RFP - 69
AEC RESEARCH & DEVELOPMENT REPORT

Criticality Hazards
(M-3679, 18th Ed.)

Neutron Multiplication Measurements on Oralloy Slabs Immersed in Solutions Part II

by
C. L. Schuske
M. G. Arthur
D. F. Smith

THE DOW CHEMICAL COMPANY

ROCKY FLATS PLANT DENVER, COLORADO
U.S. ATOMIC ENERGY COMMISSION CONTRACT AT (29-1)-1106
Legal Notice

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission to the extent that such employee or contractor prepares, handles or distributes, or provides access to, any information pursuant to his employment or contract with the Commission.

Printed in USA. Charge 30 cents. Available from the U.S. Atomic Energy Commission, Technical Information Extension, P. O. Box 1001, Oak Ridge, Tennessee. Please direct to the same address inquires covering the procurement of other classified AEC reports.
THE DOW CHEMICAL COMPANY
ROCKY FLATS PLANT
DENVER, COLORADO

U. S. Atomic Energy Contract AT(29-1)-1106

NEUTRON MULTIPLICATION MEASUREMENTS ON
ORALLOY SLABS IMMERSED IN SOLUTIONS
PART II

by

C. L. Schuske
M. G. Arthur
D. F. Smith

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 $\text{UO}_2(\text{NO}_3)_2$ (uranium enrichment $\approx 90\%$). This work covers a higher $\text{U}^{235}$ solution concentration range than that reported in RFP-66. The range for these experiments was 47.2 to 156.6 grams $\text{U}^{235}$/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

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>5 - 6</td>
</tr>
<tr>
<td>Acknowledgments</td>
<td>5 - 6</td>
</tr>
<tr>
<td>Introduction</td>
<td>9</td>
</tr>
<tr>
<td>Results and Conclusions</td>
<td>9</td>
</tr>
<tr>
<td>Experimental</td>
<td>12</td>
</tr>
</tbody>
</table>

## FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>Nitrate Solution</td>
<td>14</td>
</tr>
<tr>
<td>Figure 2</td>
<td>Water Tamped Slab</td>
<td>14</td>
</tr>
<tr>
<td>Figure 3</td>
<td>Nitrate Solution Tamped Slab I</td>
<td>15</td>
</tr>
<tr>
<td>Figure 4</td>
<td>Nitrate Solution Tamped Slab II</td>
<td>15</td>
</tr>
<tr>
<td>Figure 5</td>
<td>Nitrate Solution Tamped Slab III</td>
<td>16</td>
</tr>
<tr>
<td>Figure 6</td>
<td>Critical Slab Thickness</td>
<td>17</td>
</tr>
<tr>
<td>Figure 7</td>
<td>Determination of Asymptotic Slab Thickness</td>
<td>18</td>
</tr>
<tr>
<td>Figure 8</td>
<td>Experimental Tank</td>
<td>19</td>
</tr>
</tbody>
</table>
INTRODUCTION:

A series of neutron multiplication measurements were made on slab assemblies of Oralloy metal immersed in water and aqueous solutions of $\text{UO}_2(\text{NO}_3)_2$. The uranium metal and $\text{UO}_2(\text{NO}_3)_2$ solutions were enriched to approximately 90% $^{235}\text{U}$ and henceforth will be referred to in this report as Oy. Elsewhere in this report $^{235}\text{U}$ 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 $^{235}\text{U}$ 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 $^{235}\text{U}$ concentration for an untamped cylindrical

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 \(\text{Oy}\) slab thickness when the slab is immersed in an aqueous solution of \(\text{UO}_2(\text{NO}_3)_2\) for a \(^{235}\text{U}\) concentration of 47.2 grams/liter. The critical slab thickness is approximately 1.6 inches.

---

\(^{(2)}\) 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\textsubscript{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\textsubscript{235} concentration as a function of critical slab thickness for slabs 5 inches by 8 inches by 5 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\textsubscript{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\textsubscript{235} concentration as a function of \(\frac{1}{S-0.47}\). The linear relation which results substantiates the selected asymptotic value.

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: \(~18.0 \text{ grams per cm}^3\).
   
   Average slab size: \(0.286 \times 5 \times 8 \text{ inches}\).
   
   Average slab mass: \(3.385 \text{ kilograms}\).

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 TAMPED SLAB

Fig. 3

NITRATE SOLUTION TAMPED SLAB

Fig. 4
NITRATE SOLUTION TAMPERED SLAB

\[ \frac{1}{M} \]

- Counter 1
- Counter 2

Oy Slab size: 5"x8"x8"
156.6 g U\textsuperscript{235} per liter

Slab Thickness \( s \) in inches

Fig. 5
Critical Slab Thickness

Fig. 33

U235 Concentration in g/liter

Critical Slab Thickness s in inches

9.45" I.D. 16 ga. S.S.

8" 16"

8'
DETERMINATION OF ASYMPTOTIC SLAB THICKNESS

Fig. 7
EXPERIMENTAL TANK

9.45" I.D.  
16 ga. S.S.

$\frac{1}{4}$" S.S. threaded rod welded to tank

Oy slab

22 ga. $\frac{1}{2}$" S.S. angle welded to tank

Fig. 8