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Chinese Evaluated Fission-Product Yield Library

1987 (Preliminary)

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Abstract: The 1987 version of the Chinese evaluated data library for fission-product yields contains data in ENDF-S format for 10 fissioning systems of U-235, U-238, Pu-239, Pu-241, U-233, Th-232. The data library on magnetic tape is available, costfree, from the IAEA Nuclear Data Section.

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Citation guidelines:

Chinese evaluated fission-Product yield library

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The library is in ENDF-5 format. It contains the following materials:

Mat	Nuclide	fission systems included
101	92-U-235	thermal, fast, 14 MeV neutrons
102	92-U-238	fast and 14 MeV neutrons
103	94-Pu-239	thermal and fast neutrons
104	94-Pu-241	thermal neutrons
105	92-U-233	thermal neutrons
106	90-Th-232	fast neutrons

The evaluation is documented in a paper by Wang Dao and Zhang Dongning that was presented at the NEACRP-Meeting on Nuclear Data for the Prediction of Decay Heat, Studsvik, Sweden, 7-10 September 1987. A preprint of this paper is attached.

EVALUATION OF FISSION PRODUCT YIELDS

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ABSTRACT

A preliminary fission product yield library has been set up. At present, it contains 10 fissioning systems: U235T, U235F, U235HE, U238F, U238HE, Pu239T, Pu239F, Pu241T, U233T, and Th232F, each of them involves 1170 fission product nuclides. For every one of the nuclides, both independent and cumulative yields together with their uncertainties are given. The 10 sets of yield recommended values are compiled in two formats: one, ENDF/B-V; the other, legible form. This paper will summarize the evaluation procedure, and present some resultants compared with ENDF/B-VE yields.

I. INTRODUCTION

Since the 1950s, with the development and uses of nuclear energy, many fission product nuclear data libraries have emerged, (Ref.1) and many measurements, compilations and/or evaluations on fission product nuclear data have been actively carrying out. (Ref.2) Fission

yield data are important information in the nuclear industry, they are mainly applied to the decay heat predictions of reactors, (Ref.3) determinations of nuclear fuel burnup, (Ref.4) neutron dosimetry measurements, (Ref.5) and nuclear physics calculations.

Since 1985, we have been devoting ourselves to the project of seting up a fission product yield library. In the first phase of the project, a top priority was given to the 10 fissioning systems: U235T, U235F, U235EIE, U238F, U238HE, Pu239T, Pu239F, Pu241T, U233T, and Th232F. For every fissioning system, it involves 1170 fission product nuclides, of which 152 are stable, and the others, unstable; among the latter, there are 192 isomers. All the nuclides were shown to be observable experimentally. For every fission product nuclide, both independent and cumulative yields together with their uncertainties are given. A preliminary fission yield library has been set up. The 10 sets of yield recommended values are compiled in two formats: one, ENDF/B-V; the other, legible form.

This project is mainly based on the discontinued fission yield library of Dr. B. F. Rider, (Ref.6) at the same time, we have also consulted other papers concerned fission yield evaluations.(Ref 7-,8-,9) This project was carried out under the auspices of the IAEA Nuclear Data Section.

In the Sections II - IV, the treatment of published experimental data, the calculation of model yields, and the production of recommended values are described, respectively; in the Sections V & VI, some resultants compared with ENDF/B-VE yields, and some comments on the fission yield evaluation are given, respectively.

II. TREATMENT OF PUBLISHED EXPERIMENTAL DATA

The sources of experimental fission yield data in this library are the Rider library up to 1980, the EXFOR library of the IAEA, and recently published papers. The treatment of published experimental data includes two aspects of contents: yield adjustments and error estimates.

YIELD ADJUSTMENTS

Depending on what corrections and adjustments have to be made, the experimental data are classified as absolute yield, relative yield, and R-value.

Absolute yield is defined as Yi = Ni/Nf , where Yi is the fission yield of an investigated nuclide, i; Ni is the number of atoms of the investigated nuclide, i , formed; and Nf is the number of fission that occurred in irradiated samples. Usually it's difficult to adjust the absolutely measured yields, and they even don't require or are not amenable to adjustments. Under the circumstances, the evaluators can only apply corrections for errors assigned by measurers.

If several absolute yield data are related to the same number of fission, and one of the fission products corresponding to these yields is a frequently adopted reference nuclide, then they may also be adjusted through converting them into relative yields.

In some cases, absolute yields are obtained by normalizing measured relative yields which cover sufficient number of mass chains to 200%; usually the yield values resulted from this method cannot be adjusted as well.

Relative yield is defined as y = Yi/YS where Yi and Ys are the absolute yields of investigated and reference nuclides, respectively. Relative yield is determined by simultaneously measuring the absolute number of atoms of both nuclides concerned, thus avoiding the large source of uncertainty caused by measuring absolute number of fission. Relative yields can be adjusted by using well known reference yields in order to obtain absolute fission yields; or, absolute fission yields obtained from relative yields can be readjusted by using well known reference yields, if the relative yields concerned are able to be deduced.

R-value is defined as R = (Yi/Ys)l/(Yi/Ys)2 9 where Y is absolute yield; i refers to the investigated nuclide, and s, the reference nuclide; 1 denotes the investigated fission reaction, and 2, the reference fission reaction. If irradiation times and counting conditions are identical for both samples concerned, then, besides the errors caused by measuring absolute number of fission,

the errors due to uncertainties in decay scheme and efficiency calibration are all avoided as well. R-value can be adjusted by using a set of fission yields which are well known in order to obtain absolute fission yield; or, absolute yield obtained from R-value can be readjusted by using a set of fission yields which are well known, of course, the R-value concerned must be given.

ERROR ESTIMATES

The errors associated with measurements are reported by measurers in a variety of ways. Usually a published value is given together with the absolute accuracy that includes all of the uncertainties in the measurement (frequently erring on the side of optimism), but some with a standard deviation corresponding to the precision of the measurement only, and some even not at all. So, the errors assigned by measurers are not necessarily accepted as complete, and should be adjusted (if necessary) to what seemed to be a reasonable estimates of the absolute accuracies.

For a relative value (either relative yield or R-value), the resultant error was statistically merged with the errors in the reference yields of the reference nuclides to give an error of the absolute yield.

For an absolute yield only with the random error, a 2% uper limit of conceivable systematic error was combined with the reported one.

For different kinds of measuring techniques, the different adjusting limits are set. The error of an absolute yield was not allowed to be better than (smaller than) the limit corresponding to the measuring technique involved. These limits are:

20% for Geiger-counter-era measurements before 1955;

10% for NaI(Tl)-era measurements between 1955 and 1965;

5% for Ge(Li)-era direct {-ray spectrometry, radiochemical, and other special measurements made since 1965;

2% for mass spectrometric measurements;

30% for estimated values.

If no accuracy was reported, it was assumed to be three times the lower limit corresponding to the measuring technique involved.

If separate plus and minus errors were reported, the smaller value plus two-thirds the difference was used.

In some cases, the above limits are not suitable, e.g. the accuracy of the direct r-raY spectrometry method is just limited to +10% at best.10 At the same time, since 1975, some measurements have achieved better accuracies, e.g. 3%; 11 for this kind of data, their accuracies were directly adopted.

After making the treatments of published experimental results, all the adjusted experimental data, including independent and cumulative yields, are converted into the Rider format, and formed a preliminary experimental data file which will be further treated in order to obtain the evaluated experimental data.

EVALUATED EXPERIMENTAL INDEPENDENT YIELDS (XI) &

EVALUATED EXPERIMENTAL CUMULATIVE YIELDS (XC)

For a given group of experimental data retrieved from the preliminary experimental data file, e.g. the 99Mo cumulative yields of 235U fission induced by fission spectrum neutrons, first of all, the duplicate data are rejected from the group, if any; then, there are frequently one or more values to obviously deviate from the rest. For the deviating-from-group data, it was through statistical tests to decide wether they are outliers or not.

Based on the rejection of the duplicate and the outlier data, suppose Xl+ Ax, X2+ SX2 X"+ dXn are independently measured results, the following averages and the errors are calculated:

Weighted mean yield

$$Y_w = \frac{\sum_{i=1}^{n} \frac{1}{(\Delta X_i)^2} \cdot X_i}{\sum_{i=1}^{n} \frac{1}{(\Delta X_i)^2}}$$

Internal error of the weighted mean yield

$$\sigma_1 = \sqrt{\frac{1}{\sum_{i=1}^{n} \frac{1}{(\Delta X_i)^2}}}$$

External error of the weighted mean yield

$$\sigma_2 = \sigma_1 \cdot \varepsilon = \sigma_1 \cdot \sqrt{\frac{\sum_{i=1}^{n} \frac{(X_i - Y_w)^2}{(\Delta X_i)^2}}{n-1}}$$

Simple mean yield

$$\bar{Y} = \frac{\sum_{i=1}^{n} X_i}{n}$$

Standard deviation of the simple mean

$$\sigma_{\bar{Y}} = \sqrt{\frac{\sum_{i=1}^{n} (X_i - \bar{Y})^2}{n(n-1)}}$$

The weighted mean yield was taken as the recommended value, and its accuracy was taken to be the greater of 51 ~2^^3

Finally, an evaluated experimental data file containing independent and cumulative yields (XI,XC) is formed, which will be used to statistically merge with the following model yields.

III. CALCULATION OF MODEL YIELDS

CALCULATED INDEPENDENT YIELDS (CI)

Empirical models derived from experimental data relate the systematics of nuclear charge distribution in fission to parameters for simple mathematical functions. Two empirical models have been put forward. 2~ 3 The Zp model is adopted because of the historical reason of our work.

For a given mass chain of mass number A, the fractional independent yield of an isobar of atomic number Z is calculated by using Gaussion charge dispersion formula,

$$f(A, Z) = \frac{1}{\sigma \sqrt{2\pi}} \int_{Z-0.5}^{Z+0.5} e^{-\frac{(Z - Z_p(A))^2}{2\sigma^2}} dZ \qquad (1)$$

where σ is the Gaussion width parameter and Zp(A) is the most probable charge.

The ϵ value was taken to be 0.56+-0.06 (Ref.14) irrespective of mass number and fissioning system.

The Zp(A) values were directly taken from the JAERI-M report.(Ref.15) The Zp(A) values are calculated based on the following equation,

$$Zp(A) = Zp(A,Standard) + \Delta Zp(Ternary) + \Delta Zp(A)$$

Where Zp(A,standard) is the standard value for 235U thermal fission; (Ref.16) ΔZp(Ternary) is the correction term for ternary fission,(Ref.17) the values of which depend on fissioning systems, as shown in Table I.

Table I. Correction factor for ternary fission

Fissioning system	ΔZP(Ternary)	Zc	Ac	E*(MeV)
U235T	0.05062	92	236	6.52
U235F	-0.10021	92	236	8.31
U235HE	-0.06241	92	236	21.26
U238F	-0.00860	92	239	6.57
U238HE	-0.10089	92	239	19.52
Pu239T	0.01846	94	240	6.50
Pu239F	-0.06287	94	240	8.30
Pu241T	-0.08924	94	242	6.27
U233T	0.03989	92	234	6.81
Th232F	0.01299	90	233	6.56

ΔZp(A) is the correction term for non 235U thermal fission,(Ref.16) which is further decomposed into the following three terms:

$$\Delta Zp(A) = a(Zc - 92) + b(Ac - 236) + c(E^* - 6.52)$$

where Zc and Ac are the charge and the mass number of the compound nucleus, respectively, and E* is the excitation energy in MeV. The

values of the coefficients a, b, and c are shown in Tables II & III.

Table II. Values of the coefficients a and b

Mass Region	a	b
Light peak products	0.414+-0.016	-0.143+-0.007
Valley products	0.500+-0.03	-0.165+-0.02
Heavy peak products	0.547+-0.010	-0.188+-0.004

Table III. Values of the coefficient c

Mass No	c	Mass No.	c
66 - 74	0.0200+-0.0030	116	0.0341 +-0.0068
76	0.0200+-0.0025	118	0.0371 +-0.0067
78	0.0200+-0.0025	120	0.0402+-0.0064
80	0.0200+-0.0020	122	0.0433+-0.0061
82	0.0200+ -o .0016	124	0.0464+-0.0056
84	0.0200+-0.0016	126	0.0495+-0.0050
86	0.0200+-0.0016	128	0.0505+-0.0041
88	0.0196+-o .0012	130	0.0509+-0.0031
90	0.0189+-0.0011	132	0.0500+-0.0025
92	0.0181 + -0.0011	134	0.0472+-0.0024
94	0.0171 +-0.0010	136	0.0416+-0.0021
96	0.0160+-0.0010	138	0.0328+ -0.0016
98	0.0157+ -0.0009	140	0.0276+-0.0014
100	0.0159+-0.0013	142	0.0241 + -0.0012
102	0.0173+-0.0017	144	0.0217+-0.0013
104	0.0190+ -0.0023	146	0.0203+-0.0016
106	0.0211 +-0.0030	148	0.0195+ -0.0019
108	0.0233+ -0.0037	150	0.0195+-0.0023
110	0.0257+-0.0046	152	0.0195+-0.0027
112	0.0283+ -0.0057	154	0.0195+-0.0031
114	0.0311 +-0.0062	156	0.0195+-0.0035
		158 - 172	0.0195+ -0.0039

Considering the existences of isomeric phenomena1 (Ref.18) and odd-even pairing effects (Ref.19&20) of fission product nuclides, the calculated fractional independent yields from eq.(1) should be modified as follows:

1. The odd-even effects in proton- and neutron-pairing distort the Gaussion charge dispersion curve shape described by eq. (1). Let Fx(A,Z) be a correction factor for the odd-even effect, then the actual fractional independent yield is approximated by

$$y(A,Z) = Fx(A,Z)f(A,Z) \qquad (2)$$

where Fx(A,Z) is expressed as:

Fx(A,Z) = 1 + (p + n), for even A - even Z
= 1 + (p - n), for odd A - even Z
= 1 - (p - n), for odd A - odd Z
= 1 - (p + n), for even A - odd Z

where p is proton-pairing term and n is neutron-pairing term, the magnitudes of both parameters depend on fissioning systems, they are shown in Table IV.

Table IV. Values of parameters on pairing effects

Fissioning system	p	n
U235T	0.228+-0.034	0.044+-0.034
U235F	0.151+-0.179	0.029+-0.039
U235HE	0.015+-0.016	0.003+-0.004
U238F	0.329+-0.479	O.o63+-o.100
U238HE	0.018+-0.019	0.003+-0.004
Pu239T	0.171+-0.206	0.033+-0.044
Pu239F	0.124+-0.143	0.024+-0.031
Pu241T	0.206+-0.256	0.040+-0.055
U233T	0.210+-0.264	0.041+-o.056
Th232F	0.327+-0.469	0.063+-0.098

2. Where isomeric nuclides exist, the y(A,Z) value (eq. (2)) is divided into the metastable and the ground states on the basis

of the fraction of metastable state yield given in Table V.

Table V. Fraction (M/M+G) of metastable state yield

Nuclide	Metastable state spin	Ground state spin	M/M+G		
			Thermal	Fast	14MeV
Cu 68	(6-)	1+	0.70	0.73	0.82
Zn 69	9/2+	1/2-	0.81	0.83	0.89
Cu 70	(5-)	1+	0.75	0.78	0.85
Zn 71	(9/2+)	1/2-	0.81	0.83	0.89
Ge 73	1/2-	9/2+	0.19	0.17	0.11
Se 73	1/2-	7/2+	0.13	0.12	0.08
Ga 74	1+	(4)-	0.19	0.17	0.11
Ge 75	7/2+	1/2-	0.87	0.88	0.92
Ge 77	1/2-	7/2(+)	0.13	0.12	0.08
Se 77	7/2+	1/2-	0.87	0.88	0.92
Br 77	9/2+	3/2-	0.77	0.79	0.86
Se 79	1/2-	7/2+	0.13	0.12	0.08
Br 79	9/2+	3/2-	0.77	0.79	0.86
Kr 79	7/2+	1/2-	0.87	0.88	0.92
Br 80	5-	1+	0.75	0.78	0.85
Se 81	(7/2)+	(1/2)-	0.87	0.88	0.92
Kr 81	1/2-	7/2+	0.13	0.12	0.08
Rb 81	9/2+	3/2-	0.77	0.79	0.86
As 82	(5-)	(1+)	0.75	0.78	0.85
Br 82	2-	5-	0.30	0.27	0.18
Se 83	(1/2)-	(9/2)+	0.19	0.17	0.11
Kr 83	1/2-	9/2+	0.19	0.17	0.11
Br 84	(6-)	2-	0.64	0.68	0.78
Rb 84	(6+)	2-	0.64	0.68	0.78
Kr 85	1/2-	9/2+	0.19	0.17	0.11
Sr 85	1/2-	9/2+	0.19	0.17	0.11
Y 85	(9/2)+	(1/2)-	0.81	0.83	0.89
Rb 86	6-	2-	0.64	0.68	0.78
Sr 87	1/2-	9/2+	0.19	0.17	0.11
Y 87	9/2+	1/2-	0.81	0.83	0.89

Zr 87	(1/2-)	(9/2+)	0.19	0.17	0.11
Y 89	9/2+	1/2-	0.81	0.83	0.89
Zr 89	1/2-	9/2+	0.19	0.17	0.11
Nb 89	(1/2)-	(9/2+)	0.19	0.17	0.11
Rb 90	(4-)	(1-)	0.81	0.83	0.89
Y 90	7+	2-	0.59	0.63	0.74
Zr 90	5-	0+	0.81	0.83	0.89
Nb 90	4-	8+	0.58	0.53	0.39
Y 91	9/2+	1/2-	0.81	0.83	0.89
Nb 91	1/2+	9/2+	0.19	0.17	0.11
Mo 91	1/2-	9/2+	0.19	0.17	0.11
Nb 92	2+	7+	0.41	0.37	0.26
Y 93	9/2+	1/2-	0.81	0.83	0.89
Nb 93	1/2-	9/2+	0.19	0.17	0.11
Mo 93	21/2+	5/2+	0.38	0.43	0.58
Tc 93	1/2-	9/2+	0.19	0.17	0.11
Nb 94	3+	6+	0.41	0.37	0.26
Nb 95	1/2-	9/2+	0.19	0.17	0.11
Tc 95	1/2-	9/2+	0.19	0.17	0.11
Y 96	-	(0-)	0.5	0.5	0.5
Y 97	(9/2)+	(1/2-)	0.81	0.83	0.89
Nb 97	1/2-	9/2+	0.19	0.17	0.11
Tc 97	1/2-	9/2+	0.19	0.17	0.11
Y 98	-	(1+)	0.5	0.5	0.5
Nb 98	(5+)	1+	0.75	0.78	0.85
Nb 99	(1/2)-	(9/2)+	0.19	0.17	0.11
Tc 99	1/2-	9/2+	0.19	0.17	0.11
Rh 99	9/2+	(1/2-)	0.81	0.83	0.89
Y 100	-	-	0.5	0.5	0.5
Nb100	- N		0.33	0.33	0.33
	- M		0.33	0.33	0.33
		-	0.33	0.33	0.33
Rh101	9/2+	1/2-	0.81	0.83	0.89
Nb102	-	-	0.5	0.5	0.5
Tc102	(5)	1+	0.75	0.78	0.85
Rh102	(2-)	(6+)	0.36	0.32	0.22
Rh103	7/2+	1/2-	0.87	0.88	0.92

Ag103	(1/2)-	7/2+	0.13	0.12	0.08
Nb104	[illegible]	-	0.5	0.5	0.5
Rh104	5+	1+	0.75	0.78	0.85
Rh105	1/2-	(7/2)+	0.13	0.12	0.08
Ag105	(7/2)+	1/2-	0.87	0.88	0.92
Rh106	4,5,6+	1+	0.5	0.5	0.5
Ag106	6+	1+	0.70	0.73	0.82
Pd107	11/2-	5/2+	0.65	0.69	0.79
Ag107	7/2+	1/2-	0.87	0.88	0.92
Rh108	-	1+	0.5	0.5	0.5
Ag108	6+	1+	0.70	0.73	0.82
Pd109	11/2-	5/2+	0.65	0.69	0.79
Ag109	7/2+	1/2-	0.87	0.88	0.92
In109	1/2- M		0.42	0.47	0.63
	(19/2) M		0.11	0.09	0.04
		9/2+	0.47	0.44	0.33
Rh110	-	-	0.5	0.5	0.5
Ag110	6+	1+	0.70	0.73	0.82
Pd111	(11/2-)	(5/2+)	0.65	0.69	0.79
Ag111	(7/2+)	1/2-	0.87	0.88	0.92
Cd111	11/2-	1/2+	0.77	0.79	0.86
In111	1/2-	9/2+	0.19	0.17	0.11
In112	4+	1+	0.81	0.83	0.89
Ag113	7/2+	1/2-	0.87	0.88	0.92
Cd113	11/2-	1/2+	0.77	0.79	0.86
In113	1/2-	9/2+	0.19	0.17	0.11
Sn113	7/2+	1/2+	0.87	0.88	0.92
In114	5+	1+	0.75	0.78	0.85
Ag115	7/2+	1/2-	0.87	0.88	0.92
Cd115	11/2-	1/2+	0.77	0.79	0.86
In115	1/2-	9/2+	0.19	0.17	0.11
Ag116	-	-	0.5	0.5	0.5
In116	8- N		0.27	0.27	0.30
	5+ M		0.55	0.57	0.60
		1+	0.18	0.16	0.10
Ag117	7/2+	1/2-	0.87	0.88	0.92
Cd117	11/2-	1/2+	0.77	0.79	0.86

In117	1/2-	9/2+	0.19	0.17	0.11
Sn117	11/2-	1/2+	0.77	0.79	0.86
Ag118	-	-	0.5	0.5	0.5
In118	(8)-	(5)+	0.37	0.42	0.57
Sb118	8-	1+	0.59	0.63	0.74
Cd119	11/2-	1/2+	0.77	0.79	0.86
In119	1/2-	9/2+	0.19	0.17	0.11
Sn119	11/2-	1/2+	0.77	0.79	0.86
Te119	11/2-	1/2+	0.77	0.79	0.86
Ag120	(6-)	(3+)	0.59	0.63	0.74
In120	(5)+	1+	0.75	0.78	0.85
Sb120	8-	1+	0.59	0.63	0.74
Cd121	-	-	0.5	0.5	0.5
In121	1/2-	9/2+	0.19	0.17	0.11
Sn121	(11/2)-	3/2+	0.71	0.74	0.82
Te121	11/2-	1/2+	0.77	0.79	0.86
In122	-	(1+)	0.5	0.5	0.5
Sb122	(8-)	2-	0.53	0.57	0.70
In123	(1/2)-	(9/2)+	0.19	0.17	0.11
Sn123	(3/2)+	11/2-	0.29	0.26	0.18
Te123	11/2-	1/2+	0.77	0.79	0.86
In124	-	(2+)	0.5	0.5	0.5
Sb124	(5)+	3-	0.64	0.68	0.78
In125	-	(9/2)+	0.5	0.5	0.5
Sn125	3/2+	11/2-	0.29	0.26	0.18
Te125	11/2-	1/2+	0.77	0.79	0.86
Xe125	(9/2)-	(1/2)+	0.81	0.83	0.89
In126	-	-	0.5	0.5	0.5
Sb126	(5)+	(8-)	0.63	0.58	0.43
In127	-	-	0.5	0.5	0.5
Sn127	(3/2)+	(11/2-)	0.29	0.26	0.18
Te127	11/2-	3/2+	0.71	0.74	0.82
Xe127	(9/2-)	(1/2+)	0.81	0.83	0.89
In128	-	-	0.5	0.5	0.5
Sb128	5+	8-	0.63	0.58	0.43
In129	-	-	0.5	0.5	0.5

Sn129	(11/2-)	(3/2+)	0.71	0.74	0.82
Te129	11/2-	3/2+	0.71	0.74	0.82
Xe129	11/2-	1/2+	0.77	0.79	0.86
Ba129	(11/2)-	1/2+	0.77	0.79	0.86
Sn130	(7-)	0+	0.70	0.73	0.82
Sb130	(8-)	(4,5)+	0.5	0.5	0.5
I 130	2+	5+	0.30	0.27	0.18
Sn131	(3/2+)	-	0.5	0.5	0.5
Te131	11/2-	3/2+	0.71	0.74	0.82
Xe131	11/2-	3/2+	0.71	0.74	0.82
Ba131	9/2-	1/2+	0.81	0.83	0.89
Sb132	(8-)	(4+)	0.42	0.47	0.61
I 132	(8-)	4+	0.42	0.47	0.61
Te133	(11/2-)	(3/2+)	0.71	0.74	0.82
I 133	(19/2-)	7/2+	0.38	0.43	0.58
Xe133	11/2-	3/2+	0.71	0.74	0.82
Ba133	11/2	1/2+	0.77	0.79	0.86
Sb134	-	-	0.5	0.5	0.5
I 134	(8-)	(4)+	0.42	0.47	0.61
Xe134	(7-)	0+	0.70	0.73	0.82
Cs134	8-	4+	0.42	0.47	0.61
Xe135	11/2-	3/2+	0.71	0.74	0.82
Cs135	(19/2-)	7/2+	0.38	0.43	0.58
Ba135	11/2-	3/2+	0.71	0.74	0.82
Ce135	(11/2-)	1/2(+)	0.77	0.79	0.86
I 136	(5,6-)	(2-)	0.5	0.5	0.5
Ba136	7-	0+	0.70	0.73	0.82
Ba137	11/2-	3/2+	0.71	0.74	0.82
Ce137	11/2-	3/2+	0.71	0.74	0.82
Cs138	(6-)	3-	0.59	0.63	0.74
Ce139	11/2-	3/2+	0.71	0.74	0.82
Nd141	11/2-	3/2+	0.71	0.74	0.82
Pr142	5-	2-	0.70	0.73	0.82
Sm143	11/2-	3/2+	0.71	0.74	0.82
Xe144	-	-	0.5	0.5	0.5
Pr144	3-	0-	0.90	0.91	0.94

Pm148	6-	1-	0.70	0.73	0.82
Pr149	-	(5/2+)	0.5	0.5	0.5
Pm152	≦6 N		0.33	0.33	0.33
	(4) M		0.33	0.33	0.33
		(1+)	0.33	0.33	0.33
Eu152	8- N		0.44	0.50	0.65
	0- M		0.06	0.05	0.02
		3-	0.50	0.45	0.33
Pm154	(3,4)	(0,1)	0.5	0.5	0.5
Eu154	(8-)	3-	0.47	0.52	0.66
Tb156	(0)+	3-	0.10	0.09	0.06
Tb158	0-	3-	0.10	0.09	0.06
Ho159	1/2+	7/2-	0.13	0.12	0.08
Ho161	1/2+	7/2-	0.13	0.12	0.08
Ho162	6-	1+	0.70	0.73	0.82
Ho163	1/2+	7/2-	0.13	0.12	0.08
Ho164	6(-)	1+	0.70	0.73	0.82
Dy165	1/2-	7/2+	0.13	0.12	0.08
Ho166	(7-)	0-	0.70	0.73	0.82
Er167	1/2-	7/2+	0.13	0.12	0.08
Yb169	1/2-	7/2+	0.13	0.12	0.08
Lu169	1/2-	7/2+	0.13	0.12	0.08
Ho170	-	-	0.5	0.5	0.5
Lu171	1/2-	7/2+	0.13	0.12	0.08
Lu172	1-	4+	0.19	0.17	0.11

3. All the adjusted fractional independent yields in a same mass chain are normalized to the corresponding chain yield in order to obtain the absolute independent yield of every isobar.

CALCULATED CUMULATIVE YIELDS (CC)

In this library, all the decay chains were taken from the JNDC Nuclear Data Library of Fission Products.[9]

For a specified decay chain containing the decay branchings of beta decays, positron emissions, isomeric transitions, and delayed neutron emissions, on the basis of the well-known chain yield and the above-mentioned independent yields of all the isobars, the cumulative yields are calculated as follows:

1. Deducing the cumulative yield of the initial nuclide by subtracting the independent yields of all the isobars but the initial one from the chain yield;

2. Calculating the cumulative yields of other isobars by adding the cumulative yield starting with the initial one to the independent yield of next one.

The delayed neutron precursors, and the probabilities of neutron emission of daughter nuclides are given in Table VI.

Table VI. Delayed neutron precursors

Nuclide	Pn	Nuclide	Pn	Nuclide	Pn
30Zn79	0.003	37Rb 92	0.0001	50Sn133	0.0008
31Ga79	0.0004	36Kr 93	0.021	50Sn134	0.17
31Ga80	0.004	37Rb 93	0.0138	51Sb134m	0.0009
31Ga81	0.045	36Kr 94	0.022	51Sb135	0.139
31Ga82	0.07	37Rb 94	0.106	51Sb136	0.23
31Ga83	0.42	37Rb 95	0.089	52Te136	0.009
32Ge83	0.0005	37Rb 96	0.142	52Te137	0.022
32Ge84	0.09	37Rb 97	0.30	53I 137	0.067
33As84	0.0013	38Sr 97	0.0001	52Te138	0.056
33As85	0.23	39Y 97m	0.016	53I 138	0.026
33As86	0.105	37Rb 98	0.15	53I 139	0.102
33As87	0.44	38Sr 98	0.003	53I 140	0.22
34Se87	0.0021	37Rb 99	0.40	53I 141	0.39
35Br87	0.0237	38Sr 99	0.034	54Xe141	0.0004
34Se88	0.0075	37Y 99	0.012	55Cs141	0.0005
35Br88	0.069	47Ag122	0.004	54Xe142	0.0041
34Se89	0.05	47Ag123	0.04	55Cs142	0.0018
35Br89	0.153	49In127m	0.0045	54Xe143	0.0125
34Se90	0.11	49In128	0.004	55Cs143	0.0182
35Br90	0.212	49In129m	0.05	55Cs144	0.03
34Se91	0.21	49In129	0.036	55Cs145	0.143
35Br91	0.108	49In130	0.025	55Cs146	0.134
35Br92	0.22	49In131	0.105	55Cs147	0.254
36Kr92	0.0003	49In132	0.135		

For every one of 1170 fission product nuclides of a fissioning system, both independent and cumulative yields are calculated, not merely those who have no experimental data, so that two calculated yield data files, including independent and cumulative yields, are formed, which are used to statistically merge with the evaluated experimental data (XI,XC) described in section II.

IV. PRODUCTION OF RECOMMENDED VALUES

RECOMMENDED INDEPENDENT YIELDS (RI)

Calculated independent yields were assigned large (100%) errors. Where evaluated experimental independent yields exist, the calculated independent yields are statistically merged with the evaluated independent yields taking reciprocal variance as weight, and the associated error is calculated using the method described in section II. Where no evaluated experimental independent yields, the calculated independent yields and their errors are directly adopted.

After making above treatments to every fission product nuclide, a preliminary recommended independent yield data file is formed; then, the independent yields in a same decay chain are normalized to the corresponding well-known chain yield so that the recommended independent yields are finally obtained.

RECOMMENDED CUMULATIVE YIELDS (RC)

On the basis of the above recommended independent yields, the preliminary recommended cumulative yields are calculated using the method calculating calculated-cumulative-yields (section III), and their errors were taken to be the limiting

Absolute errors. Concerning merging with the evaluated experimental cumulative yields, the procedure is same as that obtaining recommended independent yields.

FORMAT

Since ENDF/B-V format is a international data exchange format on evaluated data, thus both recommended independent yields and recommended cumulative yields are all converted into ENDF/B-V

format. At the same time, they are all edited in an easily legible form.

V. TESTS AND COMPARISONS

Several integral tests and comparisons have been made. 21 In the first place, the decay powers of fission products of 235U and 239Pu thermal fissions were calculated by the CINDER 10 code using the Chinese yields over

10^{13} ~O - 10 second for a short irradiation (10^{-4} s), and they were compared with those calculated using ENDF/B-VE yields. In these calculations, the decay halflives and the decay branchings are based on ENDF/B-V data, and the decay energies are based in part on modifications made by JNDC. The calculated results and the comparisons are shown in Tables

VI - IX The graphical comparisons over the important cooling time ($\leq 10^{3}$ s) of interest in the hypothetical loss-of-coolant accident are given in Figures 1 - 4. For 239Pu thermal fission, the comparison with the American Nuclear Society (ANS) Draft Decay-Heat Standard (Ref.22) is also given (in the above). In the above comparisons, a least squares fit was used to produce the α , λ pairs.(Ref.23) For 235U thermal fission decay power $(\beta+\gamma)$, a fit within 1.5 % at all times was obtained.

Table X compares the prompt neutron yields, delayed neutron yields, average charges with ENDF/B-VI yields.

Table VI

CINDER10 CODE OUTPUT OF MEV/F FOR IRRADIATION TIME OF 1.0E-4 S USING ENDF/B-V DECAY DATA, PRELIMINARY CHINESE YIELDS, ANO DECAY ENERGIES BASED LARGELY ON JNDC 1.5 VALUES T. ENGLAND, LANL, 3/26/B7

SUMMARY OF PROBLEM OUTPUT

ENERGY DATA (MEV/F) ALL NUCLIDES

COOLING TIME (S)	BETA MEV/F	GAMMA MEV/F	TOTAL MEV/F
0.00000E+00	1.53705E-04	1.30822E-04	2.84528E-04
1.OOOOOE-01	1.19516E-04	9.84399E-05	2.17956E-04
2.00000E-01	9.83757E-05	7.90347E-05	1.77410E-04
5.00000E-01	6.70460E-05	5.17262E-05	1.18772E-04
8.00000E-01	5.28960E-05	4.02014E-05	9.30975E-05
1.00000E+00	4.69210E-05	3.55063E-05	8.24273E-05
2.OOOOOE+00	3.10380E-05	2.33980E-05	5.44360E-05
5.00000E+00	1.54401E-05	1.18460E-05	2.72862E-05
8.00000E+00	1.00887E-05	7.99278E-06	1.80815E-05
1.00000E+01	8.12382E-06	6.58276E-06	1.47066E-05
2.00000E+01	3.83940E-06	3.44557E-06	7.28497E-06
5.00000E+01	1.32155E-06	1.38018E-06	2.70172E-06
8.OOOOOE+01	7.72654E-07	8.54813E-07	1.62747E-06
1.00000E+02	5.89519E-07	6.69748E-07	1.25927E-06
2.00000E+02	2.41745E-07	2.89373E-07	5.31117E-07
5.00000E+02	8.44328E-08	9.94388E-08	1.83872E-07
8.00000E+02	5.28012E-08	6.36482E-08	1.16449E-07
1 OOOOOE+03	4.22960E-08	5.19056E-08	9.42016E-08
2 00000E+03	2.02676E-08	2.67567E-08	4.70244E-08
5.00000E+03	6.04266E-09	9.39282E-09	1.54355E-08
8.00000E+03	3.20855E-09	5.07967E-09	8.28822E-09
1.00000E+04	2.43604E-09	3.70040E-09	6.13645E-09
2.00000E+04	1.11831E-09	1.23575E-09	2.35406E-09
5.00000E+04	3.70582E-10	3.34203E-10	7.04785E-10
8.00000E+04	1.78713E-10	1.82569E-10	3.61283E-10
1.00000E+05	1.23519E-10	1.36362E-10	2.59881E-10
2.00000E+05	3.87477E-11	5.40993E-11	9.28470E-11
5.00000E+05	1.08781E-11	1.98353E-11	3.07134E-11
8.00000E+05	6.83303E-12	1.26523E-11	1.94853E-11
1.00000E+06	5.53518E-12	1.0023SE-11	1.55586E-11
2.00000E+06	2.85131E-12	4.51003E-12	7.36134E-12
5.00000E+06	1.03245E-12	1.27522E-12	2.30767E-12
8.00000E+06	6.00277E-13	6.74651E-13	1.27493E-12
1.00000E+07	4.66805E-13	5.12276E-13	9.800B1E-13
2.00000E+07	1.98849E-13	1.63413E-13	3.62252E-1S
5.00000E+07	6.22559E-14	8.87619E-15	7.11321E-14
8.OOOOOE+07	3.00641E-14	3.74093E-15	3.38050E-14
1.00000E+OS	1.97201E-14	2.16070E-15	2.288O8E-14
2.OOOOOE+08	6.07752E-15	2.34456E-15	8.42207E-15
5.00000E+08	3.92844E-15	1.82753E-15	5.75597E-15
8.OOOOOE+08	3.10726E-15	1.46712E-15	4.57438E-15
1.00000E+09	2.66689E-15	1.26806E-15	3.93495E-15
2.00000E+09	1.25222E-15	6.12175E-16	1.86439E-15
5.00000E+09	1.32131E-16	6.89380E-17	2.01069E-16
8.00000E+09	1.42112E-17	7.78532E-1S	2.19965E-17
1.00000E+10	3.33697E-18	1.83631E-18	5.17327E-18
2.00000E+10	8.53082E-20	2.88009E-20	1.14109E-19
5.00000E+10	6.81671E-20	2.73738E-20	9.55409E-20
8.00000E+10	6.79258E-20	2.71940E-20	9.51198E-20
1.00000E+11	6.77722E-20	2.70748E-20	9.48470E-20
2.00000E+11	6.70106E-20	2.64864E-20	9.34970E-20
5.00000E+11	6.47871E-20	2.47971E-20	8.95842E-20
8.00000E+11	6.26526E-20	2.32156E-20	8.58682E-20
1.00000E+12	6.12770E-20	2.22177E-20	8.34947E-20
2.00000E+12	5.49235E-20	1.78364E-20	7.27599E-20
5.00000E+12	4.01226E-20	9.22948E-21	4,93521E-20
8.00000E+12	2.98935E-20	4.77642E-21	3.46700E-20
1.00000E+13	2.48212E-20	3.07919E-21	2.79004E-20

NOTE: IN THIS TA8LE MEV/F=[MEV/S)/(FISSION/S]

Table VII

CINDER10 CODE OUTPUT OF MEV/F FOR IRRADIATION TIME OF 1.OE-4 S USING ENDF/B-V DECAY DATA, PRELIMINARY ENDF/B-VI YIELDS, AND DECAY ENERGIE5 BASED LARGELY ON JNDC 1.5 VALUES
T. ENGLAND, LANL, 3/26/87

SUMMARY OF PROBLEM OUTPUT

ENERGY DATX (MEV/F) ALL NUCLIDES

COOLIN& TIME (S)	BETA MEV/F	GAMMA MEV/F	TOTAL MEV/F
0.OOOOOE+OO	7.96487E-05	5.83623E-05	1.38011E-04
1.00000E-01	7.27757E-05	5.32054E-05	1.25981E-04
2.00000E-01	6.70710E-05	4.90192E-05	1.16090E-04
5.OOOOOE-01	5.45444E-05	4.00191E-05	9.45635E-05
8.00000E-01	4.61448E-05	3.40286E-05	8.01734E-05
1.00000E+00	4.19050E-05	3.09903E-05	7.28953E-05
2.00000E+00	2.88581E-05	2.15187E-05	5.03768E-05
5.00000E+00	1.48124E-05	1.12814E-05	2.60938E-05
8.00000E+00	9.81362E-06	7.71358E-06	1.75272E-05
1.00000E+01	7.93448E-06	6.37484E-06	1.43093E-05
2.00000E+01	3.74448E-06	3.33168E-06	7.07616E-06
5.00000E+01	1.27630E-06	1.32792E-06	2.60422E-06
8.00000E+01	7.48116E-07	8.28347E-07	1.57646E-06
1.00000E+02	5.72124E-07	6.52654E-07	1.22478E-06
2.00000E+02	2.37063E-07	2.88512E-07	5.25575E-07
5.00000E+02	8.33196E-08	9.96383E-08	1.82958E-07
8.00000E+02	5.19349E-08	6.28890E-08	1.14824E-07
1.00000E+03	4.15291E-08	5.09745E-08	9.25036E-08
2.00000E+03	1.97512E-08	2.59306E-08	4.56819E-08
5,00000E+03	5.83106E-09	9.08054E-09	1.49116E-08
8.00000E+03	3.10611E-09	4.95314E-09	8.05925E-09
1.00000E+04	2.36389E-09	3.62416E-09	5.98805E-09
2.00000E+04	1.08625E-09	1.21690E-09	2.30316E-09
5.00000E+04	3.61555E-10	3.31648E-10	6.93203E-10
8.00000E+04	1.76108E-10	1.82754E-10	3.58862E-10
1.00000E+05	1.22349E-10	1.36964E-10	2.59313E-10
2.00000E+05	3.87750E-11	5.47408E-11	9.35158E-11
5.00000E+05	1.0&884E-11	2.00558E-11	3.09443E-11
8.00000E+05	6.81749E-12	1.27384E-11	1.95559E-11
1.00000E+06	5.51244E-12	1.00664E-11	1.55788E-11
2.00000E+05	2.82344E-12	4.49176E-12	7.31520E-12
5.00000E+06	1.014,2E-12	1.25531E-12	2.27303E-12
8.00000E+06	5.82183E-13	6.65508E-13	1.25369E-12
1.00000E+07	4.57047E-13	5.0744BE-13	9.64495E-13
2.00000E+07	1.94155E-13	1.62807E-13	3.56962E-13
5.00000E+07	6.04459E-14	8.64914E-15	6.90951E-14
8.00000E+07	2.97780E-14	3.56935E-15	3.27474E-14
1.00000E+OS	1.51546E-14	3.01598E-15	2.21706E-14
2.00000E+09	5.97661E-15	2.24657E-15	8.22329E-15
5.00000E+09	3.89898E-15	1.75294E-15	5.65192E-15
8.0000 E+09	3.09075E-15	1.40728E-15	4.49803E-15
1.00000E+09	2.65541E-15	1.21637E-15	3.87178E-15
2.00000E+09	1.24981E-15	5.87244E-16	1.83706E-15
5.00000E+09	1.31924E-16	6.61272E-17	1.98051E-16
8.00000E+09	1.41757E-17	7.46337E-18	2.16391E-17
1.00000E+10	3.32380E-18	1.75648E-18	5.08028E-18
2.00000E+10	8.24964E-20	2.25481E-20	1.05045E-19
5.00000E+10	6.56690E-20	2.12125E-20	8.68815E-20
8.00000E+10	6.54422E-20	2.10732E-20	8.65154E-20
1.00000E+11	6.52980E-20	2.09808E-20	8.62788E-20
2.00000E+11	6.45830E-20	2.05249E-20	8.51079E-20
5.00000E+11	6.24937E-20	1.92159E-20	8.17096E-20
8.00000E+11	6.04854E-20	1.79905E-20	7.84759E-20
1.00000E+12	5 91897E-20	1.72173E-20	7.64069E-20
2.00000E+12	5 31903E-20	1.38223E-20	6.70126E-20
5.00000E+12	3,91094E-20	7.15281E-21	4.62622E-20
8.00000E+12	2.92798E-20	3.70215E-21	3.29819E-20
1.00000E+13	2.43721E-20	2.38696E-21	2.67591E-20

NOTE: IN THIS TABLE MEV/F=[MEV/S)/(FISSION/S]

Table VIII

COMPARISON OF U-235(T) DECAY HEAT FROM CINDER10 CODE
USING CHINESE YIELDS AND ENDF/B-VE YIELDS
3/25/87

VALUES AQE BASED ON A PULSE. EACH VALUE IS
TsF(T) (UNITS A2E MEV/FISSj. (SEE FOOTNOTE)

FIRST LINE IS BASED ON ENDF/B DATA AND
SECOND USES CHINESE YIELDS.

TIME (S)	BETA	GAMMA	BETA+GAMMA
1.OOOE-01	7.278E-02	5.321E-02	1.260E-01
	1.195E-01	9.844E-02	2.180E-01
2.OOOE-01	1.341E-01	9.804E-02	2.322E-01
	1.968E-01	1.581E-01	3.548E-01
5.000E-01	2.727E-01	2.001E-01	4.728E-01
	3.352E-01	2.586E-01	5.939E-01
8.OOOE-01	3.692E-01	2.722E-01	6.414E-01
	4.232E-01	3.216E-01	7.448E-01
1.000E+OO	4.191E-01	3.099E-01	7.290E-01
	4.692E-01	3.551E-01	8.243E-01
2.000E+OO	5.772E-01	4.304E-01	1.008E+00
	6.208E-01	4.680E-01	1.089E+00
5.000E+OO	7.406E-01	5.641E-01	1.305E+00
	7.720E-01	5.923E-01	1.364E+00
8.000E+OO	7.851E-01	6.171E-01	1.402E+00
	8.071E-01	6.394E-01	1.447E+00
1.OOOE+O1	7.934E-01	6.375E-01	1.431E+00
	8.124E-01	6.583E-01	1.471E+00
2.000E+01	7.489E-01	6.663E-01	1.415E+00
	7.679E-01	6.891E-01	1.457E+00
5.000E+01	6.381E-01	6.640E-01	1.302E+00
	6.60SE-01	6.901E-01	1.351E+00
8.000E+01	5.985E-01	6.627E-01	1.261E+00
	6.181E-01	6.839E-01	1.302E+00
1.000E+02	5.721E-01	6.527E-01	1.225E+00
	5.895E-01	6.697E-01	1.259E+00
2.000E+02	4.741E-01	5.770E-01	1.051E+00
	4.835E-01	5.787E-01	1.062E+00
5.000E+02	4.166E-01	4.982E-01	9.148E-01
	4.222E-01	4.972E-01	9.194E-01
8.000E+OZ	4.155E-01	5.031E-01	9.186E-01
	4.224E-01	5.092E-01	9.316E-01
1.000E+03	4.153E-O1	5.097E-01	9.250E-01
	4.230E-01	5.191E-01	9.420E-01
2.000E+O3	3.950E-01	5.186E-01	9.136E-01
	4.054E-01	5.351E-01	9.405E-01
5.000E+03	2.916E-01	4.540E-01	7.456E-01
	3.021E-01	4.696E-01	7.718E-01
8.0000+03	2.485E-01	3.963E-01	6.447E-01
	2.567E-01	4.064E-01	6.631E-01
1.OOOE+O4	2.364E-01	3.624E-01	5.988E-01
	2.436E-O1	3.700E-01	6.136E-01
2.000E+04	2.172E-01	2.434E-01	4.606E-01
	2.237E-01	2.472E-01	4.708E-01
5.000E+04	1.808E-01	1.658E-01	3.466E-01
	1.853E-01	1.671E-01	3.524E-01
8.000E+04	1.409E-01	1.462E-01	2.871E-01
	1.430E-01	1.461E-01	2.890E-01
1.000E+05	1.223E-01	1.370E-01	2.593E-01
	1.235E-01	1.364E-01	2.599E-0
2.000E+05	7.755E-02	1.095E-01	1.870E-01
	7.750E-02	1.082E-01	1.857E-01
5.000E+05	5.444E-02	1.003E-01	1.547E-01
	5.439E-02	9.918E-02	1.536E-01
8.000E+05	5.454E-02	1.019E-01	1.564E-01
	5.466E-02	1.012E-01	1.559E-01

Table VIII (CONTINUED)

TIME (S)	BETA	GAMMA	BETA+GAMMA
1.OOOE+06	5.512E-02	1.007E-01	1.558E-01
	5.535E-02	1.002E-01	1.556E-01
2.000E+06	5.647E-02	8.984E-02	1.463E-01
	5.703E-02	9.020E-02	1.472E-01
5.000E+06	5.074E-02	6.292E-02	1.137E-01
	5.162E-02	6.376E-02	1.154E-01
8.000E+06	4.705E-02	5.324E-02	1.003E-01
	4.802E-02	5.397E-02	1.020E-01
1.000E+07	4.570E-02	5.074E-02	9.645E-02
	4.668E-02	5.133E-02	9.801E-02
2.000E+07	3.883E-02	3.256E-02	7.139E-02
	3.977E-02	3.268E-02	7.245E-02
5.000E+07	3.022E-02	4.325E-03	3.455E-02
	3.113E-02	4.438E-03	3.557E-02
8.000E+07	2.334E-02	2.855E-03	2.620E-02
	2.405E-02	2.993E-03	2.704E-02
1.000E+08	1.915E-02	3.016E-03	2.217E-02
	1.972E-02	3.161E-03	2.288E-02
2.000E+08	1.195E-02	4.493E-03	1.645E-02
	1.216E-02	4.689E-03	1.684E-02
5.000E+08	1.949E-02	8.765E-03	2.826E-02
	1.964E-02	9.138E-03	2.878E-02
8.000E+08	2.473E-02	1.126E-02	3.598E-02
	2.486E-02	1.174E-02	3.660E-02
1.000E+09	2.655E-02	1.216E-02	3.872E-02
	2.667E-02	1.268E-02	3.935E-02
2.000E+09	2.500E-02	1.174E-02	3.674E-02
	2.504E-02	1.224E-02	3.729E-02
5.000E+09	6.596E-03	3.306E-03	9.903£-03
	6.607E-03	3.447E-03	1.005E-02
8.000E+09	1.134E-03	5.971E-04	1.731E-03
	1.137E-03	6.228E-04	1.760E-03
1.OOOE+10	3.324E-04	1.756E-04	5.080E-04
	3.337E-04	1.836E-04	5.173E-04
2.000E+10	1.650E-05	4.510E-06	2.101E-05
	1.706E-05	5.760E-06	2.282E-05
5.OOOE+10	3.283E-05	1.061E-05	4.344E-05
	3.408E-05	1.369E-05	4.777E-05
8.000E+10	5.235E-05	1.686E-05	6.921E-05
	5.434E-05	2.176E-OS	7.610E-OS
1.OOOE+11	6.530E-05	2.098E-05	8.628E-OS
	6.777E-05	2.707E-05	9.485E-05
2.000E+11	1.292E-04	4.105E-05	1.702E-04
	1.340E-04	5.297E-05	1.E70E-04
5.000E+11	3.125E-04	9.608E-05	4.085E-04
	3.239E-04	1.240E-04	4.479E-04
8.000E+11	4.839E-04	1.439E-04	6.278E-04
	5.012E-04	1.857E-04	6.869E-04
1.OOOE+12	5.919E-04	1.722E-04	7.641E-04
	6.128E-04	2.222E-04	8.349E-04
2.OOOE+12	1.064E-03	2.764E-04	1.340E-03
	1 098E-03	3.567E-04	1.455E-03_
5.OOOE+12	1.955E-03	3.576E-04	2.313E-03
	2.006E-03	4.615E-04	2.468E-03
8.OOOE+12	2.342E-03	2.962E-04	2.639E-03
	2.391E-03	3.821E-04	2.774E-03
1.OOOE+13	2.437E-03	2.387E-04	2.676E-03
	2.482E-03	3.079E-04	2.790E-03

ERE. MEV/F=VALUES FROM TABLE 1 AND 2 TIMES THE DECAY TIME AND DIVIDED BY THE 1.0E-4S PULSE TIME.

Table IX

CINDA10 code output of Mev/f for irradiation time of 1.0e-4 s using ENDF/V decay data, preliminary Chinese yields, and decay energies based largely on JNDC 1.5 values.

T.England, LANL, 7/27/87

Beta MeV/f:	Gamma MeV/f	total MeV/f
4.09921e-OS	2.98788e-05	7.08709e-05
8.19826e-05	5.97569e-05	1.41740e-04
7.42762e-05	5.54466e-05	1.29723e-04
6.58912e-05	4.96358e-05	1.15527e-04
4.69837e-05	3.52631e-05	8.22468e-05
3.69231e-OS	2.73998e-05	6.43229e-05
3.27904e-05	2.42051e-05	5.69955e-05
2.20789e-05	1.61605e-05	3.82394e-05
1.12015e-05	8.31705e-06	1.95186e-05
7.44694e-06	5.68797e-06	1.31349e-05
6.07578e-06	4.72888e-06	1.08047e-05
3.03896e-06	2.56286e-06	5.60183e-06
1.14518e-06	1.08389e-06	2.22907e-06
6.94322e-07	6.88596e-07	1.38292e-06
5.36641e-07	5.45015e-07	1.08166e-06
2.26734e-07	2.45170e-07	4.71904e-07
8.13673e-08	9.07217e-08	1.72089e-07
5.11868e-08	5.92640e-08	1.10451e-07
4.08074e-08	4.84862e-08	8.92936e-08
1.86015e-08	2.45876e-08	4.31891e-08
5.00259e-09	8.0664Oe-09	1.30690e-08
2.99051e-09	4.20117e-09	6.69168e-09
1.84591e-09	3.03168e-09	4.87759e-09
8.22581e-10	1.04344e-09	1.86602e-09
2.91869e-10	3.23006e-10	6.14875e-10
1.53312e-10	1.85546e-10	3.38858e-10
1.10731e-10	1.41518e-10	2.52249e-10
3.90869e-11	6.16145e-11	1.00701e-10
1.12153e-11	2.33554e-11	3.45707e-11
6.56917e-12	1.40570e-11	2.06262e-11
5.10607e-12	1.07495e-11	1.58556e-11
2.32782e-12	4.38899e-12	6.7168le-12
7.73382e-13	1.20347e-12	1.97685e-12
4.60615e-13	6.16521e-13	1.07714e-12
3.73423e-13	4.58779e-13	8.32203e-13
2.02253e-13	1.41911e-13	3.44164e-13
8.24936e-14	1.32208e-14	9.57144e-14
4.09316e-14	6.60914e-15	4.75407e-14

Table IX (continued)

39	l.OOOOOe+08	2.62997e-14	5.11185e-15	3.14116e-14
40	2.00000e+08	4.67095e-15	2.69002e-15	7.36097e-15
41	5.00000e+08	1.80145e-15	1.89221e-15	3.69366e-15
42	8.00000e+08	1.41877e-15	1.51322e-15	2.93199e-15
43	l.OOOOOe+O9	1.21886e-15	1.30723e-15	2.52609e-15
44	2.00000e+09	5.76332e-16	6.30952e-16	1.20728e-15
45	5.00000e+09	6.24287e-17	7.11182e-17	1.33547e-16
46	8.00000e+09	7.16596e-18	8.09569e-18	1.52617e-17
47	l.OOOOOe+10	1.88814e-18	1.96475e-18	3.85289e-18
48	2.00000e+10	1.20417e-19	1.01814e-19	2.22230e-19
49	5.00000e+10	9.16574e-20	9.98649e-20	1.91522e-19
50	8.00000e+10	9.12550e-20	9.92070e-20	1.90462e-19
S1	l.OOOOOe+ll	9.09999e-20	9.87712e-20	1.89771e-19
52	2.00000e+11	8.97374e-20	9.66231e-20	1.86361e-19
53	5.00000e+11	8.60763e-20	9.04592e-20	1.76535e-19
54	8.00000e+11	8.25960e-20	8.46893e-20	1.67285e-19
55	l.OOOOOe+12	8.03714e-20	8.10488e-20	1.61420e-19
56	2.00000e+12	7.02915e-20	6.50650e-20	1.35357e-19
57	5.00000e+12	4.81789e-20	3.36664e-20	8.18453e-20
58	8.00000e+12	3.41751e-20	1.74216e-20	5.15967e-20
59	l.OOOOOe+13	2.76674e-20	1.12300e-20	3.88974e-20

Note: in this table MeV/f=[MeV/s)/lfission/s]
(Divide by the l.Oe-4s irradiation time to convert to pulse values.)

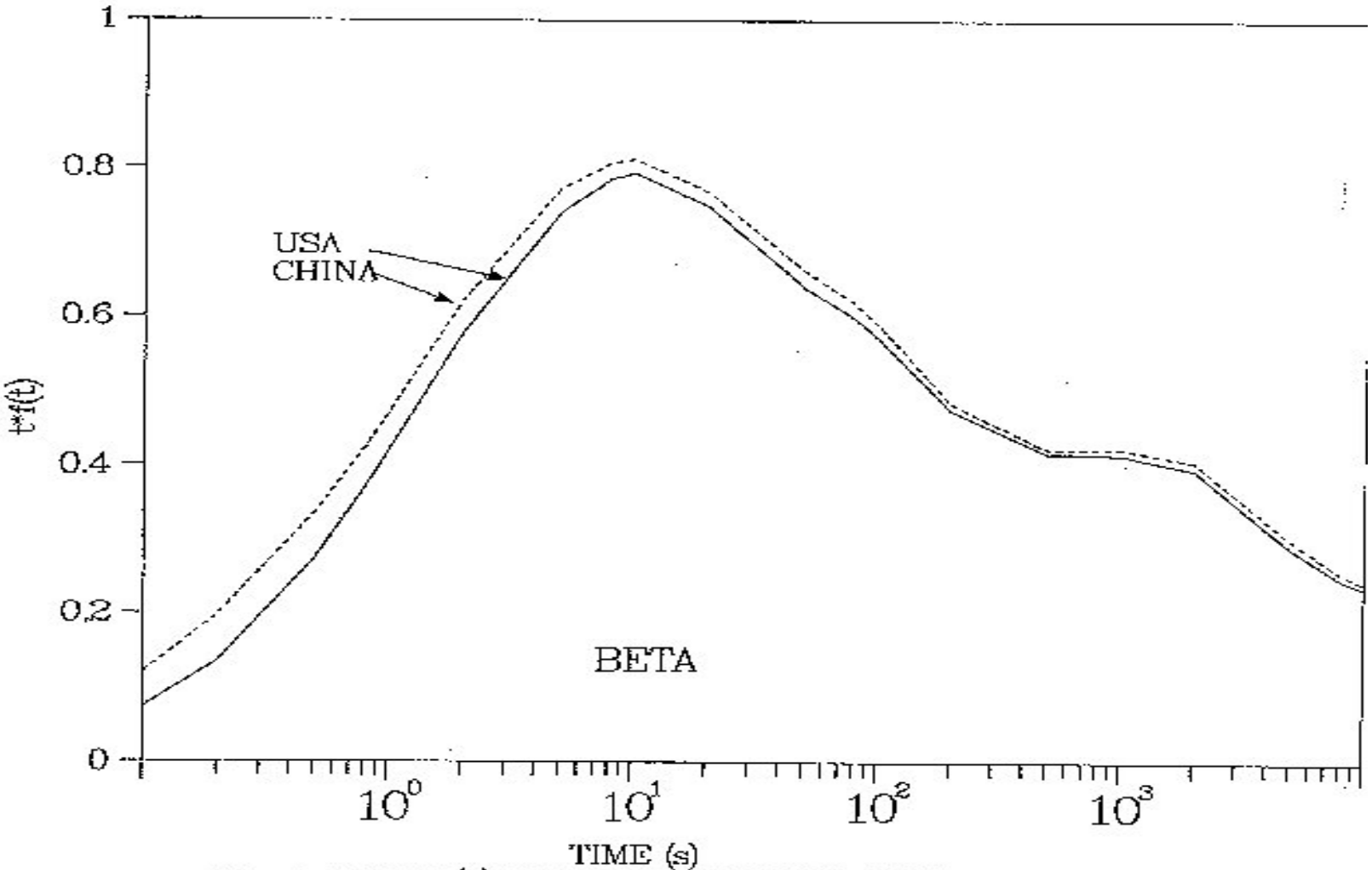

Fig. 1 U–235(1) BETA DECAY POWER COMPARISON

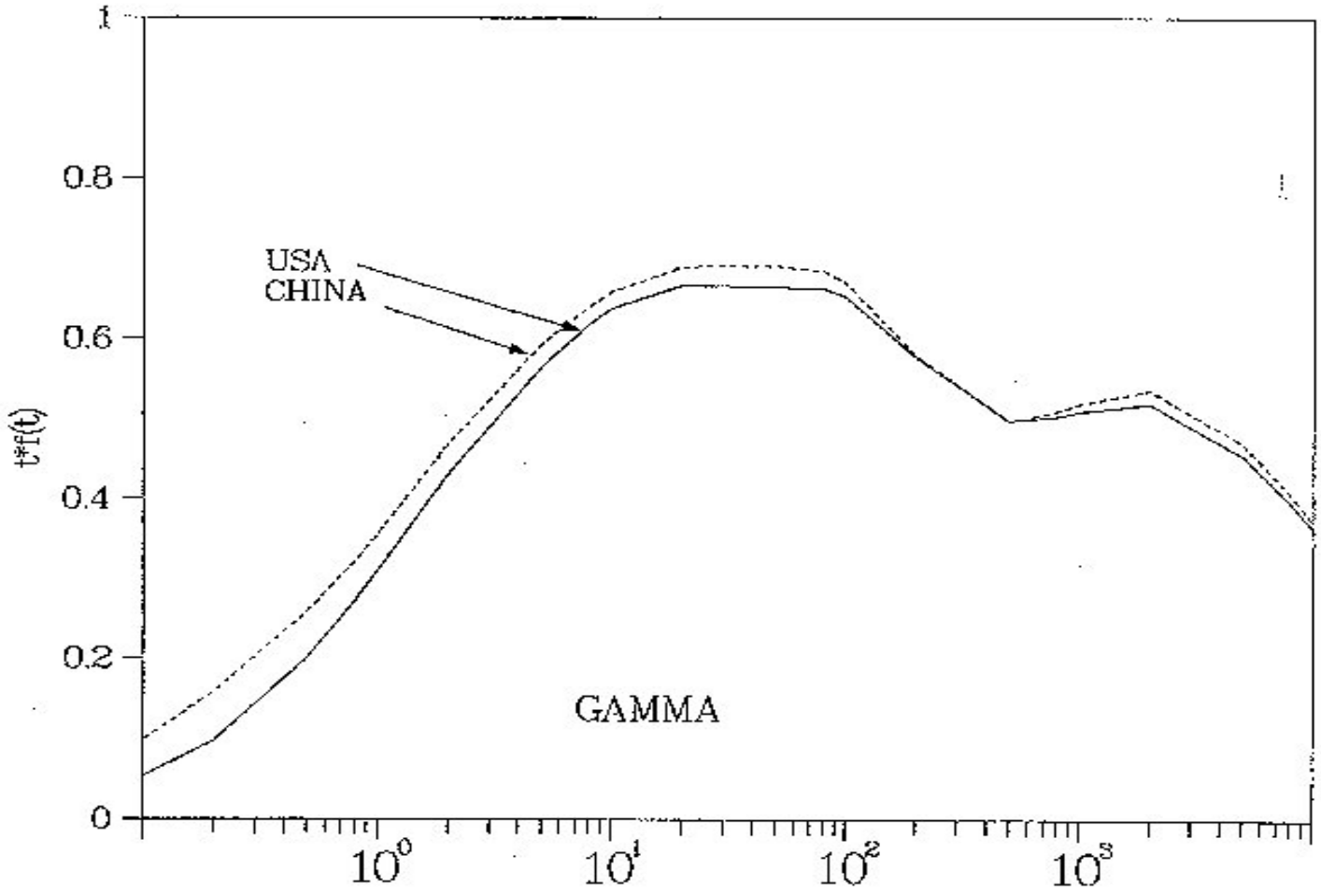

Fig. 2 U-235(T) GAMMA DECAY POWER COMPARISON

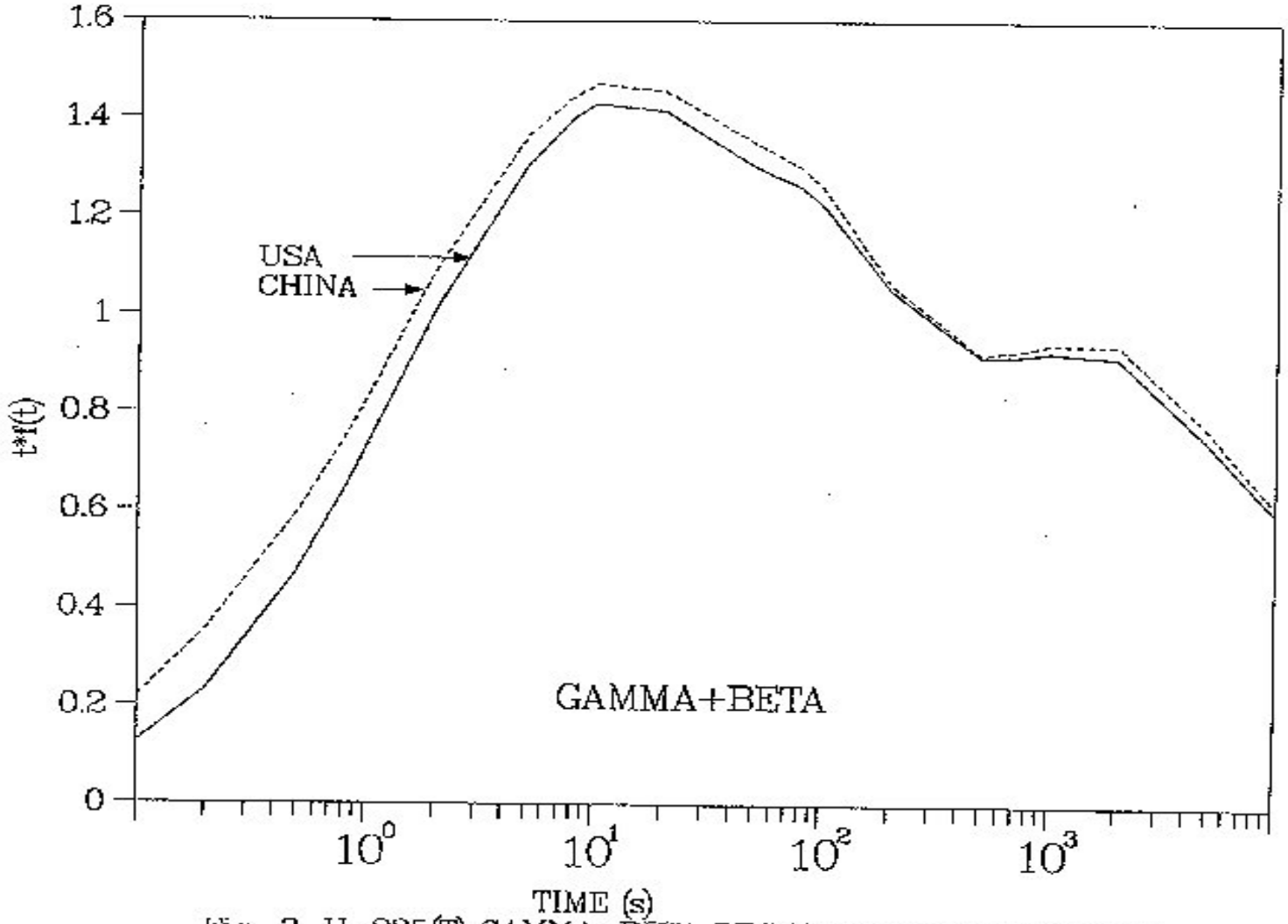

Fig. 3 U-235(T) GAMMA+BETA DECAY POWER COMPARISON

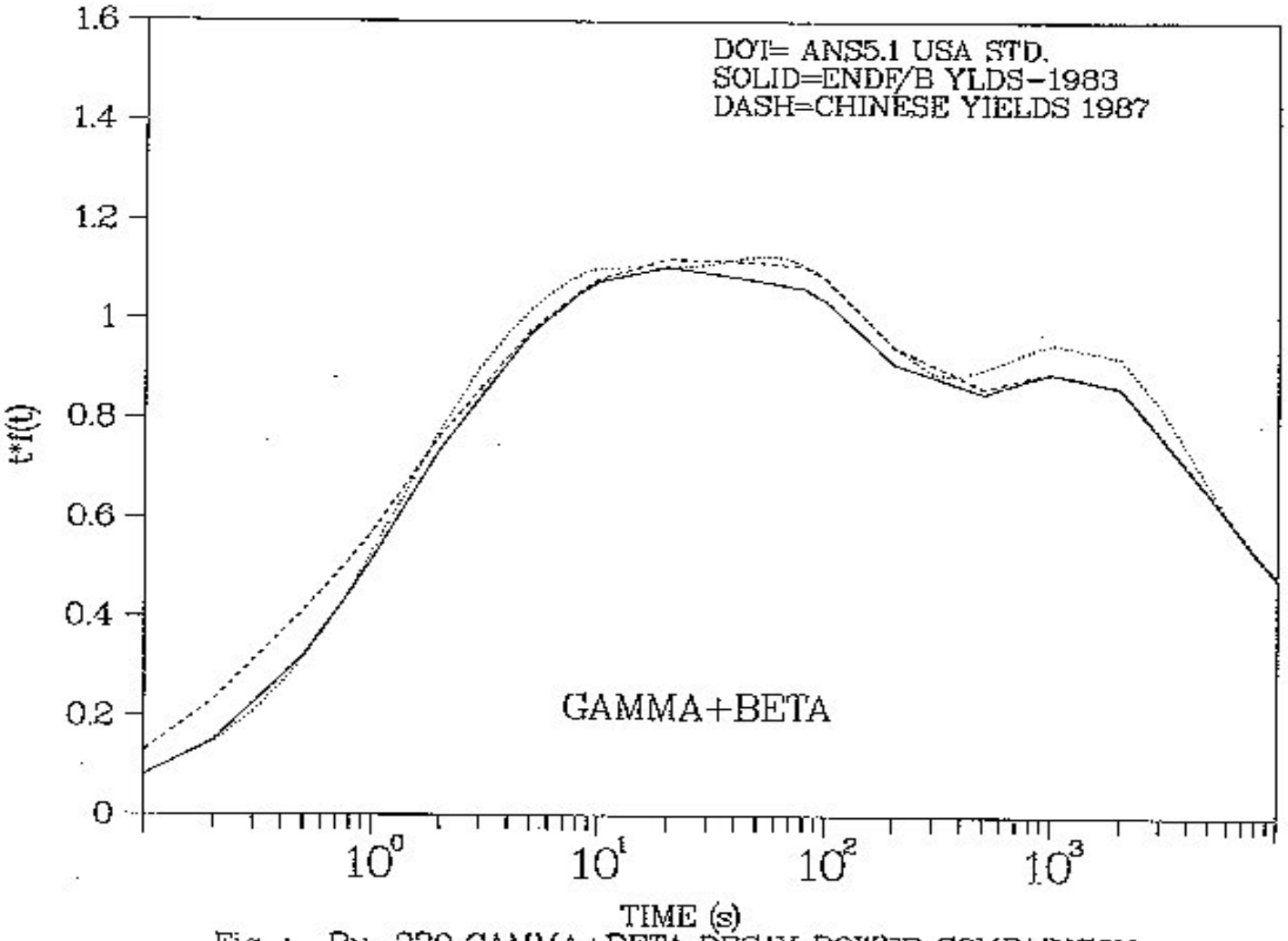

Fig. 4 Pu-239 GAMMA+BETA DECAY POWER COMPARISON

Table X

COMPARISON OF NEUTRON YIELDS

FISSIONING NUCLIDE	ν_{total}		ν_d per 100 fissions		CHINA YIELDS		
	CHINA YIELDS	PRELIMINARY ENDF/B-VI YIELDS*	CHINA YIELDS	PRELIMINARY ENDF/B-VI YIELDS*	$\sum Z$	$\sum N$	$\sum A$
U235(T)	2.5240	2.6402 (2.44)	2.0440	1.7845 (1.67)	92.05	141.42	233.48
U235(F)	2.3797	2.4356 (2.48)	2.4879	2.0583 (1.67)	91.94	141.68	233.62
U235(H)	4.1845	4.3582 (4.40)	1.2201	1.0870 (0.90)	92.06	139.75	231.82
U238(F)	2.924	2.8799 (2.47)	3.1272	4.0480 (4.40)	92.01	144.07	236.08
U238(H)	4.5236	4.4508 (4.43)	2.6310	2.7624 (2.60)	91.93	142.55	234.48
Pu239(T)	2.9567	2.8989 (2.89)	1.0005	0.7588 (0.65)	93.98	143.06	237.04
Pu239(F)	2.7827	2.8941 (2.95)	0.6787	0.683 (0.65)	94.01	143.21	237.22
Pu241(T)	3.0900	2.9322 (2.96)	1.6539	1.406 (1.62)	93.87	145.04	238.91
U233(T)	2.2470	2.5088 (2.50)	1.1787	0.9719 (0.74)	92.13	139.62	231.75
Th232(F)	2.8363	2.3128 (2.02)	4.9439	5.646 (5.27)	89.81	140.36	230.16

* Values given in parentheses are taken from the ENDF/B-V evaluation and are based on measurements.

VI. COMMENTS

This work is yet preliminary, and needs to be further improved; in the future, there are lots of problems to be solved.24 After introducing the analysis of covariance (Ref.25) into fission yield evaluation, the quality of evaluated experimental data regarded as the pillars of recommended values will be improved. Since fission yield evaluation involves wide-ranging contents and large amounts of work, and users not only macroscopically use fission yield data but also need accuracy individual data, even the energy dependence of fission yields, in order to satisfy the demands of users, an international cooperation coodinated by the IAEA, which consists of users, measurers and evaluaters in the world, is necessary.

VII. ACKNOWLEDGEMENTS

The authors express the deepest thanks to Dr. T. R. England (LASL) for testing and comparing the Chinese yields and providing us the results concerned, and to the IAEA Nuclear Data Section for their support to our work.

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