

Critical and Near-Critical Graphite-Moderated Arrays of U(93.2) Cylinders Revisited

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INTRODUCTION

An experimental series to investigate nuclear criticality in graphite moderated arrays of U(93.2)[†] metal cylinders was conducted from November 1968 to June 1969 at the Oak Ridge Critical Experiments Facility. Only a portion of the data was published in open literature at the time [1], which has since limited related information in subsequent citation. [2]

A review of both formal [3] and informal [4, 5] documentation by the original experimentalists for the complete results of the series reveals that some of the data published in open literature is in error of a potentially non-conservative nature for safety applications. This summary presents the corrected and previously unpublished data to more accurately and completely disseminate knowledge of this work.

EXPERIMENTAL DESCRIPTION

The arrays consisted of eight units arranged to form a 2 x 2 x 2 cubic lattice at table closure on a horizontal displacement split table assembly machine. Each unit was a parallelepiped constructed of a two-piece graphite block containing a central cylindrical cavity in which a uranium metal cylinder was placed. The average diameter, height, and mass of the uranium metal cylinders were 11.494 cm, 8.077 cm, and 15.694 kg, respectively.

The uranium metal cylinders were selected for their uniformity from those used in previous studies. [6] The average mass deviation for each cylinder from the mean was less than 3 grams and no single deviation exceeded +5 or -4 grams. Each cylinder also had two 0.508 cm diameter holes diametrically located 8.547 cm apart that passed through axes parallel to the major axis. The average radial clearance for a cylinder in the cavity of a graphite block was only about 0.035 cm, while the average clearance above a cylinder was about 0.137 cm.

The Speer Carbon Company Type 873S graphite blocks ($\rho = 1.766 \text{ g/cm}^3$) were stacked in contact with one another on top of a low-density aluminum framework to construct the un-reflected arrays. The axes of the uranium cylinders were parallel.

[†] This is shorthand notation for un-irradiated uranium enriched to 93.2 percent ²³⁵U, by weight. The ²³⁴U, ²³⁶U, and ²³⁸U contents were 1.0, 0.2, and 5.6 percent by weight, respectively.

In the reflected arrays, pieces of square aluminum tubing, thin aluminum sheet, and/or narrow plywood strips were used to separate the blocks from one another and from the inside surface of the 15.2 cm thick polyethylene ($\rho = 0.925 \text{ g/cm}^3$) reflector. The inside surface of the reflector was displaced from the surface of the uranium cylinders one-half the surface-to-surface spacing of the cylinders themselves. An illustrative photograph is provided in Figure 1.

More than 164 multiplication measurements were made for nine basic arrays. A substantial number determined the worth of small physical adjustments to accurately measure the observed positive or negative reactor period. Many investigated the contribution of room return and structural support, particularly for the un-reflected assemblies.

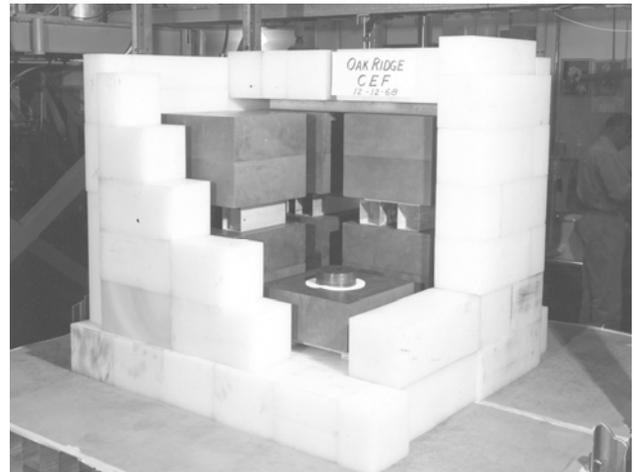


Fig. 1. A partially disassembled polyethylene-reflected array on a horizontal displacement split table assembly machine at table closure.

RESULTS

Pertinent dimensions of the arrays and their respective experimentally determined criticality conditions are given in Table I. The use of **highlighted** text identifies previously unpublished data and the use of *italicized* text indicates corrections to previously published data.

TABLE I

Experimentally Determined Criticality Conditions for Graphite-Moderated Arrays of U(93.2) Cylinders

Surface-to-Surface Spacing (cm)		Graphite Blocks	Array U Density ^b (g/cm ³)	Experimental ^c k _{eff}
U Cylinders ^a Side	End			
25.59	22.91	— ^d	0.368	0.996 ± 0.001
20.52	17.82	— ^d	0.591	0.993 ± 0.001
15.42	12.78	— ^d	1.038	0.990 ± 0.001
10.35	7.68	— ^d	2.088	0.992 ± 0.001
5.27	2.59	— ^d	5.234	— ^e
28.78	26.08	8.255 ^f	0.283	0.9995 ± 0.0004
23.68	21.04	8.255 ^f	0.436	0.9995 ± 0.0004
18.60	15.93	8.255 ^f	0.721	0.9999 ± 0.0004
13.84	11.16	8.573 ^f	1.270	0.9994 ± 0.0004

- Errors on surface separations are ± 0.02 cm for the un-reflected arrays and ± 0.03 cm for the reflected arrays
- Inferred average from array mass and dimension
- Corrected for room return and structural support based on assumed $\beta = 0.007$
- Un-reflected array with graphite blocks in contact
- Critical prior to table closure, indeterminate final k_{eff}
- Array had 15.2 cm thick polyethylene reflector

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