REFERENCE 34

J. K. FOX, L. W. GILLEY, AND J. H. MARABLE, "CRITICAL PARAMETERS O PROTON-MODERATED AND PROTON-REFLECTED SLAB OF U^{235}, " NUCL. S ENG. 3:694-697 (1958).

THE JOURNAL OF THE AMERICAN NUCLEAR SOCIETY

NUCLEAR SCIENCE and ENGINEERING

Volume 3, 1958

ACADEMIC PRESS INC., PUBLISHERS, NEW YORK 3, N. Y.

NUCLEAR SCIENCE AND ENGINEERING: **3**, 694–697 (1958)

Critical Parameters of a Proton-Moderated and Proton-Reflected Slab of U^{235}

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Received December 4, 1957

The critical thickness of proton moderated and proton reflected slab-shaped volumes of aqueous solutions of UO_2F_2 enriched to 93.2% in U^{235} were measured at chemical concentrations near that required for minimum critical volume. These data yield 1.76 ± 0.07 in. as the minimum critical thickness of an infinite slab of the materials of the experiment at a concentration of 532 g U^{235}/l. This result is compared with a three-group two-region analysis of the infinite slab.

The thickness of a critical slab-shaped volume of fissionable material is of practical interest in setting limiting vessel dimensions and is of importance in elementary reactor analyses if the area-to-thickness ratio is sufficiently large to make the system essentially unidimensional. To measure the thickness of a critical slab of a solution when all the other parameters are optimized is of even more practical interest. Evaluations of this so-called "minimum thickness of an infinite slab" have been made previously by extrapolation of the critical dimensions of water-reflected cylinders of finite area (*1*). Other estimates of the thickness of water-reflected slabs have been obtained from the extrapolation of measurements on partially reflected vessels (*2*).

An attempt has now been made to measure directly the critical thickness of a hydrogen-reflected slab of aqueous solution of UO_2F_2 (enriched to 93.2% in U^{235}) at chemical concentrations selected to give the minimum critical volume. For this purpose a reactor vessel was constructed from $\frac{3}{4}$ in.-thick Lucite sheets reinforced by stiffening members, also of Lucite, attached to the outside. The nominal inside dimensions were 58 × 71 × 2.25 in. The slab was mounted with the 71 in. dimensions vertical in such a manner that it could be filled with UO_2F_2 solution and surrounded, except for the top surface, by an effectively infinite water reflector. The size of the slab was altered by inserting plastic sheets of various thicknesses adjacent to one inside surface. Blocks of plastic

[1] Operated by Union Carbide Nuclear Company, Division of Union Carbide Corporation, Oak Ridge, Tennessee.

TABLE I

CRITICAL DIMENSIONS OF A PROTON-REFLECTED AND -MODERATED SLAB

Slab thickness (in.)	Critical solution Height (in.)	Critical solution Height^{-1} (in.$^{-1}$)	Reflector water height[a] (in.)	Critical values Volume (in.^{3})	Critical values Volume (liters)	Critical values Mass (kg of U^{235})
$H:U^{235}$ = 44.7; 0.532 g of U^{235}/cm^3						
2.12 ± 0.01	28.18	0.0355	45.7	3465	56.8	30.2
2.06 ± 0.01	35.02	0.0286	53.5	4185	68.5	36.4
2.06 ± 0.01	34.91	0.0286	51.0	4170	68.3	36.3
2.00 ± 0.01	42.09	0.0238	54.5	4885	80.0	42.6
2.00 ± 0.01	43.08	0.0232	56.7	5000	81.9	43.6
1.995 ± 0.005	45.38	0.0220	59.0	5250	86.0	45.7
1.995 ± 0.005	47.20	0.0212	64.0	5460	89.5	47.6
$H:U^{235}$ = 51.5; 0.469 g of U^{235}/cm^3						
2.06 ± 0.01	36.73	0.0272	53.5	4390	71.9	33.7
2.06 ± 0.01	37.62	0.0266	64.0	4495	73.7	34.6
1.995 ± 0.005	51.99	0.0192	65.5	6015	98.6	46.2
1.995 ± 0.005	51.28	0.0195	64.0	5935	97.2	45.6

[a] Measured from bottom of liquid slab.

about 1 in. square and of appropriate length were placed within the slab on 12-in. centers in two directions in an attempt to maintain constant thickness as the hydrostatic pressures varied with the inner and outer liquid heights.

In the experiment critical heights of solutions of two concentrations were measured over a narrow range of slab thicknesses with, of course, the other horizontal dimension fixed at 58 in. The temperature of the solution was between 72 and 75°F. The extent of the measurement was limited by the volume of solution available. It is apparent from the data recorded in Table I that the critical dimensions were sensitive to the water height because of its effect as a neutron reflector above the solution and, more importantly, because of deformations of the plastic by variations in hydrostatic forces. In some instances the slab thickness was measured with gauge blocks with the liquids only slightly below the critical levels and with a neutron absorber inserted in the solution. This dimension varied by as much as ±0.01 in. over the area of the slab. Data in which there is greatest confidence have been extrapolated to an infinite height as shown in Fig. 1. The extrapolated value is 1.81 in.

It is obvious that a 50-in. height is not "infinite" and the extrapolation of the graph evaluates this effect in only one dimension. Were the finite width (58 in.) of the slab extended indefinitely, it is estimated, from Fig. 1, that the critical thickness would be reduced by 0.15 ± 0.05 in.

An evaluation of the effect on the critical thickness of the infinite slab of re-

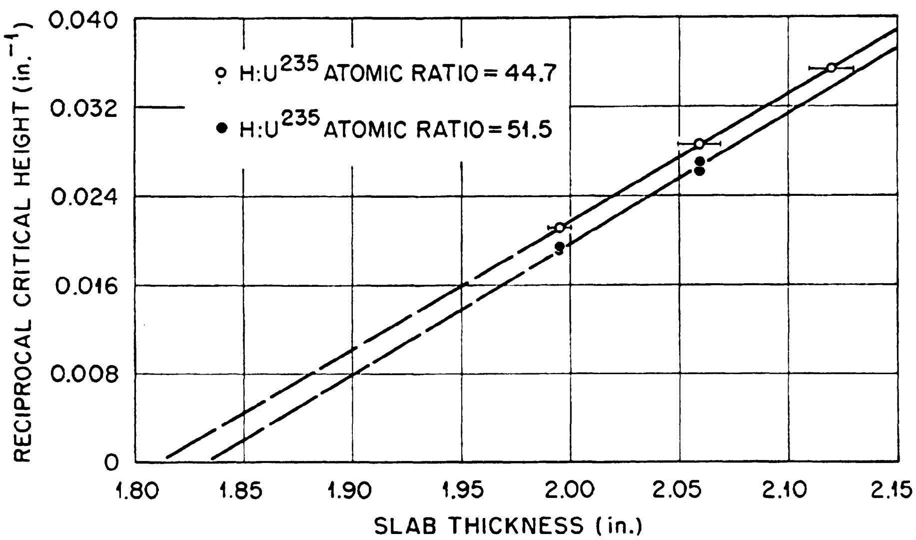

FIG. 1. Reciprocal critical height of a slab of enriched U^{235} solution as a function of the thickness of the slab.

placing the Lucite with water was made by equating the geometric buckling of the water-reflected slab to the geometric buckling of the water and Lucite-reflected slab and solving for the thickness. The extrapolation distance into the water-Lucite medium had been determined previously by equating bucklings of two similarly water-reflected and water- and Lucite-reflected critical slabs. These results indicate that replacing the Lucite with water would increase the critical thickness of the infinite slab by 0.1 in. These considerations yield for the minimum critical thickness of an infinite slab of solution with a water reflector the value of 1.76 in.

It is estimated that an uncertainty of ± 0.07 in. should be attached to these results because of uncertainties in measurements of the experimental slab thicknesses, the extrapolations of the data, and the deviation of the experimental solution concentration from that of optimum concentration.

In an attempt to analyze the experimental data, several water-reflected finite and infinite slab reactors were calculated on the Oracle using the three-group three-region (*3G3R*) reactor code (*3*). The core was assumed to be an aqueous solution of UO_2F_2 using 93.2% enriched uranium with a U^{235} concentration of 0.532 g/cc, corresponding to the experimental conditions which yielded the value of 1.76 in. for the infinite slab. The Lucite containers used in the critical experiments were assumed to be water.

Group constants were obtained from the Eyewash multigroup cross-section compilation using the Group Constant Preparation Routine (GCPR) (*3*). The multiplication factors calculated by this method for three finite slabs, which were critical experimentally, were each 1.125. The thickness of the infinite slab which gave a calculated multiplication factor of one was 1.38 in. The thickness of the infinite slab which gave a calculated multiplication factor of 1.125 was 1.88 in.

The large values obtained for the multiplication factors may be due to the method of calculating the group transfer cross sections Σ_x. These are calculated in the GCPR from ages which are obtained by an empirical method. Another method of calculating the transfer cross section from the slowing down in unreflected spheres yielded smaller values for the transfer cross sections with a corresponding value of the calculated multiplication factor of 0.92 for the finite reflected slabs. This shows that the calculated multiplication factor is very sensitive to the model used to determine transfer cross sections, and points out the value of experimental data, especially in such cases of extreme geometry.

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