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Criticality Hazards

(M-3679, 18th Ed.)

Neutron Multiplication Measurements on Oralloy Slabs Immersed in Solutions Part II

by

C. L. Schuske

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THE DOW CHEMICAL COMPANY

DOW

ROCKY FLATS PLANT DENVER, COLORADO

U.S. ATOMIC ENERGY COMMISSION CONTRACT AT (29-1)-1106

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by

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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 ~90%). This work covers a higher U^{235} solution concentration range than that reported in RFP-66. The range for these experiments was 47.2 to 156.6 grams U^{235}/liter of solution.

ACKNOWLEDGMENTS:

These tests were made possible by the generous concurrence of Mr. L. L. Zodtner and Staff. Special thanks are extended to R. P. Craig and F. J. Linck, Jr. for the assistance given during the experiments.

CONTENTS

FIGURES

INTRODUCTION:

A series of neutron multiplication measurements were made on slab assemblies of Oralloy metal immersed in water and aqueous solutions of $UO_2(NO_3)_2$. 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 button and metal scrap cleaning and etching baths which involve uranyl nitrate solutions much more concentrated than those used in RFP-66.[1] 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

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(1) Schuske, C. L., Arthur, M. G., Smith, D. F., "Neutron Multiplication Measurements on Oralloy Slabs Immersed in Solutions, RFP-66, The Dow Chemical Company, Rocky Flats Plant, August, 1956.

stainless steel vessel 9.45 inches inside diameter and filled to a height of 16 inches. Figure 1 indicates that a critical condition cannot be reached in this untamped vessel(2) filled to a height of 16 inches regardless of the solution concentration.

Figure 2 is a plot of reciprocal multiplication versus slab thickness for Oralloy slabs immersed in the above tank filled with water. Henceforth the experimental tank always filled to a height of 16 inches will be assumed.

The critical slab thickness given by extrapolation of Figure 2 is 2.7 inches. This represents a mass of 31 kilograms of Oralloy.

It should be noted that the extrapolations to the critical parameters are long and thus should be used conservatively when applied to plant problems.

Figure 3 represents a 1/M plot of critical Oy slab thickness when the slab is immersed in an aqueous solution of $UO_2(NO_3)_2$ for a U^{235} concentration of 47.2 grams/liter. The critical slab thickness is approximately 1.6 inches.

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(2) The experiments were not in the strict sense untamped since there were human bodies, walls and a stainless steel hood within 18 to 24 inches of the experimental vessel.

Figures 4 and 5 are similar to Figure 3. However, the U^{235} concentrations are 92.6 grams/liter for Figure 4 and 156.6 grams/liter for Figure 5. The respective critical slab thicknesses are 1.25 inches and 1.0 inches.

Figure 6 is a plot of U^{235} concentration as a function of critical slab thickness for slabs 5 inches by 8 inches by S inches. The data for this plot were taken from Figures 2 through 5.

It can be seen from Figure 6 that the curve swings up sharply and becomes asymptotic with a finite slab thickness. It is assumed from a practical point of view that the corresponding solution concentration for this slab thickness has a hydrogen to U^{235} ratio of approximately 50.

This ratio appears to lead to minimum critical cylinder height for untamped stainless steel walled cylinder.[3]

From Figure 6, a value for the asymptotic slab thickness was estimated to be 0.47 inches. Figure 7 is a plot of U^{235} concentration as a function of $\frac{1}{S-0.47}$. The linear relation which results substantiates the selected asymptotic value.

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(3) Beck, C. K. et al, "Critical Mass Studies Part III", K-343, K-25 Plant, Carbide & Carbon Nuclear Company, April 19, 1949.

This slab thickness is the value that would be required to bring about a critical condition in the 9.45-inch diameter cylinder with 16 inches of solution. The asymptotic slab thickness would not have meaning from a practical point of view for H/U^{235} less than 50 because the reactivity drops off as the solution concentration increases beyond the minimum. This approximation is very crude and should be used conservatively.

EXPERIMENTAL:

Materials:

a. Oralloy metal plates (~90% enriched).

Density: ~18.0 grams per cm^3.

Average slab size: 0.286 x 5 x 8 inches.

Average slab mass: 3.385 kilograms.

b. Uranyl nitrate solution. Excess nitric acid from 0.31 - 1.25 normal.

c. Stainless steel tank 9.45 inches inside diameter and 16 gauge wall thickness. Height of the tank 18 inches. See Figure 8 for details of design.

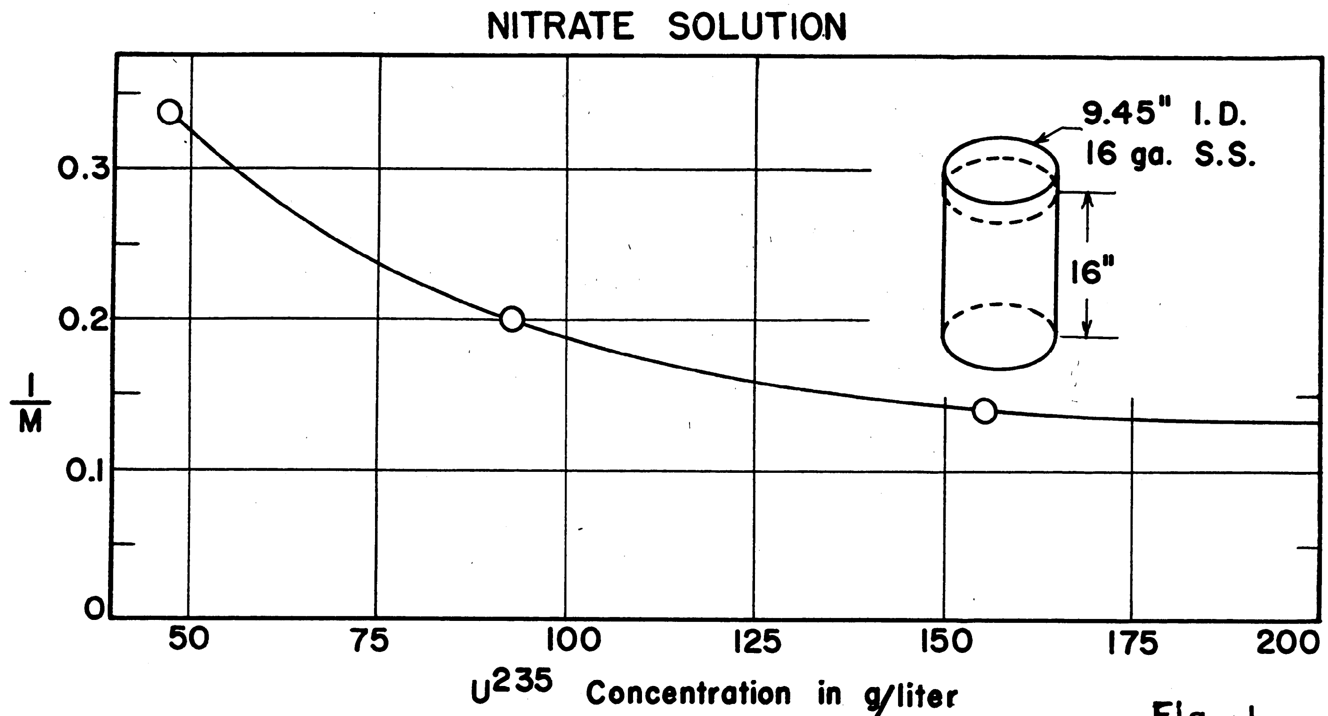
All Oralloy slabs were coated with a 0.001-0.002-inch thick layer of plastic from a pressurized spray bomb. No corrosion of the coated parts was observed during the course of the experiments.

Electronic Equipment:

The electronic equipment was the same as described in RFP-66.

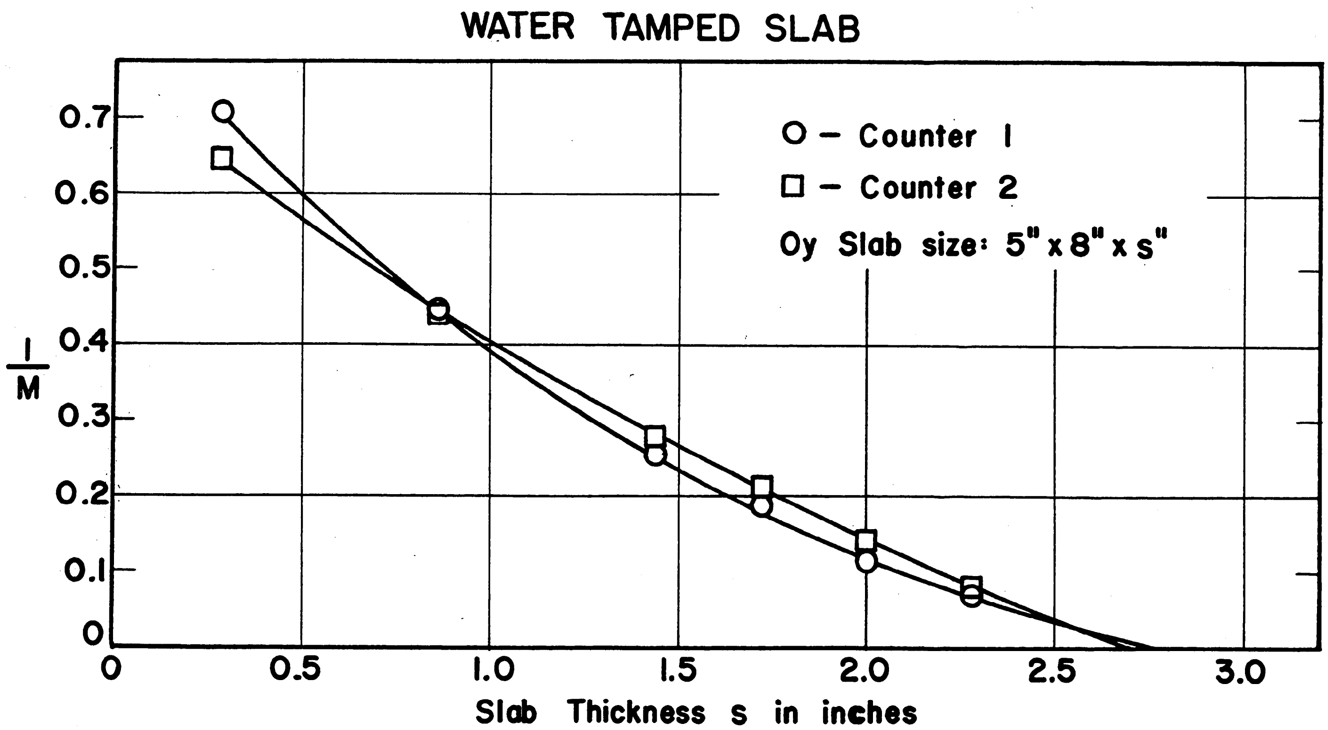
Procedure:

The slabs were made up of individual Oralloy metal plates mounted in an upright position on two stainless steel angles, which were welded to the tank walls. These angles carried the weight of the slabs. Two stainless steel threaded rods welded at one end to the stainless tank held the plates firmly together by means of wing nuts. The neutron source was placed in a special holder and located within the tank. Water and other prepared solutions were then allowed to slowly fill the tank until a 16-inch depth was reached.



NITRATE SOLUTION
9.45" I.D.
16 ga. S.S.
16"
0.3
0.2
0.1
0
$\frac{1}{M}$
50
75
100
125
150
175
200
U235 Concentration in g/liter

Fig. 1



WATER TAMPED SLAB
O – Counter 1
□ – Counter 2
Oy Slab size: 5" x 8" x s"
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
$\frac{1}{M}$
0
0.5
1.0
1.5
2.0
2.5
3.0
Slab Thickness s in inches

Fig. 2

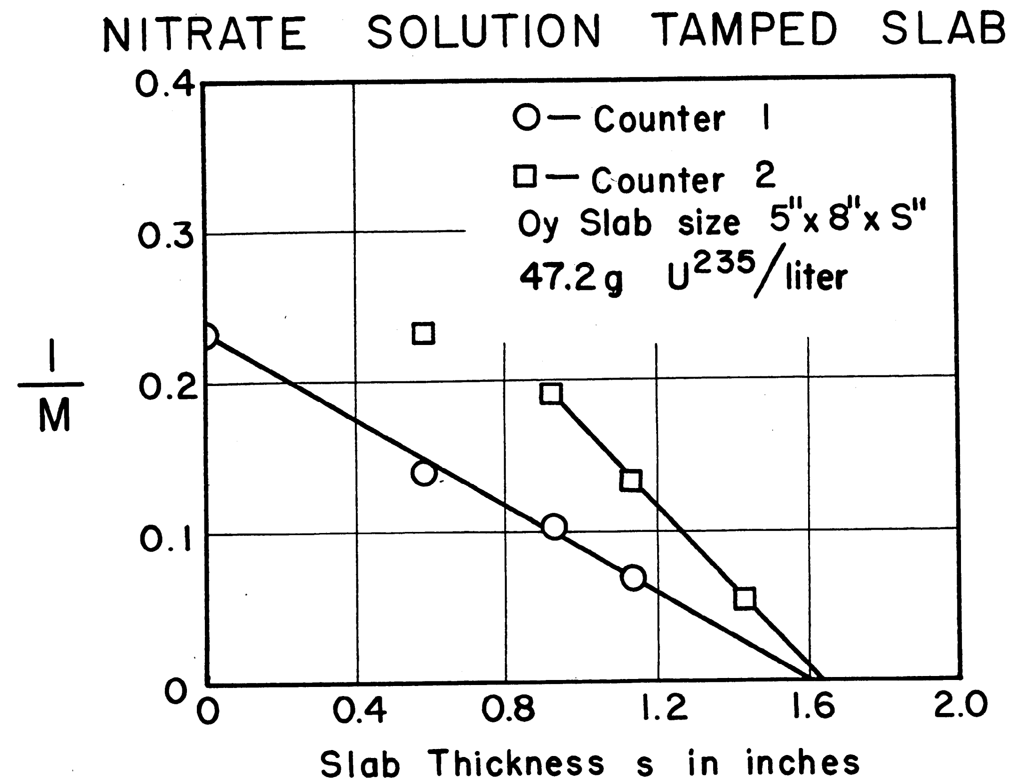

NITRATE SOLUTION TAMPED SLAB
O— Counter 1
□— Counter 2
Oy Slab size 5"x 8"x S"
47.2 g U235/liter
1/M
0.4
0.3
0.2
0.1
0
0
0.4
0.8
1.2
1.6
2.0
Slab Thickness s in inches

Fig. 3

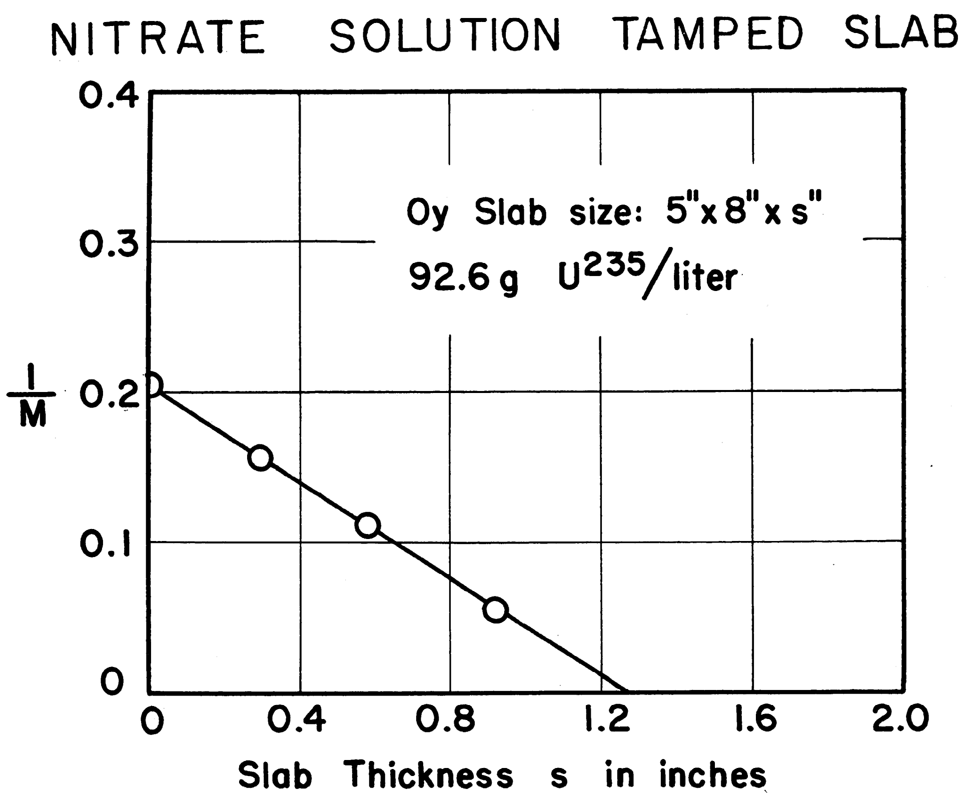

NITRATE SOLUTION TAMPED SLAB
Oy Slab size: 5"x 8"x s"
92.6 g U235/liter
1/M
0.4
0.3
0.2
0.1
0
0
0.4
0.8
1.2
1.6
2.0
Slab Thickness s in inches

Fig. 4

NITRATE SOLUTION TAMPED SLAB

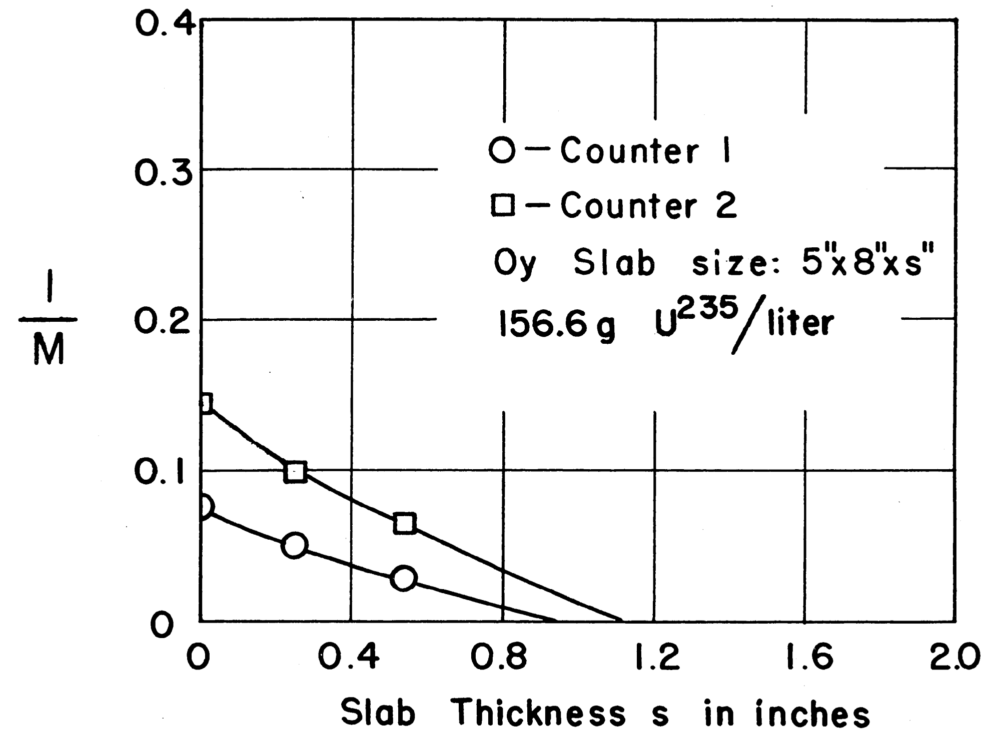


Fig. 5

CRITICAL SLAB THICKNESS

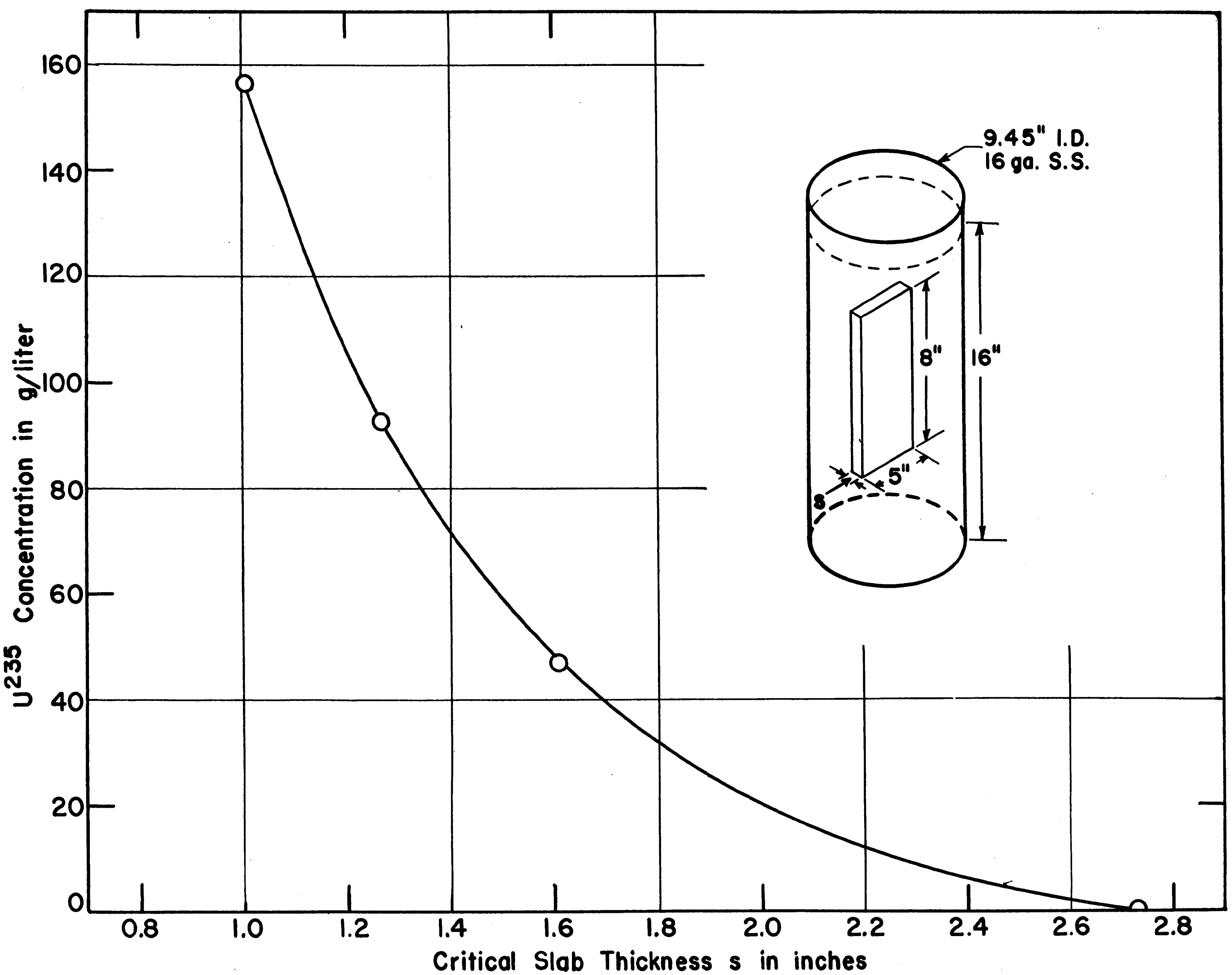


Fig. 33

DETERMINATION OF ASYMPTOTIC SLAB THICKNESS

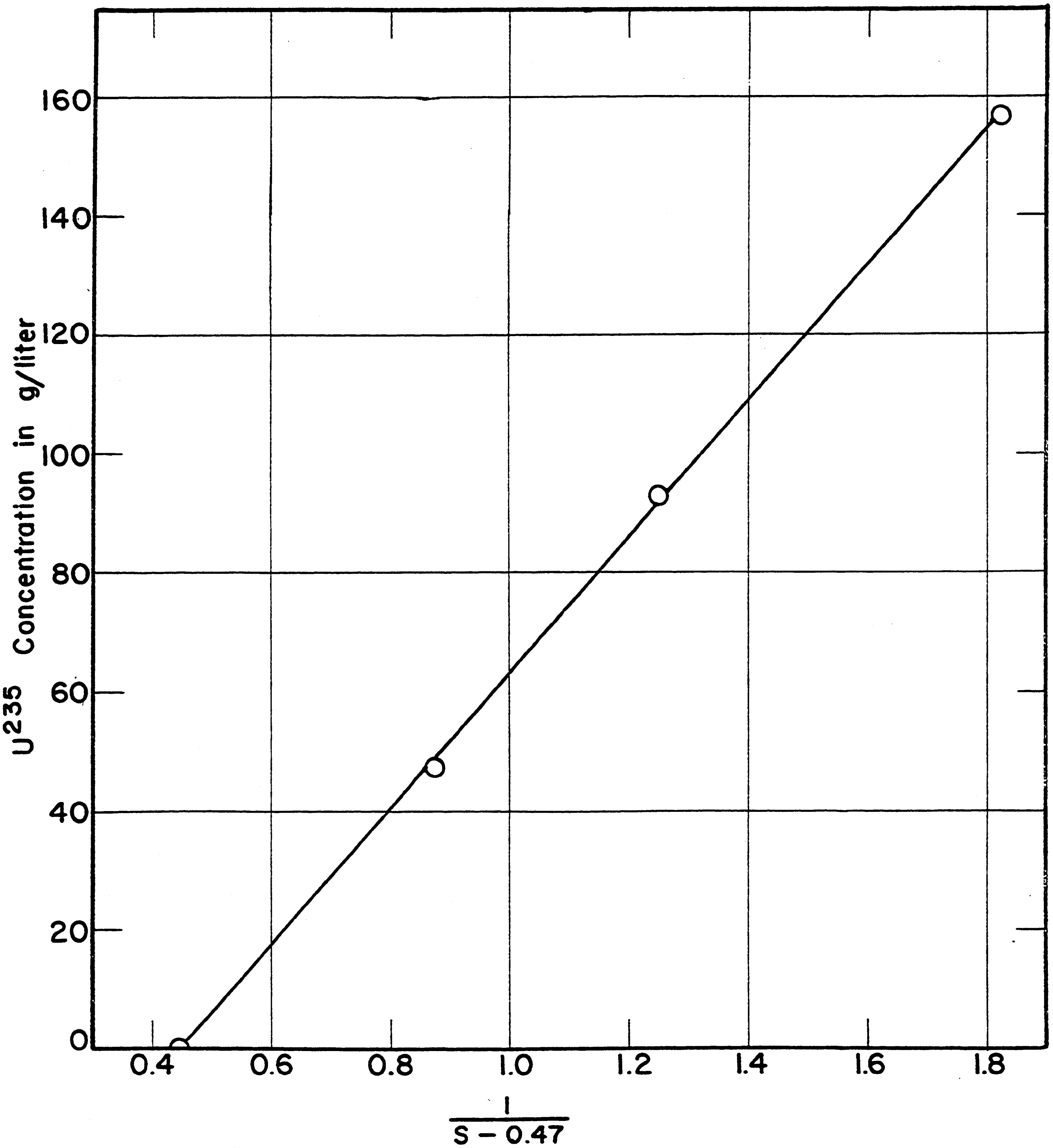


Fig. 7

EXPERIMENTAL TANK

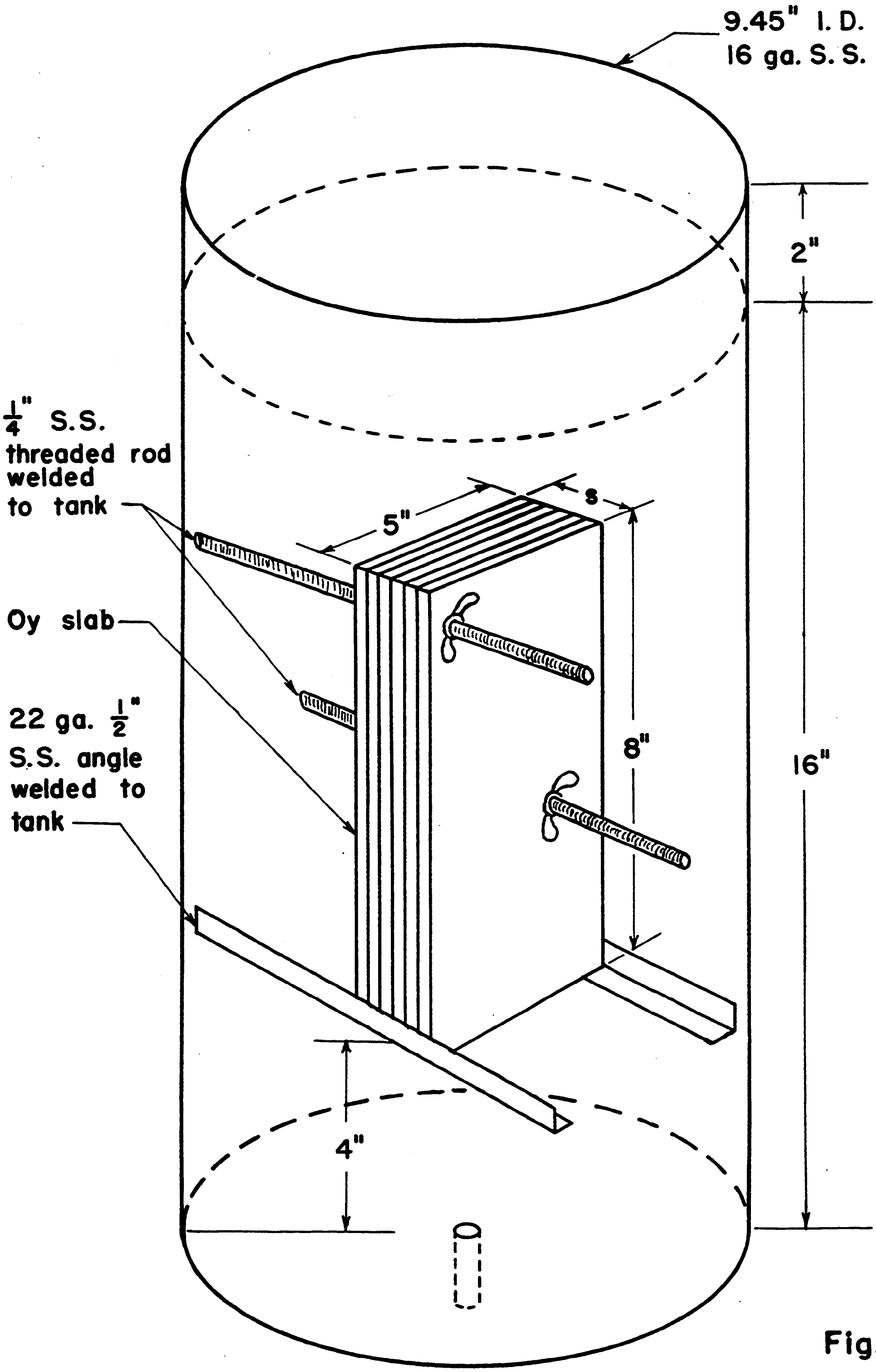


Fig. 8