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Title: A SMALL GRAPHITE-REFLECTED UO_2 CRITICAL ASSEMBLY

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ABSTRACT

An unmoderated, graphite reflected, critical assembly of UO_2, enriched to 93.2 wt% in U^{235} is described. The UO_2 pellets, density 9.71 g/cm^3, were contained in 253 1.27-cm-dia stainless steel tubes which, in turn, are closepacked in an aluminum container 22.87 cm in diameter and 31.11 cm long. Two combinations of top and side reflectors were found to make the assembly critical. In one the thicknesses of the top and the side reflectors were 12.70 and 19.25 cm, respectively; in the other these dimensions were 5.08 and 24.34 cm. Fission distribution measurements axially through the assembly and radially through the reflector showed, in one case, a peak in the reflector 3.5 greater than at the center of the core. The U^{235} cadmium ratio measured in the side reflector ranged from 1.77 to 2.43.

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A SMALL GRAPHITE-REFLECTED UO_2 CRITICAL ASSEMBLY

INTRODUCTION

A small, compact, unmoderated critical assembly of U^{235}-enriched UO_2 reflected by graphite, constructed in the Oak Ridge Critical Experiments Facility, has provided data in support of reactor calculations. The critical configurations with two reflector conditions, U^{235}-fission-rate, cadmium-ratio distributions, and various reactivity effects were measured. The results of the experiments are reported in this memo.

MATERIALS AND EQUIPMENT

The core of the assembly, nominally 22.58 cm in diameter and 30.48 cm high, was a close-packed array of 253 Type 347 stainless steel tubes each containing UO_2 pellets having a density of 9.71 g/cm^3. The U^{235} content of the uranium was 93.2 wt%. The steel tubes were stacked in a Type 1100 aluminum can, fitted with aluminum shims to preserve the close packing, which, in turn, was surrounded by Type ATL graphite. The thickness of the graphite reflector was the variable which was adjusted in steps to make the assembly critical. The fuel tubes are described in Table I and one is shown, together with the UO_2 pellets,* in Fig. 1. The properties of the assembled core and of the reflector are given in Tables II and III, respectively. The core surrounded by a 6.35-cm-thick reflector is shown in Fig. 2. The core and bottom reflector, resting on the assembly machine described below, are shown in Fig. 3. The assemblies were built on a vertical assembly machine so that the movable part was the core and bottom reflector and the fixed part was the top and side reflectors as shown in Figs. 3 and 4. Figure 5 is a sketch of the assemblies studied illustrating the difference in the reflector in the two cases.

EXPERIMENTAL RESULTS

The reactivity of the first assembly shown in Fig. 5, with the 19.25-cm-thick side reflector, was +7.2 cents and that of the second, with the 24.34-cm-thick side reflector and a thinner top reflector, was +3.4 cents. In both cases the center fuel tube was removed from the core, the bottom graphite reflector was 15.24-cm thick and one of six equally spaced, 1.27-cm-dia radial holes, extending through the side reflector at core midplane, was empty. The five remaining radial holes and one axial hole in the top reflector contained 0.95-cm-dia graphite plugs. The reactivity value of one of these plugs in a radial hole in the 19.25-cm-thick reflector was +1.5 cents. The reactivity value of the center fuel tube was about 32 cents.

*The edges of the pellets were chipped during their removal from the tube preparatory to this photograph.

Table I. Properties of a Typical Fuel Tube

Stainless Steel Tube

Type	347
Length (cm)	30.48
Outside Diameter (cm)	1.27
Wall Thickness (cm)	0.051
Weight with End Caps (g)	45.37
Weight of One End Cap (g)	0.64

Uranium Oxide

Number of UO_2 pellets per fuel tube	26
UO_2 Density (g/cc)	9.71
Mass of UO_2 per tube (g)	295.8
Diameter of pellets (cm)	1.141
Length of one pellet (cm)	1.145
Length of 26 pellets (cm)	29.88

Analyses of Uranium Oxide

Spectrochemical (ppm)		Isotopic (wt%)	
Ag	<40	U^{234}	1.01
Be	< 0.3	U^{235}	93.15
Cr	6 to 40	U^{236}	0.47
Li	< 1.5	U^{238}	5.37
Ni	< 25		
Sn	5 to 25		
Al	3 to 30		
Ca	50		
Cu	3 to 35		
Mg	< 12		
P	< 100		
B	< 1		
Fe	10 to 250		
Mn	< 8		
Ba	< 10		
K	< 50		
Na	< 10		
Si	10 to 50		

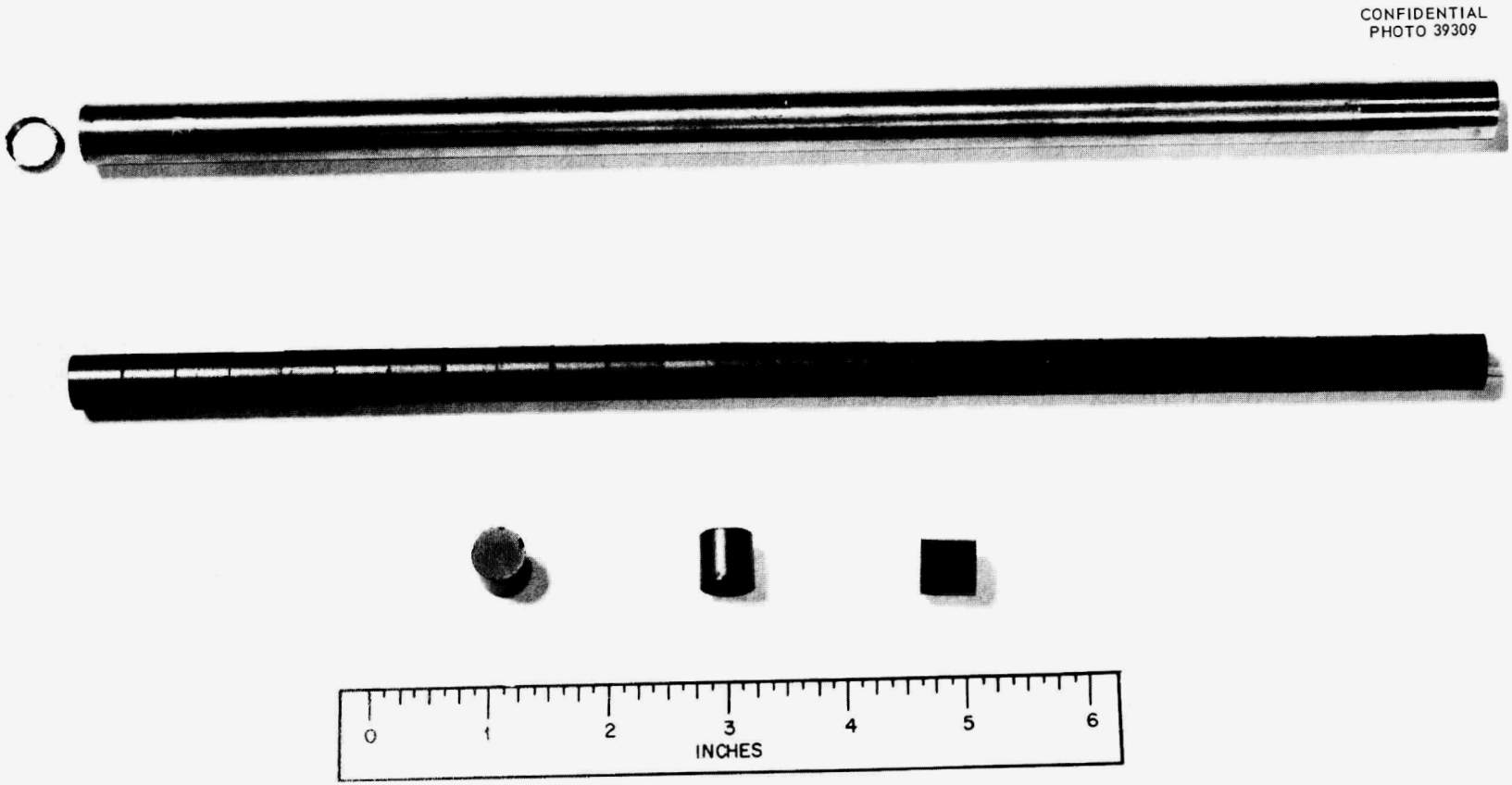

Fig. 1. Fuel Tube and UO_2 Pellets

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Table II. Core Properties

U^{235} Mass (kg)	61.39
UO_2 Mass (kg)	74.84
Stainless Steel Mass (kg)	11.48
Core Tank	
Material	Type 1100 Aluminum
Side Wall Thickness (cm)	0.29
Bottom Thickness (cm)	0.35
Outside Diameter (cm)	22.87
Outside Length (cm)	31.11
Weight (kg)	2.134
Shims for Positioning Fuel Tubes (See Fig. 2)	
Vertical Dimension (cm)	1.91
Shape	∿ 24° and 34° segments of a circle
Total Weight of 24 (g)	185

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Table III. Reflector* Properties

	First Assembly	Second Assembly
Side Reflector - Graphite (Type ATL)		
Thickness (cm)	19.25	24.34
Inside Diameter (cm)	23.07	23.07
Length (cm)	46.63	46.63
Mass (kg)	210.5	298.0
Top Reflector - Graphite (Type ATL)		
Thickness (cm)	12.70	5.08
Diameter (cm)	50.80	50.80
Mass (kg)	42.36	16.94
Bottom Reflector - Graphite (Type ATL)		
Thickness (cm)	15.24	
Diameter (cm)	22.87	
Mass (kg)	11.05	
Additional Bottom Reflector		
Aluminum (Type 1100)		
Thickness (cm)	1.94	
Diameter (cm)	21.60	
Mass (kg)	1.920	
Aluminum (Type 1100)		
Thickness (cm)	0.63	
Diameter (cm)	45.72	
Mass (kg)	2.787	
Stainless Steel (Type 304)		
Thickness (cm)	2.38	
Diameter (cm)	45.72	
Mass (kg)	3.91	
Iron		
Thickness (cm)	1.27	
Inside Diameter (cm)	23.58	
Outside Dimensions (cm)	121.9 x 121.9	
Mass (kg)	137.9	

* See Fig. 5 for the relative location of the various components of the reflector.

Table III. Reflector* Properties (Contd.)

Spectrochemical Analyses of Type ATL Graphite

Element	ppm	Element	ppm
Al	270	Mg	1
Ba	22	Mn	1
B	< 1	Mo	5
Ca	820	Na	3
Co	3	Ni	27
Cr	16	Si	54
Cu	1	Sr	5
Fe	3940	Ti	54
K	5	V	220
Li	2	Y	11
Lu	1	Yb	3

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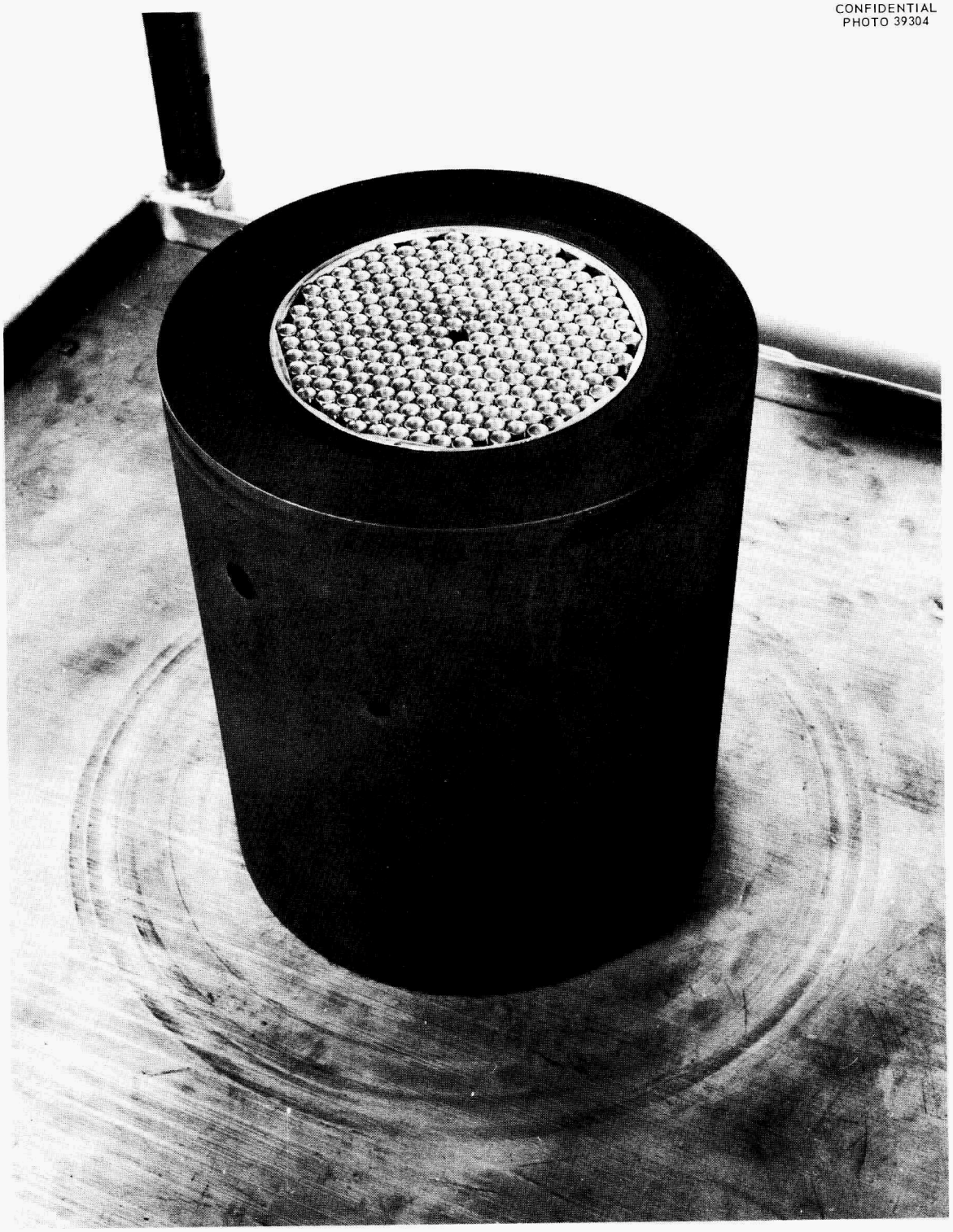

Fig. 2. Core Surrounded by 6.35-cm-thick Reflector

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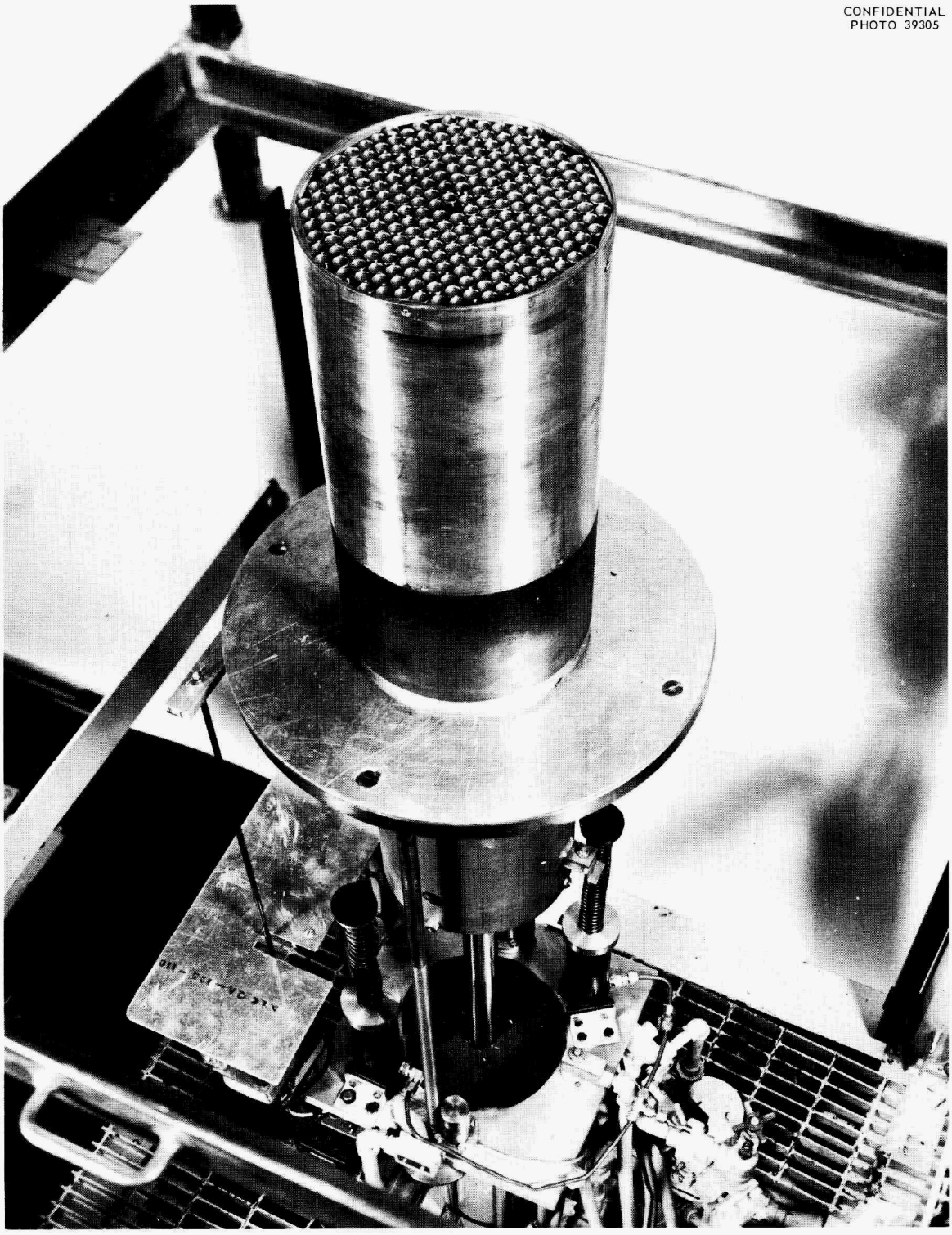

Fig. 3. Core and Bottom Reflector

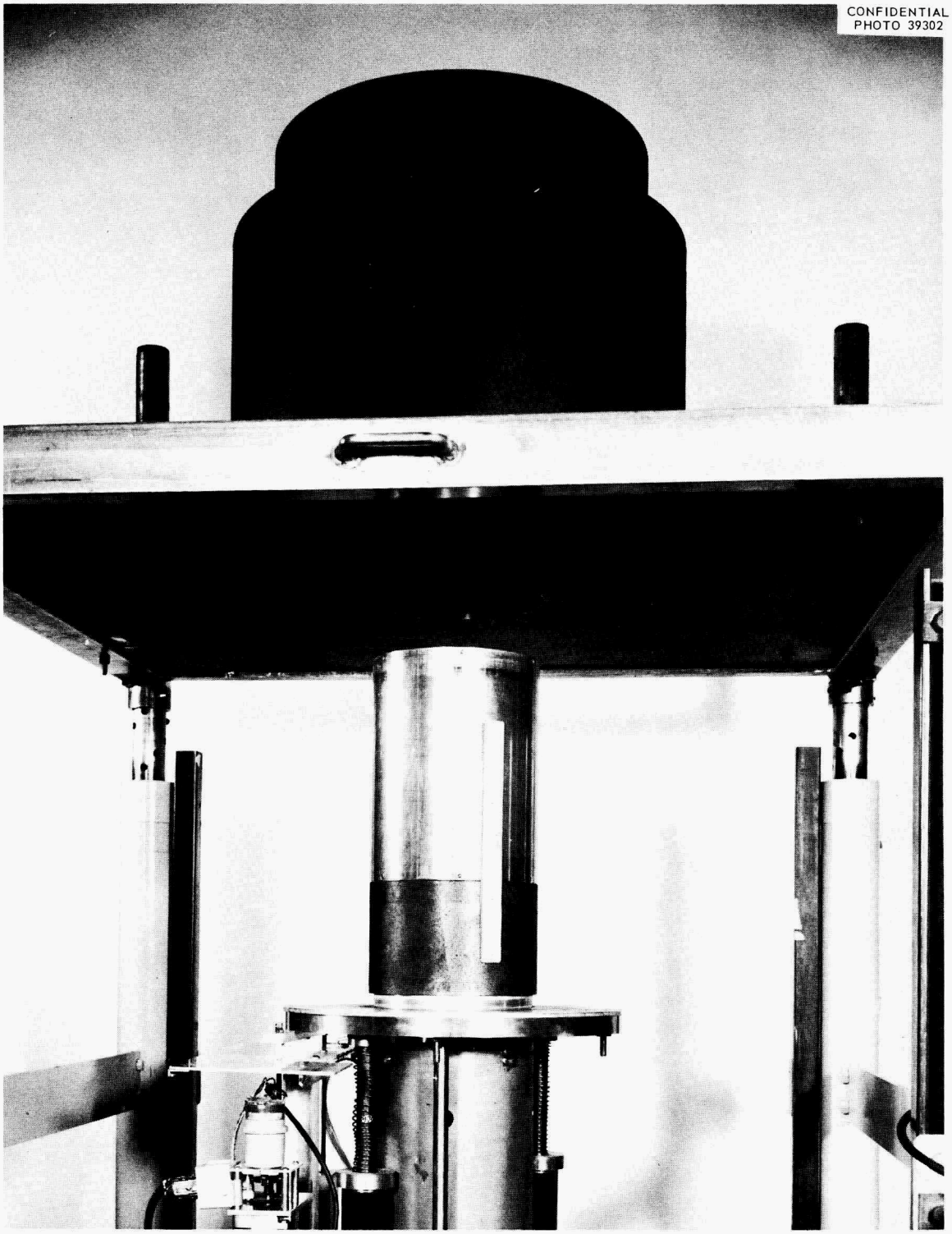

Fig. 4. Typical Assembly Showing Movable Core and Bottom Reflector and Fixed Top and Side Reflectors.

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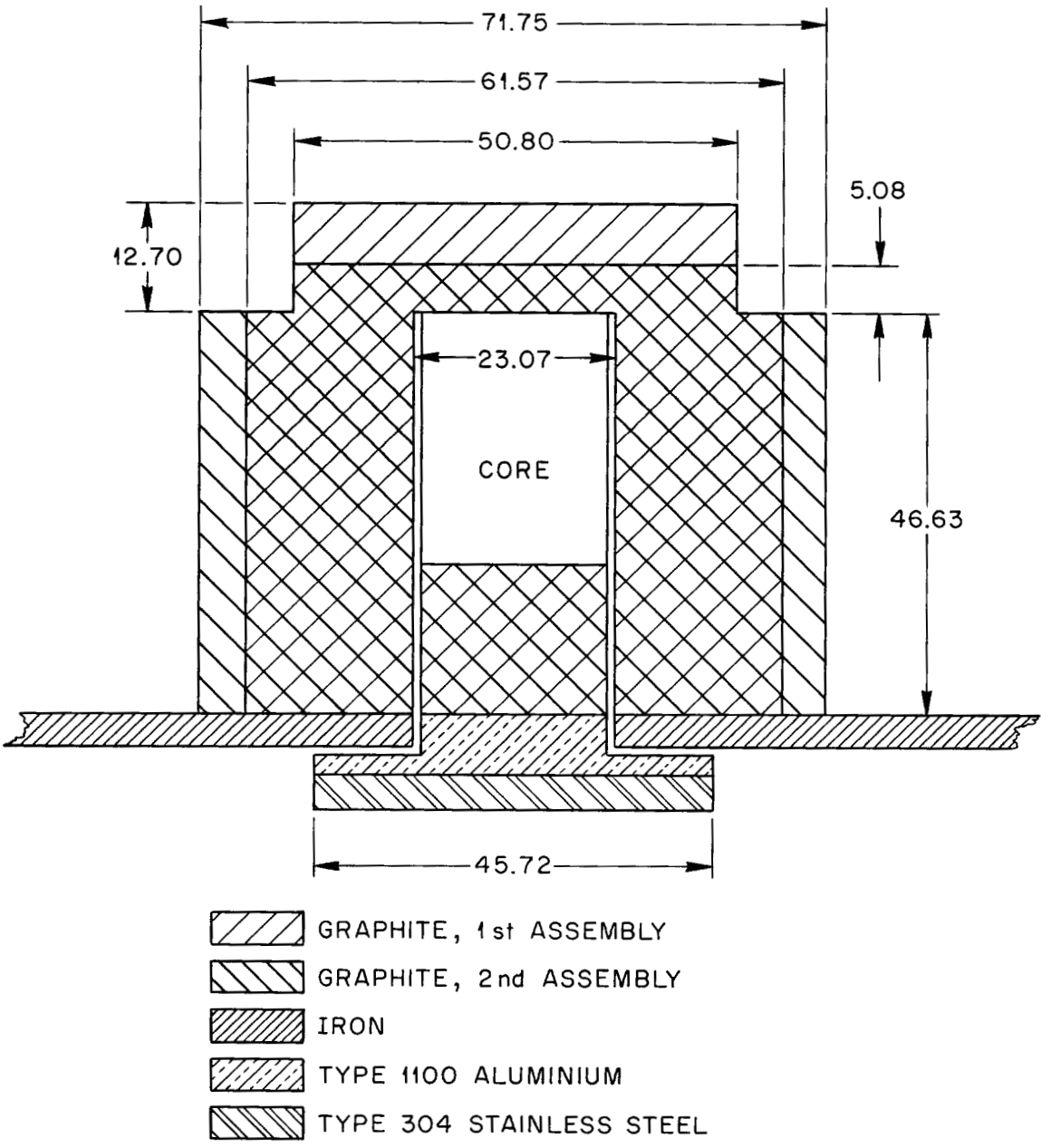

ALL DIMENSIONS IN CENTIMETERS; SEE TABLE III FOR OTHER DIMENSIONS.

Fig. 5. Reflector Arrangement in Two Assemblies

Fission rate distributions were measured with a 2.5-cm-long, 0.64-cm-dia U^{235}-fission counter along the (vertical) axis of the core in both assemblies. The fission rate as a function of the distance from the bottom of the core is plotted in Figs. 6 and 7 from the data of Table IV. The radial flux distributions and U^{235} cadmium ratios* through the 19.25-cm-thick side reflector were measured at the midplane of the core of the first assembly using as detectors 0.75-cm-dia x 0.010-cm-thick uranium metal foils with a U^{235} enrichment of 93.2 wt%. The cadmium covers were 0.051 cm thick. Table V summarizes the results of the foil measurements which are plotted in Fig. 8. The data from the axial and radial traverses in the first assembly are expressed in the same arbitrary units and show that the peak of the radial fission rate distribution in the reflector is almost a factor of 3.5 larger than that in the center of the core.

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* The cadmium ratio is defined as the bare to cadmium covered foil activations.

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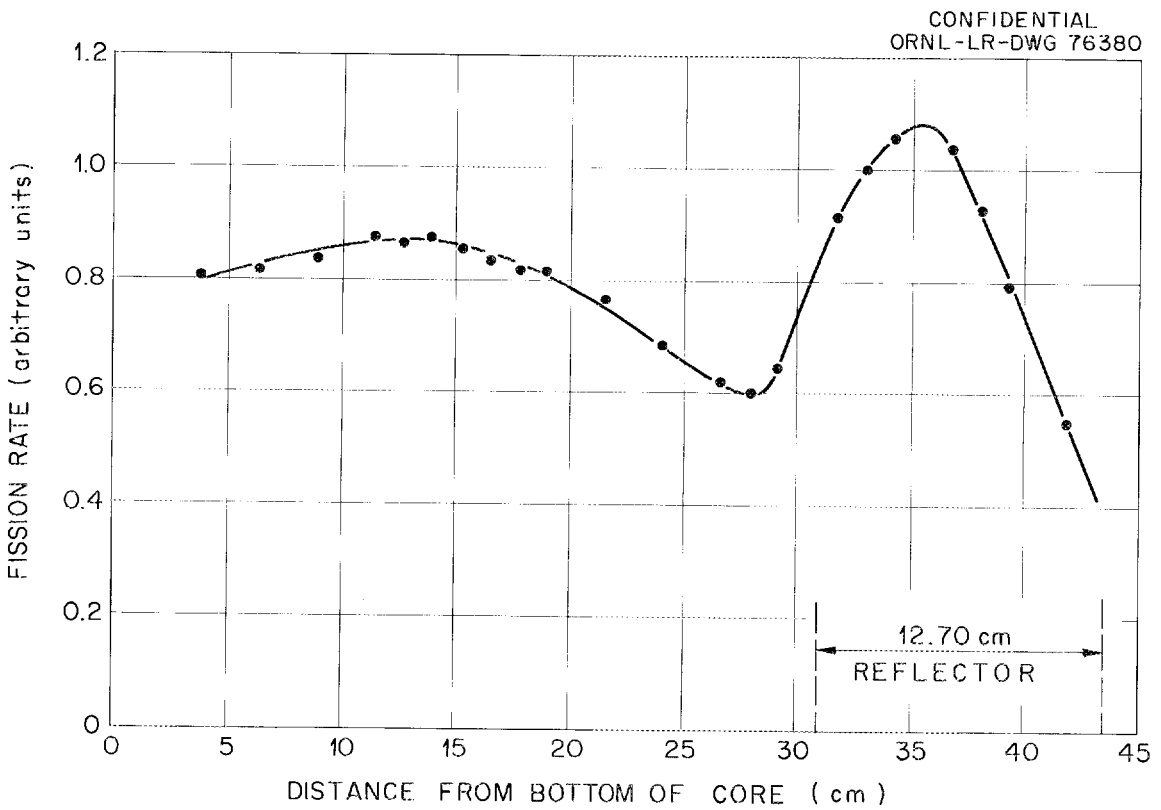

Fig. 6. Axial Fission-Rate Distribution in the First Assembly

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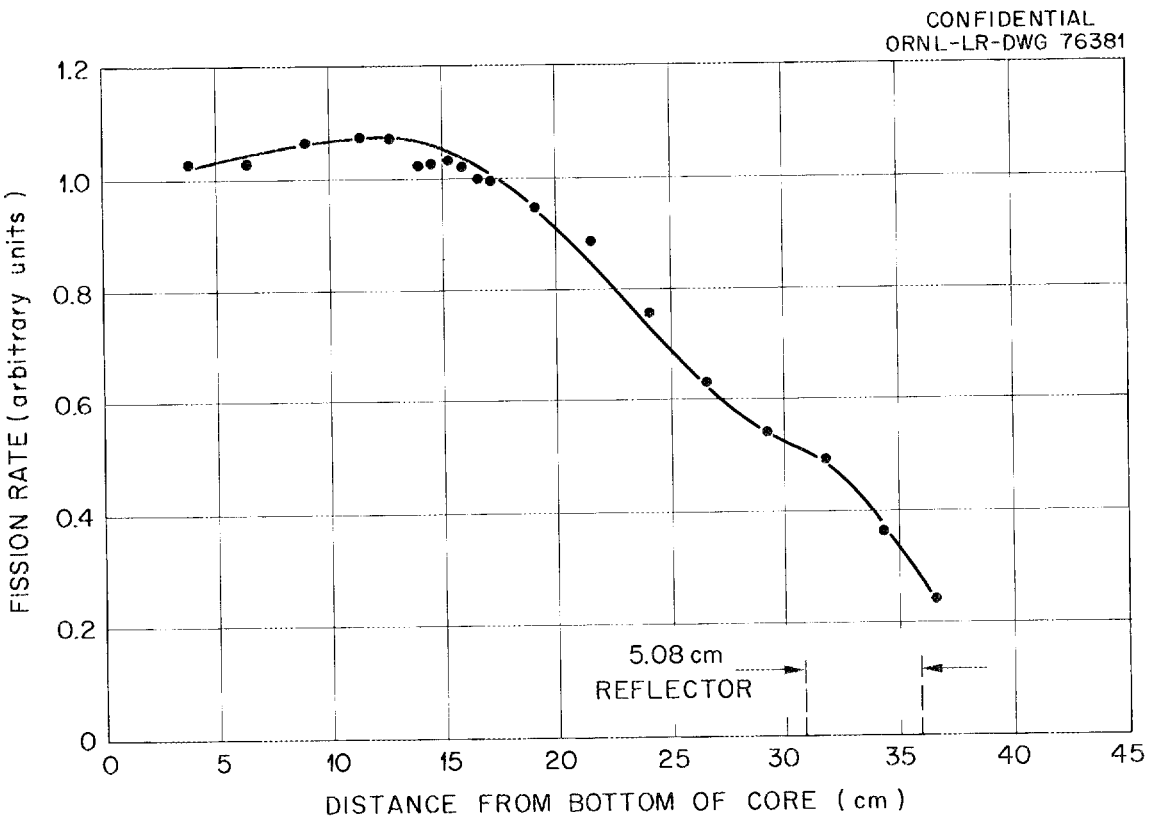

Fig. 7. Axial Fission-Rate Distribution in the Second Assembly

Table IV. Axial U^{235}-Fission Rate Distributions

Distance[a] from Bottom of Core (cm)	Fission Rate[b] (Arbitrary Units) First Assembly (12.70-cm-thick Top Reflector)	Second Assembly (5.08-cm-thick Top Reflector)
3.81	0.81	1.03
6.35	0.82	1.03
8.89	0.84	1.07
11.43	0.88	1.07
12.70	0.86	1.07
13.97	0.88	1.02
14.60	-	1.03
15.24	0.85	1.04
15.87	-	1.02
16.51	0.84	1.00
17.14	-	0.99
17.78	0.82	-
19.05	0.82	0.95
21.59	0.77	0.89
24.13	0.68	0.75
26.67	0.62	0.63
27.94	0.60	-
29.21	0.64	0.54
31.75	0.91	0.50
33.02	1.00	-
34.29	1.06	0.37
36.83	1.04	0.24
38.10	0.93	-
39.37	0.80	-
41.91	0.55	-

a. Measured from the bottom of the stainless steel fuel tubes.
b. The detector was a U^{235} fission counter 2.5 cm long x 0.64 cm diameter.

Table V. Radial Fission Rate Distribution Through the 19.25-cm-thick Reflector

Distance from Core (cm)[a]	Relative Activity	Cadmium Ratio
0.0	1.68	-
0.5	1.92	1.77
1.0	2.25	1.81
2.0	2.43	1.92
3.5	2.84	2.03
5.5	3.19	2.18
6.5	3.19	-
8.0	3.08	2.34
10.5	2.92	2.43
13.0	2.25	2.35
16.0	1.54	2.41

a. Measured from the core-reflector interface.
b. The detectors were 0.010-cm-thick x 0.75-cm-dia, 93.2%-U^{235}-enriched uranium metal foils. Cadmium covers were 0.051 cm thick.

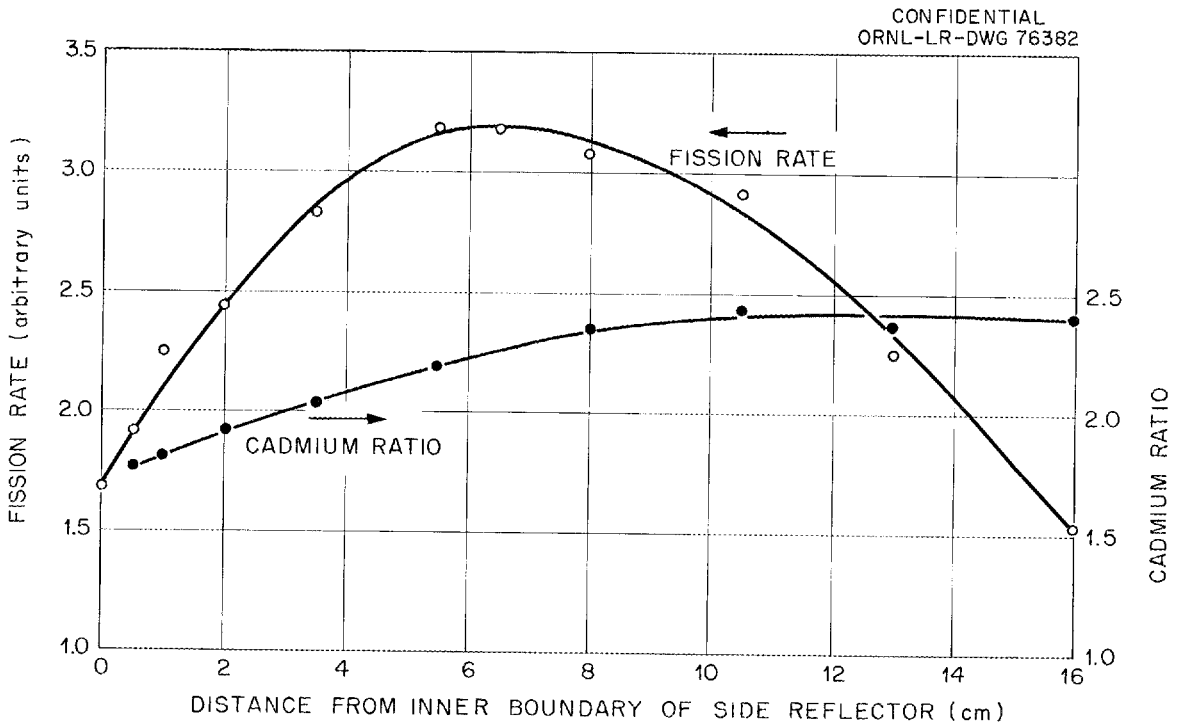

Fig. 8. Radial Fission-Rate and Cadmium-Ratio Distributions in the Side Reflector of the First Assembly. Traverses made at core midplane.