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SUBJECT: Critical Parameters for Poisoned Annular Cylinders Containing Aqueous Solutions of U^{235}

TO: Distribution

FROM: J. K. Fox and L. W. Gilley

Abstract

Experiments were performed to determine the critical parameters of aqueous solutions of 93.2% U^{235}-enriched uranyl fluoride contained in cylindrical annuli formed by various combinations of aluminum cylinders varying in diameter from 2 to 30 in. In all of the experiments the inside cylinder was lined with a 20-mil-thick cadmium sheet and filled with water to a height of 48 in., and in some experiments a water reflector was used on the sides and bottom of the outside cylinder. The data indicate that for the solution having an $H:U^{235}$ atomic ratio of 50.4 the critical infinitely high, reflected annulus would have a minimum thickness between 2.5 and 3 in., while the unreflected annulus would have a thickness between 3.75 and 4.5 in. The corresponding thicknesses for the solution having an $H:U^{235}$ atomic ratio of 309 would be between 3.5 and 4 in. for the reflected annulus and between 4.5 and 5.5 in. for the unreflected annulus.

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DISCLAIMER

Critical Parameters for Poisoned Annular Cylinders Containing Aqueous Solutions of U^{235}

Information concerning the critical parameters of U^{235}-enriched uranium solutions contained in cylindrical annuli is valuable in the design of certain uranium processing equipment as well as in nuclear safety considerations in uranium processing plant operations. In a few experiments reported previously[1] the critical parameters of aqueous solutions of 93.2% U^{235}-enriched uranyl fluoride (UO_2F_2) solutions contained in vessels of annular cylindrical geometry were investigated at a chemical concentration corresponding to an $H:U^{235}$ atomic ratio of about 73. These data have now been extended with experiments performed with solutions having $H:U^{235}$ atomic ratios of 50.4 and 309. The annuli were formed by various combinations of cylinders varying in diameter from 2 to 30 in. The cylinders were fabricated from type 2S aluminum and had wall thicknesses of 1/16 in. and bottom plate thicknesses of 1/2 in. In all of the experiments the inside cylinder was lined with a 20-mil-thick cadmium sheet and filled with water to a height of 48 in. Experiments were performed both with and without a water reflector on the sides and bottom of the outer cylinder but with no top reflector in any case.

The results of these experiments are summarized in Table 1, and the critical solution height as a function of thickness of the annulus is shown in Fig. 1 for both the water-reflected and the unreflected annuli having outside diameters of 10, 12, 15, 20 and 30 in. and a solution concentration corresponding to an $H:U^{235}$ atomic ratio of 50.4. Figure 2 is a plot of the corresponding data for an $H:U^{235}$ ratio of 309.

The earlier experiments[1] indicated that the 0.5-in.-thick bottom plate of these annuli introduces an error in the measured critical heights of about 0.5 cm, increasing the measured heights for the reflected annuli and decreasing it for the unreflected annuli. The data reported here have not been corrected for this error. Furthermore, the absence of a reflector above the surfaces of the otherwise reflected annuli makes the critical heights reported here too large by the reflector savings. This corresponds to a difference in critical heights of about 3.5 cm for the water-reflected annuli.

For all the annuli tested with solutions having an $H:U^{235}$ atomic ratio of 50.4 the critical infinitely high, reflected annulus would have a minimum thickness between 2.5 and 3 in. The corresponding infinitely high, unreflected annulus for this solution would be between 3.75 and 4.5 in. thick. The thicknesses of the critical annuli were increased by about 1 in. when the $H:U^{235}$ atomic ratio was increased to 309. Thus, for this solution the minimum thickness of the infinitely high, reflected annulus would be between 3.5 and 4 in., while the minimum thickness for the infinitely high, unreflected annulus would be between 4.5 and 5.5 in. The data indicate that the thickness of the infinitely high annulus increases with the diameter of the outer cylinder.

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1. J. K. Fox, L. W. Gilley, and D. Callihan, "Critical Mass Studies, Part IX. Aqueous U^{235} Solutions," ORNL-2367, p. 33 (1958).

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Table 1. Critical Parameters of Enriched U^{235} Solutions in Cylindrical Annular Geometry

Solution concentration:		
g of U per g of solution	0.0812	0.3230
g of U^{235} per cc of solution	0.0836	0.4813
$H:U^{235}$ atomic ratio	309	50.4
Specific gravity	1.1051	1.599

Diameter of Assembly		Annulus Thickness (in.)	$H:U^{235}$ Atomic Ratio	Critical Values		
Outside (in.)	Inside (in.)			Height (cm)	Volume (liters)	Mass (kg of U^{235})
Effectively Infinite Outside Water Reflector to Height of Fuel						
10	2	4	50.4	20.2	9.8	4.7
	4	3	50.4	40.9	17.4	8.4
	2	4	309	39.1	19.0	1.59
12	2	5	50.4	16.0	11.3	5.4
	4	4	50.4	21.8	14.2	6.8
	6	3	50.4	48.7	26.6	12.8
	2	5	309	24.0	17.0	1.42
	4	4	309	46.6	30.2	2.53
15	4	5.5	50.4	15.4	16.3	7.9
	6	4.5	50.4	19.5	18.7	9.0
	8	3.5	50.4	31.1	25.4	12.2
	10	2.5	50.4	*		
	2	6.5	309	18.3	20.5	1.71
	4	5.5	309	22.7	24.0	2.01
	6	4.5	309	34.6	33.1	2.77
	8	3.5	309	*		
20	6	7	50.4	13.3	24.5	11.8
	8	6	50.4	15.0	25.5	12.3
	10	5	50.4	18.4	28.0	13.5
	12	4	50.4	26.0	33.7	16.2
	14	3	50.4	93.3	96.4	46.4
	6	7	309	18.5	34.1	2.85
	8	6	309	21.4	36.4	3.04
	10	5	309	30.4	46.2	3.86
	12	4	309	88.3	114.5	9.57
30	15	7.5	50.4	13.4	45.8	22.0
	20	5	50.4	19.0	48.2	23.2
	24	3	50.4	91**		
	15	7.5	309	18.1	61.9	5.17
	20	5	309	31.6	80.1	6.70

Table 1 (continued)

Diameter of Assembly		Annulus Thickness (in.)	$H:U^{235}$ Atomic Ratio	Critical Values		
Outside (in.)	Inside (in.)			Height (cm)	Volume (liters)	Mass (kg of U^{235})
			No Outside Reflector			
10	2	4	50.4	101.5	49.4	23.7
12	2	5	50.4	27.8	19.7	9.5
	4	4	50.4	*		
	2	5	309	46.2	32.8	2.74
15	4	5.5	50.4	24.9	26.4	12.7
	6	4.5	50.4	50.5	48.4	23.3
	8	3.5	50.4	*		
	2	6.5	50.4	19.2	21.5	10.4
	2	6.5	309	25.8	28.9	2.42
	4	5.5	309	42.9	45.4	3.80
	6	4.5	309	*		
20	6	7	50.4	19.2	35.4	17.0
	8	6	50.4	23.1	39.3	18.9
	10	5	50.4	36.3	55.2	26.6
	12	4	50.4	*		
	6	7	309	25.5	47.0	3.93
	8	6	309	35.0	59.6	4.98
	10	5	309	*		
30	15	7.5	50.4	18.8	64.3	31.0
	20	5	50.4	38.8	98.3	47.3
	15	7.5	309	24.2	82.8	6.92

*Extrapolation of the reciprocal source neutron multiplication curve from a solution height of at least 91 cm indicates that these assemblies could not be made critical at any height.

**Extrapolation of the reciprocal source neutron multiplication curve from a solution height of 77.4 cm indicates that this assembly could not be made critical at a height less than 91 cm, if it could be made critical at all.

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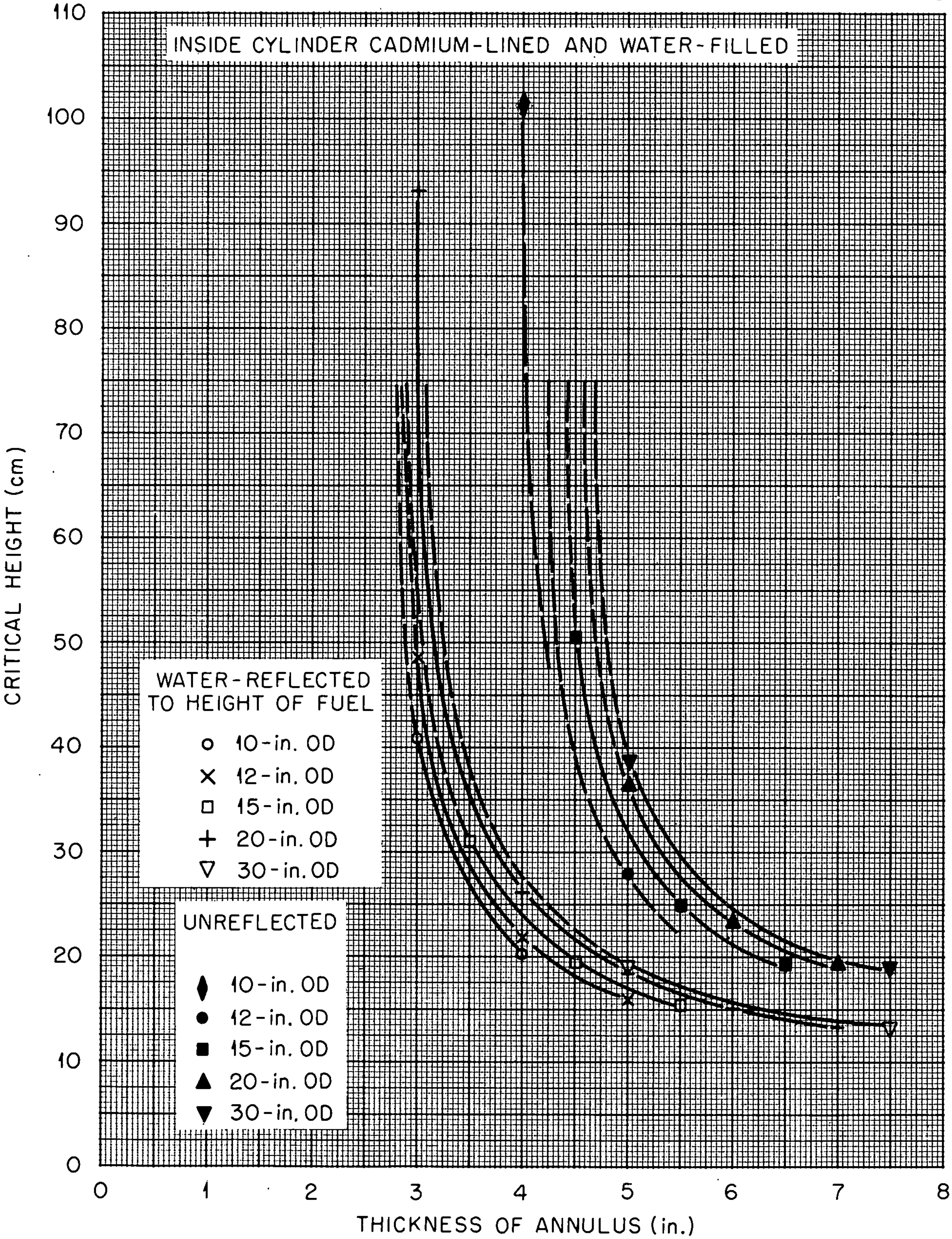

Fig. 1. Critical Heights of Cylindrical Annuli Containing Aqueous Solutions of 93.2% U^{235}-Enriched Uranyl Fluoride as a Function of the Thicknesses of the Annuli: $H:U^{235}$ Atomic Ratio = 50.4

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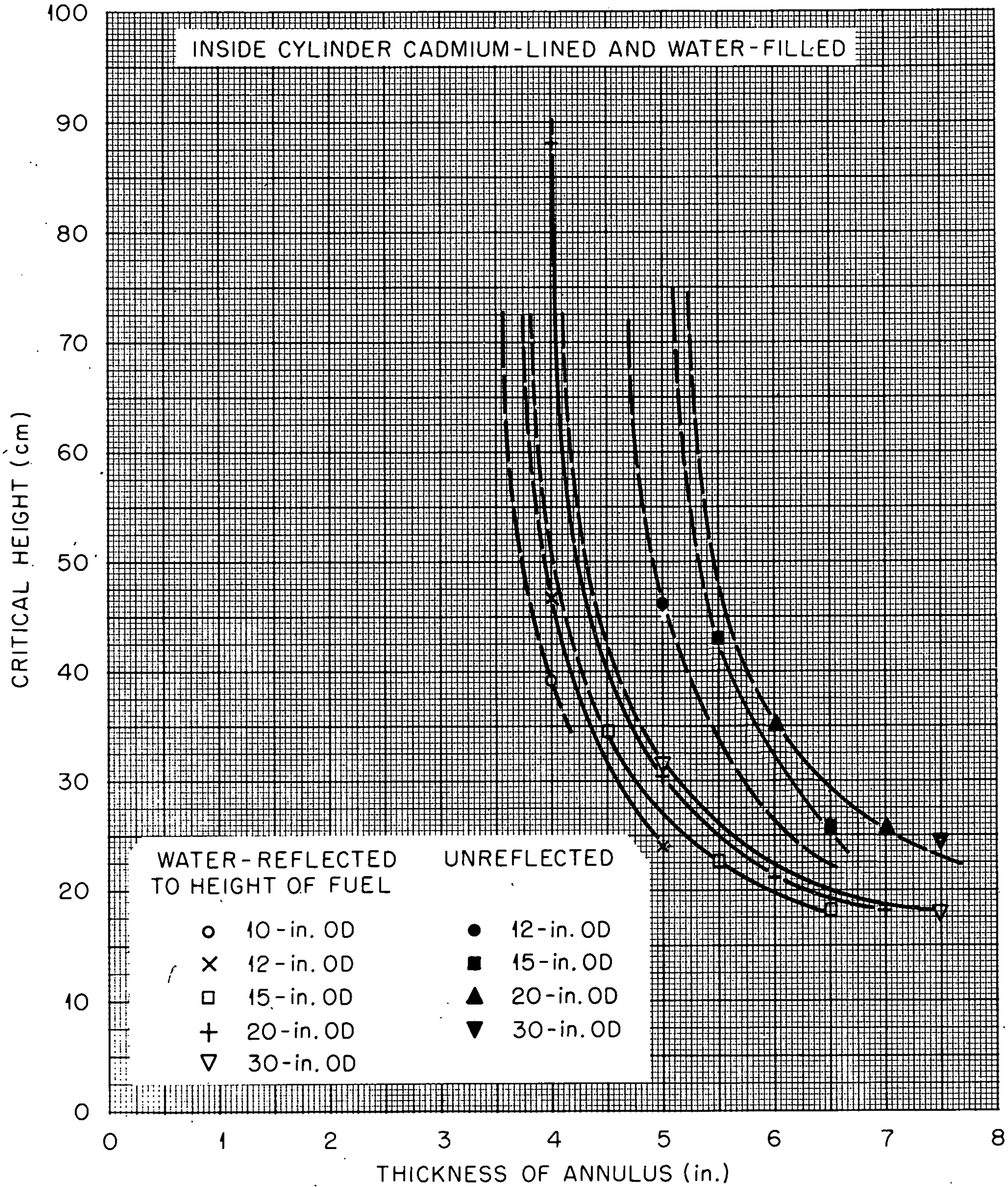

Fig. 2. Critical Heights of Cylindrical Annuli Containing Aqueous Solutions of 93.2% U^{235}-Enriched Uranyl Fluoride as a Function of the Thicknesses of the Annuli: $H:U^{235}$ Atomic Ratio = 309.

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