RFP-190

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PLUTONIUM PLEXIGLAS ASSEMBLIES

PART II

by

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ABSTRACT

Neutron multiplication measurements were made on tamped and untamped cylindrical assemblies. The assemblies consisted of plutonium metal sheet moderated with Plexiglas. Experiments were performed to evaluate the effects of inhomogeneity. This work is a continuation of RFP-178.

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1. INTRODUCTION

Neutron multiplication measurements were made on cylindrical disc assemblies of alternate layers of Plexiglas and plutonium sheet. Both bare and tamped assemblies were investigated. H:Pu atomic ratios were varied from approximately 19.6 to 90 for the tamped arrays and 19.4 to 94 for the untamped arrays.

The thickness of the plutonium sheet was varied in order to study the effects of inhomogeneity at various H:Pu atomic ratios.

An attempt was also made to convert the experimental data on cylindrical assemblies to homogeneous spherical assemblies.

2. EXPERIMENTAL MATERIALS

The measuring equipment used in these experiments included scalers, Atomic model 1050A, coupled to G.E. B¹⁰-lined counters, and Li(Eu) scintillators.

2.1 Materials

2.1.1 Moderator and Reflector

Plexiglas $\sim 1.19 \text{ g/cm}^3$.

2.1.2 Fuel

Average density $\sim 15.8 \text{ g/cm}^3$.

<u>Sheet Diameter (in.)</u>	<u>Sheet Thickness (cm)</u>	<u>Mass Per Sheet (g)</u>
12.5	0.0238	332.6
	0.0400	535.1
18.0	0.0238	648.1
	0.0400	1081.6

3. PROCEDURE AND RESULTS

Figure 1 is a schematic of the plutonium-Plexiglas assemblies. Tables I through V summarize the experimental data and results. The H:Pu atomic ratios were calculated on the assumption that the metal and the Plexiglas were homogeneously mixed. The tamped arrays were reflected with approximately 4 in. of Plexiglas on the ends of the cylindrical cores, and the lateral surfaces were tamped with 3 in. of Plexiglas.

Figures 2 and 3 are samples of the reciprocal multiplication plots to illustrate the magnitude of the extrapolations of the data to the critical state.

Figure 4 contains a plot of the extrapolated critical mass of plutonium as a function of the H:Pu atomic ratio for the 12.5-in. and 18.0-in. diameter untamped cylindrical arrays. Figure 5 is a plot of the 12.5-in. diameter tamped case. The

difference in the plot of the data given in RFP-178⁽¹⁾ and the present work is attributed mainly to the difference in the Pu^{240} content of the two cases. This is illustrated in Figure 5. This discrepancy was not illustrated for the bare case in Figure 4. The data is less certain for the bare cases, due partially to longer extrapolation to the critical state.

Figures 6 and 7 illustrate the technique used in estimating the effect of inhomogeneity for the sheet used in these experiments. The homogeneous masses were obtained by plotting several sheet thicknesses for the same moderation and extrapolating to zero sheet thickness.

It can be seen that at H:Pu ratios of less than 19, the effect of inhomogeneity is not significant (not measurable by our experimental techniques) for either the tamped or untamped case for a sheet thickness of 0.0802 cm. At an H:Pu ratio ~48, the observed homogeneous mass is about 4% less than that for an assembly containing sheet 0.0238 cm thick for the 12.5-in. diameter bare cylinder, but no reduction was observed for the bare 18-in. cylinder and tamped 12.5-in. diameter cylinder. This discrepancy is due to experimental error.

Figure 8 is an attempt to convert the experimental measurements for the 12.5-in. and 18-in. diameter bare cylinders

(1) C. L. Schuske, G. H. Bidinger, A. Goodwin, Jr., D. F. Smith, "Plutonium Plexiglas Assemblies", USAEC Report RFP-178, January 20, 1960. (Declassified)

to spherical cores. The first method used for the bare case was to assume the constant buckling relation:

$$B^2 = \frac{j_0^2}{(R + \delta)^2} + \frac{\pi^2}{(H + 2\delta)^2}$$

The extrapolation lengths, δ , used in these conversions were obtained from diffusion calculations made at Rocky Flats. These values are presented in Table IV. As previously discussed in RFP-178, considerable error can result in this method of conversion. In order to fit spherical masses from the previous work reported in RFP-178 and the present work reported here, a normalization of the plutonium densities, as a function of H:Pu atomic ratio, is necessary. The densities, as functions of H:Pu ratio used for this normalization, appear in Figure 10.

A second method used for the cylinder-to-sphere conversion was the application of GAT 189.⁽²⁾ These spherical values appear in Table V and are also plotted in Figure 8.

The method is as follows: Cylindrical values derived from experiments for the 12.5-in. and 18-in. diameter cylinders were used to obtain η as a function of the H:Pu atomic ratio. These values of η were then used to calculate spherical critical masses for the corresponding cylindrical cases,

(2) J. A. Pond; "Critical Geometries for Bare Cylinders", USAEC Report GAT 189, July 20, 1956. (Unclassified)

using GAT 189. Whenever there were multiple cylindrical values at approximately the same H:Pu ratio, the resulting η values were averaged. This average value was then used to calculate a spherical mass for a given H:Pu ratio. These values are plotted in Figure 8. This method appears more consistent than method 1. However the experimental data used in these conversions limits the accuracy of either method.

In Figure 9 and Table VI, approximated spherical critical masses for the tamped cases were developed making use of the shape conversion factors derived from critical UO_2F_2 tamped data reported in K-343.⁽³⁾ The critical mass values reported in Figure 9 should be used with caution in light of techniques used in the conversions from cylindrical to spherical values. This technique was also used on a single bare cylinder with an H:Pu ~47.6. The resulting spherical mass by this method was 9.5 kg as compared with 8.56 kg given in Table I.

Figure 10 represents dispersed plutonium metal in Plexiglas. Note these densities appear about 1% less than those calculated directly from the subcritical assemblies. This may be due to a slightly greater density for the Plexiglas than was assumed in Figure 10, coupled with error in measuring the average height of each experimental assembly. The Plexiglas was of non-uniform thickness across the diameter of each sheet.

(3) C. K. Beck, A. D. Callihan, J. W. Morfitt, R. L. Murray; "Critical Mass Studies, Part III", USAEC Report K-343, April 19, 1949. (Declassified)

TABLE I

Untamped Cylinders - 12.5-in. Diameter

<u>H:Pu</u>	<u>Extrapolated Critical Height (cm)</u>	<u>Mass in Experiment (kg)</u>	<u>Extrapolated Critical Mass (kg)</u>	<u>ρ_{Pu_3} (g/cm³)</u>	<u>Plutonium Sheet Thickness (cm)</u>	<u>Plexiglas Sheet Thickness (cm)</u>
20.3	26.6	16.05	22.2	1.056	0.0400	0.6172
47.6	27.7	8.56	10.3	0.470	0.0400	1.4910
45.7	30.6	9.63	11.9	0.492	0.0801	2.982
92.9	29.3	4.99	5.9	0.254	0.0238	1.816
94.2	37.8	5.35	7.4	0.247	0.0400	3.015
90.7	42.3	6.65	8.5	0.254	0.0476	3.632

TABLE II

Untamped Cylinders - 18-in. Diameter

<u>H:Pu</u>	<u>Extrapolated Critical Height (cm)</u>	<u>Mass in Experiment (kg)</u>	<u>Extrapolated Critical Mass (kg)</u>	<u>ρ_{Pu} (g/cm³)</u>	<u>Plutonium Sheet Thickness (cm)</u>	<u>Plexiglas Sheet Thickness (cm)</u>
19.4	18.1	24.88	32.0	1.075	0.0400	0.5829
18.7	17.4	25.95	32.0	1.120	0.0801	1.165
18.1	17.1	25.95	32.8	1.166	0.1202	1.749
48.5	20.0	12.31	15.1	0.459	0.0238	0.8801
46.4	20.2	12.96	15.7	0.474	0.0476	1.7602
45.6	19.9	13.84	15.8	0.483	0.0639	2.3876
94.1	20.2	6.48	8.0	0.241	0.0238	1.7767
88.6	22.5	7.78	9.6	0.260	0.0476	3.5534
87.0	29.3	9.72	13.0	0.270	0.0715	5.3304

TABLE III

Tamped Cylinders - 12.5-in. Diameter

<u>H:Pu</u>	<u>Calculated** Critical Height (cm)</u>	<u>Mass in Experiment (kg)</u>	<u>Extrapolated Critical Mass (kg)</u>	<u>ρ_{Pu}^* (g/cm³)</u>	<u>Plutonium Sheet Thickness (cm)</u>	<u>Plexiglas Sheet Thickness (cm)</u>
19.6	11.47	7.49	9.8	1.079	0.0400	0.6172
18.5	10.86	8.56	9.8	1.140	0.0801	1.2344
46.2	14.0	4.32	5.3	0.478	0.0238	0.9093
43.3	13.65	4.65	5.5	0.509	0.0476	1.8186
42.0	13.52	4.34	5.6	0.523	0.0639	2.3977
87.3	14.31	2.66	3.3	0.256	0.0238	1.8160
92.2	18.71	2.67	3.6	0.243	0.0400	3.0140
82.2	18.57	3.32	4.0	0.272	0.0476	3.6312

* Obtained from graph in Figure 9.

** Calculated using critical mass and density.

TABLE IV

Conversion of Untamped Cylinders to Spheres
 (Spheres corrected for homogeneity and density
 using method of RFP-178)

<u>H:Pu</u>	<u>Cylinder Diameter (in.)</u>	<u>Critical Mass in Homogeneous Cylinder (kg)</u>	<u>ρ g/cm³</u>	<u>δ (cm)</u>	<u>Critical Mass of Sphere (kg)</u>
0	12.5	61.5*	15.8	1.87	16.1
1.62	12.5	56.4*	7.435	1.96	28.4
6.07	12.5	37.8*	3.017	2.18	28.8
11.6	12.5	24.7*	1.744	2.35	20.4
18.7	18.0	32.0	1.130	2.45	19.0
19.4	18.0	32.0	1.092	2.45	19.4
20.3	12.5	22.2	1.046	2.45	20.6
47.6	12.5	9.35	0.464	2.5	8.7
48.5	18.0	15.0	0.456	2.5	10.3
92.9	12.5	4.5	0.241	2.5	4.44
94.1	18.0	7.45	0.238	2.5	4.95

* Reported in RFP-178.

TABLE V

Conversion of Untamped Cylinders to Spheres
(Spheres corrected for homogeneity and density
using method of GAT-189 and Figure 10)

<u>H:Pu</u>	<u>Cylinder Diameter (in.)</u>	<u>Critical Mass in Homogeneous Cylinder</u>	<u>ρ g/cm³</u>	<u>η (Average)</u>	<u>Critical Mass of Sphere (GAT-189)</u>
19.4	18.0	32.0	1.092	1.835	20.5
20.3	12.5	22.2	1.046	1.835	19.7
47.6	12.5	9.35	0.464	1.900	8.1
48.5	18.0	15.0	0.456	1.900	8.0
92.9	12.5	4.5	0.241	1.895	4.5
94.1	18.0	7.45	0.238	1.895	4.5

TABLE VI

Conversion of Tamped 12.5-in. Diameter Cylinders to Spheres
(Corrected for homogeneity and density)

<u>H:Pu</u>	<u>Diameter (in.)</u>	<u>Hc (cm)</u>	<u>Mc (kg)</u>	<u>ρ (g/cm³)</u>	<u>H/D</u>	<u>$\frac{M_{cyl.}^*}{M_{eq. cyl.}}$</u>	<u>Mc_{sph.} (kg)</u>
19.6	12.5	11.5	9.8	1.079	0.362	1.514	6.47
46.2	12.5	14.0	5.3	0.478	0.441	1.257	4.22
87.3	12.5	14.8	3.0	0.256	0.466	1.159	2.59

* K-343

PLEXIGLAS AND PLUTONIUM METAL ASSEMBLIES

Figure 1