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RESEARCH ESTABLISHMENT

LUCAS HEIGHTS

TEST OF THE THREE-GAUSSIAN ASSUMPTION FOR FISSION PRODUCT MASS YIELD CURVES

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ABSTRACT

A set of eight-parameter, three-Gaussian fits was made for fissile nuclides in the mass range 227 to 258. It is shown that acceptable fits are obtained in all cases, with a mean deviation from the fit usually around 25 per cent.

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ACTINIDE NUCLEI; DIAGRAMS; FISSION; FISSION PRODUCTS; FISSION YIELD; GAUSSIAN PROCESSES; PLUTONIUM 240

CONTENTS

1. INTRODUCTION

Cook *et al.* [1975] have shown that the fission product mass yields for neutron fission of ^{232}Th, ^{233}U, ^{235}U, ^{238}U and ^{239}Pu could be fitted to within 20 per cent mean deviation by a superposition of two pairs of asymmetric Gaussian curves and a single symmetric Gaussian. There was sufficient information for these nuclides to permit an examination of the energy dependence of the eight parameters obtained. For a wide range of heavy nuclides, fission product yield data have been measured at one energy only; this does not allow a check on the energy dependence.

In the present work, the three-Gaussian postulate is tested by fitting 39 measured mass yield curves ranging from ^{227}Ac to ^{257}Fm neutron fission, and some spontaneous fission values as well. Data were obtained for these nuclides from Meek & Rider [1974], Crouch [1973], Unik *et al.* [1973], John *et al.* [1971] and Hyde [1964].

2. GAUSSIAN FIT

Following Cook *et al.* [1975], we parameterise the mass yield curve by

$$Y(A) = 100 \sum_{i=1}^{5} W_i \cdot \frac{1}{\sqrt{2\pi}} \cdot \frac{1}{\sigma_i} \cdot e^{-(A-A_i)^2/2\sigma_i^2} \qquad (1)$$

where $Y(A)$ = the mass yield of a given chain of nuclides with mass number A,

σ_i^2 = the variance of the i^{th} Gaussian,

A_i = the peak of the i^{th} Gaussian, and

W_i = the weight of the i^{th} Gaussian.

The weights satisfy

$$W_1 + \frac{1}{2} \sum_{i=2}^{5} W_i = 1 \qquad (2)$$

where the first Gaussian is chosen as the symmetric one. In addition, by symmetry we have

$$A_4 = 2A_1 - A_2 \quad , \quad \sigma_2 = \sigma_4 \quad , \quad W_2 = W_4$$

$$A_3 = 2A_1 - A_5 \quad , \quad \sigma_3 = \sigma_5 \quad , \quad W_3 = W_5 \qquad (3)$$

This provides eight independent parameters if we parameterise the weights by

$$W_1 = \sin^2\theta_1$$

$$W_2 = \cos^2\theta_1\cos^2\theta_2$$

$$W_3 = \cos^2\theta_1\sin\theta_2 \qquad (4)$$

A non-linear least-squares routine was written to determine the eight parameters σ_1, σ_2, σ_3, A_1, A_3, A_5, θ_1 and θ_2, together with the error analysis; the 39 nuclides listed in Table 1 were then fitted.

3. RESULTS

The quantities E, ES and EF listed are the energy of the incident neutron, if neutron fission is involved, the excitation energy of the compound nucleus, and the fission barrier energy, in MeV, respectively On the next line for each entry are the parameters listed in the above order for each fit, together with their errors. The percentage mean deviation is shown in Table 2. This is an estimate of the quality of fit in the form of the quantity:

$$M^2 = \sum_i \frac{(Y_i^{calc} - Y_i^{exp})^2}{(\delta Y_i)^2} \qquad (5)$$

$$\Phi = \sqrt{M^2/N}$$

and, since most errors δY_i are around 10 per cent, the value of Φ multiplied by ten is around the mean deviation from the fit.

We attempted to systematise the parameters as a function of A_F and Z_F^2/A_F, where A_F is the compound nucleus mass number and Z_F is the compound nucleus charge, but did not obtain a good fit. This is because the energies of excitation of each compound nucleus are not the same distance from the fission barrier throughout Table 1, and it is known that the parameters are functions of $E_s - E_f$. Cook *et al.* [1975] in fact showed that

$$\text{(i)}\quad \sigma_i = a_i + b_i\sqrt{E-E_f}$$

$$\text{(ii)}\quad A_1 = a_4 + b_4E$$

$$\text{(iii)}\quad A_4 = a_5 + b_5\sqrt{E-E_f}$$

$$\text{(iv)}\quad A_5 = a_6 + b_6\sqrt{E-E_f}$$

$$\text{(v)}\quad \tan\theta_1 = \frac{2}{\Gamma_1}(E-E_1)$$

$$\text{(vi)}\quad \tan\theta_2 = \frac{2}{\Gamma_2}(E-E_2) \qquad (6)$$

where E = the incident neutron energy and a_i, b_i, Γ_i and E_i are constants determined from fits.

As an example of the usefulness of such fits, Table 3 contains the estimated mass yields for thermal, 2 MeV and 14 MeV fission of ^{240}Pu obtained by linear interpolation in A_F of the above constants. The results appear reasonable and could be used in fast reactor calculations provided the full energy dependence of the curve is included. In any case, Table 2 indicates that the three-Gaussian assumption for the general mass yield curve appears to hold in every example.

One trend that can be discerned in the data is that the positions of the two heavy peaks vary little from around 136 atomic mass units (amu) and 143 amu throughout the periodic table. The centre, A_1, however, for prompt fission varies as $A_F/2$. Thus at mass numbers around 272 the peaks will be almost superimposed, so we should expect symmetric fission in this region. This is borne out by the results for ^{258}Fm where the curves are already almost superimposed.

4. CONCLUSION

The three-Gaussian assumption for the shape of fission product mass yield curves appears to be valid for fissionable nuclei ranging in mass from 227 to 258. Acceptable fits were obtained in all cases and this permits the prediction of unmeasured fission product yields by way of interpolation.

5. ACKNOWLEDGEMENT

Thanks are due to G.D. Trimble for assistance in programming these calculations.

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TABLE 1

GAUSSIAN PARAMETER FOR MASS YIELD CURVES

NUCLIDE- 89AC228

E*ES*EF (MEV) = 0.0 5.035 5.869

6.840E+00 +OR- 1.996E+00	4.115E+00 +OR- 1.680E-01	1.899E+00 +OR- 2.217E-01	1.121E+00 +OR- 1.823E-03
1.379E+00 +OR- 2.882E-03	1.190E+00 +OR- 2.783E-03	1.115E-01 +OR- 1.727E-02	1.952E-01 +OR- 1.142E-02

NUCLIDE- 90TH228

E*ES*EF (MEV) = 0.0 7.129 5.908

6.840E+00 +OR- 2.965E+00	3.489E+00 +OR- 1.481E-01	5.848E+00 +OR- 6.964E-01	1.141E+00 +OR- 1.100E-04
1.377E+00 +OR- 1.285E-03	1.315E+00 +OR- 2.650E-02	4.378E-01 +OR- 3.030E-02	4.000E-01 +OR- 1.069E-01

NUCLIDE- 90TH230

E*ES*EF (MEV) = 0.0 6.790 5.892

1.349E+01 +OR- 2.805E+00	0.0 +OR- 0.0	3.600E+00 +OR- 1.741E-02	1.142E+00 +OR- 3.000E-04
0.0 +OR- 0.0	1.390E+00 +OR- 4.460E-04	4.983E-02 +OR- 4.440E-03	1.588E+00 +OR- 4.984E-01

NUCLIDE- 90TH233

E*ES*EF (MEV) = 2.000 4.787 5.950

1.144E+01 +OR- 1.092E+00	3.324E+00 +OR- 4.376E-02	2.797E+00 +OR- 7.413E-02	1.157E+00 +OR- 2.600E-04
1.427E+00 +OR- 1.621E-03	1.358E+00 +OR- 2.116E-03	8.620E-02 +OR- 3.300E-03	6.425E-01 +OR- 2.680E-02

NUCLIDE- 90TH233

E*ES*EF (MEV) = 14.000 4.787 5.950

1.256E+01 +OR- 6.469E-02	4.527E+00 +OR- 6.956E-02	2.189E+00 +OR- 3.129E-01	1.147E+00 +OR- 3.600E-04
1.395E+00 +OR- 2.526E-03	1.344E+00 +OR- 2.823E-03	4.544E-01 +OR- 5.100E-03	0.0 +OR- 0.0

TABLE 1 (Contd.)

NUCLIDE- 92 U234

E,ES,EF (MEV) = 0.0 6.841 5.490

9.917E+00 +OR- 3.060E-01 4.275E+00 +OR- 2.843E-02 3.331E+00 +OR- 7.060E-02 1.158E+00 +OR- 1.700E-04
1.407E+00 +OR- 1.609E-03 1.338E+00 +OR- 2.406E-03 3.990E-02 +OR- 8.100E-04 6.433E-01 +OR- 3.190E-02

NUCLIDE- 92 U234

E,ES,EF (MEV) = 2.000 6.841 5.490

1.395E+01 +OR- 5.502E+00 4.425E+00 +OR- 1.828E-02 1.469E+00 +OR- 9.161E-01 1.160E+00 +OR- 3.000E-04
1.396E+00 +OR- 6.530E-04 1.328E+00 +OR- 1.530E-03 1.136E-01 +OR- 1.400E-03 3.387E-01 +OR- 1.720E-02

NUCLIDE- 92 U234

E,ES,EF (MEV) = 14.800 6.841 5.490

1.059E+01 +OR- 1.585E+00 6.096E+00 +OR- 2.785E-01 8.128E+00 +OR- 2.803E+00 1.151E+00 +OR- 7.600E-04
1.368E+00 +OR- 8.434E-03 1.354E+00 +OR- 1.000E-01 4.954E-01 +OR- 2.000E-01 2.905E-01 +OR- 1.000E-01

NUCLIDE- 92 U235

E,ES,EF (MEV) = 14.800 5.306 6.150

4.973E+00 +OR- 2.571E+00 5.439E+00 +OR- 9.036E-01 7.725E+00 +OR- 8.777E-01 1.156E+00 +OR- 1.000E-03
1.386E+00 +OR- 1.703E-02 1.329E+00 +OR- 2.792E-02 2.384E-01 +OR- 1.067E-01 9.107E-01 +OR- 3.085E-01

NUCLIDE- 92 U236

E,ES,EF (MEV) = 0.0 6.545 6.100

1.068E+01 +OR- 3.388E-02 4.034E+00 +OR- 2.301E-02 2.900E+00 +OR- 4.759E-02 1.170E+00 +OR- 1.400E-04
1.421E+00 +OR- 1.308E-03 1.348E+00 +OR- 1.407E-03 4.150E-02 +OR- 5.500E-04 7.099E-01 +OR- 2.110E-02

TABLE 1 (Contd.)

NUCLIDE- 92 U236

E,ES,EF (MEV) = 2.000 6.545 6.100

1.101E+01 +OR- 6.348E-02	4.643E+00 +OR- 3.353E-02	2.970E+00 +OR- 9.105E-02	1.169E+00 +OR- 2.000E-04
1.408E+00 +OR- 1.712E-03	1.339E+00 +OR- 2.209E-03	7.070E-02 +OR- 1.000E-03	5.929E-01 +OR- 3.170E-02

NUCLIDE- 92 U236

E,ES,EF (MEV) = 14.000 6.545 6.100

1.260E+01 +OR- 4.494E-02	6.033E+00 +OR- 4.118E-02	1.734E+00 +OR- 4.250E-01	1.163E+00 +OR- 3.600E-04
1.372E+00 +OR- 1.253E-03	1.325E+00 +OR- 4.116E-03	4.116E-01 +OR- 7.300E-03	2.476E-01 +OR- 3.820E-02

NUCLIDE- 92 U237

E,ES,EF (MEV) = 14.800 5.124 5.700

2.893E+00 +OR- 2.247E+00	8.005E+00 +OR- 3.353E-01	5.563E+00 +OR- 3.326E-01	1.167E+00 +OR- 7.400E-04
1.328E+00 +OR- 1.202E-02	1.392E+00 +OR- 7.238E-03	1.251E-01 +OR- 6.640E-02	7.925E-01 +OR- 1.142E-01

NUCLIDE- 92 U238

SPONTANEOUS FISSION

0.0 +OR- 0.0	3.517E+00 +OR- 6.821E-02	1.770E+00 +OR- 5.491E-02	1.189E+00 +OR- 4.010E-04
1.433E+00 +OR- 1.942E-03	1.353E+00 +OR- 1.942E-03	1.176E-02 +OR- 2.000E-03	5.336E-01 +OR- 2.530E-02

NUCLIDE- 92 U239

E,ES,EF (MEV) = 2.000 4.803 5.900

9.876E+00 +OR- 3.172E-02	4.219E+00 +OR- 2.467E-02	2.908E+00 +OR- 4.423E-02	1.184E+00 +OR- 1.900E-04
1.437E+00 +OR- 1.215E-03	1.351E+00 +OR- 1.116E-03	7.110E-02 +OR- 1.000E-03	7.993E-01 +OR- 1.510E-02

TABLE 1 (Contd.)

NUCLIDE- 92 U239

E,ES,EF (MEV) = 14.000 4.803 5.900

1.198E+01 +OR- 7.922E-02	6.214E+00 +OR- 4.532E-02	2.250E+00 +OR- 2.892E-01	1.177E+00 +OR- 3.400E-04
1.388E+00 +OR- 1.734E-03	1.329E+00 +OR- 2.721E-03	3.149E-01 +OR- 6.900E-03	3.647E-01 +OR- 3.400E-02

NUCLIDE- 93NP238

E,ES,EF (MEV) = 2.000 5.480 5.700

5.063E+00 +OR- 7.394E-01	3.633E+00 +OR- 4.479E-02	4.156E+00 +OR- 6.108E-02	1.186E+00 +OR- 2.960E-04
1.475E+00 +OR- 2.220E-03	1.378E+00 +OR- 1.236E-03	5.715E-02 +OR- 3.600E-03	1.158E+00 +OR- 1.660E-02

NUCLIDE- 94PU240

E,ES,EF (MEV) = 0.0 6.533 6.430

4.507E+00 +OR- 7.382E-01	4.736E+00 +OR- 3.172E-02	3.588E+00 +OR- 5.825E-02	1.187E+00 +OR- 2.300E-04
1.439E+00 +OR- 1.815E-03	1.355E+00 +OR- 1.320E-03	4.560E-02 +OR- 3.200E-03	9.459E-01 +OR- 1.810E-02

NUCLIDE- 94PU240

E,ES,EF (MEV) = 2.000 6.533 6.430

5.456E+00 +OR- 1.318E+00	5.161E+00 +OR- 4.144E-02	3.843E+00 +OR- 7.519E-02	1.188E+00 +OR- 2.700E-04
1.439E+00 +OR- 2.316E-03	1.358E+00 +OR- 1.426E-03	6.700E-02 +OR- 7.300E-03	9.687E-01 +OR- 2.180E-02

NUCLIDE- 94PU240

SPONTANEOUS FISSION

0.0 +OR- 0.0	3.864E+00 +OR- 2.429E-01	1.950E+00 +OR- 2.012E-01	1.191E+00 +OR- 8.990E-04
1.406E+00 +OR- 4.687E-03	1.336E+00 +OR- 3.228E-03	3.122E-01 +OR- 5.520E-02	6.275E-01 +OR- 5.790E-02

TABLE 1 (Contd.)

NUCLIDE- 94PU242

E,ES,EF (MEV) = 0.0 6.301 6.250

1.096E+01	+OR- 3.621E-02	4.483E+00	+OR- 3.686E-02	3.340E+00	+OR- 4.135E-02	1.195E+02	+OR- 2.167E-02
1.451E+02	+OR- 1.875E-01	1.362E+02	+OR- 1.078E-01	5.644E-02	+OR- 1.016E-03	9.792E-01	+OR- 1.531E-02

NUCLIDE- 95AM242

E,ES,EF (MEV) = 0.0 5.528 5.995

0.0	+OR- 0.0	5.484E+00	+OR- 8.810E-02	2.837E+00	+OR- 1.852E-01	1.191E+00	+OR- 8.774E-04
1.394E+00	+OR- 2.208E-03	1.344E+00	+OR- 3.017E-03	2.004E-02	+OR- 5.208E-01	5.847E-01	+OR- 4.002E-02

NUCLIDE- 95AM243

E,ES,EF (MEV) = 0.0 6.377 5.987

0.0	+OR- 0.0	5.513E+00	+OR- 2.368E-01	3.720E+00	+OR- 1.311E-01	1.197E+00	+OR- 5.805E-04
1.438E+00	+OR- 8.363E-03	1.358E+00	+OR- 2.632E-03	2.378E-02	+OR- 1.176E-02	9.152E-01	+OR- 5.755E-02

NUCLIDE- 96CM242

SPONTANEOUS FISSION

0.0	+OR- 0.0	5.199E+00	+OR- 1.414E-01	2.335E+00	+OR- 1.549E-01	1.189E+00	+OR- 9.300E-04
1.380E+00	+OR- 2.388E-03	1.324E+00	+OR- 2.388E-03	0.0	+OR- 0.0	5.863E-01	+OR- 4.170E-02

NUCLIDE- 96CM244

SPONTANEOUS FISSION

0.0	+OR- 0.0	5.455E+00	+OR- 2.062E-01	3.814E+00	+OR- 9.464E-02	1.210E+00	+OR- 5.900E-04
1.446E+00	+OR- 8.720E-03	1.375E+00	+OR- 2.278E-03	0.0	+OR- 0.0	9.955E-01	+OR- 5.950E-02

TABLE 1 (Contd.)

NUCLIDE- 96CM246

SPONTANEOUS FISSION

0.0 +OR- 0.0	5.493E+00 +OR- 1.178E+00	3.946E+00 +OR- 5.328E-01	1.230E+00 +OR- 3.500E-04
1.427E+00 +OR- 3.740E-02	1.370E+00 +OR- 6.410E-03	2.268E-01 +OR- 4.140E-02	8.162E-01 +OR- 3.682E-01

NUCLIDE- 96CM246

E.ES,EF (MEV) = 0.0 6.451 6.380

0.0 +OR- 0.0	5.801E+00 +OR- 4.522E-02	2.922E+00 +OR- 1.726E-01	1.211E+00 +OR- 6.800E-04
1.410E+00 +OR- 1.209E-03	1.348E+00 +OR- 2.687E-03	2.530E-01 +OR- 4.540E-02	5.836E-01 +OR- 2.770E-02

NUCLIDE- 96CM248

SPONTANEOUS FISSION

0.0 +OR- 0.0	4.354E+00 +OR- 9.115E-02	2.033E+00 +OR- 3.682E-02	1.240E+00 +OR- 2.900E-04
1.450E+00 +OR- 2.120E-03	1.358E+00 +OR- 9.933E-04	6.680E-01 +OR- 1.270E-02	8.161E-01 +OR- 1.740E-02

NUCLIDE- 98CF245

SPONTANEOUS FISSION

5.865E+01 +OR- 8.572E+02	3.626E+00 +OR- 8.834E-01	5.074E+00 +OR- 8.012E-02	1.270E+00 +OR- 5.100E-04
1.576E+00 +OR- 1.311E-02	1.426E+00 +OR- 9.403E-04	3.342E-02 +OR- 2.552E-01	1.473E+00 +OR- 1.610E-02

NUCLIDE- 98CF250

SPONTANEOUS FISSION

0.0 +OR- 0.0	4.745E+00 +OR- 8.885E-01	4.933E+00 +OR- 1.136E-01	1.250E+00 +OR- 5.300E-04
1.532E+00 +OR- 1.111E-02	1.401E+00 +OR- 1.781E-03	2.679E-01 +OR- 2.980E-02	1.281E+00 +OR- 3.440E-02

TABLE 1 (Contd.)

NUCLIDE- 98CF250

E•ES•EF (MEV) = 0.0 6.619 4.100

0.0	+OR- 0.0	7.621E+00	+OR- 4.107E+00	5.058E+00	+OR- 2.678E-01	1.250E+00	+OR- 6.300E-04
1.495E+00	+OR- 7.200E-02	1.387E+00	+OR- 3.753E-03	1.324E-01	+OR- 1.207E-01	1.144E+00	+OR- 2.153E-01

NUCLIDE- 98CF252

SPONTANEOUS FISSION

0.0	+OR- 0.0	5.580E+00	+OR- 2.554E-01	4.215E+00	+OR- 2.814E-01	1.242E+00	+OR- 7.300E-04
1.458E+00	+OR- 1.512E-02	1.401E+00	+OR- 5.548E-03	0.0	+OR- 0.0	8.467E-01	+OR- 1.665E-01

NUCLIDE- 98CF252

E•ES•EF (MEV) = 0.0 6.166 3.800

0.0	+OR- 0.0	5.696E+00	+OR- 2.840E+00	1.763E+00	+OR- 1.231E-02	1.232E+00	+OR- 1.200E-03
1.413E+00	+OR- 3.700E-03	1.335E+00	+OR- 2.332E-03	4.221E-01	+OR- 3.880E-02	4.068E-01	+OR- 4.600E-02

NUCLIDE- 99ES253

SPONTANEOUS FISSION

0.0	+OR- 0.0	5.709E+00	+OR- 2.305E-01	3.224E+00	+OR- 1.882E-01	1.246E+00	+OR- 6.300E-04
1.456E+00	+OR- 4.940E-03	1.365E+00	+OR- 3.753E-03	2.788E-01	+OR- 4.150E-02	5.714E-01	+OR- 5.460E-02

NUCLIDE- 99ES255

E•ES•EF (MEV) = 0.0 5.980 4.200

0.0	+OR- 0.0	6.394E+00	+OR- 2.717E-01	3.768E+00	+OR- 8.090E-01	1.255E+00	+OR- 1.300E-03
1.432E+00	+OR- 8.204E-03	1.341E+00	+OR- 8.006E-03	0.0	+OR- 0.0	5.471E-01	+OR- 1.140E-01

TABLE 1 (Contd.)

NUCLIDE-100FM254

SPONTANEOUS FISSION

0.0 +OR- 0.0	7.260E+00 +OR- 1.017E+01	4.578E+00 +OR- 7.707E-01	1.248E+00 +OR- 1.300E-03
1.478E+00 +OR- 2.139E-01	1.395E+00 +OR- 6.923E-03	1.074E-01 +OR- 5.328E-01	1.098E+00 +OR- 8.285E-01

NUCLIDE-100FM256

SPONTANEOUS FISSION

0.0 +OR- 0.0	6.029E+00 +OR- 8.637E-01	3.434E+00 +OR- 4.186E-01	1.264E+00 +OR- 1.100E-03
1.442E+00 +OR- 1.833E-02	1.362E+00 +OR- 4.730E-03	3.574E-01 +OR- 3.830E-02	7.120E-01 +OR- 1.573E-01

NUCLIDE-100FM256

E,ES,EF (MEV) = 0.0 6.375 3.500

3.364E+01 +OR- 2.064E+01	7.853E+00 +OR- 4.273E-01	2.265E+00 +OR- 3.699E-01	1.256E+00 +OR- 1.600E-03
1.395E+00 +OR- 3.138E-03	1.338E+00 +OR- 3.848E-03	3.410E-01 +OR- 8.230E-02	4.629E-01 +OR- 4.510E-02

NUCLIDE-100FM257

SPONTANEOUS FISSION

1.848E+01 +OR- 0.0	0.0 +OR- 0.0	0.0 +OR- 0.0	1.280E+00 +OR- 2.300E-03
1.642E+00 +OR- 2.300E-03	1.349E+00 +OR- 2.300E-03	1.571E+00 +OR- 0.0	1.575E+00 +OR- 0.0

NUCLIDE-100FM258

E,ES,EF (MEV) = 0.0 6.375 3.400

2.478E+01 +OR- 1.129E+00	4.433E+00 +OR- 1.923E+00	9.403E+00 +OR- 2.094E+01	1.280E+00 +OR- 2.700E-03
1.532E+00 +OR- 2.395E-02	1.328E+00 +OR- 2.700E-03	9.173E-01 +OR- 8.110E-02	2.016E+00 +OR- 2.997E-01

TABLE 2

FITS TO VARIOUS NUCLIDES

COMPOUND NUCLIDE	NEUTRON ENERGY (MEV)	N	M^2	$10\sqrt{M^2/N}$
89AC228	0.0	13	21.96	13.00
90TH228	0.0	27	324.92	34.69
90TH230	0.0	50	933.04	43.20
90TH233	2.0	100	1070.00	32.71
90TH233	14.0	100	1030.00	32.09
92 U234	0.0	100	290.00	17.03
92 U234	2.0	100	300.00	17.32
92 U234	14.8	100	300.00	17.32
92 U235	14.8	24	11.45	6.91
92 U236	0.0	100	237.00	15.39
92 U236	2.0	100	240.00	15.49
92 U236	14.0	100	240.00	15.49
92 U237	14.8	37	75.00	14.24
92 U239	0.0	25	239.39	30.94
92 U239	2.0	100	350.00	18.71
92 U239	14.0	100	250.00	15.81
93NP238	2.0	91	610.06	25.89
94PU240	0.0	100	283.00	16.82
94PU240	2.0	100	277.00	16.64
94PU241	0.0	15	49.95	18.25
94PU242	0.0	100	572.00	23.92
95AM242	0.0	28	252.80	30.05
95AM243	0.0	35	65.50	13.68
96CM243	0.0	19	715.84	61.38
96CM245	0.0	40	478.71	34.59
96CM246	0.0	34	248.38	27.03
96CM247	0.0	73	938.89	35.86
96CM249	0.0	67	1622.20	49.21
98CF246	0.0	71	1428.00	44.85
98CF250	0.0	67	138.58	14.38
98CF251	0.0	67	133.63	14.12
98CF252	0.0	21	107.88	22.66
98CF253	0.0	40	609.04	39.02
99ES254	0.0	32	415.80	36.05
99ES255	0.0	28	136.53	22.08
100FM255	0.0	24	182.53	27.58
100FM256	0.0	22	65.89	17.31
100FM257	0.0	27	50.56	13.68
100FM258	0.0	32	151.93	21.79
100FM258	0.0	32	15.65	6.99

TABLE 3

MASS YIELDS FOR THERMAL FISSION OF ^{240}Pu

	NEUTRON ENERGY (MEV)		
	0.0	2.0	14.0
SIGMA(1)....	5.45630E+00	7.85528E+00	1.18884E+01
SIGMA(2)....	3.56625E+00	4.53816E+00	6.17211E+00
SIGMA(3)....	4.83678E+00	7.08791E+00	1.08725E+01
A1	1.19195E+02	1.19116E+02	1.18637E+02
A4	2.32705E+01	2.53030E+01	2.90643E+01
A5	1.55533E+01	1.67484E+01	1.91021E+01
THETA(1)....	4.06283E-02	5.92271E-02	1.70820E-01
THETA(2)....	7.49478E-01	6.48832E-01	4.49630E-02

A	Y(0.0)	Y(2.0)	Y(14.0)
66	3.73741E-13	7.59891E-06	3.05960E-02
67	1.83919E-12	1.55484E-05	4.04663E-02
68	8.71828E-12	3.12325E-05	5.30717E-02
69	3.99653E-11	6.16446E-05	6.90203E-02
70	1.78190E-10	1.19698E-04	8.90098E-02
71	7.78572E-10	2.29032E-04	1.13828E-01
72	3.36125E-09	4.32733E-04	1.44348E-01
73	1.44330E-08	8.09216E-04	1.81519E-01
74	6.17700E-08	1.50113E-03	2.26353E-01
75	2.62391E-07	2.76731E-03	2.79897E-01
76	1.09574E-06	5.07365E-03	3.43208E-01
77	4.44331E-06	9.24545E-03	4.17307E-01
78	1.72844E-05	1.67079E-02	5.03140E-01
79	6.38390E-05	2.98376E-02	6.01516E-01
80	2.22119E-04	5.24245E-02	7.13057E-01
81	7.23936E-04	9.01951E-02	8.38130E-01
82	2.20155E-03	1.51265E-01	9.76787E-01
83	6.23044E-03	2.46294E-01	1.12872E+00
84	1.63798E-02	3.88038E-01	1.29319E+00
85	3.99583E-02	5.90014E-01	1.46902E+00
86	9.03884E-02	8.64120E-01	1.65458E+00
87	1.89529E-01	1.21742E+00	1.84774E+00
88	3.68357E-01	1.64870E+00	2.04597E+00
89	6.63720E-01	2.14583E+00	2.24632E+00
90	1.10930E+00	2.68500E+00	2.44550E+00
91	1.72129E+00	3.23276E+00	2.64000E+00
92	2.48331E+00	3.75075E+00	2.82615E+00
93	3.33834E+00	4.20242E+00	3.00026E+00

TABLE 3 (Contd.)

A	Y(0.0)	Y(2.0)	Y(14.0)
94	4.19542E+00	4.55973E+00	3.15872E+00
95	4.95272E+00	4.80806E+00	3.29816E+00
96	5.52948E+00	4.94778E+00	3.41554E+00
97	5.89222E+00	4.99194E+00	3.50828E+00
98	6.06168E+00	4.96122E+00	3.57440E+00
99	6.09650E+00	4.87769E+00	3.61255E+00
100	6.06217E+00	4.75942E+00	3.62213E+00
101	6.00126E+00	4.61736E+00	3.60329E+00
102	5.91695E+00	4.45498E+00	3.55694E+00
103	5.78809E+00	4.27019E+00	3.48478E+00
104	5.56821E+00	4.05838E+00	3.38917E+00
105	5.22742E+00	3.81567E+00	3.27314E+00
106	4.75749E+00	3.54111E+00	3.14023E+00
107	4.17784E+00	3.23780E+00	2.99438E+00
108	3.52953E+00	2.91268E+00	2.83986E+00
109	2.86379E+00	2.57563E+00	2.68106E+00
110	2.22989E+00	2.23800E+00	2.52244E+00
111	1.66607E+00	1.91119E+00	2.36833E+00
112	1.19510E+00	1.60552E+00	2.22287E+00
113	8.24225E-01	1.32945E+00	2.08992E+00
114	5.48196E-01	1.08926E+00	1.97289E+00
115	3.53871E-01	8.89126E-01	1.87479E+00
116	2.24779E-01	7.31406E-01	1.79809E+00
117	1.44863E-01	6.17159E-01	1.74467E+00
118	1.01005E-01	5.46648E-01	1.71586E+00
119	8.44770E-02	5.19810E-01	1.71237E+00
120	9.16147E-02	5.36570E-01	1.73428E+00
121	1.24029E-01	5.96978E-01	1.78105E+00
122	1.88521E-01	7.01122E-01	1.85154E+00
123	2.96612E-01	8.48851E-01	1.94400E+00
124	4.63450E-01	1.03934E+00	2.05611E+00
125	7.05722E-01	1.27057E+00	2.18502E+00
126	1.03839E+00	1.53883E+00	2.32742E+00
127	1.47034E+00	1.83833E+00	2.47955E+00
128	1.99970E+00	2.16111E+00	2.63737E+00
129	2.60998E+00	2.49723E+00	2.79655E+00

TABLE 3 (Contd.)

A	Y(0.0)	Y(2.0)	Y(14.0)
130	3.26870E+00	2.83544E+00	2.95269E+00
131	3.93005E+00	3.16427E+00	3.10135E+00
132	4.54225E+00	3.47338E+00	3.23822E+00
133	5.05875E+00	3.75501E+00	3.35925E+00
134	5.45056E+00	4.00514E+00	3.46078E+00
135	5.71496E+00	4.22381E+00	3.53963E+00
136	5.87580E+00	4.41442E+00	3.59326E+00
137	5.97261E+00	4.58165E+00	3.61977E+00
138	6.04039E+00	4.72847E+00	3.61803E+00
139	6.08821E+00	4.85292E+00	3.58768E+00
140	6.08748E+00	4.94586E+00	3.52913E+00
141	5.97872E+00	4.99067E+00	3.44351E+00
142	5.69663E+00	4.96581E+00	3.33266E+00
143	5.20257E+00	4.84971E+00	3.19899E+00
144	4.50836E+00	4.62703E+00	3.04542E+00
145	3.67857E+00	4.29416E+00	2.87525E+00
146	2.81065E+00	3.86224E+00	2.69203E+00
147	2.00331E+00	3.35653E+00	2.49945E+00
148	1.32858E+00	2.81219E+00	2.30119E+00
149	8.18428E-01	2.26779E+00	2.10083E+00
150	4.67794E-01	1.75842E+00	1.90171E+00
151	2.47925E-01	1.31042E+00	1.70689E+00
152	1.21798E-01	9.38621E-01	1.51902E+00
153	5.54611E-02	6.46593E-01	1.34033E+00
154	2.34138E-02	4.28884E-01	1.17261E+00
155	9.16911E-03	2.74407E-01	1.01715E+00
156	3.33397E-03	1.69772E-01	8.74804E-01
157	1.12726E-03	1.01890E-01	7.45997E-01
158	3.55216E-04	5.95498E-02	6.30771E-01
159	1.04674E-04	3.40436E-02	5.28836E-01
160	2.89856E-05	1.91271E-02	4.39638E-01
161	7.59549E-06	1.06094E-02	3.62411E-01
162	1.90114E-06	5.83189E-03	2.96241E-01
163	4.59814E-07	3.18501E-03	2.40123E-01
164	1.08821E-07	1.72994E-03	1.93007E-01
165	2.54798E-08	9.34027E-04	1.53837E-01