Letters to the Editors

Criticality of Low Enrichment U^{235} in Hydrogen*

The spherical critical mass and radius of homogeneous mixtures of 1 to 5% U^{235}-enriched uranium and hydrogen are of theoretical interest due to the large effect of U^{238} resonance absorption on the neutron multiplication. Resonance integrals consistent with the Los Alamos multigroup description of neutron cross sections used for critical experiment analysis (*1*) have recently been computed by G. I. Bell as a function of scattering cross sections per uranium atom. These effective multigroup cross sections, along with reactor calculation methods and recent ORNL experiments with 2 to 5% enriched uranium homogeneously distributed in paraffin and in water (*2, 3*), make it possible to coordinate calculational methods and experiments for these systems.

Six experiments were performed with the uranium density in paraffin and water varying from 0.5 to 3.1 gm/cc. The corresponding $H{:}U^{235}$ atomic ratios varied from 200 to 1000. The data from these experiments are given in Table I. The critical bucklings were obtained for the 2% and 3% U^{235}-enriched UF_4-paraffin mixtures from the size of parallelepipedal assemblies and the extrapolation distance determined from flux traverses with miniature U^{238} fission chambers. The spherical critical volume was obtained from the buckling and extrapolation distance in the usual way (*4*). The reflector savings was measured by observing the change in critical height of an assembly when the reflector material was added on the top. The experiment with 4.89% enriched uranium in water solution was in spherical geometry.

The method of calculation involves the use of the DSN transport code by Carlson and neutron cross sections from

TABLE I

LOW ENRICHMENT CRITICAL EXPERIMENTS

U^{235} Enrichment	UF_4 in paraffin					UO_2F_2 in water
	2%[a]				3%[b]	4.89%[c]
Mixture density (gm/cc)	4.50	3.93	3.45	3.16	4.46	1.56
Weight fraction uranium	0.698	0.672	0.644	0.623	0.697	0.315
N(Hydrogen; $\times 10^{22}$ atoms/cc)	3.15	3.98	4.60	5.05	3.19	6.25
N(U^{238}; $\times 10^{21}$ atoms/cc)	7.79	6.55	5.51	4.88	7.73	1.11
N(U^{235}; $\times 10^{20}$ atoms/cc)	1.61	1.36	1.14	1.01	2.39	0.62
Sphere volume (liters)	380	237	203	202	200	172
Reflector saving (cm)	5.5	4.8	4.2	4.2	—	—
Extrapolation distance (cm)	2.7	2.7	2.6	2.6	2.6	—

[a] See ref. *2*.
[b] Recent unpublished ORNL experiments.
[c] See ref. *3*.

TABLE II

RESONANCE INTEGRALS OF U^{238} FOR $kT = 0.025$ ev (barns)

Energy intervals (ev)	σ_p (barns)				
	40	80	200	400	1000
3.06–8.31	7.40	8.91	14.19	20.62	34.0
8.31–22.6	2.95	4.19	6.90	10.28	15.5
22.6–61.4	2.52	3.50	5.58	8.10	10.3
61.4–419	1.95	2.50	3.20	4.50	6.4

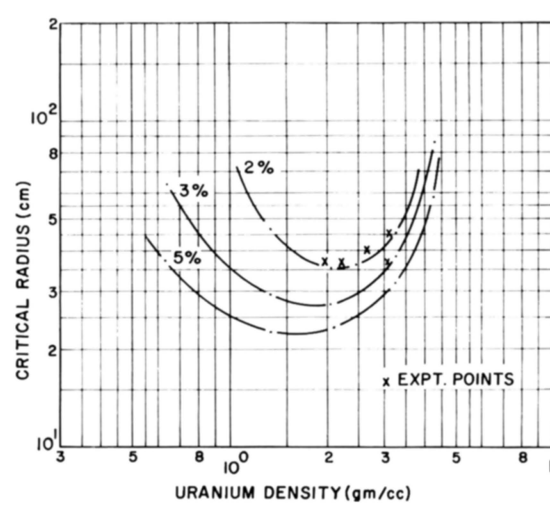

FIG. 1. Critical sphere radius as a function of uranium density in paraffin for 2%, 3%, and 5% enrichment in U^{235}.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

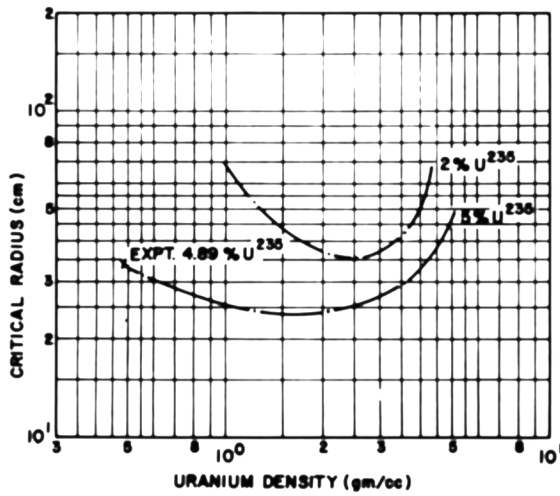

FIG. 2. Critical sphere radius as a function of uranium density in water for 2% and 5% enrichment in U^{235}.

TABLE III

DSN CALCULATED CRITICAL RADII FOR LOW ENRICHMENT URANIUM UNREFLECTED SPHERES

UF_4 in paraffin	Total uranium density (gm/cc)				
	4.00	3.28	2.12	1.34	0.64
2%, Critical radius (cm)	73.5	45.2	35.0	46.6	1000
3%, Critical radius (cm)	54.2	38.0	27.6	29.1	63.0
5%, Critical radius (cm)	43.8	31.7	23.3	22.4	27.3

UO_2F_2 in water	Total uranium density (gm/cc)				
	4.73	3.60	2.09	1.23	0.55
2%, Critical radius (cm)	66.1	42.4	36.9	52.1	1000
5%, Critical radius (cm)	37.7	29.6	24.5	24.5	31.7

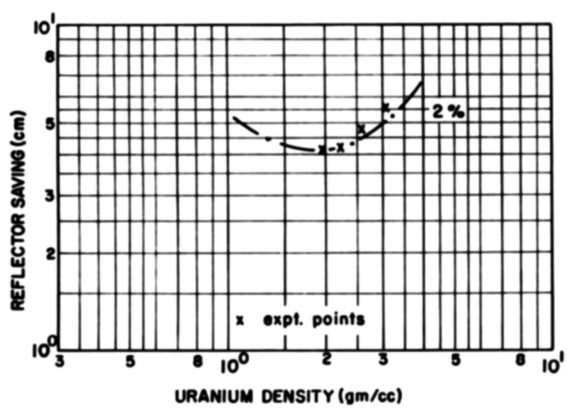

FIG. 3. Reflector saving as a function of uranium density in paraffin for 2% enrichment in U^{235}.

the work of Hansen and Bell. Both the methods and the multigroup constants have been described and tabulated recently (*5*). The U^{238} resonance integrals, consistent with the multigroup computing scheme used, are shown in Table II for values of the total scattering cross sections per U^{238} atom, σ_p, from 40 to 1000 barns.

Results of calculations of the above experiments gave $k_{eff} = 1.00 \pm 0.01$ which, considering the large effect of resonance absorption and the sensitivity of the value of k_{eff} to dimensions and materials, is adequate agreement. Since agreement with experiment was good, a parametric study of critical radius as a function of enrichment and H/U atomic ratio was initiated and will serve as a reference for future experiments of this type. In this study the displacement of the moderator by the uranium compound was established to give the uranium atomic density as a function of moderator to uranium ratio:

$$N(\text{U: atoms/cc} \times 10^{-24}) = 0.01298\,(1 + 0.636K)^{-1} \quad \text{for } UF_4 \text{ in } CH_2$$

$$N(\text{U:atoms/cc} \times 10^{-24}) = 0.01752\,(1 + 1.038K)^{-1} \quad \text{for } UO_2F_2 \text{ in } H_2O$$

where K is the H to U^{235} atomic density ratio. These formulas gave agreement with experimental values for the atomic density of U and H and so were assumed adequate for a parametric survey. The atomic densities of the other materials were constructed from them.

The critical radii of unreflected spheres calculated using the DSN transport code was shown in Figs. 1 and 2 and are given in Table III. The points for these few experiments are shown for comparison. The atomic densities used in the parametric survey were not corrected for the 1.2% density reduction in the critical experiments caused by the voids introduced in building up the assemblies.

The effect of an infinite paraffin reflector on the 2% enrichment calculations are shown in Fig. 3 as a function of total uranium density, for a direct comparison with the experimental values.

REFERENCES

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