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REFERENCE CRITICAL EXPERIMENTS

Progress Report for Period January 1 - March 31, 1978

I. Oh D. Pecora
R. E. Rothe
Rockwell International

MASTER

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U. S. Nuclear Regulatory Commission

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I. Oh D. Pecora
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Rockwell International
Atomic International Division
Rocky Flats Plant
P. O. Box 464
Golden, CO 80401

Division of Safeguards, Fuel Cycle and Environmental Research
Office of Nuclear Regulatory Research
U. S. Nuclear Regulatory Commission
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SUMMARY

This is the tenth in the series of quarterly reports describing reference critical experiments being performed at Rocky Flats for the U. S. Nuclear Regulatory Commission (NRC).

Five special cans of oxide, used to fill the regions around the driver support and source removal slots, have been packed and adjusted to an H/U of 0.75 by injecting measured quantities of water.

Handstacking of the metal and solution uranium drivers has been completed. Two pairs of solution driver cans were fabricated of type 304 stainless steel and their dimensions measured.

Handstacking of the low-enriched oxide cans at an H/U = 0.75 was performed on the horizontal split table in the concrete reflector. The first table closure of the concrete-reflected oxide experiment had the solution driver cans in the array, but they contained no solution. The reciprocal multiplication was measured as a function of the table separation, and a value of 0.55 with the table completely closed was achieved.

A proposal for thirteen critical experiments to be added to the existing low-enriched oxide experiments was submitted to NRC for approval. These additional experiments

are to determine the conditions for criticality for arrays of low-enriched oxide (H/U = 0.75) with various moderating materials interspersed among the units.

SPECIAL CLEARANCE CANS

Five aluminum cans, designed to clear the metal driver support and the source and source control equipment, have been packed with oxide. Each contains sixteen ~ 710 g oxide blocks plus several fragments weighing ~ 910 g, for a total of 12270 g (average) per can. These special cans were constructed by modifying 6" cube aluminum cans similar to those used elsewhere in the core.

The special cans, which have a 5 cm wide by 10 cm deep slot, as seen in Figure 1, measure 15.24 cm square by 15.08 cm tall (outside dimensions). A flat "U"-shaped cover increases the outer height to 15.24 cm. Thirty-two holes were drilled in four vertical rows on two opposite faces to permit later water injections. Each of the 32 holes was 0.63-cm-diameter with two holes per oxide block. One similar hole was drilled in the top of the can to allow water to be added to the oxide fragments behind the slot. All holes were sealed with vinyl tape.

After packing, water was injected into these holes (211 g per can) until an H/U ratio of 0.75 was achieved. The detailed packing and watering procedures are similar to those described in RFP-NUREG-2746 for the 132 regular oxide cans. Table I lists the properties of these special cans.

FIGURE 1

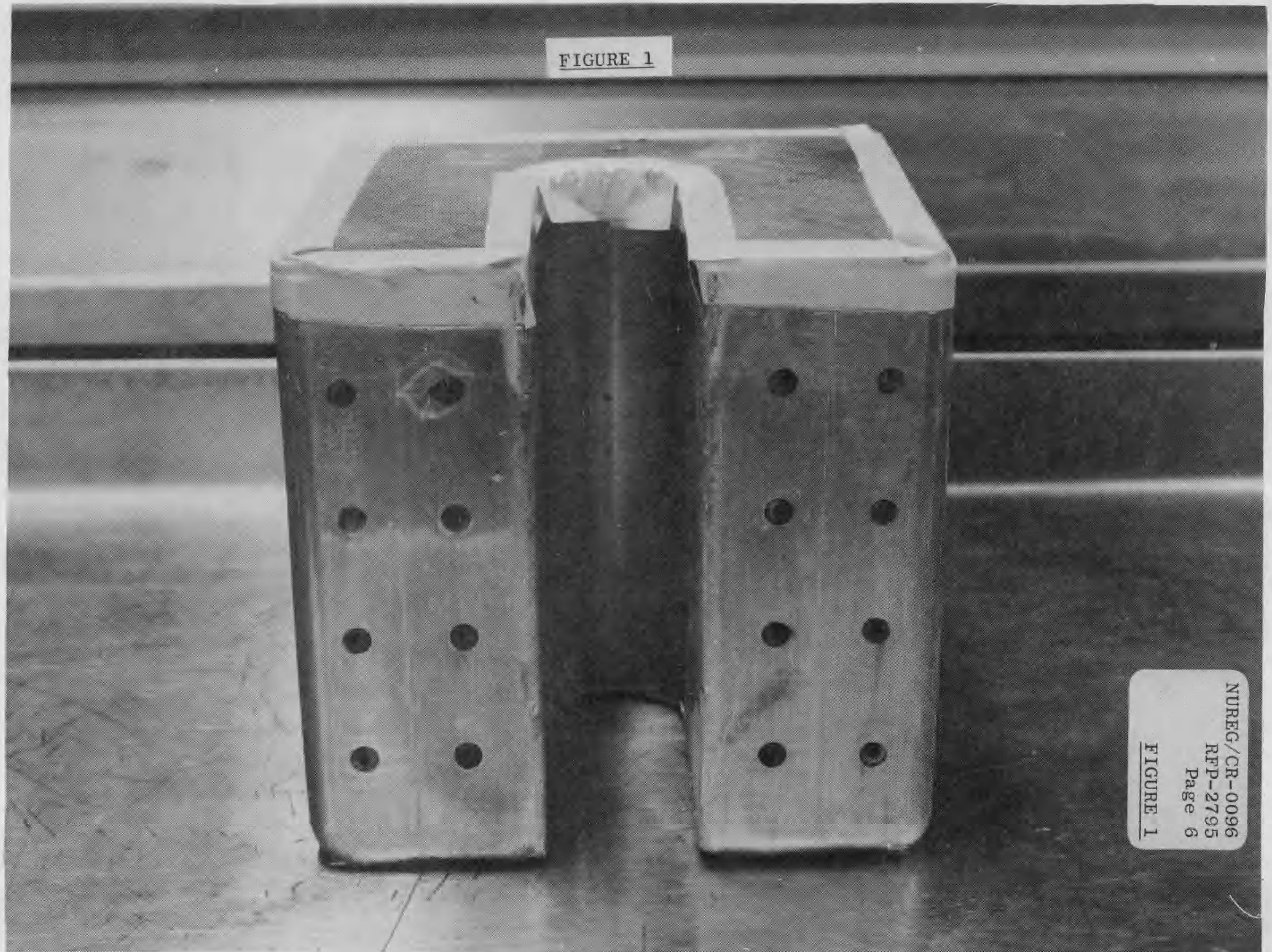


FIGURE 1

TABLE I

Properties of Special Clearance Cans

Can Number	Oxide Weight (g)	Water Weight (g)	Aluminum Weight (g)
S1	12273	209	620
S2	12292	211	619
S3	12215	211	620
S4	12343	210	623
S5	12143	212	621

METAL AND SOLUTION DRIVERS

In the oxide experiments with the H/U $\sim$ 0.75, oxide alone cannot be made critical. Hence, a "driver" consisting of 93.12% ^{235}U metal or solution will be used near the core's center to achieve criticality. Before the high-enriched uranium metal or solution driver is used with the low-enriched oxide, preliminary handstacking of the uranium metal and solution drivers was needed for safety.

Metal Driver Handstacking

Handstacking of the largest spherical uranium metal driver expected to be needed was completed. Any driver of lower mass may then be reassembled safely. The enriched uranium (93.12% ^{235}U) hemispherical shells used to assemble this driver are listed in Table II. A 3.0-cm-radius spherical void existed in the center of the uranium metal assembly to contain the neutron source. The reciprocal multiplication for the essentially-unreflected assembly was measured as a function of the total number of uranium metal parts, and a value of 0.35 was achieved for 26 uranium components (part numbers 9 through 34). The largest uranium metal sphere which will fit in the low-enriched oxide experiments as a driver is the 14.67-cm-diameter metal sphere weighing 29.87 kg (part numbers 1 through 34).

TABLE II

Properties of Assembled Metal Drivers

Part Number	Inside Radius (cm)	Outside Radius (cm)	Mass (kg)	Cumulative Mass (kg)	Cumulative Mass* (kg)
1	0.0	2.001	0.296	0.296	
2	0.0	2.001	0.296	0.592	
3	2.013	2.337	0.176	0.768	
4	2.013	2.338	0.176	0.944	
5	2.347	2.670	0.233	1.177	
6	2.347	2.670	0.234	1.411	
7	2.680	3.003	0.302	1.713	
8	2.679	3.003	0.301	2.014	
9	3.013	3.335	0.376	2.390	0.376
10	3.012	3.336	0.375	2.765	0.751
11	3.344	3.670	0.465	3.230	1.216
12	3.344	3.670	0.465	3.695	1.681
13	3.680	4.002	0.555	4.250	2.236
14	3.680	4.002	0.554	4.804	2.790
15	4.017	4.338	0.653	5.457	3.443
16	4.016	4.338	0.651	6.108	4.094
17	4.346	4.670	0.766	6.874	4.860
18	4.346	4.670	0.766	7.640	5.626
19	4.679	5.004	0.889	8.529	6.515
20	4.678	5.004	0.890	9.419	7.405
21	5.017	5.337	1.004	10.423	8.409
22	5.013	5.336	1.011	11.434	9.420
23	5.346	5.669	1.147	12.581	10.567
24	5.346	5.669	1.149	13.730	11.716
25	5.679	6.003	1.288	15.018	13.004
26	5.679	6.001	1.286	16.304	14.290
27	6.011	6.335	1.445	17.749	15.735
28	6.012	6.334	1.441	19.190	17.176
29	6.345	6.671	1.612	20.802	18.788
30	6.334	6.670	1.612	22.414	20.400
31	6.678	7.002	1.779	24.193	22.179
32	6.679	7.003	1.777	25.970	23.956
33	7.006	7.330	1.949	27.919	25.905
34	7.010	7.334	1.951	29.870	27.856

*This cumulative mass (part numbers 9 through 34) was used for the assembled metal driver.

The metal driver was also handstacked in one corner of the concrete reflector to prove the safety should the assembled sphere fall off its support. The measured reciprocal multiplication for the concrete-reflected assembly was 0.45 for 26 uranium components, and was higher than for the essentially-unreflected assembly because the source location of the concrete-reflected assembly was different from that of the essentially-unreflected assembly.

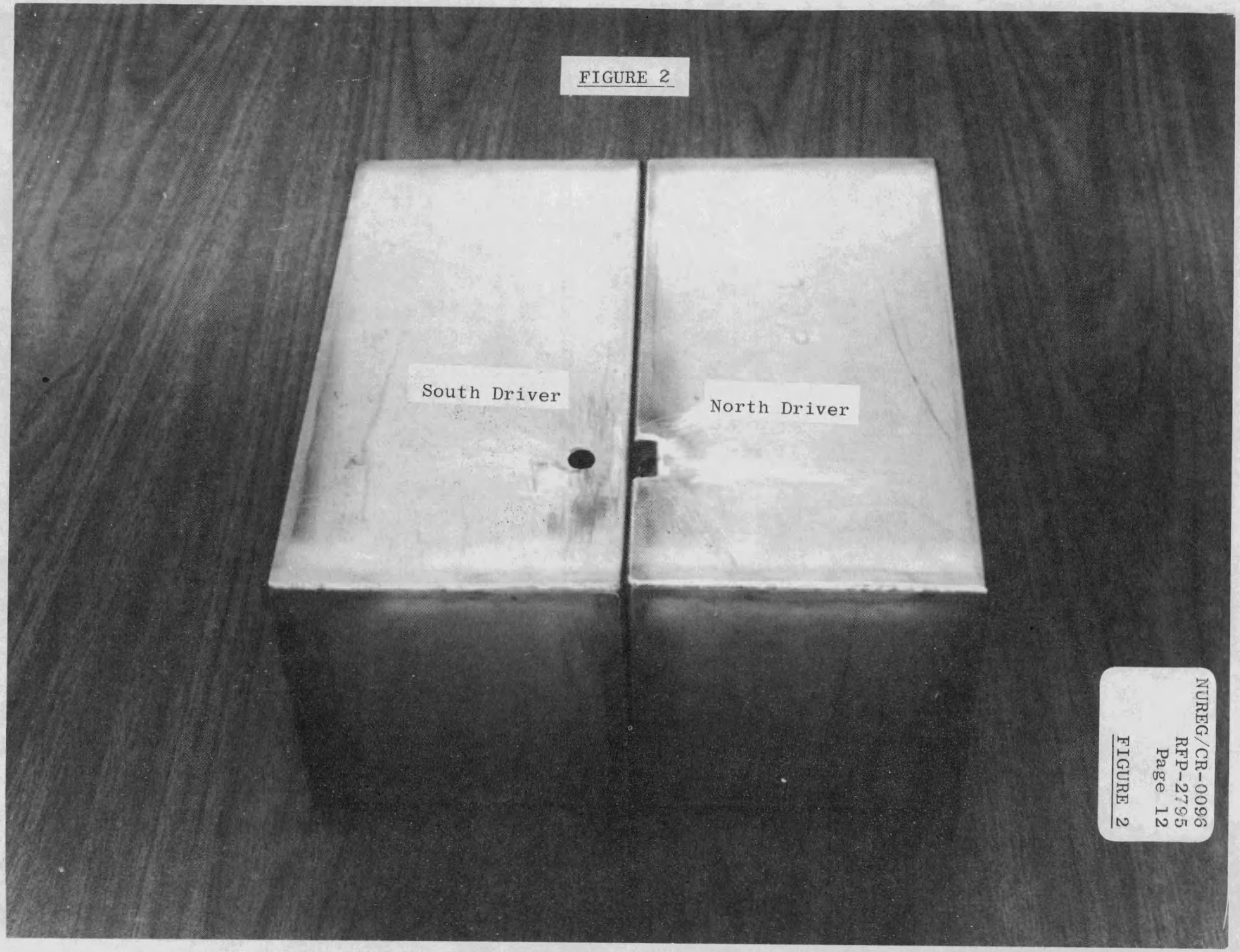
Solution Driver Cans

Two pairs of solution driver cans were fabricated for these experiments. These are made of type 304 stainless steel and have the shape of a rectangular box equivalent to two oxide cans side-by-side (see Figure 2). The original plan was to use aluminum cans painted with epoxy paint. However, the epoxy would not adhere to the metal, so it was necessary to use stainless steel. One pair will be used for high concentration uranyl nitrate solution (~ 350 g U/ℓ), and the other pair for low concentration solution (~ 80 g U/ℓ). Each pair consists of one can for the south half table with a 1.1-cm-diameter hole on the top face, and one can for the north half table with a 1.1-cm-diameter hole on an edge as shown in the figure. The hole was located on the edge because unmodified oxide cans are stacked on top of the north driver can. Solution can then be added to the driver without unstacking the oxide. For the south driver

Figure 2

One pair of solution driver cans: one for the south half table and the other for the north half table. The fill hole for the north can is in shadow in the diagonal recessed notch.

FIGURE 2



can, the special "U"-shaped oxide cans described earlier do not block the solution fill hole. Properties of these solution driver cans are listed in Table III.

Uranyl Nitrate Solutions

The low concentration solution (~ 80 g U/liter) and the high concentration solution (~ 350 g U/liter) to be used as drivers were drawn from the uranium solution tank farm maintained at this facility for other criticality programs. Two rolling carts have been provided to store four 4-liter bottles each, as shown in Figure 3. One cart is to be used for high concentration solution, the other for low.

Solution Driver Handstacking

Handstacking of the high concentration uranyl nitrate solution driver was performed in the essentially-unreflected environment. The two stainless steel driver cans were placed on the table in contact, simulating their most reactive configuration when the horizontal split table is closed. The reciprocal multiplication was measured as a function of the total volume of successive solution increments, and a value of 0.4 was attained with both cans essentially full (17747 g solution).

After completing the handstacking with the two cans in contact, they were spaced by moving one can away, keeping the source/counter geometry fixed. The reciprocal multiplication increased from 0.39 to 0.64 as the separation of two full solution driver cans increased from zero to 100 cm.

TABLE III

Solution Driver Can Properties

Property	High Concentration Driver		Low Concentration Driver	
	North	South	North	South
Weight (g)	2700	2704	2684	2692
Metal Thickness (cm)	0.15	0.15	0.15	0.15
Inside Length (cm)	29.75	29.79	29.76	29.87
Inside Width (cm)	14.95	15.04	15.00	15.00
Inside Height (cm)	15.15	15.10	15.05	15.00
Inside Volume (cm^3)	6734	6761	6714	6716
Usable Volume* (cm^3)	6269	6761	6268	6716

*Because of the hole on the edge, the south can cannot contain solution to the top of the can.

Figure 3

A rolling cart with four 4-liter solution bottles to be used for storing driver materials.

FIGURE 3

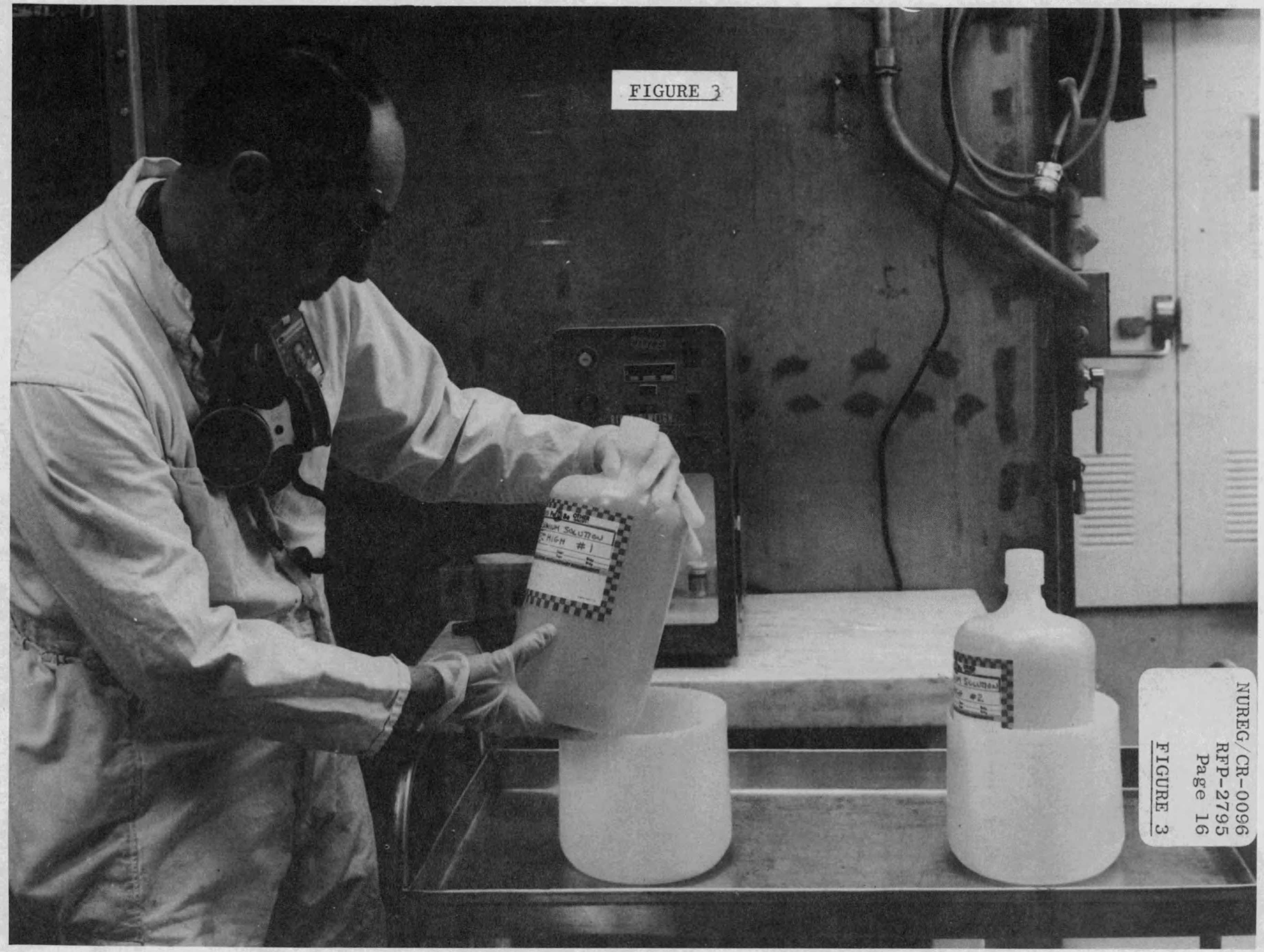


FIGURE 3

HORIZONTAL SPLIT TABLE

During the initial operation of the split table, both with and without oxide cans loaded in place, several unanticipated table scrams occurred. These were traced to a number of small functional and alignment problems. About two weeks time was spent resolving these problems. Some of the improvements include: leveling the table tracks, aligning the table, adjusting the side rollers to eliminate table creep, aligning the power screw, slotting the mounting holes on the main cylinder shaft to permit better alignment, improving the oil flow path on the accelerometer circuit, and increasing the flow rate slightly to the main cylinder.

During the preliminary closures of the horizontal split table, the following table closure speeds were measured: the north table closure speed is 1.8 cm/sec; the fastest south table normal closure speed over the initial 119 cm is 0.51 cm/sec; the fastest closure speed during the final 25 cm is 0.04 cm/sec; and the slowest continuous closure speed during this distance is 0.004 cm/sec. All the above closure speeds are much slower than the scram speeds of either half table.

HANDSTACKING OF OXIDE CANS

The oxide cans have been handstacked on the horizontal split table inside the concrete reflector shell. During the entire handstacking of these cans, no significant increase in multiplication was observed, as was expected. Figure 4 shows the entire assembly of low-enriched oxide cans hand-stacked on the south and north half tables. The end reflectors have been removed for the photograph.

Table IV shows the weights of the oxide cans at the time they were handstacked. These weights are approximately 5 g heavier than those presented in Table Va of RFP-NUREG-2746. This small weight gain has not been explained but will be investigated fully.

Figure 4

Entire assembly of low-enriched oxide cans handstacked on the north and south half tables in the concrete shells with the end reflectors removed. One solution driver can can be seen imbedded in the third layer of oxide cans in the north table.

FIGURE 4

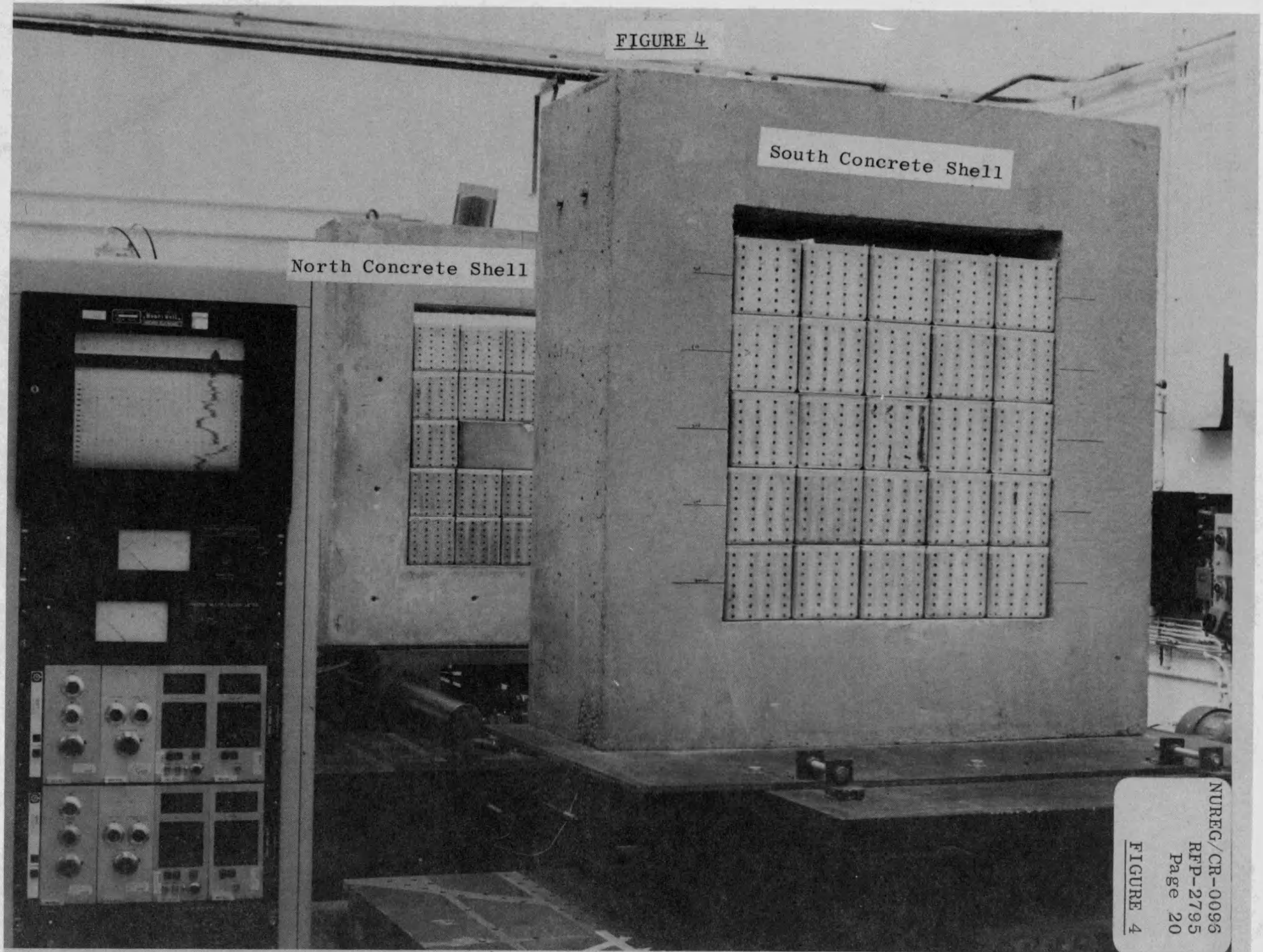


TABLE IV

Total Weight (in grams) of Experimental Cans as Placed into the Concrete-Reflected, H/U ~ 0.75 Array Having a Solution Driver[a]

ROW	LAYER				
	Bottom	Second	Third	Fourth	Top
north	15935 15925 15961 15993 15991	15970 15968 15966 15950 15950	16036 15996 16027 16035 16019	15999 15989 15996 15989 16000	16049 16037 16034 16075 16048
second	15976 15989 15982 16010 15983	15966 15923 15951 16027 15989	15985 b b 16020 16020	16014 16016 16020 16015 16005	16090 15985 15979 15974 15950
third	16015 16031 16031 16021 16000	16040 16034 16028 16023 16023	16000 b b 15954 15969	16006 16015 13150[c] 15996 16006	16011 16016 13171[c] 16025 16001
fourth	15971 15995 16015 16010 15993	15957 15944 15965 15975 15985	16016 16000 16013 15976 16023	15999 16020 16005 16025 16018	16048 16013 16030 16019 16019
south	16000 15955 15980 15976 16016	15971 15990 15954 16005 16014	15945 16000 16025 16030 16021	16021 16002 15995 15975 16001	15954 15945 15913 15950 16024
AVERAGE WEIGHT OF 119 TYPICAL CANS: 15998 ± 32 G					

[a]The five weights in any box of this table correspond to cans placed into the array from west to east in the associated row and layer.

[b]This location occupied by solution driver can.

[c]Special cans to provide clearance for source.

PRELIMINARY OXIDE EXPERIMENT

Empty solution driver cans were buried in the oxide array as shown in Figure 4. Then, the end reflectors were put in place. The reciprocal multiplication was measured as a function of the table separation, and the 1/M curve showed a continuous decrease to a value of 0.55 when the table was fully closed.

PROPOSED ADDITIONAL OXIDE EXPERIMENTS

A proposal for thirteen critical experiments to be added to the existing low-enriched oxide experiments was submitted to NRC for approval. The purpose of these additional experiments is to determine the conditions for criticality for arrays of low-enriched oxide with various moderating materials interspersed among the oxide cans. The thirteen critical measurements will be done after the 5 x 5 x 5 array measurements (Task 5) at H/U = 0.75 have been completed, and before any more water is added to the oxide. No drivers will be needed. After the additional measurements have been completed, the present program will continue according to an extended schedule. Table V shows array information for the additional experiments.

TABLE V

Additional Experimental Arrays

DESCRIPTION OF MODERATED EXPERIMENTS	REFLECTOR(S) IN WHICH EXPERIMENTS WILL BE DONE	MODERATOR(S) BETWEEN ADJACENT OXIDE CANS
optimum moderation	both	1" plastic only
undermoderated	both	3/8" plastic only
steel sheets surround oxide can	both plastic plastic	.05" Fe* plus 1" plastic .05" Fe* plus ½" plastic .02" Fe* plus 1" plastic
PVC plastic	both	3/8" full-density PVC* plus 1" plastic
expanded array	plastic	1/2" plastic* plus suitable aluminum spaces
subdivided array	both	1" plastic moderator only between 2 x 2 x 2 subarrays

*Enclosing each can like a box.

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The following personnel performed the work reported in this quarterly progress report:

B. B. Ernst

I. Oh

D. E. Payne

D. Pecora

R. E. Rothe

W. R. Sheets

G. Tuck