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CRITICAL LATTICES OF HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

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ABSTRACT

Lattices of High Flux Isotope Reactor (HFIR) fuel elements were assembled in order to determine the critical spacing between elements when moderated and reflected by water. It was found that seven elements spaced 6.37 in. in a triangular pattern were critical when submerged. Seven outer annuli in the same pattern were critical when separated 1.50 in., and seven inner annuli were subcritical even when in contact.

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The High Flux Isotope Reactor (HFIR) fuel element presently being manufactured consists of two concentric annuli, each composed of uranium-bearing plates welded to aluminum side plates. The element is described in ORNL Drawings D-42118 Rev. F and D-42126 Rev. D, both dated April 6, 1965. It contains 9.4 kg of ^{235}U as U_3O_8, of which 2.6 kg is in the inner annulus and 6.8 kg in the outer annulus. The fuel plates of the inner annulus also contain 2.8 g of ^{10}B. The uranium is enriched to 93.2% in ^{235}U.

The reactivity of each element was determined by a method developed by Thomas and Raffety[1]; the reactivities of the individual elements which were used in these experiments are listed below.

Element No.[a]	Reactivity (cents)
4-0, 4-I	- 201.8 ± 12.8
5-0, 5-I	- 203.8 ± 14.4
6-0, 6-I	- 196.1 ± 14.7
7-0, 7-I	- 200.7 ± 13.2
8-0, 8-I	- 189.6 ± 16.6
9-0, 9-I	- 191.1 ± 13.4
10-0, 10-I	- 182.1 ± 12.6
11-0, 11-I	- 186.0 ± 15.6

a. "O" and "I" designate, respectively, outer and inner annuli.

In order to determine the spacings at which lattices of these elements would be critical with water as moderator and reflector, the desired number of elements were assembled in a large (6 ft cube) tank to which water could be added by remote operation. The spacing between elements was adjusted until the lattice was critical with a water reflector at least 6 in. thick on all sides. As many as seven assembled elements were

1. J. T. Thomas and S. J. Raffety, "Experiments for the Development of a Reactivity Acceptance Test for High Flux Isotope Reactor Fuel Elements," ORNL-CF-65-8-55 (April 1, 1966).

latticed in this manner. Figure 1 shows the lattice of seven elements which was critical, at a lateral surface separation of 6.37 in., when moderated and reflected by water. Several lattices of outer annuli were also assembled. It was shown, for example, that three submerged outer annuli in contact in a triangular pattern were supercritical by about 25 cents, while four such annuli in contact in a square pattern were subcritical. Similarly, seven inner annuli separated 1.16 in. in a triangular pattern showed little source neutron multiplication. (The inner annuli are separated 1.16 in. when in contact at the top.) Table 1 is a summary of the results.

A lattice of eight inner and eight outer annuli, arranged in a square pattern, was supercritical by more than 75 cents when the annuli were spaced as closely as possible, 0.39 in. surface separation, as shown in Fig. 2; the same lattice was subcritical at a spacing of 1.39 in. These data are also listed in Table 1.

Several special experiments were performed with submerged seven-element lattices. In one, with a surface separation between elements of 6.55 in., which was subcritical by more than 28 cents (see Table 1), addition of 96.6 cents to the center element made the lattice critical. That is, the reactivity of the center element considered alone was increased from -191.1 cents to -94.5 cents by a method described in Ref. 1. Another lattice, which was subcritical by about 17 cents when the surface separation between elements was 6.40 in., was made critical by changing the reactivity of the center element alone from -191.1 cents to -99.9 cents; that is, 91.2 cents was added. In this same lattice, addition of the reactivity to the center element necessary to make it critical when submerged alone made the lattice critical with only a 5.3-cm-thick top reflector. It would have had an excess reactivity of more than 70 cents when flooded. This measurement shows the contribution of the six outer elements to the array to be more than 70 cents.

In still another seven-unit lattice, at a spacing of 6.40 in., the center unit was an assembled element and the six units in the ring were outer annuli; the lattice was subcritical. When the reactivity of the center element was increased from -191.1 cents to -4.5 cents, the lattice

had an excess reactivity of 4.5 cents when flooded; therefore, the six outer annuli contributed a total of 9 cents to the reactivity of the lattice.

The results of these experiments will guide storage of HFIR elements in water, both at the reactor and at the recovery plants.

Fig. 1. Lattice of HFIR Fuel Elements Which Was Critical When Submerged.

Fig. 2. Lattice of Separated Annuli of HFIR Fuel Elements Which Was Critical When Submerged.

Table 1. Summary of Lattices of HFIR Fuel Elements Reflected and Moderated by Water.

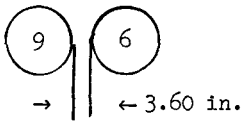
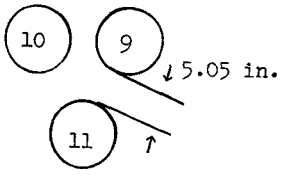
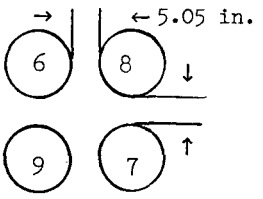
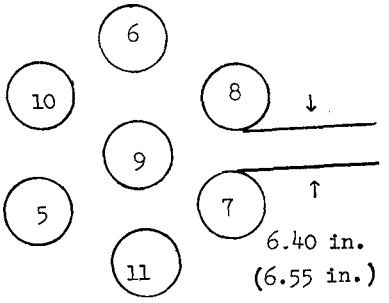
Number of Units	Pattern	Surface Separation (in.)	Remarks	Lattice Diagram[a]
2 assembled elements	Linear	3.60	k_{ex} about 15 cents	
3 assembled elements	Triangular	5.05	k_{ex} = 9 cents	
4 assembled elements	Square	5.05	k_{ex} = 3 cents	
7 assembled elements	Triangular	6.40 6.55	About 17 cents sub-critical > 28 cents subcritical	

Table 1. (Continued)

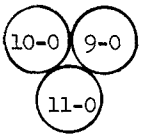
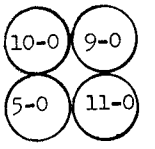
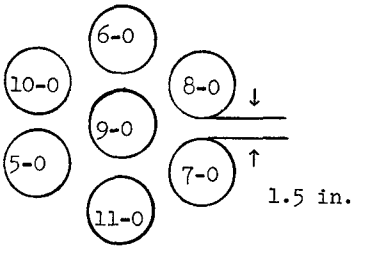
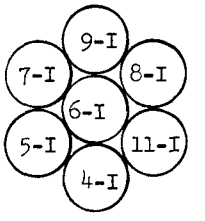
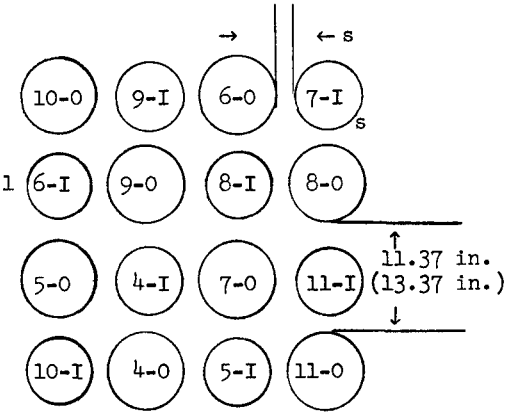
Number of Units	Pattern	Surface Separation (in.)	Remarks	Lattice Diagram[a]
3 outer annuli	Triangular	Contact	k_{ex} about 25 cents	
4 outer annuli	Square	Contact	Very sub-critical	
7 outer annuli	Triangular	1.5	Critical	
7 inner annuli	Triangular	1.16[b]	Very sub-critical	

Table 1. (Continued)

Number of Units	Pattern	Surface Separation(s) (in.)	Remarks	Lattice Diagram[a]
8 inner annuli	Square	0.39[c]	$k_{ex} > 75$ cents	
8 outer annuli		1.39	Subcritical	

a. The numbers in the circles are those of the element or of the annulus.

b. The outer lateral surfaces of adjacent annuli are separated 1.16 in. when the tops are in contact.

c. The outer lateral surfaces of adjacent annuli are separated 0.39 in. when the tops are in contact

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