[redacted]

OAK RIDGE NATIONAL LABORATORY

operated by

UNION CARBIDE CORPORATION

for the

U.S. ATOMIC ENERGY COMMISSION

UNION CARBIDE

ORNL - TM - 264

26

CRITICAL MASS STUDIES

PART XII: ROVER REACTOR FUEL ELEMENTS

E. B. Johnson
J. K. Fox

SPECIAL REREVIEW FINAL DETERMINATION
CLASS. U AUTH. ______
REVIEWERS/VERIFIERS CLASS. DATE
(1) [illegible] U 7-23-80
(2) [illegible] U 7-22-80
M. Day

CLASSIFICATION CANCELLED
authority [illegible]
4-4-73
DATE AUG 24 1973
[illegible]
DECLASSIFICATION OFFICER
OAK RIDGE NATIONAL LABORATORY
AUTHORITY DELEGATED BY AEC 1-14-71

[redacted]

[redacted]

NOTICE

[redacted]

ORNL-TM-264

Contract No. W-7405-eng-26

Neutron Physics Division

CRITICAL MASS STUDIES

PART XII: ROVER REACTOR FUEL ELEMENTS

E. B. Johnson
J. K. Fox

Date Issued

SEP 18 1962

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee
operated by
UNION CARBIDE CORPORATION
for the
U. S. ATOMIC ENERGY COMMISSION

[redacted]

[redacted]

TABLE OF CONTENT

[redacted]

ABSTRACT

Critical experiments were performed with fuel elements for the Project Rover KIWI-B-2A reactor to determine nuclearly safe conditions for their production, storage, and transportation. Each element is a 0.746-in.-dia and 50.5-in.-long uranium carbide-graphite cylinder containing seven uniformly spaced longitudinal holes. The uranium concentration is 400 mg/cm^3, of which 93.15% is U^{235}, yielding a C:U^{235} atomic ratio of about 90. Throughout the experiments each element was encased in a sealed aluminum tube. In order to establish both the minimum critical number of water-moderated and -reflected elements and the relationship between moderation and critical number, several critical arrays covering a wide range of moderation were assembled. It was found that the minimum critical number of 66 elements, containing about 5 kg of U^{235}, occurred at an H:U^{235} atomic ratio of 380. The critical number of unmoderated elements in a reflected array was greater than 2500.

Experiments were also performed with uranium oxide-graphite elements from an early stage of production. The minimum critical number of full-length elements in a moderated and reflected array was 40, containing about 4.6 kg of U^{235}. The H:U^{235} atomic ratio was 270.

Several additional experiments established that the designs of the shipping containers and graphitizing fixture used for the elements are conservative.

[redacted]

CRITICAL MASS STUDIES
PART XII: ROVER REACTOR FUEL ELEMENTS

E. B. Johnson, J. K. Fox

INTRODUCTION

The maintenance of nuclear safety in the production, storage, and transportation of nuclear materials demands that requisite criteria be established and enforced in order that a critical system will not be produced. Of necessity, large safety factors are often incorporated in these criteria because of the lack of relevant supporting experimental data. The primary purpose of the experiments here reported was to provide data useful as bases for specifying safe and efficient procedures for Project Rover fuel elements.

The scope of these experiments was wide. The areas of investigation included the determination of optimum lattice spacing and minimum critical number of both uranium carbide and uranium oxide elements moderated and reflected by water; measurement of the neutron multiplication in an array of elements latticed in graphite, a condition found in a production operation; and the comparative evaluation of Foamglas and polyurethane as packaging materials.

It is pointed out that experiments were done only with lattices of essentially finished elements, mostly enclosed in watertight aluminum containers. The results should not be extrapolated to well-homogenized aqueous slurries of uranium oxide which might result from prolonged exposure of uranium carbide elements to water.

DESCRIPTION OF FUEL ELEMENTS

The Project Rover fuel elements used in this series of experiments were designed for the KIWI-B-2A reactor. Those used in most of the experiments were composed of 93.15% U^{235}-enriched uranium carbide and graphite, with a C:U^{235} atomic ratio of 90, from which the organic binder had been removed.[*] In a few experiments it was necessary to use uranium oxide elements withdrawn from an early step in production.

Except as noted, the uranium carbide elements used in these experiments were 50.5 in. long and had a diameter of 0.746 in. Each element contained seven uniformly spaced longitudinal holes having nominal diameters ranging from 0.150 to 0.172 in.; by design all holes in a particular element were not necessarily of the same diameter. A

* The truly finished elements have a 2- to 3-mil-thick columbium carbide liner which extends approximately 18 in. of the length of each of the seven longitudinal holes and a columbium carbide coating on one end. None of the elements used in these experiments had been lined or coated.

portion of the lateral surface was fluted. Figure 1 is a sketch of the elements.* The uranium concentration was 400 mg/cm^3. Because of the variation in the quantity of material in the elements due both to intentionally different dimensions and to the fact that all elements had not been finally machined, the U^{235} content ranged between 70.4 and 81.8 g per element. In most of the arrays this range was limited, however, to between about 72 and 77 g, with an average of ~76 g. The carbide elements were installed in 0.84-in.-OD aluminum tubes with a 0.030-in. wall thickness. The ends of the tubes were closed with stoppers to prevent contact with moist air or water and to prevent mechanical damage. (Contact of uranium carbide with water results in the evolution of acetylene and in swelling of the element.)

As a consequence of the sealed tubes there was always about 190 cm^3 of air associated with each element, occupying the holes in the elements and the space between the element and the tube. Since the effective inside length of the aluminum tubes was about 53 in. and the elements were only 50.5 in. long, sponge rubber packing had been placed in the tube between one end of the element and the stopper.

In addition to the uranium carbide elements, which were always enclosed in tubes, a limited number of uranium oxide-graphite elements were made available. This is the condition of the elements at an early stage of production, before the high-temperature firing which transforms the uranium oxide to uranium carbide and completes the removal of the residual organic binder.** The $H:U^{235}$ atomic ratio at this stage of production is 1.47. No machining had been done on these elements. They were 51 in. long and had a measured average diameter of 0.775 in. The seven longitudinal holes averaged 0.135 in. in diameter. In order to minimize contamination, the elements were sprayed with plastic prior to experimental use.

EXPERIMENTAL EQUIPMENT

Equipment for Water-Moderated and -Reflected Experiments

The experiments with water-moderated and -reflected arrays of fuel were performed in a 9-ft-dia stainless-steel-lined tank, equipped with remotely operated fill and dump systems for demineralized water. The size of the tank permitted essentially infinite side and top water reflector on all arrays. In order to ensure hydrogenous reflector at the bottom of the arrays, a plastic table 12 in. high with a perforated top was placed on the floor of the tank and a Unistrut framework was used to rigidly support the tubes vertically on the table. Spacing between elements (or tubes) was usually established by milled plastic strips between the units as shown in Fig. 2. The tubes containing the elements were always positioned so that the ends of the elements lay in a plane.

---

* The elements are described on Y-12 Plant drawing E-M-36188, Rev. A.

** These are often designated as "second bake" elements.

[redacted]
ORNL-LR-DWG 70919

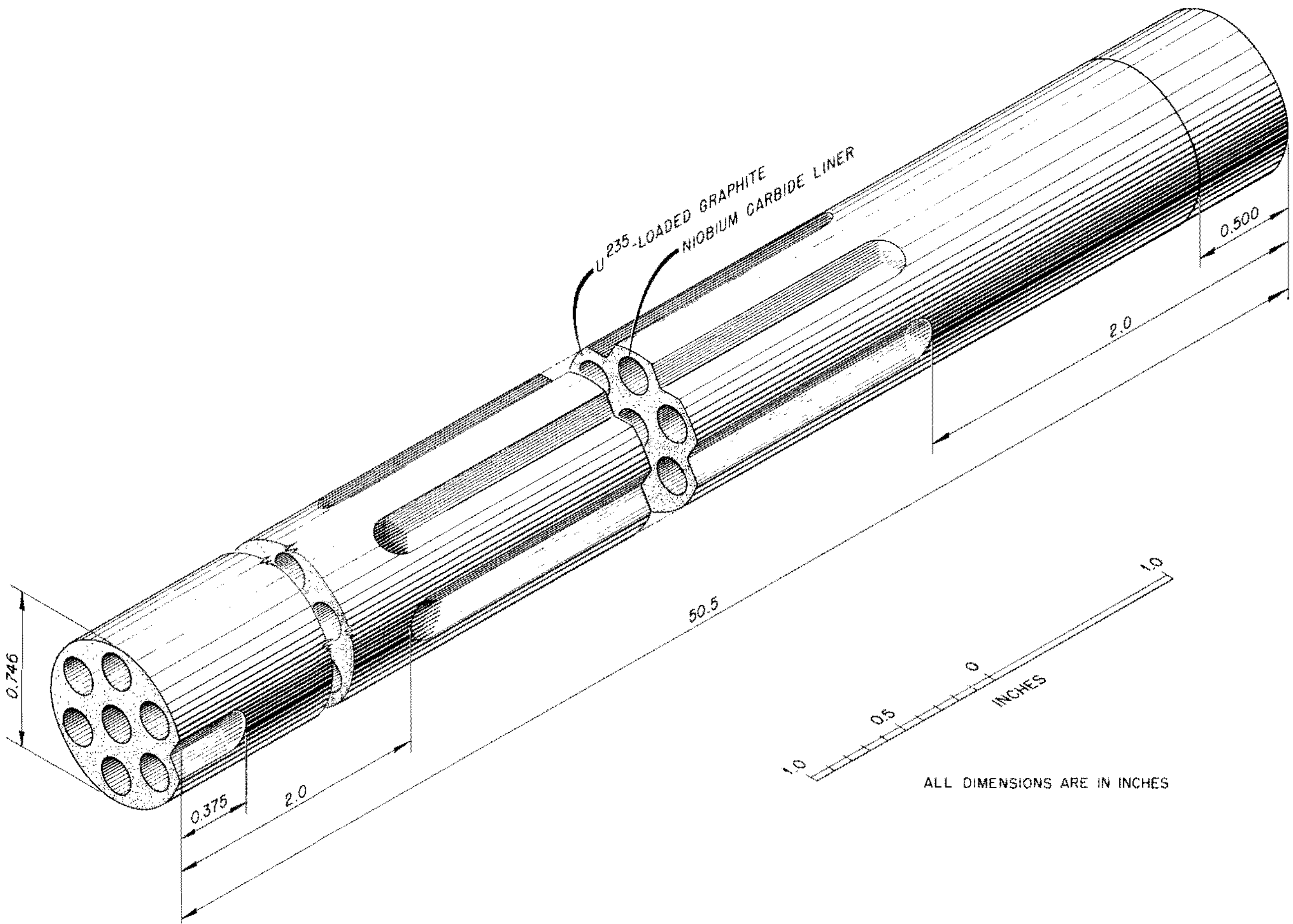


Fig. 1. Rover Reactor Fuel Element.

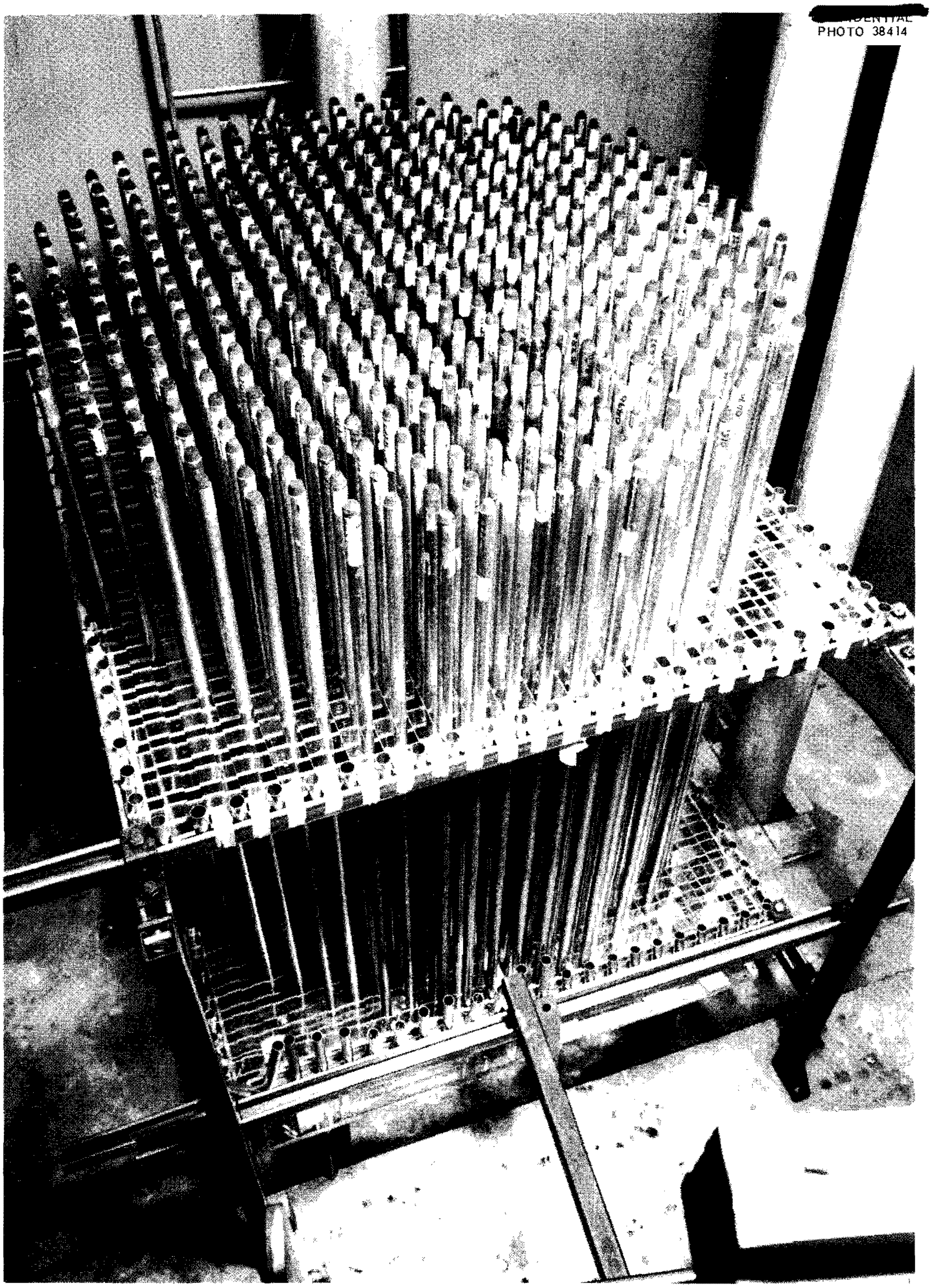


Fig. 2. Uranium Carbide Fuel Elements Encased in Aluminum Tubes Arranged in a Square Lattice.

The instrumentation was standard. Because of the presence of water, the BF_3 ion chambers, used as monitors, and the BF_3 proportional counters for neutron multiplication measures were placed inside watertight aluminum tubes or thimbles which were kept at least 6 in. from an array in order to minimize perturbations in the reflector. The neutron source was usually located at one side of an array and could be remotely withdrawn into its shield.

Safety was afforded by the water dump system and by a safety blade consisting of a corrugated stainless-steel-encased cadmium sheet, guided close to one side of an array and supported by an electromagnet.

All arrays were stacked in the absence of water and with an audible neutron counter monitoring any possible neutron multiplication. Flooding was accomplished remotely. Any alteration in an array required draining the water from the tank.

Equipment for Unmoderated Experiments

The split table apparatus described by Rohrer _et al_.[1], was employed in the experiments with unmoderated uranium carbide fuel elements. On each table an aluminum angle frame was mounted on an aluminum grid which served as a low-density support. Each frame was capable of holding 1247 fuel tubes horizontally in a close-packed triangular lattice. When the tables were brought together, a nearly perfect hexagon of 2494 fuel tubes was made. The frames were built with 8-in.-high legs so that large pieces of polyethylene or paraffin reflector at least 6 in. thick could enclose the fuel tubes. The tubes at the plane of separation were held in the frames by 1/16-in.-thick stainless steel strips fastened to the vertical aluminum angle in order to minimize the separation between the two halves of the array when the tables were closed. However, because of bowing of these strips with the addition of fuel tubes, the final separation between the halves was about 0.14 in. at the top of the array with all tubes in place and completely reflected; the tubes at the bottom of the array were in contact. Figure 3 shows the racks mounted on the split table and completely filled with fuel tubes.

The nuclear instrumentation was standard and included additional counting channels which were used to make neutron source multiplication measurements in order to better estimate the critical number of elements from measurements on significantly subcritical arrays.

EXPERIMENTAL RESULTS

Uranium Carbide Fuel Elements

In order to determine the minimum critical number of elements and the more general relationship between moderation and critical number

1. E. R. Rohrer, W. C. Tunnell, and D. W. Magnuson, "Neutron Physics Division Ann. Rep. Sept. 1, 1961," ORNL-3193, p. 171.

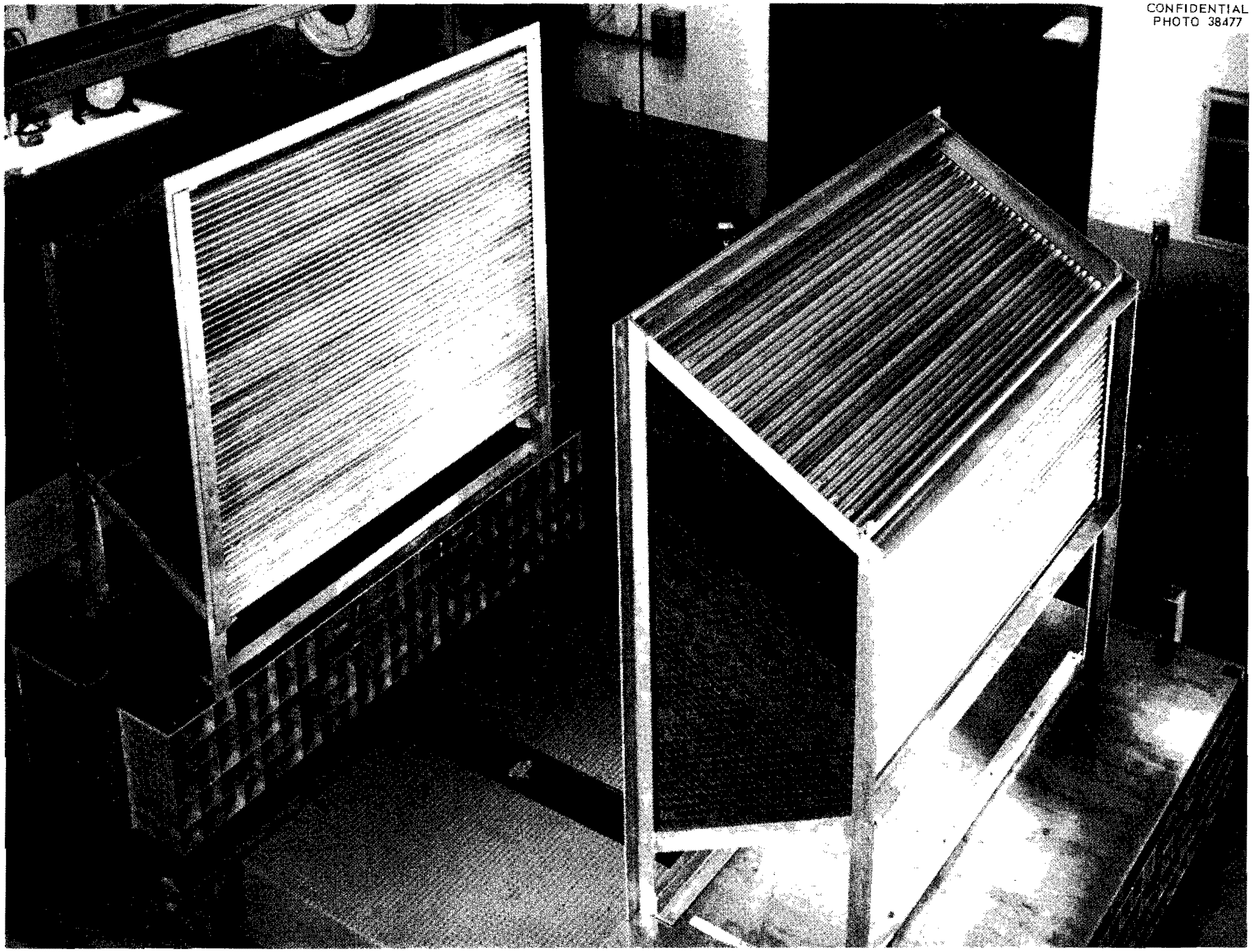


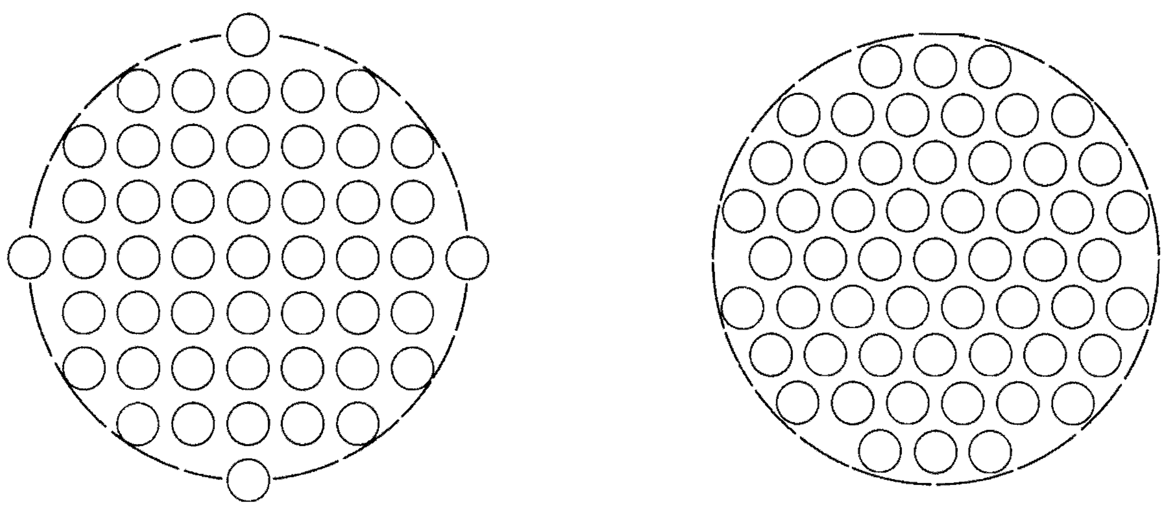
Fig. 3. Unmoderated Fuel Tubes Arranged in a Close-Packed Triangular Lattice.

several arrays of elements in their tubes were assembled in both square and triangular lattices. Square and triangular lattices are, respectively, arrangements of fuel units such that, in plan view, lines joining the centers of the units form a square or an equilateral triangle. Figure 4 shows diagramatically the two types of lattices and how each may be assembled into "rounded" arrays. One such rounded array of a square lattice was shown in Fig. 2, and Fig. 5 is a photograph of a large triangular-lattice array with the tubes in contact. The hexagonal outline of the latter was retained by filling the corners with open ended, empty aluminum tubes.

Table 1 is a summary of the data obtained with the water-moderated and -reflected arrays of fuel elements in aluminum tubes. The side-to-side spacing was determined by the thickness of the spacers and was verified by measurement of the arrays. The critical number of elements was experimentally determined, in most cases, by observing that the quoted number was indeed critical or, in some cases, by bracketing the critical number by two loadings, one being slightly subcritical and the other slightly supercritical. The uncertainty indicated for the number is perhaps excessive provided the average uranium content per element is within 2% of that listed. Since, however, fractional elements were not available and since, as discussed below, the uranium content of individual elements varied by more than 2%, the indicated uncertainty in the critical number of elements is felt to be realistic. In several cases the actual average uranium content of the elements in an array was determined. In other arrays of randomly selected elements, this average U^{235} content, 75.9 g, was assumed. The critical volume of an array includes the moderator water associated with the peripheral elements. The height of the core was assumed to be defined by the length of the fuel, i.e., 50.5 in., and no additional water layer was added to this dimension.

An investigation was made of the effect of variation in fuel element uranium content on critical mass at a side-to-side spacing of 0.535 in. in a square lattice, reflected and moderated. Using randomly selected uranium carbide elements ranging in U^{235} content between 72.2 and 80.6 g (average 76.21 g) per element, the array was critical with 68 elements containing a total of 5.182 kg of U^{235}. The experiment was repeated with elements of more nearly equal uranium content, ranging between 75.0 and 77.7 g of U^{235} per element (average 76.22 g). The critical number then was also 68, containing 5.183 kg of U^{235}. It was subsequently found necessary to substitute 58 elements of low uranium content (average 73.06 g) for 58 elements of normal content in order to increase the critical number by two. The average U^{235} content was thereby reduced from 76.22 g to 73.53 g and the critical mass was unchanged within the limits of the measures. The data are summarized in Table 2. It was concluded that the uncertainty in the critical number arising from the random selection of elements was no greater than that shown in Table 1.

UNCLASSIFIED
ORNL-LR-DWG 58124 R1



SQUARE LATTICE
ROUNDED ARRAY

TRIANGULAR LATTICE
ROUNDED ARRAY

Fig. 4. Diagrams of Lattices and Arrays.

[redacted]

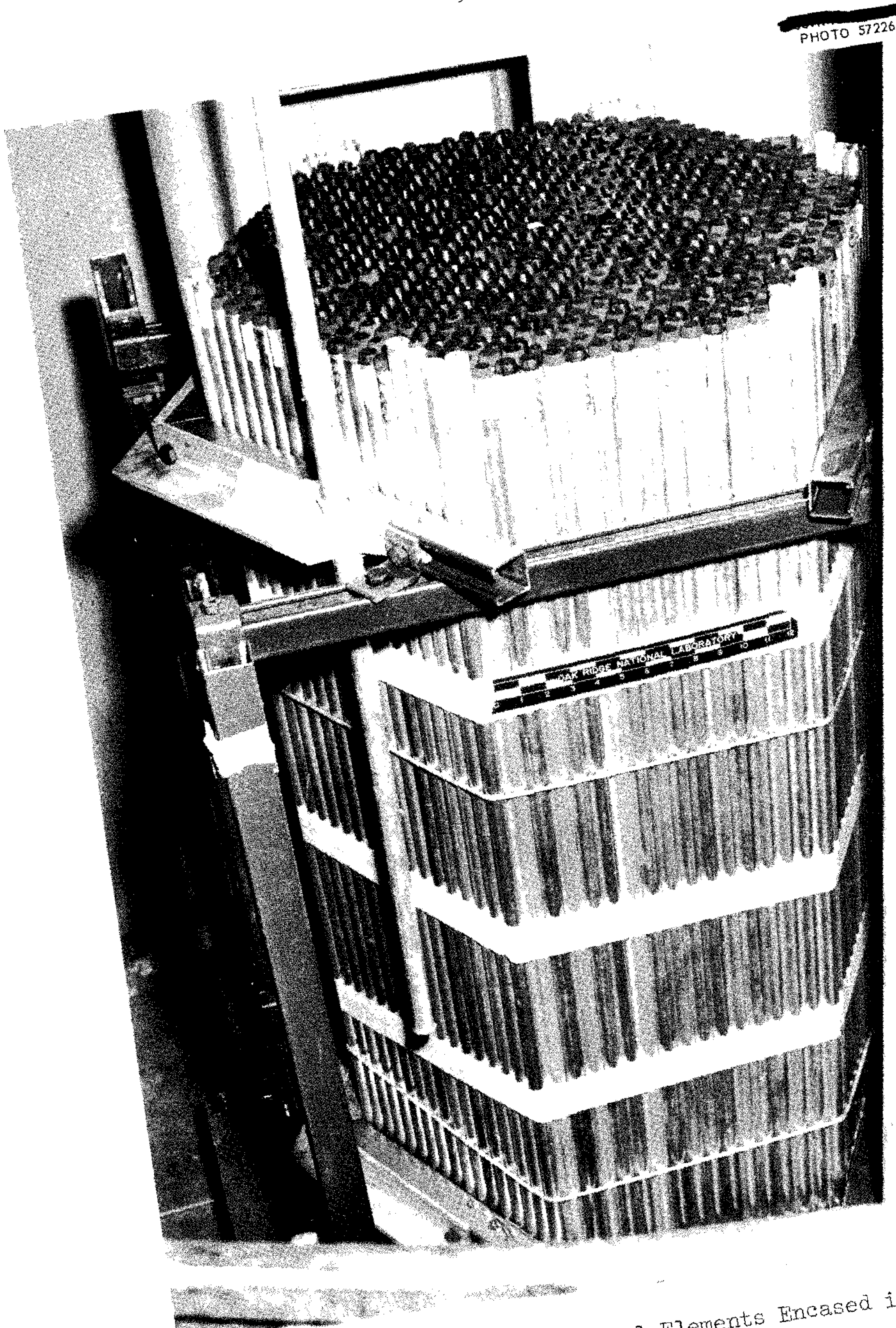


Fig. 5. Uranium Carbide Fuel Elements Encased in Aluminum Tubes Arranged in a Close-Packed Triangular Lattice.

Table 1. Summary of Water-Moderated and -Reflected Critical Arrays of Uranium Carbide Elements Encased in Sealed Aluminum Tubes

Element Spacing Side-to-Side (in.)	Critical Number of Elements	Average Element U^{235} Content (g)	$H:U^{235}$ Atomic Ratio	Critical Mass (kg of U^{235})	Critical Volume (liters)	Volume of Moderator Water (liters)	Volume Fraction of Water in Fuel Region
			Square Lattice, Rounded Arrays				
0.00	318 ± 2	75.9*	43	24.14 ± 0.15	185.8	39.9	0.215
0.11	139 ± 2	75.9*	99	10.55 ± 0.15	103.9	40.1	0.386
0.31	79 ± 1	75.51	220	5.96 ± 0.08	86.5	50.2	0.580
0.42	70 ± 1	75.77	295	5.30 ± 0.08	92.0	59.9	0.651
0.535	68 ± 1	76.21	379	5.18 ± 0.08	106.5	75.2	0.706
0.62	69 ± 1	76.06	448	5.25 ± 0.08	121.8	90.1	0.740
0.85	89 ± 1	75.75	657	6.74 ± 0.08	210.5	169.6	0.806
1.02	142 ± 1	75.64	830	10.74 ± 0.08	406.8	341.6	0.840
1.20	480 ± 5	75.9*	1026	36.43 ± 0.38	1654	1433	0.866
			Triangular Lattice, Rounded Arrays				
0.00	796 ± 3	75.9*	16	60.42 ± 0.23	402.8	37.5	0.093
0.0625	316 ± 2	75.9*	43	23.98 ± 0.15	184.6	39.6	0.215
0.26	104 ± 1	75.96	140	7.90 ± 0.08	90.2	42.5	0.471
0.50	70 ± 1	75.9*	285	5.31 ± 0.08	90.1	58.0	0.644
0.63	66 ± 1	75.9*	375	5.01 ± 0.08	102.2	72.0	0.704
0.75	68 ± 1	75.9*	466	5.16 ± 0.08	123.3	92.1	0.747
1.12	120 ± 1	76.72	780	9.21 ± 0.08	330.5	275.5	0.833

* The average uranium content of an element in these arrays was the average of those elements used in the other arrays.

Table 2. Variation of Critical Mass with U^{235} Content of Elements (Square Lattice, 0.535 in. Side-to-Side Spacing; Water Reflected and Moderated; $H:U^{235} = 380$)

Critical Number of Elements	U^{235} Content (g/element) Range	Average	Critical Mass (kg of U^{235})
68	72.2 - 80.6	76.21	5.182
68	75.0 - 77.7	76.22	5.183
70	70.6 - 77.7	73.53	5.147

It is again pointed out that these experiments utilized elements sealed in aluminum tubes which prevented water from filling the longitudinal holes in the elements and which entrapped air adjacent to the element. The volume of these spaces is estimated at 190 cm^3. The arrays are, therefore, undermoderated compared to what they would be in the absence of the tubes. The addition of water into the holes in the elements would probably decrease the critical mass somewhat since this water would be in regions of greater than average importance. Experiments attempted to substantiate this supposition and to evaluate it were unsuccessful because the rate of evolution of acetylene from a wetted element was too great to allow stable operation of a critical assembly.

Figures 6 through 8 are plots of the data summarized in Table 1. It can be seen from these curves that the minimum critical number of uranium carbide elements, and therefore the minimum critical mass of the array, occurred at spacings of about 0.54 in. and 0.64 in. for the square and triangular lattices, respectively, both corresponding to an $H:U^{235}$ atomic ratio of 380. The minimum critical mass observed was about 5 kg of U^{235}. The minimum critical volume of about 86 liters occurred at an $H:U^{235}$ atomic ratio of 200, as shown in Fig. 8.

Up to 2494 of the uranium carbide fuel elements* were stacked in a close-packed, unmoderated triangular lattice both unreflected and with an effectively infinite polyethylene and paraffin reflector. Source neutron multiplication measures were made at intervals as stacking progressed in order to estimate the critical number in both cases. Although there is considerable uncertainty in the results because of the long extrapolation, it is estimated that as few as 3500 and 4400 elements, with and without reflector, respectively, might be critical. More probable critical numbers are 4000 and 6000 elements. These results have allowed a guided extrapolation of Figs. 7 and 8.

*In order to acquire a sufficiently large inventory, it was necessary to use some elements which were only 48.9 in. long. The resultant small irregularity at the ends of the array was felt to be unimportant.

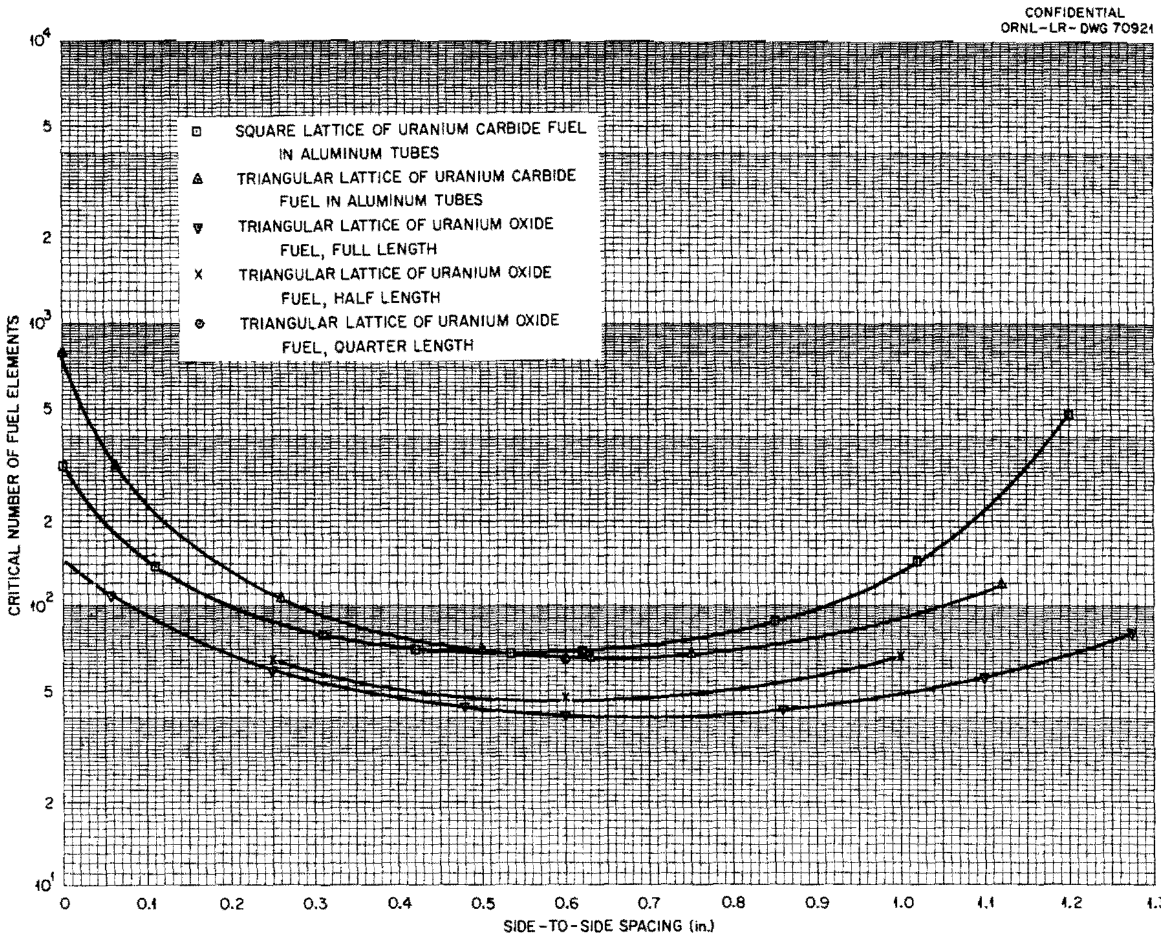


Fig. 6. Critical Number of Fuel Elements vs Side-to-Side Spacing.

CONFIDENTIAL
ORNL-LR-DWG 70923

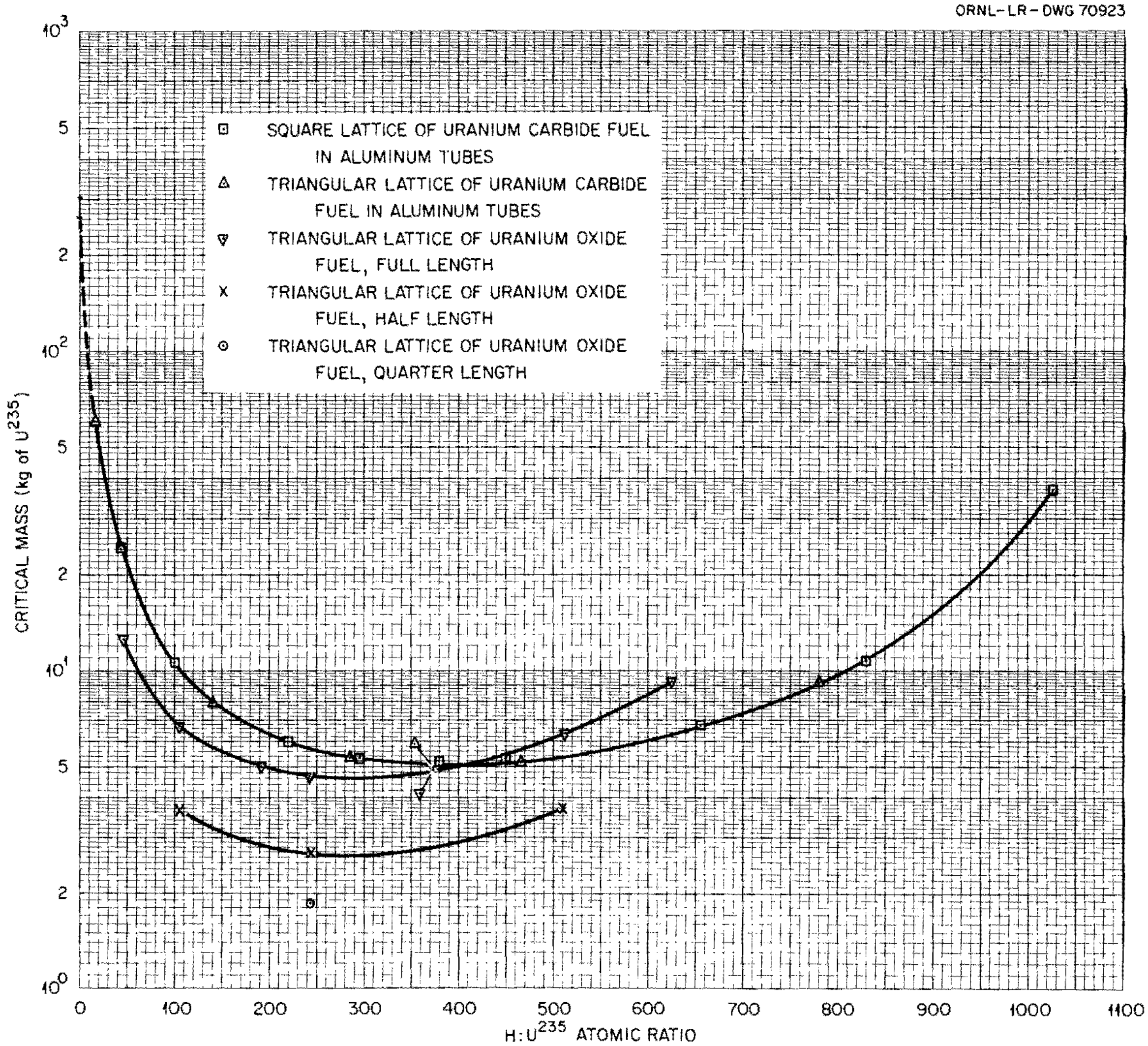


Fig. 7. Critical Mass of Fuel Elements vs H:U^{235} Atomic Ratio.

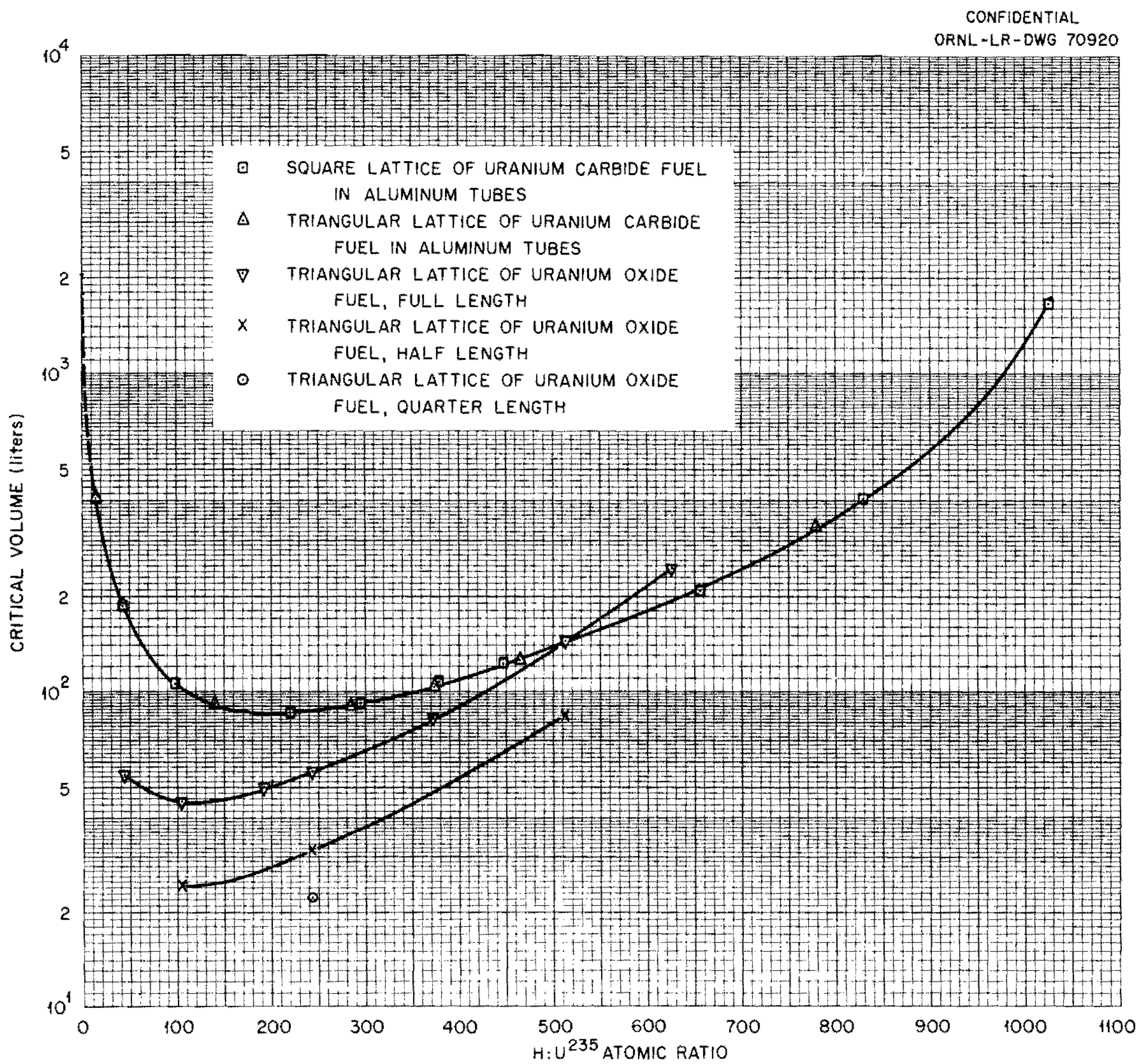


Fig. 8. Critical Volume of Arrays of Fuel Elements vs $H:U^{235}$ Atomic Ratio.

Uranium Oxide Fuel Elements

Water-reflected and moderated triangular lattices were constructed with the uranium oxide-graphite elements. Since these elements were not in aluminum tubes, the water not only surrounded the element but also entered the small longitudinal holes. The results of these experiments are summarized in Table 3 and are plotted with the data from the uranium carbide fuel elements in Figs. 6 through 8. It will be noted that the moderation at which the critical number of uranium oxide elements is minimal has shifted from that for the uranium carbide elements, possibly due to the absence of air and aluminum in the arrays of the oxide elements.

The result of replacing fuel elements in the center of an array by water was determined in the following experiments. A triangular lattice of the elements, water-reflected and -moderated, was built with a side-to-side spacing of 0.25 in. ($H:U^{235} = 104$). The critical number of elements was determined to be 59 ± 1. Removal of the central element and the first ring of six necessitated, for criticality, the addition of two elements in the fourth ring and six in the fifth ring* for a total of 60. Further removal of the 12 elements in the second ring required the addition of 24 elements in the fifth ring and five in the sixth. The critical number was then 77 ± 1.

The critical array of smallest mass of the full length oxide elements had a side-to-side spacing of 0.60 in. This array was 51 in. high and had an apparent diameter of 10 in. In order to improve the geometry, some of the oxide elements were cut in half, producing units 25.5 in. long. A sufficient number of the half-length elements were again cut in half to produce a still shorter (12.75 in.) critical array at a lattice spacing of 0.60 in. The apparent diameter of this array was almost 13 in. and the critical mass was reduced by a factor of 2.5 from that observed with the full length elements. The results obtained with these fuel units are summarized in Table 3 and are plotted in Figs. 6 through 8. These results can be predicted by equating values of the buckling using an extrapolation distance of 7 cm.

MISCELLANEOUS EXPERIMENTS

Shipping Container Experiments

Shipment of fuel elements requires that they be packaged in such a way that they will suffer no damage from mechanical shock and that no criticality hazard will arise should several shipping containers accumulate. Consequently, the shipping boxes for Project Rover elements have been designed to preclude these difficulties. Twenty seven of the shipping boxes

*The elements in partially filled rings were centered on the faces of the hexagon.

Table 3. Summary of Water-Moderated and -Reflected Arrays of Uranium Oxide-Graphite Fuel Elements in Triangular Lattices

Spacing Side-to-Side (in.)	Critical Number[a]	Average Element U^{235} Content[b] (g)	Element Length (in.)	$H:U^{235}$ Atomic Ratio	Critical Mass (kg of U^{235})	Critical Volume (liters)	Volume of Moderator Water (liters)	Volume Fraction of Water in Fuel Region
0.00	>109	114.0	51.0	30	Not critical			
0.058	109 ± 5	114.0	51.0	45	12.4 ± 0.6	54.7	20.9	0.381
0.25	59 ± 1	114.0	51.0	104	6.73 ± 0.12	44.8	26.5	0.591
0.48	44 ± 1	114.0	51.0	191	5.02 ± 0.12	50.1	36.5	0.727
0.60	41 ± 1	114.0	51.0	243	4.67 ± 0.12	56.1	43.4	0.773
0.86	43 ± 1	114.0	51.0	373	4.90 ± 0.12	83.2	69.8	0.839
1.10	56 ± 1	114.0	51.0	512	6.38 ± 0.12	142.5	125.1	0.878
1.275	81 ± 1	114.0	51.0	626	9.23 ± 0.12	246.3	221.1	0.898
0.25	64 ± 1	57.0	25.5	104	3.65 ± 0.06	24.3	14.4	0.591
0.60	46.5 ± 0.5	57.0	25.5	243	2.65 ± 0.03	31.8	24.6	0.773
1.10	66 ± 1	57.0	25.5	512	3.76 ± 0.06	83.9	73.7	0.878
0.60	65 ± 1	28.5	12.75	243	1.85 ± 0.03	22.2	17.2	0.773

a. The critical number refers to the number of units in a critical array, whether they be full length, half length, or quarter length.

b. The average uranium content was determined from the total uranium content of the 109 elements available; the uranium content of individual elements at this stage of production was unavailable. The weights of 57.0 and 28.5 g represent elements which had been cut in half or quarters, respectively. It was assumed that no uranium was lost in cutting.

currently in use* have been assembled at the Los Alamos Scientific Laboratory in an essentially cubic array with concrete reflector on three sides, and with a neutron source and appropriate detectors. Each box contained 48 fuel elements packed in foamed polyurethane. A neutron multiplication of about two was observed and extrapolation of the subcritical multiplication curve indicated that 68 boxes would be required to build a critical array.[2] In order to provide experimental data for possible redesign of the present shipping container, experiments were performed with materials and geometries of interest. The maximum array of interest was specified as one consisting of 15 close-packed rows of aluminum tubes containing uranium carbide fuel elements, adjacent rows being separated by the potential packing material. The rows were to be 30 in. long, containing 36 tubes, and were to be separated by 1-in.-thick layers of Foamglas, polyurethane, or borated polyurethane. All of these are "expanded" materials containing a large volume of closed gas-filled spaces which cannot fill with water when submerged. The composition of the polyurethane is given in Table 4.

Table 4. Analysis of Polyurethane[a]

Element	wt%
Carbon	64.44
Nitrogen	5.78
Hydrogen	8.08
Water	0.7
Chlorine	0.08
Sulfur	0.007
Oxygen	20.9
Ash	$<$ 0.01[b]

a. Analysis supplied by H. D. Whitehead, Y-12 Plant. The borated polyurethane was made by adding 5 wt% amorphous natural boron to the base material.
b. Spectrochemical analysis of the ash showed trace quantities of a number of metallic elements.

As a preliminary step toward evaluating the effectiveness of these possible packing materials, rows of fuel tubes were arranged as shown in Fig. 9. Each row contained 36 elements in contact and adjacent rows were spaced 1 in. apart. It was determined that an array consisting of four rows of fuel tubes was quite subcritical but that the addition of 18 tubes at the center of the fifth row resulted in criticality when the

---

* Y-12 Plant Dwg. No. E-C-36555, Fuel Element Facility Shipping Container.

2. Letter from H. C. Paxton, LASL, to W. T. Mee, Y-12 Plant, "Multiplication of an Array of Shipping Containers Loaded with KIWI-B-2A Fuel Elements," April 1962.

CONFIDENTIAL
ORNL-LR-DWG 70918

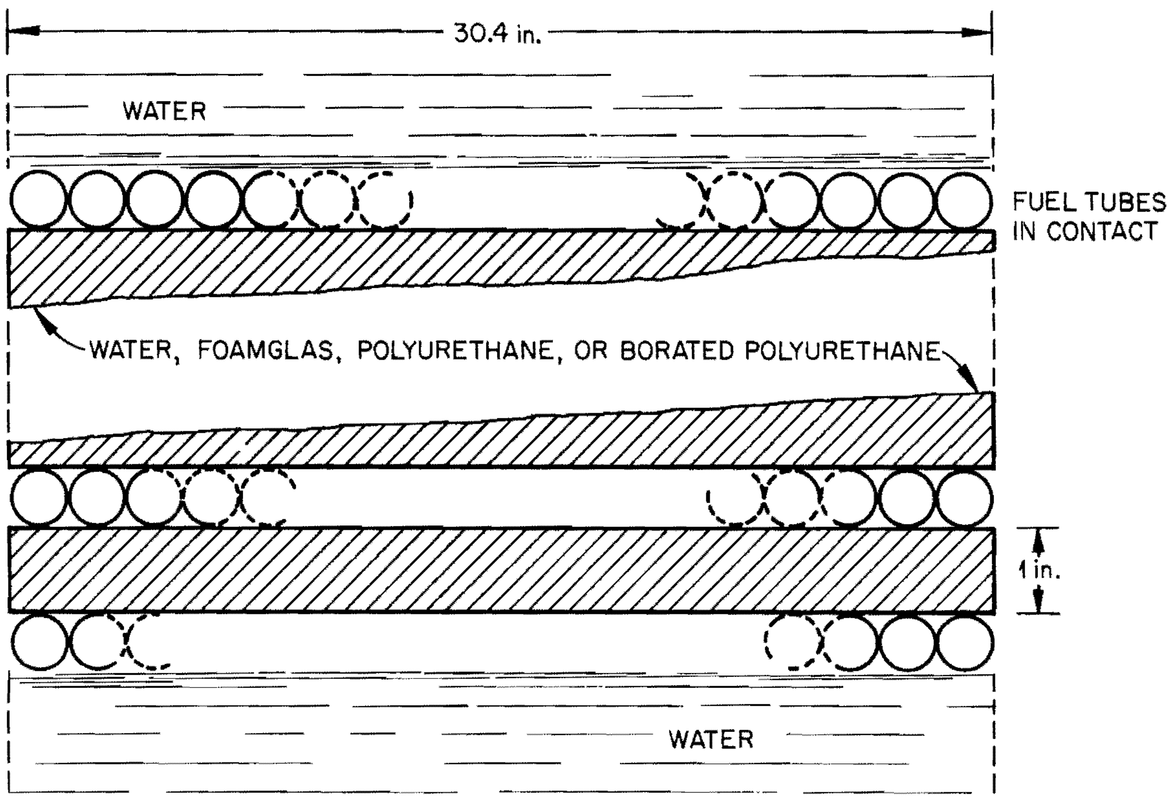


Fig. 9. Plan View of the Arrangement of Components in the Shipping Container Experiments.

array was half-flooded. It was estimated, therefore, that an array consisting of 153 elements in four complete rows with nine additional elements in the center of the fifth row would be critical when flooded. The $H:U^{235}$ atomic ratio of a flooded array was ~ 282.

Slabs of Foamglas 1 in. thick (density = 0.141 g/cm^3) containing 1.6 ± 0.2 wt% natural boron were placed between the rows of fuel tubes. A total of 15 rows of fuel tubes (540 elements) separated by 14 slabs of Foamglas showed no significant neutron multiplication when flooded. If it is assumed that the Foamglas contained no hydrogen, the $H:U^{235}$ ratio of this array was 43.

Slabs of both ordinary and borated polyurethane, 1 in. thick, were available for two additional experiments. The density of the former was 0.032 g/cm^3 and that of the borated plastic, which contained 5 wt% natural elemental boron, was 0.041 g/cm^3. (It is noted that the urethane density of the latter is greater than that of the nonborated material.)

An array identical to the one described above except that it had only 13 rows of fuel tubes (468 elements) separated by either ordinary or borated polyurethane was subcritical when completely flooded. For the next experiment, plastic was removed from between the two outermost rows on each side of the array, leaving eight slabs between the nine most central rows of tubes and water in the space between the outer rows. When the array contained ordinary polyurethane it was critical when 66 cm of the fuel was immersed. Replacing the ordinary plastic with borated plastic required increasing the water height to 107 cm for criticality. The $H:U^{235}$ ratio in the region containing the plastic was 50.

Graphitizing Fixture Experiment

Conversion of uranium oxide to uranium carbide, one of the operations in the production of elements, is accomplished by firing at high temperature. This operation is currently performed with the elements supported in longitudinal holes in a cylindrical annulus of graphite called a "fixture." The present fixture has outside and inside diameters of about 12 and 7 in., respectively, is 56 in. long, and can accommodate 60 elements. The outer diameter is fixed by the furnace dimensions, but the diameter of the axial hole, which is necessary for handling purposes, is dictated by conservative safety considerations predicated on the assumption that the furnace might become flooded. It was desirable to establish that the design was truly conservative.

Were the diameter of the center hole only 2 in., it would be possible to drill 109 longitudinal holes in the annulus in which to place fuel elements, thereby increasing the production rate provided nuclear safety would not be compromised.

In order to determine whether such a fixture loaded with 109 elements would be critical should it become flooded, one was fabricated of AGOT graphite as shown in Fig. 10. It was mounted on a grating in the tank to

UNCLASSIFIED
ORNL-LR-DWG 70922

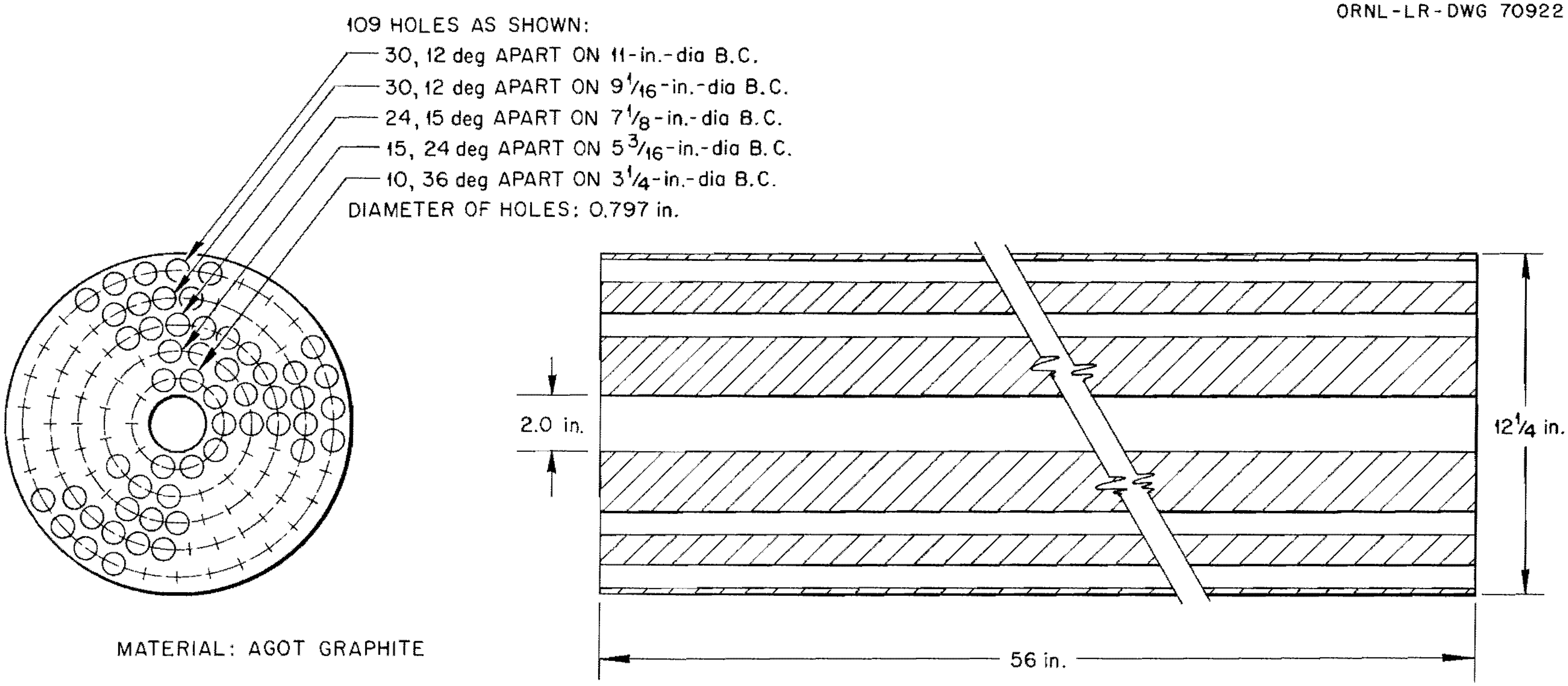


Fig. 10. Graphitizing Fixture.

ensure water entering the holes in the fuel elements and was found to be subcritical when fully loaded with uranium oxide fuel elements and flooded. The $H:U^{235}$ atomic ratio within each hole of the flooded fixture was 26. Extrapolation of the source neutron multiplication curve obtained as successive inner rings of elements were removed indicated that 115 elements might be critical in such a configuration.

ACKNOWLEDGEMENTS

The authors wish to express their appreciation to the several people who have made significant contributions toward the completion of these experiments: to D. W. Magnuson and C. Cross for performing the unmoderated experiments; to W. T. Mee, F. G. Welfare, and W. T. Crow of the Y-12 Plant for their efforts in designing the experiments and in obtaining the materials; to R. K. Reedy and F. G. Welfare for considerable assistance in performing the moderated experiments; to E. R. Rohrer for instrumentation; and to W. C. Tunnell for the design and procurement of special equipment.

Internal Distribution

1. E. P. Blizard
2. E. B. Johnson
3. F. R. Bruce
4-8. A. D. Callihan
9. J. T. Thomas
10. D. W. Magnuson
11. J. D. McLendon, Y-12
12. W. T. Mee, Y-12
13. F. M. Tench, Y-12
14. F. G. Welfare, Y-12
15. L. E. Burkhart, Y-12
16. H. G. T. Snyder, Y-12
17. R. G. Jordan, Y-12
18. W. H. Jordan
19. A. M. Weinberg
20-21. Central Research Library (CRL)
22. Document Reference Section (DRS)
23-25. Laboratory Records (LRD)
26. Laboratory Records - Record Copy (LRD-RC)

External Distribution

27. J. K. Fox, Phillips Petroleum Company, Idaho Falls, Idaho
28. W. R. Stratton, Los Alamos Scientific Laboratory
29-30. H. C. Paxton, Los Alamos Scientific Laboratory
31. L. D. P. King, Los Alamos Scientific Laboratory
32. O. C. Kolar, University of California, Lawrence Radiation Laboratory, Livermore
33. R. D. Baker, Los Alamos Scientific Laboratory
34-35. S. A. Szawlewicz, U. S. AEC, Germantown, Md.
36. C. L. Schuske, Rocky Flats Plant, Dow Chemical Company, Denver, Colorado
37-51. Division of Technical Information Extension (DTIE)
52. Research and Development Division (ORO)