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LA-4798-MS

UC-46
Reporting Date: March 1974
Issued: May 1974

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UNITED STATES
ATOMIC ENERGY COMMISSION
CONTRACT W-7405-ENG. 36

Printed in the United States of America. Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151
Price: Printed Copy $4.00; Microfiche $1.45

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ABSTRACT

The "Honeycomb" critical assembly considered here is a nominal cube of U(93.15) foil and graphite plates regularly interleaved such that the carbon-to-uranium atomic ratio is 170. The assembly description is corrected empirically to a homogeneous near-cube reflected only by a low-density aluminum matrix that extends through the core and to the outside. Critical specifications for checking calculations are given in x, y, z coordinates and in equivalent r, z coordinates.

Other quantities useful as computational checkpoints are spectral indexes, typified by $\bar{\sigma}_f(\text{U-235})/\bar{\sigma}_f(\text{U-238}) = 110$, and central reactivity contributions of foil samples at various thicknesses. Effective reactivity coefficients of ^{238}U, thorium, tungsten, and molybdenum change significantly with sample thickness, whereas the reactivity coefficient of ^{235}U is essentially constant at 9.4 ¢/g-atom for thicknesses up to 0.028 cm.

BACKGROUND

A simple graphite-uranium critical assembly, the "Honeycomb" cube, was intended to supplement metal systems as a source of effective neutron cross sections in the resonance region. Although the graphite, U(93.15) foil, and the assembly machine were originally obtained for early Rover studies, the assembly is now expected to provide information of more general neutronic interest. Figure 1, for example, indicates ways in which Honeycomb can supplement metal assemblies in contributing to LMFBR neutronics.

So far the program has produced some data that point the way toward better, more extensive results. However, the program has been interrupted and may even be terminated, and this report is a compilation of the more useful information now available, especially reactivity coefficients which yield effective cross sections.

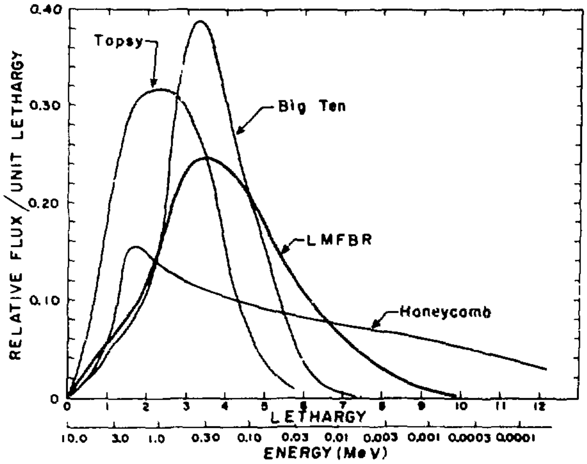

Fig. 1.
Comparison of calculated neutron spectra in LMFBR and various Pajarito assemblies.

THE ASSEMBLY

The Honeycomb assembly is a 122-cm (48-in.) cube of interleaved U(93.15) foil and graphite plates, each 7.1 cm wide, in a larger matrix of 7.62-cm-square aluminum tubes. A 91.4-cm length of the 198-cm-square matrix is on each part of a split-table assembly machine (Fig. 2). Two-thirds of the graphite-uranium cube is mounted on the stationary platform. Each core cluster consists of six 0.71-cm-thick and two 0.46-cm-thick graphite plates with fourteen 0.005-cm-thick uranium foils alternating singly and in pairs. The surrounding tube is of 0.119-cm-thick type 1100 aluminum. Clusters of fuel could be used as safety rods, indicated by the upper vacancies in Fig. 3, while others located below served as control rods.

Specifications. When control and safety rods are inserted, the average densities of materials in the core are

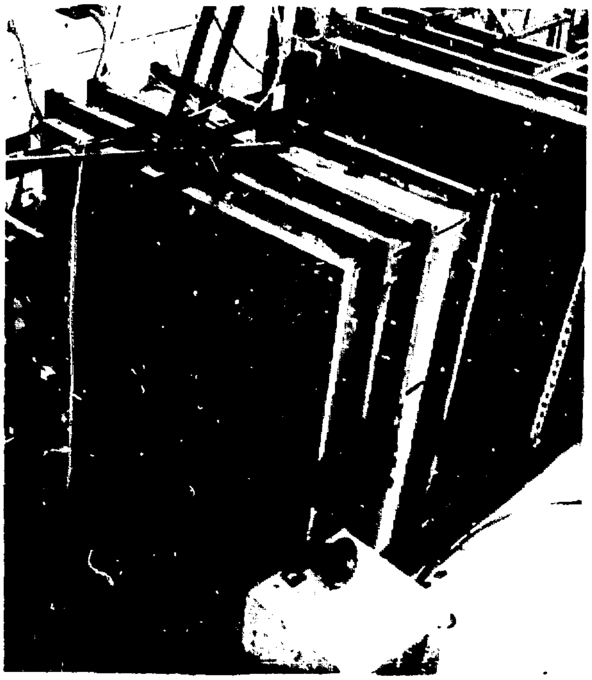

Fig. 2.
Honeycomb critical assembly supported on split-table assembly. The upper retracted core bundles serve as safety rods and the lower bundle serves as a control rod.

ρ(U-235) = 0.1456 g/cm^3,
ρ(U-238) = 0.0107 g/cm^3,
ρ(C) = 1.353 g/cm^3,
ρ(Al) = 0.165 g/cm^3,

Under the same conditions, the assembly would be 1.18$ supercritical with vertical foil-plate laminations as shown in Fig. 3.

Corrections to a homogeneous, simply reflected model are based on several auxiliary experiments. In one case, reactivity changes with changes of uranium foil thickness at constant composition (e.g., 0.06$ increase at 0.020-cm thickness) indicated a negligible 0.02$ reactivity loss in going from the normal average thickness of 0.0076 cm to zero thickness. Then, change from the loosely packed vertical foil-plate laminations (with a 0.25-cm void layer at the top of each matrix tube) to gravity-compacted horizontal laminations (with 0.75-cm void) decreased the reactivity by 0.72$. With further guidance from localized void effects throughout the core, it was estimated that reduction of streaming by removal of the 0.25-cm void layer would lead to a gain of 0.25 ± 0.15$. A single wall of concrete blocks was placed near the asssembly to serve in an assessment of the effect of a concrete-walled room. By extrapolation of the neutron return from this wall, we estimate a total neutron return from a concrete-walled room to be 0.9 ± 0.5¢. The 240-cm-square by 14.3-cm-thick wall, 75 cm from the edge of the core, increased reactivity by 0.27$, and its effect remained unchanged when a 2.5-cm-thick steel plate (like the split-table bed) was placed between the wall and assembly.

These corrections and the experimental excess reactivity led to a deduced excess reactivity of 0.5 ± 0.5$ for a homogeneous 121.9-cm by 122.3-cm-square core of the composition listed above, unreflected except for the surrounding aluminum matrix. The small departure from a cube shape is caused by imperfectly packed modules. A three-dimensional description (Table I) includes a void on the median plane for thin 15.2-cm-square samples used in measurements of reactivity contributions. The equivalent radii (r_{eff}) for an r,z description were obtained as follows. A buckling conversion with 4.45-cm extrapolation distance gave the core radius, the fractional cross section of the sample cavity was maintained, and lateral reflector thickness was not changed.

Other Characteristics. The spectral indexes measured in Honeycomb are the effective cross-section ratios $\bar{\sigma}_f$(U-235)/$\bar{\sigma}_f$(U-238) = 110, and $\bar{\sigma}_f$(U-238)/$\bar{\sigma}_{n,p}$(Al) = 101.

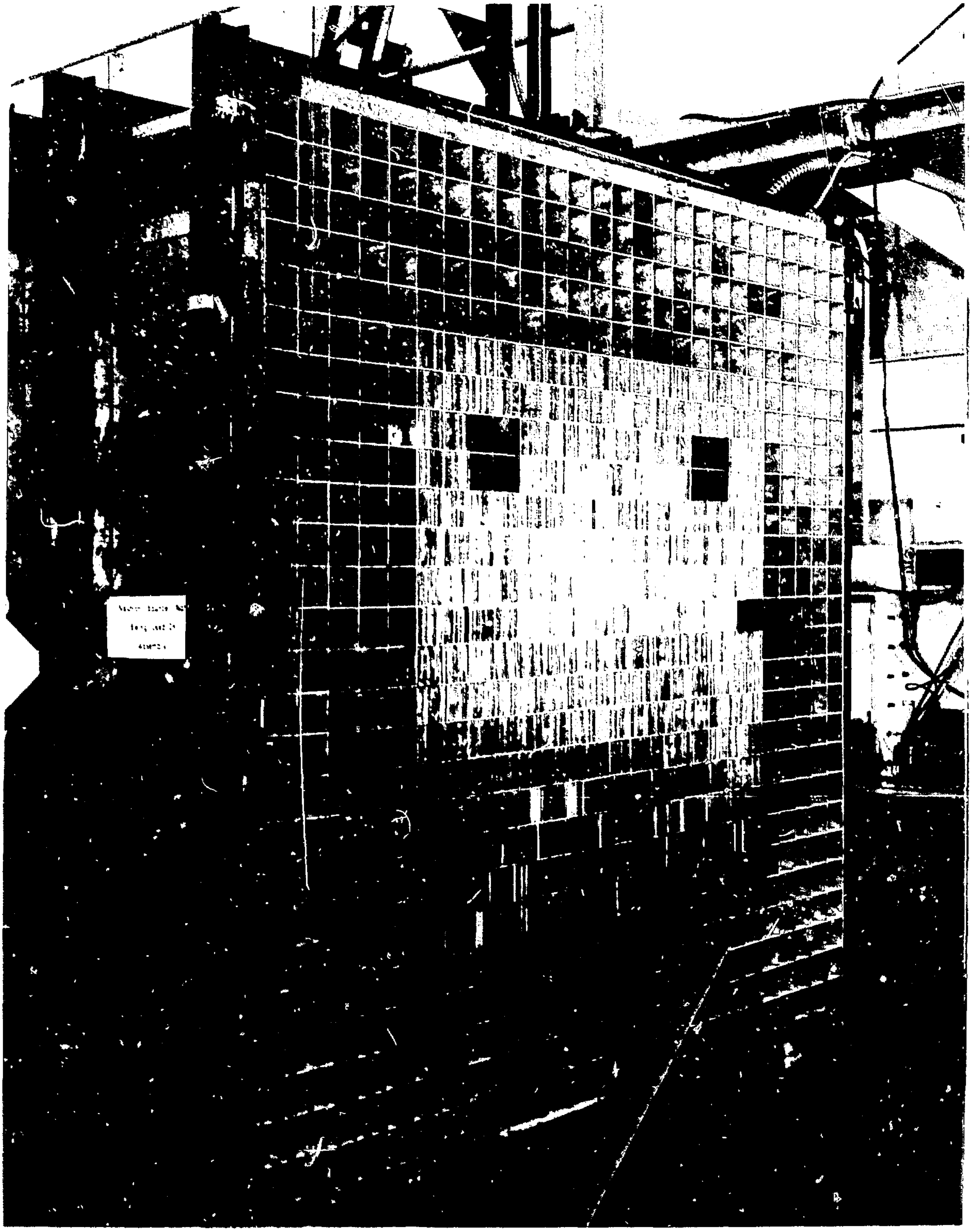

Fig. 3.

Honeycomb critical assembly separated to show the aluminum matrix. Partially withdrawn foil-graphite layers are typical of the core structure.

TABLE I

COORDINATES OF NEAR-CUBIC HONEYCOMB ASSEMBLY[a]

z (cm)	±x,y (cm)	r_{eff} (cm)	Material
0- 50.80	0-99.39	0-104.81	Al at 0.165 g/cm^3
50.80-111.50	0-61.16	0- 66.58	core[b]
50.80-111.50	61.16-99.39	66.58-104.81	Al at 0.165 g/cm^3
111.50-112.02	0- 7.62	0- 8.30	void
111.50-112.02	7.62-61.6	8.30- 66.58	core[b]
111.50-112.02	61.16-99.39	66.58-104.81	Al at 0.165 g/cm^3
112.02-172.72	0-61.16	0- 66.58	core[b]
112.02-172.72	61.16-99.39	66.58-104.81	Al at 0.165 g/cm^3
172.72-182.88	0-99.39	0-104.81	Al at 0.165 g/cm^3

[a] Excess reactivity is 0.5 ± 0.5¢.

[b] Core composition:
^{235}U at 0.1456 g/cm^3,
^{238}U at 0.0107 g/cm^3,
C at 1.353 g/cm^3,
Al at 0.165 g/cm^3.

Values of Rossi alpha at delayed criticality were obtained by several techniques. Results are α_{dc} = 850 ± 30 sec^{-1} from self-modulated chain decay, 840 ± 10 sec^{-1} from pulsed-source decay, and 800 ± 40 sec^{-1} from the Feynman variance technique. The indicated uncertainties are somewhat subjective. These values are significantly lower than a preliminary result quoted elsewhere.*

REACTIVITY COEFFICIENTS

A 20.3-cm by 0.64-cm slot was opened past the center of the simple assembly described above. Samples were lowered successively into the slot by remote control and then retracted so that effective reactivity coefficients could be measured. Samples were 15.24-cm-square foils of various thicknesses.

A single series of measurements involved 30 to 50 cycles, during which the sample was inserted for ~20 sec and withdrawn for ~40 sec. Reactivity changes were determined by measuring differences between recorded signals from an analog reactivity meter. Noise and systematic changes of signal were diminished with experience, but not to the extent that was anticipated. The spread of reactivity change per series of measurements extended to as much as ±0.1¢ instead of the ±0.01¢ maximum that should be attainable with refined instrumentation. Nevertheless, resulting sets of effective reactivity coefficients are reasonably consistent.

Table II identifies samples for which central reactivity effects are worth presenting, and gives the observed reactivity contributions. The effective reactivity coefficients in cents per gram atom apply to 15.24-cm-square samples at the stated surface densities. These effective coefficients as functions of surface density appear in Fig. 4, and corresponding coefficients for the isotopes ^{235}U and ^{238}U are listed in Table III. The ^{235}U coefficient, unlike any other, appears to be independent of sample thickness within the range investigated.

THE FUTURE

The cubic Honeycomb assembly is being retained temporarily in case this assembly or any other that

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*J. C. Hoogterp and G. E. Hansen, "Unreflected $^{235}UC_{182}$ Critical Assembly," ANS Trans. 14, No. 2, 677-678 (1971).

TABLE II

CENTRAL REACTIVITY CONTRIBUTIONS OF VARIOUS 15.24-CM-SQUARE FOILS

	Sample		Reactivity Contribution	
Material	Weight, g (Thickness, in.)	Surface Density (g-atom/m^2)	Increment (¢)	Effective Coefficient (¢/g-atom)
U(93.15)	33.65(0.003)	6.16	1.059 ± 0.03[a]	7.41 ± 0.21
U(93.15)	33.65(0.003)	6.16	1.172 ± 0.01	8.19 ± 0.07
U(93.15)	67.4(0.006)	12.35	2.35 ± 0.03	8.19 ± 0.10
U(93.15)	101.1(0.009)	18.51	3.51 ± 0.02	8.18 ± 0.05
U(93.15)	116.8(0.011)	21.4	4.00 ± 0.075[a]	8.06 ± 0.15
U(93.15)	117.5(0.011)	21.5	4.12 ± 0.02	8.24 ± 0.04
U(0.3)	24.00(0.002)	4.34	−1.225 ± 0.055	−12.15 ± 0.55
U(0.3)	24.52(0.002)	4.44	−1.285 ± 0.04	−12.47 ± 0.39
U(0.3)	48.52(0.004)	8.78	−2.01 ± 0.055	− 9.87 ± 0.27
U(0.3)	73.0(0.006)	13.20	−2.61 ± 0.04	− 8.52 ± 0.13
U(0.3)	115.7(0.010)	20.9	−3.48 ± 0.035	− 7.16 ± 0.07
U(0.3)	116.6(0.010)	21.1	−3.42 ± 0.065	− 7.04 ± 0.13
Th	70.5(0.010)	13.08	−2.42 ± 0.08	− 7.95 ± 0.26
Th	141.3(0.020)	26.2	−4.02 ± 0.065	− 6.60 ± 0.11
W	20.08(0.002)	4.70	−2.54 ± 0.05	−23.2 ± 0.5
W	57.5(0.005)	13.54	−5.17 ± 0.13	−16.52 ± 0.42
W	77.6(0.007)	18.24	−6.27 ± 0.125	−14.86 ± 0.30
Mo	11.88(0.002)	5.33	−0.489 ± 0.05	− 3.95 ± 0.40
Mo	11.88(0.002)	5.33	−0.509 ± 0.04	− 4.11 ± 0.32
Mo	24.18(0.004)	10.85	−0.897 ± 0.02	− 3.56 ± 0.08
Mo	55.4(0.009)	24.85	−1.766 ± 0.025	− 3.06 ± 0.04

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[a] Early exploratory measurement.

can be made of the enriched-uranium foil should be of value. In particular, reactivity contributions such as those surveyed can be improved and extended to other materials, but at significant cost. Inactive plans for a homogeneous central region can also be revived if required. We trust that the limited data presented here will prove adequate as checkpoints for cross sections in the ~0.1-MeV region and possibly stimulate a more extensive program.

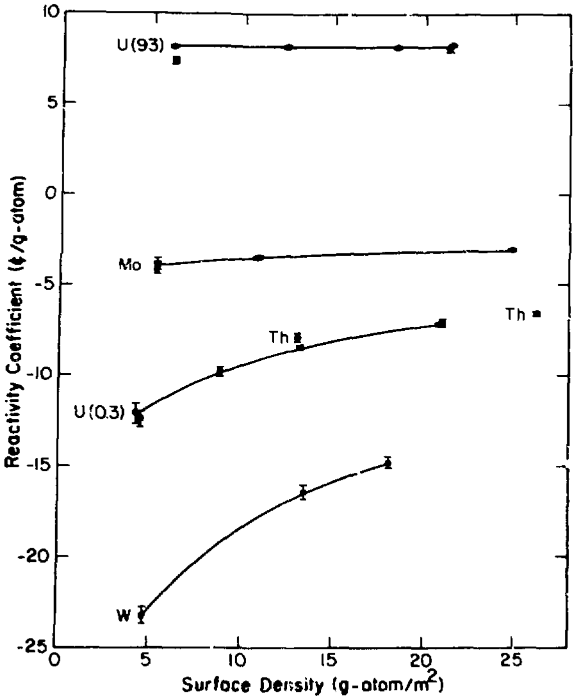

Fig. 4.
Dependence of effective reactivity coefficients upon sample thickness. The constant value for U(93) was not foreseen.

TABLE III

EFFECTIVE REACTIVITY COEFFICIENTS OF ^{235}U AND ^{238}U AS 15.24-CM-SQUARE SAMPLES

Isotope	Surface Density (g-atom/m^2)	Effective Coefficient (¢/g-atom)
^{235}U	6.16	8.76 ± 0.25[a]
^{235}U	6.16	9.60 ± 0.08
^{235}U	12.35	9.43 ± 0.11
^{235}U	18.51	9.32 ± 0.06
^{235}U	21.4	9.16 ± 0.17[a]
^{235}U	21.5	9.35 ± 0.05
^{238}U	4.34	−12.21 ± 0.55
^{238}U	4.44	−12.54 ± 0.39
^{238}U	8.78	− 9.93 ± 0.27
^{238}U	13.20	− 8.57 ± 0.13
^{238}U	20.9	− 7.21 ± 0.07
^{238}U	21.1	− 7.09 ± 0.13

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[a] From early exploratory measurement.