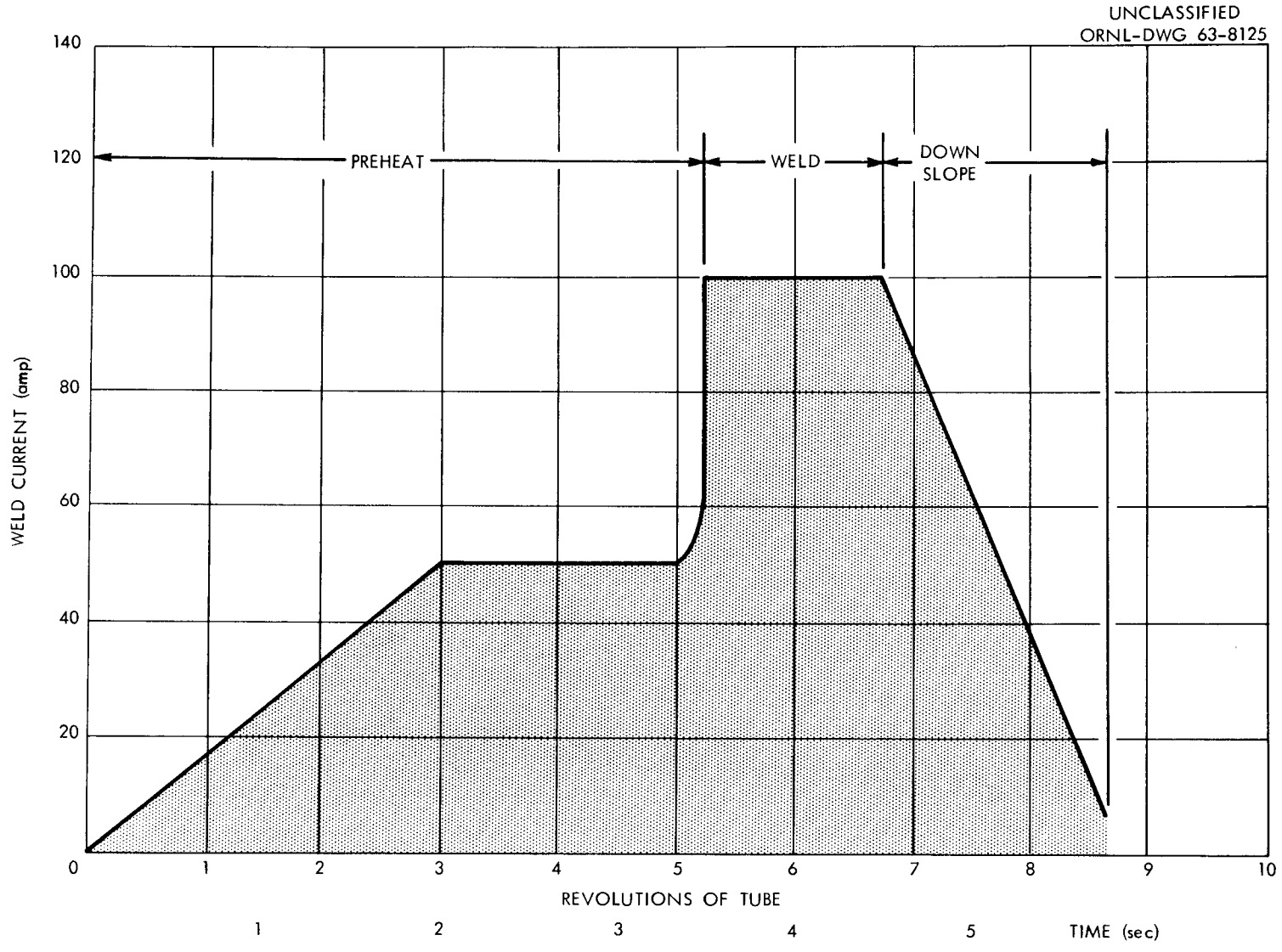


Fig. 4. Typical Weld Cycle.

FABRICATION RESULTS AND DATA

Pellets

A summary of the pellet fabrication pressing results is shown in Table 3. In the pressing of batch No. 1, it was necessary to perform press adjustments to achieve the desired density; therefore, the density spread for this batch is slightly greater than the other batches pressed to this density. In the other batches, the spread in percent of theoretical density is slightly greated than the specified ± 3% variation. The density of each pellet was calculated using as a basis the nominal PuO_2 loading; however, the validity of this assumption is doubtful since inhomogeneous mixtures can cause variations in loading as high as 10 wt %. Accordingly, it follows that the variation in pellet density was caused by variation in the nominal PuO_2 loading and is not a void volume density variation. This fact was confirmed by metallographic examination of a rejected pellet from the 97% dense pellet batch. The pellet which had a calculated density of only 88% exhibited little aluminum-associated void volume.

Table 3. Pellet Pressed Densities

Batch No.	Pressing Pressure (tsi)	Average Percent Theoretical Density for 25 Pellets	Spread in Percent Theoretical Density
1	16.3–20.6	89.85	84.40–92.45
2	20	90.89	87.8 –94.73
3	20	90.1	86.8 –92.6
4	20	89.92	87.88–93.32
5	20	90.23	86.96–92.84
6	41	96.67	93.36–101.14

Further metallographic examinations were performed (1) to determine if the aluminum was the continuous phase, (2) to characterize the physical shape of the PuO_2 particles, and (3) to quantitatively evaluate oxide concentration from pellet to pellet. These investigations were performed using reject pellets from batches 1, 2, 4, 5, and 6.

The microstructure of all the pellets examined showed that the aluminum was the continuous phase. The PuO_2 was found to exist, for the most part, as large angular particles with little porosity. A small quantity of the PuO_2 was present as low-density particles having a spongy appearance.

Oxide concentration was evaluated by areal analysis of microphotographs from two selected pellets. The two reject pellets that were analyzed were selected to represent maximum oxide variations based on density and probably to represent extreme cases. The results of the areal analysis taken at two planes approximately 1/8 in. from each end of each pellet are shown in Table 4. A variation in oxide content of +4 to −3 vol % from the ideal composition of 14 vol % is seen. Although little variation in the average PuO_2 concentration was observed from end-to-end of the pellet evaluated, considerable composition variations were found between fields of view in the plane of polishing.

Table 4. Results of Oxide Concentration Determinations by Areal Analyses

Pellet	Field[a] (68×)[b]	PuO_2 (vol %) End 1	PuO_2 (vol %) End 2	Pellet	Field[a] (68×)[b]	PuO_2 (vol %) End 1	PuO_2 (vol %) End 2
High density (pellet 5–4)[c]	1	21	19	Low density (pellet 6–28)[d]	1	10	14
	2	20	21		2	13	10
	3	10	18		3	14	15
	4	27	19		4	8	13
	5	18	17		5	9	13
	6	15	14		6	12	9
	7	16	17		7	7	13
	Average	18	18		Average	10	12
	Pellet average	18			Pellet average	11	

[a]The number of separate fields of view in one plane of the pellet was seven.

[b]Specified magnification when analyzing for −70 +325 mesh particles.

[c]The fourth pellet made from the fifth pellet batch.

[d]The 28th pellet made from the sixth pellet batch.

End Closures

The integrity of the welds was evaluated by helium-leak testing and radiography of the weld area (minimum of three planes). In welding the first closures in the starting group of 20 tubes, all welds were leaktight; however, five were unacceptable from radiography. Radiographs of the six closure welds used on the prototype irradiation samples are shown in Fig. 5a. These welds do not represent the best of the group of 20 because of the trouble experienced in the closure welding.

In the first attempt on closure welds, all welds were leaktight; however, only two acceptable and one conditional joints were obtained from 12 welding attempts as determined by the radiographic inspection. Radiographs of the reject welds were typified by large void areas at the root of the weld, apparently caused by a pressure buildup of entrapped gas inside the tube. With the swaged-end-plug-weld design, it was possible to negate this pressure buildup within the tube during welding by chilling the tube subsequent to the insertion of the end plug. The chilling, which was effected by submerging one-half of the tube in a bath of liquid nitrogen, produced excellent quality welds. Radiographs of the closure welds are shown in Fig. 5b. The three closure welds on the right were produced by the chilling technique and are definitely superior to the other three closure welds as well as the majority of the first closures. The idea of reducing the pressure inside the tube subsequent to welding may increase the reliability of the first closures as well as the final closure welds.

Contamination

No difficulties were encountered in making target elements free of transferable contamination. As a precaution, the tubes were wiped with a wetted acetone cloth, and there was no incident of a contaminated element.

Assembled Elements

Photographs of the assembled elements before and after attachment of the hex can are shown in Fig. 6. Only five rods are shown in the figure because one control specimen was retained in the uncollapsed state. A

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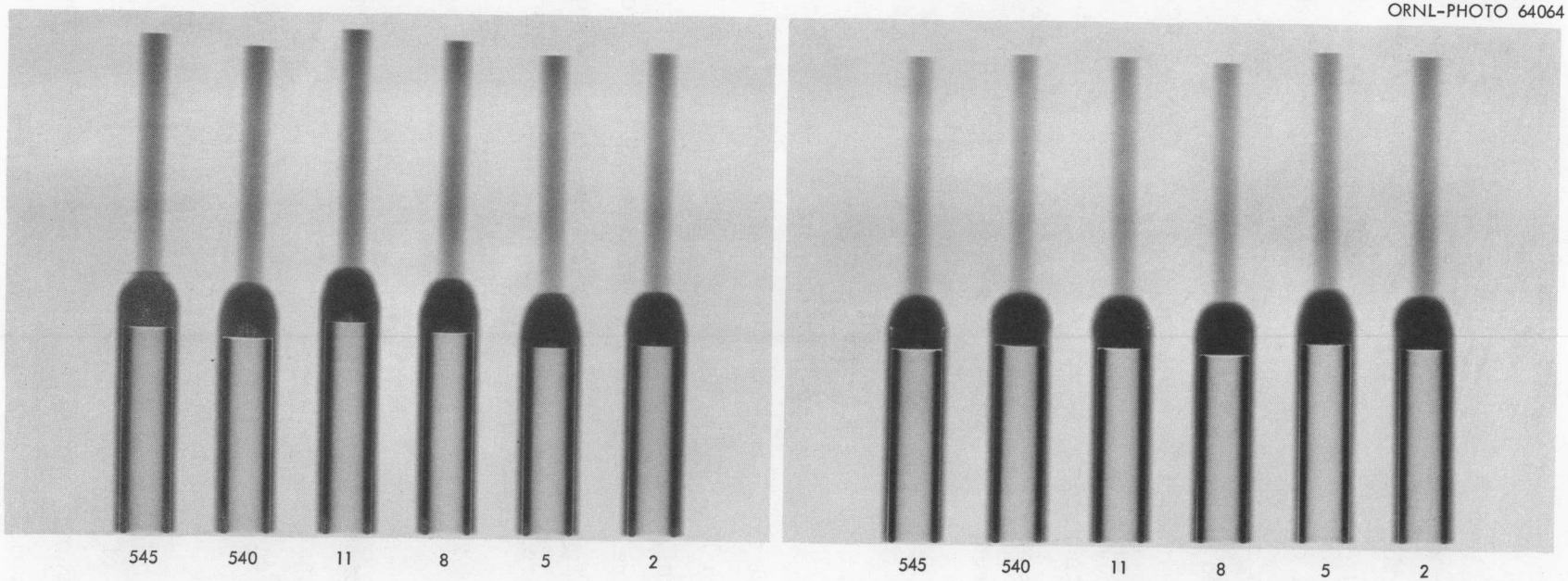

(a) First Closure End Welds

(b) Final Closure End Welds

Fig. 5. Radiographs of Target Welds.

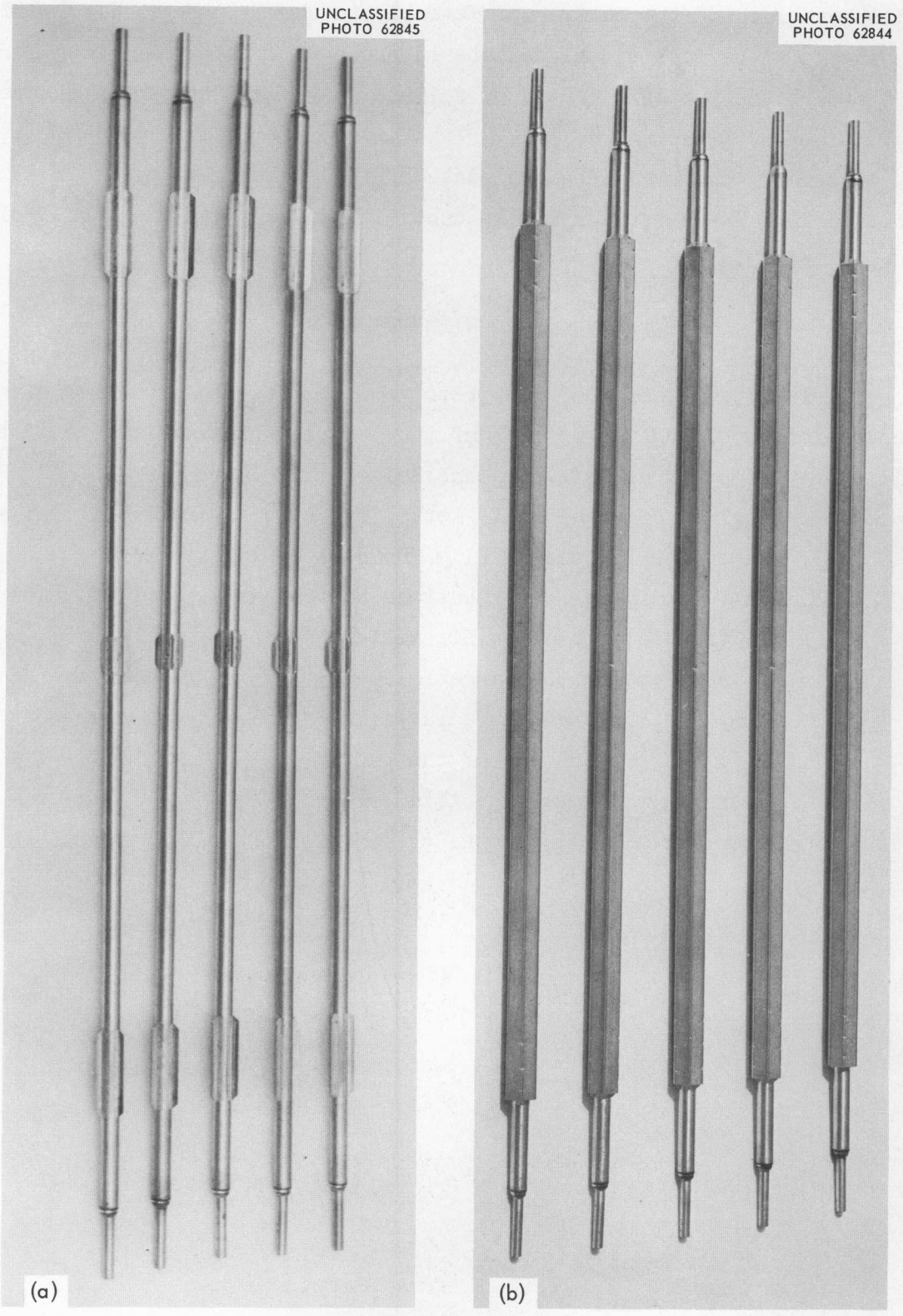

Fig. 6. Fabricated Fuel Assembly (a) Before and (b) After Hex-Can Attachment.

radiophotograph of the entire rod assembly is shown in Figs. 7, 8, and 9. The shape of the core of the pellets is shown to be somewhat irregular. This effect was probably caused by failure to vibrate or tamp the core powders before pressing.

A summary of the dimensional data of the elements is given in Tables 5–10. The selection of the control specimens was based entirely on weld integrity.

ACKNOWLEDGMENTS

The fabrication of the HFIR prototype elements required extensive preparation involving the efforts of many people. The assistance of the following persons is gratefully acknowledged:

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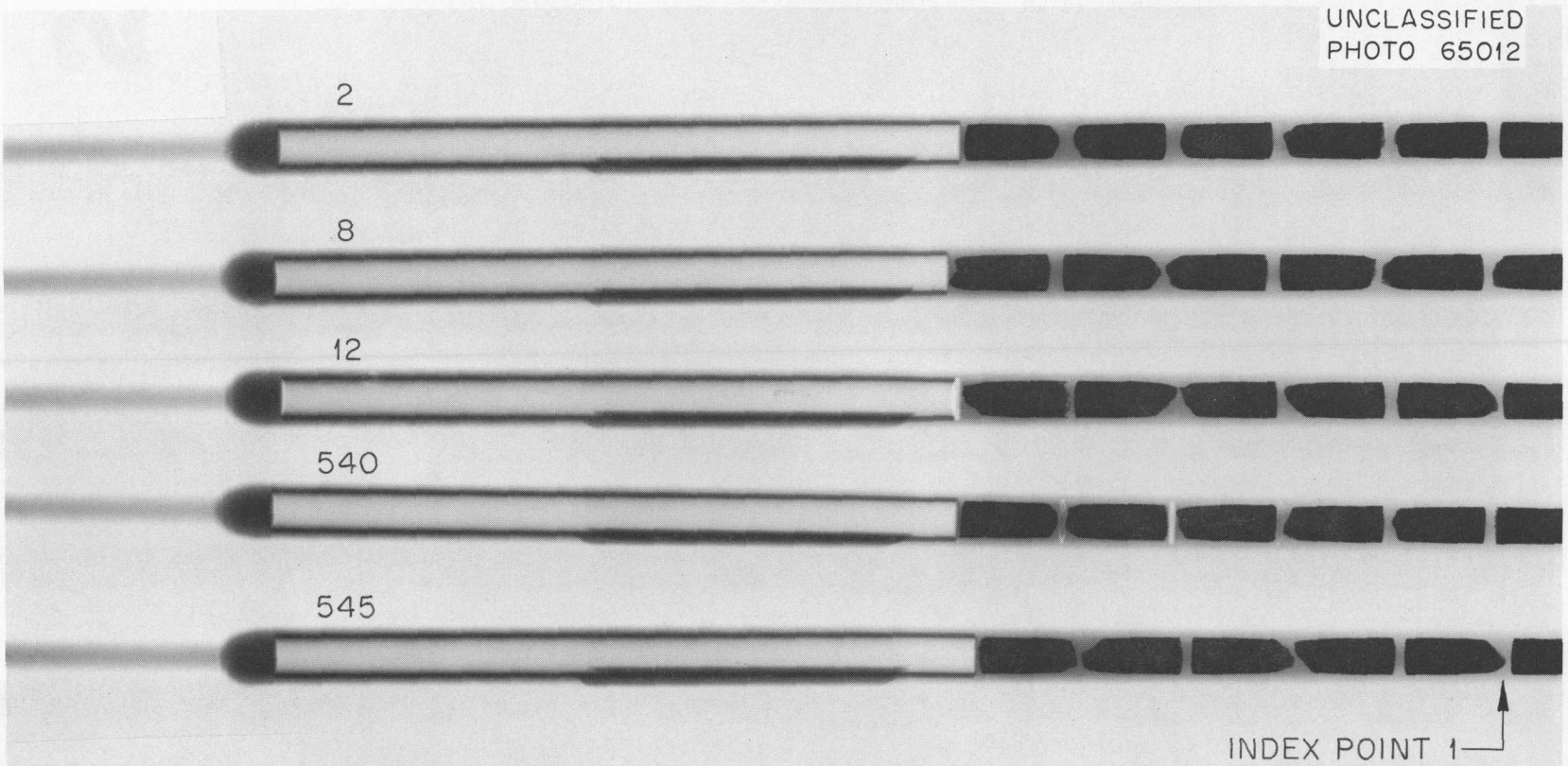

Fig. 7. Radiograph of Entire Rod Assemblies – End A.

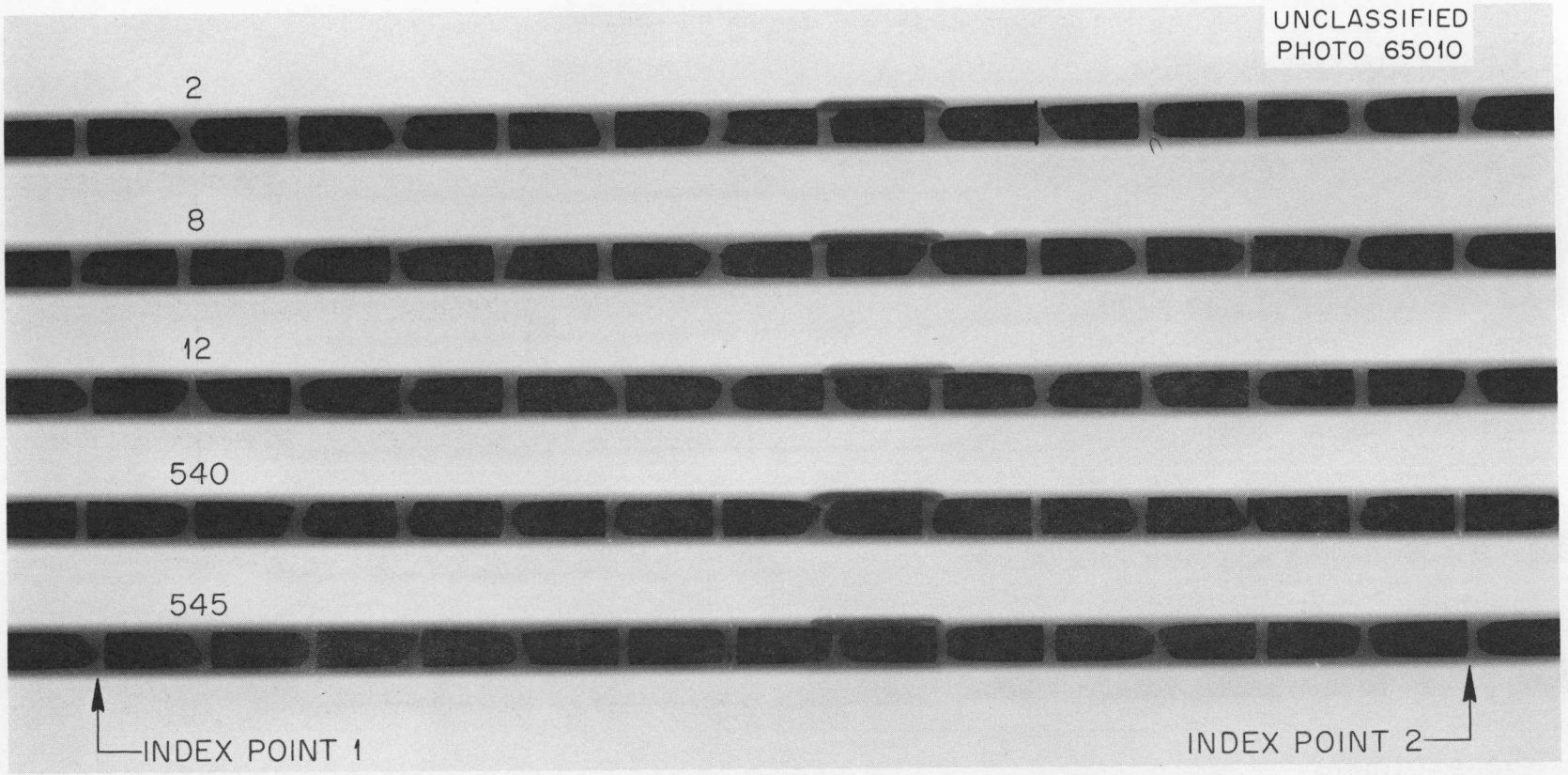

Fig. 8. Radiograph of Entire Rod Assemblies — Middle Section.

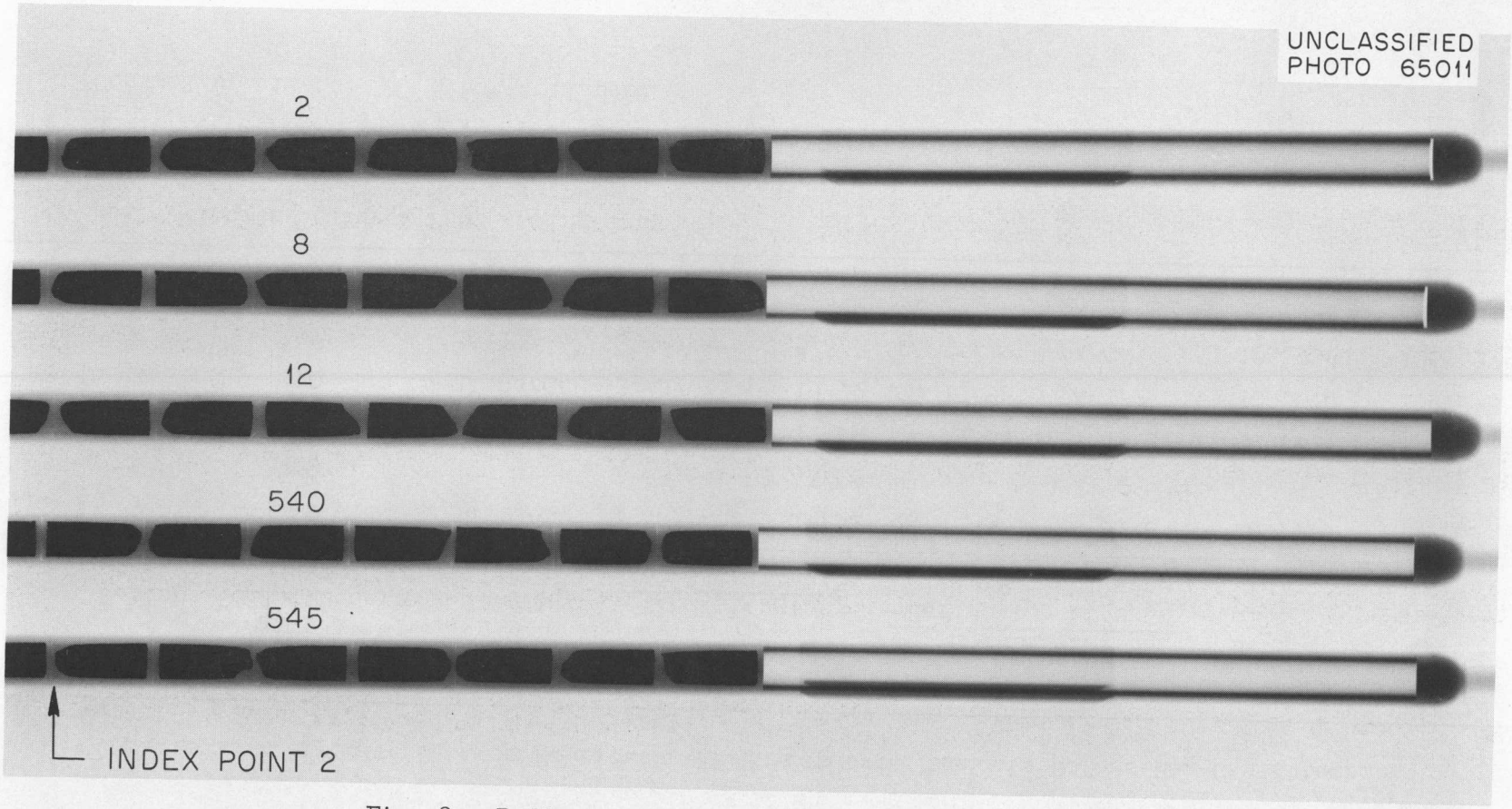

Fig. 9. Radiograph of Entire Rod Assemblies — End B.

Table 5. Composite Data on Fabricator HFIR Prototype Elements Before Hex-Can Attachment

Rod	Pellet Batch	Approximate Pellet Density (% TD)	Pellet Column Length[a] (in.)	Liner Length[b]		Rod Length		Rod Weight	
				End A	End B	Before Collapse	After Collapse[c]	Before Collapse (g)	After Collapse[c] (g)
2	1	90	14 19/64	3 41/64	3 19/32	24 17/32	24 31/64	109.659	109.658
5[d]	2	90		3 41/64	3 41/64				
8	4	90	14 11/32	3 41/64	3 19/32	24 33/64	24 15/32	110.011	110.008
12	3	90	14 23/64	3 41/64	3 19/32	24 17/32	24 1/2	109.574	109.573
540	6	97	14 17/64	3 41/64	3 5/8	24 15/32	24 7/16	106.938	106.937
545[d]	5	90	14 13/64	3 41/64	3 3/4	24 1/2	24 15/32	106.881	106.881

[a] Pellet length measured from radiographs.

[b] End A is the numbered end; End B has reference "Y."

[c] Collapse pressure was 20,000 psi for 5 min.

[d] Control specimens; No. 5 not collapsed.

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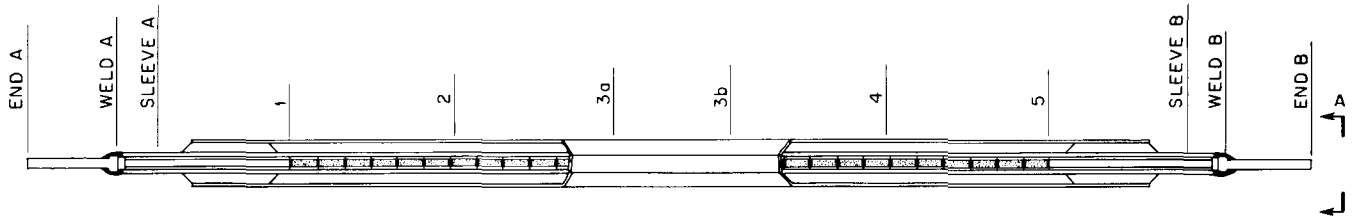
TABLE 6. DIMENSIONAL DATA FOR ROD NO. 2

POSITION[1]	INCHES FROM NUMBERED END	DIAMETER				BOW[2]				HEX CAN[3]			CAN-TO-TUBE SPACE HEX-CAN FACE					
		Before Collapse		After Collapse		Before Collapse		After Collapse										
		Max. (in.)	Min. (in.)	Max. (in.)	Min. (in.)	Amt. (in.)	Angle (deg)	Amt. (in.)	Angle (deg)	Face A to D (in.)	Face B to E (in.)	Face C to F (in.)	A (in.)	B (in.)	C (in.)	D (in.)	E (in.)	F (in.)
WELD A	1 1/2	.383	.380	.383	.380													
SLEEVE A	2 1/2	.382	.380	.375	.374													
1	5			.372	.371	.004	0	.015	135	.631	.628	.632	.094	.094	.096	.094	.090	.098
										.631	.629	.628						
2	8 1/2			.373	.373	.005	0	.018	135				.094	.096	.100	.095	.094	.098
3a	11 3/4			.373	.372	.005	0	.020	145	.632	.627	.631	.098	.096	.101	.096	.094	.096
										.631	.628	.627						
3b	12 3/4			.375	.374	.006	120	.021	145				.097	.096	.100	.098	.088	.090
4	16			.375	.374	.005	120	.016	135				.095	.093	.101	.094	.087	.089
5	19 1/2			.373	.373	.002	120	.010	150	.631	.627	.631	.090	.094	.100	.090	.088	.092
										.631	.628	.627						
SLEEVE B	22	.379	.379	.374	.373													
WLED B	23	.380	.379	.378	.377													

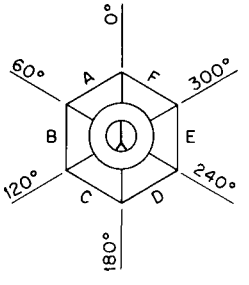
[1]Positions indicated on position diagram.

[2]Bow is 1/2 T.I.R.; angle is point of maximum bow. Before collapse bow measured only at 0, 120, and 240 degrees.

[3]Measured from edge of face to edge of opposite face.



POSITION DIAGRAM



SECTION A-A
(REF "Y" SHOWN)

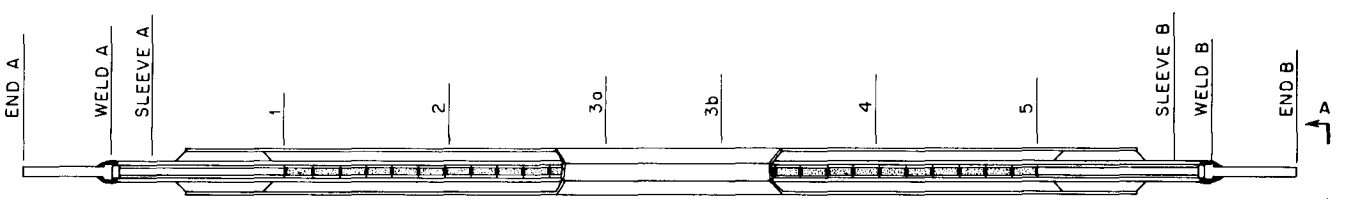
TABLE 7. DIMENSIONAL DATA FOR ROD NO. 8

POSITION[1]	INCHES FROM NUMBERED END	DIAMETER				BOW[2]				HEX CAN[3]			CAN-TO-TUBE SPACE HEX-CAN FACE					
		Before Collapse		After Collapse		Before Collapse		After Collapse										
		Max. (in.)	Min. (in.)	Max. (in.)	Min. (in.)	Amt. (in.)	Angle (deg)	Amt. (in.)	Angle (deg)	Face A to D (in.)	Face B to E (in.)	Face C to F (in.)	A (in.)	B (in.)	C (in.)	D (in.)	E (in.)	F (in.)
WELD A	1 1/2	.379	.378	.379	.378													
SLEEVE A	2 1/2	.380	.378	.373	.372													
1	5			.375	.375	.003	0	.006	90	.631	.628	.632	.097	.100	.099	.096	.093	.094
										.631	.629	.628						
2	8 1/2			.375	.374	.004	0	.008	100				.102	.100	.094	.090	.094	.102
3a	11 3/4			.375	.374	.003	240	.008	140	.632	.627	.631	.103	.098	.093	.088	.091	.096
										.631	.628	.627						
3b	12 3/4			.376	.376	.004	120	.008	100				.102	.096	.094	.091	.093	.097
4	16			.376	.376	.002	0	.004	150				.097	.099	.093	.091	.091	.095
5	19 1/2			.375	.375	.002	0	.008	180	.631	.627	.631	.100	.100	.095	.090	.095	.099
										.631	.628	.627						
SLEEVE B	22	.381	.377	.374	.372													
WELD B	23	.384	.380	.383	.378													

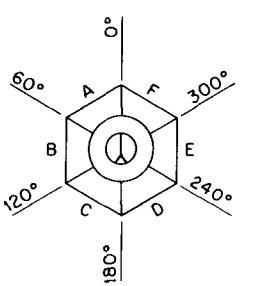
[1]Positions indicated on position diagram.

[2]Bow is 1/2 T.I.R.; angle is point of maximum bow. Before collapse measured only at 0, 120, and 240 degrees.

[3]Measured from edge of face to edge of opposite face.



POSITION DIAGRAM



SECTION A-A
(REF "Y" SHOWN)

UNCLASSIFIED
ORNL DWG. 64-2475

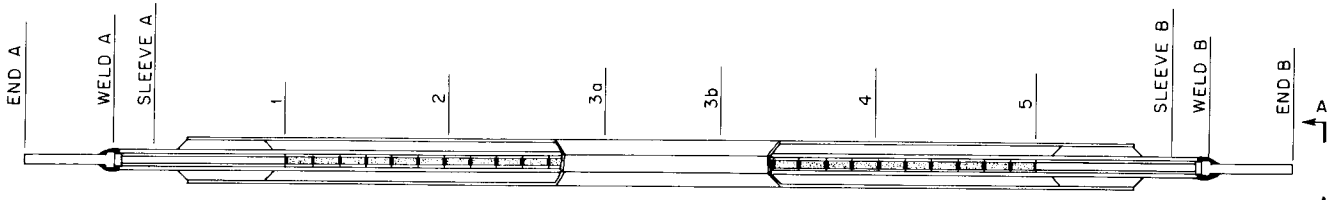
TABLE 8. DIMENSIONAL DATA FOR ROD NO. 12

POSITION[1]	INCHES FROM NUMBERED END	DIAMETER				BOW[2]				HEX CAN[3]			CAN-TO-TUBE SPACE HEX-CAN FACE					
		Before Collapse		After Collapse		Before Collapse		After Collapse										
		Max. (in.)	Min. (in.)	Max. (in.)	Min. (in.)	Amt. (in.)	Angle (deg)	Amt. (in.)	Angle (deg)	Face A to D (in.)	Face B to E (in.)	Face C to F (in.)	A (in.)	B (in.)	C (in.)	D (in.)	E (in.)	F (in.)
WELD A	1 1/2	.380	.380	.378	.377													
SLEEVE A	2 1/2	.381	.379	.375	.374													
1	5			.373	.372	.003	0	.010	315	.631	.628	.632	.099	.099	.099	.095	.095	.096
										.631	.629	.628						
2	8 1/2			.374	.372	.002	0	.011	0				.096	.096	.100	.098	.098	.096
3a	11 3/4			.374	.373	.000		.014	0	.632	.627	.631	.093	.094	.100	.099	.100	.094
										.631	.628	.627						
3b	12 3/4			.375	.374	.002	0	.010	50				.097	.095	.094	.101	.100	.097
4	16			.374	.367	.000		.006	30				.099	.101	.097	.089	.092	.096
5	19 1/2			.373	.372	.001	0	.003	80	.631	.627	.631	.095	.098	.095	.090	.093	.095
										.631	.628	.627						
SLEEVE B	22	.381	.380	.376	.374													
WELD B	23	.381	.380	.383	.378													

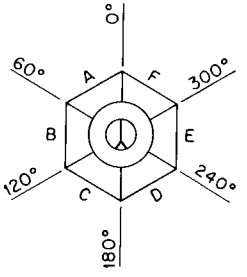
[1]Positions indicated on position diagram.

[2]Bow is 1/2 T.I.R.; angle is point of maximum bow. Before collapse bow measured only at 0, 120, and 240 degrees.

[3]Measured from edge of face to edge of opposite face.



POSITION DIAGRAM



SECTION A-A
(REF "Y" SHOWN)

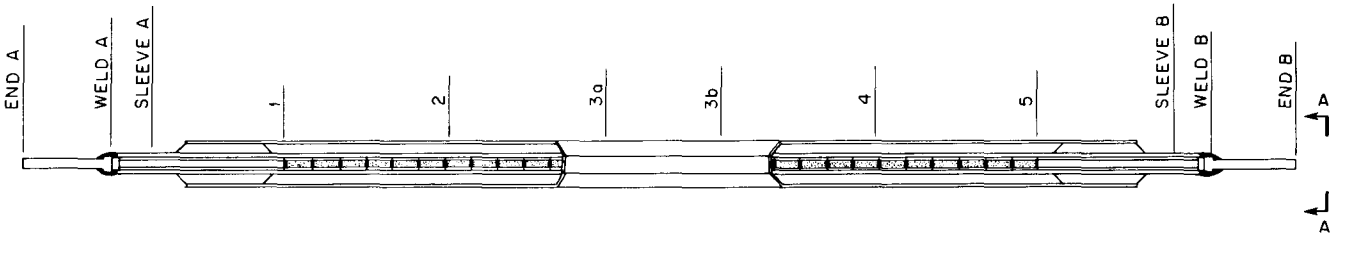
TABLE 9. DIMENSIONAL DATA FOR ROD NO. 540

POSITION[1]	INCHES FROM NUMBERED END	DIAMETER				BOW[2]				HEX CAN[3]			CAN-TO-TUBE SPACE HEX-CAN FACE					
		Before Collapse		After Collapse		Before Collapse		After Collapse										
		Max. (in.)	Min. (in.)	Max. (in.)	Min. (in.)	Amt. (in.)	Angle (deg)	Amt. (in.)	Angle (deg)	Face A to D (in.)	Face B to E (in.)	Face C to F (in.)	A (in.)	B (in.)	C (in.)	D (in.)	E (in.)	F (in.)
WELD A	1 1/2	.374	.371	.374	.370													
SLEEVE A	2 1/2	.372	.374	.371	.368													
1	5			.376	.366	.001	0	.013	310	.631	.628	.632	.103	.102	.094	.092	.096	.102
										.631	.629	.628						
2	8 1/2			.367	.367	.001	0	.025	310				.103	.104	.098	.087	.096	.103
3a	11 3/4			.369	.367	.002	0	.033	320	.632	.627	.631	.102	.102	.096	.088	.097	.102
										.631	.628	.627						
3b	12 3/4			.367	.366	.002	0	.034	320				.100	.100	.100	.096	.098	.099
4	16			.369	.368	.001	0	.036	330				.100	.102	.100	.101	.094	.090
5	19 1/2			.370	.368	.002	0	.031	330	.631	.627	.631	.098	.104	.104	.104	.096	.085
										.631	.628	.627						
SLEEVE B	22	.374	.372	.365	.366													
WELD B	23	.374	.369	.372	.368													

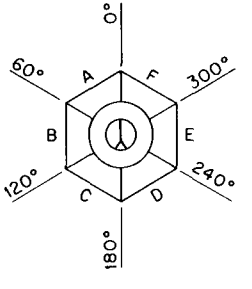
[1]Positions indicated on position diagram.

[2]Bow is 1/2 T.I.R.; angle is point of maximum bow. Before collapse bow measured only at 0, 120, and 240 degrees.

[3]Measured from edge of face to edge of opposite face.



POSITION DIAGRAM



SECTION A-A
(REF "Y" SHOWN)

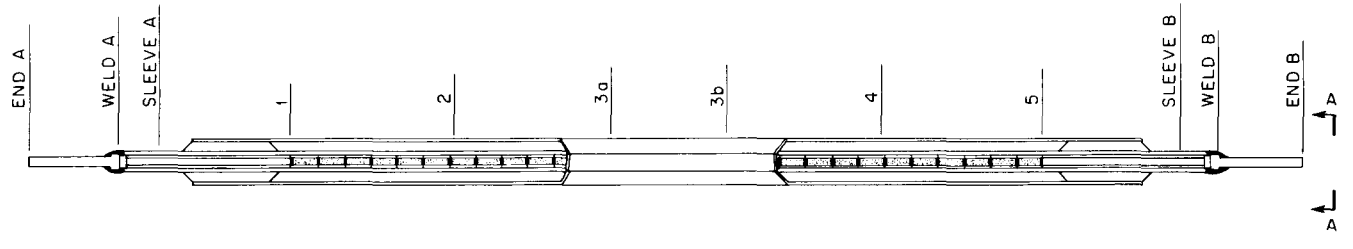
TABLE 10. DIMENSIONAL DATA FOR ROD NO. 545

POSITION[1]	INCHES FROM NUMBERED END	DIAMETER				BOW[2]				HEX CAN[3]			CAN-TO-TUBE SPACE HEX-CAN FACE					
		Before Collapse		After Collapse		Before Collapse		After Collapse										
		Max. (in.)	Min. (in.)	Max. (in.)	Min. (in.)	Amt. (in.)	Angle (deg)	Amt. (in.)	Angle (deg)	Face A to D (in.)	Face B to E (in.)	Face C to F (in.)	A (in.)	B (in.)	C (in.)	D (in.)	E (in.)	F (in.)
WELD A	1 1/2	.376	.374	.373	.374													
SLEEVE A	2 1/2	.375	.374	.369	.368													
1	5			.369	.367	.002	0	.002	210	.631	.628	.632	.097	.100	.095	.091	.092	.097
										.631	.629	.628						
2	8 1/2			.369	.367	.002	0	.003	210				.100	.100	.095	.090	.096	.099
3a	11 3/4			.365	.365	.003	120	.001	180	.632	.627	.631	.098	.099	.096	.098	.098	.100
										.631	.628	.627						
3b	12 3/4			.371	.370	.005	120	.002	0				.097	.099	.098	.096	.096	.096
4	16			.371	.371	.006	120	.002	340				.098	.099	.097	.097	.097	.096
5	19 1/2			.368	.368	.005	120	.002	340	.631	.627	.631	.099	.094	.097	.096	.098	.100
										.631	.628	.627						
SLEEVE B	22	.373	.373	.369	.366													
WELD B	23	.375	.374	.375	.372													

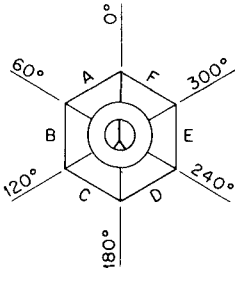
[1]Positions indicated on position diagram.

[2]Bow is 1/2 T.I.R.; angle is point of maximum bow. Before collapse bow measured only at 0, 120, and 240 degrees.

[3]Measured from edge of face to edge of opposite face.



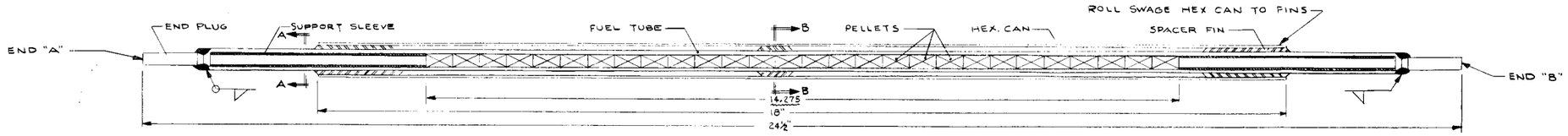
POSITION DIAGRAM



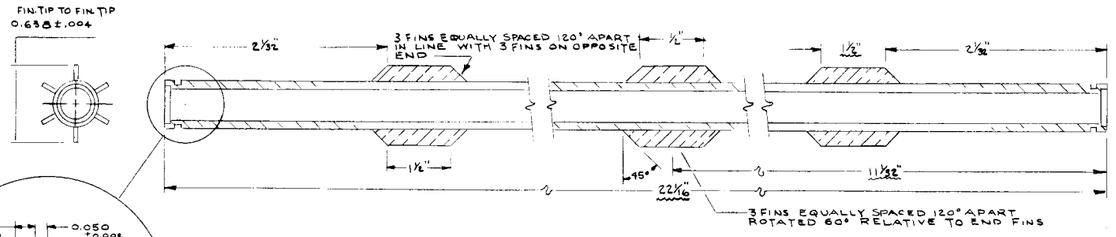
SECTION A-A
(REF "Y" SHOWN)

APPENDIX A

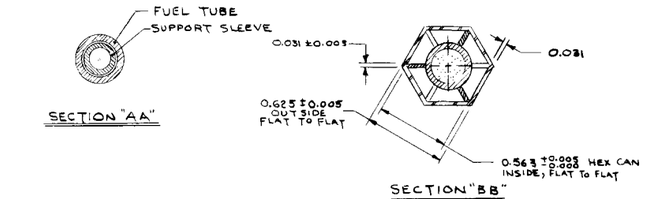
ENGINEERING DRAWING OF HFIR TARGET IRRADIATION PROTOTYPE ELEMENT



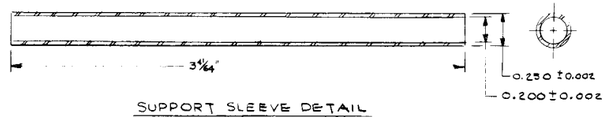
ASSEMBLY
FULL SIZE



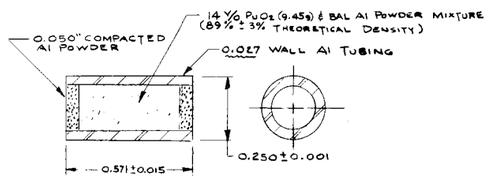
FUEL TUBE DETAIL
MAT'L: X-8001 Al
No. Req'd: 1
SCALE: 2"=1"



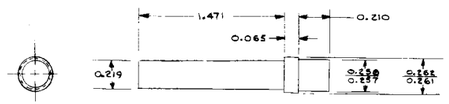
SECTION "BB"
SCALE: 2"=1"



SUPPORT SLEEVE DETAIL
MAT'L: 7075-T6 Al
NO. REQ'D: 2
SCALE: 2"=1"



PELLET (AFTER PRESSING)
No. Req'd: 25
Scale = 4"=1"



END CAP
MAT'L: X-8001 Al
No. REQ'D: 2
SCALE: 2"=1"

NOTE:
DIMENSIONS PRIOR TO COLLAPSE
STRAIGHTNESS: 0.010" T.I.R

RADIOGRAPHY EXAMINATION TO 10% WALL THICKNESS IN ACCORDANCE WITH SPEC. MET-NDT-5 PENETRANT INSPECT IN ACCORDANCE WITH SPEC. MET-NDT-4
HELIUM LEAK TEST TO 1X10⁻⁹ Std. cc He/Sec.

NO.	REVISIONS	DATE	APPD	APPD
3	CHANGED TO "AS BUILT" B&D	9-9-63	SAR	
2	REDESIGNED END CAP & FUEL TUBE B&D	7-17-63	SAR	
⚠ 1	REDESIGNED END CAPS LSN	8-6-62	SAR	

DRAWN	DATE	SUBMITTED	DATE	APPROVED	DATE
DEVALL	5/16/62				
DESIGNED S.A RABIN	DATE	APPROVED	DATE	APPROVED	DATE
CHECKED S.A. Rabin	6-4-62	APPROVED	DATE	APPROVED	DATE

REFERENCE DRAWINGS | DWG. NO.

TRU STUDIES DESIGN | BLDG. NO. 4508

TRU HFIR TARGET
IRRADIATION PROTOTYPE

LIMITS ON DIMENSIONS UNLESS OTHERWISE SPECIFIED
FRACTIONS ± 1/64
DECIMALS ± 0.005
ANGLES ±
SCALE AS NOTED

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE NUCLEAR COMPANY
DIVISION OF UNION CARBIDE CORP.
OAK RIDGE, TENNESSEE

SUBMITTED	ACCEPTED	APPROVED
	S.A Rabin	H.E. Goeller 9/4/63

RCO DEF | D-46124 | REV 3

APPENDIX B

PLUTONIUM OXIDE PREPARATION

APPENDIX B

PLUTONIUM OXIDE PREPARATION

The plutonium oxide was prepared by M. H. Lloyd of the Chemical Technology Division. The following process was developed to produce a coarse high-density oxide.

A solution of 0.5 M $Pu(NO_3)_4$ in 4 M HNO_3 was prepared using spectrographic purity plutonium and was rapidly mixed with an equal volume of 8 M NH_4OH to precipitate $Pu(OH)_4$. The precipitate was washed with 2 M NH_4OH, dried at 150°C, and fired at 1200°C. A glassy solid resulted with a density of 10.99 g/cc which is 96% of theoretical. Most of the particles were from 1–3 mm in diameter. Therefore, the material was ground and screened in an effort to bring the material into particle size specification. The resulting particle size ranges obtained by this operation are given in Table 1, page 4.

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