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THE LIMITING CRITICAL CONCENTRATIONS FOR Pu^{239} AND U^{235} IN AQUEOUS SOLUTIONS

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MARCH 27, 1963

HANFORD LABORATORIES

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THE LIMITING CRITICAL CONCENTRATIONS FOR Pu^{239} AND U^{235} IN AQUEOUS SOLUTIONS

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ABSTRACT

Measurements were made with plutonium nitrate solutions and uranyl fluoride solutions (93.15% enriched UO_2F_2) to determine the concentration at which k_∞ equals unity (the limiting critical concentration) for each of these solutions.

The limiting critical concentration for Pu^{239} in an aqueous solution occurred at an H:Pu ratio of 3392 ± 100; this limiting ratio corresponded to a concentration of 8.0 ± 0.3 g Pu^{239}/liter for the solutions used in the experiments.

In conjunction with this plutonium measurement, the limiting critical concentration for U^{235} in an aqueous solution was measured; the result (12.05 ± 0.03 g U^{235}/liter) was compared to a similar result reported by the Oak Ridge National Laboratory.[2]

THE LIMITING CRITICAL CONCENTRATIONS FOR Pu^{239} AND U^{235} IN AQUEOUS SOLUTIONS

INTRODUCTION

The limiting critical concentration (the concentration for which k_∞ equals unity) is a quantity of special interest, from the standpoint of nuclear safety, for aqueous solutions or other homogeneous, hydrogenous mixtures of fissionable materials. If the H:X ratio can be maintained at values for which k_∞ is less than unity, no further restrictions are necessary to ensure that criticality will not occur.

The measurements described in this report were made principally to determine the value of the limiting critical concentration for Pu^{239} in an aqueous solution. Plutonium nitrate ($Pu(NO_3)_4$) solutions and uranyl fluoride solutions (93.15% enriched UO_2F_2) were used in these measurements. The measurements are the first attempt to describe the limiting critical concentration for a $Pu(NO_3)_4$ solution. The results are compared with theoretical calculations made by C. R. Richey using Monte Carlo techniques.[1]

The limiting critical concentration of U^{235} in a UO_2F_2 solution was previously measured in experiments at the Oak Ridge National Laboratory.[2] The results of the present measurements on UO_2F_2 are compared with those reported by the Oak Ridge National Laboratory and serve as a check on the experimental method used.

DISCUSSION OF THE EXPERIMENTS

Measurements were made in the Physical Constants Testing Reactor (PCTR). The PCTR was designed for measuring criticality parameters of various reactor systems; included in the parameters are excess multiplication factors (k_∞ - 1) for reactor lattices.[3, 4, 5] The reactor is a 7 x 7 x 7-foot graphite moderated assembly driven by highly enriched fuel. It contains a central, 2 x 2 x 3-foot cavity in which a sample section may be placed for study. The sample section normally consists of a central test sample surrounded by a "buffer" region (a layer of material indentical to the sample). This material causes the neutron energy

spectrum to come to equilibrium in the central test cavity. Proper thickness of the buffer and proper arrangement of the driving fuel provide the conditions for an equilibrium spectrum equal to that which would exist in an infinite reactor made up of the sample material.

The method of the present experiments consists of comparing the behavior of the reactor with the central test cell in position to the behavior when the test cell is replaced by a void. (By definition a void has $k_\infty = 1$, since a neutron entering a void must simply pass through it and come out again.) For each test sample, the reactor is made slightly supercritical by withdrawing the control rods; the reactor period is then measured. These period measurements, together with a knowledge of the neutron spectrum and the sensitivity of the reactor, are then related to k_∞ by appropriate calculations. The theory behind these calculations assumes that the neutron spectrum in the sample material is identical with the spectrum that would exist in an infinite, just critical ($k_\infty = 1$) system of the material.

Measurements on the $Pu(NO_3)_4$ and UO_2F_2 solutions, though performed separately and in different tanks, were essentially identical in nature and procedures, and will be discussed as one experiment.

The tank assembly consisted of a large, cylindrical, annular, buffer tank and a central test cell, or core tank, centered in the annulus by two smaller buffer tanks (Figures 1 and 2).

The reactivities of various core tanks (containing solutions at different concentrations) were compared to the reactivity of a void by loading the PCTR to critical with highly enriched uranium fuel and measuring the reactor period with a core tank in position and again with an evacuated tank in position; this procedure was repeated for all core tanks. Any variance in control rod setting or reactor fuel loading during the measurements was corrected to a standard fuel loading and rod setting.

To obtain the proper results from the reactivity measurements, the neutron spectrum in the core tank should be identical with the equilibrium spectrum that would exist in an infinite, just critical system of

this solution. To establish whether the buffer solution around the core tank was of satisfactory thickness to cause the neutron flux to match this infinite equilibrium spectrum, the reactivity measurements were made once with the PCTR fuel placed closely around the test cavity (resulting in a relatively "fast" flux entering the buffer region) and once with the fuel spaced at a distance from the cavity (resulting in a relatively "thermal" flux impinging on the buffer tanks). Results from these two loadings were nearly identical, indicating the buffer region to be of sufficient thickness to give the desired spectrum.

MEASUREMENT OF THE LIMITING CRITICAL CONCENTRATION OF PLUTONIUM

Experimental Apparatus and Procedures

Stainless steel tanks were fabricated for the limiting concentration analysis on the $Pu(NO_3)_4$ solutions. Since difficulties were encountered in sealing the tanks, after they were filled with solutions, the fill spouts were welded shut and the tanks were placed into 1/16-inch-thick stainless steel jackets. The core and end buffer tanks were welded into their jackets; the jacket for the annular buffer tank was bolted onto two teflon gaskets (Figure 3).

The dimensions of the containers are shown in Table I; Table II gives a chemical analysis of the solution in each container. Tanks C-1, C-2, C-2', C-2", and C-3 are the core tanks, while tanks A, FEB, and REB are the buffer tanks. To evaluate the effect of the stainless steel on the reactivity measurements, two additional pairs of core and vacuum tanks were constructed to give increasingly larger wall thicknesses (9/16 and 3/4 inch) so that the change in reactivity as a function of the change in tank wall thickness could be determined. Tanks C-2' and C-2" are the core tanks having increased wall thicknesses; tanks V, V', and V" are the vacuum tanks and have wall thicknesses of 3/8, 9/16, and 3/4 inch.

TABLE I

PLUTONIUM TANK DATA

Tank	Diameter (in.)	Length (in.)	Wall Thickness (in.)	Volume (liters)	Solution Concentration (g/liter)
A	18 OD & 6-3/8 ID	33-1/2	1/8 + 1/16	112	11.5
FEB & REB	6-3/16	6-1/4	1/8 + 1/16	2.3	11.5
C-1	6-3/16	20-1/8	1/8 + 1/16	8.4	10.7
C-2	6-3/16	20-1/8	1/8 + 1/16	8.4	11.3
C-3	6-3/16	20-1/8	1/8 + 1/16	8.4	12.8
C-2'	6-3/16	20-1/8	5/16 + 1/16	6.9	11.7
C-2''	6-3/16	20-1/8	1/2 + 1/16	5.8	11.7
V	6-3/16	20-1/8	1/8 + 1/16	8.4	-
V'	6-3/16	20-1/8	5/16 + 1/16	6.9	-
V''	6-3/16	20-1/8	1/2 + 1/16	5.8	-

TABLE II

PLUTONIUM SOLUTION DATA

Tank	Pu (g/liter)	HNO_3 (g/liter)	NO_3^- (g/liter)	Fe (g/liter)	H_2O (g/liter)	Specific Gravity
A	11.5	47.7	12.0	0.3	955.7	1.022
FEB	11.7	45.3	12.1	0.5	972.0	1.032
REB	11.3	44.3	11.7	0.5	969.9	1.043
C-1	10.7	33.4	11.1	0.1	936.2	1.013
C-2	11.3	44.1	11.7	0.5	962.4	1.037
C-2'	11.7	46.3	12.1	0.5	954.5	1.044
C-2''	11.7	44.3	12.2	0.4	960.4	1.018
C-3	12.8	50.8	13.3	0.3	954.7	1.021

An additional feature of the core tanks, vacuum tanks, and the annular buffer tank was a stainless steel traverse tube placed along a diameter at the mid-point of the tanks cylindrical height (Figure 4). These tubes were used for foil irradiations during the experimental measurements. Gold and copper foils were irradiated to obtain standard cadmium ratio data; plutonium and uranium foils were irradiated to determine the spectral index or effective neutron temperature of the system.[6, 7] The experimental procedure and foil irradiations are described in Reference 7. Further details on the results of the foil irradiations follow in a later section of this report.

Special equipment had to be assembled to move the large, heavy vessels in and out of the PCTR cavity. A special cart was constructed and equipped with tracks and pneumatic lifting devices for handling the vessels.[4]

Initially, standard approach-to-criticality techniques were used to reach critical with the three buffer tanks and the most reactive core tank in place in the PCTR cavity. This procedure was then repeated at a different fuel loading, thereby establishing two standard fuel loadings, a "thermal" loading and a "fast" loading. These two loadings were then used for the measurement of all remaining core and vacuum tanks. During the initial fuel loadings, the PCTR control rod worth was evaluated; this evaluation was later used in normalizing the reactivity values to a standard condition.

$Pu(NO_3)_4$ RESULTS

Following the completion of all period measurements, the data thus acquired were converted to reactivity values (cents) by using standard conversion tables derived for the PCTR. All measurements were corrected for temperature and pressure variations as well as for variations in control rod settings and fuel loadings.

The reactivity value for each core tank was then compared to the reactivity of a void, i.e., a similar tank (equal wall thickness) under a vacuum. The results of these comparisons are shown in Table III, where

$\Delta \rho$ = reactivity of a core tank - reactivity of an evacuated tank

In Figure 5, $\Delta \rho_{C-2}$, $\Delta \rho_{C-2'}$, and $\Delta \rho_{C-2''}$ for each fuel loading are plotted versus the total stainless steel thickness of their respective tanks. The extrapolation of these curves to zero wall thickness gives the actual reactivity values ($\Delta \rho$) of the plutonium solution: + 37 cents for the thermal loading and + 71 cents for the fast loading. A least squares analysis was not made for these data. Comparisons of these values to the measured reactivities at 3/8 inch stainless steel thickness shows a difference of + 49.9 cents for the thermal loading and + 93.5 cents for the fast loading. These values are the total corrections needed to account for the effects

TABLE III

REACTIVITY VALUES ($\Delta \rho$)

$Pu(NO_3)_4$ Experiment

Tank	Pu Concentration (g/liter)	$\Delta \rho$ (Cents) Thermal Loading	$\Delta \rho$ (Cents) Fast Loading
C-2	11.3	- 13.94	- 22.44
C-3	12.8	+ 8.81	+ 16.48
C-2	11.3	- 13.81	- 23.42
C-2'	11.3	- 28.68	- 48.89
C-2''	11.3	- 34.96	- 59.59

of the stainless steel containment vessels. These corrections were assumed to hold for the remaining core tank, C-1. A mistake had been made in the filling of tank C-3, which caused the resulting data obtained from this tank to be deleted from the experimental results.

In Figure 6, $\Delta \rho_{C-1}$ and $\Delta \rho_{C-2}$ are plotted versus the concentration (g/liter) of plutonium. The dotted curves connect the measured reactivities and give 12.2 g Pu/liter as the limiting critical concentration of plutonium.

The stainless steel corrections were then applied to the data; the corrected results are shown by the solid curves in Figure 6 and give an average result of 8.7 g Pu/liter for the limiting critical concentration of plutonium in the solution used. This concentration of plutonium occurs at an H:Pu ratio of 3114 ± 100 (the limiting hydrogen to plutonium ratio for criticality in the solution used). Comparison of the corrected and uncorrected values of the limiting critical concentration (8.7 g Pu/liter; 12.2 g Pu/liter) shows the stainless steel correction to lower the result by approximately 31%.

To correct the limiting H:Pu ratio (and the limiting concentration) obtained from the experiment for the effects of Pu^{240}, Pu^{241}, and NO_3^- present in the solutions, multigroup diffusion theory calculations were made using the HFN and 9-Zoom multigroup diffusion codes.[8, 9] One set of calculations was made for the $Pu(NO_3)_4$ solution used in the measurements; a second set of calculations was made for a hypothetical Pu^{239}-water

solution. The experimental value (H:Pu = 3114 ± 100 at 8.7 g Pu/liter) was then reduced by the difference of these two sets of calculations to give a final value for the limiting H:Pu ratio of 3392 ± 100 (8.0 ± 0.3 g Pu^{239}/liter) for criticality in an infinite Pu^{239}-water solution. Figure 7 is a plot of these computer calculations versus the H:Pu ratio, showing the above mentioned results. C. R. Richey obtained a value of 7.71 ± 0.46 g Pu^{239}/liter from calculations by using Monte Carlo techniques.(1)

SUPPORTING MEASUREMENTS (UO_2F_2 SOLUTIONS)

In conjunction with the plutonium measurement, two measurements were performed on UO_2F_2 solutions to obtain further data pertinent to the analysis of the plutonium measurement.

As stated previously in this report, the limiting critical concentration of U^{235} in a UO_2F_2 solution was known from measurements at the Oak Ridge National Laboratory; their results gave the limiting concentration as 12.1 g U^{235}/liter.(2) The initial UO_2F_2 measurement performed in conjunction with the present plutonium experiment was a remeasurement of the limiting critical concentration of U^{235} for comparison with the results reported by the Oak Ridge National Laboratory.(10) The results from this measurement were used to check the accuracy of the PCTR and the experimental method used.

The containers used in this measurement were fabricated from aluminum to eliminate effects of the containment material on the measured results; the dimensions of these tanks and chemical analysis of the solutions contained in them are shown in Table IV. For this experiment helium was used in place of a void for the comparison of reactivity values; helium, like a void, does not absorb neutrons and therefore by definition has a k_∞ essentially equal to unity.

TABLE IV

URANIUM TANK DATA FOR INITIAL UO_2F_2 EXPERIMENT

Tank	Diameter (in.)	Length (in.)	Wall Thickness (in.)	Volume (liters)	Solution Concentration (g/liter)
A	21 OD & 7 1/2 ID	33-1/2	1/8	141	11.7
FEB	7-3/8	6-3/4	1/8	3.9	11.6
REB	7-3/8	6-3/4	1/8	4.1	11.7
C-1	7-3/8	20	1/8	12.6	9.5
C-2	7-3/8	20	1/8	12.6	12.9
C-3	7-3/8	20	1/8	12.6	14.1
He	7-3/8	20	1/8	12.6	

The reactivities for this measurement are given in Table V. The reactivity difference, as used in this table, between a fuel tank and the helium tank is $\Delta\rho$. In Figure 8 the values of $\Delta\rho$ are plotted versus the solution concentration. Again, as in the plutonium measurement, two fuel loadings were used to evaluate the effectiveness of the buffer region. The two loadings produced almost equal results; 12.94 ± 0.03 g U/liter for the thermal loading and 12.97 ± 0.03 g U/liter for the fast loading. Foil measurements indicated the spectrum of the thermal loading more nearly approached the spectrum which would exist in an infinite system, and for this reason the thermal loading was taken to be more accurate. Use of the thermal results gives a value of 12.05 ± 0.03 g U^{235}/liter as the limiting critical concentration of U^{235}; this result is in close agreement with the value of 12.1 g U^{235}/liter reported by the Oak Ridge National Laboratory.[2] Calculations by C. R. Richey, using Monte Carlo techniques, give 13.29 ± 0.41 g U/liter(12.38 g U^{235}/liter) as the limiting critical concentration.[1]

The second and final measurement on the UO_2F_2 solutions was made to determine the accuracy of the correction used for the effect of the stainless steel containers. The aluminum tanks used in the initial UO_2F_2 experiment were replaced by stainless steel tanks fabricated with 3/8-inch-thick walls. Additional tanks were fabricated with wall thicknesses

of 9/16 and 3/4 inch, matching the stainless steel thicknesses used in the plutonium measurement. Table VI gives the container and solution data for these tanks; Table VII lists the reactivity values obtained from measurements with the tanks. As in the plutonium measurement, evacuated tanks were used for reactivity comparisons, with

$$\Delta\rho = \rho_{\text{core tank}} - \rho_{\text{vacuum tank}}.$$

Only the thermal fuel loading was used for this measurement, as it was considered unnecessary to repeat both fuel loadings.

TABLE V

REACTIVITY VALUES ($\Delta\rho$)

INITIAL UO_2F_2 EXPERIMENT

Tank	Concentration (g/liter)	$\Delta\rho$ (Cents) (Thermal Loading)	$\Delta\rho$ (Cents) (Fast Loading)
C-2	12.9	+ 0.04	- 0.21
C-3	14.1	+ 9.81	+ 13.33

TABLE VI

CONTAINER AND SOLUTION DATA FOR FINAL UO_2F_2 EXPERIMENT

Tank	Diameter (in.)	Length (in.)	Wall Thickness (in.)	Volume (liters)	Material*	Solution Concentration (g/liter)	Specific Gravity
A	ID = 7-1/2 OD = 21	33-1/2	Inner = 1/4 Outer = 3/8	141.6	Al	11.6	1.01
FEB	7-3/8	6-3/4	1/8	3.9	Al	11.8	1.01
REB	7-3/8	6-3/4	1/8	4.1	Al	11.8	1.01
C-1	7-3/8	20	3/8	11.0	SS	15.6	1.02
C-2	7-3/8	20	3/8	11.0	SS	17.8	1.02
C-3	7-3/8	20	3/8	11.0	SS	19.9	1.02
C-2'	7-3/8	20	9/16	9.8	SS	17.8	1.02
C-2''	7-3/8	20	3/4	8.7	SS	17.8	1.02
V	7-3/8	20	3/8	11.0	SS	-	-
V'	7-3/8	20	9/16	9.8	SS	-	-
V''	7-3/8	20	3/4	8.7	SS	-	-

*Al = Aluminum. SS = Stainless Steel.

TABLE VII
REACTIVITY VALUES ($\Delta \rho$)
FINAL UO_2F_2 EXPERIMENT

Tank	Concentration (g/liter)	Thermal Loading $\Delta \rho$ (Cents)
C-1	15.6	- 9.429
C-2	17.8	- 2.534
C-3	19.9	+ 4.623
C-2	17.8	- 2.534
C-2'	17.8	- 7.221
C-2''	17.8	- 10.472

In Figure 9, $\Delta \rho$ values are plotted versus the stainless steel thickness; extrapolation of this curve to zero wall thickness gives a total stainless steel correction of + 16.93 cents. Figure 10 shows the values of $\Delta \rho$ plotted versus the solution concentrations. The experimental values give 18.55 g U/liter as the uncorrected limiting concentration; the corrected values give 13.0 ± 0.1 g U/liter(12.1 ± 0.1 g U^{235}/liter) as the limiting critical concentration of uranium in a UO_2F_2 solution. Comparison of this result to that of the previous measurement shows agreement within 0.5% between the two measurements, the first using aluminum tanks (no container correction), and the second using stainless steel tanks. For the UO_2F_2 measurement, the correction reduced the final value obtained for the limiting concentration by approximately 30%, this reduction is almost identical to that found in the plutonium measurement.

FOIL IRRADIATIONS

As mentioned in an earlier section of this report, several foil irradiations were made to obtain some knowledge of the neutron spectra. Gold and copper foils, 0.005 inch thick, were irradiated during the plutonium measurement to obtain cadmium ratios of the system; Pu^{239} and U^{235} foils were also irradiated during this measurement, to determine the spectral index and effective neutron temperature of the system.[6, 7]

The ratio of the activities of these foils (Pu^{239} and U^{235}), due only to fission of thermal neutrons, is defined as the spectral index of the system; the actual neutron temperature is then found by comparison of the index of the system in question to that of a known system.

After completion of the reactivity measurements for the plutonium solutions, the stainless steel jackets of all fuel tanks were removed, and all but tank C-2 had their filling spouts cut open. The solutions from tanks C-1 and C-3 were mixed together; the resulting solution was used in refilling the two tanks. The vacuum tank (V) was filled with solution from tanks C-2' and C-2''. This procedure resulted in four identical core tanks filled with solutions of nearly equal concentrations. The filling spouts for these tanks were then welded closed, foils were placed in the traverse tubes, and the four tanks were again enclosed in stainless steel jackets.[10]

One of these tanks contained three sets of bare, gold and copper foils, at positions 1-1/4 inch from each edge and at the center of the 6-inch-diameter tank, the second tank contained corresponding sets of cadmium covered gold and copper foils at similar positions. The foils were doubled up since irradiations had shown that doubling up had no effect on cadmium ratios. The cadmium covers were 0.030-inch thick, and the foils were 0.005-inch thick. The remaining two tanks each contained two sets of Pu^{239} and U^{235} foils; one tank contained bare foils, while the remaining tank contained cadmium covered foils (0.030-inch cadmium covers). Foils in the latter two tanks were positioned at the center of the core tanks and also 1/2 inch from their edge. All foil irradiations for this and for the UO_2F_2 measurements were made at the thermal loading.

The gold and copper foils gave center cadmium ratios of 4.83 and 14.89. Pu^{239} and U^{235} foils gave spectral index values of 1.52 ± 0.01 at the center of these tanks and 1.54 ± 0.01 at the edge. Although no attempt was made to correct these values for the stainless steel traverse tubes, the figures clearly indicate the spectral index of the solutions to

be approximately 1.50. This value, when compared to known systems, gives an effective neutron temperature of 390 K as compared to the physical temperature of the solutions, 299 K.

Bare and cadmium covered gold foils were irradiated during the initial UO_2F_2 experiment. These were placed at positions 1/2 and 3-1/2 inches from the center annulus in the buffer region; and they were also placed at the center of the core tank and 2 inches from its boundary. Results of these foil irradiations, as well as the reactivity measurements, indicated that the core spectrum changed only slightly in going from a fast to a thermal loading. The irradiations also indicated that the thermal loading more nearly approached the spectrum of an infinite system because of smaller changes in the spectrum in going from the edge of the buffer region to the center of the core region. Foil irradiations gave a cadmium ratio of 9.6 at the center of the core tank. As in the plutonium measurement, the foils were 0.005-inch thick and the cadmium covers were 0.0030-inch thick.

CONCLUSIONS AND ERROR ANALYSIS

The limiting critical concentration for Pu^{239} in a Pu-water solution was found to occur at an H:Pu ratio of 3392 ± 100; the concentration of Pu^{239} at this H:Pu ratio was 8.0 ± 0.3 g Pu^{239}/liter for the solutions used. This compares to the value of 7.71 ± 0.46 g Pu^{239}/liter reported by C. R. Richey from theoretical calculations using the Monte Carlo technique.[1]

The measurements with UO_2F_2 solutions produced a result of 12.05 ± 0.03 g U^{235}/liter as the limiting critical concentration for U^{235} in an aqueous solution. This result was in close agreement with the value of 12.1 g U^{235}/liter reported by the Oak Ridge National Laboratory[2] and with the value of 12.38 ± 0.41 g U^{235}/liter(13.29 ± 0.41 g U/liter) reported by C. R. Richey.[1]

The uncertainties quoted in this document for the measured results are estimated values, based on the accuracy of the data obtained and their analysis, including normalization, curve plotting, and corrections for the

effects of the various materials present. An additional error of approximately 1% was introduced into the plutonium measurement because of uncertainties in the solution analysis.

ACKNOWLEDGEMENTS

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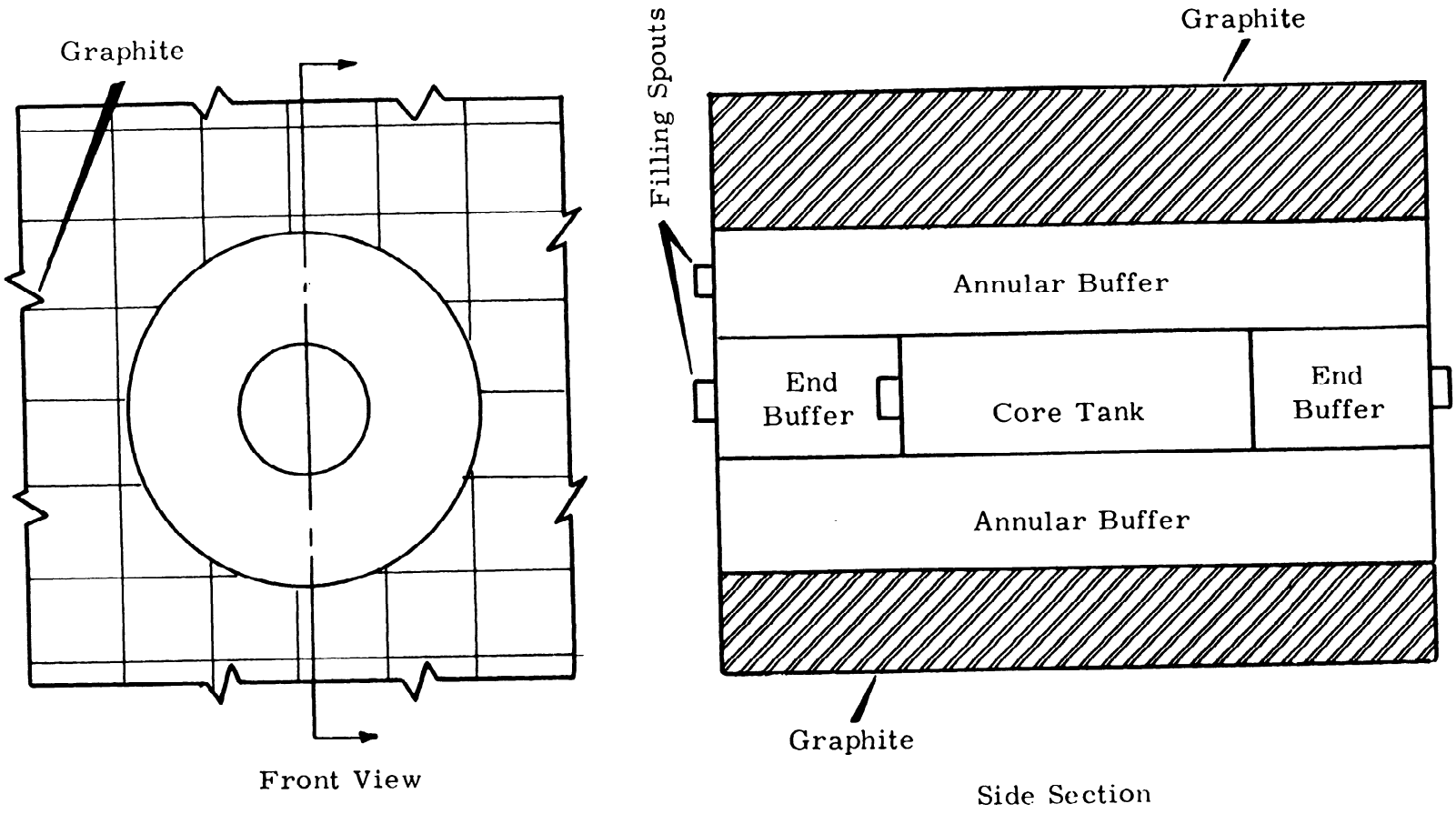

FIGURE 1

Experimental Tank Arrangement in the PCTR Test Cavity

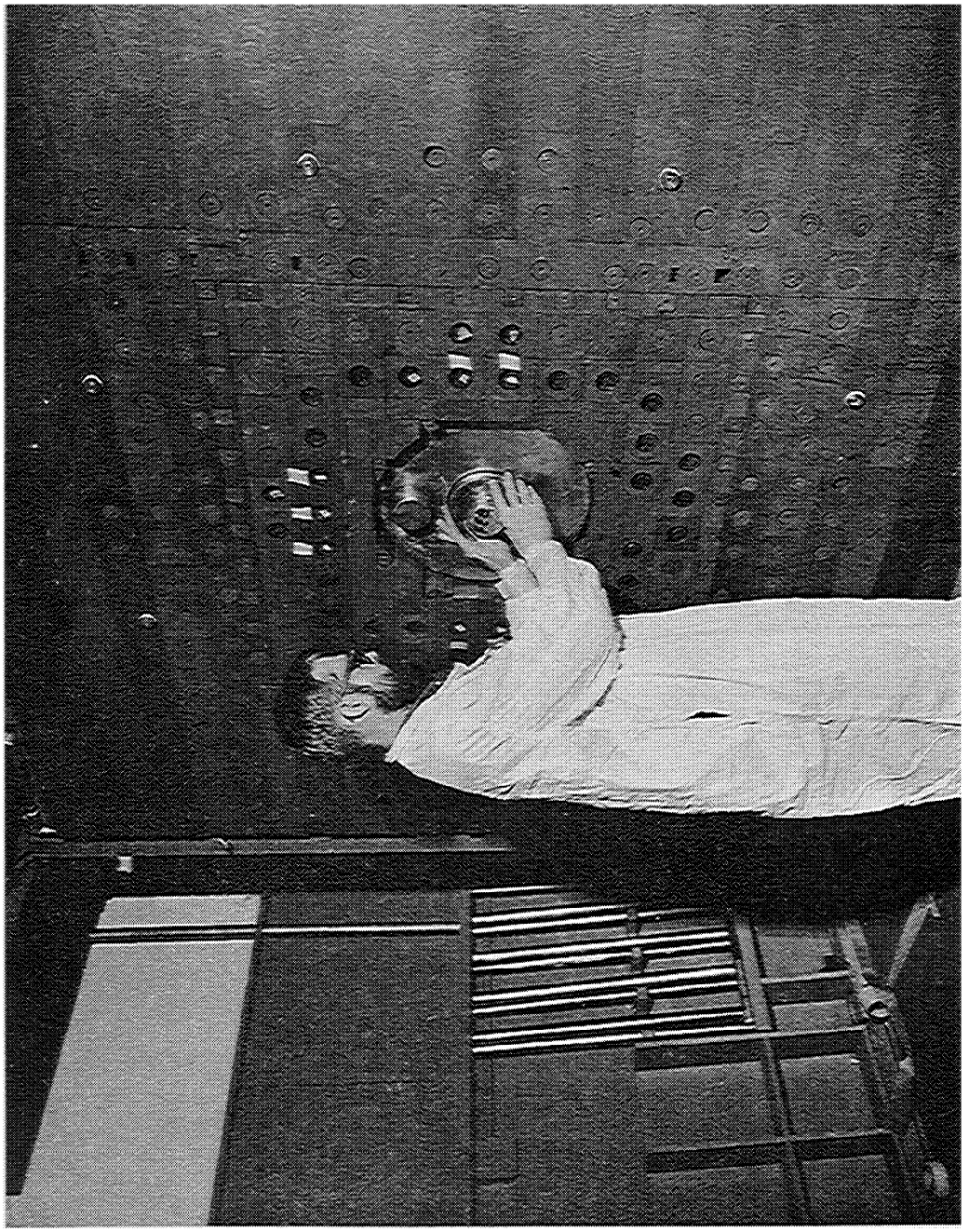

FIGURE 2

Tank Assembly in the PCTR

Plutonium Experiment ("Fast" Loading)

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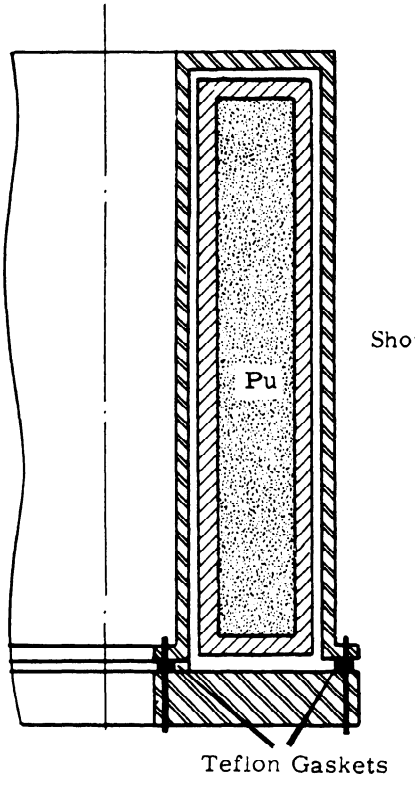
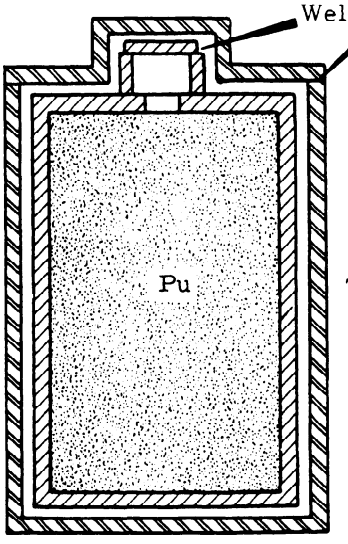


Sectional View
Showing Annular Buffer
Tank and Jacket



Sectional View
Showing Core
Tank and Jacket

FIGURE 3

Plutonium Tanks and Jackets

AEC-GE RICHLAND, WASH

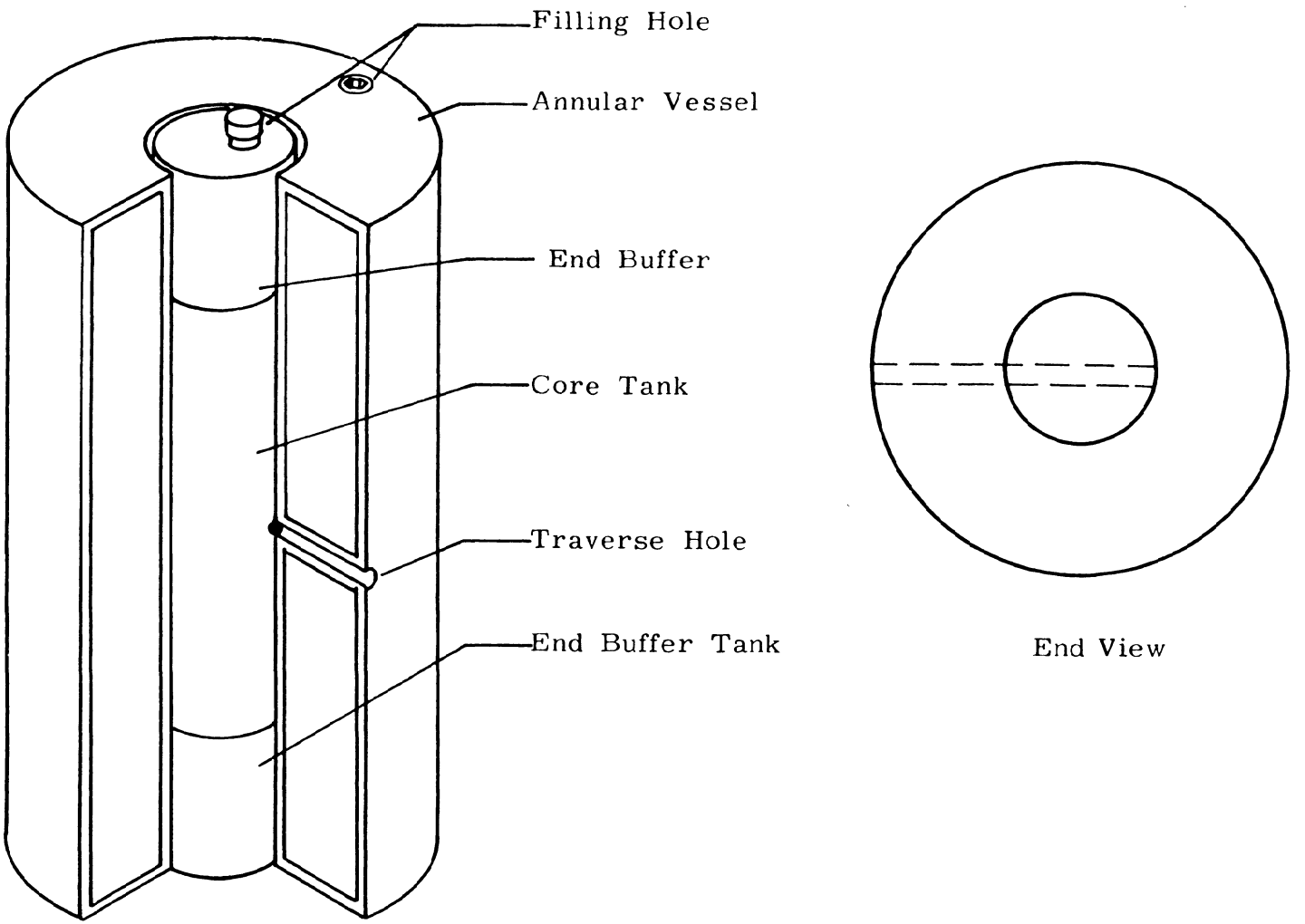


FIGURE 4

Side View Arrangement of Traverse Tubes in the Experimental Tanks

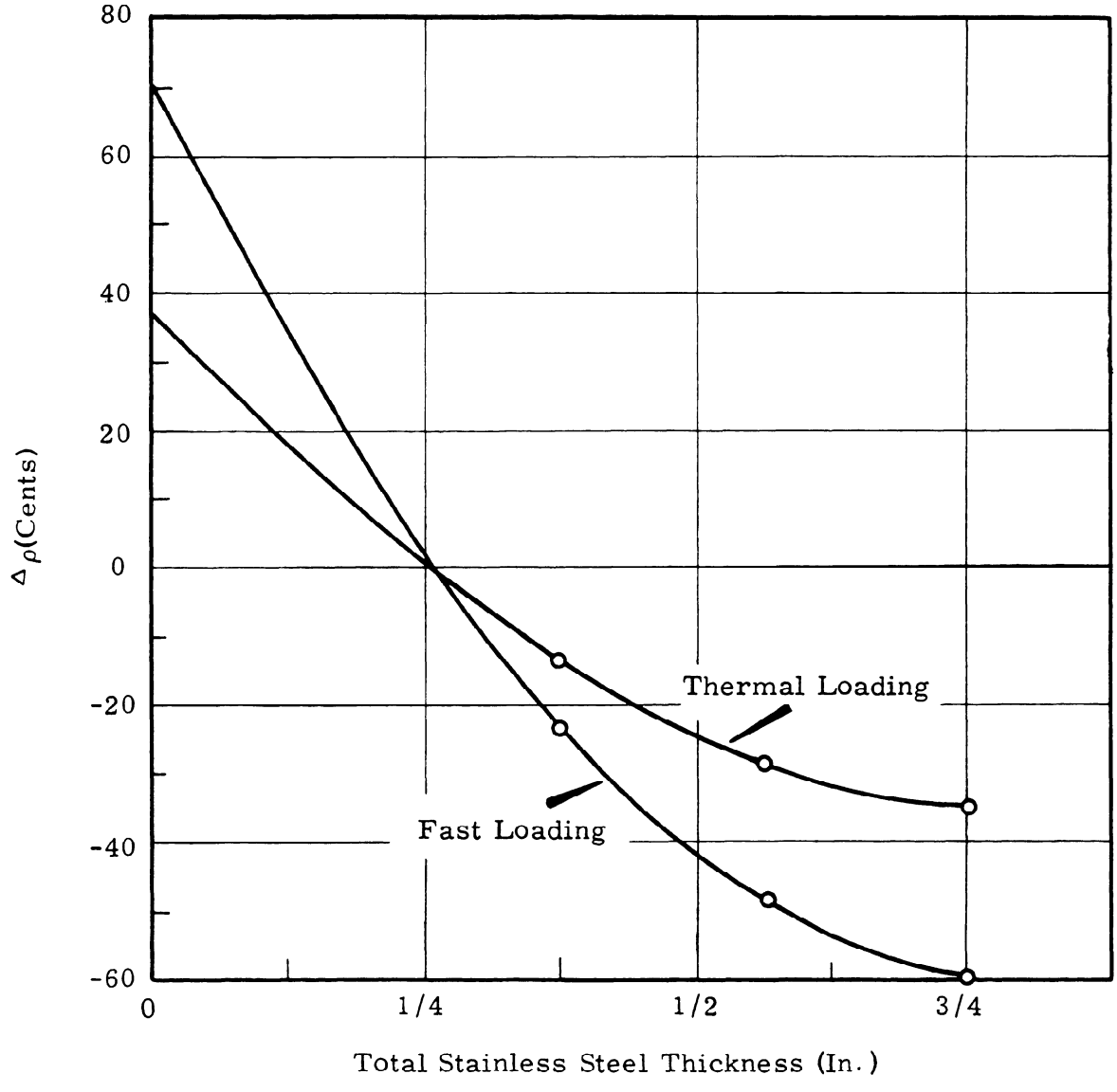


FIGURE 5

Solution Reactivity ($\Delta\rho$) versus Total Stainless Steel Thickness (In.)
(Plutonium Experiment)

AEC-GE RICHLAND, WASH

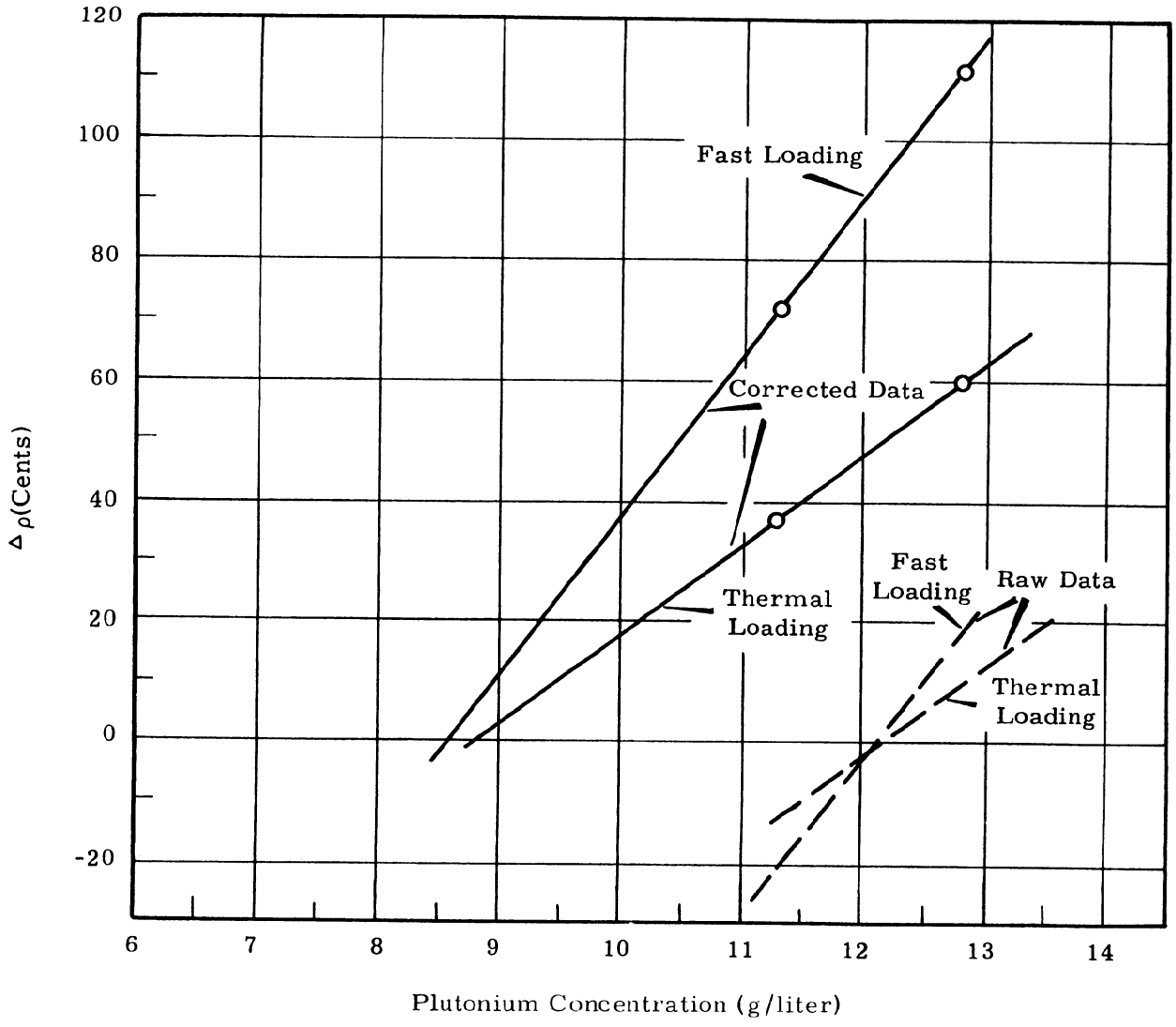


FIGURE 6

Solution Reactivity (Δ ρ) Versus Concentration of Plutonium (g/liter)

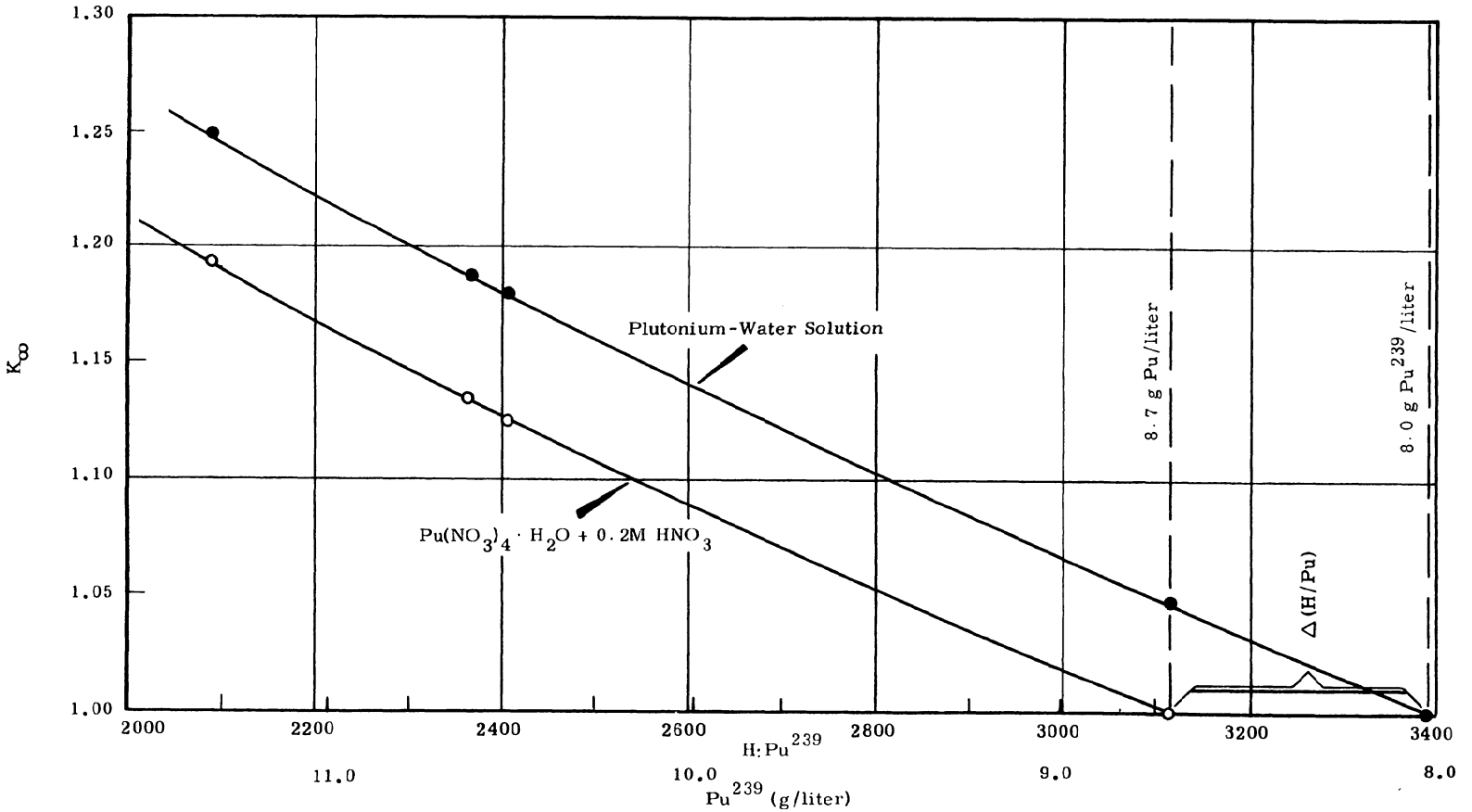


FIGURE 7

K_∞ Versus H:Pu^{239} for a Plutonium-Water Solution and for a $Pu(NO_3)_4$ Solution

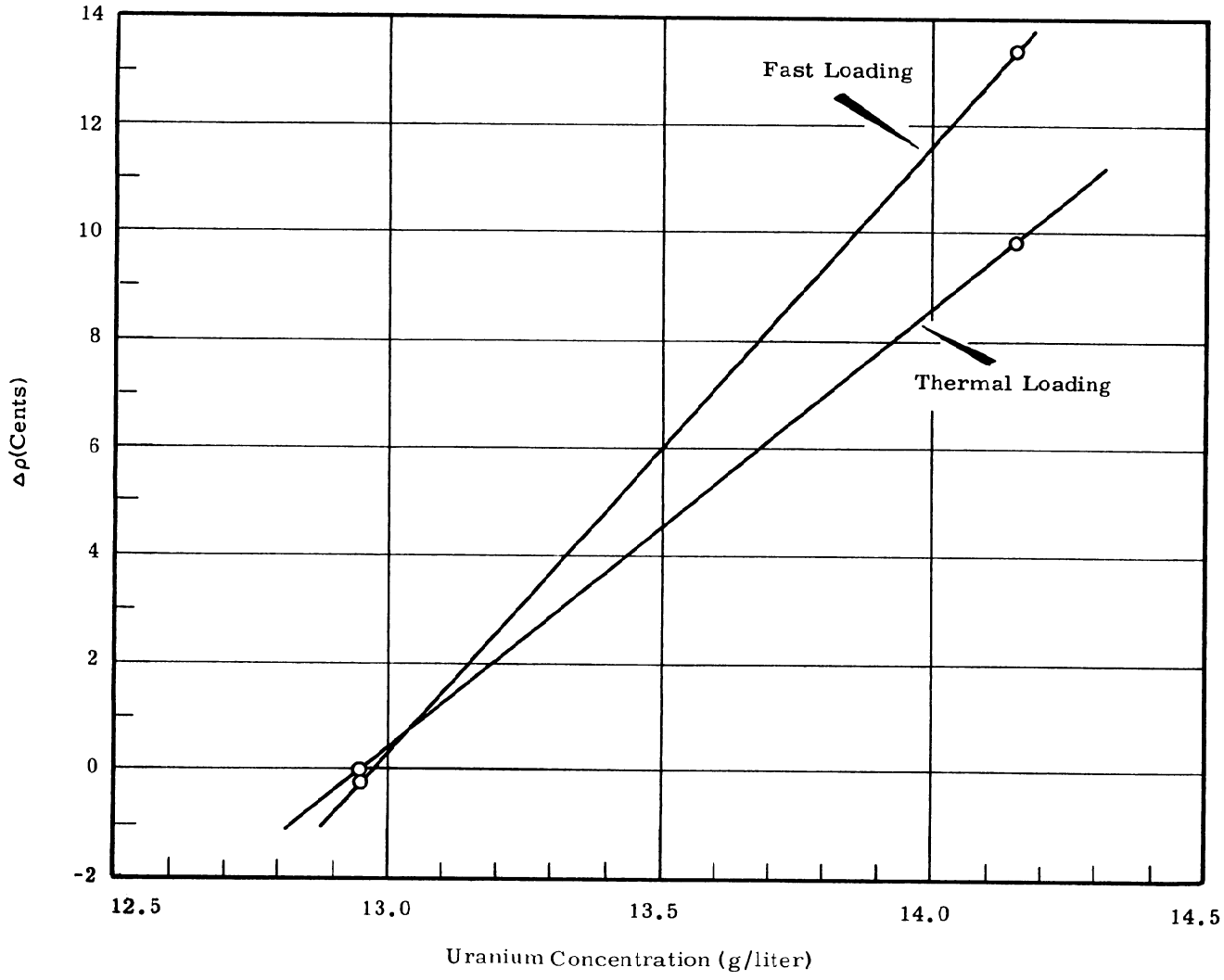


FIGURE 8

Solution Reactivity ($\Delta \rho$) Versus Uranium Concentration (g/liter)
(Initial Experiment)

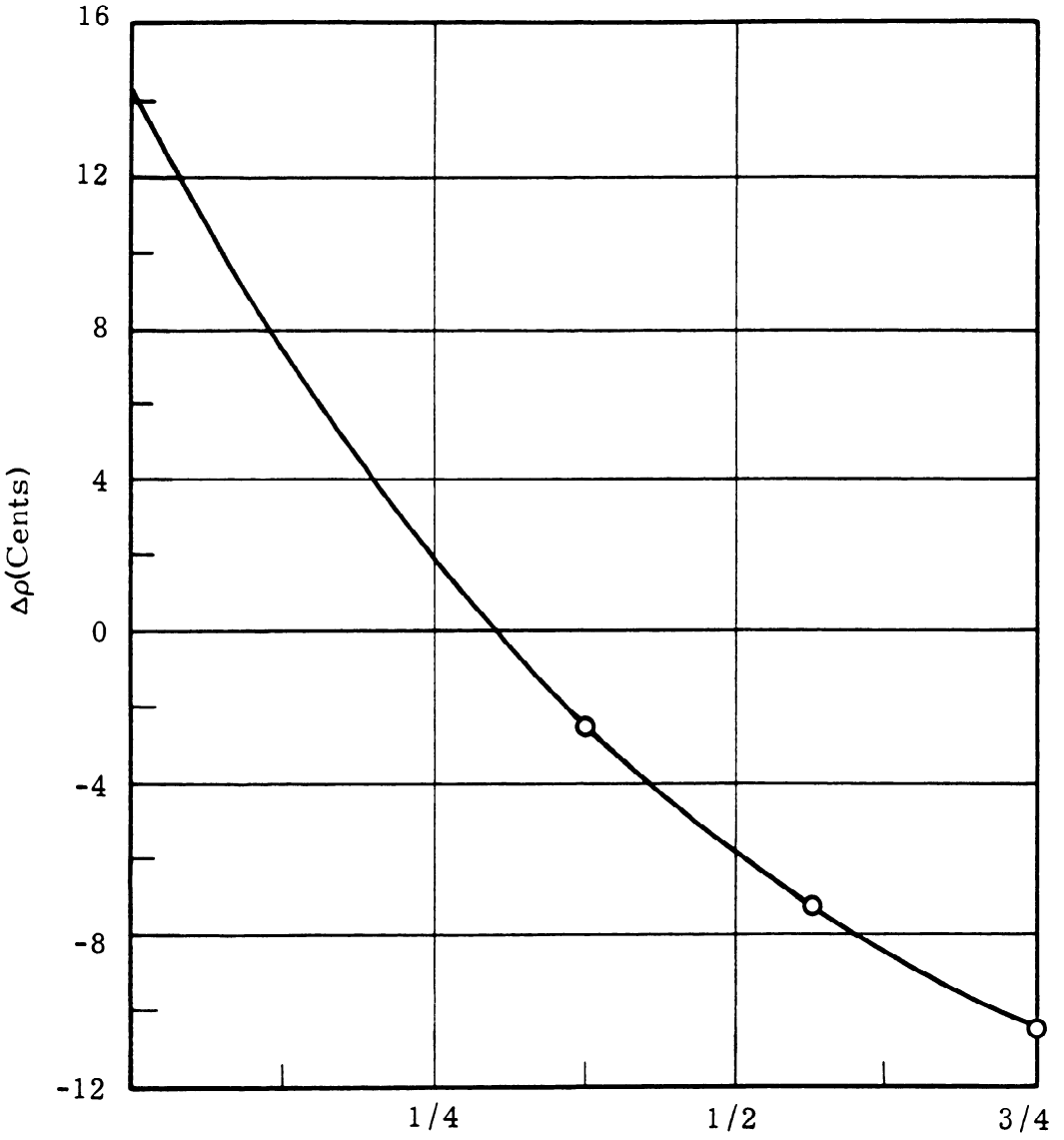


FIGURE 9

Solution Reactivity ($\Delta\rho$) versus Total Stainless Steel Thickness (UO_2F_2 Experiment)

AEC-GE RICHLAND, WASH

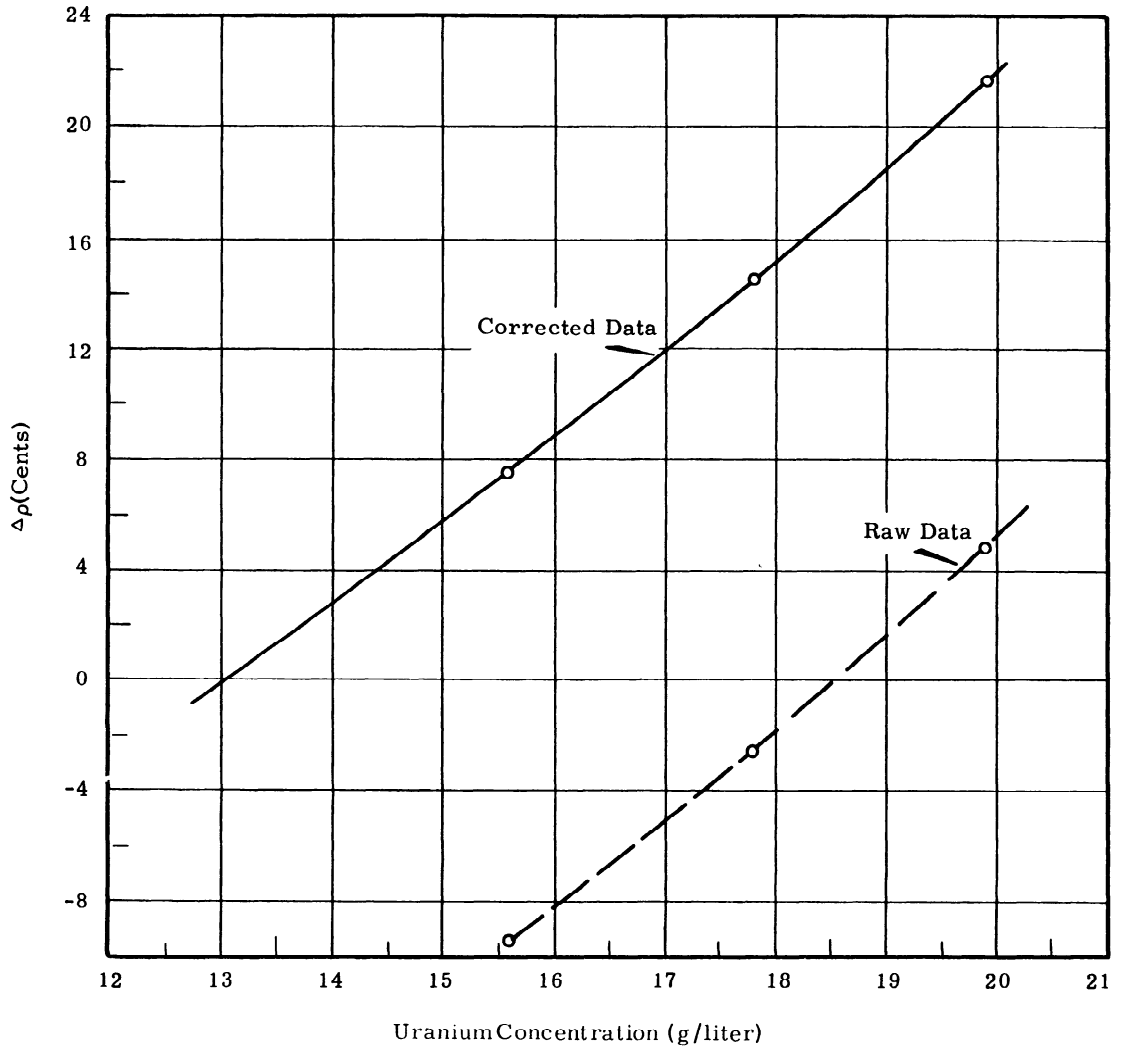


FIGURE 10

Solution Reactivity ($\Delta\rho$) Versus Uranium Concentration (g/liter)
(Final UO_2F_2 Experiment)

REFERENCES

1. C. R. Richey. "Limiting Critical Concentration of Pu^{239} and U^{235} in Aqueous Solutions by Monte Carlo Techniques," Physics Research Quarterly Report, April, May, June, 1962, HW-74190, July, 1962.

2. R. Gwin and D. W. Magnuson. Critical Experiments for Reactor Physics Studies, ORNL-60-4-12, Oak Ridge National Laboratory, September 16, 1960.

3. D. J. Donahue, D. D. Lanning, R. A. Bennett, and R. E. Heinman. "Determination of k_∞ from Critical Experiments with the PCTR," Nuclear Science and Engineering, vol. 4, pp. 297-321, 1958.

4. V. I. Neeley and H. E. Handler. Measurement of Multiplication Constant for Slightly Enriched Homogeneous UO_3-Water Mixtures and Minimum Enrichment for Criticality, HW-70310, August 21, 1961.

5. H. L. Henry, P. F. Nichols, and E. C. Watson. Revised Report of the Reactor Hazards for the Physical Constants Testing Reactor, HW-73021, March 1962.

6. F. G. Dawson. Proposed Studies on Thermal Spectra, HW-66623, July 6, 1960.

7. W. P. Stinson, L. C. Schmid, and R. E. Heineman. An Investigation of the Effective Neutron Temperature, HW-60778, June 17, 1959.

8. J. R. Lilley. Computer Code HFN-Multigroup, Multiregion Neutron Diffusion Theory in One Space Dimension, HW-71545, November 17, 1961.

9. S. P. Stone, E. T. Collins, and S. R. Lenihan, 9-Zoom - A One Dimensional Multigroup, Neutron Diffusion Theory Reactor Code for the IBM 709, UCRL-5682, University of California Radiation Laboratory, August 25, 1959.

10. R. H. Masterson, V. I. Neeley, and T. J. Powell. "Limiting Critical Concentrations for a Plutonium Nitrate Solution and for a Uranium-235 Solution," Physics Research Quarterly Report, January, February, March, 1962, HW-73116, April 16, 1962.