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PRELIMINARY SOLUTION CRITICAL
EXPERIMENTS FOR THE HIGH-FLUX
ISOTOPE REACTOR

J. K. Fox
L. W. Gilley
D. W. Magnuson

OAK RIDGE NATIONAL LABORATORY

operated by

UNION CARBIDE CORPORATION

for the

U.S. ATOMIC ENERGY COMMISSION

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Date Issued

JUN 12 1963

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Abstract

The design of the High-Flux Isotope Reactor (HFIR) was supported by a series of preliminary experiments performed at the Oak Ridge Critical Experiments Facility in 1960. The experiments yielded results describing directly some of the expected performance characteristics of the reactor and strengthened the calculational methods used in its design. The critical assembly, like the reactor, was of a flux-trap type in which a central 6-in.-dia column of H_2O was surrounded by an annulus of fissile material and, in turn, by an annular neutron reflector. To allow variations in reactor parameters, such as the fuel concentration, all the materials of the experiments were liquid. The fuel region contained a solution of enriched uranyl nitrate in a mixture of H_2O and D_2O and the reflector was a composite of two annuli, the inner one of D_2O surrounded by one of H_2O . The nominal widths of these annuli were, respectively, 5, 8, and 6 in. In most experiments the ends of the assembly were reflected by H_2O .

Important results evaluate the absolute thermal-neutron flux to be expected in the design reactor and describe the flux distributions within this type of assembly. Concomitant measures of the absolute value of the thermal-neutron flux at the center and the fission rate producing it gave a value of 5.8×10^7 neutrons. $cm^{-2}.sec^{-1}.w^{-1}$ consistent with the thermal-neutron flux of the order of 10^{15} neutrons. $cm^{-2}.sec^{-1}$ expected in the reactor at 100-Mw operation. It was also observed that the cadmium ratio along the axis of the assembly was about 100, showing that a highly thermal-neutron flux was truly developed in the trap. The intensity of this thermal-neutron flux on the axis was measured by U^{235} fission counters to be 17.0 and 3.3 times greater than the thermal-neutron flux at the center of the fuel annulus and of the D_2O reflector annulus, respectively.

It was shown that reduction of the hydrogen density in the central water column to about 60% of its normal value increased the reactivity about 6% and that further hydrogen density reduction decreased the reactivity as the effect of the loss of neutron moderation dominated the effect of the increased coupling across the central column. These considerations are of importance to the safety of the reactor.

Additional experiments gave values of the usual critical dimensions and explored the effects on both the dimensions and the flux distributions of changing the concentration of the uranyl nitrate solution, of changing the composition of the solvent, and of adding neutron-absorbing materials to the D_2O reflector. These changes were made to alter the neutron properties of the fuel solution over a range including those expected in the reactor itself.

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I. Introduction

A flux-trap type of critical assembly was studied at the ORNL Critical Experiments Facility to aid in the determination of design parameters for the High-Flux Isotope Reactor (HFIR). The critical assembly consisted essentially of a central H_2O cylinder, the flux-trap, which was surrounded by concentric annuli of fuel, D_2O reflector, and H_2O reflector, and had flat cylinders of H_2O above and below as end reflectors. The fuel used in this study was $\text{UO}_2(\text{NO}_3)_2$ in which the uranium was enriched to 93.15 wt % in the U^{235} isotope and dissolved in a mixture of D_2O and H_2O .

The experiments consisted in determining the critical parameters of the assembly with varying amounts of neutron absorber in the D_2O reflector, measuring the relative neutron flux distribution for various conditions of reflector poison and fissile solution concentration, determining the ratio of the absolute thermal-neutron flux in the center of the assembly to the power in the fissile solution, and determining the effect on reactivity of reducing the hydrogen density in the central region of the assembly. In one experiment the end reflectors were removed to obtain a value of the reflector savings.

Nuclear calculations were made by Claiborne¹ for the experiments described in this report.

II. Assembly and Apparatus

The mechanical facilities for the HFIR solution critical experiments are described in Appendix A, an abridged version of a detailed report.² The essential details of the vessel used in these experiments are shown in Fig. 1. The vessel consisted primarily of four concentric aluminum cylinders with 1/8-in.-thick walls and nominal outside diameters of 6, 16, 32, and 44 in. The four compartments formed by these cylinders are referred to as Regions I-IV. Immediately below these cylinders was a 6-in.-deep compartment (Region V) that could be filled with water to give an effectively infinite bottom reflector.

1. H. C. Claiborne, Solution Critical Experiments for the High-Flux Isotope Reactor: Preliminary Calculations, ORNL-CF-61-8-37 (Aug. 15, 1961).
2. C. A. Burchsted, High-Flux Isotope Reactor Critical Experiment -- Equipment, ORNL-CF-60-4-120 (Apr. 20, 1960).

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Fig. 1. Section Through Vertical Mid-plane of HFIR Solution Critical Experiment Apparatus.

A central flux trap (Region I) was surrounded by the fuel solution in Region II, which was filled remotely from a storage system (described in Appendix A). A partial D_2O reflector was contained in Region III, also filled remotely from a storage system, and was surrounded by H_2O reflector in Region IV.

The thicknesses of Regions II, III, and IV were nominally 5, 8, and 6 in., their exact thicknesses at various elevations being given in Appendix B. Region III was nominally 18 in. high and above it was a fixed H_2O -filled reflector compartment 12 in. high. A similar but removable compartment could be placed above Region II; with the compartment in position, Region II was 17.68 ± 0.05 in. high.

Both Regions II and III could be drained automatically by the instrument-scam system. In addition, a 5.50-in.-OD cadmium cylinder with a 3.0-in. slot removed along its length was used in Region I as a safety device and was estimated to have a reactivity worth of more than 10 dollars.

Miniature U^{235} fission counters were used to determine the spatial distribution of the relative neutron flux in each experiment. In experiment 1 (see below) miniature $B^{10}F_3$ counters (described in Appendix C) were also used for comparative flux mapping. Each counter was contained in a 5/16-in.-OD by 4-in.-long aluminum tube attached to the bottom of a 1/4-in.-OD by 36-in.-long aluminum tube. For the cadmium-covered detector traverses the 5/16-in.-OD tube was enclosed in a close-fitting 0.030-in.-thick cadmium sleeve with a bottom plate. These assemblies were sealed with a thin coat of plastic. In Regions II, III, and IV the aluminum tubes were offset so that, when rotated by a common drive, the counters moved across each region. From angular positions indicated by a selsyn it was possible to calculate the corresponding radial positions. The counter in Region I could be moved radially by a second drive mechanism. All four counters were attached to a common supporting apparatus which could be moved vertically by known amounts indicated by a selsyn. The lower reflector, Region V, was traversed by three 3/8-in.-ID aluminum guide tubes with centers 9.4, 11.8, and 14.5 in. below the vertical midplane of the assembly so that relative radial flux distributions could be obtained. No flux

distributions were measured in the top reflector, since they should be similar to those in the bottom reflector.

III. Critical Experiments and Parameters

For convenience in describing the results, the experiments are designated as 1, 2, 3, and 4, each experiment number referring to a particular fuel solution and D₂O reflector condition. The critical parameters for these experiments are given in Table 1. In experiment 1A the assembly was fully reflected, and in experiment 1B the end reflectors were removed. The slight difference between the fissile solution analysis of experiment 1A and the analysis of 1B resulted from the additional fuel required for experiment 1B. The difference between the fully reflected critical height, 17.68 in., and the critical height with ends bare, 24.08 in., corresponds to an end reflector savings of 3.20 in.

In experiment 2 natural boron, as Na₂B₄O₇·10H₂O, was added to Region III to a concentration of 0.037 g/liter, and the fuel concentration was increased to 119.7 g of U²³⁵ per liter to make the reactor critical when approximately full. The deuterium concentration in the moderator was reduced from 95.4 to 93.8 at. %, probably because the solvent in the added fuel did not have the same D to H ratio as the original solvent. Experiment 2B shows the small effect on reactivity of the fission counters in the reactor. It was this poisoning effect of the counters, especially when cadmium-covered, that caused the fuel region to be slightly less than full when critical for experiments in which the counters had been removed, since the solution concentration was adjusted for a just-full critical reactor with the counters in place. The small positive reactivity that could be gained by allowing the solution to rise in the vent tube and in the clearance around the Region-II top reflector annulus gave additional reactor control when making flux traverses.

More boron was added to the D₂O of Region III for experiment 3. Since the counters were not removed for this experiment, the reported critical height corresponded to a small amount of solution in the vent system. From positive reactor periods resulting from incremental height changes, it was determined that this amount of fuel in the vent tubes was worth about 23 cents in reactivity.

Table 1. Critical Parameters of HFIR Solution Critical Experiments

Uranium enrichment: 93.15 wt% U^{235}
 N:U atomic ratio: 2.007
 Region-III D_2O reflector assay: 99.7 at. % D

Experi- ment No.	Critical Fuel Height ^a (in.)	Fuel Concentra- tion (g of U^{235} /liter)	Specific Gravity of Fuel at 23°C	Critical Mass (kg of U^{235})	Deuterium Content in Region II (at. %)	H: U^{235} Atomic Ratio	D: U^{235} Atomic Ratio	Reactor Temperature (°C)	Boron Concentration in Region III D_2O (g/liter)	Reflector Conditions ^b	U^{235} Fission Counter Positions
1A	17.68	93.17	1.2352	4.49	95.4	12.46	258.4	21		Totally reflected	None present
1E	24.08 ^c	92.54	1.2358	6.07	95.4	12.55	260.3	23.5		No end reflectors	None present
2A	17.61	119.7	1.2711	5.75	93.8	13.08	195.9		0.037	Totally reflected	None present
2B	17.88	119.7	1.2711	~ 5.78 ^d	93.8	13.08	195.9	23.7	0.037	Totally reflected	Centered in 4 regions
3	17.95	137.5	1.2958	~ 6.64 ^d	93.8	11.33	169.5	23.7	0.056	Totally reflected	Centered in 4 regions
4	17.59	105.9	1.2262	5.08	70.1	70.9	166.3		2.35	Totally reflected	At outer wall near top of Regions II and III

^aReactor is full at 17.68 ± 0.05 in.; critical heights reported above this value have excess fuel in vent tubes except for the case with no end reflectors.

^bSee Fig. 1 for details of reflector regions.

^c H_2O and D_2O in other regions at this height.

^dMasses for the just-full reactor.

For experiment 4 water was added to the fuel solution to reduce the neutron age. Since this reduction in the concentration of both the deuterium in the moderator and the U^{235} in the fuel resulted in a net increase in reactivity, it was necessary to add boron, to a concentration of 2.35 g/liter, in Region III to achieve criticality with Region II filled with solution.

Some qualitative observations made during all four experiments as the assembly temperature varied between 21 and 24°C indicated that the over-all temperature coefficient of reactivity was positive within this range. The H: U^{235} and D: U^{235} atomic ratios were calculated from the chemical and isotopic analyses. The N:U ratio of 2.007 showed that the amount of free nitric acid present was negligible.

Relative Flux Distributions

Bare and cadmium-covered U^{235} fission-counter traverses were made radially and vertically in three of the four experiments. Radial traverses extended from the center of Region I through Regions II, III, and IV, which comprised the flux trap, the fuel, and the two side reflector regions. Radial traverses were also made in the bottom reflector. Vertical traverses were generally made through the center of each region and extended only about 4.5 in. above the mid-plane and 6.5 in. below it because of limitations inherent in the equipment design. Since no two counters have the same sensitivity, it was necessary to adjust the observed data by factors obtained from a single counter located successively at the center of each of the four regions (see Appendix D). Counting rates were, of course, corrected for fluctuations in operating power. For purposes of reporting, the data are normalized to a bare-detector counting rate of unity at the assembly center.

Experiment 1. -- The relative flux distributions were studied extensively in experiment 1. Bare U^{235} fission-counter traverses were made radially at three elevations in the fuel: at mid-plane, 4.5 in. above mid-plane, and 5.8 in. below mid-plane (Tables E.1 - E.3 in Appendix E and Figs. 2 - 4). The bare U^{235} fission-counter vertical traverses were made through the center of each region (Table E.4 and Fig. 5). Cadmium-covered radial U^{235} fission-counter traverses were made at mid-plane and

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Fig. 2. Radial Traverse of Bare U^{235} Fission Counter at Mid-plane of HFIR Solution Critical Experiment No. 1.

Fig. 3. Radial Traverse of Bare U^{235} Fission Counter 4.5 in. Above Mid-plane of HFIR Solution Critical Experiment No. 1.

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Fig. 4. Radial Traverse of Bare U^{235} Fission Counter 5.8 in. Below Mid-plane of HFTR Solution Critical Experiment No. 1.

Fig. 5. Vertical Traverses of Bare U^{235} Fission Counter in Regions I-IV of HFIR Solution Critical Experiment No. 1.

vertical traverses were made through the center of each region (Table E.5, Fig. 6, and Table E.6, Fig. 7, respectively). From data taken at mid-planes the cadmium ratios, that is, the ratio of the counting rates with the detector both bare and cadmium-covered, in the center of Regions I, II, and III were, respectively, 104, 3.58, and 35.6. Also from the mid-plane data the ratios of the thermal-neutron counting rate in the center of Region I to the thermal-neutron counting rate in the centers of Regions II and III were 17.0 and 3.29, respectively. The thermal-neutron counting rates are defined as the differences between the counting rates of the bare and cadmium-covered counters. The three radial traverses in the bottom reflector were made with bare U^{235} fission counters at 9.6, 12.0, and 14.7 in. below the vertical mid-plane of the assembly (Table E.7 and Fig. 8).

For comparison with the U^{235} fission-counter data of experiment 1, four traverses were made with miniature $B^{10}F_3$ -filled counters of about the same physical size. Radial traverse data at mid-plane for bare and cadmium-covered counters are shown in Tables E.8 and E.9 and in Figs. 9 and 10, respectively. The vertical traverses in Regions I, II, and III are given in Tables E.10 and E.11 and in Figs. 11 and 12 for the bare and cadmium-covered counters, respectively. For the bare-counter vertical traverse the radial position of the counter in Region II was inadvertently displaced about 1.6 in. horizontally from the center of the region, and therefore these data are not valid for cadmium ratio evaluations. The flux distributions obtained from the radial traverses with the bare $B^{10}F_3$ counter agreed with the corresponding U^{235} fission counter to within the experimental error except near the center of the fuel. The cadmium ratios obtained from $B^{10}F_3$ measurements in the center of Regions I, II, and III were 103, 5.13, and 43.1, respectively. The ratios of the thermal-neutron counting rate at the center of Region I to those at the centers of Regions II and III were 12.8 and 3.31, respectively.

Experiment 2. -- The bare U^{235} fission counter radial traverse data at mid-plane obtained in experiment 2 are presented in Table E.12 and Fig. 13.

Experiment 3. -- Bare and cadmium-covered U^{235} fission counter traverses were made along a radius at the mid-plane in experiment 3 and are presented in Tables E.13 and E.14 and in Figs. 14 and 15. The

Fig. 6. Radial Traverse of Cadmium-Covered U^{235} Fission Counter at Mid-plane of HFIR Solution Critical Experiment No. 1.

Fig. 7. Vertical Traverses of Cadmium-Covered U^{235} Fission Counter in Regions I and II of HFIR Solution Critical Experiment No. 1.

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Fig. 8. Radial Traverses of Bare U^{235} Fission Counter in Bottom Reflector of HFIR Solution Critical Experiment No. 1.

Fig. 9. Radial Traverse of Bare Miniature BF_3 Counter at Mid-plane of HFIR Solution Critical Experiment No. 1.

Fig. 10. Radial Traverse of Cadmium-Covered $B^{10}F_3$ Counter at Mid-plane of HFIR Solution Critical Experiment No. 1.

Fig. 11. Vertical Traverses of Bare $B^{10}F_3$ Counter in Regions I-III of HFIR Solution Critical Experiment No. 1.

Fig. 12. Vertical Traverses of Cadmium-Covered $B^{10}F_3$ Counter in Regions I-III of HFIR Solution Critical Experiment No. 1.

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Fig. 13. Radial Traverse of Bare U^{235} Fission Counter at Mid-plane of HFIR Solution Critical Experiment No. 2.

Fig. 14. Radial Traverse of Bare U^{235} Fission Counter at Mid-plane of HFIR Solution Critical Experiment No. 3.

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Fig. 15. Radial Traverse of Cadmium-Covered U^{235} Fission Counter at Mid-plane of HFIR Solution Critical Experiment No. 3.

corresponding vertical traverses are shown in Tables E.15 and E.16 and in Figs. 16 and 17 for the various regions. The cadmium ratios for the centers of Regions I, II, and III were 101, 2.78, and 32.6. The poisoning of the D_2O reflector caused some decrease in the flux in Region III in this experiment.

Experiment 4. -- The results of the bare and cadmium-covered U^{235} fission-counter radial traverses and vertical traverses made in experiment 4 are shown in Figs. 18 and 19 and in Figs. 20 and 21, respectively (see also Tables E.17 and 18 and E.19 and 20). The cadmium ratios were 102, 7.51, and 4.38 for the centers of Regions I, II, and III, respectively. The high ratio in Region II and the low ratio in Region III resulted from changes in the fuel and in the D_2O reflector poison. The subcadmium neutron-flux suppression by the boron in Region III was very pronounced in this experiment.

Ratio of the Thermal-Neutron Flux in the Center of Region I to the Total Power in the Fuel

Two methods were used to measure the ratio of the thermal-neutron flux in the center of Region I to the power generated in the fuel of Region II. In the first method the flux was measured by irradiating bare and cadmium-covered gold foils in the center of Region I and determining the corresponding average fission-rate density in the fuel by radiochemical analysis of a fuel sample. The foils and the counters used for determining foil activities had been previously calibrated against similar gold foils irradiated in the ORNL Standard Pile. In determining the saturated foil activities, the methods of Trubey *et al.*³ were used to correct for the epithermal absorption in the cadmium cover and for self-shielding and flux depression. In two determinations the flux-to-power ratio was found to be 5.86×10^7 and 5.79×10^7 neutrons $cm^{-2} sec^{-1} w^{-1}$, based on 1 w being equivalent to 3.38×10^{10} fissions sec^{-1} .

The second method made use of the results of the bare and cadmium-covered U^{235} fission chamber counter traverses in Regions I and II.

3. D. K. Trubey, T. V. Blosser, and G. M. Estabrook, Neutron Phys. Div. Ann. Prog. Rep., Sept. 1, 1959, ORNL-2842, p 204.

Fig. 16. Vertical Traverses of Bare U^{235} Fission Counter in Regions I-IV of HFIR Solution Critical Experiment No. 3.

Fig. 17. Vertical Traverses of Cadmium-Covered U^{235} Fission Counter in Regions I-III of HFIR Solution Critical Experiment No. 3.

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Fig. 18. Radial Traverse of Bare U^{235} Fission Counter at Mid-plane of HFIR Solution Critical Experiment No. 4.

Fig. 19. Radial Traverse of Cadmium-Covered U^{235} Fission Counter at Mid-plane of HFIR Solution Critical Experiment No. 4.

Fig. 20. Vertical Traverses of Bare U^{235} Fission Counter in Regions I-IV of HFIR Solution Critical Experiment No. 4.

Fig. 21. Vertical Traverses of Cadmium-Covered U^{235} Fission Counter in Regions I-III of HFIR Solution Critical Experiment No. 4.

The thermal-neutron flux in the center of Region I was proportional to the thermal-neutron counting rate. The average fission rate in the fuel region (Region II) was assumed to be proportional to the average counting rate of the bare fission counter. Corrections were made for counter differences. The average counting rates of the bare counter in the center of Regions I and II are given by

$$\begin{aligned} \bar{R}_I &= K \left[\int_0^{\infty} \phi_M \sigma_f(E) dE + \int_{0.4}^{\infty} \phi_{\text{epi}} \sigma_f(E) dE \right] \\ &= 0.886 \sigma_f(2200) K \left[1 + \frac{\int_{0.4}^{\infty} \phi_{\text{epi}} \sigma_f(E) dE}{\int_0^{\infty} \phi_M \sigma_f(E) dE} \right] \int_0^{\infty} \phi_M \end{aligned} \quad (1)$$

and

$$\bar{R}_{II} = K \int_0^{\infty} \bar{\phi}_F \sigma_f(E) dE,$$

where

$$\left[1 + \frac{\int_{0.4}^{\infty} \phi_{\text{epi}} \sigma_f(E) dE}{\int_0^{\infty} \phi_M \sigma_f(E) dE} \right] \equiv \frac{CR}{CR - 1}, \quad (2)$$

and

- ϕ_M = Maxwellian thermal-neutron flux in Region I,
- ϕ_{epi} = episcadmium-neutron flux in Region I,
- $\bar{\phi}_F$ = total flux in fuel, averaged over fuel volume,
- $\sigma_f(E)$ = U^{235} fission cross section,

$\sigma_f(2200) = U^{235}$ fission cross section for 2200-m/sec neutrons,

CR = cadmium ratio,

K = counter efficiency.

Thus,

$$\frac{\bar{R}_I}{\bar{R}_{II}} = \frac{0.886\sigma_f(2200) \frac{CR}{CR-1} \int_0^\infty \phi_M dE}{\int_0^\infty \phi_F \sigma_f(E) dE}.$$

The ratio of the thermal-neutron flux in the center of Region I to the total number of fissions per second in Region II is given by

$$\frac{\int_0^\infty \phi_M dE}{V N_F \int_0^\infty \phi_F(E) \sigma_f(E) dE}, \quad (3)$$

where N_F = fissile atom density and V = fuel volume. Combining Eqs. (1) and (2),

$$\frac{\text{thermal-neutron flux}}{\text{total fissions per second}} = \frac{\bar{R}_I/\bar{R}_{II}}{0.886\sigma_f(2200) \frac{CR}{CR-1} N_F V}.$$

This method of analysis gives 5.73×10^7 neutrons $\text{cm}^{-2} \text{sec}^{-1} \text{w}^{-1}$.

Reactivity Effects of Reducing the Hydrogen Content in the Central Flux Trap

Since the water-filled Region I was expected to have a positive void coefficient, the reactivity effects of displacing the water by air and plastic or by aluminum were determined for the conditions of experiments 2, 3, and 4. In each experiment the displacing material was inserted in Region I only, leaving the end reflectors undisturbed. The hydrogen density changes were expressed in terms of the equivalent percent reduction in the hydrogen content. Small changes in hydrogen density were achieved by

replacing water with plastic, which had less hydrogen per unit volume. Larger density changes were introduced by inserting 3/8-in.-ID plastic tubes filled with air. The hydrogen density was finally reduced to zero by removing all the water in Region I. In still other experiments aluminum was used to displace up to 73% of the water. Since the neutron scattering and absorption properties vary with each element, the effect of a given hydrogen density change depends upon the replacement material and its density. The results of displacements by air and plastic were recorded together, since a combination of the two was used in most experiments. The results with aluminum varied significantly between experiments and were tabulated separately. Since removal of hydrogen caused an increase in reactivity, the reactor was not full at criticality; that is, an air void was present between the fuel and the top reflector of Region II. Positive periods associated with small increases in fuel height above delayed critical were used to obtain values of $\Delta k/\Delta h$ at the critical heights corresponding to various displacements. The reactivity resulting from small changes in height from delayed critical was calculated by using the Keepin et al.⁴ value of the delayed-neutron fission yield ($\beta = 0.0064$) and the additional effective delayed-neutron contribution from the (γ, n) reaction in D_2O from the work of Bernstein et al.⁵ In calculations of $\Delta k/\Delta h$ delayed and prompt neutrons were assumed to be of equal importance.

Table 2 gives the critical height as a function of percent reduction in hydrogen density for the conditions of experiment 2 and also a description of the displacing material used in all the void coefficient experiments. The data are tabulated for displacements of water by aluminum, plastic, or combinations of air and plastic. The critical heights and $\Delta k/\Delta h$ values as a function of hydrogen displacement are given in Table 3 for the conditions of experiment 3 and in Table 4 for the conditions of experiment 4. Only combinations of air and water introduced by 1/2-in.-OD plastic tubes were used in experiment 3.

The variation of the critical height as a function of reduction in hydrogen density of Region I for the conditions of experiments 2, 3, and

4. G. R. Keepin, T. F. Wimett, and R. K. Zeigler, Phys. Rev. 107, 1044 (1957).

5. S. Bernstein et al., Phys. Rev. 71, 573 (1947).

Table 2. Critical Height as a Function of Percent Reduction in Hydrogen Density in Region I of Experiment 2

Hydrogen Reduction in Region I (%)	Critical Height (in.)	Displacing Materials
Displacements Introduced by Plastic Tubes or Rods ^a		
0	17.88 ^b	H ₂ O only in Region I
3.71	17.40	One 3-in.-diam Plexiglas rod
7.19	17.16	Fourteen 1/2-in.-OD by 3/8-in.-ID polystyrene tubes containing trapped air
10.16	16.95	One 3-in.-diam and ten 1.25-in.-diam Plexiglas rods
13.87	16.64	Twenty-seven 1/2-in.-OD by 3/8-in.-ID polystyrene tubes containing trapped air
18.50	16.31	Thirty-six 1/2-in.-OD by 3/8-in.-ID polystyrene tubes containing trapped air
39.9	15.09	Ninety (47 polystyrene and 43 polyethylene) 1/2-in.-OD by 3/8-in.-ID tubes containing trapped air
71.8	14.82	Ninety tubes containing air, as above, but with no surrounding H ₂ O
72.2	14.93	Sixty-eight (47 polystyrene and 21 polyethylene) 1/2-in.-OD by 3/8-in.-ID tubes containing air and two 1.25-in.-OD Plexiglas rods, with no surrounding H ₂ O
88.6	16.01	Forty-seven 1/2-in.-OD by 3/8-in.-ID polystyrene tubes containing air, with no surrounding H ₂ O
100	17.51	Air only in lower 18 in. of Region I
Displacements Introduced by Aluminum Rods ^a		
24.2	16.73	Eight 1-in.-diam Al rods
42.4	15.95	Fourteen 1-in.-diam Al rods
60.6	15.62	Twenty 1-in.-diam Al rods
72.8	15.77	Twenty-four 1-in.-diam Al rods

^a In each case the tubes or rods were 18 in. long and displaced the water in the lower 18 in. of Region I. A water reflector was always present above the lower 18 in. of Region I. For those cases in which no water surrounded the tubes, the upper water reflector was held in a polyethylene container.

^b Includes about 0.20 in. of fuel in top vents.

Table 3. Critical Height and $\Delta k/\Delta h$ as a Function of Percent Reduction in Hydrogen Density in Region I of Experiment 3

Hydrogen Reduction in Region I ^a (%)	Critical Height (in.)	Δh for Period (in.)	Period (sec)	Reactivity, $\Delta k \times 10^4$			$\Delta k/\Delta h$ (in. ⁻¹)		
				No Photo- neutrons	50% Photo- neutron Efficiency	100% Photo- neutron Efficiency	No Photo- neutrons	50% Photo- neutron Efficiency	100% Photo- neutron Efficiency
Displacements Introduced by Plastic Tubes or Rods ^b									
0.0	18.08 ^c								
7.19	17.27	0.0177	300	2.50	3.19	3.88	0.0141	0.0180	0.0219
7.19 ^d	17.31	0.0176	320	2.35	3.02	3.69	0.0134	0.0172	0.0210
18.50	16.38	0.0172	290	2.56	3.26	3.96	0.0149	0.0190	0.0230
18.50 ^d	16.40	0.0173	285	2.60	3.31	4.02	0.0150	0.0191	0.0232
39.9	15.22	0.0140	283	2.62	3.33	4.04	0.0187	0.0238	0.0289
59.9 ^e	14.76	0.0180	191	3.71	4.55	5.39	0.0206	0.0253	0.0299
71.8	14.96	0.0127	275	2.69	3.41	4.13	0.0212	0.0269	0.0325
100	17.59	0.0163	273	2.70	3.42	4.13	0.0166	0.0210	0.0253
Displacements Introduced by Aluminum Rods ^b									
0.0	18.08								
24.2	16.61								
42.4	15.89								
60.6	15.56								
72.8	15.76								

^a Refer to Table 2 for description of displacing materials.

^b In each case the tubes or rods were 18 in. long and displaced the water in the lower 18 in. of Region I. A water reflector was always present above the lower 18 in. in Region I. For those cases in which no water surrounded the tubes, the upper water reflector was held in a polyethylene container.

^c Critical height with no displacement corresponds to 0.40 in. of fuel in top vents.

^d Re-run to check on reproducibility of critical heights and periods.

^e Displacements introduced by forth-three 1/2-in.-OD by 3/8-in.-ID polyethylene tubes containing air and twenty-eight 1/2-in.-OD by 3/8-in.-ID polystyrene tubes containing water, with no surrounding water.

Table 4. Critical Height and $\Delta k/\Delta h$ as a Function of Percent Reduction in Hydrogen Density in Region I of Experiment 4

Hydrogen Reduction in Region I ^a (%)	Critical Height (in.)	Δh for Period (in.)	Period (sec)	Reactivity, $\Delta k \times 10^4$			$\Delta k/\Delta h$ (in. ⁻¹)		
				No Photo- neutrons	50% Photo- neutron Efficiency	100% Photo- neutron Efficiency	No Photo- neutrons	50% Photo- neutron Efficiency	100% Photo- neutron Efficiency
Displacements Introduced by Plastic Tubes ^b									
0.0	17.59 ^c	0.0215	270	2.73	3.45	4.17	0.0127	0.0160	0.0194
7.19	17.02	0.0224	245	2.98	3.74	4.50	0.0133	0.0167	0.0201
18.50	16.31	0.0187	274	2.69	3.42	4.13	0.0144	0.0183	0.0221
39.9	15.14	0.0208	191	3.71	4.55	5.39	0.0178	0.0219	0.0259
59.9 ^d	14.74	0.0173	211	3.39	4.20	5.01	0.0196	0.0243	0.0290
71.8	14.79	0.0210	163	4.24	5.15	6.05	0.0202	0.0245	0.0288
88.6	15.67	0.0173	218	3.30	4.05	4.89	0.0191	0.0234	0.0283
100	16.85	0.0173	204	3.50	4.32	5.13	0.0202	0.0257	0.0296
Displacements Introduced by Aluminum Rods ^b									
24.2	16.46	0.0180	299	2.49	3.18	3.87	0.0138	0.0177	0.0215
42.4	15.76	0.0166	272	2.72	3.44	4.16	0.0164	0.0207	0.0251
60.6	15.42	0.0204	204	3.50	4.32	5.13	0.0172	0.0212	0.0251
72.8	15.50	0.0204	200	3.56	4.39	5.21	0.0175	0.0215	0.0255

^a Refer to Table 2 for description of displacing materials.

^b In each case the tubes or rods were 18 in. long and displaced the water in the lower 18 in. of Region I. A water reflector was always present above the lower 18 in. in Region I. For those cases in which no water surrounded the tubes, the upper water reflector was held in a polyethylene container.

^c Reactor not full because the counters were removed from each region.

^d Displacements introduced by forty-three 1/2-in.-OD by 3/8-in.-ID polyethylene tubes containing air and twenty-eight 1/2-in.-OD by 3/8-in.-ID polystyrene tubes containing water, with no surrounding water.

4, shown graphically in Fig. 22, had a broad minimum at about 60%. The critical heights for each type of displacement were not significantly different for the various fuel and reflector compositions. Table 5 summarizes the maximum reactivities associated with the optimum water displacements in experiments 3 and 4. These values were obtained by a graphical summation of a plot of $\Delta k/\Delta h$ vs critical height for each experiment. In calculating the Δk values, efficiencies of 0, 50, and 100% were assumed for the production of photoneutrons in D_2O .

Fig. 22. Critical Height as a Function of Reduction in Hydrogen Density of Region I in HFIR Solution Critical Experiments 2-4.

Table 5. Maximum Total Reactivity Associated with Reduction of Hydrogen Density in Region I of Experiments 3 and 4

Assumed (γ, n) Efficiency (%)	$\Delta k_{\max}$	U^{235} Concentration in Region II (g/liter)	Boron Concentration in Region III (g/liter)
Displacements Introduced by Plastic Tubes Containing Trapped Air; $\Delta k_{\max}$ Derived from Data in Table 3			
0	0.047	137.5	0.056
50	0.060	137.5	0.056
100	0.072	137.5	0.056
Displacements Introduced by Plastic Tubes Containing Trapped Air; $\Delta k_{\max}$ Derived from Data in Table 4			
0	0.043	105.9	2.35
50	0.055	105.9	2.35
100	0.065	105.9	2.35
Displacements Introduced by Aluminum Rods; $\Delta k_{\max}$ Derived from Data in Table 4			
0	0.031	105.9	2.35
50	0.040	105.9	2.35
100	0.048	105.9	2.35

Appendix A
Description of Apparatus*

Core Vessel

The core vessel, Fig. A.1, consisted of a number of concentric aluminum cylinders contained in a 44-in.-OD by 36-in.-high aluminum tank. The central cylinder, Region I, known as the island or flux trap, is 5 3/4-in. (14.6 cm) ID as compared with 14-cm ID for the proposed reactor island. The fuel annulus, Region II-A, was 4 7/8 in. (12.4 cm) thick and approximately 30 in. deep. The thickness of the HFIR fuel annulus will be 12.5 cm and the height of the active portion of the elements will be 18 in. In the critical experiments, however, it was necessary to provide extra depth in the fuel annulus to facilitate initial experiments to determine the critical fuel concentration. In subsequent experiments the fuel height was limited to 17.68 ± 0.05 in. by insertion of the annular can, Region II-B. The D₂O reflector, Region III-A, was 7 7/8 in. thick and 18 in. deep. A removable plug between Regions III-A and III-B permitted the reflector height to be increased to match the fuel height during initial fuel concentration experiments. There were 6-in.-thick light-water reflectors, contained in annular Region IV, in Region V below the fuel region, and in Regions II-B and III-B above the fuel region.

Region I was made from 6-in.-OD by 1/8-in.-wall type 1100-O aluminum tubing; the remainder of the vessel was made from type 6061-T6 aluminum sheet and plate. The annular walls were rolled from 1/8-in. sheet and welded; the bottom and intermediate bottom between Region V and the remainder of the core were made from 1/4-in. plate. To facilitate assembly and to meet dimensional specifications, 1/8-in.-deep concentric grooves were milled in the intermediate bottom to position the ends of the rolled cylinders during welding. Over-all roundness and concentricity of the walls of the chambers were held well within the specified $\pm 1/8$ -in. tolerance as indicated in Appendix B; however, localized distortions somewhat beyond these limits resulted from welding. A 1/4-in.-thick

*Taken from C. A. Burchsted, High-Flux Isotope Reactor Critical Experiment -- Equipment, ORNL-CF-60-4-120 (Apr. 20, 1960).

Fig. A.1.

aluminum lid covered Regions II and III; neoprene gaskets glued to the underside of the lid prevented leakage, contamination, and intermixture of the fuel solution and D_2O . Since the critical experiment was conducted at atmospheric pressure, rubber tape was adequate to seal the penetrations through the lid. The top of Region IV was left open to facilitate placement of the neutron source and the control plate. The 6-in. tube of Region I was extended 3 in. above the remainder of the core vessel to provide a bearing surface for the safety blade.

All surfaces of the core vessel in contact with the uranyl nitrate fuel solution were given a baked coating of Heresite (red), a phenol base resin of low-neutron absorption, for corrosion resistance. On receipt of the vessel at the Critical Experiments Laboratory, a number of pin-hole leaks in this coating were discovered, necessitating recoating of much of these surfaces with Glyptal. Two-inch drain lines from Regions II-A and III-A permitted rapid dumping of the reactor liquids in the event of an emergency.

Storage Systems

The fuel and D_2O storage systems are shown schematically in Fig. A.2. The fuel was stored in a stainless steel slab tank 5 ft x 5 ft x 2-3/4 in.; this geometry is safe from the standpoint of criticality. The D_2O was stored in a pair of modified stainless steel 55-gal drums. The valves, pump volutes and impellers, and piping to the connections to the core vessel were of stainless steel to minimize contamination of the fuel solution and of the D_2O by corrosion. Neoprene gaskets were used in all flanged joints; all welds were fluid-penetrant-inspected upon completion, and the entire system was soap-bubble tested under 5-psig air. A higher test pressure was considered inadvisable in view of the 7-psi maximum pressure specified for the D_2O storage drums.

All valves were of the diaphragm-type (Hills-McCanna) and pumps were of the canned-rotor type. The D_2O feed pump was a Model C-2 Chempump; the fuel feed pump was an in-line-mounted, Model E Chempump. The 3-in. dump valves and 3/4-in. feed lines were air-operated, the former normally open and the latter normally closed. A valved bypass from each of the pump discharge lines to the respective storage tanks was provided to permit control

- NOTES-
1. ALL PIPING TO BE S.S. SCH. 40 EXCEPT WHERE NOTED.
 2. ALL FITTINGS TO BE S.S. WELD END FOR 150" SERVICE.
 3. ALL FLANGES TO BE S.S. FOR 150" SERVICE
 4. GASKET MATERIAL
 5. D.O. STORAGE TANKS ARE 55GAL. S.S.
 6. ALL PIPE WELDING TO CONFORM WITH SPEC. Y-ES-9.3-11 & Y-ES-9.3-12

NO.		REVISIONS			DATE	APPD	APPD
DRAWN	DATE	SUBMITTED	DATE	APPROVED	DATE		
W. Raines	9/25/59	OK	10-11-59				
DESIGNED	DATE	APPROVED	DATE	APPROVED	DATE		
CHECKED	DATE	APPROVED	DATE	APPROVED	DATE		

CORE TANK		TD-D-376
CORE TANK SUPPORT		TD-D-376
FUEL STORAGE TANK DETAILS		BRN1709
CRITICAL EXPERIMENT 2 & 3 LAB TANK DETAILS		6-M-2273
REFERENCE DRAWINGS		DWG. NO.
		BLDG. NO.
<p><i>id.</i></p> <p>HFIR CRITICAL EXPERIMENT PIPING SYSTEM</p>		
<p>OAK RIDGE NATIONAL LABORATORY OPERATED BY UNION CARBIDE NUCLEAR COMPANY A DIVISION OF UNION CARBIDE CORPORATION OAK RIDGE, TENNESSEE</p>		
<p>REVISIONS</p> <p>1. <i>Revised</i></p>	<p>APPROVED</p> <p><i>[Signature]</i></p>	<p>DATE</p> <p><i>9/1</i></p>
<p>TD-F-3770</p>		<p>1</p>

Fig. A.2.

of the pumping rates, and to permit mixing of the reactor liquids prior to pumping them into the core vessel. Both storage systems and the sight glasses of Regions II-A and III-A were vented to their respective regions in the core vessel in order to operate as completely closed systems.

Safety and Control Equipment

The control blade drive and the photo-cell followers of the sight glasses were fitted with selsyn transmitters; Veeder-Root counters in the control room, driven by the selsyn receivers, provided a numerical read-out of the control rod position and the liquid levels of the fuel and D₂O in the core to the nearest 0.01 in.

Emergency shutdown of the reactor was effected by dropping a cadmium safety blade into Region I and by opening the fuel and D₂O dump valves, all upon signal from radiation detectors. The safety blade, Fig. A.3, was a thin (0.020-in.-thick) sheet of cadmium contained, for rigidity, in a seam-welded stainless steel jacket. Because a flux monitor, having a vertical traverse of 18 in., also operated within Region I, it was necessary to leave one side of the blade open and to make the total assembly more than double the active depth of the fuel solution to prevent interference in any position of the monitor.

Flux Monitors

Flux measurements in the critical experiment were made with miniature counters supported from the drive assembly shown in Fig. A.4. An exploded view of a typical monitor is shown in Fig. A.5. The sensitive element was approximately 1 in. long and located about 1 1/2 in. from the bottom tip of the completed counter assembly. The jacket, cap, and 1/4-in.-OD "dog leg" counter tube were made from type 1100 aluminum; the jacket and cap were attached to the tube by an epoxy resin after installation of the cable and sensitive element. After assembly the counter was made water-tight by a coat of Glyptal.

Since the counter tube formed one side of the electrical circuit, nylon was used as the bearing material for mounting the counters in the core vessel. In addition to electrically isolating the counters from the core tank and from one another, the nylon also provided greaseless

OAK RIDGE, TENNESSEE			
SUBMITTED	ACCEPTED	APPROVED	
J.R. McWhorter 10-18-59			
Dinnell		10/19	TD-D3780

GENERAL SPECIFICATIONS:

1. Break all sharp edges 1/64 max., unless otherwise specified.
2. The fabricator may choose the type, grade or finish of material unless otherwise specified.

MACHINE FINISH SPECIFICATIONS:

1. Finish symbols are in accordance with ASA Standard B46.1-1956.
2. Roughness height values are the maximum arithmetic average deviation from the mean surface, expressed in microinches.
3. For surfaces not otherwise indicated, roughness height shall not exceed
✓

CLASSIFICATION

NOT CLASSIFIED

CAB

LIMITS ON DIMENSIONS UNLESS OTHERWISE SPECIFIED

FRACTIONS: $\pm \frac{1}{32}$

DECIMALS: $\pm$ _____

ANGLES: $\pm 1^\circ$

SCALE: AS NOTED

LTR	REVISIONS				DATE	APPRO	APPRO
DRAWN <i>H.E. Panton</i>	DATE	CHECKED <i>CALB</i>	DATE <i>10-17-59</i>	APPROVED	DATE		
DESIGNED	DATE	SUBMITTED <i>10-17-59</i>	DATE <i>10-19-59</i>	APPROVED	DATE		

Fig. A.3.

PHOTO 35245
UNCLASSIFIED

Fig. A.4. HFIR Solution Critical Experiment Flux Monitor Drive Assembly

UNCLASSIFIED
PHOTO 35894

Fig. A.5. Typical Flux Monitor Assembly (Exploded View)

lubrication. Two types of bearings were used, the cover-plate-supported model used in Regions II-A and IV and the longer model in Regions II-B and III-B. The latter type screwed into threaded holes in the bottom plates of those regions, preventing leakage of light water into the fuel or reflector fluids, and were supported at the upper end by holes in the cover plate of the reactor vessel. The cover plate was doweled to the reactor tank to assure accurate alignment of the bearings. The Amphenol plug at the top of the counter tube provided both an electrical coupling between the counter and its preamplifier and a mechanical counter between the tube and its drive mechanism.

The monitor drive assembly, shown in Fig. A.6, consisted essentially of a table, raised and lowered by a screw drive, on which was mounted a motor and pulley system for the rotating counters in Regions II, III, and IV, and a horizontal screw drive for the reciprocating counter in Region I. To avoid reduction of the signal, it was necessary to mount the preamplifier as close as possible to the counter and to provide a fixed relationship between the position of the counter and its preamplifier. The Region I (reciprocating) counter tube was attached directly to its preamplifier, and the combined assembly was moved by the screw drive. Nylon blocks electrically isolated the assembly from the remainder of the drive system. The rotating counter tubes were attached by Amphenol plugs to short lengths of stainless steel tubing, to which were rigidly attached the nylon drive pulleys; the hubs of the pulleys served as bearing surfaces. The counter preamplifiers were attached to the opposite ends of the stainless steel tubes by means of Amphenol plugs, and rotated with the counter tubes.

Position-indicating selsyn transmitters were mounted at one end of the Region I monitor drive screw, on the drive motor of the rotating counter pulley system, and on the table elevating drive; Veeder-Root tally counters on the control console, driven by the selsyn receivers, provided a read-out of the flux monitor positions. Since these selsyns actually indicated the positions of the driving mechanisms, considerable care had to be exercised in mounting the counter tubes to their respective drives to assure correspondence between the indicated and actual positions of the sensitive elements of the flux monitors. Originally a TV antenna rotator was used to drive the rotating counter pulley system; this was later replaced with a 1/40-hp, 1000-rpm universal motor and 900:1 speed reducer. The selsyn transmitter for this drive was operated through the

ENTRY NO	DWG NO	NO REQD	DESCRIPTION
1 THRU 15	TD-B-2192		
16 THRU 29	TD-O-3759		
30	FURNISHED	1	BORNIE GEAR MOTOR - 60 RPM TYPE WYC-23 RD
31		1	CAPACITOR - .05 TO 1.05 MFD X114AB
32		2	MICRO SWITCH- ANS 224-1-V31 w/ JV5 ACTUATOR
33		1	CABLE CONNECTOR
34			CABLE
35		2	POR AMP ASSY - MODEL 219 B SER NO 45 B
36		2	POR AMP ASSY - MODEL 200 B SER NO 502
37		1	"TALENT" SER NO 13330 TO 1HG
38		1	GEAR TRAIN - T2 TO 1 (FROM BORNIE GEAR MOTOR)
39		1	"ALPROCO" THERMOSTAT w/ CLAMPS & CONTROL
40		1	1/2" SMART COUPLING "BOTTOM GEAR" CR B
41		1	AMPHIPHOL 90° CONNECTOR
42		1	AMPHIPHOL - 1" TUBE TO CONNECTOR
43		3	AMPHIPHOL - 1/2" TUBE TO 1/2" TUBE COUPLING
44		1	B COUPLING - MAKE FROM 1/2" I.D. x 3/4" WALL TUBING
45	THIS DWG	2	ODX .065 WALL x 2 1/2" LG. SST TUBING
A	TD-B-2192	1	WELDED ASSY (SPEC: WYS-93-32)
B	TD-O-3759	1	(SPEC: WYS-93-32)
C		1	(SPEC: RD-12-1, SCH C)
1	STOCK	16	PLAIN WASHER 1/16 ID x 1/8 O.D. .012 THK
8		8	PLAIN WASHER 1/16 x 1/8 x .012 O.D. THK
12		12	PLAIN WASHER .004 x 1/2 SCREW
18		18	PLAIN WASHER FOR P.D SCREW
1		1	HEX SEMI-FIN NUT 1/8 NC
10		10	" - 1/8 NC
8		8	" - 1/8 NC
8		8	" - #12-24 NC
24		24	" - #8-32 NC
2		2	CAP SCREW - HEX - 1/16 NC x 1 1/2 LG
2		2	MACH SCREW PL HO - #12-24 NC x 1 LG
4		4	HEX OD SQ. BOLT - #12-24 NC x 1 1/2 LG
4		4	MACH SCREW RD HO - #12-24 NC x 1 LG
4		4	MACH SCREW FL HO - #8-32 NC x 3/4 LG
2		2	HEADLESS SET SCW CAP PT - 1/2-20 NC x 1 LG
4		4	" - 1/2-20 NC x 3/4 LG
4		4	" - 3/8-32 NC x 1 LG

NO.	REVISIONS				DATE	APPD	APPD
CHANGING	DATE	SUBMITTED	DATE	APPROVED	DATE		
10-28-57	10-28-57	10-28-57	10-28-57	10-28-57	10-28-57		
DEBARG	DATE	APPROVED	DATE	APPROVED	DATE		
10-28-57	10-28-57	10-28-57	10-28-57	10-28-57	10-28-57		
CHECKED	DATE	APPROVED	DATE	APPROVED	DATE		

DETAILS SHEET 82		TOD-3788	
DETAILS SHEET 81		TOD-3789	
REFERENCE DRAWINGS		DWG. NO.	
HFLR		ELEC 9213	
CLASSIFICATION NOT CLASSIFIED			
LIMITS AND DIMENSIONS TO BE SPECIFICALLY SPECIFIED FINISHES: <u>2</u> <u>2</u> DIMENSIONS: <u>2</u> <u>005</u> GRIND: <u>2</u>		OAK RIDGE NATIONAL LABORATORY OPERATED BY UNION FEDERAL NUCLEAR COMPANY A BRANCH OF UNION FEDERAL CORPORATION ONE NINE, TENNESSEE	
DRAWN BY: J. H. H. 4		CHECKED BY: [Signature]	
APPROVED BY: [Signature]		APPROVED BY: [Signature]	
WORK: <u>W-2</u>		TDS-3781	

Fig. A.6.

gear head of a 25-rpm (72:1 gear ratio) Bodine motor, providing, with the 1:10 ratio of the Veeder-Root counter, a position indication to the nearest $1/2$ deg.

The reciprocating monitor for Region I was driven by a 60-rpm Bodine motor through a $1/4$ -20 drive screw, permitting the monitor to be moved from the edge to the center of the 6-in. tube in 1 min. The horizontal position of this monitor was indicated to the nearest 0.005 in. Originally a modified prototype control rod for the Bulk Shielding Facility was used for the vertical drive; this was later replaced with a screw drive having a more accurate position-indicating selsyn. The four vertical guide rods of the drive assembly minimized the lateral displacement of the flux monitors that was caused by the unavoidable eccentric loading of the moving table and the change in the center of gravity with motion of the monitors and their preamplifiers. The guide rod bearings were rigidly fixed to a stationary table (see Fig. A.4), which in turn was clamped to the framework surrounding the critical experiment. Ball bushings in the guide rod bearings minimized friction.

The monitor drive assembly was completely separate from the core vessel, the only connections being through the counter tube bearings that were attached to the vessel. The cable driving the rotating counters was locked by set screws into the pulleys; a spring-loaded idler pulley was located between the drive pulley and the Region IV pulley to take up slack and assure uniform rotation of all pulleys in the system. Since it was necessary to replace the tension spring several times, an additional idler between the drive pulley and the Region I pulley or individual cables from the drive pulley to each driven pulley are indicated for any future drive system. Only one drive motor is recommended, however, because of the very limited amount of space available.

When operating the experiment with the top reflector, that is, with light water in Regions II-B and III-B, it was necessary to maintain a water-tight seal between these and the fuel and reflector regions. Rotating counters were required for these chambers because of the necessity of maintaining this seal, which was provided by the counter tube bearings. In plotting the flux measurements made in these regions it was necessary therefore to translate the angular position indications

to their respective projections on the vessel diameter. The "dog legs" of the counter tubes permitted making measurements across the entire thickness of the chamber while necessitating only a single penetration into the chamber. A reciprocating monitor was specified for Region I because of the necessity of also providing for operation of the safety blade in that region. Flux measurements in the bottom reflector, Region V, were made by drawing miniature counters through the three 1/4-in. diametrical tubes indicated in Fig. A.1. These counters were positioned by screw drives of the same type as used for the control and safety blades and for the vertical drive of the monitor drive assembly discussed above. One of the tubes was located directly below the intermediate bottom, and the others were spaced at 2 1/2-in. intervals. Since the flux was essentially symmetrical about the axes of the core, flux measurements in the top reflector were not required.

Because of distortion due to welding, these tubes were slightly bowed downward. The effect of this bowing must be considered in flux measurements made in this region. Some inaccuracies will also be introduced into the flux measurements due to compromises necessary in the design and fabrication of the core vessel. Most important of these is that, due to the annular spaces between the can which constitutes Region II-B and the walls of Region II-A, the fuel level must be very carefully controlled to prevent it from rising into these spaces. Other inaccuracies may be introduced by the flux monitors themselves or by "holes" in the reflector due to drain and vent lines. A somewhat heavier plate than might have been desired was used for the intermediate bottom, but was necessitated by the need of grooves to maintain the concentricity and roundness of the annular cylinders of the core. A certain degree of inaccuracy may also be introduced by the slight bowing of the bottom of the core tank under the load of the reactor fluids.

Appendix BMeasurements of Thicknesses of Regions II, III, and IV*

The following tabulation shows the variation in annuli thickness of the HFIR critical experiment core vessel. The measurements were made at four stations 90° apart, at 6 in. intervals from top to bottom. Station A corresponded to the vent pipe from Region V. Since Region III-B had a false bottom 12 in. from the top of the vessel, only three measurements could be made in Region III; however, the variations can to some degree be inferred by comparison of corresponding measurements in Regions II and IV.

Region II: Nominal annulus thickness = 4.875 in.

<u>Elevation (in.)</u>	<u>Measured Thickness (in.)</u>			
	<u>Station A</u>	<u>Station B</u>	<u>Station C</u>	<u>Station D</u>
2	4.875	4.921	4.843	4.812
6	4.880	4.921	4.870	4.843
12	4.890	4.921	4.875	4.859
18	4.875	4.921	4.875	4.843
24	4.875	4.921	4.869	4.843
30	4.875	4.906	4.875	4.843
Average	4.878	4.919	4.869	4.841

Overall average: 4.876 in.

Maximum variations: +0.045 to -0.064 in.

Region III (III-B only): Nominal annulus thickness = 7.875 in.

<u>Elevation (in.)</u>	<u>Measured Thickness (in.)</u>			
	<u>Station A</u>	<u>Station B</u>	<u>Station C</u>	<u>Station D</u>
2	7.843	7.845	7.906	7.890
6	7.843	7.843	7.906	7.890
12	7.875	7.859	7.937	7.890
Average	7.854	7.848	7.916	7.890

Overall average: 7.877 in.

Maximum variations: +0.060 to -0.034 in.

*Taken from C. A. Burchsted, High-Flux Isotope Reactor Critical Experiment Equipment, ORNL-CF-60-4-120 (Apr. 20, 1960).

Region IV: Nominal annulus thickness = 5.875 in.

<u>Elevation (in.)</u>	<u>Measured Thickness (in.)</u>			
	<u>Station A</u>	<u>Station B</u>	<u>Station C</u>	<u>Station D</u>
2	5.815	5.875	5.875	5.921
6	5.835	5.843	5.875	5.937
12	5.790	5.828	5.812	5.859
18	5.865	5.859	5.890	5.890
24	5.875	5.859	5.890	5.875
30	5.865	5.875	5.890	5.875
Average	5.841	5.857	5.872	5.893

Overall average: 5.866 in.

Maximum variations: +0.071 to -0.076 in.

Region II-B (light-water reflector insert over fuel): Nominal annulus thickness = 4.375 in.

<u>Elevation (in.)</u>	<u>Measured Thickness (in.)</u>			
	<u>Station A</u>	<u>Station B</u>	<u>Station C</u>	<u>Station D</u>
2	4.380	4.380	4.390	4.390
6	4.312	4.375	4.375	4.406
12	4.375	4.359	4.360	4.365
Average	4.356	4.371	4.375	4.387

Overall average: 4.372 in.

Maximum variations: +0.034 to -0.060 in.

Appendix CDescription of Miniature Counters

The fission counters used in most of these experiments were 3/16 in. in outside diameter and 1-1/2 in. in length (see Fig. C-1 for details of the construction). The uranium was enriched to 99% in U^{235} . Approximately 1 mg of UO_2 was plated onto a 2-mil-thick platinum foil and rolled into a cylinder that fitted inside the Kovar cylinder. The counters were filled with argon at atmospheric pressure.

The miniature boron counters (Fig. C-1) were filled to a pressure of 152 cm Hg with BF_3 , in which B^{10} enrichment was 96%. Both types of miniature counters were made by the ORNL Instrument Department.

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Miniature Fission Chamber

Miniature BF_3 Counter Assembly

Fig. C.1. Diagram of Miniature Fission and B^{10}F_3 Counters

Appendix D

Procedure for Intercalibration and Normalization of Individual Counter Data

Since the U^{235} fission counters and BF_3 counters used to map the flux in each region of the HFIR solution critical experiments were not identical, it was necessary to calibrate each one in terms of a standard. The most simple method was to use the counter in Region I as the standard and relate each of the others to it. To do this, it was first necessary to correct all individual counter rates to the same power level by dividing them by the rate of a power-normalizing counter, a large BF_3 counter external to the reactor. These power-normalized counting rates are designated by the subscript N. A superscript giving the number of each region is used to differentiate between each counter: C_N^I , C_N^{II} , C_N^{III} , and C_N^{IV} . The intercalibration was done by moving the Region I counter to the center of each of the three other regions and obtaining the counting rates. These values are designated as C_{N1}^I , C_{N2}^I , C_{N3}^I , and C_{N4}^I , respectively. The efficiencies of the counters at the centers of Regions II, III, and IV relative to the counter at the center of Region I are designated by E^{II} , E^{III} , and E^{IV} . The data are further normalized to unity at the center of Region I by dividing by $C_N^I(0)$.

The normalized and corrected counting rate is designated by $C_R(r,h)$. Then for Region I,

$$C_R^I(r,h) = \frac{C_N^I(r,h)}{C_N^I(c)} ;$$

for Region II,

$$E^{II} = \frac{C_{N2}^I(c)}{C_N^{II}(c)} ;$$

and

$$C_R^{II}(r,h) = \frac{E^{II} C_N^{II}(r,h)}{C_N^I(c)} = \frac{C_{N2}^I(c)}{C_N^{II}(c) C_N^I(c)} \times C_N^{II}(r,h).$$

The normalized and corrected counting rate in Region III is

$$C_R^{III}(r,h) = \frac{C_{N3}^I(c)}{C_N^{III}(c) C_N^I(c)} \times C_N^{III}(r,h),$$

and in Region IV is

$$C_R^{IV}(r,h) = \frac{C_{N4}^I(c)}{C_N^{IV}(c) C_N^I(c)} \times C_N^{IV}(r,h),$$

where (c) is used to denote values at the center of each region.

Appendix ETabulations of Relative Flux Distribution Data

The flux distribution measurements for Experiments 1-4 are given in Tables E-1 through E-20 as follows:

Expt. No.	Counter	Traverse	Position	Table No.
1	Bare U ²³⁵ fission counter	Radial through Regions I-IV	At mid-plane	E.1
1	"	"	4.5 in. above mid-plane	E.2
1	"	"	5.8 in. below mid-plane	E.3
1	"	Vertical in Regions I-IV	r* = 0 in. in Region I r = 5.52 in. in Region II r = 11.87 in. in Region III r = 18.65 in. in Region IV	E.4
1	Cd-covered U ²³⁵ fission counter	Radial through Regions I-IV	At mid-plane	E.5
1	"	Vertical in Regions I and II	r = 0 in. in Region I r = 5.52 in. in Region II	E.6
1	Bare U ²³⁵ fission counter	Radial in bottom reflector	At three vertical positions	E.7
1	Bare miniature B ¹⁰ F ₃ counter	Radial through Regions I-IV	At mid-plane	E.8
1	Cd-covered miniature B ¹⁰ F ₃ counter	"	"	E.9
1	Bare miniature B ¹⁰ F ₃ counter	Vertical in Regions I-III	r = 0 in. in Region I r = 7.15 in. in Region II r = 11.87 in. in Region III	E.10

*r = radial position, i.e., distance from vertical centerline.

Expt. No.	Counter	Traverse	Position	Table No.
1	Cd-covered Miniature B ¹⁰ F ₃ counter	Vertical in Regions I-III	r = 0 in. in Region I r = 7.15 in. in Region II r = 11.87 in. in Region III	E.11
2	Bare U ²³⁵ fission counter	Radial through Regions I-IV	At mid-plane	E.12
3	"	"	"	E.13
3	Cd-covered U ²³⁵ fission counter	Radial through Regions I-III	"	E.14
3	Bare U ²³⁵ fission counter	Vertical in Regions I-IV	r = 0 in. in Region I r = 5.52 in. in Region II r = 11.87 in. in Region III r = 18.65 in. in Region IV	E.15
3	Cd-covered U ²³⁵ fission counter	Vertical in Regions I-III	r = 0 in. in Region I r = 5.52 in. in Region II r = 11.87 in. in Region III	E.16
4	Bare U ²³⁵ fission counter	Radial through Regions I-IV	At mid-plane	E.17
4	Cd-covered U ²³⁵ fission counter	Radial through Regions I-III	"	E.18
4	Bare U ²³⁵ fission counter	Vertical in Regions I-IV	r = 0 in. in Region I r = 5.52 in. in Region II r = 11.87 in. in Region III r = 18.65 in. in Region IV	E.19
4	Cd-covered U ²³⁵ fission counter	Vertical in Regions I-III	r = 0 in. in Region I r = 5.52 in. in Region II r = 11.87 in. in Region III	E.20

Table E.1 Bare U^{235} Fission-Counter Radial Traverse Data at
Mid-plane of HFIR Solution Critical Experiment No. 1^a

Deuterium in Region II: 95.4 at. %
 U^{235} Concentration in Region II: 93.17 g/liter

Region I		Region II		Region III		Region IV	
Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate
1.70	0.893	7.62	0.134	15.42	0.249	21.40	0.00336
1.95	0.815	7.71	0.141	15.59	0.244	21.55	0.00234
2.20	0.715	7.34	0.124	14.92	0.252	21.00	0.00590
2.46	0.571	6.86	0.104	14.12	0.268	20.36	0.00743
2.71	0.404	6.25	0.090	13.07	0.291	19.55	0.0141
2.20	0.720	5.52	0.083	11.87	0.305	18.65	0.0280
1.70	0.887	4.73	0.084	10.60	0.311	17.77	0.0474
1.20	0.956	3.40	0.137	8.61	0.263	16.50	0.116
0.68	0.977	3.17	0.212	8.30	0.221	16.32	0.136
0.08	0.991	5.52	0.082	11.87	0.310	18.65	0.0333
0.02	0.993	5.71	0.084	12.18	0.307	18.88	0.0287
-0.04	0.995	5.90	0.081	12.48	0.301	19.11	0.0248
0.07	0.991	5.52	0.082	11.87	0.306	18.65	0.0300
0.19	1.009	3.17	0.221	8.30	0.218	16.32	0.138
-0.08	1.008	3.40	0.137	8.61	0.267	16.50	0.118
-0.34	1.008	3.98	0.102	9.44	0.299	17.02	0.0854
-0.59	1.003	4.73	0.086	10.60	0.314	17.77	0.0527
-0.34	1.004	5.13	0.083	11.23	0.314	18.20	0.0413
-0.08	1.007	5.52	0.083	11.87	0.313	18.65	0.0316
0.18	1.003	5.90	0.083	12.48	0.307	19.11	0.0234
0.42	1.004	6.25	0.086	13.07	0.298	19.55	0.0171
0.68	0.997	6.57	0.092	13.63	0.287	19.97	0.0125
0.94	0.985	6.86	0.097	14.12	0.276	20.36	0.00926
1.19	0.973	7.12	0.106	14.56	0.267	20.70	0.00713
1.44	0.936	7.34	0.115	14.92	0.261	21.00	0.00560

^a Data normalized to 1 at reactor center.

Table E.2 Bare U^{235} Fission-Counter Radial Traverse Data 4.5 in. Above
Mid-plane of HFIR Solution Critical Experiment No. 1^a

Deuterium in Region II: 95.4 at. %
 U^{235} Concentration in Region II: 93.17 g/liter

Region I		Region II		Region III		Region IV	
Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate
0.15	0.903	3.17	0.189	8.30	0.207	16.32	0.098
-0.52	0.878	3.40	0.175	8.61	0.209	16.50	0.095
0.18	0.883	3.98	0.112	9.44	0.241	17.02	0.074
0.08	0.881	4.73	0.081	10.60	0.278	17.77	0.048
0.42	0.879	5.13	0.075	11.23	0.298	18.20	0.037
0.69	0.869	5.52	0.071	11.87	0.296	18.65	0.026
0.94	0.867	5.90	0.070	12.48	0.291	19.11	0.018
1.19	0.855	6.25	0.070	13.07	0.286	19.55	0.012
1.44	0.836	6.57	0.074	13.63	0.287	19.97	0.009
1.70	0.805	6.86	0.080	14.12	0.277	20.36	0.006
1.95	0.752	7.12	0.086	14.56	0.264	20.70	0.004
2.20	0.688	7.34	0.095	14.92	0.253	21.00	0.003
2.46	0.607	7.62	0.011	15.42	0.238	21.40	0.002
2.71	0.523	7.71	0.127	15.59	0.209	21.55	0.002
2.46	0.584	7.62	0.117	15.42	0.235	21.40	0.002
1.95	0.751	7.34	0.098	14.92	0.249	21.00	0.003
1.44	0.835	6.86	0.081	14.12	0.269	20.36	0.005
0.94	0.874	6.25	0.071	13.07	0.288	19.55	0.012
0.42	0.867	5.90	0.070	12.48	0.297	19.11	0.017
0.05	0.865	5.71	0.069	12.18	0.300	18.88	0.021
-0.08	0.865	5.52	0.069	11.87	0.300	18.65	0.025
-0.34	0.860	4.73	0.080	10.60	0.291	17.77	0.046
-0.52	0.855	3.98	0.107	9.44	0.257	17.02	0.072
-0.08	0.861	3.40	0.165	8.61	0.210	16.50	0.092
0.18	0.859	3.17	0.181	8.30	0.202	16.32	0.095
0.18	0.855	3.23	0.185	8.38	0.215	16.37	0.089
0.18	0.855	3.20	0.185	8.34	0.209	16.34	0.092
0.18	0.858	3.17	0.182	8.30	0.206	16.32	0.096

^a Data normalized to 1 at reactor center.

Table E.3 Bare U^{235} Fission-Counter Radial Traverse Data 5.8 in.
Below Mid-plane of HFIR Solution Critical Experiment No. 1^a

Deuterium in Region II: 95.4 at. %

U^{235} Concentration in Region II: 93.17 g/liter

Region I		Region II		Region III		Region IV	
Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate
-0.59	0.775	3.17	0.169	8.30	0.169	16.32	0.0901
-0.34	0.777	3.40	0.111	8.61	0.207	16.50	0.0770
-0.08	0.779	3.98	0.078	9.44	0.236	17.02	0.0556
0.17	0.781	4.73	0.067	10.60	0.247	17.77	0.0357
0.42	0.779	5.13	0.065	11.23	0.245	18.20	0.0284
0.68	0.777	5.52	0.066	11.87	0.240	18.65	0.0224
0.94	0.765	5.90	0.067	12.48	0.236	19.11	0.0177
1.19	0.756	6.25	0.070	13.07	0.230	19.55	0.0135
1.44	0.734	6.57	0.074	13.63	0.224	19.97	0.0102
1.70	0.697	6.86	0.080	14.12	0.214	20.36	0.00763
1.95	0.644	7.12	0.087	14.56	0.217	20.70	0.00571
2.20	0.565	7.34	0.095	14.92	0.209	21.00	0.00438
2.46	0.461	7.50	0.103	15.21	0.205	21.23	0.00348
2.71	0.316	7.69	0.115	15.55	0.199	21.50	0.00223
2.58	0.393	7.71	0.115	15.59	0.199	21.55	0.00194
2.08	0.603	7.62	0.115	15.42	0.199	21.40	0.00244
1.57	0.710	7.23	0.097	14.75	0.212	20.86	0.00430
1.06	0.756	6.73	0.081	13.87	0.225	20.18	0.00721
0.36	0.771	6.08	0.070	12.80	0.240	19.34	0.0120
0.18	0.777	5.90	0.070	12.48	0.251	19.11	0.0150
0.04	0.777	5.71	0.067	12.18	0.252	18.88	0.0170
-0.08	0.777	5.52	0.066	11.87	0.254	18.65	0.0191
-0.47	0.779	4.34	0.070	9.99	0.263	17.36	0.0427
-0.58	0.776	3.52	0.097	8.77	0.236	16.60	0.0706
0.04	0.773	3.17	0.164	8.30	0.182	16.32	0.0876

^a Data normalized to 1 at reactor center.

Table E.4 Bare U²³⁵ Fission-Counter Vertical Traverse Data in the Four Regions of HFIR Solution Critical Experiment No. 1^a

Deuterium in Region II: 95.4 at. %

U²³⁵ Concentration in Region II: 93.17 g/liter

Region I ^b		Region II ^b		Region III ^b		Region IV ^b	
Distance from Vertical Mid-plane (in.)	Relative Counting Rate	Distance from Vertical Mid-plane (in.)	Relative Counting Rate	Distance from Vertical Mid-plane (in.)	Relative Counting Rate	Distance from Vertical Mid-plane (in.)	Relative Counting Rate
-7.09	0.6851	-6.72	0.0672	-6.94	0.244	-6.82	0.0223
-6.51	0.7408	-6.14	0.0673	-6.36	0.251	-6.24	0.0221
-6.01	0.7885	-5.64	0.0689	-5.86	0.258	-5.74	0.0223
-5.51	0.8243	-5.14	0.0705	-5.36	0.266	-5.24	0.0226
-5.01	0.8589	-4.64	0.0723	-4.86	0.273	-4.74	0.0229
-4.51	0.8874	-4.14	0.0737	-4.36	0.279	-4.24	0.0237
-4.01	0.9141	-3.64	0.0763	-3.86	0.288	-3.74	0.0237
-3.51	0.9362	-3.14	0.0778	-3.36	0.291	-3.24	0.0244
-3.01	0.9595	-2.64	0.0797	-2.86	0.295	-2.74	0.0246
-2.51	0.9692	-2.14	0.0816	-2.36	0.302	-2.24	0.0246
-2.01	0.9851	-1.64	0.0823	-1.86	0.303	-1.74	0.0247
-1.01	1.004	-0.64	0.0832	-0.86	0.308	-0.74	0.0246
-0.51	1.004	-0.14	0.0832	-0.36	0.310	-0.24	0.0249
0.49	0.9899	0.86	0.0812	0.64	0.302	0.76	0.0242
1.49	0.9828	1.86	0.0805	1.64	0.302	1.76	0.0236
2.49	0.9487	2.86	0.0778	2.64	0.295	2.76	0.0226
2.99	0.9282	3.36	0.0752	3.14	0.283	3.26	0.0225
3.49	0.9084	3.86	0.0735	3.64	0.281	3.76	0.0215
4.30	0.8647	4.67	0.0701	4.45	0.272	4.57	0.0199
3.24	0.9186	3.61	0.0743	3.39	0.284	3.51	0.0215
2.24	0.9544	2.61	0.0784	2.39	0.295	2.51	0.0233
1.24	0.9823	1.61	0.0810	1.39	0.301	1.51	0.0239
0.24	0.9964	0.61	0.0824	0.39	0.306	0.51	0.0246
-0.76	0.9925	-0.39	0.0826	-0.61	0.305	-0.49	0.0251
-1.76	0.9783	-1.39	0.0813	-1.61	0.302	-1.49	0.0250
-2.76	0.9492	-2.39	0.0792	-2.61	0.291	-2.49	0.0247
-3.76	0.9089	-3.39	0.0764	-3.61	0.270	-3.49	0.0239
-4.76	0.8481	-4.39	0.0727	-4.61	0.267	-4.49	0.0231
-5.76	0.7777	-5.39	0.0681	-5.61	0.240	-5.49	0.0215
-6.76	0.6897	-6.39	0.0651	-6.61	0.226	-6.49	0.0195

^a Data normalized to 1 at the reactor center.

^b Radial counter position (in.): Region I, 0.0; Region II, 5.52; Region III, 11.87; Region IV, 18.65.

Table E.5 Cadmium-Covered U²³⁵ Fission-Counter Radial Traverse Data
at Mid-plane of HFIR Solution Critical Experiment No. 1^a

Deuterium in Region II: 95.4 at. %
U²³⁵ Concentration in Region II: 93.17 g/liter

Region I		Region II		Region III		Region IV	
Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate
0.14	0.00965	4.34	0.0222	9.99	0.0140	17.36	0.00033
-0.05	0.00977	4.73	0.0225	10.60	0.0123	17.77	0.00021
0.34	0.00982	5.13	0.0226	11.23	0.0108	18.20	0.00013
0.65	0.01023	5.52	0.0226	11.87	0.00909	18.65	0.000081
0.95	0.0108	5.90	0.0220	12.48	0.00841	19.11	0.000045
1.26	0.0122	6.25	0.0212	13.07	0.00721		
1.46	0.0128	6.57	0.0210	13.63	0.00529	19.97	0.000017
1.66	0.0136	6.86	0.0203	14.12	0.00453		
1.86	0.0148	7.12	0.0200	14.56	0.00390		
2.07	0.0158	7.34	0.0192	14.92	0.00393		
2.27	0.0170	7.50	0.0188	15.21	0.00284		
2.37	0.0175	7.62	0.0187	15.42	0.00264		
2.27	0.0169	7.69	0.0184	15.55	0.00266		
2.42	0.0180	7.34	0.0189	14.92	0.00321		
0.14	0.00965	4.34	0.0215	9.99	0.0134	17.36	0.00032
0.34	0.00963	5.13	0.0227	11.23	0.0108	18.20	0.00013
0.95	0.0108	5.90	0.0220	12.48	0.00771	19.11	0.000048
1.46	0.0128	6.57	0.0210	13.63	0.00546	19.97	0.000021
1.86	0.0147	7.12	0.0196	14.56	0.00413		
2.27	0.0169	7.50	0.0187	15.21	0.00381		
2.22	0.0166	7.69	0.0184	15.55	0.00274		
2.42	0.0178	7.34	0.0191	14.92	0.00326		
0.14	0.00972	5.71	0.0226	12.18			

^a Data normalized to 1 for the same counter bare at the reactor center.

Table E.6 Cadmium-Covered U²³⁵ Fission-Counter Vertical Traverse Data for Regions I and II of HFIR Solution Critical Experiment No. 1^a

Deuterium in Region II: 95.4 at. %
U²³⁵ Concentration in Region II: 93.17 g/liter

Region I ^b		Region II ^b	
Distance from Vertical Mid-plane (in.)	Relative Counting Rate	Distance from Vertical Mid-plane (in.)	Relative Counting Rate
4.27	0.00853	4.64	0.0188
3.49	0.00875	3.86	0.0195
2.49	0.00907	2.86	0.0201
1.49	0.00924	1.86	0.0208
0.49	0.00945	0.86	0.0214
-0.47	0.00947	-0.10	0.0214
-1.51	0.00948	-1.14	0.0218
-2.51	0.00932	-2.14	0.0210
-3.51	0.00890	-3.14	0.0202
-4.51	0.00862	-4.14	0.0192
-5.51	0.00797	-5.14	0.0178
-6.51	0.00729	-6.14	0.0161
-6.01	0.00764	-5.64	0.0176
-4.01	0.00864	-3.64	0.0197
-2.01	0.00940	-1.64	0.0212
-0.01	0.00943	0.36	0.0211
1.99	0.00913	2.36	0.0203
3.99	0.00839	4.36	0.0183

^a Data normalized to 1 for the same counter bare at the reactor center.

^b Radial positions of counter (in.): Region I, 0.0; Region II, 5.52.

Table E.7 Bare U²³⁵ Fission-Counter Radial Traverse Data in Bottom Reflector at Various Distances from the Fuel for HFIR Solution Critical Experiment No. 1^a

Deuterium in Region II: 95.4 at. %
U²³⁵ Concentration in Region II: 93.17 g/liter

Upper Traverse ^b		Middle Traverse ^b		Lower Traverse ^b	
Radial Distance from Axis (in.)	Relative Counting Rate	Radial Distance from Axis (in.)	Relative Counting Rate	Radial Distance from Axis (in.)	Relative Counting Rate
0.7	0.375	1.15	0.183	-2.00	0.0358
2.7	0.297	3.15	0.193	0.00	0.0359
4.7	0.174	5.15	0.193	2.00	0.0375
7.7	0.169	7.15	0.167	4.00	0.0375
10.7	0.215	9.15	0.127	6.00	0.0343
13.7	0.175	12.15	0.0668	10.00	0.0182
17.7	0.0545	15.15	0.0298	12.00	0.0107
20.7	0.00980	18.15	0.00921	15.00	0.00446
15.7	0.127	14.15	0.0392	11.00	0.0140
11.7	0.208	10.15	0.105	3.00	0.0382
5.7	0.159	6.15	0.184	8.00	0.0280
1.7	0.345	2.15	0.182	-1.00	0.0352
-1.3	0.331	-0.85	0.182	-4.00	0.0339
-3.3	0.193	-2.85	0.192	-6.00	0.0296
-5.3	0.159	-3.85	0.193	-8.00	0.0235
-7.3	0.183	-4.85	0.191	-10.00	0.0144
-10.3	0.218	-6.85	0.159	-14.00	0.00481
-13.3	0.167	-9.85	0.0949	-15.72	0.00314
-16.3	0.0741	-12.85	0.0453	-12.00	0.00858
-20.3	0.00565	-16.85	0.00117	-9.00	0.0184
-15.3	0.113	-10.85	0.0748	-5.00	0.0326
-11.3	0.206	-7.85	0.139	-3.00	0.0354
-9.3	0.218	-5.85	0.178	1.00	0.0369
-4.3	0.169	-1.85	0.191		
-0.3	0.364	0.15	0.181		
9.7	0.212	4.15	0.195		
		-1.85	0.190		
		-0.85	0.185		
		2.15	0.187		

^aData normalized to 1 at the reactor center.

^bDistances of centers of active chambers below center of assembly (in.): upper traverse, 9.42; middle traverse, 11.83; lower traverse, 14.45.

Table E.8 Bare Miniature B^{10}F_3 Counter Radial Traverse Data at
Mid-plane of HFIR Solution Critical Experiment No. 1^a

Deuterium in Region II: 95.4 at. %
 U^{235} Concentration in Region II: 93.17 g/liter

Region I		Region II		Region III		Region IV	
Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate
0.77	0.989	6.25	0.105	13.07	0.293	19.55	0.0143
1.08	0.971	6.86	0.118	14.12	0.272	20.36	0.00720
1.28	0.964	7.34	0.140	14.92	0.255	21.00	0.00410
1.53	0.949	7.62	0.157	15.42	0.247	21.40	0.00278
1.79	0.908	7.71	0.165	15.59	0.248	21.55	0.00249
2.09	0.786	7.34	0.139	14.92	0.254	21.00	0.00404
2.40	0.647	6.86	0.116	14.12	0.271	20.36	0.00709
2.60	0.516	6.25	0.103	13.07	0.293	19.55	0.0143
2.29	0.697	5.13	0.102	11.23	0.310	18.20	0.0414
1.99	0.813	4.34	0.117	9.99	0.294	17.36	0.0759
1.69	0.893	3.52	0.174	8.77	0.246	16.60	0.126
1.38	0.948	3.17	0.242	8.30	0.201	16.32	0.154
0.97	0.981	4.34	0.117	9.99	0.296	17.36	0.0757
0.67	1.009	5.52	0.103	11.87	0.307	18.65	0.0295
0.47	1.014	5.90	0.099	12.48	0.302	19.11	0.0208
0.0	1.004	6.57	0.109	13.63	0.283	19.97	0.0104

^a Data normalized to 1 at reactor center.

Table E.9 Cadmium-Covered Miniature $B^{10}F_3$ Counter Radial Traverse Data
at Mid-plane of HFIR Solution Critical Experiment No. 1^a

Deuterium in Region II: 95.4 at. %
 U^{235} Concentration in Region II: 93.17 g/liter

Region I		Region II		Region III		Region IV	
Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate
1.09	0.0121	5.52	0.0190	11.87	0.00732	18.65	0.000046
1.29	0.0130	5.90	0.0185	12.48	0.00616	19.11	0.000029
1.49	0.0138	6.25	0.0179	13.07	0.00525	19.55	0.000020
1.70	0.0149	6.86	0.0170	14.12	0.00380	20.36	0.000011
1.90	0.0154	7.34	0.0167	14.92	0.00288	21.00	0.000070
2.10	0.0162	7.62	0.0164	15.42	0.00242	21.40	0.000054
2.56	0.0174	7.62	0.0163	15.42	0.00239	21.40	0.000052
2.31	0.0168	7.50	0.0163	15.21	0.00254	21.23	0.000057
0.68	0.0108	7.12	0.0164	14.56	0.00330	20.70	0.000084
0.48	0.0104	6.57	0.0170	13.63	0.00447	19.97	0.000014
0.27	0.0100	6.08	0.0177	12.80	0.00568	19.34	0.000023
0.03	0.00974	5.32	0.0186	11.55	0.00769	18.42	0.000053
0.17	0.00974	4.73	0.0189	10.60	0.00922	17.77	0.00011
0.99	0.0110	4.14	0.0189	9.70	0.0108	17.18	0.00021
1.19	0.0115	3.52	0.0191			16.60	0.00043
1.39	0.0126	4.34	0.0192	9.99	0.0103	17.36	0.00017
1.80	0.0149	5.13	0.0183	11.23	0.00815	18.20	0.000068
2.05	0.0160	5.90	0.0177	12.48	0.00593	19.11	0.000028
2.36	0.0171	6.42	0.0174	13.37	0.00467	19.77	0.000016

^aData normalized to 1 for the same counter bare at the reactor center.

Table E.10 Bare Miniature $B^{10}F_3$ Counter Vertical Traverse Data in
Regions I, II, and III of HFIR Solution Critical Experiment No. 1^a

Deuterium in Region II = 95.4 at. %
 U^{235} Concentration in Region II = 93.17 g/liter

Region I ^b		Region II ^b		Region III ^b	
Distance from Vertical Mid-plane (in.)	Relative Counting Rate	Distance from Vertical Mid-plane (in.)	Relative Counting Rate	Distance from Vertical Mid-plane (in.)	Relative Counting Rate
-2.65	0.950	-2.42	0.136	-2.22	0.280
-1.65	0.985	-1.42	0.139	-1.22	0.285
-0.65	0.996	-0.42	0.140	-0.22	0.287
0.35	0.977	0.58	0.139	0.78	0.284
1.35	0.959	1.58	0.138	1.78	0.279
2.35	0.939	2.58	0.135	2.78	0.273
3.35	0.898	3.58	0.129	3.78	0.262
4.35	0.871	4.58	0.125	4.78	0.249
4.63	0.813	4.86	0.123	4.86	0.242
3.85	0.874	4.08	0.127	4.28	0.254
2.85	0.907	3.08	0.131	3.28	0.263
1.85	0.942	2.08	0.136	2.28	0.274
0.85	0.956	1.08	0.137	1.28	0.279
-0.15	1.00	0.08	0.139	0.28	0.284
-1.15	0.982	-0.92	0.139	-0.72	0.284
-2.15	0.946	-1.92	0.137	-1.72	0.279
-3.15	0.898	-2.92	0.130	-2.72	0.268
-4.15	0.861	-3.92	0.126	-3.72	0.263
-5.15	0.810	-4.92	0.121	-4.72	0.253
-6.15	0.733	-5.92	0.116	-5.72	0.240
-5.65	0.777	-5.42	0.119	-5.22	0.247
-4.65	0.864	-4.42	0.125	-4.22	0.261
-3.54	0.921	-3.42	0.133	-3.22	0.276

^a Data normalized to 1 at the reactor center.

^b Radial position of counters (in.): Region I, 0.0; Region II, 7.15; Region III, 11.87.

Table E.11 Cadmium-Covered Miniature $B^{10}F_3$ Counter Vertical Traverse
Data in Regions I, II, and III of HFIR Solution Critical Experiment No. 1^a

Deuterium in Region II: 95.4 at. %

U^{235} Concentration in Region II: 93.17 g/liter

Region I ^b		Region II ^b		Region III ^b	
Distance from Vertical Mid-plane (in.)	Relative Counting Rate	Distance from Vertical Mid-plane (in.)	Relative Counting Rate	Distance from Vertical Mid-plane (in.)	Relative Counting Rate
4.72	0.0106	3.08	0.0198	3.28	0.00646
0.94	0.0123	4.08	0.0185	4.28	0.00595
1.94	0.0123	4.86	0.0174	5.06	0.00558
2.94	0.0116	3.58	0.0192	3.78	0.00614
3.94	0.0111	1.58	0.0207	1.78	0.00676
3.44	0.0114	0.58	0.0208	0.78	0.00694
-1.06	0.0122	-0.42	0.0209	-0.22	0.00701
-2.06	0.0120	-1.42	0.0204	-1.22	0.00700
-3.06	0.0117	-3.42	0.0189	-3.22	0.00659
-4.06	0.0110	-5.42	0.0162	-5.22	0.00573
-5.06	0.0104				
-6.06	0.00952				
-5.56	0.00984				
-3.56	0.0112				
-1.56	0.120				
-0.56	0.0122				
0.44	0.0122				
-0.56	0.0123				
1.44	0.0118				

^a Data normalized to 1 for the same counter bare at the reactor center.

^b Radial counter position (in.): Region I, 0.0; Region II, 5.52; Region III, 11.87.

Table E.12 Bars U²³⁵ Fission-Counter Radial Traverse Data at
Mid-plane in HFIR Solution Critical Experiment No. 2^a

Deuterium in Region II: 93.8 at. %
U²³⁵ Concentration in Region II: 119.7 g/liter

Region I		Region II		Region III		Region IV	
Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate
2.68	0.424	3.17	0.195	8.30	0.164	16.32	0.108
2.38	0.640	3.40	0.156	8.61	0.194	16.50	0.106
2.17	0.737	3.98	0.0992	9.44	0.231	17.02	0.0807
1.97	0.816	4.34	0.0980	9.99	0.234	17.36	0.0810
1.67	0.894	4.73	0.0754	10.60	0.249	17.77	0.0519
1.47	0.926	5.13	0.0697	11.23	0.251	18.20	0.0389
1.16	0.964	5.52	0.0671	11.87	0.248	18.65	0.0272
0.96	0.980	5.90	0.0661	12.48	0.240	19.11	0.0197
0.65	0.997	6.25	0.0679	13.07	0.233	19.55	0.0128
0.40	0.998	6.57	0.0706	13.63	0.222	19.97	0.00862
0.25	0.997	6.57	0.0748	13.63	0.215	19.97	0.00625
0.04	0.999	7.12	0.0820	14.56	0.208	20.70	0.00451
-0.02	1.005	7.50	0.0982	15.21	0.198	21.23	0.00252
0.14	1.007	7.71	0.111	15.59	0.196	21.55	0.00147
0.35	1.006	7.62	0.105	15.42	0.195	21.40	0.00200
0.55	1.001	7.34	0.0888	14.92	0.203	21.00	0.0332
0.76	1.002	7.00	0.0775	14.24	0.212	20.19	0.00536
1.06	0.991	6.57	0.0703	13.63	0.221	19.97	0.00866
1.26	0.971	6.25	0.0667	13.07	0.231	19.55	0.0128
1.47	0.937	5.90	0.0651	12.48	0.236	19.11	0.0180
1.67	0.897	5.52	0.0666	11.87	0.240	18.65	0.0259
1.92	0.828	5.13	0.0689	11.23	0.244	18.20	0.0372
2.17	0.731	4.73	0.0751	10.60	0.242	17.77	0.0520
2.38	0.622	4.34	0.0828	9.99	0.236	17.36	0.0630
2.53	0.523	3.51	0.140	8.81	0.195	16.60	0.0994
2.68	0.408	3.17	0.189	8.30	0.157	16.32	0.105

^aData normalized to 1 at the reactor center.

Table E.13 Bare U²³⁵ Fission-Counter Radial Traverse Data at
Mid-plane of HFIR Solution Critical Experiment No. 3^a

U²³⁵ Concentration in Region II: 137.5 g/liter
Boron Concentration in Region II: 0.056 g/liter
Deuterium in Region II: 93.8 at. %

Region I		Region II		Region III		Region IV	
Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate
-0.12	0.975	5.52	0.0637	11.87	0.242	18.65	0.0275
-0.02	0.972	5.90	0.0632	12.48	0.237	19.11	0.0197
0.21	0.977	6.25	0.0642	13.07	0.230	19.55	0.0133
0.44	0.977	6.57	0.0670	13.63	0.221	19.97	0.00907
0.78	0.966	6.86	0.0710	14.12	0.212	20.36	0.00655
1.02	0.956	7.12	0.0762	14.56	0.208	20.70	0.00476
1.30	0.932	7.34	0.0844	14.92	0.201	21.00	0.00350
1.55	0.892	7.50	0.0930	15.21	0.196	21.23	0.00260
1.80	0.839	7.71	0.105	15.59	0.191	21.55	0.00160
2.05	0.760	7.62	0.0993	15.42	0.190	21.40	0.00206
2.30	0.651	7.42	0.0869	15.07	0.194	21.11	0.00310
2.51	0.532	7.12	0.0755	14.56	0.203	20.70	0.00461
2.71	0.389	6.57	0.0655	13.63	0.215	19.97	0.00907
2.40	0.605	6.08	0.0627	12.80	0.231	19.33	0.0162
2.40	0.611	5.52	0.0631	11.87	0.240	18.65	0.0279
2.20	0.714	5.52	0.0631	11.87	0.240	18.65	0.0279
1.90	0.825	5.13	0.0660	11.23	0.242	18.20	0.0386
1.60	0.901	4.73	0.0720	10.60	0.243	17.77	0.0523
1.34	0.928	4.34	0.0810	9.99	0.243	17.36	0.0677
1.09	0.946	3.66	0.124	8.97	0.208	16.72	0.0975
0.88	0.956	3.31	0.180	8.49	0.178	16.43	0.108
0.68	0.971	3.17	0.200	8.30	0.157	16.32	0.109
0.48	0.980	3.40	0.164	8.61	0.189	16.50	0.109
0.27	1.002	3.98	0.0996	9.44	0.231	17.02	0.0861
0.06	0.991	4.73	0.0736	10.60	0.252	17.77	0.0539
-0.12	0.996	5.13	0.0684	11.23	0.253	18.20	0.0406
0.06	0.980	5.52	0.0655	11.87	0.249	18.65	0.0285

^aData normalized to 1 at the reactor center.

Table E.14 Cadmium-Covered U²³⁵ Fission-Counter Radial Traverse Data at
Mid-plane of HFIR Solution Critical Experiment No. 3^a

U²³⁵ Concentration in Region II: 137.5 g/liter
Boron Concentration in Region III: 0.056 g/liter
Deuterium in Region II: 93.8 at. %

Region I		Region II		Region III	
Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate
2.56	0.01880	7.69	0.0191	15.55	0.00226
2.32	0.01800	7.50	0.0192	15.21	0.00250
2.07	0.01674	7.23	0.0196	14.75	0.00294
1.82	0.01521	6.86	0.0202	14.12	0.00375
1.56	0.01409	6.57	0.0212	13.63	0.00444
1.31	0.01289	6.25	0.0218	13.07	0.00536
1.05	0.01183	5.90	0.0221	12.48	0.00638
0.80	0.01105	5.52	0.0228	11.87	0.00788
0.57	0.01062	5.13	0.0229	11.23	0.00937
0.30	0.01018	4.73	0.0227	10.60	0.01085
0.15	0.01002	4.34	0.0225	9.99	0.0123
-0.05	0.01000	3.98	0.0220	9.44	0.0137
-0.25	0.00985	3.66	0.0217	8.97	0.0151
-0.05	0.00978	3.98	0.0219	9.44	0.0138
0.15	0.00978	4.34	0.0223	9.99	0.0123
0.30	0.00983	4.73	0.0225	10.60	0.0108
0.57	0.01021	5.13	0.0223	11.23	0.00902
0.80	0.01063	5.52	0.0219	11.87	0.00765
1.05	0.01160	5.90	0.0216	12.48	0.00642
1.31	0.01259	6.25	0.0212	13.07	0.00537
1.56	0.01365	6.57	0.0205	13.63	0.00447
1.82	0.01515	6.86	0.0199	14.12	0.00371
2.07	0.01632	7.23	0.0192	14.75	0.00289
2.32	0.01748	7.50	0.0186	15.21	0.00240
2.56	0.01813	7.69	0.0183	15.55	0.00222
-0.05	0.00977	3.98	0.0218	9.44	0.0134
-0.15	0.00978	3.66	0.0214	8.97	0.0147

^a Data normalized to 1 for the same counter bare at the reactor center.

Table E.15¹ Bare U²³⁵ Fission-Counter Vertical Traverse Data in the Four Regions of HFIR Solution Critical Experiment No. 3^a

U²³⁵ Concentration in Region II: 137.5 g/liter
 Boron Concentration in Region III: 0.056 g/liter
 Deuterium in Region II: 93.8 at. %

Region I ^b		Region II ^b		Region III ^b		Region IV ^b	
Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate
6.43	0.743	6.27	0.0493	6.43	0.206	6.24	0.0249
5.43	0.825	5.27	0.0529	5.43	0.217	5.24	0.0257
4.43	0.894	4.27	0.0574	4.43	0.228	4.24	0.0268
3.43	0.944	3.27	0.0591	3.43	0.237	3.24	0.0282
2.93	0.967	2.77	0.0611	2.93	0.241	2.74	0.0283
2.43	0.981	2.27	0.0629	2.43	0.244	2.24	0.0285
1.93	0.995	1.77	0.0639	1.93	0.247	1.74	0.0290
1.43	1.005	1.27	0.0640	1.43	0.249	1.24	0.0282
0.93	1.009	0.77	0.0647	0.93	0.249	0.74	0.0283
0.43	0.998	0.27	0.0643	0.43	0.249	0.24	0.0282
-0.07	1.004	-0.23	0.0650	-0.07	0.250	-0.26	0.0276
-0.57	1.000	-0.73	0.0647	-0.57	0.251	-0.76	0.0275
-1.07	0.993	-1.23	0.0639	-1.07	0.249	-1.26	0.0268
-1.57	0.983	-1.73	0.0623	-1.57	0.247	-1.76	0.0261
-2.07	0.974	-2.23	0.0616	-2.07	0.242	-2.26	0.0256
-2.57	0.955	-2.73	0.0601	-2.57	0.240	-2.76	0.0250
-3.57	0.914	-3.73	0.0572	-3.57	0.234	-3.76	0.0234
-4.35	0.873	-4.51	0.0544	-4.35	0.224	-4.54	0.0221
-3.57	0.913	-3.73	0.0567	-3.57	0.231	-3.76	0.0231
-2.57	0.955	-2.73	0.0600	-2.57	0.239	-2.76	0.0245
-1.57	0.984	-1.73	0.0624	-1.57	0.245	-1.76	0.0260
-1.07	0.994	-1.23	0.0623	-1.07	0.247	-1.26	0.0268
-0.57	1.004	-0.73	0.0640	-0.57	0.248	-0.76	0.0272
-0.07	1.008	-0.23	0.0642	-0.07	0.249	-0.26	0.0275
0.43	1.008	0.27	0.0648	0.43	0.251	0.24	0.0281
0.93	1.005	0.77	0.0640	0.93	0.251	0.74	0.0285
1.43	0.996	1.27	0.0636	1.43	0.247	1.24	0.0285
1.93	0.987	1.77	0.0633	1.93	0.247	1.74	0.0286
2.43	0.960	2.27	0.0620	2.43	0.244	2.24	0.0288
3.43	0.929	3.27	0.0607	3.43	0.239	3.24	0.0284
4.43	0.880	4.27	0.0570	4.43	0.227	4.24	0.0279
5.43	0.810	5.27	0.0531	5.43	0.218	5.24	0.0265
6.43	0.728	6.27	0.0494	6.43	0.205	6.24	0.0247

^a Data normalized to 1 at the reactor center.

^b Radial counter positions (in.): Region I, 0.0; Region II, 5.52; Region III, 11.87; Region IV, 18.65.

Table E.16 Cadmium-Covered U²³⁵ Fission-Counter Vertical Traverse Data
in Regions I, II, and III of HFIR Solution Critical Experiment No. 3^a

U²³⁵ Concentration in Region II: 137.5 g/liter
Boron Concentration in Region III: 0.056 g/liter
Deuterium in Region II: 93.8 at. %

Region I ^b		Region II ^b		Region III ^b	
Distance from Vertical Mid-plane (in.)	Relative Counting Rate	Distance from Vertical Mid-plane (in.)	Relative Counting Rate	Distance from Vertical Mid-plane (in.)	Relative Counting Rate
4.55	0.00847	4.71	0.0185	4.55	0.00626
3.77	0.00878	3.93	0.0196	3.77	0.00688
2.27	0.00953	2.43	0.0214	2.27	0.00733
0.77	0.00975	0.93	0.0221	0.77	0.00759
-0.73	0.00981	-0.57	0.0221	-0.73	0.00775
-2.23	0.00944	-2.07	0.0213	-2.23	0.00738
-3.73	0.00903	-3.57	0.0202	-3.73	0.00701
-5.23	0.00814	-5.07	0.0179	-5.23	0.00624
-4.23	0.00873	-4.07	0.0195	-4.23	0.00656
-2.73	0.00954	-2.57	0.0212	-2.73	0.00709
-1.23	0.00977	-1.07	0.0219	-1.23	0.00749
0.27	0.00988	0.43	0.0220	0.27	0.00749
1.72	0.00958	1.93	0.0216	1.72	0.00730
3.27	0.00914	3.43	0.0203	3.27	0.00696

^a Data normalized for the same counter bare at the reactor center.

^b Radial counter positions (in.): Region I, 0.00; Region II, 5.52; Region III, 11.87.

Table E.17 Bare U²³⁵ Fission-Counter Radial Traverse Data at Mid-plane
of HFIR Solution Critical Experiment No. 4^a

U²³⁵ Concentration in Region II: 105.9 g/liter
Boron Concentration in Region III: 2.35 g/liter
Deuterium in Region II: 70.1 at. %

Region I		Region II		Region III		Region IV	
Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate
0	1.005	3.17	0.272	8.30	0.0633	16.32	0.0185
0.19	1.004	3.40	0.232	8.61	0.0563	16.50	0.0202
0.31	0.999	3.98	0.158	9.44	0.0424	17.02	0.0200
0.59	0.990	4.73	0.130	10.60	0.0323	17.77	0.0153
0.82	0.979	5.52	0.115	11.87	0.0235	18.65	0.0086
1.10	0.960	5.90	0.109	12.48	0.0210	19.11	0.0062
1.33	0.927	6.25	0.103	13.07	0.0180	19.55	0.0044
1.60	0.844	6.86	0.0931	14.12	0.0165	20.36	0.0022
1.85	0.784	7.34	0.0824	14.92	0.0175	21.00	0.0012
2.16	0.740	7.62	0.0757	15.42	0.0193	21.40	0.0007
2.35	0.628	7.71	0.0733	15.59	0.0193	21.55	0.0005
2.61	0.435	7.62	0.0757	15.42	0.0193	21.40	0.0007
2.30	0.628	7.34	0.0828	14.92	0.0171	21.00	0.0012
1.90	0.812	6.86	0.0923	14.12	0.0161	20.36	0.0023
		6.25	0.103	13.00	0.0184	19.55	0.0044
		5.71	0.111	12.18	0.0228	18.88	0.0074
		5.13	0.120	11.23	0.0277	18.20	0.0117
		4.34	0.139	9.99	0.0373	17.36	0.0179
		3.53	0.208	8.79	0.0518	16.61	0.0212
		3.17	0.264	8.30	0.0622	16.32	0.0186

^aData normalized to 1 at the reactor center.

Table E.18 Cadmium-Covered U²³⁵ Fission-Counter Radial Traverse Data
at Mid-plane of HFIR Solution Critical Experiment No. 4^a

U²³⁵ Concentration in Region II: 105.9 g/liter
Boron Concentration in Region III: 2.35 g/liter
Deuterium in Region II: 70.1 at. %

Region I		Region II		Region III	
Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate	Distance from Axis (in.)	Relative Counting Rate
-0.04	0.0098	4.45	0.0165	10.20	0.0094
0.56	0.0101	4.93	0.0163	10.82	0.0078
1.04	0.0112	5.71	0.0155	12.18	0.0053
1.38	0.0122	6.41	0.0143	13.35	0.0037
1.76	0.0135	6.99	0.0129	14.33	0.0026
2.02	0.0144	7.50	0.0177	15.21	0.0019
2.12	0.0148	7.70	0.0113	15.56	0.0017
0.26	0.0097	4.32	0.0162	9.95	0.0098
0.06	0.0097	4.39	0.0165	10.11	0.0095
1.17	0.0114	5.52	0.0156	11.87	0.0058
1.40	0.0122	6.08	0.0148	12.80	0.0044

^aData normalized to 1 for the same counter bare at the reactor center.

Table E.19 Bare U²³⁵ Fission-Counter Vertical Traverse Data in the Four Regions of HFIR Solution Critical Experiment No. 4^a

U²³⁵ Concentration in Region II: 105.9 g/liter
 Boron Concentration in Region III: 2.35 g/liter
 Deuterium in Region II: 70.1 at. %

Region I ^b		Region II ^b		Region III ^b		Region IV ^b	
Distance from Mid-plane (in.)	Relative Counting Rate	Distance from Mid-plane (in.)	Relative Counting Rate	Distance from Mid-plane (in.)	Relative Counting Rate	Distance from Mid-plane (in.)	Relative Counting Rate
0.77	1.004	0.93	0.114	0.77	0.0234	0.96	0.0085
-0.23	0.996	-0.07	0.115	-0.23	0.0236	-0.04	0.0088
-1.23	0.969	-1.07	0.113	-1.23	0.0229	-1.04	0.0087
-2.23	0.925	-2.07	0.109	-2.23	0.0221	-2.04	0.0084
-3.23	0.873	-3.07	0.104	-3.23	0.0212	-3.04	0.0080
-4.73	0.769	-4.57	0.0923	-4.73	0.0197	-4.54	0.0072
-6.23	0.623	-6.07	0.0770	-6.23	0.0180	-6.04	0.0062
-5.23	0.720	-5.07	0.0865	-5.23	0.0186	-5.04	0.0070
-3.73	0.842	-3.57	0.0996	-3.73	0.0207	-3.54	0.0078
-2.73	0.901	-2.57	0.106	-2.73	0.0211	-2.54	0.0082
-1.73	0.953	-1.57	0.110	-1.73	0.0222	-1.54	0.0085
-0.73	0.985	-0.57	0.112	-0.73	0.0229	-0.54	0.0086
0.27	1.001	0.43	0.112	0.27	0.0232	0.46	0.0085
1.27	0.995	1.43	0.111	1.27	0.0227	1.46	0.0083
2.77	0.954	2.93	0.104	2.27	0.0214	2.96	0.0077
3.77	0.912	3.93	0.0978	3.77	0.0205	3.96	0.0071
4.55	0.866	4.71	0.0915	4.55	0.0195	4.74	0.0063
3.27	0.928	3.43	0.101	3.27	0.0210	3.46	0.0075
1.77	0.982	1.93	0.109	1.77	0.0221	1.96	0.0081

^aData normalized to 1 in the reactor center.

^bRadial position of counters (in.): Region I, 0.0; Region II, 5.52; Region III, 11.87; Region IV, 18.65.

Table E.20 Cadmium-Covered U^{235} Fission-Counter Vertical Traverse
Data in Regions I, II, and III of HFIR Solution Critical
Experiment No. 4^a

U^{235} Concentration in Region II: 105.9 g/liter
Boron Concentration in Region III: 2.35 g/liter
Deuterium in Region II: 70.1 at. %

Region I ^b		Region II ^b		Region III ^b	
Distance from Mid-plane (in.)	Relative Counting Rate	Distance from Mid-plane (in.)	Relative Counting Rate	Distance from Mid-plane (in.)	Relative Counting Rate
4.54	0.00905	4.70	0.0134	4.54	0.00465
3.27	0.00930	3.43	0.0146	3.27	0.00528
1.77	0.00961	1.93	0.0153	1.77	0.00536
0.27	0.00971	0.43	0.0157	0.27	0.00562
-0.73	0.00959	-0.57	0.0157	-0.73	0.00550
-2.23	0.00925	-2.07	0.0151	-2.23	0.00529
-3.73	0.00850	-3.57	0.0139	-3.73	0.00495
-5.73	0.00682	-5.57	0.0115	-5.73	0.00402
-6.23	0.00636	-6.07	0.0108	-6.23	0.00379
-4.73	0.00764	-4.57	0.0128	-4.73	0.00450
-3.23	0.00870	-3.07	0.0143	-3.23	0.00500
-1.73	0.00937	-1.57	0.0153	-1.73	0.00526
-0.23	0.00960	-0.07	0.0156	-0.23	0.00541
1.27	0.00962	1.43	0.0153	1.27	0.00541
2.77	0.00934	2.93	0.0146	2.77	0.00514

^a Data normalized to 1 for the same counter bare at the reactor center.

^b Radial position of counters (in.): Region I, 0.0; Region II, 5.52; Region III, 11.87.

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