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Reference Critical Experiments

Progress Report
April - June 1979

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REFERENCE CRITICAL EXPERIMENTS

Progress Report for Period
April 1, 1979, through June 30, 1979

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SUMMARY

This is the fifteenth (15^{th}) in the series of quarterly progress reports describing reference critical experiments being performed at the Critical Mass Laboratory at Rockwell International's Rocky Flats Plant for the U. S. Nuclear Regulatory Commission (NRC).

The results of eight critical experiments are reported using the low-enriched, damp (H/U $\sim$ 1.25) uranium oxide (U_3O_8) in the concrete reflector and the minimal steel reflector.

The oxide alone is not critical; hence, a high-enriched (93% U-235) uranium driver section near the core center was required. The drivers used in these experiments were a uranium metal sphere, high concentration uranyl nitrate solution, and low concentration uranyl nitrate solution.

CRITICAL EXPERIMENTS AT ROCKY FLATS

Introduction to Critical Experiments

All experiments were conducted using the horizontal split table, consisting of two halves which can close slowly toward each other. Each half of the table supports a portion of the oxide array and the concrete or steel reflector. A more detailed description of the horizontal split table and reflectors can be found in References 1-4.

The uranium oxide (U_3O_8) is enriched to 4.46 wt-% ^{235}U and has a density of 4.68 g/cm^3. Approximately 15.2 kg of uranium oxide is packed in 15.3 cm cubical aluminum cans, and each filled can weighs ~ 16.2 kg. Water was injected into the oxide to achieve an H/U atomic ratio of ~ 1.25 (Reference 5).

The concrete and steel reflectors and the array of oxide cans are the same ones used for earlier experiments at H/U = 0.77 (Reference 4).

The critical experiments were performed using either the uranium metal (~ 93% ^{235}U) driver, the low concentration uranyl nitrate solution (~ 86 g U/ℓ) driver, or the high concentration uranyl nitrate solution (~ 351 g U/ℓ) driver. Detailed properties of the drivers can be found in References 1, 4, and 5.

Concrete-Reflected Critical Experiments

Five concrete-reflected critical experiments were performed using the metal and solution drivers. Criticality was achieved twice using the low concentration solution driver. The experimental 5 x 5 x 5 array (Figure 1) consisted of 119 regular oxide cans, two special oxide cans, and two solution driver cans (Reference 4). The total oxide can weight was 1959.7 kg. The first experiment was critical with a core separation of 0.749 cm using 5.100 kg of solution in the north table solution can and 5.099 kg of solution in the south table solution can, for a total of 10.199 kg of solution. The second experiment was critical with a core separation of 0.344 cm. The north table solution can contained 5.000 kg of solution, and the south table solution can contained 4.999 kg of solution, for a total weight of 9.999 kg of solution.

Two critical experiments were performed using the high concentration solution. The experimental array was identical to the one used for the low concentration solution. Criticality was achieved at a core separation of 1.820 cm for the first experiment using a total of 12.296 kg of solution equally divided between the north and south solution cans. The second critical experiment used 11.496 kg of solution, also equally divided between the north and south solution cans, and was critical with a core separation of 0.512 cm.

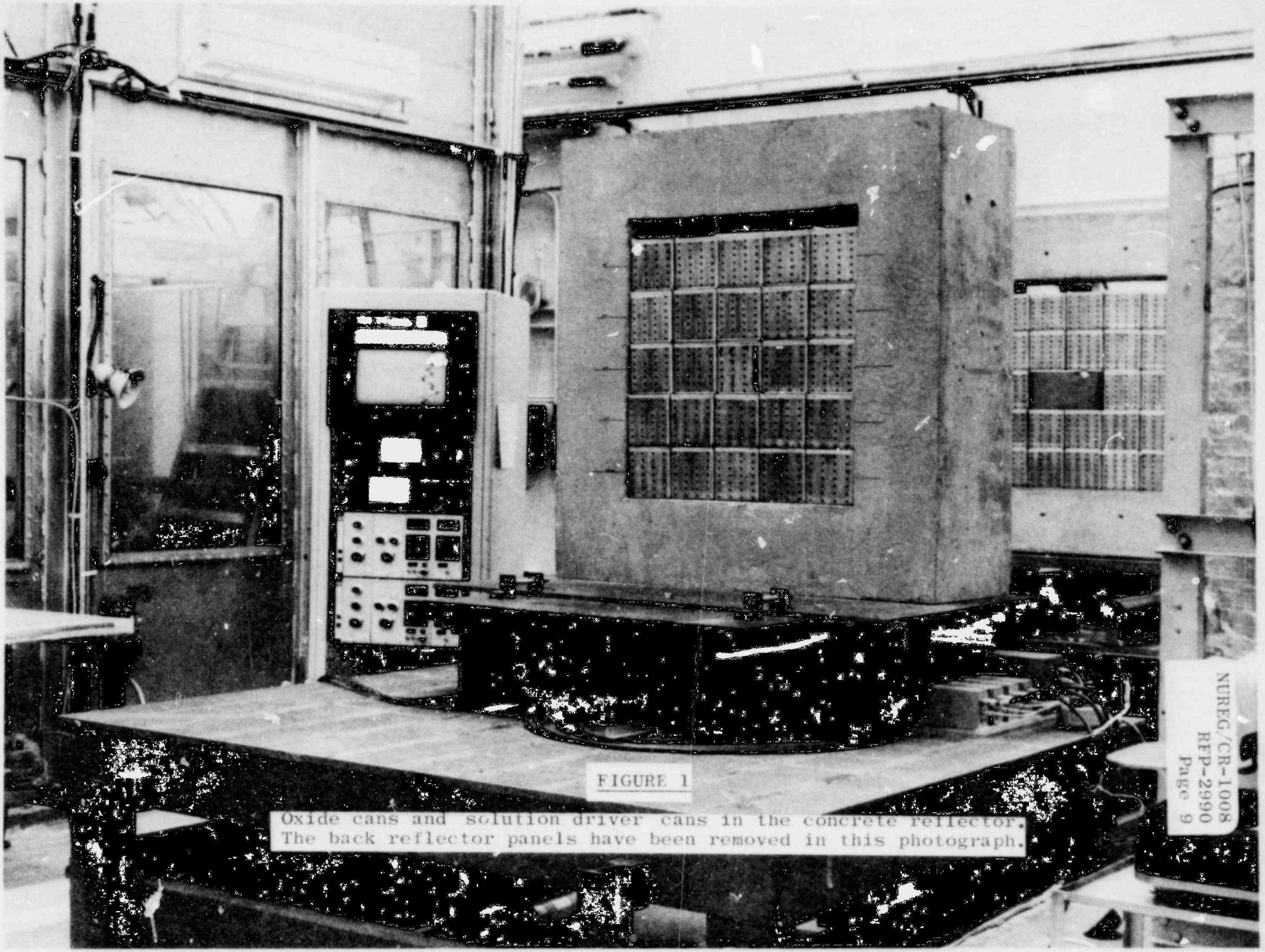


FIGURE 1

Oxide cans and solution driver cans in the concrete reflector. The back reflector panels have been removed in this photograph.

One critical experiment was performed using a 25.378 kg spherical metal uranium driver. The driver's outside radius was 7.00 cm and the inside radius was 2.01 cm. The experimental array consisted of 124 cans, weighing 2002.7 kg, in a 5 x 5 x 5 array with an empty space for the driver. The assembly was critical with a core separation of 0.565 cm. Critical parameters for the concrete-reflected experiments, including period information, are given in Table I. Cuboid dimensions are given in another section of this report.

Minimum Steel Reflected Critical Experiments

Three minimal steel reflected critical experiments were performed using the metal and solution drivers. The array configurations were the same as for the concrete-reflected case described in the previous section.

The first criticality was attained with the low concentration solution driver in the 5 x 5 x 5 array when the core separation between the core parts was 0.423 cm. The array consisted of 119 oxide cans, two special oxide cans, and two solution driver cans equivalent to four oxide cans. For the solution driver, the south and north cans each contained 6.111 kg solution, for a total of 12.222 kg.

When the high concentration solution driver was used, the critical core separation was 0.451 cm. In this critical experiment, the south and north driver cans each had 7.000 kg, for a total of 14.000 kg of solution.

TABLE I

Critical Parameters

TYPE OF DRIVER	TOTAL DRIVER MASS (kg)	CRITICAL CORE SEPARATION (cm)	PERIOD DATA				REFLECTOR	DRY OXIDE WEIGHT (kg)	TOTAL[a] OXIDE CAN WEIGHT (kg)	NUMBER OF CANS[b]
			Negative Period (min)	Separation (cm)	Positive Period (min)	Separation (cm)				
93.12% Enriched Uranium Metal	25.378	0.577	8.7	0.593	10.8	0.565	concrete	1864.6	2002.7	120 and 4(S)
	29.278	0.845	5.5	0.871	6.8	0.825	minimal steel			
High Concentration Solution (351.2 kg U/m^3)	12.296	1.845	5.6	1.877	7.0	1.820	concrete	1824.9	1959.7	119 and 2(S)
	11.496	0.529	8.7	0.546	8.9	0.512	concrete			
	14.000	0.451	4.5	0.472	7.0	0.438	minimal steel			
Low Concentration Solution (86.4 kg U/m^3)	10.199	0.749	12.3	0.755	10.7	0.743	concrete	1824.9	1959.7	119 and 2(S)
	9.999	0.358	19.1	0.365	8.1	0.344	concrete			
	12.222	0.423	10.7	0.431	8.4	0.413	minimal steel			

[a]The total weight of oxide, can, water, tape, etc., as of March 30, 1979.

[b]S = Special oxide can (see Reference 4).

A 14.67-cm-diameter uranium metal sphere with a 4.00-cm-diameter spherical void at the center was used as a driver in the 5 x 5 x 5 array of oxide. The metal driver weighed 29.278 kg and consisted of part numbers 3 through 34 as listed in Table VIII of Reference 4. The critical core separation was 0.845 cm. Figure 2 shows the experimental cans loaded inside the steel reflector on the horizontal split table. The gaps between the sphere and cans were 0.25 cm at the west side, 0.47 cm at the east, 0.16 cm at the north, and 0.32 cm at the top.

Cuboid dimensions for the minimal steel reflected critical experiments are given in another section of this report. Critical parameters, table separations, period data, etc., for the minimal steel reflected critical experiments are given in Table I.

Critical Assembly Dimensions

Three north-south pairs of cuboids, outer reflector cuboid, inner reflector cuboid, and core cuboid, are defined to describe the dimensions of the critical assemblies. A more detailed definition of the cuboids can be found in Reference 2. Cuboid dimensions for the concrete-reflected critical experiments and the minimal steel reflected critical experiments are given in Table II. Figure 3 is the key to Table II. The core was not unstacked between critical runs for a given reflector, only the drivers were changed; thus,

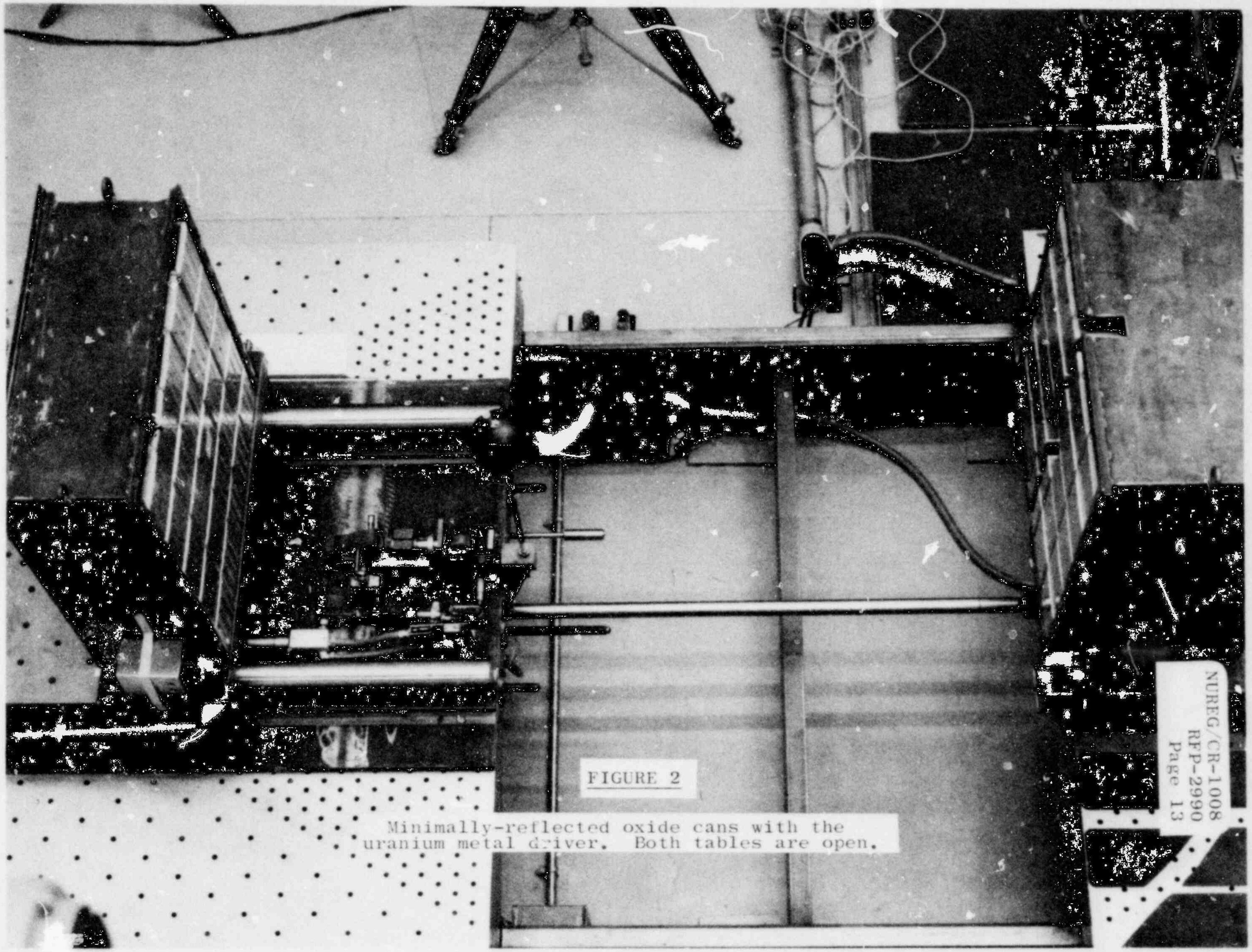


FIGURE 2

Minimally-reflected oxide cans with the uranium metal driver. Both tables are open.

TABLE II

Critical Cuboid Dimensions

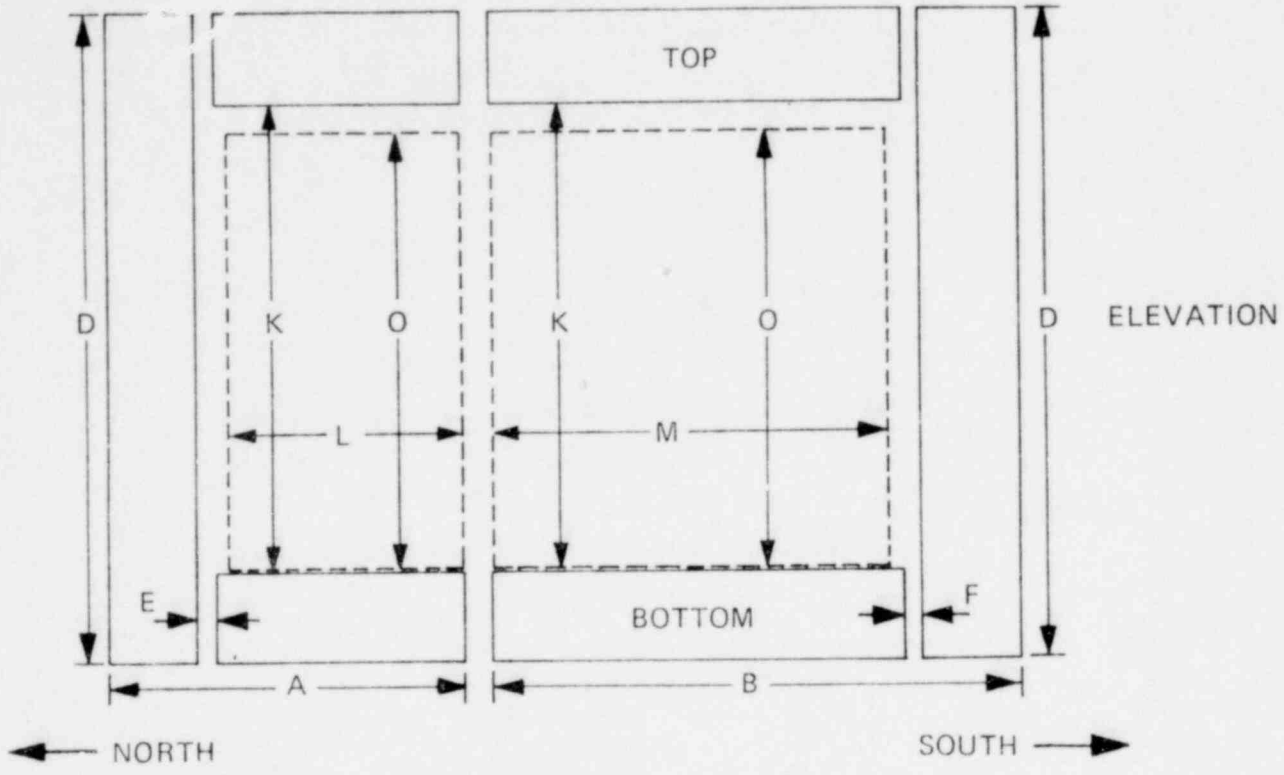
EXPERIMENT	OUTER REFLECTOR CUBOID						INNER REFLECTOR CUBOID					CORE CUBOID			
	Dimensions (cm)				**Gap (cm)		Dimensions (cm)					Dimensions (cm)			
	N-S		E-W	Vertical	N-S Direction		N-S		E-W		Vertical	N-S		E-W	Vertical
	North Table	South Table			North Table	South Table	North Table	South Table	North Table	South Table		North Table	South Table		
	* A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Concrete Reflected	58.4 ± 0.2	73.5 ± 0.2	128.3 ± 0.2	134.4 ± 0.1	0.9 ± 0.2	0.8 ± 0.2	32.6 ± 0.1	47.7 ± 0.1	77.5 ± 0.1	76.9 ± 0.4	83.2 ± 0.3	30.9 ± 0.1	46.1 ± 0.1	76.8 ± 0.3	77.3 ± 0.2
Minimal Steel Reflected	32.6 ± 0.1	47.9 ± 0.1	77.7 ± 0.2	85.1 ± 0.2	--	--	32.0 ± 0.1	47.3 ± 0.1	77.6 ± 0.1	77.8 ± 0.4	83.2 ± 0.2	30.8 ± 0.1	46.3 ± 0.1	77.0 ± 0.3	76.9 ± 0.1

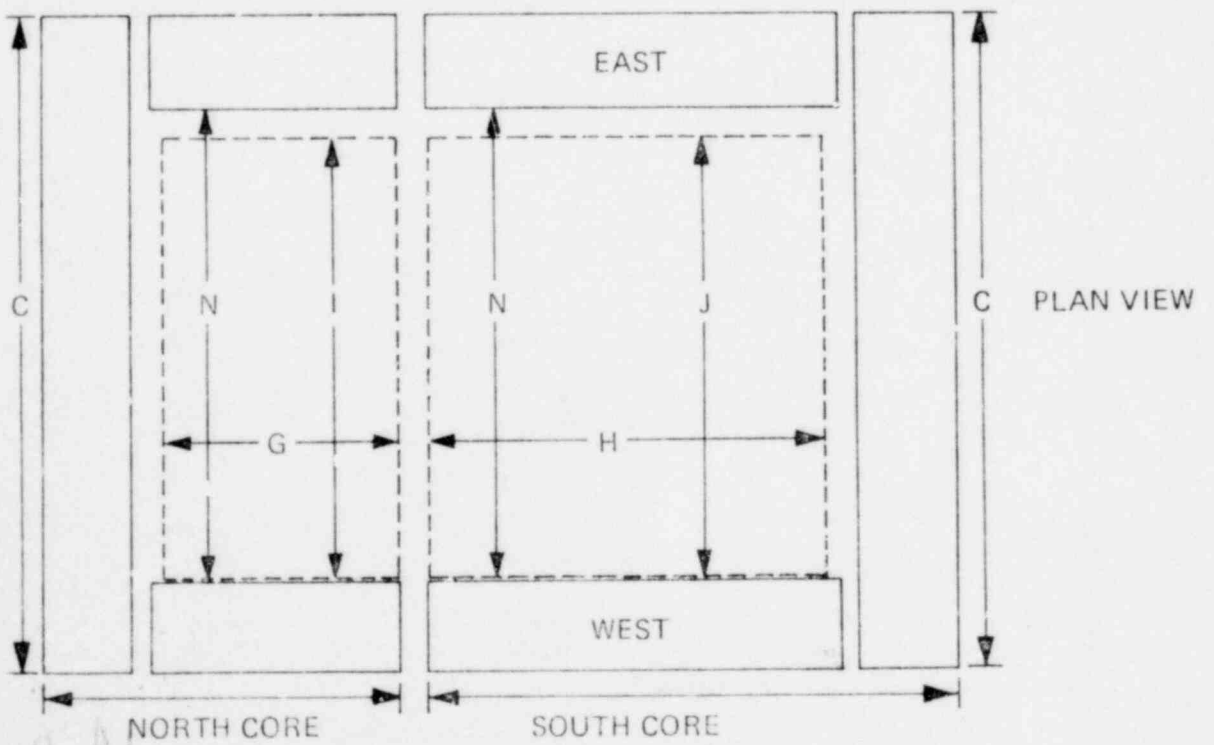
*See Figure 3.

**Only gaps where neutron leakage might occur are reported.

FIGURE 3

Dashed lines indicate core boundaries and solid lines represent reflector boundaries.





only one set of dimensions is given for the series of concrete-reflected critical experiments and one set of dimensions for the minimal steel reflected critical experiments.

PROGRESS OF TOPICAL REPORTS

Topical Report on Low-Enriched Uranium Oxide Systems (H/U = 0.77)

At the time of writing this report, the final draft of the "Benchmark Critical Experiments on Low-Enriched Uranium Oxide Systems with H/U = 0.77" topical report is being typed.

Topical Report on Interstitially-Moderated Experiments (H/U = 0.77)

The writing of the topical report on "Benchmark Critical Experiments with Interstitially-Moderated Arrays of Damp, Low-Enriched Uranium Oxide" at H/U = 0.77 (References 2-4) is in progress. At the time of writing this report, fifty percent of the first draft of the topical was completed.

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6. B. B. Ernst, I. Oh, and G. Tuck, Reference Critical Experiments Progress Report for Period April 1, 1978, through June 30, 1978, NUREG/CR-0297(RFP-2829), U. S. Nuclear Regulatory Commission (September, 1978).

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