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**A Compilation of Yields from Neutron-Induced
Fission of ^{232}Th , ^{235}U , ^{238}U , ^{237}Np , ^{238}U , and
 ^{239}Pu Measured Radiochemically at Los Alamos**

by

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A COMPILATION OF YIELDS FROM NEUTRON-INDUCED FISSION OF

^{232}Th , ^{235}U , ^{236}U , ^{237}Np , ^{238}U , AND ^{239}Pu MEASURED

RADIOCHEMICALLY AT LOS ALAMOS

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ABSTRACT

Radiochemically measured relative fission yields have been compiled for targets of ^{232}Th , ^{235}U , ^{236}U , ^{237}Np , ^{238}U , and ^{239}Pu that were irradiated with neutrons, the average energies of which were in the 0.0253-eV to 14-MeV range. The yields were examined for consistency by means of the two-mode-of-fission hypothesis. The circumstances associated with inconsistencies were investigated, but the yields in question were rejected only when good cause was found. Finally, the relative fission yields were converted to absolute values.

Most samples were irradiated in the following Los Alamos reactors: BIG-TEN, Clementine, Flattop (oralloy core), Flattop (Pu core), Godiva-I, Godiva-IV, Jezebel (Pu core), Jezebel (^{233}U core), Topsy, Tungsten-Carbide Critical Assembly, and Water Boiler. Other samples were irradiated at the Los Alamos Cockcroft-Walton and Van de Graaff accelerators. Still others were irradiated in the Coupled Fast Reactivity Measurements Facility at INEL.

For each irradiation, the yields of some nuclides in the following list were measured: ^{82}Kr , ^{83}Br , ^{89}Sr , ^{90}Sr , ^{91}Sr , ^{91}Y , ^{95}Zr , ^{96}Nb , ^{97}Zr , ^{103}Ru , ^{105}Rh , ^{106}Ru , ^{109}Pd , ^{111}Ag , ^{115}Cd , ^{115}Cd , ^{127}Sb , ^{129}Sb , ^{131}I , ^{132}Te , ^{136}Cs , ^{137}Cs , ^{139}Ba , ^{140}Ba , ^{141}Ce , ^{142}Ce , ^{144}Ce , ^{147}Nd , ^{153}Sm , ^{156}Eu , and ^{161}Tb .

I. INTRODUCTION

Since 1949, relative fission yields for neutron-induced fission have been measured by the Los Alamos Radiochemistry Group (known successively as J-2, J-11, and CNC-11). Target nuclei were ^{232}Th , ^{235}U , ^{236}U , ^{237}Np , ^{238}U , and ^{239}Pu . Many of these relative yields (known as R-values) have been collected from internal documents (reports, tabulations, memoranda, laboratory notebooks, etc.) and converted into absolute yields, which are reported here. The same item sometimes appeared with a different name in different documents, and every effort was made to eliminate such duplications. Sometimes the relative yields were the result of interpolation rather than measurement, and every effort was made to eliminate such yields. Different measurements

made under identical conditions but from different sources were not combined.

The two-mode-of-fission hypothesis¹ was applied in a new way to convert relative yields to absolute yields. It was also used to check collections of relative yields for internal consistencies. Data were not rejected because of inconsistencies, but were rejected when other reasons were found.

Symbols are defined and relations between them are discussed in Sec. II. The conversion of relative yields to absolute yields is described, and the use of the two-mode-of-fission hypothesis is discussed. The assessment of errors is described. Neutron sources and targets are described in Sec. III. Cumulative and independent yields for thermal-neutron-induced fission of ^{235}U are given in Table I. Neutron sources are described in Table II.

R-values, errors, and fission yields are given in Tables III through VIII.

II. FISSION YIELDS

A. R-Values and Fission Yields

Yields of the radioactive fission products presented here result from many experiments in which both the fissionable target material and the energy spectrum of the neutrons varied. In each case, however, the target material was dissolved after irradiation, and radiochemical procedures such as those described in Ref. 2 were used to prepare samples in a standardized form for assay with beta-proportional counters or gamma-ray detectors. For historical reasons, the measured activities were converted to activities to be expected in an instantaneous irradiation with the same neutron spectrum and the same number of fissions. The activities A_{ji} are given by

$$A_{ji} = \epsilon_i \lambda_i Y_{ji} F$$

where ϵ is a counting efficiency, λ is a decay constant, Y is a fission yield and F is a number of fissions. For quantities with two indices, the first refers to a fission process and the second to a fission product. Indices used in the text are T for thermal-neutron-induced fission of ^{235}U , 14 for fission induced by 14-MeV neutrons, and 99 for the cumulative yield of ^{99}Mo . The fission yield indices and the associated isotopes are given in Table I. These indices are used in computer-generated tables and graphs to be presented later. The indices T and 14 are not used in the tables.

We assume, temporarily, that A's are activities of isotopes without parents or daughters; the actual situation is discussed below in Sec. II-F. No chemical separations were done until all precursor decay was essentially complete. A ratio r_{ji} is defined by

$$r_{ji} = \frac{A_{ji}}{A_{j99}} = \frac{\epsilon_i \lambda_i Y_{ji}}{\epsilon_{99} \lambda_{99} Y_{j99}} F \quad (1)$$

for a particular irradiation. Note that the F's cancel in the ratio. Quantities R_{ji} are defined by

$$R_{ji} = \frac{r_{ji}}{r_{Ti}} = \frac{A_{ji}/A_{i,99}}{A_{Ti}/A_{T,99}} \quad (2)$$

From (1) and (2) it follows that

$$Y_{ji} = Y_{Ti} \frac{Y_{j,99}}{Y_{T,99}} R_{ji} \quad (3)$$

Eq. (3) was used to calculate the desired absolute fission yields Y_{ji} .

Y_{Ti} and Y_{ji} are the same type of yield, i.e., independent or cumulative. The yields of shielded nuclides (^{82}Br , ^{96}Nb , and ^{136}Cs) are independent yields, because they cannot be formed by beta-decay of precursors. The fission-yield indices given in Table I for these include the letter I. If all of the decay of precursors goes through the isotope being measured, then the yield is a cumulative yield. Indices do not contain any special symbol to indicate cumulative yields. ^{115}Cd , ^{121}Sn , and ^{125}Sn have two isomers, and the metastable state decays at least partially by beta-decay. For these we give R-values but not yields.

Values of Y_{Ti} from ENDF/B-IV were used in Eq. (3). These values are given in Table I. Equation (3) also depends on the ratio $Y_{j,99}/Y_{T,99}$, which is denoted by $Q_{j,99}$. $Q_{j,99}$ has been measured for some cases. Such measurements are described in Sec. II-B. Other values of $Q_{j,99}$ were derived from measured values through use of the two-mode-of-fission hypothesis, as discussed in Sec. II-C. There were no measurements for ^{232}Th , ^{236}U , and ^{237}Np ; for these we guess that $Q_{j,99} = 1$.

B. K-Factors and Q-Values

A quantity $K_{j,99}$ is defined by

$$K_{j,99} = 1/(\epsilon_{99} \lambda_{99} Y_{j,99}) \quad (4)$$

In a sample in which F fissions have occurred, the radiochemically measured activity of ^{99}Mo is given by

$$A_{j,99} = \epsilon_{99} \lambda_{99} Y_{j,99} F = F/K_{j,99} \quad (5)$$

From (4) it follows that

$$Q_{j,99} = K_{T,99}/K_{j,99} \quad (6)$$

$A_{j,99}$ and F are measured for a particular j , and Eq. (5) is used to determine $K_{j,99}$. For this purpose, a sample of fissionable material was irradiated between two thin standard foils of fissionable material in a double back-to-back fission counting chamber.³ The standard foils are usually of the same material as the sample, in which case it is assumed that the number of fissions per milligram of sample is the same as the average of the number of fissions per milligram in the standards as measured by the two back-to-back fission counting chambers. $A_{j,99}$ was measured for the sample. In some experiments a small, known fraction of the sample was made into a foil like the standards and related to the standards by comparison fission counting with the same apparatus. Equations relating values of $Q_{j,99}$ to values of $R_{j,111}$ for neutron-induced fission of ^{235}U , ^{238}U , and ^{239}Pu are given in Sec. II-C.

C. Two-Mode-of-Fission Hypothesis

The two-mode-of-fission hypothesis^{1,4,5} implies that¹

$$Y_{ji} = a_i Y_{j,111} + b_i Y_{j,99} \quad (7)$$

for a particular target and for a variety of fissioning conditions, i.e., neutrons with different spectra. $Y_{j,111}$ and $Y_{j,99}$ are called the yields of base nuclides in Ref. 1. The following relations are derived from the definitions:

$$Y_{j,99} = Y_{T,99} Q_{j,99}, \quad (8)$$

$$Y_{j,111} = Y_{T,111} R_{j,111} Q_{j,99}, \quad (9)$$

and

$$Y_{ji} = Y_{Ti} R_{ji} Q_{j,99}. \quad (10)$$

From (7), (8), (9), and (10) it follows that

$$R_{ji} = a_i \frac{Y_{T,111}}{Y_{T,i}} R_{j,111} + \frac{Y_{T,99}}{Y_{T,i}} b_i. \quad (11)$$

Thus the two-mode-of-fission hypothesis implies that R_{ji} is a linear function of $R_{j,111}$ as j varies. It is clear that any other mass number could be used instead of 111. A plot of R_{ji} vs $R_{j,111}$ is called a

two-mode plot. Such plots are shown in Figs. 1 through 14 for ^{235}U , in Figs. 15 through 24 for ^{238}U , and in Figs. 25 through 34 for ^{239}Pu . Plots are not shown if there are less than three points. R -values for neutron energies of 0.1- and 14-MeV neutrons, where second-chance fission is energetically possible, have been omitted from the two-mode plots and the associated least-squares calculation. In all figures the lines were determined by least squares. The method of Deming^{1,6} was used with a maximum of 25 iterations to provide an initial approximation for the method of steepest descent. The equation for the line is given below each figure. The three numbers following the equation are, respectively, the standard deviations of the two constants in the equation and their correlation coefficient. The arguments of the function P , also given in the figures, are the minimized sum of the squares of the weighted deviations S and the number of degrees of freedom f . The value of $P(S, f)$ is the integral from S to infinity of the χ^2 probability density function with f degrees of freedom. $P(S, f)$ is the same as $q(S, f)$ of Ref. 1, where its use is described. P is a measure of the quality of fit obtained from the least-squares calculation; P increases as the quality of the fit improves. In the least-squares calculation it was assumed that R_{ji} and $R_{j,111}$ were uncorrelated, because the correlation coefficient was not known. This assumption is incorrect, as will be discussed in Sec. II-D. Therefore, it is not appropriate to use the values of P for a statistical test of the two-mode-of-fission hypothesis.

In the following, sums indicated by Σ are over all mass chains with nonzero yields except for the $A = 99$ and $A = 111$ chains. Then with this convention it follows that

$$\sum_i Y_{ji} + Y_{j,111} + Y_{j,99} = 2$$

for a normalized fission yield curve with index j . From Eq. (7) it follows that

$$\sum_i (a_i Y_{j,111} + b_i Y_{j,99}) + Y_{j,111} + Y_{j,99} = 2$$

and

$$Y_{j,111} (1 + \Sigma a_i) + Y_{j,99} (1 + \Sigma b_i) = 2.$$

From (8) and (9) it follows that

$$R_{j,111} Y_{T,111} Q_{j,99} (1 + \Sigma a_i) + Y_{T,99} Q_{j,99} (1 + \Sigma b_i) = 2$$

and

$$\frac{2}{Q_{j,99}} = R_{j,111} Y_{T,111} (1 + \Sigma a_i) + Y_{T,99} (1 + \Sigma b_i). \quad (12)$$

Thus $1/Q_{j,99}$ is a linear function of $R_{j,111}$. It is this implication of the two-mode-of-fission hypothesis that is used to interpolate values of $Q_{j,99}$ for ^{235}U , ^{238}U , and ^{239}Pu from measured values. It is clear that any index other than 99 can be used instead of 111. It was necessary to do this when $R_{j,111}$ was not measured. Also, once the constants $Y_{T,111} (1 + \Sigma a_i)$ and $Y_{T,99} (1 + \Sigma b_i)$ are determined by measuring $Q_{j,99}$ and $R_{j,111}$ for two different j 's, a linear relation from a two-mode plot can be used to substitute for $R_{j,111}$ to obtain a linear relation between $1/Q_{j,99}$ and some other R-value. In the above discussion it was assumed that the indices 99 and 111 represent entire chain yields. For the cases reported here, charge distribution systematics⁷ support such a representation.

By definition, $Q_{T,99} = 1$ and $R_{T,111} = 1$ for ^{235}U . From Ref. 8, $Y_{T,99} = 6.14\%$, and from Ref. 9, $Y_{14,99} = 5.17\%$. Although 6.14% is not the ENDF/B-IV value, it was measured with the same K-factor apparatus (which differed only in detail from that of Ref. 3) as was used to obtain the value 5.17% and is appropriate to use in obtaining $Q_{14,99} = 0.8420$. Also from Ref. 9, $R_{14,111} = 101.4$. The resulting linear relation for ^{235}U is

$$1/Q_{j,99} = 0.001868526 R_{j,111} + 0.99813147.$$

Our measured values of K-factors for ^{238}U and the corresponding R-values are $K_{j,99} = 2.327 \times 10^5$ and $R_{j,111} = 3.96$ for Godiva-I center, and $K_{j,99} = 2.607 \times 10^5$ and $R_{j,111} = 65.5$ for 14-MeV neutrons. These 14-MeV results are from the same measurements reported in Ref. 9. The resulting linear relation for ^{238}U is

$$1/Q_{j,99} = 0.001465475 R_{j,111} + 0.9844095.$$

For thermal-neutron-induced fission of ^{239}Pu , we have $K_{j,99} = 2.448 \times 10^5$ and $R_{j,111} = 16.4$. Our value of $K_{T,99}$ is 2.369×10^5 , from which $Q_{j,99} = 0.9677$ for thermal-neutron-induced-fission of ^{239}Pu . Two experiments were done to measure $K_{j,99}$ for 14-MeV-neutron-induced-fission of ^{239}Pu , in which aluminum monitor foils were used to determine fluxes and known fission cross sections were used to calculate F for use in Eq. (5). The two results differed by 4.5%. The resulting average value of $Q_{j,99}$ is 0.88047. The corresponding R-value for ^{111}Ag is 121.0. From this is derived the relation for ^{239}Pu :

$$1/Q_{j,99} = 0.0009783939 R_{j,111} + 1.0173343.$$

It cannot be expected⁵ that the two-mode-of-fission hypothesis will hold exactly for collections of fission yields that include fission induced by 14-MeV neutrons, because fission is possible then from nuclei de-excited by neutron evaporation as well as from prompt fission. This second- and third-chance fission is unlikely to cause serious difficulty. It is, however, very desirable to measure K-factors for a variety of neutron spectra as a check on the validity of the two-mode-of-fission hypothesis.

D. Errors

Values of R_{ji} given in the original documents sometimes had errors based on the dispersion of replicate measurements. When such was the case, these errors were taken into account, as will be explained.

Values of r_{Ti} for some of the i 's measured over a period of about 25 yr were collected into groups of determinations made under what were believed to be identical conditions. Different groups for the same fission product were characterized by different radiochemical procedures. The percentage standard deviation of each group is given in Table I. Yield index i was associated with $\sqrt{2}$ times the appropriate standard deviation. The factor $\sqrt{2}$ was used because a given R-value depends on two values of r .

When only one of the above standard deviations was available, it was used; if both were available, the larger was used. When the above procedure did not produce a standard deviation, one was calculated whenever possible from standard deviations given by

Browne and Halbing (Ref. 10). When all the above failed, a standard deviation of 3% was assigned.

Errors of different R_{ji} 's for the same j are statistically correlated, because the same value A_{ji} , and possibly $A_{T,99}$, occurs in both. The value of the correlation coefficient is not known.

F. Effect of Precursors and Daughters

The assumptions of Sec. II-A hold for the shielded nuclides ^{96}Nb and ^{136}Cs . For these, Y_{T1} and Y_{j1} are independent yields.

The first failure of the above assumptions concerns daughter activities. In some cases, such as ^{99}Mo , there is a short-lived daughter. In these cases, counting is not started until the daughter is in equilibrium, and the only effect is an enhanced ϵ which cancels in (2). For ^{95}Zr , the ^{95}Nb daughter is removed in the chemical procedure, and all counting is done before an appreciable amount of ^{95}Nb grows in. In the case of ^{140}Ba , which has a 40-h ^{140}La daughter, empirically determined factors were often used to convert observed counting rates to those that would have been obtained after equilibrium was reached.

The second failure of the above assumptions concerns the existence of precursors. All of the cases to which we have applied (2) and (3) can be treated as one- or two-member chains, because no chain has more than one precursor with a half-life long enough to be significant. For the two-member chains, the A 's in (1) and (2) should be divided by⁹

$$k_1 + \frac{k_2 \lambda_1}{\lambda_2 - \lambda_1}, \quad (13)$$

where $k_1 + k_2 = 1$, subscripts 1 and 2 indicate parent and daughter, respectively, and k_1 and k_2 are relative rates of formation. For ^{82}Br , ^{89}Sr , ^{90}Sr , ^{91}Y , ^{91}Sr , ^{95}Zr , ^{97}Zr , ^{103}Ru , ^{106}Ru , ^{109}Pd , ^{112}Pd , ^{127}Sb , ^{132}Te , ^{137}Cs , ^{140}Ba , ^{141}Ce , ^{143}Ce , ^{144}Ce , ^{147}Nd , ^{153}Sm , and ^{161}Tb , the factor $\lambda_1/(\lambda_2 - \lambda_1)$ is sufficiently near 1 that (13) can be neglected, and Eq. (3) is used. The factors $\lambda_1/(\lambda_1 - \lambda_2)$ for ^{83}Br , ^{105}Ru , ^{111}Ag , ^{129}Sb , ^{131}I , ^{139}Ba , and ^{156}Eu are, respectively, 1.210, 1.125, 1.032, 1.036, 1.183, 1.120, and 1.027. For these k_1 and k_2 could be used if known, to determine (13). The use of (13) is not

necessary to correct the measured yields, even when $\lambda_1/(\lambda_1 - \lambda_2)$ is as large as 1.210, as the following analysis shows. Charge distribution systematics⁷ can be used to estimate values for k_1 and k_2 . When k_1 and k_2 , thus obtained, are used in the numerator and denominator of (2), the largest ratio of the factors (13) is 1.0036 for ^{139}Ba . Thus corrections are unnecessary.

III. NEUTRON SOURCES AND TARGET MATERIALS

The neutron sources used in these fission yield studies are listed in Table II. The row headings in Table II correspond to the first index of doubly indexed quantities such as R_{ji} , as discussed in Sec. II.

The target materials had the following isotopic compositions:

^{232}Th	100%
^{235}U	93.1 wt%; ^{234}U , 1.0 wt%; ^{236}U , 0.7 wt%; ^{238}U , 5.2 wt%
^{236}U	99.62 wt%; ^{235}U , 0.16 wt%; ^{238}U , 0.22 wt%
^{238}U	enriched 1540:1 with respect to ^{235}U
^{237}Np	99.99% isotopically pure
^{239}Pu	≈ 95 wt%; ^{240}Pu ≈ 5 wt%.

In the first BIG-TEN irradiation, the isotopic compositions of the ^{235}U and ^{239}Pu targets differed from the compositions listed above. The ^{235}U target for the data labeled BIG-TEN*, $R = 6.98$ mm in Table IV, was enriched to 99.98% ^{235}U . The ^{239}Pu target for the data with the same label in Table VIII was enriched to 99.11% ^{239}Pu .

IV. EQUIVALENCES

Certain irradiation positions were considered equivalent to others with respect to the neutron energies inducing fission. The positions of the individual members listed in each group are described in Table II.

Godiva-I Center, Godiva-IV Glory H, Oy-Flattop Center, and Oy-Flattop with radii ≤ 12 mm are equivalent. Beyond 12 mm, those Oy-Flattop positions that differ from one another by less than 1 mm are equivalent to each other; for example, 63.1 and 63.2 mm are considered equivalent.

For Pu-Flattop irradiations, the center position and the 13.6-mm position are equivalent.

For 23-Jezebel irradiations, the 0.5- and the 2.5-mm positions are equivalent.

Comparisons of fission yields for irradiations at the listed equivalent positions did not reveal any discrepancies large enough to invalidate the asserted equivalences.

V. TABULATION OF R-VALUES AND YIELDS

A computer program was used to produce tables of R-values, percentage errors of R-values, and yields. The E of FORTRAN formats was suppressed to save space. The table numbers and target nuclei are: III, ^{232}Th ; IV, ^{235}U ; V, ^{236}U ; VI, ^{237}Np ; VII, ^{238}U ; and VIII, ^{239}Pu . Column headings correspond to the first index of R_{ji} , Y_{ji} , and Q_{ji} which have been explained in Sec. III. The row headings are the fission-yield indices given in Table I. In each column the value of $Q_{j,99}$ is given along with the second index of the R-value (if any) used to calculate it.

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TABLE I
INDICES AND CUMULATIVE AND INDEPENDENT YIELDS FOR
THERMAL-NEUTRON-INDUCED FISSION OF ^{235}U FROM ENDF/B-IV

<u>Isotope</u>	<u>Index</u>	<u>Yield</u>	<u>Standard Deviation (%)</u>
^{82}Br	82 I	1.251×10^{-4}	
^{83}Br	83	0.5313	
^{89}Sr	89	4.846	1.67, 1.25
^{90}Sr	90	5.913	
^{91}Sr	91 S	5.919	
^{91}Y	91 Y	5.919	1.76, 2.37
^{95}Zr	95	6.464	1.64, 2.77
^{96}Nb	96 I	5.993×10^{-4}	
^{97}Zr	97	5.948	
^{103}Ru	103	3.137	
^{105}Rh	105	1.020	
^{106}Ru	106	0.3912	
$^{109}\text{Pd}^g$	109	2.995×10^{-2}	
^{111}Ag	111	1.976×10^{-2}	2.08, 4.86, 1.93
$^{115}\text{Cd}^m$	115 M		3.08, 3.94
$^{115}\text{Cd}^g$	115 G		1.36, 0.523
^{127}Sb	127	0.1303	
^{129}Sb	129	0.6354	
^{131}I	131	2.836	
^{132}Te	132	4.231	2.69, 3.03
^{136}Cs	136 I	5.308×10^{-3}	1.87, 3.18
^{137}Cs	137	6.268	1.76, 2.86
^{139}Ba	139	6.486	
^{140}Ba	140	6.320	1.06, 1.05
^{141}Ce	141	5.890	
^{143}Ce	143	5.972	0.578, 0.315, 2.73
^{144}Ce	144	5.457	3.21, 1.36, 3.08, 2.45
^{147}Nd	147	2.271	1.89, 2.31
^{153}Sm	153	0.1621	
^{156}Eu	156	1.351×10^{-2}	1.23, 2.13
^{161}Tb	161	8.874×10^{-5}	3.94, 2.11

TABLE II
NEUTRON SOURCES

Source	Neutron Source Description and Sample Location	References
BIG-TEN, R = 6.98 mm BIG-TEN*, R = 6.98 mm BIG-TEN, R = 7.75 mm	BIG-TEN is a critical assembly designed to produce a neutron spectrum similar to that expected in a liquid-metal fast breeder reactor. The core consists of a central region of homogeneous 10% enriched uranium with an assembly of alternating annular metal plates of 93% enriched and natural uranium of the proper respective thickness to simulate 10% enriched material. The core is reflected in all directions with depleted uranium metal. The assembly is cylindrically symmetrical, with a horizontal axis of rotation. The samples were located 6.98 or 7.75 mm above the midpoint of the symmetry axis. The asterisk in the heading indicates that the ^{235}U or ^{239}Pu was isotopically purer than the usual target materials (see text).	E. J. Dowdy, E. J. Lozito, and E. A. Plassman, "The Central Neutron Spectrum of the Fast Critical Assembly Big-Ten," Nucl. Tech. <u>25</u> , 381-389 (1975).
Capsule at 8 in. Capsule at 20 in. Capsule at 35 in. Capsule at 48 in.	Samples were irradiated inside a hollow cylinder of nickel-plated uranium metal that was approximately 93% ^{235}U . The cylinder was 15.25 mm high and 16.05 mm in diameter. The wall thickness was 3.97 mm. The uranium cylinder was coaxially embedded in a cylinder of 2S aluminum. The aluminum cylinder was 88.3 mm high and 75.8 mm in diameter. The top of the uranium cylinder was 27.2 mm from the top of the aluminum cylinder. There was a gold collar around the uranium cylinder starting 3.10 mm from the top and extending to the bottom. The gold collar was 1.5 mm thick just below its top and 1.1 mm thick at a point 2.3 mm from its bottom. The assembly was irradiated in the thermal column of the Los Alamos Fast Plutonium Reactor at positions 8, 20, 35, and 48 in. from the face of the 15-in.-long bismuth block. The other face of the bismuth block was adjacent to the reactor core.	E. T. Journey, J. H. Hall, D. B. Hall, A. M. Gage, N. H. Godbold, A. R. Sayer, E. O. Swickard, "The Los Alamos Fast Plutonium Reactor," Los Alamos Scientific Laboratory report LA-1679 (May 1954).
Cd-Wrapped	The sample was wrapped with cadmium and irradiated in a thermal-neutron flux 30 in. from the bismuth curtain in the north column of the Los Alamos Homogeneous Reactor. The cadmium ratio was 550 to 1.	L. D. P. King, "Design and Description of Water Boiler Reactors," Proc. Intern. Conf. Peaceful Uses of At. Energy (United Nations, NY, 1956), Vol. 2, Part C, pp. 372-391.
CFRMF	The samples were irradiated in the center of the Coupled Fast Reactivity Measurements Facility, CFRMF, located at the Idaho National Engineering Laboratory. The CFRMF is a zoned-core critical assembly with a fast-neutron spectrum zone in the center of an enriched ^{235}U , water-moderated thermal "driver" zone. The radiochemical measurements were made at LASL.	J. W. Rogers, D. A. Millsap, and Y. D. Harkner, "CFRMF Neutron Field Flux Spectral Characterization," Nucl. Tech. <u>25</u> , 330-348 (1975).

TABLE II (cont)

Source	Neutron Source Description and Sample Location	References
Clementine, 5W	Samples were irradiated in the Los Alamos Fast Plutonium Reactor (Clementine) 5W port, where the neutron spectrum with the highest mean energy was available.	E. T. Jurney, J. H. Hall, D. B. Hall, A. M. Gage, N. H. Godbold, A. R. Sayer, E. O. Swickard, "The Los Alamos Fast Plutonium Reactor," Los Alamos Scientific Laboratory report LA-1679 (May 1954). The 5W port is drawn on p. 127.
Godiva-I, Center	Samples were irradiated in the center of an unreflected ^{235}U critical assembly called, at various times, Lady Godiva, Godiva, or Godiva I.	R. E. Peterson and G. A. Newby, "An Unreflected U-235 Critical Assembly," Nucl. Sci. Eng. <u>1</u> , 112-125 (1956).
Godiva-IV, Glory H	Samples were irradiated in the Glory Hole of the Godiva IV unreflected ^{235}U critical assembly.	T. F. Wimett, R. H. White, and R. G. Wagner, "Godiva IV," in Proc. Nat. Topical Meeting on Fast Burst Reactors, Univ. New Mexico, Albuquerque, January 28-30, 1969 (USAEC Div. Tech. Inf. Ext., Oak Ridge, TN, 1969), pp. 95-104. The Glory Hole location is indicated in Fig. 2, p. 97.
Oy-Flattop, Center	The Flattop critical assembly accommodates interchangeable 8-in. spherical cores of or alloy, which is uranium-enriched to 93.8% in ^{235}U , and δ -phase plutonium. The core is surrounded by a thick natural uranium reflector. Sample irradiation locations are given in millimeters from the center of the spherical core.	The best available description of the Flat-top critical assembly is given in the one paragraph and two photographs on pp. 7 & 8 of the report by W. U. Geer, P. G. Koontz, J. D. Orndoff, and H. C. Paxton, "Safety Analysis for the Los Alamos Critical-Assembly Facility," Los Alamos Scientific Laboratory report LA-4273 (May 1969). Some spectral index data have been published by G. E. Hansen, "Status of Computational and Experimental Correlations for Los Alamos Fast-Neutron Critical Assemblies," in <u>Physics of Fast and Intermediate Reactors</u> (IAEA, Vienna, 1962), pp. 445-455.
Oy-Flattop, R = 0.1 mm		
Oy-Flattop, R = 3 mm		
Oy-Flattop, R = 4 mm		
Oy-Flattop, R = 6 mm		
Oy-Flattop, R = 8 mm		
Oy-Flattop, R = 10 mm		
Oy-Flattop, 10.2 mm		
Oy-Flattop, 10.3 mm		
Oy-Flattop, R = 12 mm		
Oy-Flattop, 36.9 mm		
Oy-Flattop, 37.0 mm		
Oy-Flattop, R = 39 mm		
Oy-Flattop, R = 41 mm		
Oy-Flattop, R = 48 mm		
Oy-Flattop, R = 49 mm		
Oy-Flattop, R = 50 mm		
Oy-Flattop, R = 51 mm		
Oy-Flattop, 51.6 mm		
Oy-Flattop, 56.0 mm		
Oy-Flattop, 63.1 mm		
Oy-Flattop, 63.2 mm		
Oy-Flattop, R = 81 mm		
Oy-Flattop, R = 83 mm		
Oy-Flattop, 101.6 mm		
Oy-Flattop, R = 110 mm		

TABLE II (cont)

Source	Neutron Source Description and Sample Location	References
Oy-Flattop, R = 112 mm		
Oy-Flattop, 121.7 mm		
Oy-Flattop, 151.6 mm		
Oy-Flattop, R = 153 mm		
Oy-Flattop, R = 155 mm		
Pu-Flattop, Center		
Pu-Flattop, 13.6 mm		
Pu-Flattop, 15.2 mm		
Pu-Flattop, 28.8 mm		
Pu-Flattop, 30.6 mm		
Pu-Flattop, 44.3 mm		
Pu-Flattop, 46.3 mm		
Pu-Flattop, 59.5 mm		
Pu-Flattop, 62.0 mm		
Pu-Flattop, 74.8 mm		
Pu-Flattop, 90.1 mm		
Pu-Jezebel, Center		
23-Jezebel, R = 0.5 mm		
23-Jezebel, R = 2.5 mm		
23-Jezebel, 24.8 mm		
23-Jezebel, 27.0 mm		
23-Jezebel, 39.5 mm		
23-Jezebel, 40.0 mm		
23-Jezebel, 52.0 mm		
23-Jezebel, 53.0 mm		
23-Jezebel, 55.5 mm		
TCCA, R = 112.365 mm		
TCCA, R = 112.504 mm		
TCCA, R = 121.275 mm		
TCCA, R = 121.470 mm		
TCCA, R = 129.585 mm		
TCCA, R = 129.836 mm		
TCCA, R = 138.595 mm		
TCCA, R = 138.902 mm		
TCCA, R = 147.605 mm		
TCCA, R = 147.968 mm		
TCCA, R = 162.815 mm		
TCCA, R = 163.234 mm		
TCCA, R = 206.525 mm		
TCCA, R = 207.000 mm		
TCCA, R = 293.035 mm		
TCCA, R = 293.566 mm		
	Jezebel is the name given to a bare plutonium critical assembly. Pu-Jezebel refers to the original assembly, which contained 16.6 kg Pu, of which 4.5% was ^{240}Pu . A similar bare critical assembly was constructed of 16.6 kg ^{233}U , and this assembly is called 23-Jezebel. The sample irradiation positions indicated were measured from the center of the critical assembly.	<p><u>Pu-Jezebel</u>: G. A. Jarvis, G. A. Linenberger, J. D. Orndoff, and H. C. Paxton, "Two Plutonium-Metal Critical Assemblies," Nucl. Sci. Eng. <u>8</u>, 525-531 (1960).</p> <p><u>23-Jezebel</u>: G. E. Hansen and H. C. Paxton, "Reevaluated Critical Specifications of Some Los Alamos Fast-Neutron Systems," Los Alamos Scientific Laboratory report LA-4208 (June 1969).</p>
	The Tungsten-Carbide Critical Assembly (TCCA) consisted of three concentric spherical shells. The inner shell contained 65 kg uranium, enriched to 93.16% in ^{235}U . The uranium was surrounded by a 334-kg tungsten-carbide shell that contained .5 wt% cobalt. The outer shell was 1508 kg of type 4340 steel. Sample irradiation distances are given relative to the center of the uranium spherical shell.	G. E. Hansen and H. C. Paxton, "A Tungsten-Carbide Critical Assembly," Los Alamos Scientific Laboratory report LA-5946-MS (April 1975).

TABLE II (cont)

Source	Neutron Source Description and Sample Location	References
Thermal	Thermal-neutron irradiations were performed either at the Los Alamos Homogeneous Reactor (Water-Boiler) or at the Fast Plutonium Reactor (Clementine). The cadmium thermal to epithermal ratio generally was $\approx 500:1$.	<u>Water Boiler reactor:</u> L. D. P. King, "Design and Description of Water Boiler Reactors," in Proc. Intern. Conf. Peaceful Uses of At. Energy (United Nations, NY, 1956), Vol. 2, Part C, pp. 372-391. <u>Fast Plutonium Reactor:</u> E. T. Jurney, J. H. Hall, D. B. Hall, A. M. Gage, N. H. Godbold, A. R. Sayer, and E. O. Swickard, "The Los Alamos Fast Plutonium Reactor," Los Alamos Scientific Laboratory report LA-1679 (May 1954).
Topsy, 1.1 MeV	Topsy is the name of a natural uranium reflected, spherical ^{235}U core critical assembly. The sample irradiation position (presumably at the center of the assembly) was not recorded, but the neutron energy is stated to be 1.1 MeV.	R. H. White, "Topsy, A Remotely Controlled Critical Assembly Machine," Nucl. Sci. Eng. <u>1</u> , 53-51 (1956).
VDG, 1.2 MeV	The samples were irradiated at the 2.7-MeV "short tank" Van de Graaff accelerator. Neutrons were produced by the $^3\text{H}(p,n)^3\text{He}$ reaction. The spread in neutron energies was 0.4 MeV.	The "short tank" Van de Graaff accelerator, although used many years at Los Alamos, is not well documented, even in Laboratory reports. The accelerator is mentioned by R. Taschek and A. Hemminger in "Reaction Constants for $\text{Li}^7(p,n)\text{Be}^7$," Phys. Rev. <u>74</u> , 373 (1948).
VDG, 5 MeV VDG, 8.1 MeV	The Los Alamos vertical Van de Graaff accelerator was the source of 5- and 8.1-MeV neutrons from the $^2\text{H}(d,n)^3\text{He}$ reaction. The spread in energies is 1 MeV for the former and 0.4 MeV for the latter.	A discussion of the vertical Van de Graaff accelerator is given by R. Woods, J. L. McKibben, and R. L. Henkel in "The Los Alamos Three-Stage Van de Graaff Facility," Nucl. Instrum. Methods <u>122</u> , 81-97 (1974).
CW, 14 MeV	The Los Alamos Cockcroft-Walton accelerator was the source of 14-MeV neutrons from the $^3\text{H}(d,n)^4\text{He}$ reaction.	G. R. Keepin, <u>Physics of Nuclear Kinetics</u> (Addison-Wesley, Reading, MA, 1965), p. 260 has a photograph of the Los Alamos Cockcroft-Walton accelerator.

TABLE III
NEUTRON-INDUCED FISSION OF ^{232}Th

CN, 14 MEV Q = 1.0000				

	R	PSD	YIELD	

97	1,370	1,4	8,149+00	97
109	90,90	1,4	2,723+00	109
111	195,7	2,9	3,868+00	111
112	220,6	1,3	2,793+00	112
115G	276,2	1,9		115G
SEJ				

TABLE IV
NEUTRON-INDUCED FISSION OF ^{235}U

CD-WRAPPED Q = 1.0001(111)				RIG-YEN, R=7,75 MM Q = 1.0000(147)			OY-FLATTOP, R=39 MM Q = 1.0000(147)			OY-FLATTOP, R=155MM Q = 1.0000(147)			OY-FLATTOP, R=83 MM Q = 1.0000(147)		
-----				-----			-----			-----			-----		
R	PSD	YIELD		R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD
-----				-----			-----			-----			-----		
95				,9790 3,9 6,328+00											95
97	,9910	1,4	5,895+00												97
111	,9270	2,9	1,832+00												111
112	,8640	1,3	1,094+00												112
115G	,8250	1,9													115G
136I	,9340	2,7	4,799+00												136I
140				,9630 1,5 6,086+00											140
147				,9800 3,3 2,225+00			,9700	3,3	2,202+00	,9700	3,3	2,202+00	,9650	3,3	2,192+00 147

TABLE IV (cont)
NEUTRON-INDUCED FISSION OF ^{235}U

89	0Y=FLATTOP,R=112MM Q = 1,0000(147) R PSD YIELD	0Y=FLATTOP,R=51 MM Q = 1,0000(147) R PSD YIELD	0Y=FLATTOP,R=48 MM Q = 1,0000(147) R PSD YIELD	TCCA,M=293,035 MM Q = ,9999(111) R PSD YIELD	0Y=FLATTOP,151.6MM Q = ,9998(115G) R PSD YIELD	89
111				1,047 2,4 5,000:00		111
115G				1,062 2,9 2,097-02	1,173 1,9	115G
136I				1,256 2,7 6,660-03		136I
137				1,008 2,5 6,312+00		137
140				,9920 1,5 6,260+00		140
143				1,029 ,8 6,139+00		143
144				1,030 4,5 5,615+00		144
147				,9900 2,7 2,546+00		147
153	0628 3,3 2,183+00	0570 3,3 2,171+00	0470 3,3 2,149+00	1,120 3,0 1,814-01		153
156				1,078 1,7 1,455+02		156

TABLE IV (cont)
NEUTRON-INDUCED FISSION OF ^{235}U

	TCCA, R=206.525 MM Q = .9996(111)			OY=FLATTOP, 121.7MM Q = .9993(1156)			BIG-TEN=, R=6.98 MM Q = .9992(111)			CLEMENTINE, 5W Q = .9991(111)			CLEMENTINE, 5W Q = .9991(111)		
	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD
89	1.002	2.4	4.020+00				.9540	1.8	4.618+00						89
91Y							.9710	3.4	5.741+00						91Y
95							.9630	3.9	6.218+00						95
97										.9690	1.4	5.757+00			97
109													2.211	1.4	6.613+02 109
111	1.201	2.9	2.356+02				1.441	6.9	2.845+02	1.506	2.9	2.973+02			111
112										1.500	1.3	1.998+02			112
1156				1.404	1.9		1.462	.7		1.610	1.9				1156
1361	1.329	2.7	7.003+03				1.520	4.5	8.059+03	1.490	2.7	7.400+03			1361
137	.9990	2.5	6.216+00				.9720	4.0	6.086+00						137
140	.9710	1.5	6.092+00				.9530	1.5	6.016+00						140
141							1.021	3.0	6.006+00						141
143	1.050	.8	6.225+00				.9940	3.9	5.930+00						143
144	.9960	4.5	5.395+00				.9490	4.4	5.172+00	.9430	4.5	5.140+00			144
147	.9950	2.7	2.243+00				.9610	3.3	2.100+00						147
153	1.000	3.0	1.009+01												153
156	1.153	1.7	1.547+02				1.210	3.1	1.633+02						156

TABLE IV (cont)
NEUTRON-INDUCED FISSION OF ²³⁵U

	TCCA, R=162.815 MM Q = .9990(111) ----- R PSD YIELD -----	CFRNF Q = .9989(111) ----- R PSD YIELD -----	PU=FLATTOP, 90.1 MM Q = .9989(111) ----- R PSD YIELD -----	OY=FLATTOP, 101.6MM Q = .9989(115G) ----- R PSD YIELD -----	TCCA, R=147.625 MM Q = .9986(111) ----- R PSD YIELD -----	
89	.9910 2.4 4.795+00		.9462 2.4 4.576+00		.9810 2.4 4.742+00	89
95		.9640 3.9 6.221+00				95
111	1.510 2.9 2.996+02	1.595 2.7 3.147+02	1.610 2.9 3.176+02		1.735 2.9 3.421+02	111
115G		1.550 .7	1.630 1.9	1.568 1.9		115G
1361	1.490 2.7 7.897+03	1.514 4.5 8.022+03			1.644 2.7 8.704+03	1361
137	.9980 2.5 6.196+00	.9650 4.8 6.038+00			.9950 2.5 6.221+00	137
140	.9730 1.5 6.141+00	.9250 1.5 5.836+00	.9460 1.5 5.930+00		.9530 1.5 6.008+00	140
143	.9970 .8 5.945+00				.9600 .8 5.838+00	143
144	.9740 4.5 5.307+00		.8990 4.5 4.897+00		.9680 4.5 5.269+00	144
147	1.000 2.7 2.200+00	.9420 3.3 2.136+00	.9960 2.7 2.258+00		.9950 2.7 2.254+00	147
153	1.000 3.0 1.619+01				1.030 3.0 1.666+01	153
156	1.252 1.7 1.690+02		1.270 1.7 1.713+02		1.315 1.7 1.773+02	156

TABLE IV (cont)
NEUTRON-INDUCED FISSION OF ^{235}U

	PU-FLATTOP, 74.6 MM Q = .9985(111)			CAPSULE AT 0 IN. Q = .9983(115G)			TCCA, R=138.595 MM Q = .9982(111)			PU-FLATTOP, 59.5 MM Q = .9981(111)			TCCA, R=129.585 MM Q = .9977(111)		
	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD
89			.9420 2,4 4,550+00						.9900 2,4 4,782+00			.9310 2,4 4,499+00			.9730 2,4 4,701+00 89
97				.9850 1,4 5,840+00											97
111	1,790	2,9	3,530+02				1,904	2,9	3,870+02	2,040	2,9	4,021+02	2,240	2,9	4,430+02 111
112				1,900	1,3	2,390+02									112
115G	1,030	1,9		1,060	1,9					2,140	1,9				115G
136I							1,803	2,7	9,540+03				1,924	2,7	1,010+02 136I
137							1,001	2,5	6,255+00				.9840	2,5	6,149+00 137
140	.9440	1,5	5,952+00				.9600	1,5	6,099+00	.9530	1,5	6,007+00	.9570	1,5	6,030+00 140
143							.9830	.8	5,852+00				.9530	.8	5,674+00 143
144	.8940	4,5	4,667+00	.9230	4,5	5,021+00	.9640	4,5	5,244+00	.8740	4,5	4,756+00	.9210	4,5	5,010+00 144
147	.9790	2,7	2,210+00				1,005	2,7	2,275+00	.9600	2,7	2,192+00	.9800	2,7	2,237+00 147
153							1,250	3,0	2,020+01				1,220	3,0	1,972+01 153
156	1,310	1,7	1,766+02				1,405	1,7	1,893+02	1,380	1,7	1,860+02	1,473	1,7	1,985+02 156
161							2,600	5,6	2,459+04				3,200	5,6	2,878+04 161

TABLE IV (cont)
NEUTRON-INDUCED FISSION OF ^{235}U

	VDG, 1.2 MEV Q = .9975(115G)			TCCA, R=121,275 MM Q = .9973(111)			PU-FLATTOP, 44.3 MM Q = .9970(111)			OY-FLATTOP, 63.2 MM Q = .9969(115G)			OY-FLATTOP, 63.1 MM Q = .9969(115G)		
	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD
89				.9920	2,4	4,786+00	.9240	2,4	4,458+00						89
111				2,474	2,9	4,868-02	2,630	2,9	5,175-02						111
115G	2,200	1,9					2,810	1,9		2,488	1,9		2,488	1,9	115G
1301				2,840	2,7	1,078-02									1301
137				.9860	2,5	6,153+00									137
140				.9400	1,5	5,914+00	.9410	1,5	5,921+00						140
143				.9910	.8	5,892+00									143
144				.9590	4,5	5,209+00	.8630	4,5	4,688+00						144
147				1,002	2,7	2,265+00	.9650	2,7	2,162+00						147
153				1,270	3,0	2,050+01									153
156				1,507	1,7	2,028-02	1,520	1,7	2,045-02						156
161				3,507	5,6	3,137-04									161

TABLE IV (cont)
NEUTRON-INDUCED FISSION OF ^{235}U

	OY-FLATTOP, CENTER Q = .9964(111)			OY-FLATTOP, R=8 MM Q = .9964(111)			OY-FLATTOP, R=12 MM Q = .9964(111)			OY-FLATTOP, CENTER Q = .9964(111)			OY-FLATTOP, CENTER Q = .9964(111)			
	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	
95	.9580	3.9	6.162+00	.9920	3.9	6.581+00										95
144										.8750	4.5	4.757+00				144
147	.9703	3.3	2.192+00	.9540	3.3	2.156+00	.9600	3.3	2.169+00	.9910	2.7	2.242+00	.9470	2.7	2.140+00	147
	GODIVA-IV GLORY H Q = .9964(111)			GODIVA-I CENTER Q = .9964(111)			PU-FLATTOP, 13.6 MM Q = .9961(111)			PU-FLATTOP, 28.8 MM Q = .9961(111)			PU-FLATTOP, CENTER Q = .9961(111)			
	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	
89				.9250	2.4	4.466+00	.9280	2.4	4.481+00	.9300	2.4	4.490+00				89
90				.9150	1.5	5.391+00										90
97				.9730	1.4	5.766+00										97
109				2.020	1.4	8.415+02										109
111				2.960	2.9	5.829+02	3.090	2.9	6.085+02	3.090	2.9	6.085+02				111
112				3.160	1.3	3.986+02										112
1156							3.530	1.9		3.330	1.9					1156
1361				2.400	2.7	1.269+02										1361
137				.9740	2.5	6.083+00										137
140							.9260	1.5	5.831+00	.9210	1.5	5.800+00				140
144							.8530	4.5	4.630+00	.8530	4.5	4.630+00				144
147	.9310	3.3	2.107+00				.9760	2.7	2.208+00	.9830	2.7	2.224+00	.9620	2.7	2.177+00	147
156				1.740	1.7	2.343+02	1.710	1.7	2.303+02	1.660	1.7	2.235+02				156
161							4.405	5.6	3.855+04	4.450	5.6	3.895+04				161

TABLE IV (cont)
NEUTRON-INDUCED FISSION OF ^{235}U

	OY=FLATTOP,50.0 MM Q = .9959(115G)			OY=FLATTOP,36.9 MM Q = .9955(115G)			OY=FLATTOP,51.6 MM Q = .9955(115G)			OY=FLATTOP,37.0 MM Q = .9954(115G)			OY=FLATTOP,R=0.1MM Q = .9951(115G)			
	-----			-----			-----			-----			-----			
	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	
	-----			-----			-----			-----			-----			
115G	2,902	1,9		3,090	1,9		3,102	1,9		3,164	1,9		3,288	1,9		115G

	OY=FLATTOP, 10.2 MM Q = .9951(115G)	CAPSULE AT 20 IN, Q = .9950(115G)	OY=FLATTOP, R=4 MM Q = .9950(115G)	OY=FLATTOP, 10.3 MM Q = .9950(115G)	PU=JEZEBEL, CENTER Q = .9948(111)	
	R PSD YIELD	R PSD YIELD	R PSD YIELD	R PSD YIELD	R PSD YIELD	
89					.9140 1,0 4,429+00	89
91Y					.8940 3,4 5,291+00	91Y
95					.9560 3,9 6,180+00	95
97		1,020 1,4 6,067+00				97
111					3,790 6,9 7,491+02	111
112		3,320 1,3 4,203+02				112
115G	3,200 1,9	3,310 1,9	3,310 1,9	3,330 1,9		115G
132					.4060 4,3 1,718+00	132
130I					2,070 4,5 1,520+02	130I
137					1,041 4,0 6,525+00	137
140					.9560 1,5 6,042+00	140
141					.8980 3,0 5,209+00	141
143					.8020 3,9 5,268+00	143
144		.9490 4,5 5,178+00			.8720 4,4 4,758+00	144
147					.9740 3,3 2,212+00	147
156					1,950 3,0 2,635+02	156
161					5,200 3,0 4,568+04	161

TABLE IV (cont)
NEUTRON-INDUCED FISSION OF ^{235}U

	CAPSULE AT 40 IN, Q = ,9946(111)			CAPSULE AT 46 IN, Q = ,9948(111)			CAPSULE AT 45 IN, Q = ,9934(115G)			23-JEZEBEL, R=2,5MM Q = ,9938(115G)			PU-JEZEBEL, CENTER Q = ,9929(115G)		
	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD
97				1,030	1,4	6,003+00	1,020	1,4	6,023+00						97
129	4,795	1,4	1,426+01												129
111				3,792	2,9	7,441+02									111
112				4,090	1,3	5,141+02									112
115G				4,290	1,9		4,060	1,9		4,250	1,9		4,260	1,9	115G
140													,9350	1,5	5,066+00 140
144													,8480	4,5	4,594+00 144
147													,9720	2,7	2,191+00 147
	23-JEZEBEL, R=2,5MM Q = ,9929(115G)			23-JEZEBEL, 52,0 MM Q = ,9928(115G)			23-JEZEBEL, 40,0 MM Q = ,9928(115G)			23-JEZEBEL, 27,0 MM Q = ,9927(115G)			23-JEZEBEL, 39,5 MM Q = ,9927(115G)		
	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD
115G	4,290	1,9		4,310	1,9		4,320	1,9		4,360	1,9		4,360	1,9	115G
	23-JEZEBEL, 24,0 MM Q = ,9927(115G)			23-JEZEBEL, 53,0 MM Q = ,9927(115G)			23-JEZEBEL, 55,5 MM Q = ,9926(115G)			VDC, 5 MEV Q = ,9921(111)			VDC, 8,1 MEV Q = ,9571(111)		
	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD
111										9,122	2,9	1,772+01	25,00	2,9	4,724+01 111
115G	4,370	1,9		4,380	1,9		4,420	1,9		11,10	1,9		10,00	1,9	115G
136I										6,100	2,7	3,190+02			136I
143										,4610	,8	5,054+00			143

TABLE IV (cont)
NEUTRON-INDUCED FISSION OF ^{235}U

	CW, 14 MEV Q = .8794(111)			CW, 14 MEV Q = .8785(111)			CW, 14 MEV Q = .8780(111)			CW, 14 MEV Q = .8780(111)			
	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	
821							44.70	3.0	4.833-03				821
83							2.500	3.0	1.166+00				83
89	1.010	2.4	4.324+00				1.090	2.4	4.638+00				89
90				.9710	1.5	5.044+00				.9340	1.5	4.849+00	90
913							.9900	2.5	5.145+00				913
961							6.000	3.0	3.157-03				961
97							1.050	1.4	5.484+00				97
103							1.300	3.0	3.802+00				103
105							2.410	3.0	2.159+00				105
106							4.860	3.0	1.669+00				106
109							51.00	1.4	1.341+00				109
111	74.40	2.9	1.293+00				76.30	2.9	1.324+00				111
112							94.70	1.3	1.053+00				112
115M	102.4	4.4											115M
115G	99.40	1.9					101.4	1.9					115G
121							96.00	3.0					121
125							74.60	3.0					125
126							30.00	3.0	1.930+00				126
127							20.60	3.0	2.357+00				127
129							2.700	3.0	1.506+00				129
131							1.620	2.2	4.030+00				131
132							1.130	3.0	4.198+00				132
136I							46.00	2.7	2.144-01				136I
139							.8900	3.0	5.064+00				139
140	.8740	1.5	4.050+00				.8600	1.5	4.772+00				140

TABLE IV (cont)

NEUTRON-INDUCED FISSION OF ^{235}U

	CW, 14 MEV Q = .8794(111)	CW, 14 MEV Q = .8785(111)	CW, 14 MEV Q = .8780(111)	CW, 14 MEV Q = .8780(111)	
	R PSD YIELD	R PSD YIELD	R PSD YIELD	R PSD YIELD	
143	.7830 ,8 4,112+80		,7780 ,8 4,038+80		143
144	,6910 4,5 3,316+80		,6980 4,5 3,386+80		144
147	,8720 2,7 1,737+80				147
156	4,850 1,7 5,764-82		4,680 1,7 5,459-82		156
161	66,20 5,6 5,114-83				161
SEE					

TABLE V
NEUTRON-INDUCED FISSION OF ^{236}U

147	QY-FLATTOP, R=8 MM Q = 1.0000 R PSD YIELD 0.9820 3.3 2.230+00	QY-FLATTOP, R=50 MM Q = 1.0000 R PSD YIELD 0.9990 3.3 2.269+00	QY-FLATTOP, R=10 MM Q = 1.0000 R PSD YIELD 1.0000 3.3 2.271+00	QY-FLATTOP, R=39 MM Q = 1.0000 R PSD YIELD 1.061 3.3 2.410+00	QY-FLATTOP, R=49 MM Q = 1.0000 R PSD YIELD 1.050 3.3 2.305+00 147
89	QY-FLATTOP, R=81 MM Q = 1.0000 R PSD YIELD	QY-FLATTOP, R=110 MM Q = 1.0000 R PSD YIELD	QY-FLATTOP, R=153 MM Q = 1.0000 R PSD YIELD	QY-FLATTOP, R=3 30+00 0.7920 1.0 3.030+00	89
111				3.270 6.9 6.463+02 111	111
1150				3.020 .7	1150
1361				0.000 4.5 4.246+03 1361	1361
137				0.9680 4.0 6.060+00 137	137
140				0.9980 1.5 6.300+00 140	140
144				0.9210 4.4 5.026+00 144	144
147	0.9850 3.3 2.237+00	0.9900 3.3 2.248+00	1.020 3.3 2.335+00	1.034 3.3 2.346+00 147	147
156				2.510 3.0 3.392+02 156	156
161				5.550 3.0 4.075+04 161	161
8E3					8E3

TABLE VI
NEUTRON-INDUCED FISSION OF ^{237}Np

	BIG-TEN, R=6.98 MM $Q = 1.0000$			TOPSY, 1.1 MEV $Q = 1.0000$			
	R	PSD	YIELD	R	PSD	YIELD	
89				.2700	2.4	1.300+00	89
95	.9720	3.9	6.203+00				95
97				1.040	1.4	6.106+00	97
111	4.260	2.7	8.420-02	5.300	2.9	1.040-01	111
115G	2.300	.7		3.500	1.9		115G
125				4.700	3.0		125
127				3.000	3.0	3.909-01	127
132				1.150	3.8	4.866+00	132
136I	9.720	4.5	5.159-02				136I
137	.9260	4.0	5.004+00				137
140	.8450	1.5	5.341+00	.8000	1.5	5.056+00	140
144				.7500	4.5	4.092+00	144
147	.9550	3.3	2.169+00				147
156				8.300	1.7	1.122-01	156
3EJ							

TABLE VII
NEUTRON-INDUCED FISSION OF ^{238}U

	PU-FLATTOP, CENTER Q = 1,0140(147)			DY-FLATTOP, CENTER Q = 1,0140(147)			DY-FLATTOP, CENTER Q = 1,0140(147)			PU-GEZEEL, CENTER Q = 1,0140(147)			BIG-TEN, R=7.75 MM Q = 1,0140(147)		
	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD
95									.7550 3,9 4,928+00				.7690 3,9 5,021+00	95	
140	.9130	1,5	5,627+00							.9000 1,5 5,744+00			.8730 1,5 5,573+00	140	
144				.7760	4,5	4,276+00				.7730 4,5 4,254+00				144	
147				1,180	2,7	2,706+00	1,170	3,3	2,683+00	1,143	2,7	2,621+00	1,130	3,3	2,613+00 147

	CAPSULE AT 48 IN, Q = 1,0124(1156)			TCCA, R=293,566 MM Q = 1,0118(111)			TCCA, R=207,000 MM Q = 1,0107(111)			TCCA, R=163,234 MM Q = 1,0104(111)			TCCA, R=147,968 MM Q = 1,0103(111)		
	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD
89													.5740 2,4 2,821+00	89	
97	.9060	1,4	5,444+00											97	
111				2,669	2,9	5,330-02	3,387	2,9	6,766-02	3,620	2,9	7,255-02	3,674	2,9	7,363-02 111
112	4,600	1,3	5,884+02											112	
1156	3,350	1,9		1,542	1,9		2,280	1,9		2,587	1,9		2,625	1,9	1156
140				.9320	1,5	5,952+00	.9070	1,5	5,794+00	.9000	1,5	5,755+00	.8920	1,5	5,717+00 140
143	.8190	.8	4,942+00							.9090	.8	5,493+00	.8240	.8	4,990+00 143
144										.8620	4,5	4,759+00	.8310	4,5	4,598+00 144
147				1,179	2,7	2,705+00	1,177	2,7	2,702+00	1,174	2,7	2,698+00	1,170	2,7	2,694+00 147
153				1,680	3,0	2,752-01	2,170	3,0	3,556-01	2,420	3,0	3,969-01	2,540	3,0	4,175-01 153

TABLE VII (cont)
NEUTRON-INDUCED FISSION OF ^{238}U

TCCA, R=138.922 MM Q = 1.2131(111)				GODIVA-1 CENTER Q = 1.0099(111)				BIG-TEN, R=6.98 MM Q = 1.0098(111)				TCCA, R=112.504 MM Q = 1.0098(111)				TCCA, R=129.836 MM Q = 1.0098(111)			
R PSD YIELD				R PSD YIELD				R PSD YIELD				R PSD YIELD				R PSD YIELD			
89	.5740	2,4	2,807+00	.5540	2,4	2,710+00		.5760	2,4	2,818+00		.5730	2,4	2,816+00		89			
90				.5780	1,5	3,450+00										90			
95								.8030	3,9	5,240+00						95			
97				.9120	1,4	5,475+00										97			
100				7,150	1,4	2,162-01										100			
111	3,791	2,9	7,562-02	3,960	2,9	7,900-02	4,000	2,7	7,900-02	4,003	2,9	7,907-02	4,003	2,9	8,023-02	111			
112				3,900	1,3	4,984+02										112			
1150	2,714	1,9		3,000	1,9		2,980	.7		2,814	1,9		2,888	1,9		1150			
137							.8910	4,0	5,638+00	.9820	2,5	6,214+00				137			
140	.8930	1,5	5,697+00				.9220	1,5	5,882+00	.9080	1,5	5,794+00	.9170	1,5	5,877+00	140			
143	.7610	.8	4,587+00							.7890	.8	4,757+00	.7780	.8	4,711+00	143			
144	.8170	4,5	4,540+00							.8430	4,5	4,644+00	.8340	4,5	4,615+00	144			
147	1,142	2,7	2,618+00				1,197	3,3	2,744+00	1,160	2,7	2,660+00	1,176	2,7	2,700+00	147			
153	2,540	3,0	4,156-01							2,630	3,0	4,304-01	2,690	3,0	4,422-01	153			
156	4,771	1,7	6,508+02	4,820	1,7	6,575+02				4,900	1,7	6,821+02	4,971	1,7	6,812+02	156			
161										13,60	5,6	1,206+03				161			

TABLE VII (cont)

NEUTRON-INDUCED FISSION OF ^{238}U

	TCA, R=121.478 MM Q = 1.0098(111)			PU-FLATTOP, 46.3 MM Q = 1.0096(111)			PU-FLATTOP, 46.3 MM Q = 1.0095(111)			PU-FLATTOP, 25.6 MM Q = 1.0074(111)			PU-FLATTOP, 15.2 MM Q = 1.0283(111)		
	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD
89	.5720	2.4	2.799+00	.5420	2.4	2.663+00	.5340	2.4	2.620+00	.5430	2.4	2.668+00	.5514	2.4	2.694+00
111	4.002	2.9	8.067+02	4.160	2.9	8.337+02	4.250	2.9	8.504+02	4.290	2.9	8.598+02	4.340	2.9	8.655+02
115G	2.859	1.9		3.030	1.9		3.140	1.9		3.180	1.9		3.210	1.9	
137	.9110	2.5	5.766+00												
140	.9110	1.5	5.814+00	.9050	1.5	5.800+00	.8940	1.5	5.721+00	.8890	1.5	5.697+00	.8960	1.5	5.714+00
145	.7900	.8	4.764+00												
144	.8410	4.5	4.634+00	.7860	4.5	4.349+00	.7660	4.5	4.232+00	.7760	4.5	4.294+00	.7650	4.5	4.234+00
147	1.158	2.7	2.656+00	1.160	2.7	2.671+00	1.160	2.7	2.667+00	1.160	2.7	2.671+00	1.150	2.7	2.635+00
153	2.590	3.0	4.240+01												
156	4.985	1.7	6.803+02	4.960	1.7	6.797+02	4.970	1.7	6.800+02	5.060	1.7	6.934+02	5.020	1.7	6.818+02
161													13.60	5.6	1.205+03

TABLE VII (cont)
NEUTRON-INDUCED FISSION OF ^{238}U

	PU-JEZEBEL, CENTER Q = 1.0090(111)			PU-JEZEBEL, CENTER Q = 1.0090(111)			VDS, 8.1 MEV Q = .9895(111)			CW, 14 MEV Q = .9300(111)			CW, 14 MEV Q = .9276(111)		
	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD
89				.5450	1.8	2.665+00				.6640	2.4	2.992+00			89
90													.5890	1.5	3.231+00
91Y				.5650	3.4	3.374+00									91Y
95				.7860	3.9	4.605+00									95
111				4.560	6.9	9.094-02	18.00	2.9	3.300+01	62.00	2.9	1.140+00			111
115M										84.40	4.4				115M
115G							16.00	1.9		73.70	1.9				115G
136I				.2950	4.5	1.580-03							5.100	2.7	2.511-02
137				.9130	4.0	5.774+00									137
140	.9000	1.5	5.770+00	.9350	1.5	5.963+00				.8110	1.5	4.767+00			140
141				.7840	3.0	4.659+00									141
143				.7430	3.9	4.477+00				.7210	.8	4.004+00			143
144	.7730	4.5	4.279+00	.8040	4.4	4.427+00				.7260	4.5	3.684+00			144
147	1.140	2.7	2.626+00	1.147	3.3	2.628+00				1.030	2.7	2.175+00			147
156				5.300	3.0	7.227-02				8.950	1.7	1.125-01			156
161				14.09	3.0	1.320-03				101.0	5.4	8.251-03			161

TABLE VII (cont)
NEUTRON-INDUCED FISSION OF ^{238}U

	CM, 14 MEV Q = .9276(111)			CM, 14 MEV Q = .9252(111)			
	R	PSD	YIELD	R	PSD	YIELD	
89				.6900	2.4	3.308+00	89
90	.6120	1.5	3.348+00				90
97				.9400	1.4	5.531+00	97
105				3.900	3.0	4.018+00	105
111				65.60	2.9	1.207+00	111
115G				74.00	1.9		115G
121				69.00	3.0		121
125				36.00	3.0		125
127				14.10	3.0	1.017+00	127
132				1.140	3.0	4.772+00	132
136I	5.000	2.7	2.455+02	5.100	2.7	2.678+02	136I
140				.7900	1.5	4.940+00	140
144				.7500	4.5	4.049+00	144
150				0.100	1.7	1.003+01	150
SEJ							

PU-JEZERELE, CENTER Q = 1,0200	CAPSULE AT 40 IN, Q = ,9841(115G)	CAPSULE AT 40 IN, Q = ,9841(115G)	OY-FLATTOP, R=155MM Q = ,9822(147)	OY-FLATTOP, R=83 MM Q = ,9822(147)
R PSD YIELD	R PSD YIELD	R PSD YIELD	R PSD YIELD	R PSD YIELD
69 ,3940 2,4 1,875+00				
97 ,8700 1,4 5,003+00		,8990 1,4 5,252+00		
109	,69,00 1,4 2,032+00			
112		10,40 1,3 1,791+01		
1156		7,500 1,9		1156
1361 24,60 2,7 1,387+01		26,20 2,7 1,366+01		1361
137 1,020 2,5 6,200+00				137
144 ,6530 4,5 3,500+00				144
147			,8890 3,3 1,983+00	,8940 3,3 2,030+00 147

	QY-FLATTOP,R=81 MM Q = ,9822(147)	QY-FLATTOP,R=112MM Q = ,9822(147)	QY-FLATTOP,R=51 MM Q = ,9822(147)	QY-FLATTOP,R=48 MM Q = ,9822(147)	THERMAL Q = ,9677(111)
	R PSD YIELD	R PSD YIELD	R PSD YIELD	R PSD YIELD	R PSD T FLD
89					,3470 2,4 1,626+00 89
90					,3310 1,5 1,893+00 90
97					,8680 1,4 4,947+00 97
111					16.40 2,9 3,135+01 111
112					9,860 1,3 1,207+01 112
115G					3,850 1,9 115G
136I					15,80 2,7 8,111+02 136I
137					1,070 2,5 4,487+00 137
140					,8420 1,5 5,147+00 140
144					,6710 4,5 3,541+00 144
147	,8960 3,3 2,092+00	,8980 3,3 1,973+00	,9080 3,3 1,995+00	,9170 3,3 2,015+00	147
156					9,000 1,7 1,187+01 156

TABLE III (cont)
NEUTRON-INDUCED FISSION OF ^{239}Pu

	THERMAL Q = .9677(111)			THERMAL Q = .9678(111)			BIG-1ENR224.9d MM Q = .9671(111)			CLEMENTINE, SW Q = .9668(111)			CLEMENTINE, SW Q = .9666(111)		
	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD
89							.3500	1.8	1.630+00						89
91Y							.4300	3.4	2.490+00						91Y
95							.6930	3.9	4.317+00						95
97										.8720	1.4	4.998+00			97
109	67.16	1.4	1.985+00										63.60	1.4	1.838+00
111				16.50	2.9	3.153+01	17.00	2.7	3.238+01	17.40	2.9	3.314+01			111
112										18.30	1.3	1.257+01			112
115G				3.485	1.9		4.110	.7		4.510	1.9				115G
136I				14.96	2.7	7.677+02	14.70	4.5	9.565+02	14.90	2.7	7.622+02			136I
137							1.820	4.0	6.161+00						137
140							.8280	1.5	5.483+00						140
141							.8610	3.0	4.887+00						141
143							.7570	3.9	4.357+00						143
144							.6730	4.4	3.539+00	.6570	4.5	3.455+00			144
147							.8830	3.3	1.932+00						147
150							9.650	3.0	1.257+01						150

TABLE VIII (cont)
NEUTRON-INDUCED FISSION OF ^{239}Pu

	OY-FLATTOP, R=12 MM Q = .9637(111)			OY-FLATTOP, CENTER Q = .9637(111)			OY-FLATTOP, CENTER C = .9637(111)			GODIVA-I CENTER Q = .9637(111)			OY-FLATTOP, R=6 MM Q = .9637(111)		
	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD	R	PSD	YIELD
89										.3760	2.4	1.755+00			89
92										.3820	1.5	2.176+00			92
95				.7210	3.9	4.491+00							.7490	3.9	4.665+00
97										.8620	1.4	4.940+00			97
109										45.60	1.4	1.316+00			109
111										20.80	2.9	3.961+01			111
112										13.00	1.3	1.506+01			112
115G										6.220	1.9				115G
116I										22.60	2.7	1.156+01			116I
147	.9100	3.3	1.992+00	.9600	3.3	2.110+00	.8900	2.7	1.967+00				.8960	3.3	1.960+00

TABLE VIII (cont.)
NEUTRON-INDUCED FISSION OF ^{239}Pu

	ON-FLATTOP, CENTER Q = .9633(111)	PU-FLATTOP, CENTER Q = .9633(111)	PU-FLATTOP, CENTER Q = .9633(111)	PU-JEJECU, CENTER Q = .9628(111)	CH, 10 MEV Q = .9835(111)
	R PSD YIELD	R PSD YIELD	R PSD YIELD	R PSD YIELD	R PSD YIELD
89		3678 2.4 1.747+00		3763 1.6 1.793+23	89
91V				.4230 3.4 2.464+00	91V
95				.7288 3.9 4.631+00	95
97					.8330 1.4 4.377+00 97
99					94.40 1.4 2.498+00 109
111					117.1 2.9 2.845+00 111
112					123.4 1.3 1.380+00 112
1154	5.770 4.4		21.10 2.9 4.096+01		115M
1155		6.060 4.4			115C
1156		6.170 1.9			
1157				.3770 4.3 1.574+00	132
1301		25.40 2.7 1.324+01		26.30 4.5 1.374+01	1361
137		1.020 2.5 6.268+00		1.010 4.0 6.279+00	137
143		.0250 1.5 5.122+00		.0400 1.5 5.224+00	140
141				.0220 3.0 4.764+00	141
143				.7000 3.9 4.114+00	143
144	6.670 4.5 3.398+00		.6100 4.5 3.291+00	.6360 4.4 3.015+00	144
147	.9290 2.7 2.630+00	.9270 2.7 2.660+00	.0950 2.7 1.996+00	.9270 3.3 2.872+00	147
156		11.00 1.7 1.468+01		11.99 3.0 1.595+01	156
161		92.00 5.6 7.937+03		101.2 3.0 8.747+03	161

TABLE VIII (cont)
NEUTRON-INDUCED FISSION OF ^{239}Pu

	$C^H, 14 \text{ MEV}$		$C^H, 14 \text{ MEV}$	
	$G = .6828(111)$		$G = .8865(111)$	
	R	PSD YIELD	R	PSD YIELD
99			.4970	2.4 2.121+80
97	.8500	1.4 4.459+03		
111			121.0	2.9 2.186+80
1156			133.0	1.9
1361			162.0	2.7 7.571-01
140			.7520	1.5 4.105+80
144			.5980	4.5 2.673+80
147			.9430	2.7 1.886+80
156			19.30	1.7 2.297+01
161			254.0	5.6 1.964+02
3EJ

Fig. 1. Neutron-induced fission of ^{235}U .

Fig. 3. Neutron-induced fission of ^{235}U .

Fig. 2. Neutron-induced fission of ^{235}U .

Fig. 4. Neutron-induced fission of ^{235}U .

Fig. 5. Neutron-induced fission of ^{235}U .

Fig. 7. Neutron-induced fission of ^{235}U .

Fig. 6. Neutron-induced fission of ^{235}U .

Fig. 8. Neutron-induced fission of ^{235}U .

Fig. 9. Neutron-induced fission of ^{235}U .

Fig. 11. Neutron-induced fission of ^{235}U .

Fig. 10. Neutron-induced fission of ^{235}U .

Fig. 12. Neutron-induced fission of ^{235}U .

Fig. 13. Neutron-induced fission of ^{235}U .

Fig. 15. Neutron-induced fission of ^{238}U .

Fig. 14. Neutron-induced fission of ^{235}U .

Fig. 16. Neutron-induced fission of ^{238}U .

Fig. 17. Neutron-induced fission of ^{238}U .

Fig. 19. Neutron-induced fission of ^{238}U .

Fig. 18. Neutron-induced fission of ^{238}U .

Fig. 20. Neutron-induced fission of ^{238}U .

Fig. 21. Neutron-induced fission of ^{238}U .

Fig. 23. Neutron-induced fission of ^{238}U .

Fig. 22. Neutron-induced fission of ^{238}U .

Fig. 24. Neutron-induced fission of ^{238}U .

Fig. 25. Neutron-induced fission of ^{239}Pu .

Fig. 27. Neutron-induced fission of ^{239}Pu .

Fig. 26. Neutron-induced fission of ^{239}Pu .

Fig. 28. Neutron-induced fission of ^{239}Pu .

Fig. 29. Neutron-induced fission of ^{239}Pu .

Fig. 31. Neutron-induced fission of ^{239}Pu .

Fig. 30. Neutron-induced fission of ^{239}Pu .

Fig. 32. Neutron-induced fission of ^{239}Pu .

Fig. 33. Neutron-induced fission of ^{239}Pu .

Fig. 34. Neutron-induced fission of ^{239}Pu .