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Criticality Hazards

(M-3679, 18th Ed.)

Neutron Multiplication Measurements on Oralloy Slabs Immersed in Solutions

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L.A. Matheson - Technical Director
J. G. Epp - Assistant Technical Director

ABSTRACT:

This report reviews a series of sub-critical experiments on uranium metal immersed in water and aqueous solutions of $UO_2(NO_3)_2$ (uranium enrichment $\sim$ 90%) and $Cd(NO_3)_2$.

ACKNOWLEDGEMENTS:

These tests were made possible by the generous concurrence of Mr. L. L. Zodtner and Mr. D. M. Bassler and Staffs. Special thanks are extended to B. L. Kelchner, G. F. Andrews, R. P. Craig, and F. J. Linck, Jr.

CONTENTS

INTRODUCTION:

A series of neutron multiplication measurements were made on slab assemblies of Oralloy metal immersed in water and aqueous solutions of $UO_2(NO_3)_2$, $UO_2(NO_3)_2 + Cd(NO_3)_2$, and $Cd(NO_3)_2$. The uranium metal and $UO_2(NO_3)_2$ solutions were enriched to approximately 90% U^{235} and henceforth will be referred to in this report as Oy. Elsewhere in this report U^{235} will be used to designate actual amounts of this isotope.

The purpose of these experiments is to obtain data which can be used to arrive at safe U^{235} concentrations in sheet and plate cleaning baths. No recommendations for safe concentrations in such baths are given in this report due to the complexity of this type of problem.

RESULTS AND CONCLUSIONS:

Figure 1 is a plot of reciprocal multiplication as a function of U^{235} concentration for an untamped cylindrical stainless steel vessel approximately 30 inches in diameter and filled to a height of 28 inches. The critical concentration for this vessel appears to be 16.3 grams U^{235} per liter.

Figures 2 and 3 are plots of reciprocal multiplication versus slab thickness for Oralloy slabs immersed in a tank of water 30 inches in diameter filled to a height of 28 inches. The critical thicknesses, given by extrapolations of the curves, are 1.31 inches for the 10-inch by 16-inch slab and 1.14 inches for the 16-inch by 20-inch slab.

Figures 4 and 5 contain critical extrapolation of slab thickness for total immersion of the Oralloy slabs in the above mentioned tank containing aqueous solutions of $UO_2(NO_3)_2$. It should be noted that the extrapolations to critical conditions are long and the data should thus be used conservatively when applied to plant problems.

Figure 6 contains a plot of U^{235} concentration as a function of critical slab thickness for a 10-inch by 16-inch Oralloy slab.

Since this data is represented approximately by a straight line, other such lines can be drawn connecting critical slab thicknesses for zero U^{235} concentration (i.e., water) and the limiting U^{235} concentration for the 30-inch tank. This idea can perhaps be extended to include graphs of the type suggested in Figure 7.

Figure 7 was drawn by making use of the four-factor equation[1]

$$\eta f \epsilon p = 1$$

where ϵ and p are assumed to be near unity for these solutions. The limiting critical U^{235} concentration as calculated from

1. Glasstone, Samuel; Edlund, Milton C., "The Elements of Nuclear Reactor Theory", Van Nostrand, Feb., 1954.

the above formula is approximately 11.6 grams of U^{235} per liter of solution. This limiting value is plotted on the ordinate for zero slab thickness. On the abscissa are plotted several critical alab thicknesses corresponding to no dissolved U^{235} in the tamper. The ordinate point is connected to the abscissa points by straight lines designated as A, B, and C C = 0.724 inches was obtained by using extrapolation b.[1]

These lines will then correspond to critical assemblies of uranium sheet and plate immersed in large tanks when there is dissolved U^{235}. The slab sizes are expressed in terms of $\sqrt{A}$ where A is the area of the slab in square inches. This type of analysis can perhaps be applied to plutonium and U^{233} as well.

Figures 8 and 9 contain critical extrapolations of slab thicknesses for various aqueous cadmium solutions with and without a close-fitting 1/64-inch cadmium covering. Although the extrapolations are long, the data is semiquantitative.

These curves show that six grams per liter of cadmium produces near maximum effect in the reduction of the water reflector effectiveness. This is illustrated in Figure 10 where the extrapolated critical slab thicknesses are plotted as a function of the grams of dissolved cadmium per liter.

Figures 11 and 12 illustrate the effect of various amounts of

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1. Gwin, Reginald; Mee, W. T., "Critical Assemblies of Oralloy", Y-A2-124, Y-12 Plant, Carbide & Carbon Nuclear Company, Sept. 8, 1953.

dissolved cadmium and cadmium sheet on the critical slab thicknesses in 4.7 and 11.7 grams per liter aqueous solution of U^{235} as $UO_2(NO_3)_2$. The dissolved cadmium and the 1/64-inch cadmium sheet are quite effective in reducing the interaction between the slab and the $UO_2(NO_3)_2$ solution.

Figures 13 and 14 illustrate an attempt to determine the least amount of dissolved cadmium necessary in the 4.7 grams U^{235} per liter and 11.7 grams U^{235} per liter solutions to produce values of critical slab thickness which coincide with the extrapolated critical slab thickness in a water tamper. It can be seen from Figures 13 and 14 that very small amounts of cadmium in solution are quite effective. A qualitative reason is as follows: the cadmium serves two purposes; viz., that of poisoning the uranium solution, and that of reducing the water reflector effectiveness around the Oralloy slabs.

EXPERIMENTAL:

Equipment:

The neutron flux measurements were made with General Electric B^{10} lined neutron counters and associated decade scalers. The counters were incased in cylindrical polystryene moderators. The neutron source consisted of a polonium-beryllium unit having a strength of 2.6×10^6 neutrons per second.

Materials:

a. Oralloy metal plates (90+% enrichment).

Density: 18.6 grams per cm^3.

Average slab size: 0.279 x 8 x 10 inches.

Average slab mass: 6.67 kilograms.

b. Uranyl nitrate solutions. Excess nitric acid pH ~ 2.

c. Cadmium nitrate solutions. Excess nitric acid (pH 1.0-1.8).

d. Cadmium-uranyl nitrate solutions. Excess nitric acid (pH 1.0-1.8) (concentration values are within ± 2% of values indicated on graphs).

e. Cadmium sheet, 1/64-inch thick.

f. Stainless steel process tank, 0.105-inch wall thickness, 30 inches diameter and 30 inches deep.

All cadmium and Oralloy slabs were coated with a 0.001-inch thick layer of plastic from a pressurized plastic spray bomb. No corrosion of the coated metal parts was observed during the course of the experiments.

Procedure:

The slabs were made up of individual Oralloy metal plates mounted in an upright position on a light weight stainless steel rack (see Figure 15). The 0.279 x 8 x 10-inch Oralloy plates were bolted securely to the rack with 1/8-inch stainless steel bolts through holes in each corner of the Oralloy plates. The rack was then lowered into place in the 30-inch diameter stainless steel tank. The neutron source was placed in a special holder for location in the tank. Water and other solutions were then allowed to slowly fill the tank until a 28-inch depth was reach

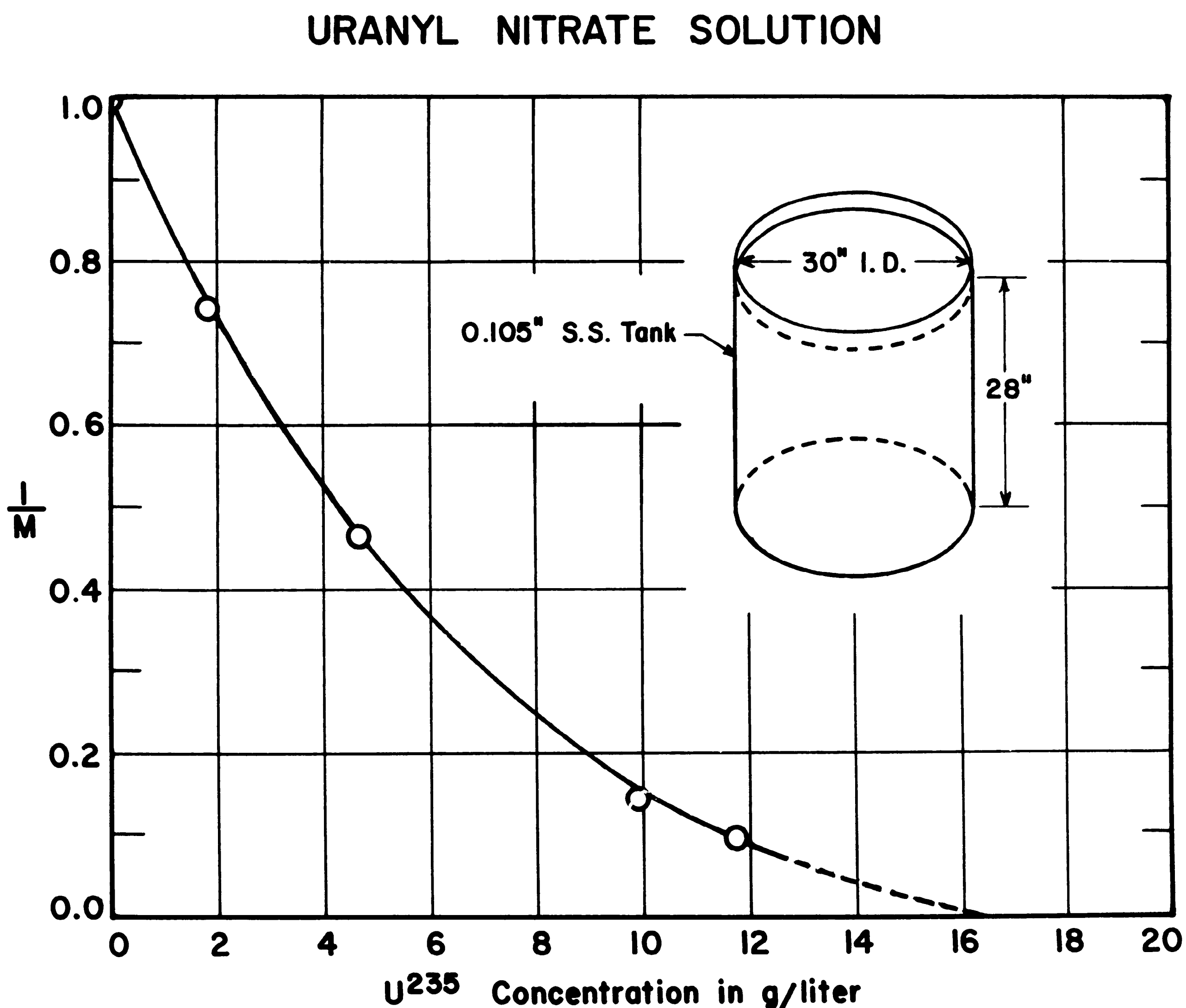

URANYL NITRATE SOLUTION
1.0
0.8
0.6
0.4
0.2
0.0
1/M
0
2
4
6
8
10
12
14
16
18
20
U^{235} Concentration in g/liter
30" I.D.
0.105" S.S. Tank
28"

Figure 1.

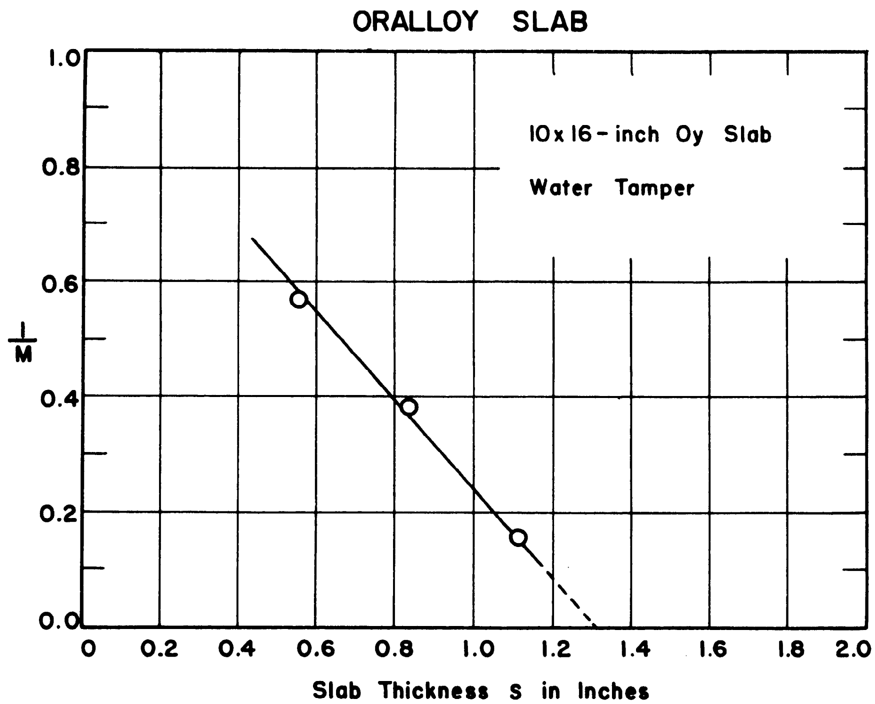


Figure 2.

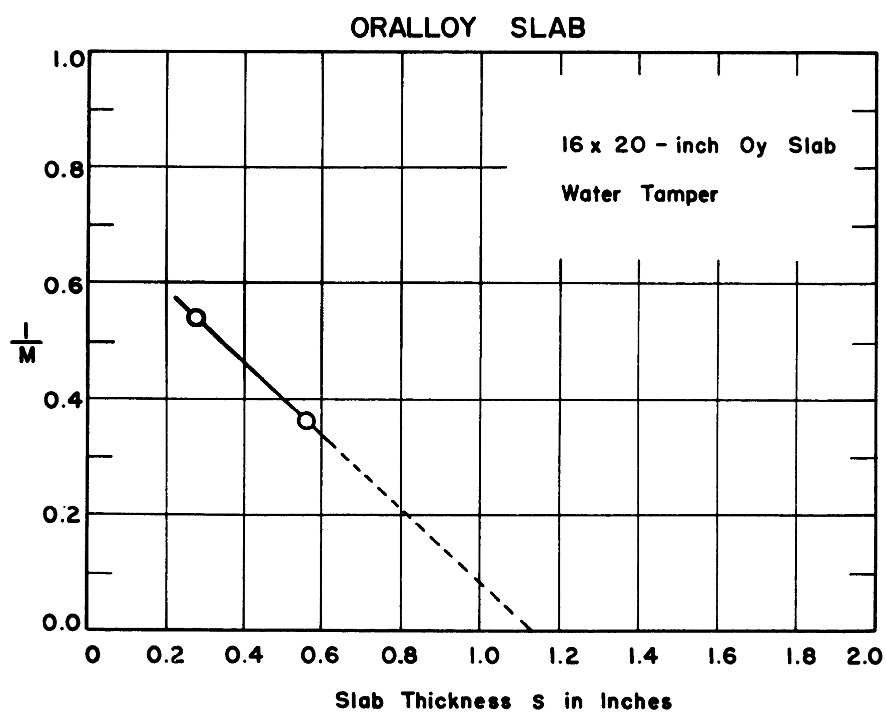


Figure 3.

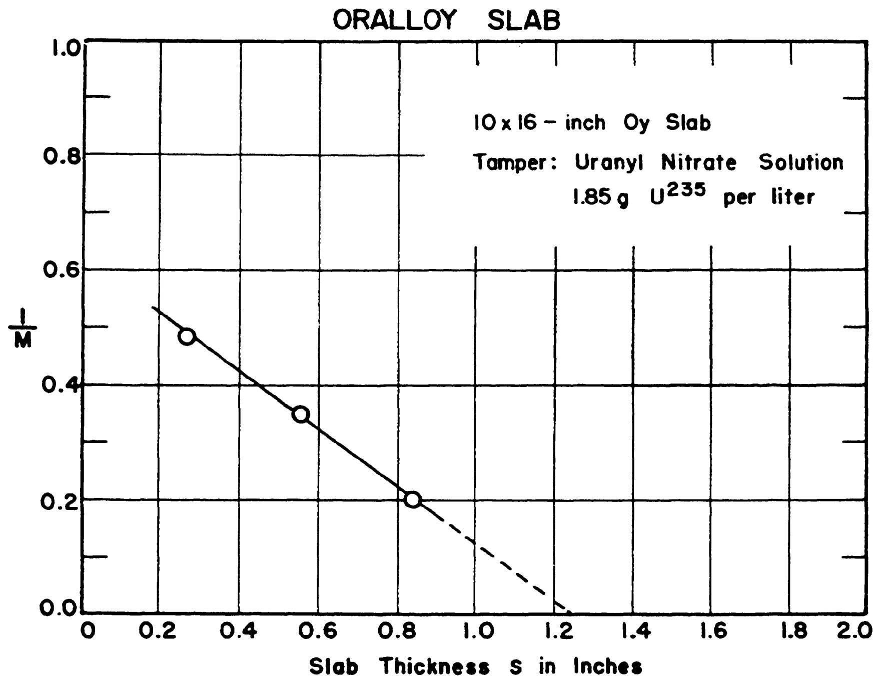


Figure 4.

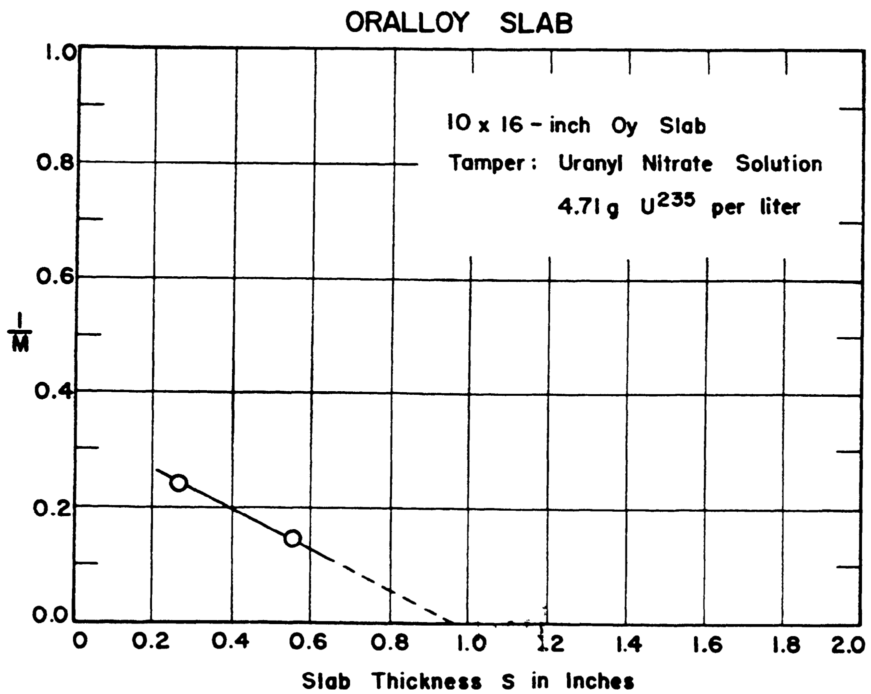


Figure 5.

CRITICAL SLAB THICKNESS

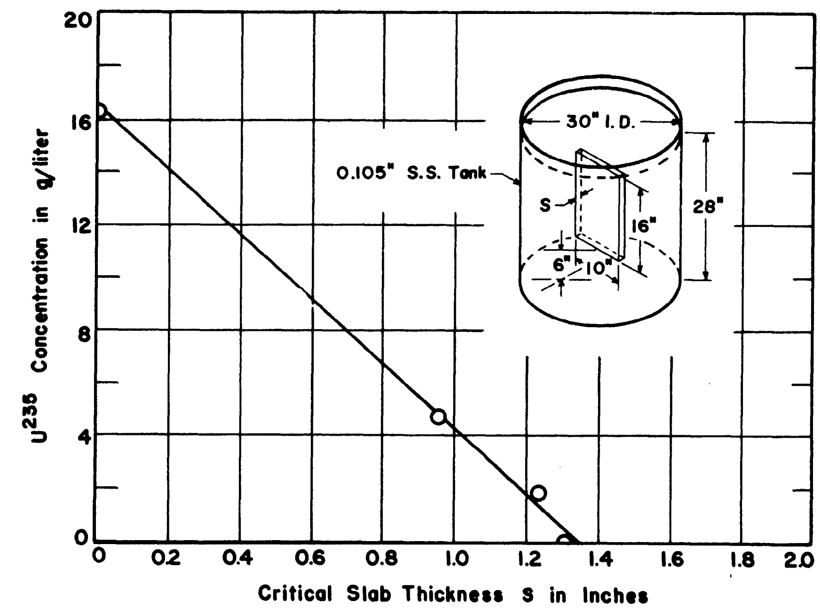


Fig. 31

CRITICAL SLAB THICKNESS IN AN INFINTE SYSTEM

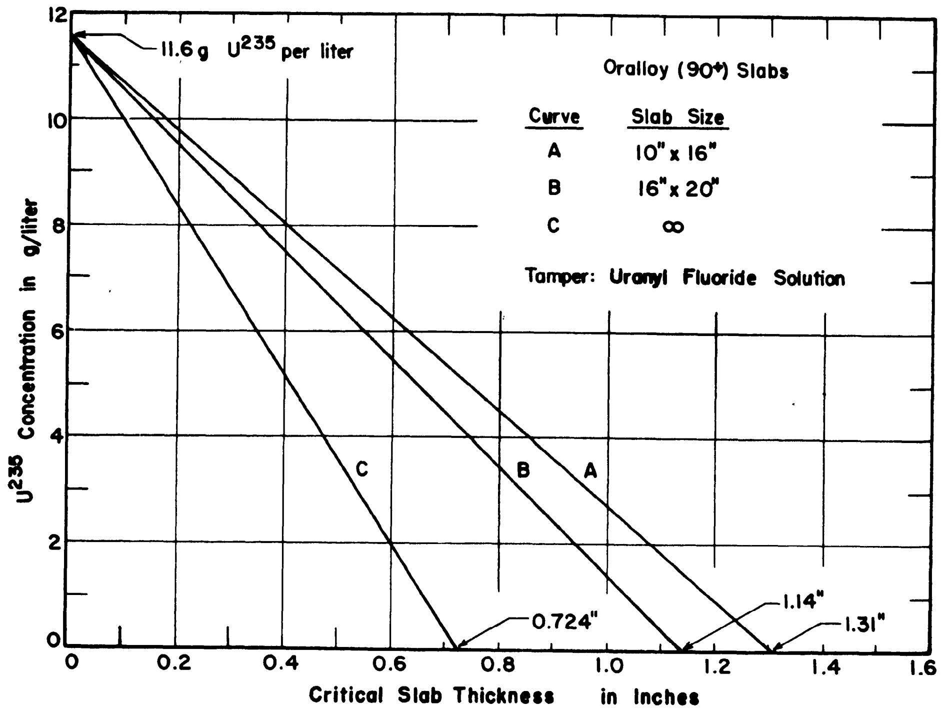


Fig. 32

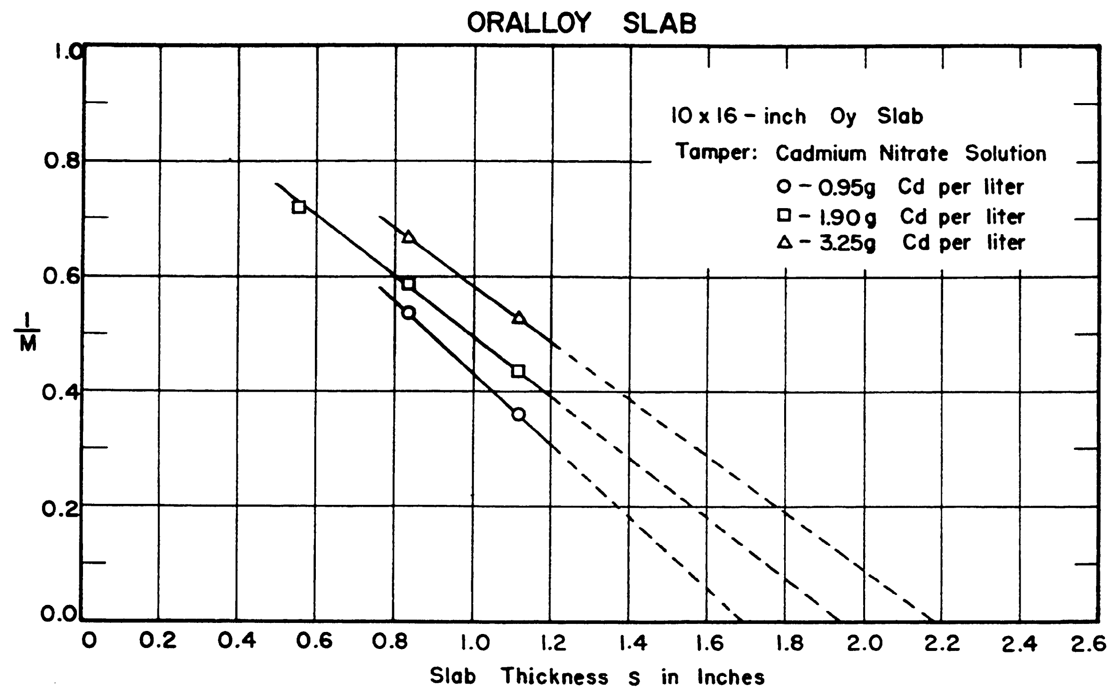


Figure 8.

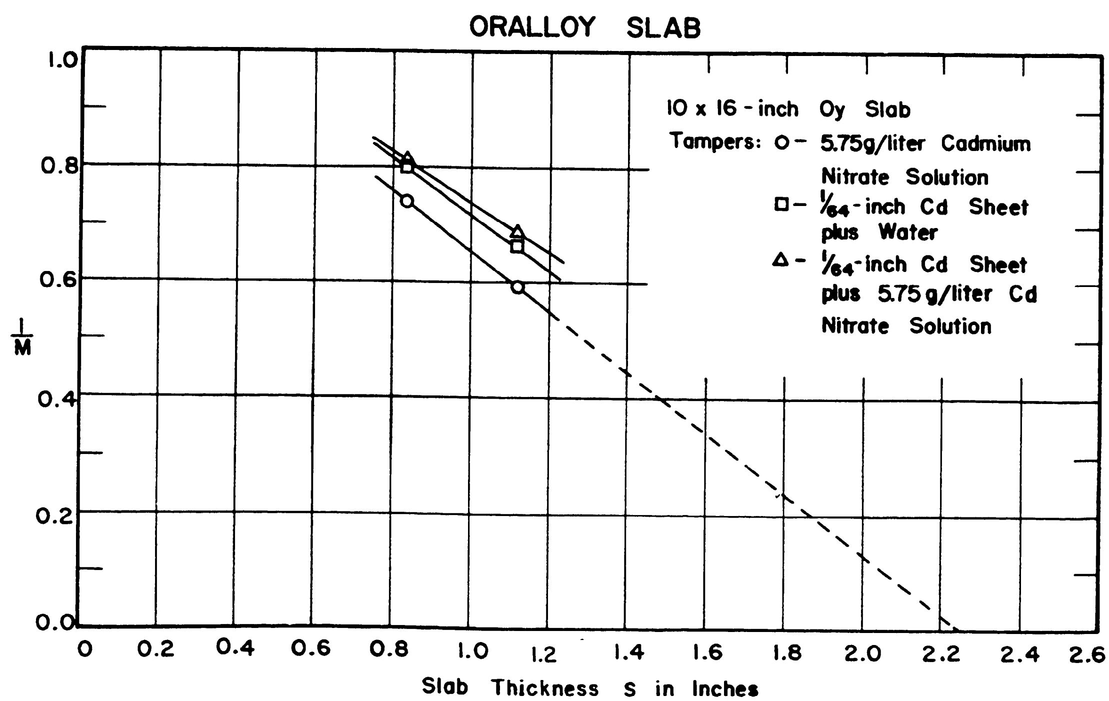


Figure 9.

POISONING EFFECT OF CADMIUM

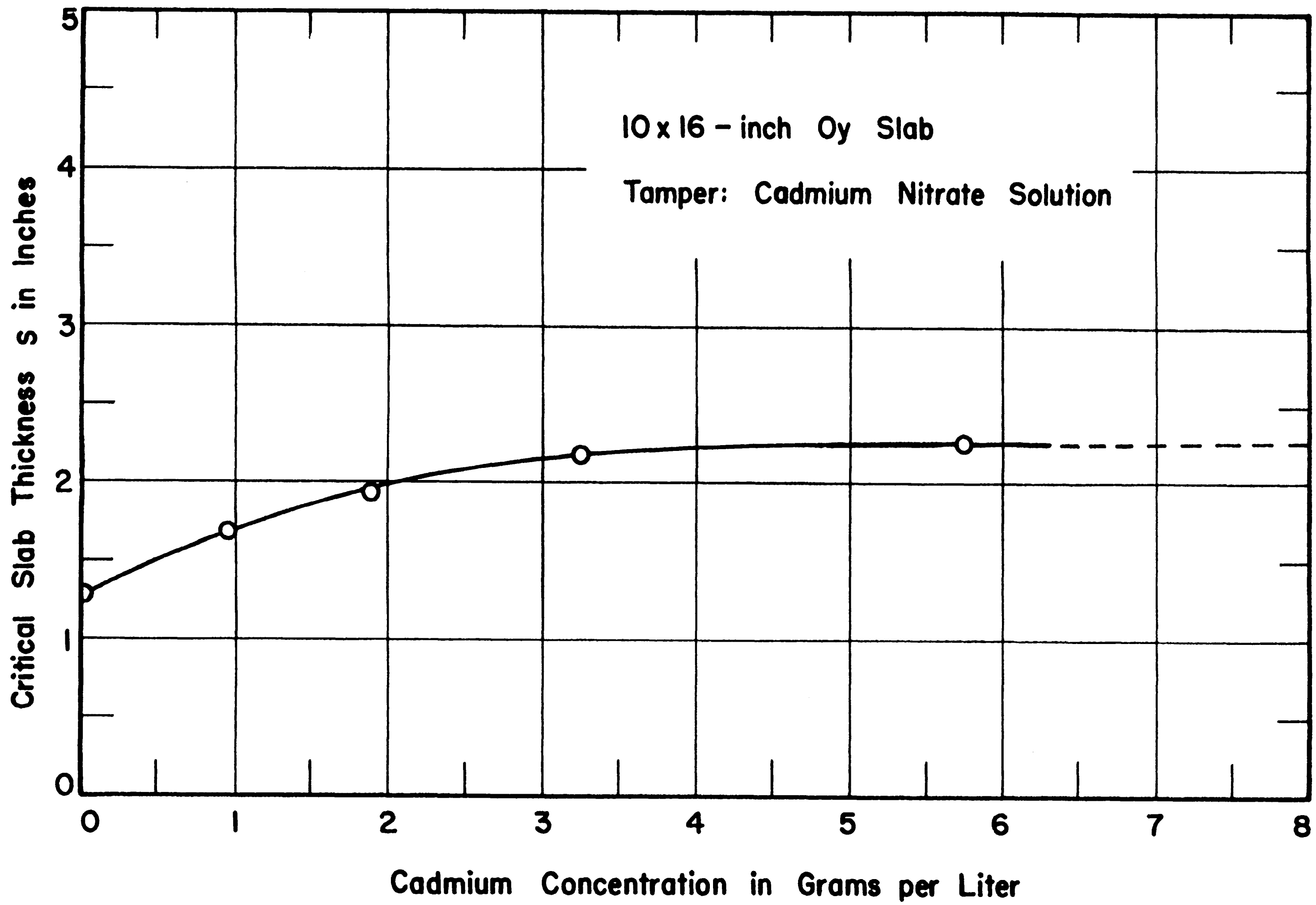


Figure 10.

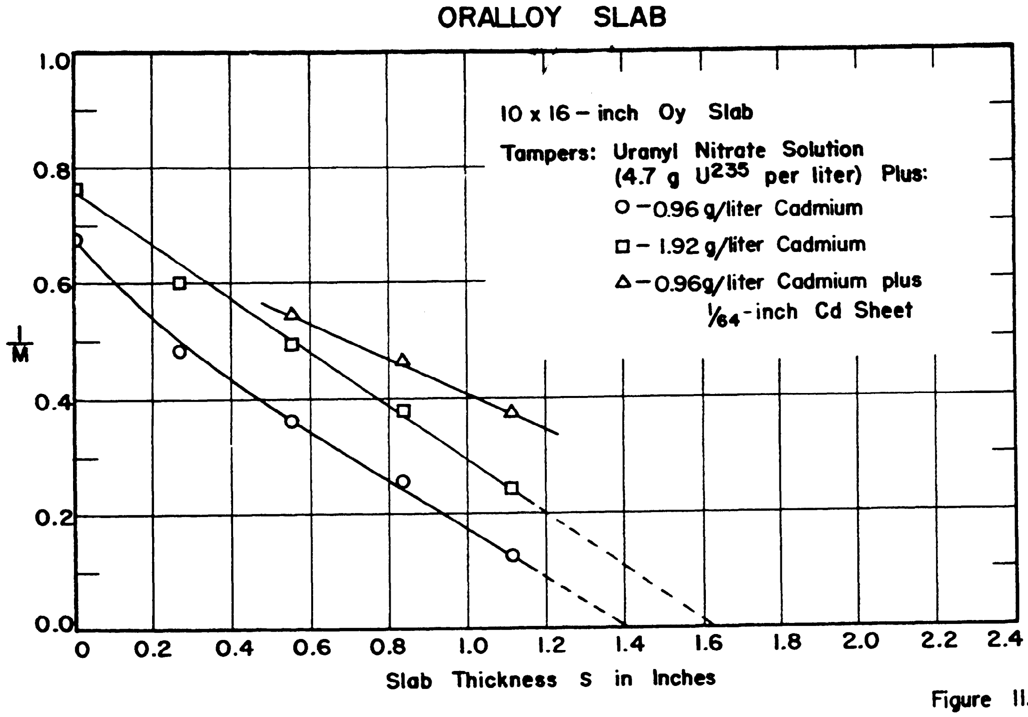
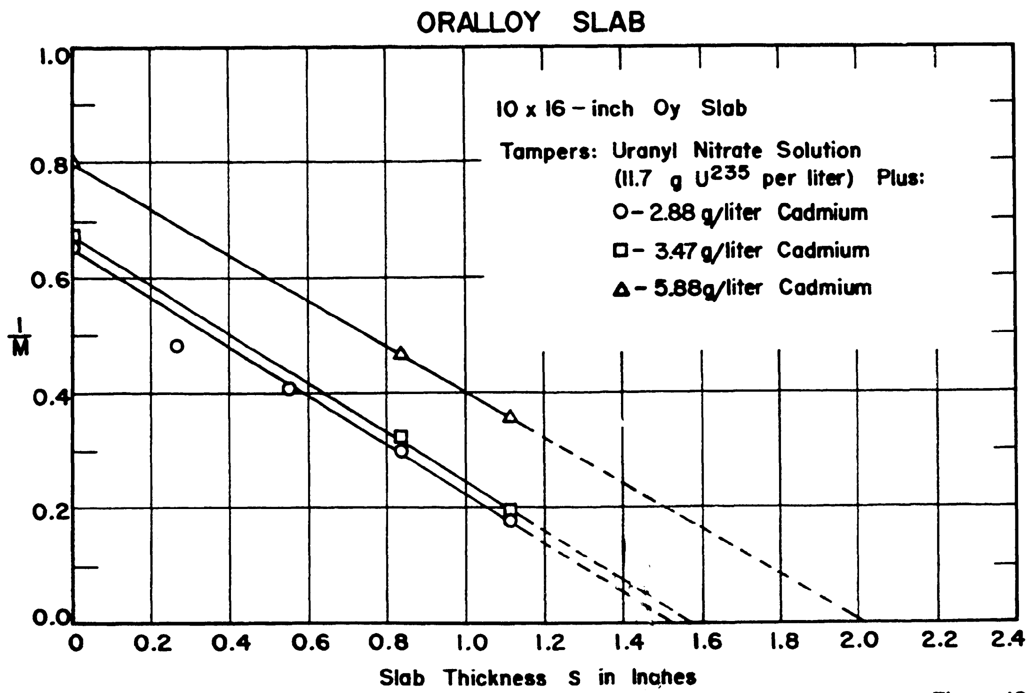


Figure 11.



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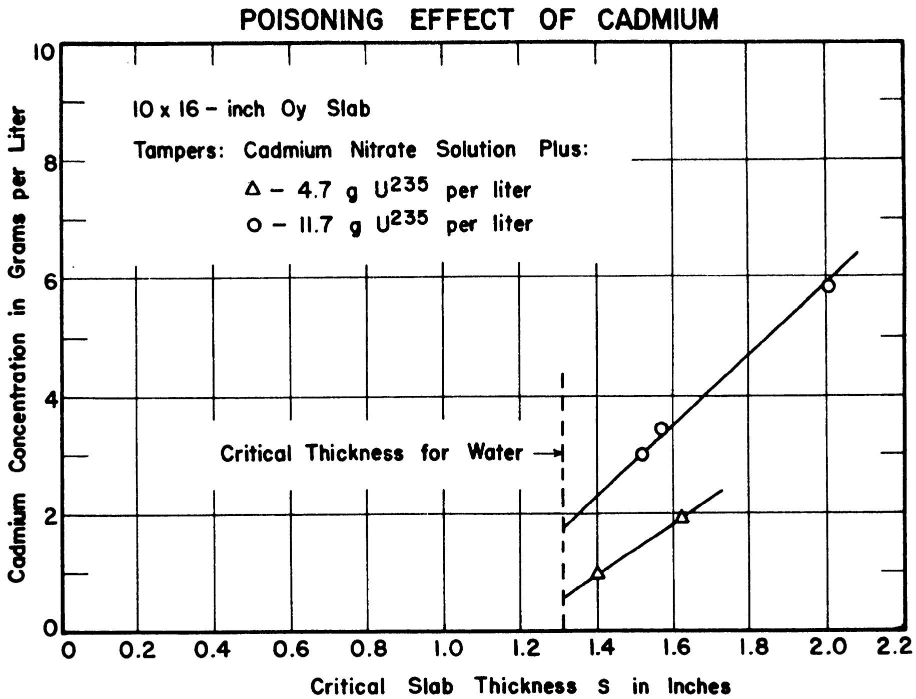

Figure 13.

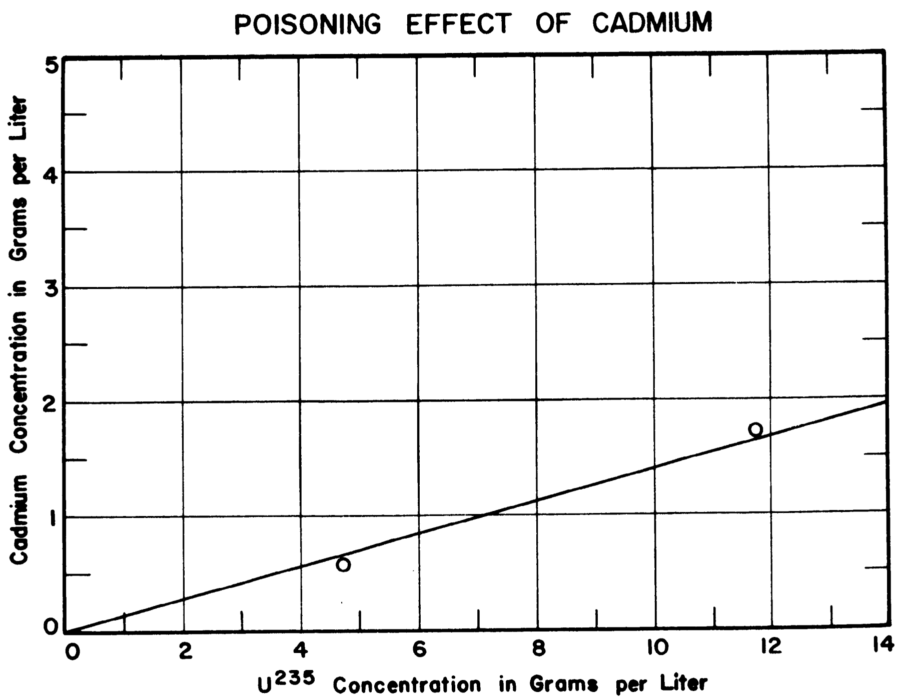

Figure 14.

EXPERIMENTAL RACK AND TANK

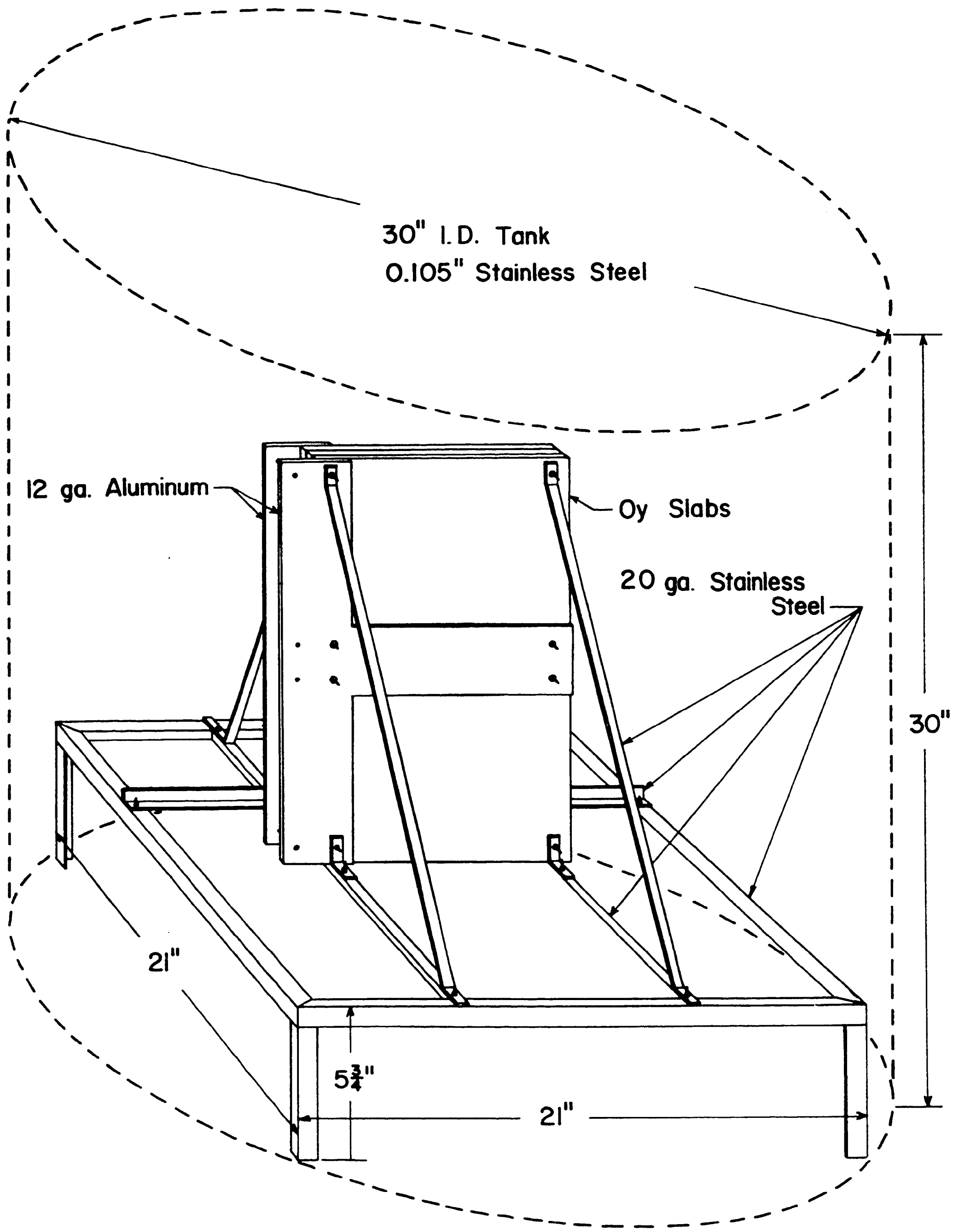

Figure 15.