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A SMALL GRAPHITE-REFLECTED UO_2 ASSEMBLY*

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ABSTRACT

An unmoderated, graphite-reflected, critical assembly of UO_2 , enriched to 93.15 wt % in ^{235}U , is described. The UO_2 pellets (density, 9.71 g/cm^3) were contained in 253 1.27-cm-diam stainless steel tubes, which, in turn, are close packed in an aluminum container 22.87 cm in diameter and 31.11 cm long. This mockup of a small, potassium-cooled space power reactor, which was under study at Oak Ridge National Laboratory in 1963, provided data for validation of reactor physics methods. Two combinations of top and side reflectors were found to make the assembly critical. In one configuration, the thickness of the top and the side reflectors was 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 with the thicker radial reflector and radially through the reflector showed a peak in the reflector 3.5 greater than at the center of the core. The ^{235}U cadmium ratio measured in the side reflector at the core midplane for the assembly with the 19.25-cm-thick side reflector varied from 1.77 near the core boundary to 2.43 beyond 10 cm into the side reflector.

INTRODUCTION

A small, compact, unmoderated critical assembly of ^{235}U -enriched UO_2 reflected by type ATL Graphite constructed in the Oak Ridge National Laboratory (ORNL) Critical Experiments Facility at the Oak Ridge Y-12 Plant has provided data in support of reactor physics calculations. This mockup of a small, potassium-cooled space power reactor, which was under study at ORNL in 1963, provided data for validation of reactor physics methods. The fuel tubes were close packed with two delayed critical reactor conditions: thick radial reflector with thin top reflector and thin radial reflector with thick top reflector. The critical configurations are described in detail, and the results of the ^{235}U fission rate distribution and cadmium ratio measurements are reported.

MATERIAL AND EQUIPMENT

The fissile region of the close-packed assembly, nominally 22.58 cm in diameter and 30.48 cm high, was an array of 253 type 347 stainless steel tubes containing UO_2 pellets having a density of 9.71 g/cm^3 . The ^{235}U content of the uranium was 93.15 wt % with the other uranium isotopes at 1.01 wt % ^{234}U , 0.47 wt % ^{236}U and 5.37 wt % ^{238}U . The tubes were adjacent and were arranged in a type 1100 aluminum cylindrical can fitted with

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aluminum shims to maintain the close packing. The fuel tubes and the uranium oxide pellets are described in Table I, and one tube and its end cap are shown together with the UO_2 pellets in Fig. 1. In this photograph the edges of the pellets were chipped during their removal from the tube preparatory to this photograph. Each fuel tube contained 26 UO_2 pellets weighing a total of 295.8 g. The pellets were each 1.141 cm in diameter and 1.145 cm long. The pellets were pressed and sintered at the Oak Ridge Y-12 Plant. The total length of 26 pellets was 29.88 cm, which includes a total of 0.110 cm of void, or ~ 0.0044 cm of void between each pellet. The properties of the

core are given in Table II. The dimensions, material types, and masses of the reflector are given in Table III. The thicknesses of the reflector on the top and side of the core were the variables that were adjusted in steps to make the assembled configurations delayed critical. The aluminum can with the fuel tubes and the bottom reflector are shown in Fig. 2. A top view looking down on the configuration of the close packed core inside the thin radial reflector is shown in Fig. 3. The inner portion of the radial reflector had radial holes for insertion of graphite plugs for fine adjustment of the reactivity and can be seen in Fig. 3. The larger two radial holes (2.54-cm-diam) were

Table I. Properties of a Typical Fuel Tube and the Uranium Oxide

Stainless Steel Tube		Uranium Oxide	
Type	347	Number of UO_2 pellets per fuel tube	26
Length, cm	30.48	UO_2 density, g/cm^3	9.71
Outside diameter, cm	1.27	Mass of UO_2 per tube, g	295.8
Wall thickness, cm	0.051	Diameter of pellets, cm	1.141
Weight with end caps, g	45.37	Length of one pellet, cm	1.145
Weight of one end cap, g	0.64	Length of 26 pellets, cm	29.88

Fig. 1. Fuel Tube and UO_2 Pellets

Table II. Core Properties

^{235}U mass, kg	61.39
UO_2 mass, kg	74.84
Stainless steel mass, kg	11.48
Number of fuel tubes	253
Fuel tube pitch, cm	1.27 cm

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	$\sim 24^\circ$ and 34° segments of a circle
Total weight of 24, g	185

for lifting and were always plugged in the experiments. The lower holes were for reactivity adjustment. The top and the thick side reflector are mounted from the four vertical poles of the vertical assembly machine and are shown at the top of Fig. 4. This reflector rests on an aluminum plate with a hole in it. The assembly was built on the vertical assembly machine so that the movable part was the core and bottom reflector. It was moved up inside the radial reflector until it was adjacent to the top reflector. The dimensions of the major components of the assembly are shown in the sketch of Fig. 5. The assembly was located in the east experimental cell of the Oak Ridge Critical Experiments Facility. The vertical assembly machine was located in the 10.7- $\times$ 10.7-m-square, 9.1-m-high experimental room so that the center of the

core regions was 3.67 m from the 1.5-m-thick west wall, 3.9 m from the 0.6-m-thick north wall, and 2.8 m above the concrete floor.

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. These reactivities were obtained from positive reactor period measurements using the delayed neutron parameters of Keepin, Wimett, and Zeigler [1]. In both cases the center fuel tube was removed from the core; the bottom graphite reflector was 15.24 cm thick; and one of the six equally spaced, 1.27-cm-diam 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-diam 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 32 cents.

Fission rate distributions were measured with a 2.5-cm-long, 0.64-cm-diam ^{235}U -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. The radial flux distributions and ^{235}U 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-diam $\times$ 0.010-cm-thick uranium metal foils with a ^{235}U enrichment of 93.2 wt %. The cadmium covers were 0.051 cm thick. The results of the foil measurements are plotted in Fig. 8. The data from the axial and radial

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

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	7.76	
Iron		
Thickness, cm	1.27	
Inside diameter, cm	23.58	
Outside dimensions, cm	121.9 × 121.9	
Mass, kg	137.9	

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

Fig. 2. Core and Bottom Reflector

Fig. 3. Core Surrounded by 6.35-cm-thick Reflector

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

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

Fig. 5. Reflector Arrangement in Two Assemblies

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

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

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

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. The cadmium ratio at 0.5 cm into the radial reflector at the midplane is 1.77. This indicates that 60% of the neutrons producing fission in the ^{235}U foil at this point have energies above the cadmium cutoff of 0.5 eV. Thus, most of the fissions in the core are from neutrons with energies well above 0.5 eV.

CONCLUSIONS

These experiments provide benchmark data for an assembly with a large fraction of fissions at high neutron energy. This results

from the lack of moderators in the core and the thin radial reflector. The large amount of oxygen in a core without moderator may make calculations of these critical configurations very dependent on the oxygen cross sections at higher neutron energies and thus provide a good test of the ENDF/B-VI oxygen cross sections. This is of particular current interest, since the ENDF/B-VI oxygen data has significant modifications at high neutron energies.

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