HW-66757

UC-25, Metallurgy and Ceramics
(TID-4500, 15th Ed.)

FABRICATION OF ALUMINUM CLAD
PLUTONIUM-ALUMINUM ALLOY PIN ELEMENTS

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September 1, 1960

HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

Work performed under Contract No. AT(45-1)-1350 between the
Atomic Energy Commission and General Electric Company

Printed by/for the U. S. Atomic Energy Commission

Printed in USA. Price 50 cents. Available from the
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FABRICATION OF ALUMINUM CLAD
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INTRODUCTION

The Plutonium Metallurgy Operation of the Hanford Laboratories was requested to prepare 60 plutonium-aluminum alloy pins, clad in aluminum, for the duPont Company, Aiken, South Carolina. The specifications were as follows:

Over-all OD of pin	0.0625 $\begin{smallmatrix} +0.000 \\ -0.002 \end{smallmatrix}$ inch
Over-all length of pin	0.500 $\begin{smallmatrix} +0.000 \\ -0.005 \end{smallmatrix}$ inch
Cladding thickness	0.005 to 0.015 inch
Cladding material	1100 or 6063 aluminum
Core dimensions	To depend on cladding dimensions
Core alloy concentration	To be varied based upon actual core dimensions, but to range between 7 and 19 weight per cent (w/o) Pu ²³⁹ in Pu-Al alloy. The approximate concentration to be used can be determined from an attached curve of weight per cent in Pu in Pu-Al alloy versus volume of pin core in cubic inches (Figure 1). In other words, the larger the opening for the core the lower the concentration of Pu in the alloy should be in filling the core.
General	The function of the cladding is to prevent Pu contamination; hence, there need be no bonding between the cladding and the core.

FABRICATION

The cladding components were fabricated from 1100 Al wire 1/16 inch in diameter. Cans were cut to 0.532 inch lengths and a 0.035-inch diameter hole was drilled 0.517 inch deep, with a flat bottom #65 drill, leaving a 0.015-inch thick bottom cap. End cap material was fabricated from the same material by a series of passes through draw plates to 0.035-inch diameter. Cleaning of the cladding components was accomplished by rinsing in trichloroethylene and drying in a vacuum oven for two hours at 150 C.

The core material was cast as cylinders 0.375 inch in diameter, approximately 2 inches long in a heated graphite mold.⁽¹⁾ The alloy composition was 15.75 w/o Pu.

Billets 1/4 inch long were cut from the cylinders. These were extruded through an 87 to 1 reduction in area to final size of 0.032 $\pm$ 0.001 inch.

The extrusion was of the vertical forward type through a flat face shear die with a 0.035-inch diameter die opening. A 20-ton hydraulic press, ordinarily used for oxide compacting, was used for the extrusion (Figure 2). Temperature measured at the top of the extrusion container was 450 C for the first extrusion and 500 C for the final two extrusions. Extrusion pressure ranged between 150,000 psi and 220,000 psi on the 0.370-inch diameter stem. Approximately 24 inches of wire were obtained from each extrusion. The wire was inserted into a lucite fixture and cut to 0.470-inch length, the ends faced with a file; and after final gaging for length and diameter, the cores were weighed. Each core was cleaned in ethyl alcohol and wiped dry. Smearable contamination was generally less than 1000 disintegrations per minute.

For loading, the cans were inserted in a lucite fixture and placed in an open front hood, the cores dropped in, and the can opening swabbed

(1) Bloomster, C. H. Casting Aluminum Plutonium Alloys, HW-63166. March 1960.

with a cotton applicator that was damp with ethyl alcohol. The 0.035-inch diameter end cap wire was then pressed into the can opening until it contacted the core and was cut off level with the top of the can. Approximately 5 per cent of the loaded cans counted 500 disintegrations per minute or greater at the unsealed end and the cores had to be decanned and reloaded.

Sealing of the final end was done by fusion welding using alternating current with the tungsten inert gas process. The pins were inserted into a two piece cylindrical copper chill block which was held together by spring tension (Figure 3). The end to be welded protruded 0.040 inch from the chill block. Fusing the entire end of the pin required 2 to 4 seconds welding time. Welding was done manually with a 0.040 inch, 1 per cent thoriated electrode and an argon flow rate of 10 cubic feet per hour using 31 amperes and 23 volts. Final sizing of the pins to 0.515 inch length and 0.0625-inch diameter was done with a file (Figure 4).

The completed pins were checked for smearable contamination and monitored in a standard chamber counter for alpha radiation.

For shipping, the pins were individually packed in cotton lined plastic vials and placed in a wooden container (Figure 5).

The Appendix gives all pertinent core and cladding data.

DISCUSSION

The average Pu analysis was given as 15.75 w/o Pu. This was an average of six samples of the extruded wire. The maximum analysis was 16.05 w/o Pu and the minimum 15.5 w/o Pu.

The extrusion conditions were quite critical due to the 87 to 1 reduction and the relatively low ductility of the alloy. Six extrusions were attempted and only three were successful within the limits of the press. The reason for this appeared to be die and billet container finish rather than temperature. A stem fracture occurred on the sixth and final attempt to extrude. Some galling was observed on the extruded surface of the alloy.

The most critical part of the fabrication process was the welding of the unsealed end of the pin. This was due to the difficulty in controlling depth of penetration in order to keep from alloying the weld metal with the core material. The original specifications called for an over-all length of $0.500^{+0.000}_{-0.005}$ inch leaving a maximum of 0.015-inch thick end cap, but when the first ten closures were attempted and only one did not have a contaminated weld zone, the length specifications were relaxed to $0.500^{+0.015}_{-0.005}$ inch. With this new length the over-all welding reject rate was still 65 per cent. It was found that the distance the pin protruded from the chill block was very important in controlling depth of penetration. The established distance of 0.040 inch appeared to be optimum. Of the last 12 welds attempted only one had a contaminated weld zone.

FIGURE 1
Curve of Weight Per Cent Pu^{239}
in Pu-Al Alloy vs. Volume of Pin Core

FIGURE 2

Twenty-ton Hydraulic Press with Extrusion Tooling

FIGURE 3
Copper Chill Block with Welded Pin

FIGURE 4

(a) Unassembled Components (b) Assembled Pin (c) As Welded (d) Finished Pin Element

FIGURE 5
Shipping Container

APPENDIX

No.	Core Data				Cladding Data		Alpha Radiation (counts/min.)	Wt. Pu $\times 10^3$ gm	Wt. Pu ²³⁹ $\times 10^3$ gm
	Length (in.)	Diameter (mils)	Volume $\times 10^3$ in. ³	Weight (gm)	Length (in.)	Diameter (mils)			
1	0.470	32	378	0.0184	0.512	63	<10	2.90	2.73
2	0.470	32	378	0.0187	0.5015	63	<10	2.95	2.78
3	0.470	32.5	389.9	0.0203	0.512	63	<10	3.20	3.01
4	0.470	32	378	0.0184	0.515	63	47	2.90	2.73
5	0.471	33	402.8	0.0181	0.511	62.5	40	2.85	2.68
6	0.471	32	378.8	0.0180	0.500	62.5	<10	2.835	2.67
7	0.469	32	377.2	0.0182	0.515	62.5	<10	2.87	2.70
8	0.471	32.3	385.9	0.0199	0.511	63	<10	3.13	2.95
9	0.468	32.5	388.2	0.0182	0.508	63	<10	2.87	2.70
10	0.471	33	402.8	0.0208	0.515	63	39	3.28	3.09
11	0.470	32.5	389.9	0.0186	0.513	63	64	2.93	2.76
12	0.467	32	375.6	0.0183	0.512	63	66	2.88	2.71
13	0.470	32	378	0.0181	0.514	62.5	<10	2.85	2.68
14	0.466	33	398.6	0.0198	0.497	61.5	<10	3.12	2.94
15	0.466	32	374.8	0.0185	0.512	62	<10	2.91	2.74
16	0.471	32	378.8	0.0185	0.508	63	<10	2.91	2.74
17	0.470	32	378	0.0178	0.509	63	<10	2.80	2.64
18	0.470	33	402	0.0208	0.510	63	<10	3.28	3.09
19	0.469	33.5	413.4	0.0180	0.514	62.5	<10	2.835	2.67
20	0.470	32.5	389.9	0.0191	0.514	62.5	<10	3.01	2.83
21	0.470	32.5	389.9	0.0181	0.511	63	<10	2.85	2.68
22	0.470	32	378	0.0184	0.514	62.5	<10	2.90	2.73
23	0.471	32.5	390.7	0.0181	0.512	63	<10	2.85	2.68

No.	Core Data				Cladding Data		Alpha Radiation (counts/min.)	Wt. Pu $\times 10^3$ gm	Wt. Pu ²³⁹ $\times 10^3$ gm
	Length (in.)	Diameter (mils)	Volume $\times 10^6$ in. ³	Weight (gm)	Length (in.)	Diameter (mils)			
24	0.468	32	376.4	0.0171	0.514	63	<10	2.69	2.53
25	0.470	32.5	389.9	0.0180	0.515	63	<10	2.835	2.67
26	0.468	33	400.3	0.0197	0.510	63	<10	3.10	2.92
27	0.470	33	402	0.0191	0.511	62.5	<10	3.01	2.83
28	0.468	32.7	393	0.0195	0.513	63	<10	3.07	2.89
29	0.470	33.5	414.2	0.0199	0.512	62.5	30	3.13	2.95
30	0.470	32.2	387	0.0180	0.509	62.5	<10	2.835	2.67
31	0.470	32	378	0.0183	0.512	63	<10	2.88	2.71
32	0.470	32	378	0.0181	0.513	62.5	<10	2.85	2.68
33	0.469	33	401.1	0.0193	0.510	63	<10	3.04	2.86
34	0.470	32	378	0.0185	0.513	63	<10	2.91	2.74
35	0.464	31.9	370.8	0.0177	0.515	62.5	<10	2.79	2.63
36	0.470	32	378	0.0180	0.514	63	<10	2.835	2.67
37	0.470	32.5	389.9	0.0188	0.514	62.5	<10	2.96	2.79
38	0.470	32	378	0.0181	0.505	62.5	77	2.85	2.68
39	0.470	33.5	414.2	0.0196	0.514	63	<10	3.09	2.91
40	0.471	32	378.8	0.0199	0.515	63	62	3.13	2.95
41	0.470	32	378	0.0192	0.515	62	<10	3.02	2.84
42	0.469	32	377.2	0.084	0.514	62.5	<10	2.90	2.73
43	0.470	32	378	0.0180	0.514	63	<10	2.835	2.67
44	0.471	31.6	369.4	0.0178	0.515	62.5	<10	2.80	2.64
45	0.470	33	402	0.0202	0.515	63	<10	3.18	2.99
46	0.471	32	378.8	0.0179	0.505	62.5	<10	2.82	2.65

No.	Core Data				Cladding Data		Alpha Radiation (counts/min.)	Wt. Pu $\times 10^3$ gm	Wt. Pu ²³⁹ $\times 10^3$ gm
	Length (in.)	Diameter (mils)	Volume $\times 10^6$ in. ³	Weight (gm)	Length (in.)	Diameter (mils)			
47	0.470	33.5	414.2	0.0201	0.515	62.5	31	3.17	2.98
48	0.471	32	378.8	0.0183	0.514	63	<10	2.88	2.71
49	0.470	32	378	0.0180	0.510	63	<10	2.835	2.67
50	0.470	32	378	0.0185	0.513	63	36	2.91	2.74
51	0.465	33	397.7	0.0187	0.514	62.5	<10	2.95	2.78
52	0.470	32	378	0.0183	0.514	63	<10	2.88	2.71
53	0.468	33	400.2	0.0181	0.515	63	20	2.85	2.68
54	0.468	32	376.4	0.0175	0.515	62.5	<10	2.76	2.60
55	0.470	32	378	0.0187	0.513	63	24	2.91	2.74
56	0.469	33	401.1	0.0197	0.512	63	<10	3.10	2.92
57	0.470	32.6	392.3	0.0187	0.496	62.5	25	2.85	2.68
58	0.470	32	378	0.0188	0.515	63	<10	2.96	2.79
59	0.469	32	377.2	0.0180	0.515	63	<10	2.835	2.67
60	0.470	32.7	394.7	0.0184	0.508	63	<10	2.90	2.73

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Isotopic Analysis 94.14 weight per cent Pu²³⁹.

Chemical Analysis 15.75 weight per cent Pu-Al alloy.

Total SS Weight 0.1763 gm Pu.

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