ACTINIDE AND FISSION PRODUCT NUCLIDES ACCUMULATED IN PWR SPENT FUELS

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Abstract

In the course of dissolution study of spent nuclear fuels, destructive analyses of actinides and fission product nuclides formed in PWR spent fuels of which mean assembly burnups ranged from 6.9 to 34.2 GWd/t wered carried out. The measurements of thirty nuclides of uranium, transuranium and fission products elements were done by mass spectrometry, α-ray and 7-ray spectrometry after dissolution of round sliced pellets by nitric acid solution. The amounts of nuclides measured were compared with those calculated by two burnup codes, ORIGEN2 and SRAC-FPGS.

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1. INTRODUCTION

Knowing the concentration of actinides and fission products(FPs) in spent nuclear fuels as accurately as possible is essential to such fields as reactor operation, spent-fuel reprocessing, safeguards, waste disposal management and especially transmutation ofactinides and FPs.

Although the destructive analyses of nucl ides is mostly accurate and reliable, it is not applicable to the analyses of whole assemblies of spent fuels. Thus, from the practical point of view, the prediction of the amounts of the nuclides based on calculation is indispensable. Some burnup codes have been developed, but there have been few studies comparing observed with calculated values over a wide range of burnup rates and varieties of nuclides. The calculation method and nuclear data used in the codes must be improved by comparing the calculated values with the observed ones. In the present work, the amounts of nucl ides measured were compared with those calculated by two burnup codes, ORIGEN2[1] and SRAC-FPGS[2,3].

2. Experimental

Spent fuel samples whose measured burnup ranged 6.9 to 38.1 GWd/MTU were shown in Table 1. Other precise data such as Initial fuel compositions and irradiation histories were already reported elsewhere).

Analytical methods used were briefly illustrated in Table 2. The precise descriptions were also reported in Ref. 4). The data were all corrected for the time at 5 year after the discharge of the spent fuels. Approximate precision for each method are given in Table 3.

The burnup expressed in GWd/MTU was derived by multiplying 9.6 by the values expressed as the number of fissions per initial metal atom in percent (%FIMA);burnup(%FIMA) was obtained from the measured data by using the following equation):

$$\text{Burnup(\%FIMA)} = \left(\frac{100 \cdot {}^{148}\text{Nd}}{\text{U} \cdot Y_{148}}\right)\left(1 + \frac{\text{Pu}}{\text{U}} + \frac{{}^{148}\text{Nd}}{\text{U} \cdot Y_{148}}\right)^{-1} \qquad (1)$$

where $^{148}Nd/U$ and Pu/U stand for atom ratios of neodymium-148 to uranium and plutonium to uranium, respectively. Y_{148} denotes fission yield of ^{148}Nd, for which a value of ^{235}U for the thermal neutron was used.

3. Burnup calculations

Burnup calculations and nuclides compositions were performed using two diffrent codes, ORIGEN2 and SRAC-FPGS. The precise explanations for these codes are also given in the Ref. 4).

‘4. Results and discussion

The whole numerical data for measured and calculated values are given in Appendix 1 to 6 based on the amounts of uranium after and before irradiation.

The formatin and depletion of actinides in one sample, of which burnup was 34,100 MWd/t, is presented in Fig.1. After irradiation, total uranium decreased from 100 to 95.5, whereas formation of plutonium and total actinides were 0.95 and 0.1, respectively. The remainder 3.5 corresponded to number of fission originated from ^{235}U, ^{238}U and plutonium.

A series of actinides generated from ^{235}U and from 238U are seen in Figs. 2 and 3, respectively. The slope of these curves come to high as the number of neutrons included in the neutron capture reaction. So in low burnup accumulation of mainor actinides is low, but at high burnup amount of minor actinides increased very rapidly. In Figs. 2 and 3, calculated values are also shown for comparison. Calculated values by ORIGEN2 gave lager underestimation. Largest discrepency(about 30 %) was found for ^{243}Am, by both code, and for ^{244}Cm, by ORIGEN2. By ORIGEN2 calculation gave good agreement for uranium isotopes , there can be seen systematic lower estimation for plutonium isotopes, and this effected again the underestimation of 243Am and ^{244}Cm. This may be related to the estimation of neutron spectrum in ORIGEN2 code to be too soft, and this resulted to weak estimation of ^{238}U depletion, and weak estimation of Pu formation. SRAC-FPGS code

gave generally good estimation.

Formation of fission products are seen in Figs. 4 and 5 with calculated values. The slope for ^{137}Cs is unity, whereas for ^{134}Cs and ^{154}Eu is two, since latter nuclides are formed from ^{133}Cs and ^{153}Eu by neutron capture. Concerning the comparison measured with calculated values, 0RIGEN2 gave considerable overestimation for ^{154}Eu and ^{125}Sb. And the difference for ^{154}Eu increased with burnup. These discrenpency may be related to incorrect nuclear data used in calculation codes.

From the data for heavy nucl ides, one can calculate the fission rate, i.e. contribution of ^{235}U, ^{238}U, ^{239}Pu and ^{241}Pu fissions to total fission, shown in Fig. 6. In the calculation, one can adopt the empirical fission to capture ratio of fissile nucl ides given for typical PWR fuel. With the increase of burnup, rate of U-235 decreased and that of Pu-239 and 241 increased. The rate of U-238 fission keeps constant.

Acknowledgement

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References

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3) K. Tasaka: DCHAIN Code for Analysisi of Build-up and Decay of Nucl ides, JAERI 1250(1977).

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5) ASTM, E321(1979).

Figure Caption

Fig. 1 Amounts of actinides in formation/depletion chain of actinides in nuclear fuels for 87C08(34.1GWd/MTU).

Fig. 2 Comparison of observed and calculated values for actinides generated from U-235.

O ,● :Measured, ——:ORIGEN2, ---:SRAC-FPGS.

Fig. 3 Comparison of observed and calculated values for actinides generated from U-238.

O ,:Measured, ——:ORIGEN2, ---:SRAC-FPGS.

Fig. 4 Comparison of observed and calculated values for fission products Cs-134, Cs-137 and Eu-154.

O ,:Measured, ——:ORIGEN2, ---:SRAC-FPGS.

Fig. 5 Comparison of observed and calculated values for fission products Ce-144, Ru-106 and Sb-125.

O ,:Measured, ——:ORIGEN2, ---:SRAC-FPGS.

Fig. 6 Fission rate(%) of U-235, U-238, Pu-239 and Pu-241.

Appendix 1 Measured data based on the amounts of uranium after irradiation.

Appendix 2 Measured data based on the amounts of uranium before irradiation.

Appendix 3 Calculated data by ORIGEN2 based on the amounts of uranium after irradiation.

Appendix 4 Calculated data by ORIGEN2 based on the amounts of uranium before irradiation.

Appendix 5 Calculated data by SRAC-FPGS based on the amounts of uranium after irradiation.

Appendix 6 Calculated data by SRAC-FPGS based on the amounts of uranium before irradiation.

Appendix 7 Explanations of terms in Appendix 1-6.

Table 1 CHARACTERISTICS OF SPENT FUEL

No.	SAMPLE No.	BURNUP (GWd/t)	IRRAD. CYCLE	REACTOR (PWR)	INIT. ENRICHMENT (wt%)
1	86B02	8,3	1	M3(826MWe)	3.24
2	86B03	6.9	1	M3(826MWe)	3.24
3	86G03	21.2	2	M3(826MWe)	3.24
4	86G05	15.3	2	M3(826MWe)	3.24
5	86G07	14.6	2	M3(826MWe)	3.24
6	87C03	**29.4**	3	M3(826MWe)	**3,24**
7	87C04	**32,3**	3	M3(826MWe)	3.24
8	87C07	**33.7**	3	M3(826MWe)	3.24
9	87C08	34,1	3	M3(826MWe)	3.24
10	87H01	38,7	3	G1(559MWe)	3.42
11	87H05	38,1	3	G1(559MWe)	3.42

Table 2 ANALYTICAL METHODS

U, Pu, Nd (AMOUNT, ISOTOPIC COMPOSITION)	: MS IDMS
U-232, Np-237, Pu-236, Pu-238, Am-241, Am-242m, Am-243 Cm-242, Cm-244	: α-SPECTROMETRY
Ru-106, Sb-125, Cs-134, Cs-137, Ce-144, Eu-154	: γ-SPECTROMETRY

THE DATA ARE NORMALIZED AT 5 Y AFTER THE DISCHARGE OF SPENT FUELS

Table 3 PRECISION OF ANALYSIS

MS, IDMS

Nd- 142, 144, 145, 146, 148, 150: <0. 1%
U-238：<0. 1%, U-235：<1%, U-236: <2%,
Pu-239, 240, 241:<1%, Pu-24 2：<2%

CY-SPECTROMETRY

Pu-238：<0. 5%, Am-241, Cm244：<2%
Am-243：<5%, U-232, Am-242m, Cm-242：<3-10%
Np-237, Am-243：<10%

γ-SPECTROMETRY

Cs-134, 137, Eu-154：<3%, Ru-106：<5%
Sb-125, Ce-144：< 10%

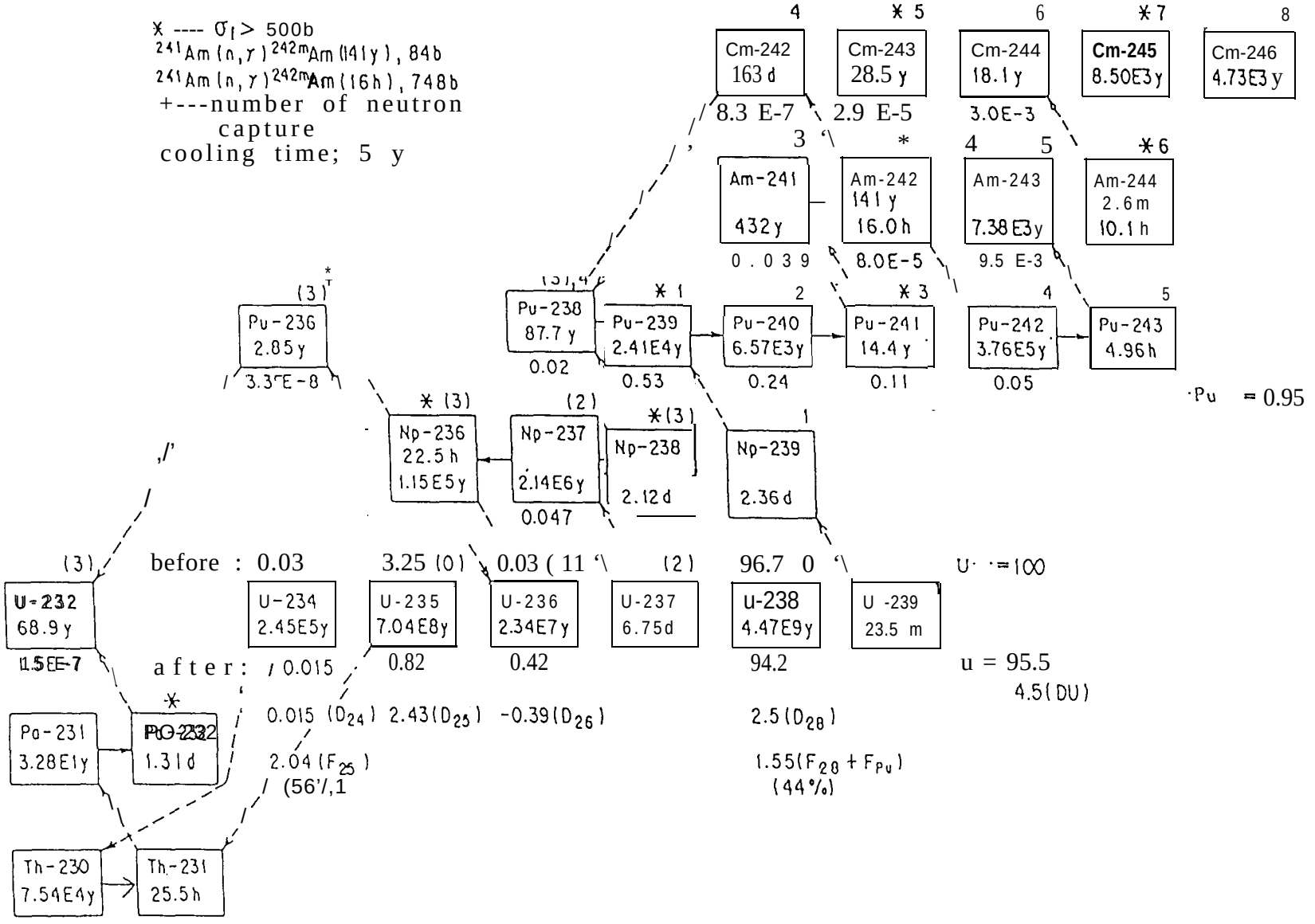

* ---- σf > 500b
241Am(n,γ)242mAm(141y), 84b
241Am(n,γ)242mAm(16h), 748b
+---number of neutron capture
cooling time; 5 y
Cm-242 163 d
Cm-243 28.5 y
Cm-244 18.1 y
Cm-245 8.50E3y
Cm-246 4.73E3 y
8.3 E-7
2.9 E-5
3.0E-3
Am-241 432y
Am-242 141 y 16.0 h
Am-243 7.38E3y
Am-244 2.6m 10.1 h
0.039
8.0E-5
9.5 E-3
Pu-236 2.85 y
3.3E-8
Pu-238 87.7 y
Pu-239 2.41E4y
Pu-240 6.57E3y
Pu-241 14.4 y
Pu-242 3.76E5y
Pu-243 4.96h
0.02
0.53
0.24
0.11
0.05
Np-236 22.5 h 1.15E5y
Np-237 2.14E6y
Np-238 2.12d
Np-239 2.36d
0.047
·Pu = 0.95
before : 0.03 3.25 (0) 0.03 (11 '\ (2) 96.7 0 '\
U· ·=100
U-232 68.9 y
U-234 2.45E5y
U-235 7.04E8y
U-236 2.34E7y
U-237 6.75d
u-238 4.47E9y
U -239 23.5 m
1.5EE-7
after : 0.015 0.82 0.42 94.2
u = 95.5
4.5(DU)
0.015 (D24) 2.43(D25) -0.39(D26) 2.5(D28)
Pa-231 3.28E1y
Pa-232 1.31d
2.04 (F25)
(56'/,1
1.55(F28 + FPu)
(44%)
Th-230 7.54E4y
Th-231 25.5h

Fig. 1

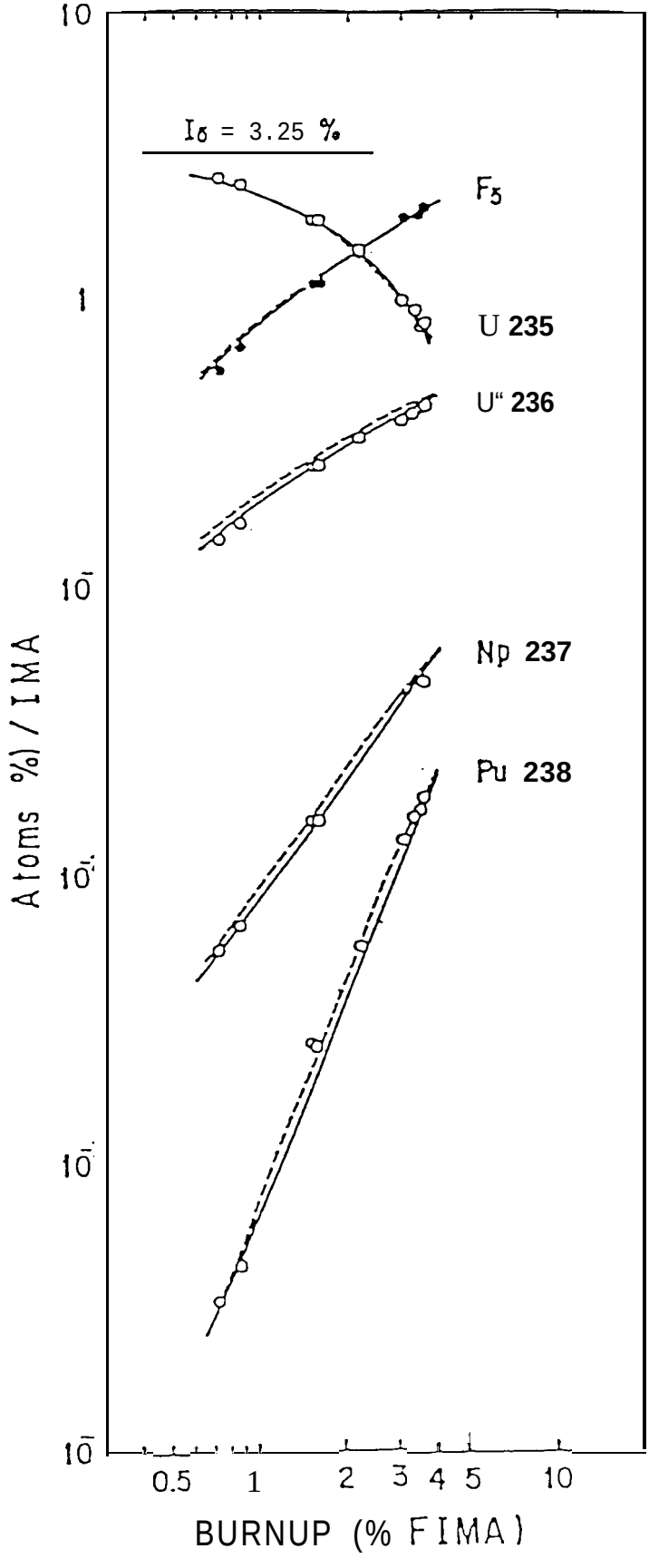
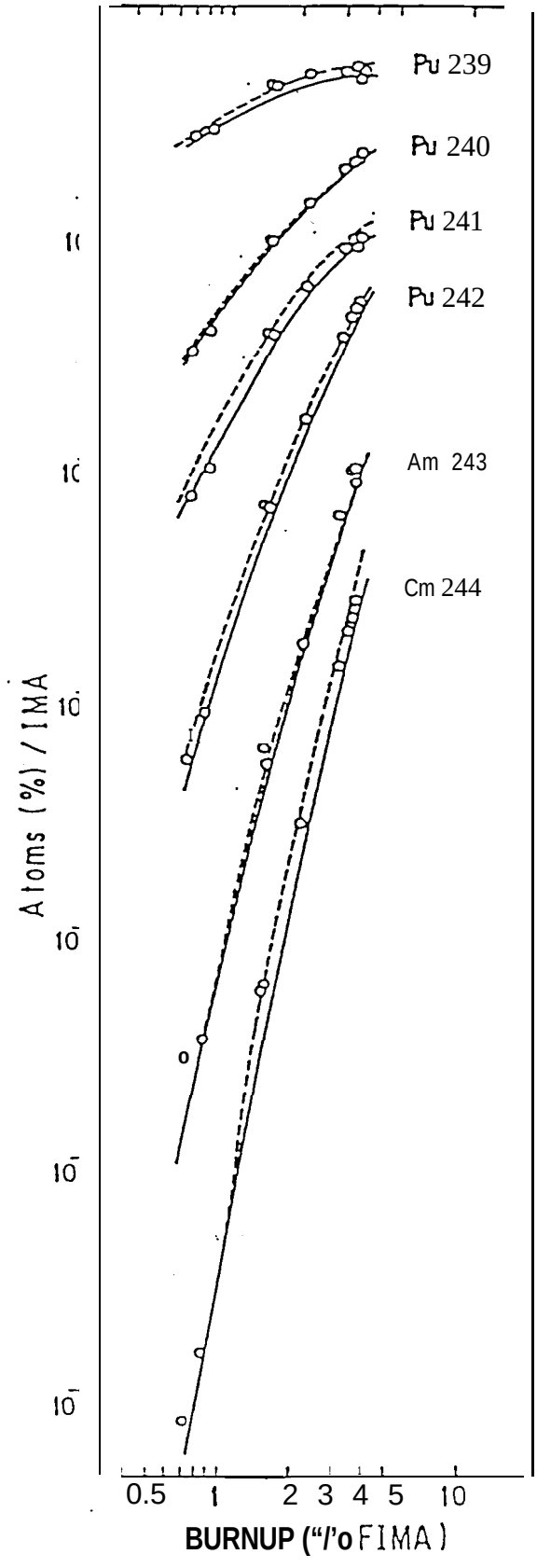

10
1
10⁻¹
10⁻²
10⁻³
Atoms %) / IMA
I₅ = 3.25 %
F₅
U 235
U" 236
Np 237
Pu 238
0.5
1
2
3
4
5
10
BURNUP (% FIMA)

Fig. 2


Pu 239
Pu 240
Pu 241
Pu 242
Am 243
Cm 244
Atoms (%) / IMA
0.5
1
2
3
4
5
10
BURNUP ("/'o FIMA)

147

Fig. 3

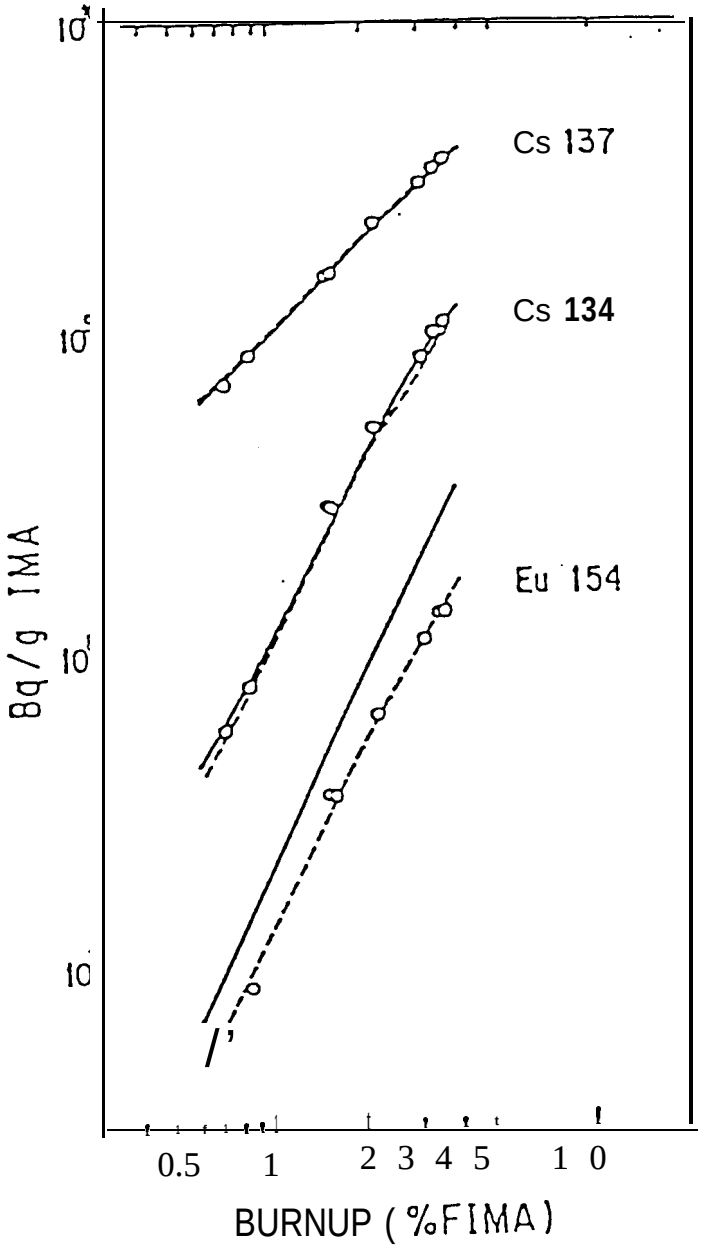


Fig. 4

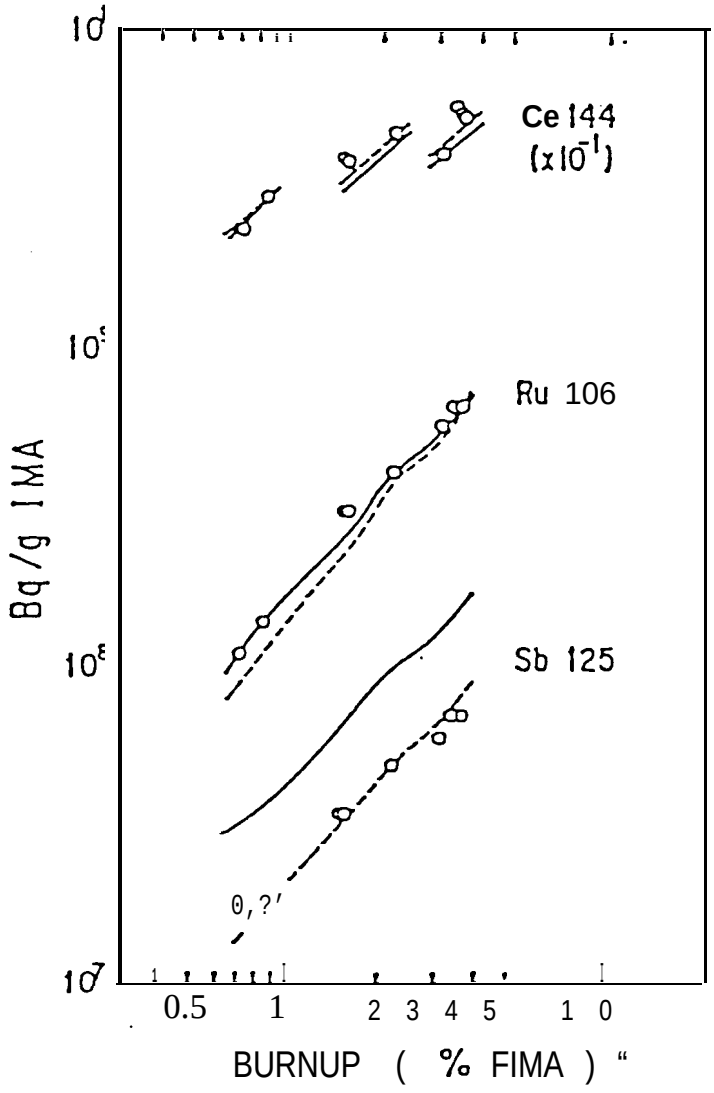


Fig.5

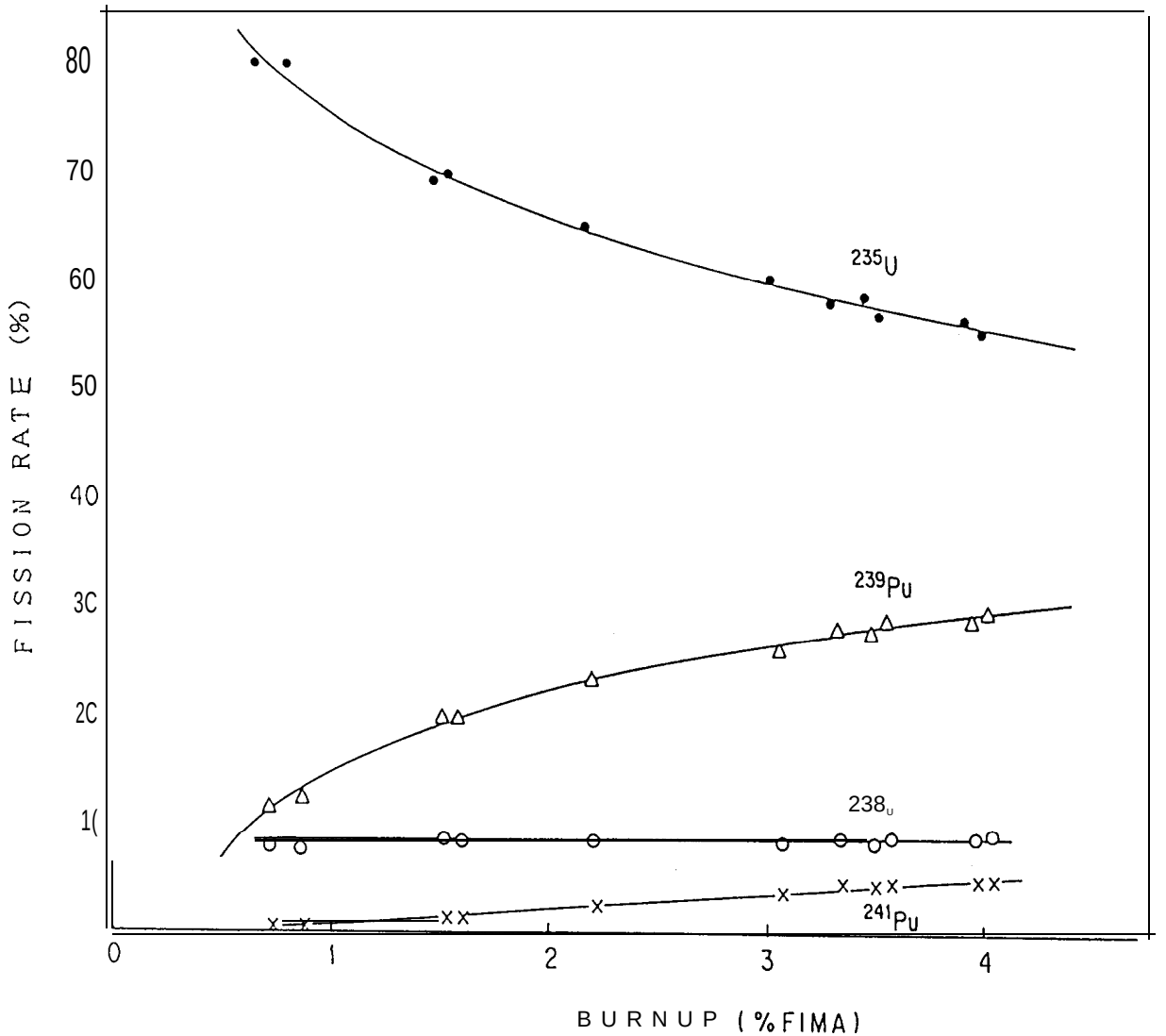


Fig. 6 FISSION RATE (%) OF U-235, U-238, Pu-239 AND Pu-241

Appendix 1 Measured . data based on the amounts of uranium after irradiation

********** ME AS URED DATA **********

	86B02	86B03	86G05	86G03	86G07	87C03	87C04	0? Co?	87C08	87H01	87H05
	00271	00272	00273	00274	00275	00276	00277	00270	00279	00280	00281
BURNUP XFIMA	8.600E-01	7.210E-01	1. 590E+00	2.204E+00	1.518E+00	3.067E+00	3.341E+00	3.497E+00	3.557E+00	4.029E+00	3.966E+00
BURNUP MWD/T	8.300E+03	6.900E+03	1.530E+04	2.120E+04	1.460E+04	2.944E+04	3.230E+04	3.370E+04	3.410E+04	3.870E+04	3.810E+04
INIT.U-234 X	2.900E-02	2.900E-02	2.900E-02	2.900E-02	2.900E-02	3.000E-02	3.000E-02	3.000E-02	2.999E-02	2.948E-02	2.948E-02
INIT.U-235 X	3.248E+00	3.248E+00	3.243E+00	3.243E+00	3.243E+00	3.250E+00	3.250E+00	3.250E+00	3.250E+00	3.457E+00	3.457E+00
INIT.U-236 X	2.100E-02	2.100E-02	1.100E-02	1.100E-02	I.100E-02	3.300E-02	3.300E-02	3.300E-02	3.296E-02	2.210E-02	2.210E-02
INIT.U-238 .X	9.670E+01	9.670E+01	9.672E+01	9.672E+01	9.672E+01	9.669E+01	9.669E+01	9.669E+01	9.669E+01	9.649E+01	9.649E+01
FINL.U-234 X	2.300E-02						1.850E-02	1.850E-02		1.900E-02	1.900E-02
FINL.U-235 X	2. 450E+00	2. 580E+00	1.920E+00	1.518E+00	1.909E+00	1.032E+00	9.590E-01	8.350E-01	8.520E-01	8.140E-01	8.300E-01
FINL.U-236 X	1.680E-01	1.490E-01	2.730E-01	3.400E-01	2.740E-01	4.020E-01	L.210E-01	L.410E-01	4.430E-01	A.910E-01	4.880E-01
FINL.U-238 X	9.736E+01	9.725E+01	9.779E+01	9.812E+01	9.780E+01	9.855E+01	9.861E+01	9.871E+01	9.869E+01	9.868E+01	9.866E+01
Pu-210 X	1.270E-01	1.050E-01	4.200E-01	7.720E-01	4.270E-01	1.402E+00	1.695E+00	1.881E+00	1.950E+00	2.430E+00	2.289E+00
PU-239 X	8.479E+01	8.669E+01	7.519E+01	6.828E+01	7.503E+01	5.974E+01	5.806E+01	5.553E+01	5.565E+01	5.490E+01	5.531E+01
PU-240 X	1.179E+01	1.051E+01	1.666E+01	1.994E+01	1.670E+01	2.356E+01	2.400E+01	2.580E+01	2.532E+01	2.454E+01	2.464E+01
PU-241 X	3.020E+00	2.520E+00	6.540E+00	8.680E+00	6.670E+00	1.068E+01	1.089E+01	1.111E+01	1.110E+01	1.167E+01	1.154E+01
PU-242 X	2.630E-01	1.830E-01	1.180E+00	2.330E+00	1.175E+00	4.543E+00	5.138E+00	5.899E+00	5.890E+00	6.463E+00	6.223E+00
PU/U	3.593E-03	3.280E-03	6.300E-03	7.634E-03	6.423E-03	9.193E-03	9.803E-03	9.319E-03	9.960E-03	1.120E-02	1.091E-02
ND-143 X	2.651E+01	2.682E+01	2.475E+01	2.318E+01	2.479E+01	2.112E+01	2.069E+01	1.981E+01	1.989E+01	1.941E+01	1.933E+01
ND-144 X	2.778E+01	2.748E+01	2.898E+01	3.023E+01	2.896E+01	3.212E+01	3.244E+01	3.338E+01	3.305E+01	3.346E+01	3.322E+01
ND-145 X	1.842E+01	1.848E+01	1.796E+01	1.760E+01	1.796E+01	1.708E+01	1.690E+01	1.683E+01	1.675E+01	1.646E+01	1.636E+01
ND-146 X	1.512E+01	1.507E+01	1.568E+01	1.609E+01	1.563E+01	1.662E+01	1.681E+01	1.686E+01	1.701E+01	1.730E+01	1.723E+01
ND-148 X	8.558E+00	8.538E+00	8.754E+00	8.900E+00	8.754E+00	8.936E+00	8.974E+00	8.975E+00	9.055E+00	9.068E+00	8.983E+00
ND-150 X	3.614E+00	3.614E+00	3.871E+00	4.012E+00	3.905E+00	4.125E+00	4.180E+00	4.145E+00	4.252E+00	4.304E+00	4.326E+00
ND148/U	1. 458E-04	1.221E-04	2.722E-04	3.804E-04	2.597E-04	5.347E-04	5.845E-04	6.126E-04	6.237E-04	7.109E-04	6.991E-04
KR-83 X			9.000E+00	9.000E+00	1.600E+01	1.330E+01	1.300E+01	1.200E+01	1.240E+01	1.200E+01	1.380E+01
KR-84 X			2.800E+01	2.900E+01	3.100E+01	3.140E+01	3.160E+01	3.280E+01	3.240E+01	3.220E+01	3.310E+01
KR-85 X					5.300E+00	5.300E+00	5.330E+00	5.200E+00	4.900E+00	4.100E+00	5.600E+00
KR-86 X			6. 100E+01	6.200E+01	4.800E+01	4.920E+01	4.960E+01	4.820E+01	4.960E+01	5.110E+01	4.440E+01
XE-131 X			9.000E+00	8.800E+00	9.000E+00	9.100EI00	9.100E+00	9.000E+00	9.410E+00	8.600E+00	8.200E+00
XE-132 I			1.900E+01	2.000E+01	1.800E+01	2.160E+01	2.160E+01	2.140E+01	2.320E+01	2.230E+01	2.330E+01
XE-134 X			3.000E+01	3.000E+01	2.900E+01	2.840E+01	2.840E+01	2.820E+01	3.050E+01	2.840E+01	2.850E+01
XE-136 I			4.300E+01	4.200E+01	4.400E+01	4.080E+01	4.060E+01	4.080E+01	3.690E+01	4.100E+01	4.100E+01
u-232 G/TU	6.900E-05	7.200E-05	3.300E-04	3.009E-04	4.306E-04	1.400E-03	1.490E-03	1.520E-03	1.520E-03	2.490E-03	1.970E-03
NP-237 G/TU	6.800E+01	5.600E+01	1.600E+02		1.600E+02				4.900E+02	5.700E+02	6.100E+02
PU-236 G/TU							4.600E-04	3.700E-04	3.500E-04		4.600E-04
API-241 G/TU	3.025E+01	2.287E+01	1.200E+02	1.965E+02	1.193E+02	3.127E+02	3.131E+02	3.351E+02	3.518E+02	4.289E+02	4.300E+02
AM242M G/TU	1.240E-02	8.000E-03	1.940E-01	5.200E-01	1.760E-01		7.000E-01	7.500E-01	8.400E-01	1.200E+00	1.030E+00
AM-243 G/TU	3.900E-01	3.200E-01	5.900E+00	2.000E+01	6.800E+00	7.100E*01	1.100E+02	1.140E+02	9.900E+01	1.350E+02	1.520E+02
CM-242 G/TU	3.200E-05	2.000E-05	4.900E-04	1.300E-03	4.500E-04		8.600E-03	9.300E-03	8.700E-03		
CM-243 G/TU							2.900E-01	3.400E-01	3.000E-01	4.700E-01	5.800E-01
CM-21.4 G/TU	1.730E-02	0.900[-03	6.700E-01	3.270E+00	7.400E-01	1.(I10EI01	2.320E+01	2.620E+01	3.110E+01	5.300E+01	4.570E+01
RU-106 BQ/GU	1.390E+08	1.100E+08	3.090E+08	4.200E+08	3.080E+08	5.880E+08	6.830E+08	6.610EI00	6.850E+08	8.070E+08	7.510E+08
SB-125 BQ/GU	1.880E+07	1.576E+07	3.565E+07	5.066E+07	3.536E+07	6.133E+07	7.205E+07	7.213E+07	7.220E+07	7.870E+07	7.675E+07
CS-134 BQ/GU	8.080E+07	5.830E+07	2.910E+08	5.210EI00	2.930E+08	8.900E+08	1.070E+09	1.080E+09	1.140E+09	1.480E+09	1.440E+09
CS-137 BQ/GU	8.790E+08	7.080E+08	1.620E+09	2.330E+09	1.610E+09	3.160E+09	3.550E+09	3.670E+09	3.720E+09	4.240E+09	4.190E+09
CE-144 BQ/GU	3.000E+08	2.380E+08	3.910E+08	4.890E+08	4.000E+08	4.270E+08	6.030E+08	5.710E+08	5.620E+08	3.600E+08	3.690E+08
lu-154 BQ/GU	9.050E+06	6.500E+06	3.620E+07	6.730E+07	3.660E+07	1.160E+08	1.390E+08	1.390E+08	1.400E+08	2.030E+08	1.960E+08

Appendix 2 Measured .. data based on the amounts of uranium before irradiation

********** MEASURED DATA **********

	86B02	86B03	86G05	86G03	86G07	87C03	87C04	87C07	87C08	87H01	87H05
	00271	00272	00273	00274	00275	00276	00277	00278	00279	00280	00281
FT/IMA X	8.600E-01	7.215E-01	1.590E+00	2.205E+00	1.517E+00	3.067E+00	3.341E+00	3.498E+00	3.556E+00	4.029E+00	3.966E+00
FT MWD/MTU	8.300E+03	6.900E+03	1.530E+04	2.120E+04	1.460E+04	2.944E+04	3.230E+04	3.370E+04	3.410E+04	3.879E+04	3.810E+04
1.U234/IMA X	2.900E-02	2.900E-02	2.900E-02	2.900E-02	2.900E-02	3.000E-02	3.000E-02	3.000E-02	2.999E-02	2.948E-02	2.948E-02
1.U235/IMA x	3.248E+00	3.248E+00	3.243E+00	3.243E+00	3.243E+00	3.250E+00	3.250E+00	3.250E+00	3.250E+00	3.457E+00	3.457E+00
1.U236/IMA X	2.100E-02	2.100E-02	1.100E-02	1.100E-02	1.100E-02	3.300E-02	3.300E-02	3.300E-02	3.296E-02	2.213E-02	2.213E-02
1.U238/IMA X	9.670E+01	9.670E+01	9.672E+01	9.672E+01	9.672E+01	9.669E+01	9.669E+01	9.669E+01	9.669E+01	9.649E+01	9.649E+01
F.U234/IMA X	2.272E-02						1.771E-02	1.769E-02		1.803E-02	1.805E-02
F.U235/IMA X	2.420E+00	2.553E+00	1.870E+00	1.473E+00	1.860E+00	9.912E-01	9.180E-01	7.984E-01	8.136E-01	7.726E-01	7.885E-01
F.U236/IMA X	1.660E-01	1.474E-01	2.670E-01	3.300E-01	2.681E-01	3.861E-01	4.030E-01	4.216E-01	4.230E-01	4.660E-01	4.636E-01
F.U238/IMA X	9.618E+01	9.623E+01	9.563E+01	9.523E+01	9.570E+01	9.466E+01	9.439E+01	9.438E+01	9.424E+01	9.366E+01	9.372E+01
PU238/IMA x	4.508E-04	3.408E-04	2.588E-03	5.720E-03	2.684E-03	1.309E-02	1.591E-02	1.676E-02	1.655E-02	2.583E-02	2.372E-02
PU239/IMA X	3.009E-01	2.814E-01	4.632E-01	5.059E-01	4.716E-01	5.275E-01	5.448E-01	4.948E-01	5.293.S-01	5.036E-01	5.732E-01
PU240/IMA X	f.. 185E-02	3.411E-02	1.026E-01	1.477E-01	1.050E-01	2.080E-01	2.252E-01	2.299E-01	2.409E-01	2.609E-01	2.554E-01
PU241/IMA X	1.072E-02	8.179E-03	4.029E-02	6.431E-02	4.192E-02	9.430E-02	1.043E-01	9.703E-02	1.063S-01	1.240E-01	1.194E-01
PU242/IMA X	9.335E-04	5.940E-04	7.270E-03	1.726E-02	7.305E-03	4.011E-02	4.821E-02	5.256E-02	5.602E-02	6.870E-02	6.450E-02
PU/IMA X	3.549E-01	3.246E-01	6.161E-01	7.409E-01	6.205E-01	8.830E-01	9.384E-01	8.910E-01	9.511E-01	1.063E+00	1.036E+00
ND143/IMA X	4.462E-02	3.795E-02	7.526E-02	9.616E-02	7.196E-02	1.214E-01	1.290E-01	1.293E-01	1.308E-01	1.444E-01	1.429E-01
ND144/IMA X	4.675E-02	3.889E-02	8.012E-02	1.254E-01	8.407E-02	1.846E-01	2.022E-01	2.170E-01	2.174E-01	2.490E-01	2.456E-01
I101L5I!IMA X	I.100E-02	2.615E-02	5.461E-02	7.301E-02	5.214E-02	9.816E-02	1.054E-01	1.093E-01	1.102E-01	1.225E-01	1.210E-01
ND146/IMA .x	2.545E-02	2.133E-02	4.768E-02	6.675E-02	4.537E-02	9.552E-02	1.040E-01	1.100E-01	1.119E-01	1.207E-01	1.274E-01
)1OILOI IMA X	1.440E-02	1.208E-02	2.662E-02	3.692E-02	2.541E-02	5.136E-02	5.595E-02	5.857E-02	5.956E-02	6.747E-02	6.641E-02
1/0150/ IMA x	6.082E-03	5. 114E-03	1.177E-02	1.664E-02	1.134E-02	2.371E-02	2.606E-02	2.705E-02	2.797E-02	3.202E-02	3.198E-02
U/UO Ill ATOM	9.879[-01	9.895E-01	9.779E-01	9.705E-01	9.785E-01	9.605E-01	9.572E-01	9.561E-01	9.549E-01	9.491E-01	9.500E-01
U/UO IN WEIG	9.880E-01	9.897E-01	9.781E-01	9.707E-01	9.787E-01	9.607E-01	9.575E-01	9.564E-01	9.552E-01	9.494E-01	9.503E-01
F25/IHA X	6.828E-01	5.685E-01	1. 109E+00	1.451E+00	1.118E+00	1.906E+00	1.962E+00	2.063E+00	2.046E+00	2.241E+00	2.227E+00
D29/IMA X	5.229E-01	4.673E-01	1.087E+00	1.490E+00	1.019E+00	2.032E+00	2.300E+00	2.312E+00	2.449E+00	2.835E+00	2.765E+00
(F-FS)/IMA X	1.772E-01	1.529E-01	4.802E-01	7.539E-01	3.996E-01	1.161E+00	1.379E+00	1.435E+00	1.510E+00	1.788E+00	1.739E+00
PU/(F-FS) X	2.003E+00	2.122E+00	1.283E+00	9.828E-01	1.573E+00	7.604E-01	6.805E-01	6.211E-01	6.298E-01	5.944E-01	5.961E-01
D25/IMA X	0.270[-01	6.950E-01	1.365E+00	1.770E+00	1.375E+00	2.259E+00	2.332E+00	2.452E+00	2.436E+00	2.684E+00	2.669E+00
D26/IMAX	-1.450E-01	-1.264E-01	-2.560E-01	-3.190E-01	-2.571E-01	-3.531E-01	-3.700E-01	-3.806E-01	-3.901E-01	-4.430E-01	-4.414E-01
ALPHA-U235	2.123E-01	2.224E-01	2.307E-01	2.199E-01	2.300E-01	1.853E-01	1.886E-01	1.884E-01	1.906E-01	1.981E-01	1.982E-01
u232 G/TUO	6.817E-05	7.126E-05	3.220E-04	2.921E-04	4.214E-04	1.345E-03	1.427E-03	1.454E-03	1.452E-03	2.364E-03	1.872E-03
NP237 G/TUO	6.718E+01	5.542E+01	1.565E+02		1.566E+02				4.600E+02	5.412E+02	5.796E+02
PU236 G/TUO							4.405E-04	3.539E-04	3.343E-04		4.371E-04
AM241 G/TUO	2.989E+01	2.263E+01	1.174E+02	1.907E+02	1.168E+02	3.004E+02	2.998E+02	3.205E+02	3.360E+02	4.072E+02	4.086E+02
AM242M G/TUO	1.225E-02	7.917E-03	1.898E-01	5.048E-01	1.723E-01		6.703E-01	7.173E-01	8.023E-01	1.139E+00	9.737E-01
AM243 G/TUO	3.853E-01	3.167E-01	5.771E+00	1.941E+01	6.655E+00	6.821E+01	1.053E+02	1.090E+02	9.456E+01	1.282E+02	1.444E+02
CM242 G/TUO	3.161[-05	1.979E-05	4.793E-04	1.262E-03	4.404E-04		8.235E-03	8.894E-03	0.310E-03		
CM243 G/TUO							2.777E-01	3.252E-01	2.865E-01	4.462E-01	5.511E-01
CM244 G/TUO	1.709[-02	8.808E-03	6.553E-01	3.174E+00	7.242E-01	1.547E+01	2.221E+01	2.506E+01	2.971E+01	5.032E+01	4.343E+01
RU106 BQ/GUO	1.373E+08	1.089E+08	3.022E+08	4.077E+08	3.014E+08	5.649E+08	6.540E+08	6.322[101%	6.543E+08	7.662E+08	7.136E+08
SB125 BQ/GUO	1.857E+07	1.560E+07	3.487E+07	4.910E+07	3.461E+07	5.892E+07	6.899E+07	6.898E+07	6.896E+07	7.472E+07	7.293E+07
CS134 BQ/GUO	7.983E+07	5.770E+07	2.846E+08	5.086E+08	2.868E+08	8.550E+08	1.025E+09	1.033E+09	1.009E+09	1.405E+09	1.368E+09
CS137 BQ/GUO	8.684E+08	7.007[108	1.585E+09	2.262E+09	1.576E+09	3.036E+09	3.399E+09	3.510E+09	3.553E+09	4.026E+09	3.982E+09
CE144 BQ/GUO	2.964E+08	2.355E+08	3.824E+08	4.747E+08	3.915E+08	4.102E+08	5.774E+08	5.461E+08	5.368E+08	5.418E+08	5.506E+08
EU154 BQ/GUO	8.941E+06	6.433E+06	3.541E+07	6.533E+07	3.582E+07	1.114E+08	1.331E+08	1.329E+08	1.337E+08	1.927E+08	1.870E+08

Appendix 3 'Calculated data by ORIGEN 2 based on the amounts of uranium after irradiation

********** ORIGEN2 DATA **********

	86B02	86B03	86G05	86G03	86G07	07C03	87C04	87C07	87C08	87H01	87H05
	00291	00292	00293	00294	00295	00296	00297	00290	00299	00300	00301
BURNUP XFIMA	8.830E-01	7.240E-01	1.590E+00	2.221E+00	1.530E+00	3.060E+00	3.342E+00	3.491E+00	3.557E+00	4.015E+00	4.057E+00
BURNUP MWD/T	8.300E+03	6.900E+03	1.540E+04	2.130E+04	1.470E+04	2.950E+04	3.220E+04	3.370E+04	3.415E+04	3.854E+04	3.810E+04
INIT.U-234 .x	2.900E-02	2.900E-02	2.900E-02	2.900E-02	2.900E-02	3.000E-02	3.000E-02	3.000E-02	2.999E-02	2.948E-02	2.948E-02
INIT.U-235 x	3.248E+00	3.248E+00	3.243E+00	3.243E+00	3.243E+00	3.250E+00	3.250E+00	3.250E+00	3.250E+00	3.457E+00	3.457E+00
INIT.U-236 x	2.100E-02	2.100E-02	1.100E-02	1.100E-02	1.100E-02	3.300E-02	3.300E-02	3.300E-02	3.296E-02	2.218E-02	2.210E-02
INIT.U-238 x	9.670E+01	9.670E+01	9.672E+01	9.672E+01	9.672E+01	9.669E+01	9.669E+01	9.669E+01	9.669E+01	9.649E+01	9.649E+01
FINL.U-234 x	2.600E-02	2.700E-02	2.400E-02	2.300E-02	2.400E-02	2.100E-02	2.000E-02	2.000E-02	1.982E-02	1.880E-02	1.895E-02
FINL.U-235 x	2.406E+00	2.534E+00	1.854E+00	1.450E+00	1.901E+00	1.010E+00	8.880E-01	8.250E-01	8.007E-01	7.280E-01	7.500E-01
FINL.U-236 x	1.790E-01	1.550E-01	2.680E-01	3.360E-01	2.600E-01	4.250E-01	4.420E-01	4.500E-01	4.531E-01	4.870E-01	4.840E-01
FINL.U-238 x	9.737E+01	9.728E+01	9.785E+01	9.819E+01	9.782E+01	9.854E+01	9.865E+01	9.871E+01	9.873E+01	9.877E+01	9.875E+01
PU-238 x	1.340E-01	1.020E-01	3.840E-01	7.000E-01	3.560E-01	1.443E+00	1.673E+00	1.807E+00	1.863E+00	2.210E+00	2.153E+00
PU-239 x	8.389E+01	8.634E+01	7.385E+01	6.698E+01	7.466E+01	5.940E+01	5.734E+01	5.628E+01	5.586E+01	5.385E+01	5.420E+01
PU-240 x	1.254E+01	1.106E+01	1.815E+01	2.153E+01	1.768E+01	2.464E+01	2.533E+01	2.565E+01	2.565E+01	2.652E+01	2.649E+01
PU-241 x	3.176E+00	2.347E+00	6.517E+00	8.553E+00	6.306E+00	1.043E+01	1.089E+01	1.110E+01	1.130E+01	1.133E+01	1.124E+01
PU-242 x	2.560E-01	1.530E-01	1.101E+00	2.227E+00	1.003E+00	4.092E+00	4.771E+00	5.160E+00	5.326E+00	6.090E+00	5.923E+00
PU/U	3.662E-03	3.162E-03	5.681E-03	7.092E-03	5.514E-03	8.623E-03	9.078E-03	9.320E-03	9.402E-03	9.885E-03	9.802E-03
HO-143 x	2.638E+01	2.675E+01	2.441E+01	2.282E+01	2.458E+01	2.057E+01	1.986E+01	1.947E+01	1.931E+01	1.846E+01	1.861E+01
ND-144 x	2.758E+01	2.730E+01	2.914E+01	3.043E+01	2.901E+01	3.222E+01	3.280E+01	3.311E+01	3.324E+01	3.401E+01	3.389E+01
ND-145 x	1.846E+01	1.856E+01	1.800E+01	1.756E+01	1.804E+01	1.697E+01	1.676E+01	1.664E+01	1.659E+01	1.635E+01	1.639E+01
ND-146 x	1.516E+01	1.508E+01	1.561E+01	1.601E+01	1.557E+01	1.659E+01	1.678E+01	1.689E+01	1.694E+01	1.718E+01	1.714E+01
ND-148 x	8.652E+00	8.616E+00	8.744E+00	8.843E+00	8.733E+00	8.921E+00	8.955E+00	8.974E+00	8.981E+00	8.971E+00	8.965E+00
ND-150 x	3.658E+00	3.616E+00	3.846E+00	3.983E+00	3.831E+00	4.153E+00	4.206E+00	4.235E+00	4.247E+00	4.262E+00	4.252E+00
ND148/U	1.545E-04	1.278E-04	2.820E-04	3.964E-04	2.700E-04	5.500E-04	6.030E-04	6.320E-04	6.367E-04	7.188E-04	7.151E-04
KR-83 x	1.384E+01	1.396E+01	1.330E+01	1.274E+01	1.336E+01	1.196E+01	1.168E+01	1.152E+01	1.146E+01	1.108E+01	1.115E+01
KR-84 x	2.847E+01	2.830E+01	2.935E+01	3.009E+01	2.928E+01	3.118E+01	3.153E+01	3.173E+01	3.181E+01	3.221E+01	3.213E+01
KR-85 x	5.085E+00	5.083E+00	4.855E+00	4.854E+00	4.855E+00	4.661E+00	4.660E+00	4.660E+00	4.659E+00	4.630E+00	4.630E+00
KR-86 x	5.253E+01	5.260E+01	5.237E+01	5.214E+01	5.240E+01	5.195E+01	5.185E+01	5.180E+01	5.178E+01	5.176E+01	5.178E+01
XE-131 x	1.061E+01	1.080E+01	1.011E+01	9.420E+00	1.020E+01	8.676E+00	8.380E+00	8.217E+00	8.154E+00	7.840E+00	7.903E+00
XE-132 x	1.761E+01	1.758E+01	1.874E+01	1.918E+01	1.871E+01	2.029E+01	2.052E+01	2.065E+01	2.070E+01	2.114E+01	2.109E+01
XC-134 x	2.847E+01	2.878E+01	2.856E+01	2.792E+01	2.866E+01	2.789E+01	2.770E+01	2.760E+01	2.757E+01	2.766E+01	2.769E+01
XE-136 x	4.326E+01	4.280E+01	4.246E+01	4.334E+01	4.232E+01	4.288E+01	4.312E+01	4.323E+01	4.327E+01	4.302E+01	4.298E+01
U-232 G/TU	4.510E-05	3.360E-05	1.870E-04	3.480E-04	1.730E-04	8.230E-04	9.720E-04	1.060E-03	1.096E-03	1.275E-03	1.237E-03
NP-237 G/TU	7.050E+01	5.450E+01	1.577E+02	2.566E+02	1.483E+02	4.310E+02	4.848E+02	5.149E+02	5.267E+02	6.040E+02	5.918E+02
PU-236 G/TU	8.943E-06	5.849E-06	3.375E-05	7.590E-05	3.044E-05	1.684E-04	2.076E-04	2.313E-04	2.410E-04	2.935E-04	2.828E-04
AM-241 G/TU	3.300E+01	2.110E+01	1.101E+02	1.800E+02	1.035E+02	2.794E+02	3.053E+02	3.186E+02	3.265E+02	3.494E+02	3.443E+02
AM242M G/TU	1.180E-02	8.570E-03	1.510E-01	2.710E-01	1.380E-01	7.000E-01	7.420E-01	7.610E-01	7.703E-01	9.583E-01	9.523E-01
AM-243 G/TU	3.640E-01	1.545E-01	4.860E+00	1.830E+01	4.080E+00	5.900E+01	8.010E+01	9.370E+01	9.956E+01	1.334E+02	1.265E+02
CM-242 G/TU	7.660E-05	4.090E-05	1.160E-03	2.650E-03	1.030E-03	6.920E-03	8.000E-03	8.610E-03	8.864E-03	1.076E-02	1.051E-02
CM-243 G/TU	5.180E-04	2.220E-04	2.230E-02	8.280E-02	1.870E-02	2.840E-01	3.720E-01	4.270E-01	4.508E-01	5.432E-01	5.190E-01
CM-244 G/TU	1.500E-02	5.220E-03	4.040E-01	2.330E+00	3.200E-01	1.150E+01	1.760E+01	2.200E+01	2.399E+01	3.600E+01	3.340E+01
IIU-106 BQ/GU	1.420E+08	1.090E+08	2.580E+08	4.250E+08	2.420E+08	5.430E+08	6.230E+08	6.700E+08	6.890E+08	7.250E+08	7.065E+08
SB-125 BQ/GU	4.040E+07	3.270E+07	6.880E+07	1.020E+08	6.540E+07	1.330E+08	1.480E+08	1.570E+08	1.600E+08	1.750E+08	1.715E+08
CS-134 BQ/GU	8.490E+07	5.870E+07	2.580E+08	5.010E+08	2.370E+08	8.560E+08	1.020E+09	1.120E+09	1.156E+09	1.370E+09	1.327E+09
CS-137 BQ/GU	9.000E+08	7.450E+08	1.630E+09	2.290E+09	1.560E+09	3.150E+09	3.450E+09	3.620E+09	3.683E+09	4.160E+09	4.095E+09
CE-144 BQ/GU	2.960E+08	2.460E+08	3.370E+08	4.600E+08	3.240E+08	4.310E+08	4.670E+08	4.860E+08	4.937E+08	4.890E+08	4.823E+08
[u-154 BQ/GU	1.500E+07	1.010E+07	5.450E+07	1.120E+08	4.970E+07	2.150E+08	2.630E+08	2.870E+08	2.972E+08	3.520E+08	3.416E+08

Appendix 4. Calculated data by ORIGEN 2 based on the amounts of uranium before irradiation

********** ORIGEN2 DATA **********

	06002	86B03	86G05	86G03	86G07	87C03	87C04	0? Co?	87C08	87H01	071105
	00291	00292	00293	00294	00295	00296	00297	00290	00299	00300	00301
FT/1MA X	9.108E-01	7.550E-01	1.647E+00	2.296E+00	1.578E+00	3.153E+00	3.445E+00	3.604E+00	3.630E+00	4.077E+00	4.057E+00
FT MWD/MTU	8.300E+03	6.900E+03	1.540E+04	2.130E+04	1.470E+04	2.950E+04	3.220E+04	3.370E+04	3.415E+04	3.854E+04	3.810E+04
1.U234/1MA X	2.900E-02	2.900E-02	2.900E-02	2.900E-02	2.900E-02	3.000E-02	3.000E-02	3.000E-02	2.999E-02	2.940E-02	2.940E-02
1.U235/1MA X	3.248E+00	3.248E+00	3.243E+00	3.243E+00	3.243E+00	3.250E+00	3.250E+00	3.250E+00	3.250E+00	3.457E+00	3.457E+00
1.U236/1MA X	2.100E-02	2.100E-02	1.100E-02	1.100E-02	1.100E-02	3.300E-02	3.300E-02	3.300E-02	3.296E-02	2.210E-02	2.210E-02
1.U238/1MA X	9.670E+01	9.670E+01	9.672E+01	9.672E+01	9.672E+01	9.669E+01	9.669E+01	9.669E+01	9.669E+01	9.649E+01	9.649E+01
F.U234/1MA X	2.567E-02	2.671E-02	2.347E-02	2.231E-02	2.349E-02	2.016E-02	1.914E-02	1.910E-02	1.892E-02	1.786E-02	1.800E-02
F.U235/1MA X	2.375E+00	2.507E+00	1.813E+00	1.407E+00	1.861E+00	9.698E-01	8.497E-01	7.879E-01	7.644E-01	6.915E-01	7.126E-01
F.U236/1MA X	1.767E-01	1.533E-01	2.621E-01	3.260E-01	2.545E-01	4.081E-01	4.229E-01	4.298E-01	4.326E-01	4.626E-01	4.599E-01
F.U238/1MA X	9.613E+01	9.624E+01	9.569E+01	9.526E+01	9.575E+01	9.462E+01	9.439E+01	9.427E+01	9.426E+01	9.382E+01	9.382E+01
PU238/1MA X	4.844E-04	3.191E-04	2.133E-03	4.817E-03	1.921E-03	1.195E-02	1.453E-02	1.608E-02	1.672E-02	2.075E-02	2.005E-02
PU239/1MA X	3.033E-01	2.701E-01	4.103E-01	4.609E-01	4.030E-01	4.918E-01	4.981E-01	5.010E-01	5.014E-01	5.056E-01	5.040E-01
PU240/1MA X	4.533E-02	3.460E-02	1.008E-01	1.481E-01	9.542E-02	2.040E-01	2.200E-01	2.283E-01	2.302E-01	2.490E-01	2.467E-01
PU241/1MA X	1.140E-02	7.342E-03	3.621E-02	5.805E-02	3.403E-02	8.635E-02	9.459E-02	9.800E-02	1.014E-01	1.064E-01	1.047E-01
PU242/1MA X	9.255[-01	4.786E-04	6.117E-03	1.532E-02	5.413E-03	3.308E-02	4.144E-02	4.593E-02	4.701E-02	5.710E-02	5.516E-02
PU/1MA X	3.615E-01	3.128E-01	5.556E-01	6.881E-01	5.397E-01	8.279E-01	8.606E-01	8.901E-01	8.976E-01	9.389E-01	9.313E-01
ND143/1MA X	4.651E-02	3.925E-02	7.699E-02	9.924E-02	7.438E-02	1.210E-01	1.280E-01	1.310E-01	1.307E-01	1.405E-01	1.410L-01
ND144/1MA X	4.862E-02	4.006E-02	9.191E-02	1.323E-01	8.779E-02	1.907E-01	2.113E-01	2.227E-01	2.250E-01	2.508E-01	2.560E-01
ND145/1MA X	3.254E-02	2.724E-02	5.677E-02	7.637E-02	5.459E-02	1.005E-01	1.080E-01	1.119E-01	1.123E-01	1.244E-01	1.242E-01
ND146/1MA .X	2.673E-02	2.213E-02	4.923E-02	6.963E-02	4.712E-02	9.821E-02	1.081E-01	1.136E-01	1.147E-01	1.307E-01	1.299E-01
ND148/1MA .X	1.525E-02	1.264E-02	2.758E-02	3.846E-02	2.643E-02	5.281E-02	5.770E-02	6.036E-02	6.079E-02	6.827E-02	6.794E-02
ND150/1MA X	6.449E-03	5.306E-03	1.213E-02	1.732E-02	1.159E-02	2.458E-02	2.710E-02	2.848E-02	2.875E-02	3.244E-02	3.222E-02
U/UO IN A10H	9.873E-01	9.893E-01	9.780E-01	9.702E-01	9.788E-01	9.602E-01	9.569E-01	9.551E-01	9.547E-01	9.498E-01	9.501E-01
U/UO IN WEIG	9.872E-01	9.894E-01	9.781E-01	9.703E-01	9.790E-01	9.604E-01	9.571E-01	9.553E-01	9.550E-01	9.502E-01	9.504E-01
F25/1MA X	7.169E-01	6.087E-01	1.179E+00	1.521E+00	1.139E+00	1.905E+00	2.010E+00	2.065E+00	2.086E+00	2.325E+00	2.307E+00
D28/1MA X	5.689E-01	4.588E-01	1.025E+00	1.460E+00	9.717E-01	2.073E+00	2.296E+00	2.416E+00	2.430E+00	2.674E+00	2.666E+00
(F-F5)/1MA X	1.939E-01	1.463E-01	4.681E-01	7.751E-01	4.394E-01	1.248E+00	1.435E+00	1.539E+00	1.544E+00	1.752E+00	1.750E+00
PU/(F-F5) X	1.864E+00	2.138E+00	1.187E+00	8.877E-01	1.228E+00	6.632E-01	6.053E-01	5.784E-01	5.814E-01	5.360E-01	5.321E-01
D25/1MA X	8.726E-01	7.411E-01	1.430E+00	1.836E+00	1.382E+00	2.280E+00	2.400E+00	2.462E+00	2.486E+00	2.766E+00	2.744E+00
D26/1MA X-	1.557E-01	-1.323E-01	-2.511E-01	-3.150E-01	-2.435E-01	-3.751E-01	-3.899E-01	-3.968E-01	-3.996E-01	-4.404E-01	-4.377E-01
ALPHA-U235	2.172E-01	2.174E-01	2.130E-01	2.070E-01	2.138E-01	1.969E-01	1.940E-01	1.921E-01	1.916E-01	1.894E-01	1.897E-01
u232 G/TUO	1.452E-05	3.324E-05	1.829E-04	3.377E-04	1.694E-04	7.904E-04	9.303E-04	1.013E-03	1.047E-03	1.211E-03	1.176E-03
NP237 G/TUO	6.960E+01	5.392E+01	1.542E+02	2.490E+02	1.452E+02	4.139E+02	4.640E+02	4.919E+02	5.030E+02	5.739E+02	5.625E+02
PU236 G/TUO	8.829E-06	5.787E-06	3.301E-05	7.365E-05	2.980E-05	1.617E-04	1.987E-04	2.210E-0L	2.302E-04	2.709E-04	2.680E-04
AM241 G/TUO	3.258E+01	2.088E+01	1.077E+02	1.747E+02	1.013E+02	2.603E+02	2.922E+02	3.044E+02	3.118E+02	3.320E+02	3.272E+02
AM242M G/TUO	1.165E-02	6.500E-03	1.477E-01	2.630E-01	1.351E-01	6.723E-01	7.102E-0I	7.270E-01	7.356E-01	9.106E-0I	9.051E-01
AM243 G/TUO	3.593E-01	1.529E-01	4.753E+00	1.776E+01	3.994E+00	5.666E+01	7.666E+01	8.951E+01	9.508E+01	1.268E+02	1.202E+02
CM242 G/TUO	7.562E-05	4.047E-05	1.135E-03	2.571E-03	1.008E-03	6.646E-03	7.657E-03	8.225E-03	8.465E-03	1.022E-02	9.989E-03
CM243 G/TUO	5.114E-04	2.196E-04	2.10IE-02	8.034E-02	1.831E-02	2.727E-01	3.560E-01	4.079E-01	4.305E-01	5.161E-01	4.933E-01
CM244 G/TUO	1.481E-02	5.165E-03	3.951E-01	2.261E+00	3.133E-01	1.104E+01	1.684E+01	2.102E+01	2.291E+01	3.421E+01	3.174E+01
RU106 BQ/GUO	1.402E+08	1.078E+08	2.523E+08	4.124E+08	2.369E+08	5.215E+08	5.963E+08	6.401E+08	6.580E+08	6.809E+08	6.715E+08
S012S BQ/GUO	3.988E+07	3.235E+07	6.729E+07	9.897E+07	6.403E+07	1.277E+08	1.416E+08	1.500E+08	1.528E+08	1.663E+08	1.630E+08
CS134 BQ/GUO	8.381E+07	5.808E+07	2.523E+08	4.861E+08	2.320E+08	8.221E+08	9.762E+08	1.070E+09	1.104E+09	1.302E+09	1.261E+09
CS137 BQ/GUO	8.885E+08	7.371E+08	1.594E+09	2.222E+09	1.527E+09	3.025E+09	3.302E+09	3.458E+09	3.517E+09	3.953E+09	3.892E+09
CE144 BQ/GUO	2.922E+08	2.434E+08	3.296E+08	4.463E+08	3.172E+08	4.139E+08	4.470E+08	4.643E+08	4.715E+08	4.646E+08	4.584E+08
EU154 BQ/GUO	1.481E+07	9.993E+06	5.330E+07	1.087E+08	4.866E+07	2.065E+08	2.517E+08	2.742E+08	2.838E+08	3.345E+08	3.247E+08

Appendix 5 Calculated data by SRAC-FPGS based on the amounts of uranium after irradiation

********** SRAC-FPGS DATA **********

	86D02	86D03	86G05	86G03	86G07	87C03	87C04	87C07	0? Coo	87H01	87H05
	00311	00312	00313	00314	00315	00316	00317	00310	00319	00320	NO OATA
BURNUP XFIMA	8.920E-01	7.450E-01	1.633E+00	2.261E+00	1.566E+00	3.111E+00	3.389E+00	3.544E+00	3.605E+00	4.062E+00	
BURNUP MWD/T	8.300E+03	6.900E+03	1.540E+04	2.130E+04	1.470E+04	2.950E+04	3.220E+04	3.370E+04	3.415E+04	3.854E+04	
INIT.U-234 X	2.900E-02	2.900E-02	2.900E-02	2.900E-02	2.900E-02	3.000E-02	3.000E-02	3.000E-02	2.999E-02	2.940E-02	
INIT.U-235 X	3.248E+00	3.248E+00	3.243E+00	3.243E+00	3.243E+00	3.250E+00	3.250E+00	3.250E+00	3.250E+00	3.457E+00	
INIT.U-236 X	2.100E-02	2.100E-02	1.100E-02	1.100E-02	1.100E-02	3.300E-02	3.300E-02	3.300E-02	3.296E-02	2.210E-02	
INIT.U-238 X	9.670E+01	9.670E+01	9.672E+01	9.672E+01	9.672E+01	9.669E+01	9.669E+01	9.669E+01	9.669E+01	9.649E+01	
FINL.U-234 X	2.600E-02	2.700E-02	2.400E-02	2.200E-02	2.400E-02	2.100E-02	2.000E-02	2.000E-02	1.997E-02	1.905E-02	
FINL.U-235 X	2.381E+00	2.507E+00	1.819E+00	1.432E+00	1.865E+00	1.029E+00	9.150E-01	8.570E-01	8.346E-01	7.900E-01	
FINL.U-236 X	1.910E-01	1.660E-01	2.860E-01	3.550E-01	2.780E-01	4.430E-01	4.600E-01	4.680E-01	4.708E-01	5.080E-01	
FINL.U-238 X	9.740E+01	9.730E+01	9.787E+01	9.819E+01	9.783E+01	9.851E+01	9.861E+01	9.866E+01	9.868E+01	9.868E+01	
PU-238 X	1.290E-01	9.800E-02	4.080E-01	7.340E-01	3.780E-01	1.488E+00	1.712E+00	1.840E+00	1.891E+00	2.268E+00	
PU-239 X	8.381E+01	8.606E+01	7.420E+01	6.796E+01	7.495E+01	6.112E+01	5.931E+01	5.836E+01	5.802E+01	5.620E+01	
PU-240 X	1.203E+01	1.077E+01	1.691E+01	1.937E+01	1.659E+01	2.170E+01	2.221E+01	2.246E+01	2.255E+01	2.345E+01	
PU-241 X	3.709E+00	2.866E+00	7.207E+00	9.448E+00	6.919E+00	1.132E+01	1.172E+01	1.191E+01	1.197E+01	1.192E+01	
PU-242 X	3.160E-01	2.000E-01	1.274E+00	2.488E+00	1.162E+00	4.372E+00	5.042E+00	5.418E+00	5.568E+00	6.166E+00	
PU/U	3.962E-03	3.423E-03	6.223E-03	7.746E-03	6.040E-03	9.480E-03	9.961E-03	1.022E-02	1.031E-02	1.113E-02	
NO-I(3 X	2.658E+01	2.690E+01	2.473E+01	2.334E+01	2.488E+01	2.142E+01	2.083E+01	2.050E+01	2.037E+01	1.967E+01	
ND-144 X	2.776E+01	2.750E+01	2.923E+01	3.037E+01	2.911E+01	3.185E+01	3.233E+01	3.260E+01	3.270E+01	3.321E+01	
ND-145 X	1.853E+01	1.862E+01	1.808E+01	1.770E+01	1.813E+01	1.718E+01	1.700E+01	1.690E+01	1.686E+01	1.662E+01	
ND-146 X	1.513E+01	1.505E+01	1.559E+01	1.597E+01	1.555E+01	1.653E+01	1.671E+01	1.681E+01	1.685E+01	1.710E+01	
ND-148 X	8.442E+00	8.414E+00	8.546E+00	8.635E+00	8.536E+00	8.748E+00	8.783E+00	8.801E+00	8.809E+00	8.856E+00	
ND-150 X	3.500E+00	3.478E+00	3.699E+00	3.802E+00	3.687E+00	4.007E+00	4.052E+00	4.076E+00	4.085E+00	4.176E+00	
ND148/U	1.520E-04	1.263E-04	2.010E-0L	3.965E-04	2.697E-04	5.540E-04	6.074E-04	6.374E-04	6.494E-04	7.360E-04	
KR-83 X	1.384E+01	1.393E+01	1.343E+01	1.299E+01	1.347E+01	1.247E+01	1.226E+01	1.215E+01	1.210E+01	1.188E+01	
KR-84 X	2.869E+01	2.856E+01	2.944E+01	3.002E+01	2.938E+01	3.090E+01	3.112E+01	3.132E+01	3.178E+01	3.173E+01	
KR-85 X	5.148E+00	5.148E+00	4.909E+00	4.902E+00	4.910E+00	4.705E+00	4.702E+00	4.700E+00	4.699E+00	4.664E+00	
KR-86 X	5.252E+01	5.235E+01	5.220E+01	5.207E+01	5.221E+01	5.190E+01	5.184E+01	5.181E+01	5.180E+01	5.169E+01	
XE-131 X	1.035E+01	1.056E+01	9.930E+00	9.273E+00	1.001E+01	8.702E+00	8.450E+00	8.313E+00	8.260E+00	8.038E+00	
XE-132 X	1.748E+01	1.749E+01	1.868E+01	1.896E+01	1.864E+01	2.007E+01	2.023E+01	2.032E+01	2.036E+01	2.084E+01	
XE-134 X	2.954E+01	2.984E+01	2.964E+01	2.902E+01	2.974E+01	2.899E+01	2.881E+01	2.871E+01	2.867E+01	2.872E+01	
XE-136 X	4.261E+01	4.211E+01	4.174E+01	4.270E+01	4.159E+01	4.216E+01	4.243E+01	4.257E+01	4.263E+01	4.231E+01	
U-232 G/TU	3.759E-09	2.590[-09	1.381E-08	2.767E-08	1.263E-08	6.169E-08	7.385E-08	8.114E-08	8.412E-08	1.082E-07	
NP-237 G/TU	7.649E+01	5.899E+01	1.751E+02	2.807E+02	1.646E+02	4.572E+02	5.084E+02	5.367E+02	5.478E+02	6.261E+02	
PU-236 G/TU	1.000E+38	1.000E+38	1.000E+38	1.000E+38	1.000E+38	1.000E+38	1.000E+38	1.000E+38	1.000E+38	1.000E+38	
AM-241 G/TU	4.042E+01	2.698E+01	1.299E+02	2.116E+02	1.211E+02	3.275E+02	3.548E+02	3.687E+02	3.741E+02	4.097E+02	
AM242M G/TU	1.000E+38	1.000E+38	1.000E+38	1.000E+38	1.000E+38	1.000E+38	1.000E+38	1.000E+38	1.000E+38	1.000E+38	
AM-243 G/TU	3.925[-01	1.748E-01	5.964E+00	2.108E+01	5.029E+00	6.199E+01	8.180E+01	9.410E+01	9.923E+01	1.428E+02	
CM-242 G/TU	6.213E-05	3.386E-05	1.025E-03	2.492E-03	9.050E-04	6.404E-03	7.608E-03	8.281E-03	8.536E-03	1.023E-02	
CM-243 G/TU	5.015E-04	2.252E-04	2.449E-02	8.439E-02	2.065E-02	2.579E-01	3.322E-01	3.769E-01	3.951E-01	4.985E-01	
CM-244 G/TU	1.333E-02	4.734E-03	7.450E-01	4.048E+00	5.947E-01	1.897E+01	2.839E+01	3.488E+01	3.768E+01	7.10ACI01	
RU-106 BQ/GU	I.110E$00	8.838E+07	2.360E+08	3.877E+08	2.213E+08	5.140E+08	5.902E+08	6.343E+08	6.518E+08	7.230E+08	
SO-125 BQ/GU	1.748E+07	1.425E+07	3.345E+07	5.016E+07	3.175E+07	6.924E+07	7.740E+07	8.210E+07	8.395E+07	9.481E+07	
CS-134 BQ/GU	7.860E+07	5.480E+07	2.480E+08	4.750E+08	2.280E+08	8.078E+08	9.570E+08	1.045E+09	1.081E+09	1.281E+09	
(S-137 BQ/GU	9.136E+08	7.599E+08	1.683E+09	2.368E+09	1.610E+09	3.289E+09	3.607E+09	3.786E+09	3.879E+09	4.375E+09	
CE-144 BQ/GU	3.045E+08	2.543E+08	3.521E+08	4.844E+08	3.377E+08	4.596E+08	4.998E+08	5.220E+08	5.306E+08	5.204E+08	
EU-154 BQ/GU	1.002E+07	7.050E+06	3.368E+07	6.306E+07	3.101E+07	1.163E+08	1.351E+08	1.459E+08	1.501E+08	1.842E+08	

Appendix 6 Calculated data by SRAC-FPGS based on the amounts of uranium before irradiation

********** SRAC-FPGS DATA **********

	06002	86003	86G05	86G03	86G07	87C03	87C04	O? Co?	O? Con	87H01	87H05
	00311	00112	00313	00314	00315	00316	00317	00318	00319	00320	NO OATA
FT/IMA x	8.960E-01	7.460E-01	1.645E+00	2.296E+00	1.576E+00	3.173E+00	3.467E+00	3.631E+00	3.696E+00	4.165E+00	
FT MWD/MTU	8.300E+03	6.900E+03	1.540E+04	2.130E+04	1.470E+04	2.950E+04	3.220E+04	3.370E+04	3.415E+04	3.854E+04	
1.U234/IMA x	2.900E-02	2.900E-02	2.900E-02	2.900E-02	2.900E-02	3.000E-02	3.000E-02	3.000E-02	2.999E-02	2.940E-02	
1.U235/IMA x	3.240E+00	3.240E+00	3.243E+00	3.243E+00	3.243E+00	3.250E+00	3.250E+00	3.250E+00	3.250E+00	3.457E+00	
1.U236/IMA x	2.100E-02	2.100E-02	1.100E-02	1.100E-02	1.100E-02	3.300E-02	3.300E-02	3.300E-02	3.296E-02	2.210E-02	
1.U238/IMA x	9.670E+01	9.670E+01	9.672E+01	9.672E+01	9.672E+01	9.669E+01	9.669E+01	9.669E+01	9.669E+01	9.649E+01	
F.U234/IMA x	2.567E-02	2.671E-02	2.346E-02	2.133E-02	2.340E-02	2.014E-02	1.912E-02	1.908E-02	1.904E-02	1.806E-02	
F.U235/IMA x	2.350E+00	2.480E+00	1.778E+00	1.388E+00	1.825E+00	9.870E-01	8.746E-01	8.175E-01	7.955E-01	7.480E-01	
F.U236/IMA x	1.885E-01	1.642E-01	2.796E-01	3.442E-01	2.720E-01	4.249E-01	4.397E-01	4.464E-01	4.488E-01	4.815E-01	
F.U238/IMA x	9.615E+01	9.624E+01	9.566E+01	9.520E+01	9.571E+01	9.449E+01	9.425E+01	9.412E+01	9.406E+01	9.353E+01	
PU238/IMA x	5.045E-04	3.310E-0L	2.402E-03	5.512E-03	2.234E-03	1.353E-02	1.630E-02	1.793E-02	1.850E-02	2.393E-02	
PU239/IMA x	3.270E-01	2.914E-01	4.513E-01	5.104E-01	4.429E-01	5.550E-01	5.647E-01	5.687E-01	5.702E-01	5.929E-01	
PU240/IMA x	4.705E-02	3.647E-02	1.029E-01	1.455E-01	9.803E-02	1.973E-01	2.115E-01	2.189E-01	2.216E-01	2.474E-01	
PU241/IMA x	1.451E-02	9.704E-03	4.384E-02	7.095E-02	4.089E-02	1.029E-01	1.116E-01	1.161E-01	1.176E-01	1.257E-01	
PU242/IMA x	1.236E-03	6.772E-04	7.749E-03	1.868E-02	6.866E-03	3.975E-02	4.800E-02	5.280E-02	5.472E-02	6.504E-02	
PU/IMA x	3.911E-01	3.386E-01	6.083E-01	7.510E-01	5.909E-01	9.093E-01	9.521E-01	9.746E-01	9.820E-01	1.055E+00	
ND143/IMA x	4.724E-02	3.994E-02	7.971E-02	1.039E-01	7.691E-02	1.301E-01	1.377E-01	1.416E-01	1.431E-01	1.549E-01	
ND144/IMA x	4.934E-02	4.083E-02	9.421E-02	1.352E-01	8.998E-02	1.935E-01	2.137E-01	2.252E-01	2.298E-01	2.616E-01	
ND145/IMA x	3.293E-02	2.765E-02	5.827E-02	7.880E-02	5.604E-02	1.044E-01	1.124E-01	1.168E-01	I.105E-01	1.309E-01	
ND146/IMA x	2.689E-02	2.235E-02	5.025E-02	7.110E-02	4.807E-02	1.004E-01	1.105E-01	1.161E-01	1.184E-01	1.347E-01	
ND148/IMA x	1.500E-02	1.249E-02	2.755E-02	3.844E-02	2.639E-02	5.314E-025.806E-02		6.080E-02	6.190E-02	6.976E-02	
ND150/IMA x	6.221E-03	5.164E-03	1.192E-02	1.693E-02	1.140E-02	2.434E-02	2.678E-02	2.816E-02	2.871E-02	3.289E-02	
U/UO IN ATOM	9.871E-01	9.892E-01	9.775E-01	9.695E-01	9.783E-01	9.592E-01	9.558E-01	9.539E-01	9.532E-01	9.478E-01	
U/UO IN WEIG	9.872E-01	9.893E-01	9.776E-01	9.697E-01	9.784E-01	9.594E-01	9.561E-01	9.542E-01	9.535E-01	9.481E-01	
F25/IMA X	7.301E-01	6.250E-01	1.196E+00	1.521E+00	1.157E+00	1.871E+00	1.969E+00	2.019E+00	2.03917100	2.249E+00	
D20/IMA x	5.536E-01	4.553E-01	1.055E+00	1.521E+00	1.009E+00	2.202E+00	2.437E+00	2.574E+00	2.627E+00	2.961E+00	
(F-F5)/IMA X	1.659E-01	1.210E-01	4.484E-01	7.741E-01	4.102E-01	1.302E+00	1.498E+00	1.612E+00	1.658E+00	1.917E+00	
PU/(F-F5) x	2.350E+00	2.798E+00	1.357E+00	9.702E-01	1.413E+00	6.984E-01	6.356E-01	6.046E-01	5.928E-01	5.504E-01	
D25/IMA x	8.976E-01	7.682E-01	1.465E+00	1.855E+00	1.418E+00	2.263E+00	2.375E+00	2.432E+00	2.454E+00	2.708E+00	
D26/IMAX	-1.675E-01	-1.432E-01	-2.686E-01	-3.332E-01	-2.610E-01	-3.919E-01	-4.067E-01	-4.134E-01	-4.158E-01	-4.593E-01	
ALPHA-U235	2.29S[-0!	2.291E-01	2.245E-01	2.190E-01	2.255E-01	2.095E-01	2.066E-01	2.048E-01	2.040E-01	2.042E-01	
U232 G/TUO	3.711E-09	2.562E-09	1.350E-08	2.683E-08	1.236E-08	5.919E-08	7.061E-08	7.743E-08	8.021E-08	1.026E-07	
NP237 G/TUO	7.551E+01	5.836E+01	1.712E+02	2.722E+02	1.610E+02	4.386E+02	4.861E+02	5.121E+02	5.223E+02	5.936E+02	
PU236 G/TUO	9.872E+37	9.893E+37	9.776E+37	9.697E+37	9.784E+37	9.594E+37	9.561E+37	9.542E+37	9.535E+37	9.481E+37	
AM241 G/TUO	3.990E+01	2.669E+01	1.270E+02	2.052E+02	1. 185E+02	3.142E+02	3.392E+02	3.510E+02	3.567E+02	3.884E+02	
AM242M G/TUO	9.872E+37	9.893E+37	9.776E+37	9.697E+37	9.784E+37	9.594E+37	9.561E+37	9.542E+37	9.535E+37	9.481E+37	
AM243 G/TUO	3.875E-01	1.729E-01	5.830E+00	2.044E+01	4.920E+00	5.947E+01	7.821E+01	8.979E+01	9.461E+01	1.354E+02	
CM242 G/TUO	6.134E-05	3.350E-05	1.002E-03	2.416E-03	8.855E-04	6.144E-03	7.274E-03	7.902E-03	8.139E-03	9.699E-03	
CM243 G/TUO	4.951E-04	2.228E-04	2.394E-02	8. 183E-02	2.020E-02	2.474E-01	3.176E-01	3.596E-01	3.767E-01	4.726E-01	
CM244 G/TUO	1.316E-02	4.683E-03	7.283E-01	3.925E+00	5.819E-01	1.820E+01	2.714E+01	3.328E+01	3.593E+01	6.735E+01	
ITU106 BQ/GUO	1.104E+08	8.743E+07	2.307E+08	3.759E+08	2.165E+08	4.931E+08	5.643E+08	6.053E+08	6.215E+08	6.854E+08	
SB125 BQ/GUO	1.726E+07	1.410E+07	3.270E+07	4.864E+07	3.106E+07	6.643E+07	7.400E+07	7.834E+07	8.005E+07	8.989E+07	
CS134 BQ/GUO	7.760E+07	5.421E+07	2.424E+08	4.606E+08	2.231E+08	7.750E+08	9.150E+08	9.972E+08	1.031E+09	1.214E+09	
CS137 BQ/GUO	9.019E+08	7.517E+08	1.645E+09	2.296E+09	1.575E+09	3.156E+09	3.449E+09	3.613E+09	3.699E+09	4.148E+09	
CE144 BQ/GUO	3.006E+08	2.516E+08	3.442E+08	4.697E+08	3.304E+08	4.409E+08	4.778E+08	4.981E+08	5.059E+08	4.934E+08	
EU154 BQ/GUO	9.892E+06	6.974E+06	3.293E+07	6.115E+07	3.034E+07	1.116E+08	1.292E+08	1.392E+08	1.431E+08	1.746E+08	

Appendix 7 Explanations of terms in Appendix 1-6

BURNUP %FIMA(FT/I MA), BURNUP MWD/T(FT MWD/MTU)	Burnup(%FIMA) and Burnup(MWd/t)
IN IT. U-234 %, IN IT. U-235 %, IN IT. U-236 %, IN IT. U-238 %	Isotopic ratio(atom %) of initial U(before irradiat ion)
FINL.U-234 %, FINL. U-235 %, FINL.U-236 %, FINL.U-238 %	Isotopic ratio(atom%) of U after irrn.dinted
PU-238 %, PU-239 %, PU-240 %, PU-241 %, PU-242 %	Isotopic ratio(atom%) of Pu after irradeation
ND-143 %, ND-144 %, ND-145 %, ND-146 %, ND-148 %, ND-150%	Isotopic ratio(atom%) of Nd after irradiation
KR-83 %, KR-84 %, KR-85 %, KR-86 %	Isotopic ratio(atom%) of Kr after irradiation
XE-131 %, XE-132 %, XE-134 %, XE-136 %	Isotopic ratio(atom%) of Xe after irradiation
PU/U, ND-148/u	Atoms of Pu and Nd-148 per Atoms of U after irradiation
U-232 G/TU, NP-237 G/TU, PU-236 G/TU, AM-241 G/TU, AM-242M G/TU	Grams of ^{232}U,^{237}Np,^{236}Pu,^{241}Am, ^{242m}Am per ton U after irrad.
AM-243 G/TU, CM-242 G/TU, CM-243 G/TU, CM-244 G/TU	Grams of ^{243}Am,^{242}Cm,^{243}Cm,^{244}Cm per ton U after irrad.
RU-106 BQ/GU, SB-125 BQ/GU, CS-134 BQ/GU, CS-137 BQ/GU	Activity of ^{106}Ru,^{125}Sb, ^{134}Cs, ^{137}Cs per g U after irrad.
CE-144 BQ/GU, EU-154 BQ/GU	Activity(Bq) of ^{144}Ce,^{154}Eu per g U after irrad.
1. U234/I MA %, 1. U235/I MA %, 1. U236/I MA %, 1. U238/I MA %	Atomic % of initial U isotopes per initial heavy metals(U)
F.U234/IMA %, F.U235/IMA %, F.U236/IMA %, F.U238/IMA %	Atomic % of U isotopes after irrad. per initial heavy metals
PU-238/IMA %, PU-239/IMA %, PU-240/IMA %, PU-241/IMA %, PU-242/IMA %	Atomic % of Pu isotopes after irrad. per initial heavy metals(U)
ND-143/IMA %, ND-144/IMA %, NO-145/IMA %, ND-146/IMA %, ND-148/IMA %, ND-150/IMA %	Atomic % of Nd isotopes after irrad. per initial heavy metals(U)
PU/IMA %	Atomic % of Pu after irrad. per initial heavy metals(U)
U/UO IN ATOM, U/UO IN WEIG	Ratio of U after irrad. per initial U in atoms nnd weights
F25/IMA %, (F-F5)/IMA %	Fission atoms(%) of ^{235}U nnd others per initial heavy metals
D25/IMA %, D26/IMA %, D28/IMA %	Depleted atoms(%) of ^{235}U,^{236}U,^{238}U per initial heavy metals
PU/(F-F5)	Atoms of Pu(%) per fission atoms other than ^{235}U
ALPHA-U235	Alpha value(neutron capture/fission) of ^{235}U
U-232 G/TUO, NP-237 G/TUO, PU-236 G/TUO	Grams of ^{232}U,^{237}Np,^{236}Pu per ton initial heavy metals
AM-241, AM242M G/TUO, AM-243 G/TUO	Grams of ^{241}Am,^{242m}Am,^{243}Am per ton initialheavymetals
CM-242, CM-243, CM-244 G/TUO	Grams of ^{242}Cm,^{243}Cm,^{244}Cm per toninitialheavymetals
RU-106 BQ/GUO, SB-125 BQ/GUO, CS-134 BQ/GUO	Activity of ^{106}Ru,^{125}Sb,^{134}Cs per g initial heavy metals
CS-137 BQ/GUO, CE-144 BQ/GUO, EU-154 BQ/GUO	Activity of ^{137}Cs, ^{144}Ce,^{154}Eu per g initial heavy metals

Cooling times: 5years after discharge of fuels