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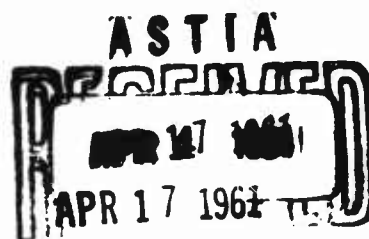
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ENERGY AND TIME BETA RAY SPECTRA OF FISSION PRODUCTS OF
 U^{235} BY FISSION NEUTRONS AND U^{238} BY 14 MEV NEUTRONS

Robert B. Heller

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OF FISSION PRODUCTS OF U^{235} BY FISSION NEUTRONS
AND U^{238} BY 14 MEV NEUTRONS

Robert B. Heller

16 February 1961

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ENERGY AND TIME BETA RAY SPECTRA OF FISSION PRODUCTS
OF U^{235} BY FISSION NEUTRONS AND U^{238} BY 14 MEV NEUTRONS^{1/}

INTRODUCTION

The primary purpose of this memorandum is to provide a practical estimate of the beta ray spectrum from fission products at short times after fission.

The machine program developed to furnish this information automatically provides the spectrum for later times at very little additional effort, together with the distribution of beta radiation by specific nuclides.

This information has been developed and is presented in this memorandum for 14 MEV neutron fissioning of U^{238} and also for U^{235} fissioned by fission neutrons.

METHOD

The disintegration rate $\beta_j(t)$, for the j^{th} fission fragment of a chain was generated by solving the differential equation for the decay chain and computing the activity $\beta_j(t)$ at a series of times t .

^{1/} Acknowledgement is made of the valuable assistance given to me by Dr. George E. Pugh, Miss Joanna Frawley, Mrs. Elaine Marcuse, and Mrs. Juanita Price in the development and calculations needed for this paper.

$\beta_j(t)$ was then multiplied by a function $\rho_j(E)$ which gives the probability that the decay yields a beta ray with kinetic energy E . The product $\beta_j(t)\rho_j(E)dE$ gives the number of beta rays at a given energy and time from the j^{th} isotope, in the energy range between E and $E + dE$.

The product $\beta_j(t)\rho_j(E)$ was summed over all known or postulated members of a specific fission chain with mass number A . This yields

$$\sum_j \beta_j(t)\rho_j(E). \quad (1)$$

If the above expression is then summed over all fission chains with mass numbers from about 72 to 162, the complete energy and time function is obtained for the beta activity from fission.

$$\beta(E,t) = \sum_A \sum_j \beta_j(t)\rho_j(E). \quad (2)$$

INPUT DATA

The complete summation expressed in equation (2) requires input data of two general categories; they are:

- a. The initial fission abundance of the isotopes by chain mass number A and by charge distribution Z within the chain A . This, plus the decay time constants, suffice to calculate $\beta_j(t)$.

b. The beta ray end point energy E_0 plus the forbidden degree of the beta transition. These factors enable the calculation of the probability function $p_j(E)$.

The initial mass yields from fission of U^{235} by 14.7 MEV neutrons actually used in this development were experimentally determined and reported in Los Alamos Report, LA 1997. The solid line in Figure 1 represents data taken from LA 1997. The dashed line fills in the mass yields below $A = 90$. These were taken from the work of J. G. Cuninghame^{1/} and smoothed into the Los Alamos results. Figure 2 gives the fission spectrum neutron mass yield from U^{235} fission. This curve was synthesized by altering the thermal neutron yield so that the valley fragment yields were increased to lie between capsule and 1 MEV neutron fission yields, the double peaks suppressed to lie between the known 14 MEV and thermal yields, and the wings opened to half the difference between the 14.7 MEV and thermal yields.

The distribution of nuclear charge in fission occurring within a given mass chain has been, and remains, a somewhat uncertain theoretical experimental problem.^{2/}

^{1/} J. G. Cuninghame, The Mass Yield Curve for Fission of Natural Uranium by 14 MEV Neutrons, J. Inorg. Nucl. Chem. 5, 1 (1957).

^{2/} For a more complete discussion see L. E. Glendenin, D. C. Coryell, and R. R. Edwards, Paper 52, p. 489, Radio Chemical Studies, The Fission Products Book 1, McGraw-Hill.

The postulate of equal charge displacement was used in this study to obtain the most probable division of charge between the two fission fragments of U^{235} . The most probable charge^{1/} division leads to equal $(Z_A - Z_p)$ values for the two fission fragments, where Z_p is the most probable charge for the fragment and Z_A the hypothetical charge of maximum stability for a given mass chain number A .

It was assumed that the distribution of charge around the most probable charge Z_p is symmetrical. The fraction of the total initial chain yield in any chain number Z is calculated from its $Z - Z_p$ value using Figure 52.2 on page 495 of footnote 2, page 3 of this paper.

The equal charge displacement and symmetrical distribution around this most probable charge appears reasonable in view of the experimental agreement for the observed shielded nuclides Br^{82} , Rb^{86} , Cs^{136} and Xe^{135} . The fraction of the total initial number of U^{235} fission products in various chain positions was determined using the above procedure.

^{1/} The most probable nuclear charge division defines, for primary fission products of a specific mass chain, the hypothetical Z_p value around which other initial members of the chain are distributed according to the various charge distribution postulates, e.g., for the equal charge displacement postulate the predicted most probable nuclear charges for primary products of masses 82 and 86 are 32.4 and 34.0.

The decay constants^{1/} of more than 50 percent of the possible 412 fission fragments have not been experimentally observed nor investigated. The decay schemes used by Bolles and Ballou^{2/} were used in the computations described herein for U^{235} . Some 202 nuclides half lives in these decay schemes have not as yet been observed but calculated values were used.

In the case of the decay constants and independent yields of U^{238} by 14 MEV neutrons the values used were those calculated by P. J. Dolan^{3/}. In these calculations, the most probable charge for a fission fragment of given mass was determined according to the theory of Pappas^{4/} as extended by Ford and Gilmore.^{5/}

It was necessary to assign a fraction of parent activity going to each isomer where a chain contained an isomeric pair.

- 1/ Latest data from D. Strominger, J. M. Hollander, and G. T. Seaborg, Rev. Mod. Phys. 30, 585 (1958).
- 2/ R. C. Bolles and N. E. Ballou, Calculated Activities and Abundances of U^{235} Fission Products, U.S. Radiological Defense Laboratories, USNRDL-456, 30 August 1956.
- 3/ P. J. Dolan, Gamma Spectra of U^{238} Fission Products at Various Times after Fission, Defense Atomic Support Agency Report 526, May 1959.
- 4/ A. C. Pappas, A Radiochemical Study of Fission Yields in the Region of Shell Perturbations on the Effects of Closed Shells in Fission, Laboratory for Nuclear Science, Massachusetts Institute of Technology, Technical Report No. 63, 15 September 1953.
- 5/ G. P. Ford and J. S. Gilmore, Mass Yields From Fission By Neutrons Between Thermal and 14.7 MEV, Los Alamos Scientific Laboratory of University of California, LA 1997, February 1956.

Most of these proportions were known from experimental determination. When lacking, isomeric activity was estimated from measured fission yield of one isomer and the total chain yield. Arbitrary ratios of 50-50 of the parent activity of Rb^{91} , In^{117} , and Cs^{119} were assigned to each daughter isomer.

THE BETA END POINT ENERGIES

Available experimentally determined beta ray end point kinetic energies were assigned to their corresponding isotopes.

For a rough prediction of the total beta decay energy Q_β of unknown nuclides or beta activity too short to have been determined, the procedure suggested by Coryell^{1/} was used. (See Table I for the calculated results.) Any loss of this available energy Q_β to gamma ray transitions in the short half life unknown decays was ignored. By so doing, this report can only hope to develop an approximate upper limit for the high energy portion of the beta spectrum and for times less than 30 seconds after fission.

ALLOWED AND FORBIDDEN SPECTRA

In general, where experimentation classified the transitions as allowed or forbidden, the appropriate energy-shaping expression or correction factors were used. When experimental

^{1/} C. D. Coryell, Beta Decay Energetics, Annual Review of Nuclear Science, Vol. 2, 1953, p. 331, (UNCLASSIFIED).

results were lacking, the forbiddenness was chosen to agree with the F_t values of Feingold^{1/} or the classification based upon the nuclear shell structure of M. G. Mayer.^{2/3/}

LIMITATIONS OF THE HALF LIFE, END POINT ENERGY AND FORBIDDENNESS INPUT DATA

While it is common practice to assume 100 percent beta transition between ground states whenever experimental information is unavailable, studies by Perkins and King^{4/} have shown that this simplification may lead to errors in both the beta and gamma radiation associated with fission. In their procedure, which is adjusted to be consistent with the experimentally measured total gamma energy from all the fission product decay, a single "effective" beta and gamma transition is used and adjusted to account for the mass difference between parent and daughter.

This sharing of the total energy between effective beta and gamma would result in somewhat lower beta and point energies than that used in this study. In addition, if the single "effective" beta and gamma transition recipe for unknown decays were used, a readjustment of half lives towards smaller values would result.

- 1/ A. M. Feingold, Table of F_t Values in Beta Decay, Review of Modern Physics, Vol. 23, 1951, pp. 10-18.
- 2/ M. G. Mayer and S. A. Moszkowski, Nuclear Shell Structure and Beta Decay, I. Odd A Nuclei, Review of Modern Physics, Vol. 23, 1951, pp. 315-321.
- 3/ L. W. Nordheim, Nuclear Shell Structure and Beta Decay II. Even A Nuclei, Review of Modern Physics, Vol. 23, 1951, pp. 322-327.
- 4/ R. W. King and J. F. Perkins, Inverse Beta Decay and the Two Component Neutrons, Phys. Rev. Vol. 112, No. 3, pp. 903-960, November 1, 1958.

In the near future it is planned to investigate the effect on our results of incorporating new data for the unknown decays, based upon the procedure suggested by King and Perkins.

INPUT DATA TABULATION

Table II displays all the input data used in carrying out the calculations. The tabulated data, from left to right, is: λ (decay constant), F_{U235} and F_{U238} (initial fission abundance), E_0 (beta end point energy), Δ (the fraction going by beta decay), and symbols 0 for allowed and 1 for forbidden spectra. The values of λ , F_{U235} , F_{U238} , and E_0 are printed directly from a computer tabulation. The last two digits represent the power of 10 by which the remaining digits, treated as an eight place decimal, are to be multiplied. 51 in this position represents 10^1 , 50 represents 10^0 , 49 represents 10^{-1} , etc.

Many of the decay schemes contain disintegrations yielding beta, gamma and neutrons. The concern in this report is only with isotopes yielding beta rays. In order to maintain the proper rate of change and growth for the isotopes in these chain decay schemes and avoid unnecessary complication of the program, a simple procedure was used which includes transitions due to all emissions. However, in the computation of $\beta_j(t)$, each member of a chain was assigned a multiplication operator Δ , expressing the percent of the decay that proceeds by beta emission. Where only isomeric gamma decays or neutron decays

occur, Δ is taken as zero. By assigning zero ~~and~~ end-point beta energy to non-beta transitions, we are assured of their not being calculated or tabulated either in the end product of the $\beta_j(t)\rho_j(E)$ calculation or in the machine summation of $\beta_j(t)$, which tests for non-zero end point energy.

TABULATION OF FORMULAE

There is an assigned initial abundance to every possible isotope resulting from fission. As time proceeds each isotope will decay in abundance, characteristic of its decay constant. In addition, the instantaneous amount of each isotope may be increased due to the decay of the members of the chain.

The machine program used to analyze the decay of the fission fragments and compute $\beta_j(t)$ was based upon the following differential equation:

$$\frac{dA_j}{dt} + \lambda_j A_j = A_{j-1} \times \lambda_{j-1} \quad , \quad (3)$$

where $\beta_j(t) = \lambda_j A_j(t)$

and $A_j(t)$ is the amount of the j^{th} isotope at time t ,

where $j = 1 \dots i_0$. The time differential expresses the rate of change of an isotope (A_j) with decay constant λ_j , in terms of all previous members of a chain and their decay constants.

We assume a solution of the form

$$A_j(t) = \sum_{i=1}^j \gamma_{ij} e^{-\lambda_i t} \quad (4)$$

where the constants γ_{ij} are to be determined from the following recursion relationships:

$$\gamma_{ij} = \left(\frac{\lambda_{j-1}}{\lambda_j - \lambda_1} \right) \gamma_{i,j-1} \quad \text{for } i < j, \text{ and} \quad (5)$$

$$\gamma_{jj} = A_j(0) - \sum_{i=1}^{j-1} \gamma_{ij} \quad (6)$$

If a fission fragment mass chain A has a nuclear charge distribution from Z to (Z+n), the total instantaneous chain activity is

$$\sum_{j=Z}^{Z+n} \beta_j(t) \quad (7)$$

The total activity at $t=t_1$ from all fission chains (A= 72 to 162) used in this study is

$$\sum_{A=72}^{162} \sum_{j=Z}^{Z+n} \beta_{j,A}(t_1) \quad (8)$$

THE PROBABILITY FUNCTION $\rho(E)$

$\rho(E)dE$ is the probability that a beta emitted from the j^{th} isotope has an energy between E and $E+dE$, and is of the form:

$$\rho_j(E) = \frac{E(E^2 - 1)^{\frac{1}{2}} (E_0 - E)^2 F(Z + 1, E) \cdot g^2 \xi}{\int_1^{E_0} E(E^2 - 1)^{\frac{1}{2}} (E_0 - E)^2 F(Z + 1, E) \cdot g^2 \xi dE} \quad (9)$$

where

E = beta energy in rest mass ($m_0 c^2$) units

E_0 = beta end point energy in $m_0 c^2$ units

$F(Z + 1, E)$ = energy correction term due to the Coulomb distortion of an electron wave amplitude in the Coulomb field of the nucleus^{1/}

g = Fermi's fundamental coupling constant

$\xi = |C_V|^2 \cdot |<1>|^2 + |C_A|^2 \cdot |<\sigma>|^2$

A coefficient in the general expression indicating a nuclear matrix element mixture of vector and pseudo-vector coupling.

If it can be assumed that the nuclear matrix element expression in (9) is not a function of the beta or neutrino energy, then (9) reduces to

$$\rho_j(E) = \frac{E(E^2 - 1)^{\frac{1}{2}} (E_0 - E)^2 F(Z + 1, E)}{\int_1^{E_0} E(E^2 - 1)^{\frac{1}{2}} (E_0 - E)^2 F(Z + 1, E) dE} \quad (10)$$

which covers in our study the allowed and once forbidden transitions having allowed shapes. To allow for isotopes having forbidden shapes, $\rho_j(E)$ is modified as follows:

^{1/} Values for this Coulomb Function were calculated using The Table of the Gamma Function for Complex Arguments, U.S. Bureau of Standards.

$$\rho_j(E) = \frac{E(E^2 - 1)^{\frac{1}{2}} (E_0 - E)^2 F(Z + 1, E) \cdot [(E^2 - 1) + (E_0 - E)^2]^\alpha}{\int_1^{E_0} E(E^2 - 1)^{\frac{1}{2}} (E_0 - E)^2 F(Z + 1, E) [(E^2 - 1) + (E_0 - E)^2]^\alpha dE} \quad (11)$$

where α is the degree of forbiddenness. In this study $\alpha = 0$ covers all allowed and once forbidden transitions having allowed shapes. $\alpha = 1$ is used to cover other once or twice forbidden transitions. The energy expression in the brackets is the well-known $p^2 + q^2$ electron and neutrino momentum correction term in $m_0 c^2$ units.

FINAL EXPRESSION

For the member $j = Z$ of chain A in equation (11)

$$\beta_{Z,A}(E, t) dE = \beta_{Z,A}(t) \cdot \Delta \cdot \rho_Z(E) dE \quad (12)$$

$\beta_{ZA}(t)$ is given by equation (5), and Δ is the fraction of the decay that goes by a beta ray.

RESULTS

Some selected results^{1/} of this analysis, as carried out on the IBM 650, are plotted in Figure 3 for U^{235} and Figure 4 for U^{238} . These two figures give the number of beta rays per fission per energy interval for any specific energy. The short time contribution from highly energetic short-lived isotopes is quite apparent.

^{1/} The complete calculation for expression (12) for all values of time is on file in IDA/WSEG and is available upon request.

Figures 5(a) through 5(q) and 6(a) through 6(q) present some processed data, the percent of total beta energy per fission per isotope versus time. All fission chains and their constituent members are included for U^{235} and U^{238} .

Figures 7 and 8 present for U^{235} and U^{238} the total beta activity per fission summed over all energy versus time.

Figures 9 and 10 present the total beta energy released per fission per second versus the kinetic energy of the beta rays from fission fragment of U^{235} and U^{238} .

Figures 11 and 12 present the percent of the total beta activity per fission for a few selected times versus the kinetic energy of the beta rays from U^{238} and U^{235} fission fragments.

Figures 13 and 14 present the percent of the total beta energy per interval for a few selected times versus the kinetic energy of the beta rays from U^{235} and U^{238} fission fragments.

Figure 15 compares the result of this study with its assumption of all beta transition to ground state for short half-life unknowns, to those of Cameron^{1/} and King.^{2/} While

^{1/} A. G. W. Cameron, Chalk River Project - 690, 1957.

^{2/} R. W. King and J. F. Perkins, Inverse Beta Decay and the Two-Component Neutrons, Phys. Rev., Vol. 112, No. 3, pp. 963-966, November 1, 1958.

this study used fission spectrum neutrons in U^{235} fission, the expected difference with thermal neutrons should be very small. It is apparent from Figure 15 that the King and Perkins assumption--of Q_{β} being shared by beta transitions to non-ground levels as well as gamma from the excited levels to ground--yields a somewhat lower number of high energy betas. The results of this study agree very well with those based upon Cameron's total disintegration energies for the unknown decays.

TABLE I
CALCULATED BETA END POINT ENERGIES ^{a/}

^{a/} Two primary sources were used in these calculations.
 Z_A values were taken from Coryell and Sugarman.

Radiochemical Studies: The Fission Product Book 1,
McGraw-Hill, page 494, Figure 51.1 and Table 52.10,
page 512.

B_A , δ_A , and ϵ_A , from Table II (page 325), Table IV
(page 331) and Table I (page 320), respectively, of
Annual Review of Nuclear Science, Vol. II, 1953.

The basic equations are:

$$(1) \quad Q_B = B_A(Z_A - Z - 0.5) \pm \delta_A \quad \text{for } (A \text{ even}).$$

$$(2) \quad Q_B = B_A(Z_A - Z - 0.5) \pm \epsilon_A \quad \text{for } (A \text{ odd}).$$

TABLE I

CALCULATED BETA END POINT ENERGIES

<u>A</u>	<u>Z</u>	<u>Z_A</u>	<u>B_A</u>	<u>A even</u> <u>δ A</u>	<u>A odd</u> <u>ε A</u>	<u>Use eq.</u> <u>with</u>	<u>Z_A - Z -.5</u>	<u>B_A(Z_A - Z -.5)</u>	<u>Q^B(MEV)</u>
72	28	32	2.45	2.82		-	3.5	8.58	5.76
	29					+	2.5	6.12	8.94
73	28	32.3	2.42		-.3	-	3.8	9.20	9.50
	29					+	2.8	6.78	6.48
	30					-	1.8	4.36	4.66
74	28	32.7	2.38	2.38		-	4.2	10.00	7.17
	29					+	3.2	7.62	10.45
	30					-	2.2	5.24	2.41
75	29	33	2.36		-.3	+	3.5	8.26	7.96
	30					-	2.5	5.90	6.20
	31					+	1.5	3.54	3.24
76	29	33.4	2.34	2.84		+	3.9	9.13	11.97
	30					-	2.9	6.79	3.95
77	29	33.8	2.31		-.3	+	4.3	9.93	9.63
	30					-	3.3	7.62	7.92
	31					+	2.3	5.31	5.01
	32					-	1.3	3.00	3.30
	33				-.1	+	0.3	0.69	.59
78	30	34.2	2.29	2.86		-	3.7	8.47	5.61
	31					+	2.7	6.18	9.04
79	30	34.6	2.27		-.3	-	4.1	9.31	9.61
	31					+	3.1	7.04	6.74
	32					-	2.1	4.77	5.07
80	30	35	2.24	2.86		-	4.5	10.08	7.22
	31					+	3.5	7.84	10.70
	32					-	2.5	5.60	2.74
81	31	35.5	2.21		-.3	+	4.0	8.84	8.54
	32				-.3	-	3.0	6.63	6.93
	33				-.1	+	2.0	4.42	4.32
	34				-.1	-	1.0	2.21	2.31
82	31	36	2.18	2.87		+	4.5	9.81	12.68
	32					-	3.5	7.63	4.76
	33					+	2.5	5.45	8.32

TABLE I (Continued)

<u>A</u>	<u>Z</u>	<u>Z_A</u>	<u>B_A</u>	<u>A even</u> <u>δA</u>	<u>A odd</u> <u>ε_A</u>	<u>Use eq.</u> <u>with</u>	<u>Z_A - Z - .5</u>	<u>B_A(Z_A - Z - .5)</u>	<u>Q^B(MEV)</u>
83	32	36.2	2.16		- .3	-	3.8	8.21	8.51
	33				- .1	+	2.8	6.05	5.95
	34				- .1	-	1.8	3.89	3.99
84	32	36.7	2.14	2.88		-	4.2	8.99	6.11
	33					+	3.2	6.85	9.73
85	32	37	2.12		- .3	-	4.5	9.54	9.84
	33				- .1	+	3.5	7.42	7.32
	34				- .1	-	2.5	5.30	5.40
	36				- .1	-	0.5	1.06	1.16
86	32	37.5	2.09	2.88		-	5.0	10.45	7.57
	33					+	4.0	8.36	11.24
	34					-	3.0	6.27	3.39
	35					+	2.0	4.18	7.06
87	33	2.06			- .1	+	4.5	9.27	9.17
	34				- .1	-	3.5	7.21	7.31
	36				- .1	+	1.5	3.09	2.99
88	34	28.5	2.03	2.88		-	4.0	8.12	5.24
	35					+	3.0	6.09	8.97
	36					-	2.0	4.06	1.18
89	34	39	2.01		- .1	-	4.5	9.04	9.14
	35				- .1	+	3.5	7.04	6.94
	36				- .1	-	2.5	5.02	5.12
90	34	39.4	1.99	2.88		-	4.9	9.75	6.87
91	35	39.9	1.97		- .1	+	4.4	8.67	8.57
	36				- .1	-	3.4	6.70	6.80
	37				- .1	+	2.4	4.73	4.63
	39				+ .4	+	0.4	0.79	1.19
92	35	40.3	1.96	2.88		+	4.8	9.41	12.29
	36+					-	3.8	7.45	4.57
	37					+	2.8	5.49	8.37
93	36	40.7	1.94		- .1	-	4.2	8.15	8.25
	37				- .1	+	3.2	6.21	6.11
	38				- .1	-	2.2	4.27	4.37
94	36	41.1	1.92	2.88		-	4.6	8.83	5.95
	37					+	3.6	6.91	9.79
	38					-	2.6	4.99	2.11

TABLE I (Continued)

<u>A</u>	<u>Z</u>	<u>Z_A</u>	<u>B_A</u>	<u>A even</u> <u>δ A</u>	<u>A odd</u> <u>ε A</u>	<u>Use eq.</u> <u>with</u>	<u>Z_A -Z -.5</u>	<u>B_A(Z_A -Z -.5)</u>	<u>Q^B(MEV)</u>
95	36	41.6	1.90		-.1	-	5.1	9.69	9.79
	37				-.1	+	4.1	7.79	7.69
	38				-.1	-	3.1	5.89	5.99
	39				+.4	+	2.1	3.99	4.39
	41				+.4	+	0.1	0.19	.59
96	37	42.1	1.88	2.87		+	4.6	8.65	11.52
	38					-	3.6	6.77	3.90
	39					+	2.6	4.89	7.76
97	37	42.6	1.86		-.1	+	5.1	9.49	9.39
	38				-.1	-	4.1	7.63	7.73
	39				+.4	+	3.1	5.77	5.17
	41				+.4	+	1.1	2.05	2.45
98	38	43	1.85	2.85		-	4.5	8.32	5.47
	39					+	3.5	6.48	9.33
	40					-	2.5	4.62	1.77
	41					+	1.5	2.78	5.63
99	39	43.5	1.83		.4	+	4.0	7.32	7.72
	40				.4	-	3.0	5.49	5.09
	43				.4	+	0.0	0	.4
100	39	44	1.81	2.84		+	4.5	8.14	10.98
	40					-	3.5	6.34	3.50
	41					+	2.5	4.52	7.36
101	39	44.4	1.79		+.4	+	4.9	8.77	9.17
	40				+.4	-	3.9	6.98	6.58
	41				+.4	+	2.9	5.19	5.59
102	40	44.8	1.78	2.82		-	4.3	7.65	4.83
	41					+	3.3	5.87	8.69
	42					-	2.3	4.09	1.27
103	40	45.2	1.76		.4	-	4.7	8.27	7.87
	41				.4	+	3.7	6.51	6.91
	42				.4	-	2.7	4.75	4.35
104	40	45.6	1.75	2.80		-	5.1	8.92	6.12
	41					+	4.1	7.18	9.98
	42					-	3.1	5.42	2.62

TABLE I (Continued)

<u>A</u>	<u>Z</u>	<u>Z_A</u>	<u>B_A</u>	<u>A even</u> <u>δ_A</u>	<u>A odd</u> <u>ϵ_A</u>	<u>Use eq.</u> <u>with</u>	<u>Z_A - Z - .5</u>	<u>B_A(Z_A - Z - .5)</u>	<u>Q^B(MEV)</u>
105	41	46.0	1.73		.4	+	4.5	7.78	8.18
	42				.4	-	3.5	6.06	5.66
	43				.4	+	2.5	4.32	4.72
	45				.4	+	0.5	.86	1.26
106	41	46.4	1.72	2.77		+	4.9	8.43	11.20
	42					-	3.9	6.71	3.94
						+	2.9	4.99	7.76
107	41	56.8	1.70		.4	+	5.3	9.01	9.41
	42				.4	-	4.3	7.31	6.91
					.4	+	3.3	5.61	6.01
108	42	47.2	1.68	2.74		-	4.7	7.90	5.16
	43					+	3.7	6.22	8.96
	44					-	2.7	4.54	1.80
109	42	47.5	1.67		.4	-	5.0	8.35	7.95
	43				.4	+	4.0	6.68	7.08
	44				.4	-	3.0	5.01	4.61
	45				.2	+	2.0	3.34	3.54
110	42	47.8	1.66	2.72		-	5.3	8.80	6.08
	43					+	4.3	7.14	9.86
	44					-	3.3	5.48	2.76
	45					+	2.3	3.82	6.54
111	43	48.1	1.65		.4	+	4.6	7.59	7.99
	44				.4	-	3.6	5.94	5.54
	45				.2	+	2.6	4.29	4.49
112	43	48.4	1.64	2.69		+	4.9	8.04	10.73
	44					-	3.9	6.40	3.71
	45					+	2.9	4.76	7.45
113	44	48.7	1.62		.4	-	4.2	6.80	6.40
	45				.2	+	3.2	5.18	5.38
	46				0	-	2.2	3.56	3.56
114	44	49.0	1.61	2.66		-	4.5	7.24	4.58
	45					+	3.5	5.64	8.30
	46					-	2.5	4.02	1.36
	47					+	1.5	2.41	5.07

TABLE I (Continued)

<u>A</u>	<u>Z</u>	<u>Z_A</u>	<u>B_A</u>	<u>A even</u> <u>δ A</u>	<u>A odd</u> <u>ε A</u>	<u>Use eq.</u> <u>with</u>	<u>Z_A - Z - .5</u>	<u>B_A(Z_A - Z - .5)</u>	<u>Q^B(MEV)</u>
115	44				0	-	4.8	7.68	7.68
	45	49.3	1.60		.2	+	3.8	6.08	6.28
	46				0	-	2.8	4.48	4.48
	48				0	-	0.8	1.28	1.28
	49				.5	+	-0.2	-.32	.18
116	45	49.6	1.59	2.62		+	4.1	6.52	9.14
	46					-	3.1	4.93	2.31
117	45	49.9	1.58		.2	+	4.4	6.95	7.15
	46				0	-	3.4	5.37	5.37
	47				0	+	2.4	3.79	3.79
	48				0	-	1.4	2.21	2.21
	49				.5	+	0.4	.63	1.13
118	45	50.2	1.57	2.58		+	4.7	7.38	9.96
	46					-	3.7	5.81	3.23
	47					+	2.7	4.24	6.82
	48					-	1.7	2.67	.09
119	45	50.5	1.56		.2	+	5.0	7.80	8.00
	46				0	-	4.0	6.24	6.24
	47				0	+	3.0	4.68	4.68
	48				0	-	2.0	3.12	3.12
	49				.5	+	1.0	1.56	2.06
120	46	50.8	1.54	2.55		-	4.3	6.62	4.07
	47					+	3.3	5.08	7.63
	48					-	2.3	3.54	.99
	49					+	1.3	2.00	4.55
121	46	51.1	1.53		0	-	4.6	7.04	7.04
	47				0	+	3.6	5.51	5.51
	48				0	-	2.6	3.98	3.98
	49				.5	+	1.6	2.45	2.95
	50				0	-	0.6	.92	.92
122	46	51.4	1.52	2.51		-	4.9	7.45	4.94
	47					+	3.9	5.93	8.44
	48					-	2.9	4.41	1.90
	49					+	1.9	2.89	5.40
123	47	51.7	1.51		0	+	4.2	6.34	6.34
	48				0	-	3.2	4.83	4.83
	49				.5	+	2.2	3.32	3.82

TABLE I (Continued)

A	Z	Z_A	B_A	$\frac{A \text{ even}}{\delta A}$	$\frac{A \text{ odd}}{\epsilon A}$	Use eq. with	$Z_A - Z - .5$	$B_A (Z_A - Z - .5)$	$Q^B (\text{MEV})$
124	47	52.0	1.51	2.47		+	4.5	6.80	9.27
	48				-	3.5	5.28	2.81	
	49				+	2.5	3.78	6.25	
125	47	52.3	1.50		0	+	4.8	7.20	7.20
	48			-	3.8	5.70	5.70		
				.5	+	2.8	4.20	4.70	
126	48	52.6	1.49	2.40		-	4.1	6.11	3.71
	49				+	3.1	4.62	7.02	
	50				-	2.1	3.13	.73	
127	48	52.9	1.48		0	-	4.4	6.51	6.51
	49			.5	+	3.4	5.03	5.53	
	50			0	-	2.4	3.55	3.55	
	52			0	-	0.4	.59	.59	
128	48	53.2	1.47	2.35		-	4.7	6.91	4.56
	49				+	3.7	5.44	7.79	
	50				-	2.7	3.97	1.62	
129	48	53.5	1.46		.5	+	4.0	5.84	6.34
	50			0	-	3.0	4.38	4.38	
	51			-.4	+	2.0	2.92	2.52	
	52			0	-	1.0	1.46	1.46	
130	49	53.9	1.46	2.29		+	4.4	6.42	8.71
	50				-	3.4	4.96	2.67	
	51				+	2.4	3.50	5.79	
131	49	54.2	1.45		.5	+	4.7	6.81	7.31
	50			0	-	3.7	5.36	5.36	
	51			-.4	+	2.7	3.92	3.52	
	52			0	-	1.7	2.46	2.46	
	53			0	+	0.7	1.01	1.01	
	54			0	-	-0.3	-.44	-.44	
132	50	54.5	1.44	2.24		-	4.0	5.76	3.52
	51				+	3.0	4.32	6.56	
133	50	54.9	1.43		0	-	4.4	6.29	6.29
	51			-.4	+	3.4	4.86	4.46	
	52			0	-	2.4	3.43	3.43	

TABLE I (Continued)

<u>A</u>	<u>Z</u>	<u>Z_A</u>	<u>B_A</u>	<u>A even</u> <u>0_A</u>	<u>A odd</u> <u>ε_A</u>	<u>Use Eq.</u> <u>with</u>	<u>Z_A - Z - .5</u>	<u>B_A(Z_A - Z - .5)</u>	<u>Q^B(MEV)</u>
134	51	55.3	1.42	2.19		+	3.8	5.40	7.59
	52					-	2.8	3.98	1.79
135	51	55.7	1.41		-.4 0	+	4.2	5.92	5.52
	52					-	3.2	4.51	4.51
136	51	56.1	1.40	2.14		+	4.6	6.44	8.58
	52					-	3.6	5.04	2.90
137	52	56.5	1.39		0	-	4.0	5.56	5.56
138	52	57.0	1.37	2.09		-	4.5	6.165	4.07
	53					+	3.5	4.80	6.89
139	53	57.5	1.36		0 0 0	+	4.0	5.44	5.44
	54					-	3.0	4.08	4.08
	55					+	2.0	2.72	
140	53	58.0	1.35	2.05		+	4.5	6.075	8.13
	54					-	3.5	4.72	2.67
	55					+	2.5	3.38	5.43
141	54	58.5	1.34		0 0	-	4.0	5.36	5.36
	55					+	3.0	4.02	4.02
142	54	59.0	1.33	2.0		-	4.5	5.98	3.98
	55					+	3.5	4.65	6.65
	56					-	2.5	3.32	1.32
	57					+	1.5	2.00	4.00
143	55	59.5	1.32		0 0 .35	+	4.0	5.28	5.28
	56					-	3.0	3.96	3.96
	57					+	2.0	2.64	2.99
144	55	59.9	1.31	1.97		+	4.4	5.76	7.73
	56					-	3.4	4.45	2.48
	57					+	2.4	3.14	5.11
145	55	60.4	1.30		0 0 .35	+	4.9	6.37	6.37
	56					-	3.9	5.07	5.07
	57					+	2.9	3.77	4.12
146	56	60.9	1.28	1.93		-	4.4	5.63	3.70
	57					+	3.4	4.35	6.28

TABLE I (Continued)

A	Z	Z_A	B_A	$\frac{A \text{ even}}{0_A}$	$\frac{A \text{ odd}}{\epsilon_A}$	Use eq. with	$Z_A - Z - .5$	$B_A(Z_A - Z - .5)$	$Q^B(\text{MEV})$
147	56	61.4	1.27		0	-	4.9	6.22	6.22
	57				.35	+	3.9	4.95	5.30
	58				0	-	2.9	3.68	3.68
	59				.35	+	1.9	2.41	2.76
	60				0	-	0.9	1.14	1.14
148	57	61.9	1.26	1.89		+	4.4	5.54	7.43
	58					-	3.4	4.28	2.39
	59					+	2.4	3.02	4.91
149	57	62.3	1.25		.35	+	4.8	6.00	6.35
	58				0	-	3.8	4.75	4.75
	59				.35	+	2.8	3.50	3.85
150	58	62.6	1.25	1.86		-	4.1	5.12	3.26
	59					+	3.1	3.88	5.74
151	58	62.9	1.24		0	-	4.4	5.45	5.45
	59				.35	+	3.4	4.22	4.57
152	58	63.2	1.24	1.84		-	4.7	5.83	3.99
	59					+	3.7	4.59	6.43
	60					-	2.7	3.35	1.51
	61					+	1.7	2.11	3.95
153	59	63.5	1.23		.35	+	4.0	4.92	5.27
	60				0	-	3.0	3.69	3.69
	61				.35	+	2.0	2.46	2.81
154	59	63.9	1.22	1.80		+	4.4	5.37	7.17
	60					-	3.4	4.15	2.35
	61					+	2.4	2.93	4.73
155	59	64.3	1.21		.35	+	4.8	5.81	6.16
	60				0	-	3.8	4.60	4.60
	61				.35	+	2.8	3.39	3.74
156	60	64.6	1.21	1.77		-	4.1	4.96	3.19
	61					+	3.1	3.75	5.52
157	60	64.8	1.20		0	-	4.3	5.16	5.16
	61				.35	+	3.3	3.96	4.31
	62				0	-	2.3	2.76	2.76

TABLE I (Continued)

<u>A</u>	<u>Z</u>	<u>Z_A</u>	<u>B_A</u>	<u>A even</u> <u>A</u>	<u>A odd</u> <u>A</u>	<u>Use Eq.</u> <u>with</u>	<u>Z_A - Z -.5</u>	<u>B_A(Z_A - Z -.5)</u>	<u>Q^B(MEV)</u>
158	60	65.1	1.20	1.74		-	4.6	5.52	3.78
	61					+	3.6	4.32	6.06
	62					-	2.6	3.12	1.38
159	61	65.3	1.20		.35	+	3.8	4.56	4.91
	62				0	-	2.8	3.36	3.36
160	65.5		1.19	1.72		+	4.0	4.76	6.48
	62					-	3.0	3.57	1.85
	63					+	2.0	2.38	4.10
161	62	65.7	1.19		0	-	3.2	3.81	3.81
	63				.2	+	2.2	2.62	2.82
162	62	65.9	1.19	1.70		-	3.4	4.05	2.35
	63					+	2.4	2.86	4.56
	64					-	1.4	1.67	-.03

[illegible]

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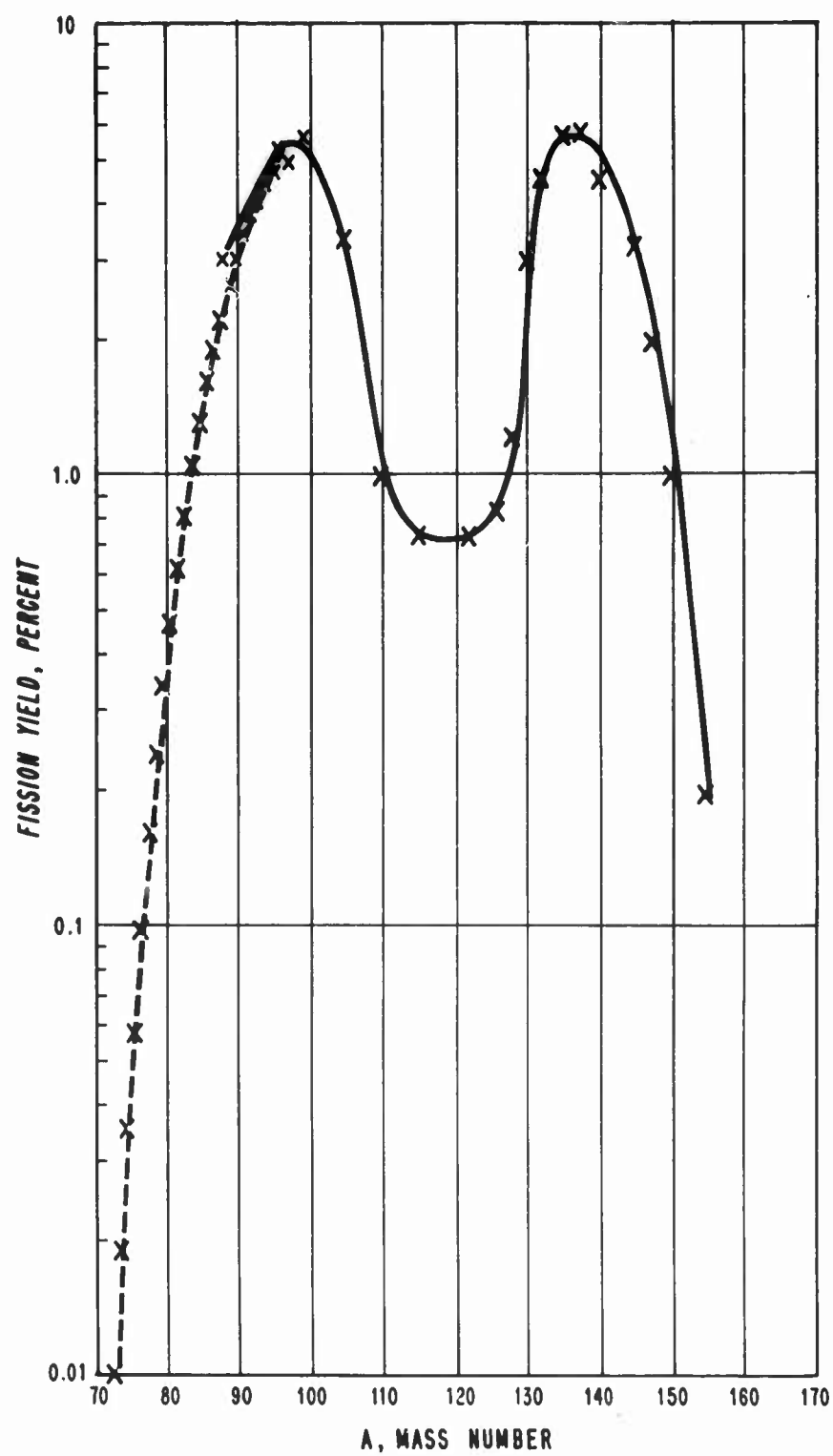
EO	Δ	Forbidden	A	Z	LAMBO	FU238	FU235	EO	Δ	Forbidden	A	Z	LAMBO	FU238	FU235	EO	Δ
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52	1000000051	0	91	37	6930000048	1700000048	3720000048	9200000051	1000000051	0	109	44	4330000049	4180000048	2300000047	9220000051	10000000
50	9500000050	0	91	37	6930000048	2550000048	5580000048	9200000051	1000000051	0	109	46	2890000047	1000000048	1000000048	7080000051	10000000
51	5000000049	0	91	37	8250000047	3400000048	7360000048	8400000051	2400000050	1	109	48	1380000048	4400000048	2000000047	2000000051	99000000
51	4200000050	0	91	38	1990000046	6120000047	3060000048	4060000051	4000000049	0	110	42	6930000050	4600000047	1300000047	1215000052	10000000
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51	1000000050	0						2180000051	3300000050	0	110	44	6930000049	4230000048	1340000047	5520000051	10000000
51	9000000049	0						1840000051	7000000049	0	111	45	3460000049	1790000048	9000000046	1308000052	10000000
51	8000000049	0						3080000051	1000000051	1	111	43	4620000050	1610000048	5400000046	1600000052	10000000
52	1000000051	0	91	39	1380000044	5000000044		2800000052	1000000051	1	111	45	1730000050	3780000048	1300000047	1108000052	10000000
52	1000000051	0	92	35	4620000050	4620000048	3900000048	9140000051	1000000051	0	111	45	5780000049	2610000048	1098000047	8980000051	10000000
51	1000000051	0	92	36	2310000050	1550000049	1990000049	1674000052	1000000051	0	111	48	4440000047	3930000047	2180000046	4300000051	10000000
51	1000000051	0	92	37	8640000048	1370000049	2430000049	1100000051	9000000050	1	111	47	1060000045	6000000044		2080000051	91000000
51	1000000051	0	92	38	7400000046	3140000048	9600000048	3000000051	1000000050	0						1600000051	10000000
52	1000000051	0						7200000051	3300000050	1	112	43	4620000050	6960000047	2500000046	1400000051	80000000
51	1000000051	0	92	39	9350000046	4100000046	3000000047	5400000051	3300000050	0	112	44	2310000050	2960000048	1022000047	7420000051	10000000
51	3330000050	0						2600000051	3300000050	0	112	45	9900000049	3200000048	1146000047	1490000052	10000000
51	3330000050	0						1650000052	1000000051	0	112	46	9170000045	9370000047	3780000046	5000000050	10000000
52	1000000051	0	93	36	3460000050	1500000049	1210000049	1220000052	1000000051	0	112	47	6020000046	6200000045	6000000044	8200000051	25000000
52	1000000051	0	93	37	9900000049	1800000049	2590000049	8740000051	1000000051	0						7000000051	40000000
52	1000000051	0	93	38	1410000048	6800000048	1910000049	8760000051	8800000050	1						5400000051	20000000
51	1000000051	0	93	39	1890000046	1400000047	2900000048	5200000051	9500000049	0						2800000051	18000000
51	8580000050	0						3680000051	4700000049	0	113	44	3460000050	2140000048	9120000046	1280000052	10000000
51	1500000050	0						2960000051	1800000049	0	113	45	1730000050	3440000048	1218000047	1076000052	10000000
51	1000000051	0						1480000051	3100000049	0	113	46	8250000048	1700000048	6300000046	7020000051	10000000
51	1030000051	0	94	36	4950000050	9700000048	4200000048	1190000052	1000000051	0	113	47	3630000046	1110000047	4000000045	4200000051	10000000
51	1000000051	0	94	37	2310000050	1980000049	2130000049	1930000052	1000000051	0	114	44	4620000050	1110000048	5260000046	9060000051	10000000
51	1000000051	0	94	38	8880000048	1280000049	2600000049	4220000051	1000000051	0	114	45	2310000050	3170000048	1124000047	1660000052	10000000
51	1000000051	0	94	39	7000000047	1720000048	1020000049	1080000052	1000000051	1	114	46	4810000048	2450000048	8260000046	2720000051	10000000
51	1000000051	0	95	36	6930000050	4110000048	4570000048	1960000052	1000000051	0	114	47	5780000048	4480000047	1240000046	1014000052	10000000
51	4200000050	1	95	37	3460000050	1790000049	1500000049	1630000052	1000000051	0	115	44	6930000050	4840000047	2480000046	1536000052	10000000
51	2300000050	0	95	38	1850000049	1930000049	2740000049	1200000052	1000000051	0	115	45	2770000050	2780000048	8580000046	1254000052	10000000
51	9800000050	0	95	39	1100000046	5660000048	1830000049	8680000051	1000000051	1	115	46	1540000049	3080000048	8580000046	8960000051	10000000
51	1000000051	0	95	40	1230000044	3500000046	2200000048	7200000050	4300000050	1	115	47	5470000047	1120000050	2420000046	5800000051	10000000
51	1000000051	0						7920000050	5500000050	0	115	48	1860000044	1400000045		3220000051	98000000
51	1000000051	0						1780000051	2000000049	0						1400000051	20000000
51	1000000051	0	95	41	2140000045			1000000051	1000000051	0	115	48	3630000045			3220000051	58000000
51	1000000051	0	95	41	2290000044			1000000051	1000000051	1						1160000051	42000000
51	3000000050	0	96	37	6930000050	1570000049	5700000048	2890000052	1000000051	0	115	49	4280000046			1660000051	90600000
51	1000000051	0	96	38	2770000050	2360000049	7800000049	7800000051	1000000051	0	116	44	3460000050	1720000048	7000000046	1285000052	10000000
51	1000000051	0	96	39	6930000049	1120000049	2620000049	1850000052	1000000051	0	116	46	6930000049	3210000048	9500000046	4620000051	10000000
51	1000000051	0	96	37	6930000050	8270000048	9200000048	1870000052	1000000051	0	116	47	4620000050	1790000048	4300000046	1000000052	10000000
51	1000000051	0	97	36	4620000050	2380000049	1800000049	1840000052	1000000051	0	117	45	4620000050	2410000048	4780000046	1430000052	10000000
51	1000000051	0	97	38	1390000050	1840000049	2790000049	1234000052	1000000051	0	117	46	1390000050	3040000048	8700000046	1074000052	10000000
51	1000000051	0	97	40	1130000046	3510000048	1650000049	3820000051	9900000050	0	117	47	1050000049	1290000048	5800000046	7580000051	10000000
51	1000000051	0						9200000050	1000000049	0	117	48	7080000046	3300000046	7200000045		10000000
51	1000000051	0	97	41	1160000049	7500000048	7000000047	1000000051	1000000051	0	117	49	1010000047			3540000051	55000000
51	1000000051	0	97	41	1540000047	7500000047	7000000047	1000000051	1000000051	0						3240000051	23000000
51	1000000051	0	98	38	6930000050	8150000048	6800000048	2040000052	1000000051	0	117	49	1750000047			1480000051	10000000
51	1000000051	0	98	39	2770000050	2430000049	2420000049	1846000052	1000000051	0	118	45	4620000050	1970000048	3020000046	1992000052	10000000
51	1000000051	0	98	40	4620000049	1980000049	2420000049	3500000051	1000000051	0	118	46	1540000050	3160000048	9000000046	6460000051	10000000
51	1000000051	0	98	41	4440000047	4240000046	6800000048	1120000052	1000000051	0	118	47	2770000049	1560000048	8040000046	1364000052	10000000
51	1000000051	0	99	39	4620000050	2170000049	1690000049	1540000052	1000000051	0	118	48	2310000047	1020000047		1800000050	10000000
51	1000000051	0	99	40	2310000049	2540000049	2480000048	1020000052	1000000051	0	118	49	1260000050			8800000051	10000000
51	1000000051	0	99	41	3040000048	9700000048	1590000049	6460000051	1000000051	0	119	49	4620000050	1060000048	1640000046	1600000052	10000000
51	1000000051	0	99	42	2920000045	2000000047	1400000048	2340000050	8300000050	0	119	48	2310000048	3040000048	8240000046	1246000052	10000000
51	1000000051	0						1600000051	3000000049	0	119	47	4080000048	2390000048	1010000047	9360000051	10000000
51	1000000051	0						8200000050	1400000050	0	119	48	3980000048	2240000047	1120000046	1000000051	10000000
51	1000000051	0	100	39	4620000050	1290000049	7800000048	2200000052	1000000051	0	119	48	1160000048	2240000047	1120000046	6240000051	10000000
51	8000000050	0	100	40	1980000050	2600000049	7000000049	7000000051	1000000051	0	119	49	6600000047	9700000044	1000000045	5400000051	10000000
51	1000000051	0	100	41	2570000049	1580000049	2080000049	1470000052	1000000051	0	120	46	3460000050	2780000048	6760000046	8140000051	10000000
51	1000000051	0	101	39	6930000050	6180000048	6867000048	1830000052	1000000051	0							

Forbidden	A	Z	LAMBO	FU238	FU235	EO	Δ	Forbidden	A	Z	LAMBO	FU238	FU235	EO	Δ	Forbidden
0	109	43	2770000050	4520000048	2040000047	1416000052	1000000051	0	129	51	4580000046	7540000048	2020000048	3740000051	2000000050	0
0	109	44	4330000049	4180000049	2300000047	9220000051	1000000051	0						3400000051	2000000050	0
0	109	45	2890000047	1000000048	7600000046	7080000051	1000000051	0						3120000051	2000000050	0
1	109	46	1380000046	4400000045		2000000051	9900000050	1						2000000051	2000000050	0
1	110	42	6930000050	4600000047	1300000047	1215000052	1000000051	0						2680000051	2000000050	0
0	110	43	3460000049	2930000048	1740000047	1972000052	1000000051	0	129	52- 2390000044	1550000047	6000000046		2160000051	1000000051	0
0	110	44	6930000049	4230000048	1360000046	9520000051	1000000051	0	129	52 1600000047	5800000047	7000000046		1000000051	1000000051	0
0	110	45	3460000049	1790000048	9000000046	1308000052	1000000051	0						5600000050	1000000051	0
0	111	43	4620000050	1610000048	5400000046	1607000052	1000000051	0						1380000051	4000000049	0
1	111	44	1730000050	3780000048	1300000047	1108000052	1000000051	0						1480000051	1300000050	0
0	111	45	5780000049	2610000048	1098000047	9980000051	1000000051	0	130	49 4620000050	4180000048	3840000048		2900000051	7100000050	0
0	111	46	4400000047	3930000047	2180000046	4300000051	1000000051	0	130	50 4440000048	1480000049	8210000048		1742000052	1000000051	0
0	111	47	1060000045	6000000044		2080000051	9100000050	1	130	51 1630000048	1370000049	3040000048		5250000051	1000000051	0
1						1400000051	1000000049	0						1158000052	1000000051	0
1						1400000051	8000000049	0						1462000052	1000000051	1
1	112	43	4620000050	6960000047	2500000046	2146000052	1000000051	0	131	50 3400000048	1490000047	1117000049		1072000052	1000000051	0
0	112	44	2310000050	2960000048	1022000047	7420000051	1000000051	0	131	51 5000000047	1890000049	1270500049		1000000051	1000000051	0
0	112	45	9900000049	3200000048	1146000047	1490000052	1000000051	0						8400000050	5200000050	0
0	112	46	9170000045	9370000047	3780000046	5000000050	1000000051	0						1140000051	1700000050	0
0	112	47	6020000046	6200000045	6000000044	8200000051	2500000050	1						1960000051	4600000049	0
1						7000000051	4000000050	0	131	52 4620000047	7580000048	2100000048		4700000049	4700000049	0
1						5400000051	2000000050	0						2700000051	1500000050	0
0						2000000051	1500000050	0						2380000051	2300000050	0
0	113	44	3460000050	2140000048	9120000046	1280000052	1000000051	0	131	53 9900000046	2060000047	1030000047		4280000051	6000000050	0
0	113	45	1730000050	3440000048	1218000047	1076000052	1000000051	0						8000000050	2800000049	1
0	113	46	6250000048	1700000048	6300000046	7020000051	1000000051	0						1630000051	7000000048	0
0	113	47	3630000046	1110000047	4000000046	4200000051	1000000051	0						1216000051	8720000049	0
0	114	44	4620000050	1110000048	5260000046	9060000051	1000000051	0	132	50 8250000048	9080000048	1130000049		6700000050	9300000049	0
0	114	45	2310000050	3170000048	1124000047	1660000052	1000000051	0						7040000051	1000000051	0
0	114	46	4810000046	2450000046	8260000046	2720000051	1000000051	1	132	51 5530000048	2110000049	1740000049		1312000052	1000000051	0
0	114	47	5780000048	4640000047	1240000046	1014000052	1000000051	1						6000000050	1000000051	0
0	115	44	6930000050	4840000047	2420000046	1936000052	1000000051	0	132	53 8520000046	2210000048	9000000047		4240000051	1800000050	1
0	115	45	2770000050	2780000048	8580000046	1254000052	1000000051	0						3060000051	2400000050	0
0	115	46	1540000049	3080000048	8580000046	8960000051	1000000051	0						2320000051	2300000050	0
0	115	47	5470000047	1120000050	2420000046	5800000051	1000000051	0	133	50 3470000050	4440000048	8600000048		1800000051	2000000050	0
0	115	48	1860000044	1400000045		3220000051	9800000050	1						1258000052	1000000051	0
1						1400000051	2000000049	0	133	51 2620000048	1940000049	2610000049		8920000051	1000000051	0
0	115	48	3630000045			3220000051	9800000050	0	133	52- 1830000047	1090000049	1190000049		1066000051	1000000051	0
0						1140000051	4200000049	0	133	53 1830000047	6460000051			6460000051	1000000051	0
0						1640000051	5000000049	0						4800000051	3000000050	0
0	116	45	4280000046			1640000051	5000000049	0	133	52 7570000048	1050000049	1190000049		2600000051	7000000050	0
0	116	45	3460000050	1720000048	7000000046	1828000052	1000000051	0						2600000051	9100000049	1
0	116	46	6930000049	3210000048	9900000046	4620000051	1000000051	0						8000000050	9000000049	0
0	116	47	4620000048	1790000048	4300000046	1000000052	1000000051	0	133	54- 3490000045	1000000048			1000000051	1000000051	0
0	117	45	4620000050	2410000048	6780000046	1430000052	1000000051	0						7000000050	1000000051	1
0	117	46	1390000050	3060000048	8700000046	1074000052	1000000051	0	134	51 1520000045	3900000046			1818000052	1000000051	0
0	117	47	1850000049	1290000048	5800000046	7800000051	1000000051	0						3580000049	1000000051	0
0	117	48	7080000046	3300000046	7200000045	1000000051	1000000051	0	134	52 2610000047	2480000049	3200000049		5000000051	5000000050	1
0	117	49	1010000047			3540000051	5500000050	1						3000000051	5000000050	0
0						3240000051	2300000050	1	135	51 1160000050	1010000049	1220000049		1114000052	1000000051	0
0	117	49	1750000047			1480000051	1000000051	1						9000000051	1000000051	0
0	118	45	4620000050	1970000048	3020000046	1992000052	1000000051	0	135	52 5780000048	2510000049	2590000049		1000000051	3500000050	1
0	118	46	1540000050	3160000048	9000000046	6460000051	1000000051	0						2000000051	4000000050	0
0	118	47	2770000049	1580000048	8040000046	1364000052	1000000051	0	135	53 2880000046	1810000049	1910000049		2800000051	2500000050	0
0	118	48	2310000047	1520000047	1960000046	1800000050	1000000051	1						1000000051	1000000051	0
Forbidden	A	Z	LAMBO	FU238	FU235	EO	Δ	Forbidden	A	Z	LAMBO	FU238	FU235	EO	Δ	Forbidden
0	118	49	1260000050			8800000051	1000000051	1	135	54 2110000046	2170000048	1400000048		1100000051	3000000049	1
0	119	45	4620000050	1060000048	1640000046	1600000052	1000000051	0						1820000051	9700000050	0
1	119	46	2310000050	3040000048	8240000046	1248000052	1000000051	0	136	51 2310000050	4230000049	5400000048		1716000052	1000000051	0
0	119	47	4080000049	2350000048	1010000047	9360000051	1000000051	0						5800000051	1000000051	0
0	119	48	3980000048	2240000047	1120000046	6240000051	1000000051	0	136	52 1160000050	1980000049	2230000049		1400000052	2500000050	0
0	119	49	1160000048	2240000047	1120000046	6240000051	1000000051	0						1112000052	2500000050	0
0	120	45	4620000050	2780000048	6760000046	8140000051	1000000051	0	136	53 8060000048	2430000049	2490000049		8600000051	2500000050	0
0	120	46	3460000050	2780000048	6760000046	8140000051	1000000051	0						5400000051	2500000050	0
0	120	47	1160000050	3080000048	1044000047	1524000052	1000000051	0	136	55 6220000044	2730000047	3038000047		6420000050	9300000049	1
0	120	48	9620000047	1120000048	6220000046	1980000051	1000000051	0						1314000051	7000000049	0
0	120	49	1260000050	1500000046	5600000045	2000000051	1000000051	0						1102000052	1000000051	0
1	121	46	4620000050	1800000048	4400000046	1408000052	1000000051	0	137	52 2310000050	3040000048	1780000049		1000000051	1000000051	0
0	121	47	1730000050	3350000048	1092000047	1102000052	1000000051	0						1300000052	1000000051	0
0	121	48	2770000049	1870000048	8920000046	9660000051	1000000051	0	137	53 3150000049	1835000049	2704000049		7000000051	1000000051	0
0	121	49	9240000048	1800000047	1780000046	5900000051	1000000051	0						102		

TABLE II
INPUT DATA CHARACTERISTICS U²³⁵ AND U²³⁸

Z	LAMBO	Fuz38	Fuz35	EO	Δ	Forbidden	A	Z	LAMBO	Fuz38	Fuz35	EO	Δ	Forbidden
51	4580000046	7540000048	2020000048	3740000051	2000000050	0	143	59	5830000044	4720000048	6800000048	4000000050	6000000049	0
				3400000051	2000000050	0	144	55	4620000050	1420000049	2050000049	1546000052	1000000051	0
				3120000051	2000000050	0	144	56	1980000050	1420000049	2050000049	4960000051	1000000051	0
				2680000051	2000000050	0	144	57	4620000049	1420000049	1820000049	1022000052	1000000051	0
				2180000051	2000000050	0	144	58	2810000043	2480000048	4500000048	6800000050	7800000050	0
52- 2390000044	1550000047	6000000048	5800000050	1000000051	1000000050	1						5000000050	5000000049	0
52- 1800000047	5800000047	7000000048	1380000051	4000000049	4000000049	0						3400000050	2000000050	0
			1480000051	1800000050	1800000050	0	144	59	6690000047	3600000045	6000000051	9800000050	0	
			2900000051	7100000050	7100000050	0						4600000051	2000000049	0
49	4620000050	4180000048	3840000048	1742000052	1000000051	0	145	55	6930000050	1670000048	1854000048	1274000052	1000000051	0
50	4440000048	1480000049	8210000048	1198000052	1000000051	0	145	56	3460000050	9280000048	1430000049	1014000052	1000000051	0
51	1630000048	1370000049	6040000048	1482000052	1000000051	1	148	57	7700000049	1290000049	1910000049	8240000051	1000000051	0
49	6930000050	2430000048	2700000048	1072000052	1000000051	0	145	58	3850000048	5050000048	9900000048	4000000051	1000000051	0
50	3400000048	1490000049	1110000049	7040000051	1000000051	0	145	59	3240000046	1000000047	6000000047	3400000051	1000000051	1
51	5000000047	1890000049	1270000049	8400000050	5200000050	0	146	56	4620000050	5690000048	6400000048	7400000051	1000000051	0
52- 6420000045	3990000047	2100000048	1140000051	1700000050	1700000050	0	146	57	1730000050	1150000049	1600000049	1294000052	1000000051	0
			1960000051	4600000049	4600000049	0	146	58	8310000047	7000000048	1300000048	1800000051	1000000051	0
			4920000051	4700000049	4700000049	0	146	59	4730000047	8000000047	2600000048	7400000051	7500000050	0
52	4620000047	7580000048	2100000048	2700000051	1900000050	0						4600000051	2500000050	0
			2380000051	2800000050	2800000050	0	147	56	6930000050	2420000048	2689000048	1244000052	1000000051	0
			4280000051	6000000050	6000000050	1	147	57	3460000050	8180000048	1060000049	1060000051	1000000051	0
53	9900000046	2060000047	1000000047	9000000050	2800000049	1	147	58	7700000049	8580000048	1280000048	7760000051	1000000051	0
			1630000051	7000000048	7000000048	0	147	59	2890000048	2410000048	5700000048	9520000051	1000000051	0
			1214000051	6720000049	6720000049	0	147	60	7230000044	1200000048	2000000047	1640000051	6000000050	1
			6700000050	9300000049	9300000049	0						1200000051	1500000050	0
50	5250000046	9080000048	1130000049	7040000051	1000000051	0						7600000050	2500000050	0
51	5500000048	2110000049	1740000049	1312000052	1000000051	0	147	61	8320000042	2740000048	4440000048	4800000050	1000000051	0
52	2480000045	1460000049	1040000049	6000000050	1000000051	1	148	57	3460000050	8180000048	1060000049	1060000051	1000000051	0
53	6520000046	2210000048	9000000047	4240000051	1800000050	1	148	58	7700000049	8580000048	1280000048	7760000051	1000000051	0
			3060000051	2400000050	2400000050	0	149	59	2890000048	2410000048	5700000048	9520000051	1000000051	0
			2320000051	2300000050	2300000050	0	149	60	7230000044	1200000048	2000000047	1640000051	6000000050	1
			1800000051	2000000050	2000000050	0	149	58	3460000050	8180000048	1060000049	1060000051	1000000051	0
50	3470000050	4440000048	8600000048	1258000052	1000000051	0	149	59	2310000049	7040000048	5730000048	7700000051	1000000051	0
51	2620000048	1940000049	2610000049	8920000051	1000000051	0	139	60	9620000046	2560000048	1890000048	3000000051	3330000050	1
52- 1830000047	1050000049	1190000049	6860000051	1000000051	1000000051	0						2200000051	3330000050	0
52- 1830000047	1050000049	1190000049	6860000051	1000000051	1000000051	0						1900000051	3330000050	0
53	9250000045	6120000048	4400000048	4800000051	3000000050	0	149	61	3560000045	3500000046	3000000046	2000000051	1000000051	1
			2600000051	7000000048	7000000048	0	150	58	2770000049	2840000048	2584000048	6842000051	1000000051	0
			2600000051	9100000050	9100000050	1	150	59	4620000049	5980000048	3920000048	1146000052	1000000051	0
			8000000050	9000000049	9000000049	0	150	61	7130000046	4200000047	2070000047	6100000051	2000000050	0
54- 3490000045	1000000048	1000000048	1000000051	1000000051	1000000051	0						4020000051	8000000050	0
54	1920000045	3900000046	2710000049	7000000050	1000000051	0	151	58	3460000050	1300000048	6800000047	1090000052	1000000051	0
51	1390000049	1670000049	3200000049	1918000052	1000000051	0	151	59	9900000049	4420000048	2080000048	9140000051	1000000051	0
52	2620000047	2480000049	1440000049	3880000051	1000000051	0	151	60	7700000047	3880000048	1830000048	3860000051	1000000051	0
53	2200000047	1190000049	1440000049	5000000051	9000000050	1	151	61	7000000045	8900000047	4500000047	2200000051	1000000051	1
			3000000051	9000000050	9000000050	0	151	62	2360000041	2800000045	1520000045	1520000051	1000000051	1
51	1180000050	1010000049	1220000049	1118000051	1000000051	0	152	58	4620000050	3900000047	2580000047	7960000051	1000000051	0
52	5780000048	2510000049	2590000049	9000000051	1000000051	0	152	59	1390000050	2300000048	1130000048	1286000052	1000000051	0
53	2880000046	1810000049	1910000049	1000000051	3500000050	1	152	60	3850000048	3380000048	1340000048	3020000051	1000000051	0
			2000000051	4000000050	4000000050	0	152	61	1920000047	1420000048	6000000047	7900000051	1000000051	0
			2800000051	2800000050	2800000050	0	153	59	2310000050	1610000048	3620000047	1054000052	1000000051	0
54- 7400000047	9300000047	1400000048	1000000051	1000000051	1000000051	0	153	60	3850000049	2390000048	6960000047	7380000051	1000000051	0
			1000000051	1000000051	1000000051	0	153	61	1280000048	1140000048	6460000047	5620000051	1000000051	0
			1000000051	1000000051	1000000051	0	153	62	4100000045	5700000046	5800000046	1640000051	2000000050	0
			1000000051	1000000051	1000000051	0						1440000051	4000000050	0
Z	LAMBO	Fuz38	Fuz35	EO	Δ	Forbidden	A	Z	LAMBO	Fuz38	Fuz35	EO	Δ	Forbidden
54	2110000046	2170000048	1400000048	1100000051	3000000049	0		59	3460000050	5600000047	9000000046	1300000051	4000000050	0
			1820000051	9700000050	9700000050	0		60	5780000049	1890000048	3200000047	4700000051	1000000051	0
51	2310000050	4230000048	5400000048	1718000052	1000000051	0	154	61	3850000048	1220000048	3200000047	9460000051	1000000051	0
52	1160000050	1980000049	2230000049	9800000051	1000000051	0	154	62	3460000050	1800000047	2000000047	1232000052	1000000051	0
53	8060000048	2430000049	2490000049	1400000052	2900000050	0	155	60	1390000050	8800000047	1170000047	9200000051	1000000051	0
			1120000052	2900000050	2900000050	0	155	61	1160000049	1080000048	1380000047	1380000051	1000000051	0
			8400000051	2900000050	2900000050	1	155	62	4910000047	3500000047	6200000046	3400000051	1000000051	0
55	6220000044	2730000047	3038000047	6820000050	9300000050	1	155	63	1290000043	3700000045	2000000045	2000000050	8000000050	1
			1314000051	7000000049	7000000049	0	155	60	1940000050	4000000047	3430000046	4860000050	2000000050	0
			1102000052	1000000051	1000000051	0	155	61	2770000049	7400000047	7340000046	6380000051	1000000051	0
52	2310000050	3040000048	1780000049	1020000051	9200000050	1	156	62	2140000046	4200000047	5410000046	1800000051	1000000051	0
53	3150000049	1840000049	3700000049	2340000051	8000000049	0	156	63	5210000044	4000000046	8200000045	4800000051	4000000050	1
54	2960000048	2380000049	1500000049	8140000051	1030000051	0	157	60	3460000050	1200000047	1000000046	1032000052	1000000051	0
55	8260000041	8640000049	1300000048	1000000051	1000000051	0	157	61	5330000049	4200000047	3030000046	8620000051	1000000051	0
			4760000051	1500000050	1500000050	0	157	62	5780000048	3700000047				

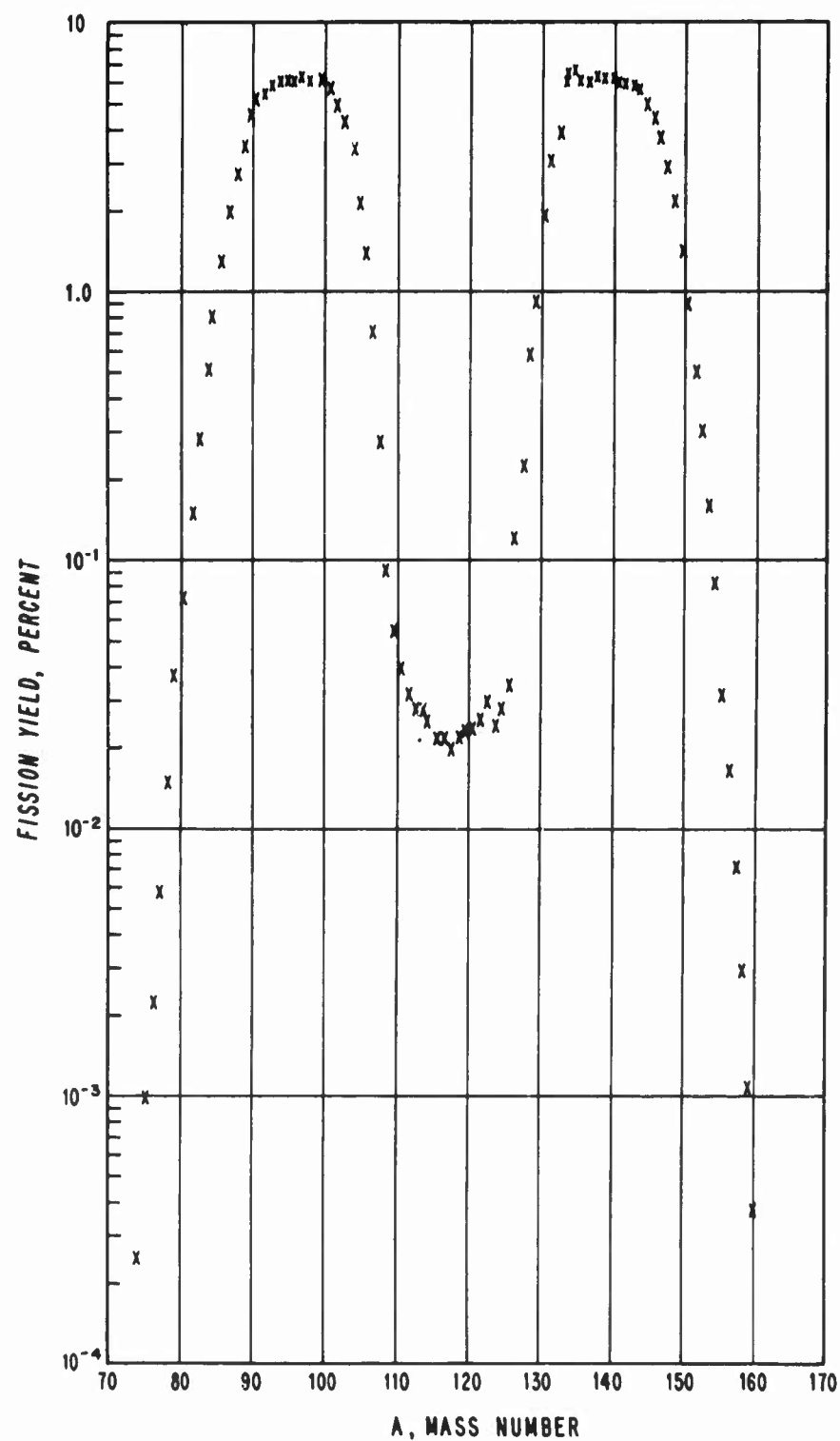
MASS YIELD FROM 14 MEV NEUTRON FISSION OF U^{238}



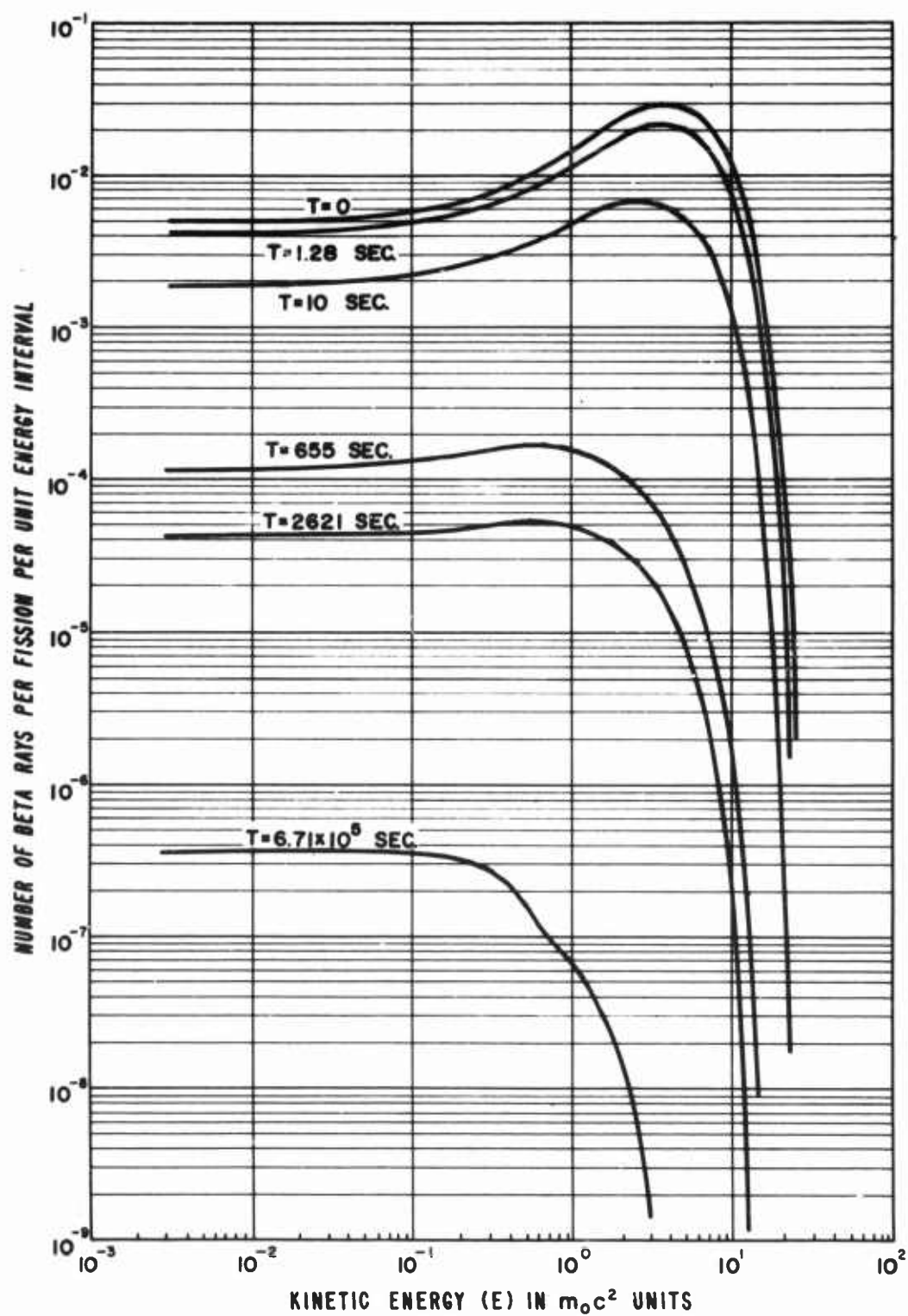
6-28-60-1

FIGURE 1
WSEG RM 19

MASS YIELD FROM FISSION SPECTRUM NEUTRON FISSION OF U^{235}



THE BETA RAYS FROM U^{235} FISSION BY FISSION SPECTRUM NEUTRONS



THE BETA RAYS FROM 14 MEV NEUTRON FISSION OF U^{238}

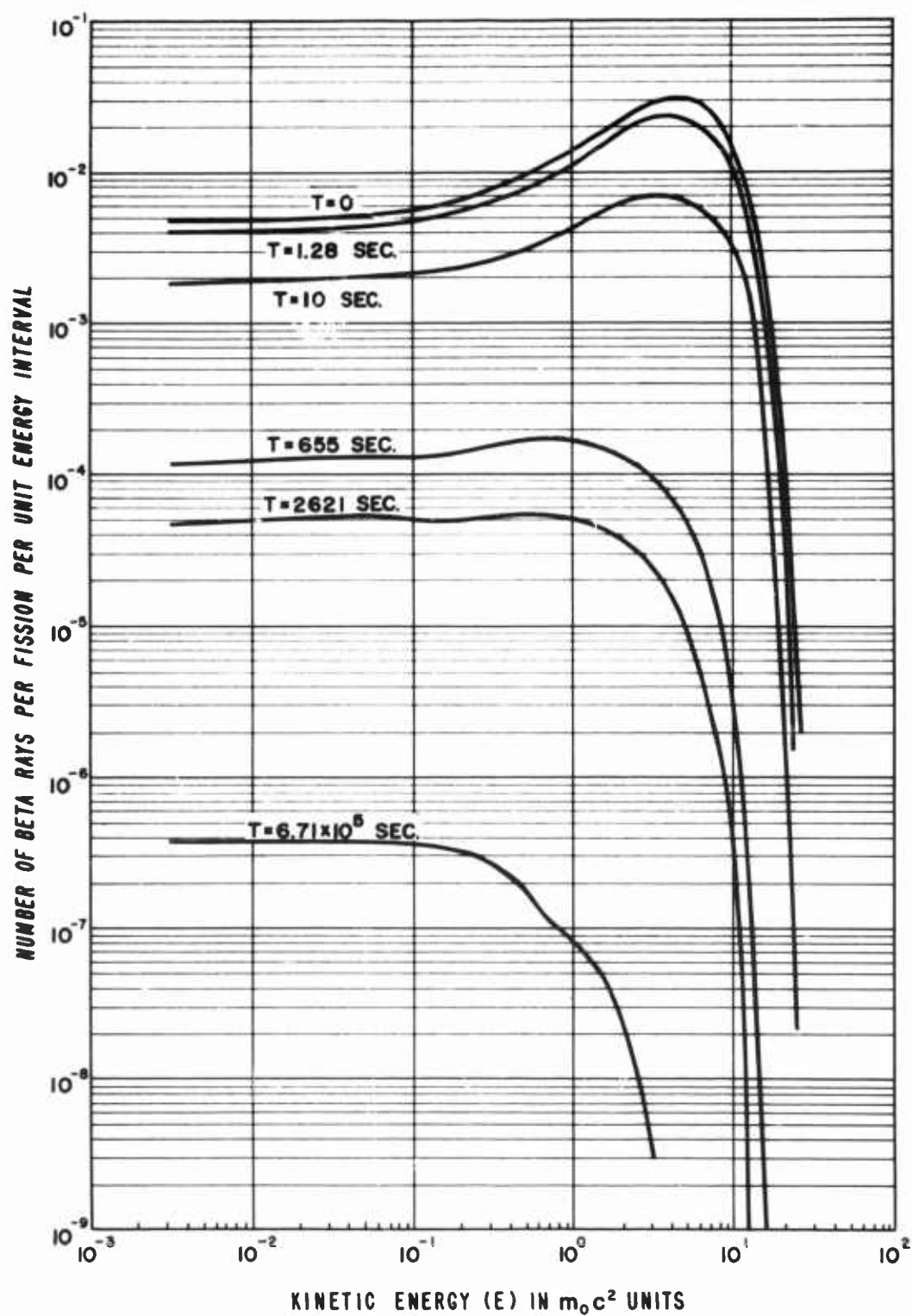
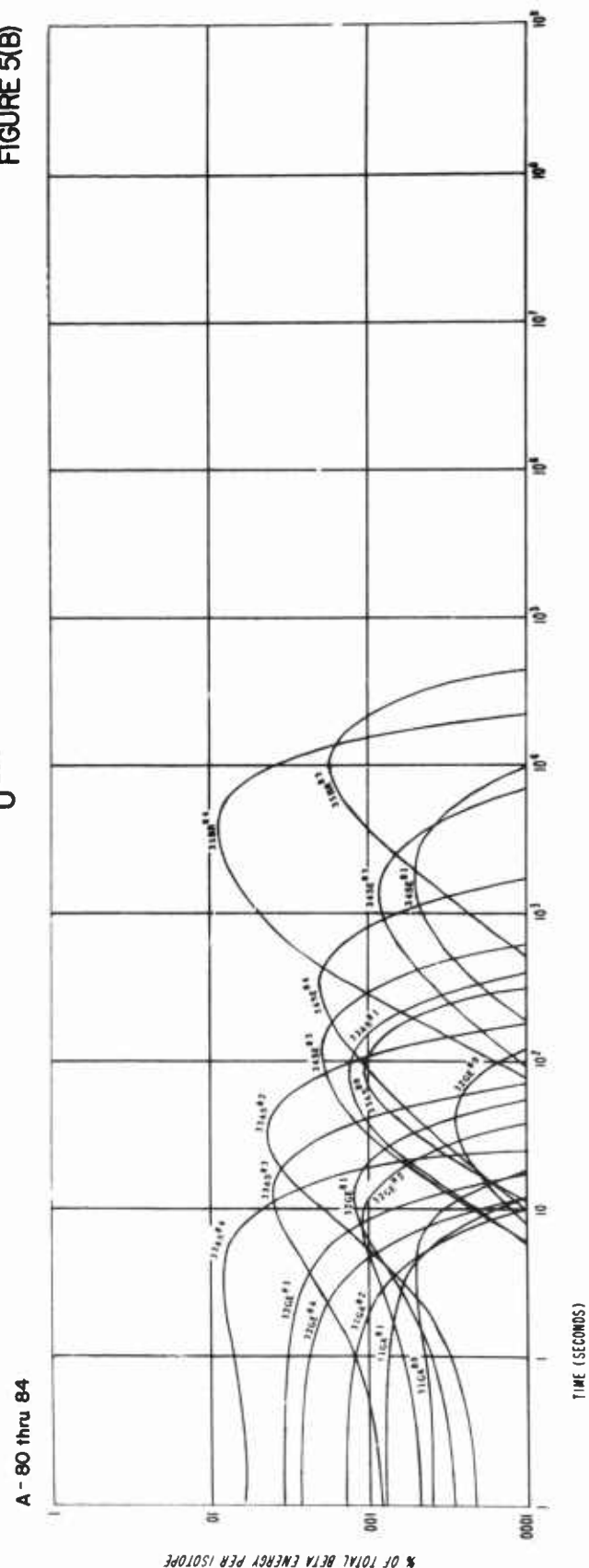
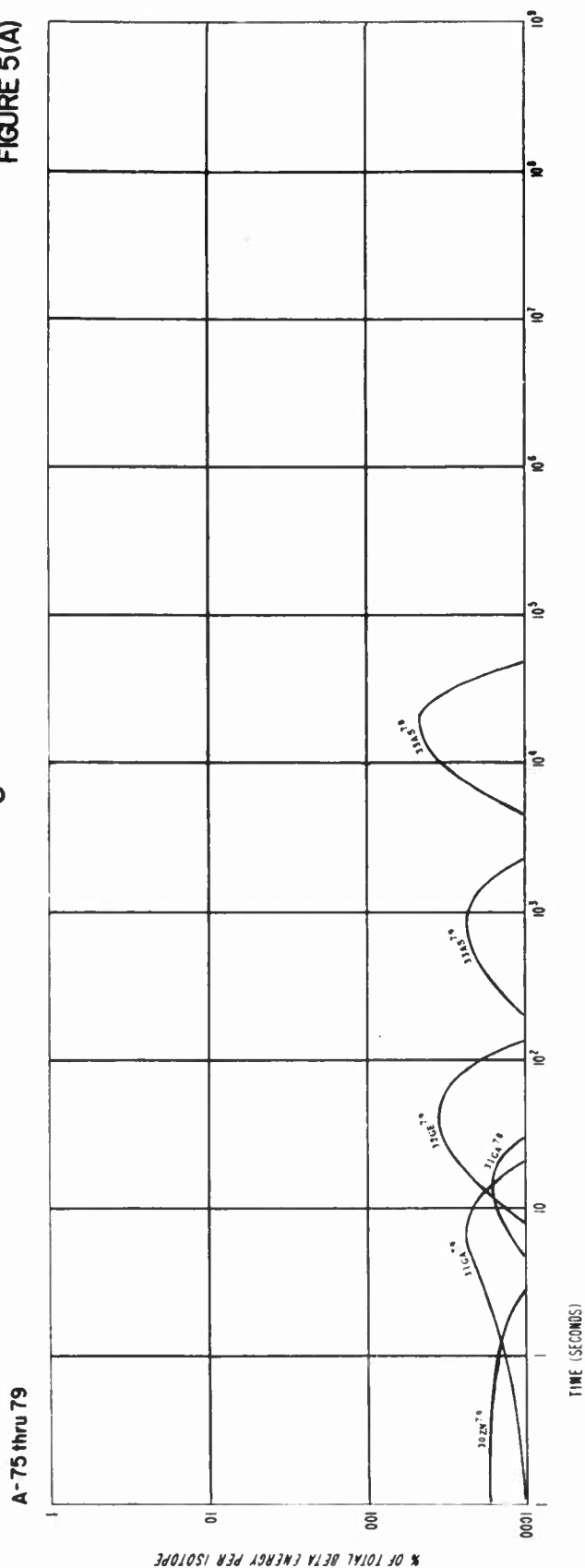
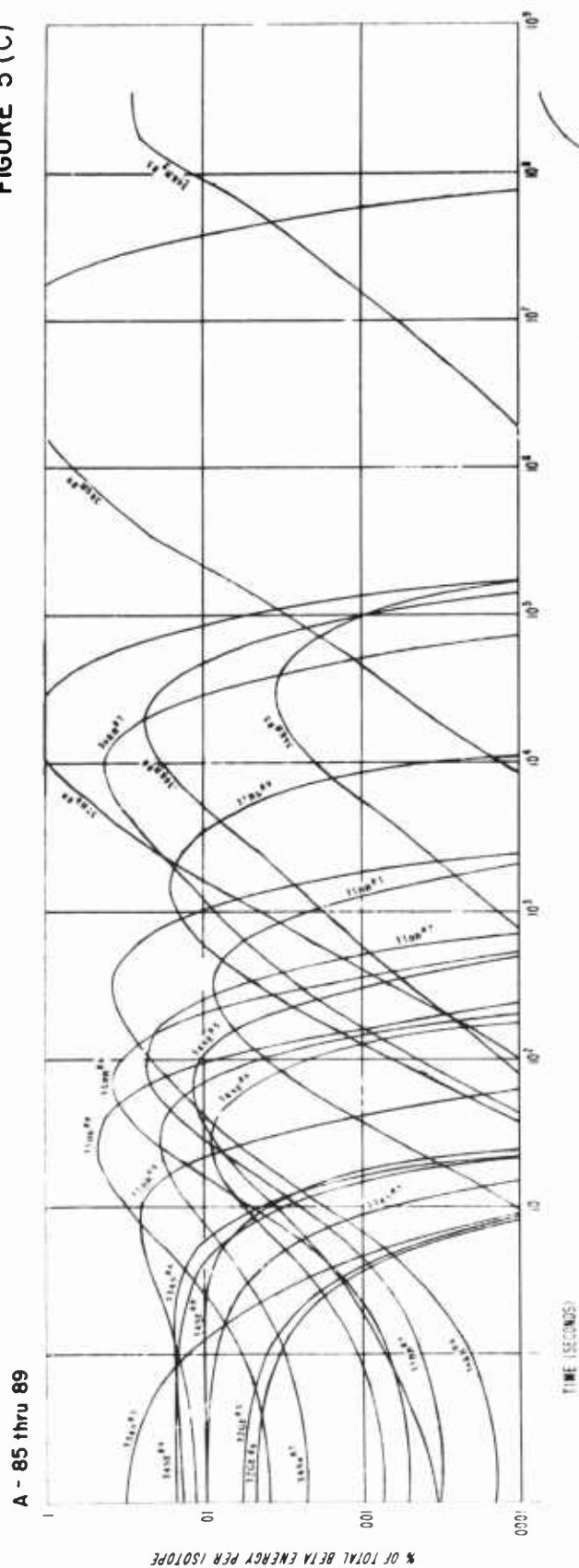


FIGURE 5(A)



U 235

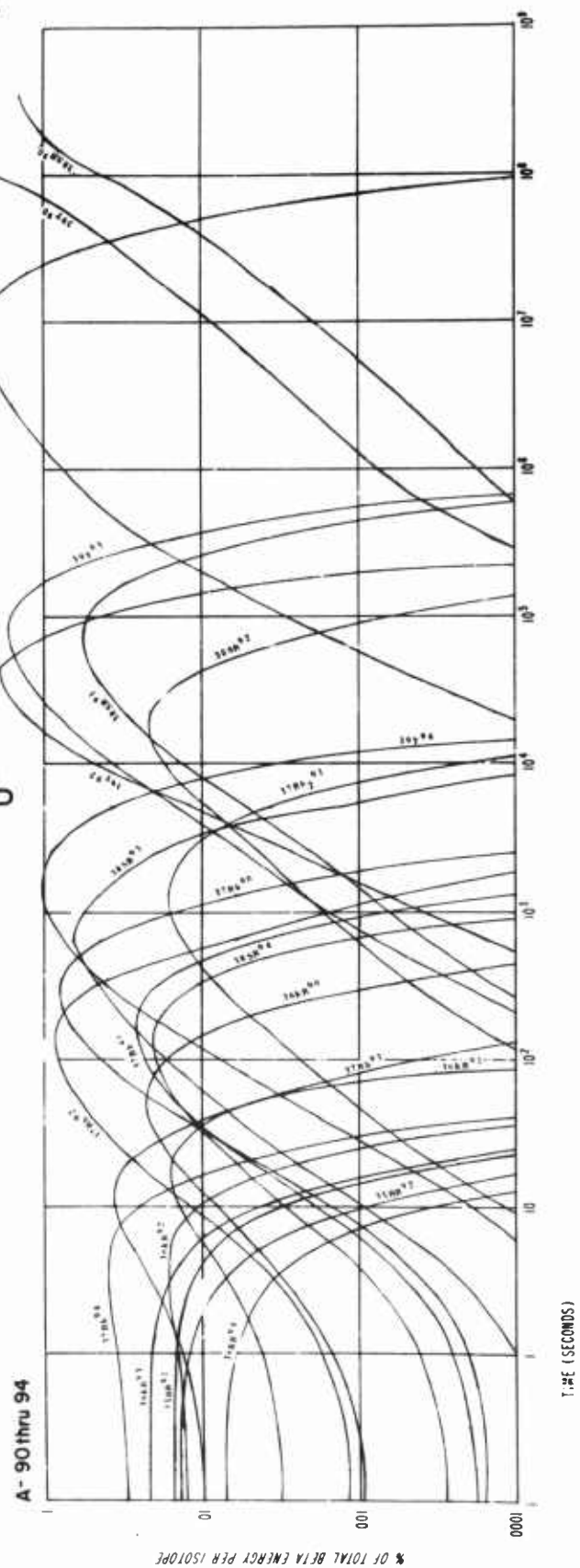
FIGURE 5 (C)



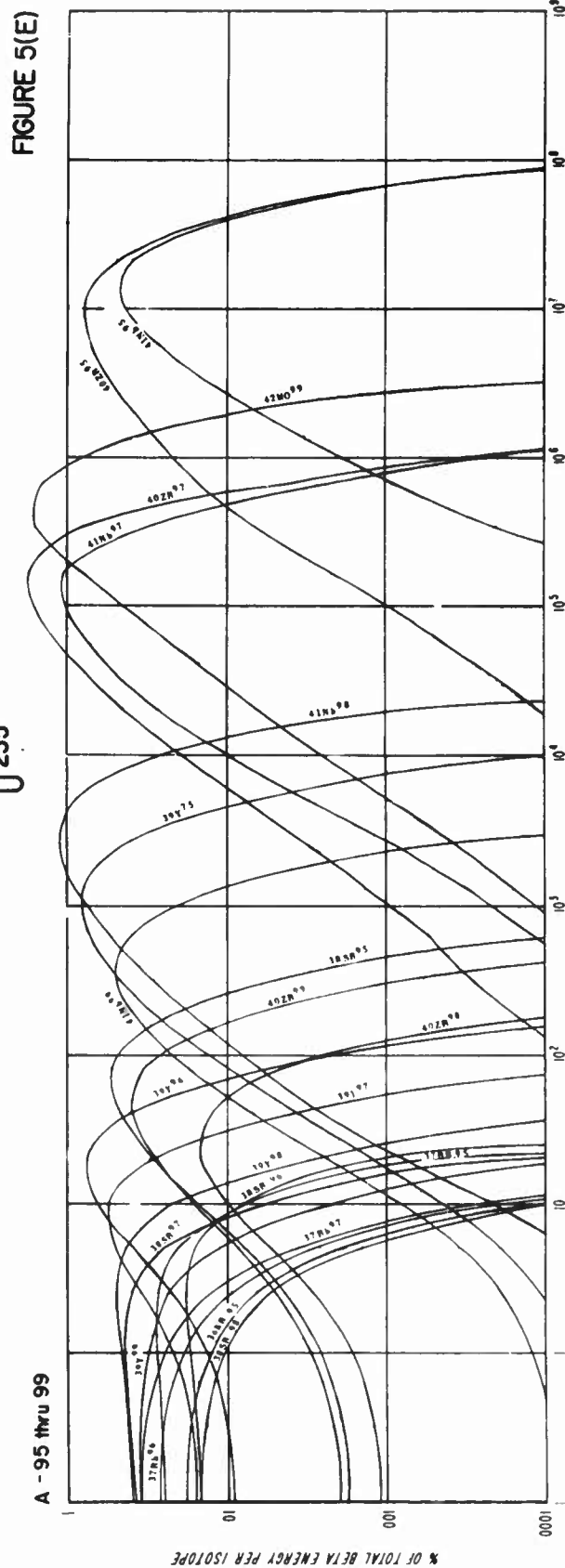
8-22-60-2

 ${}^{235}\text{U}$

FIGURE 5 (D)

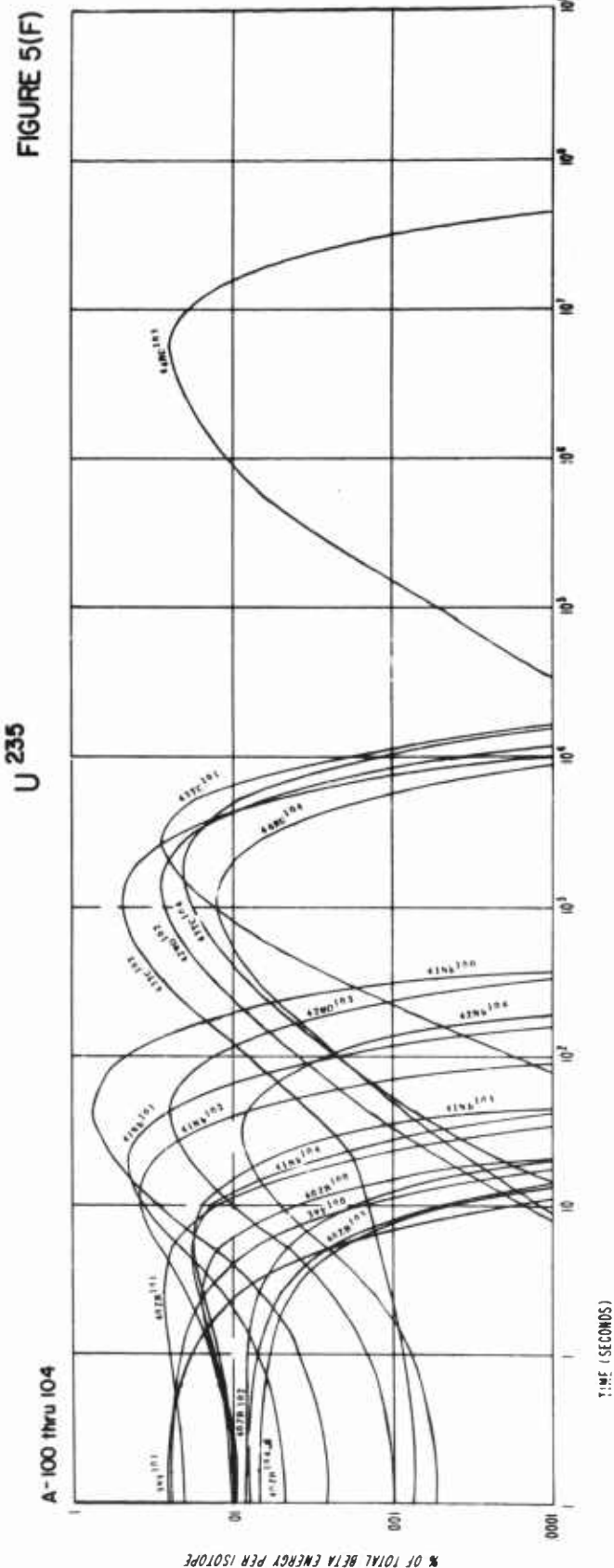


U 235

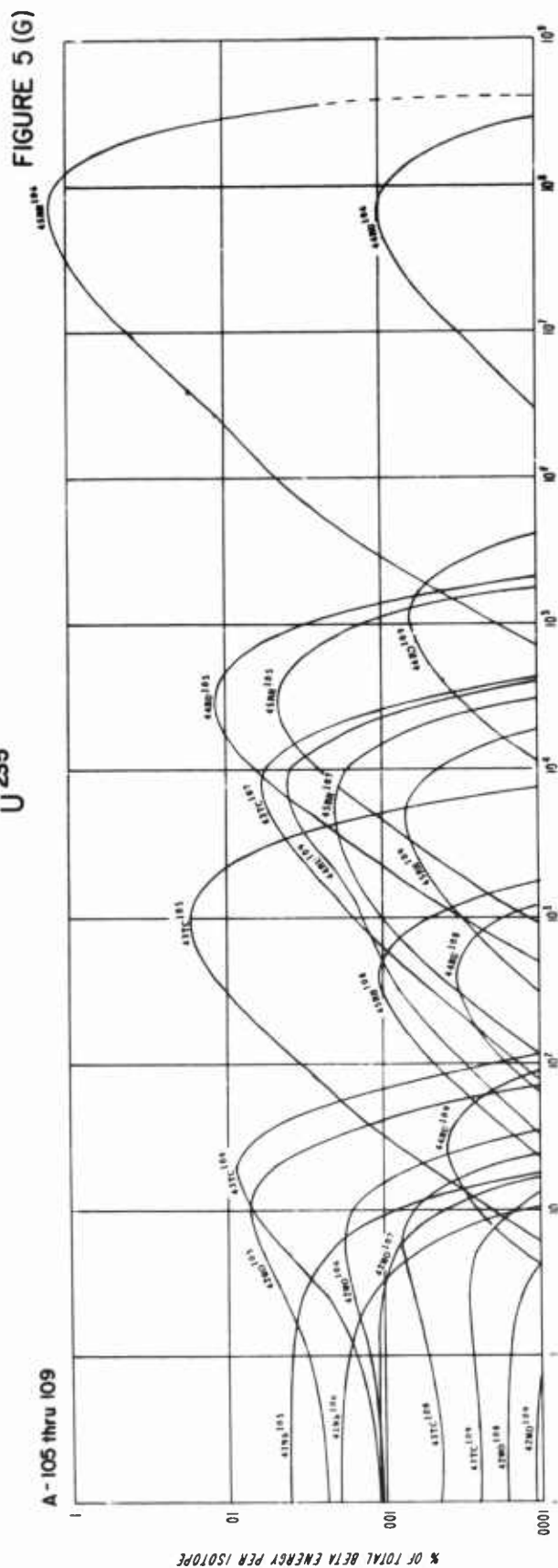


8-22-60-3

U 235

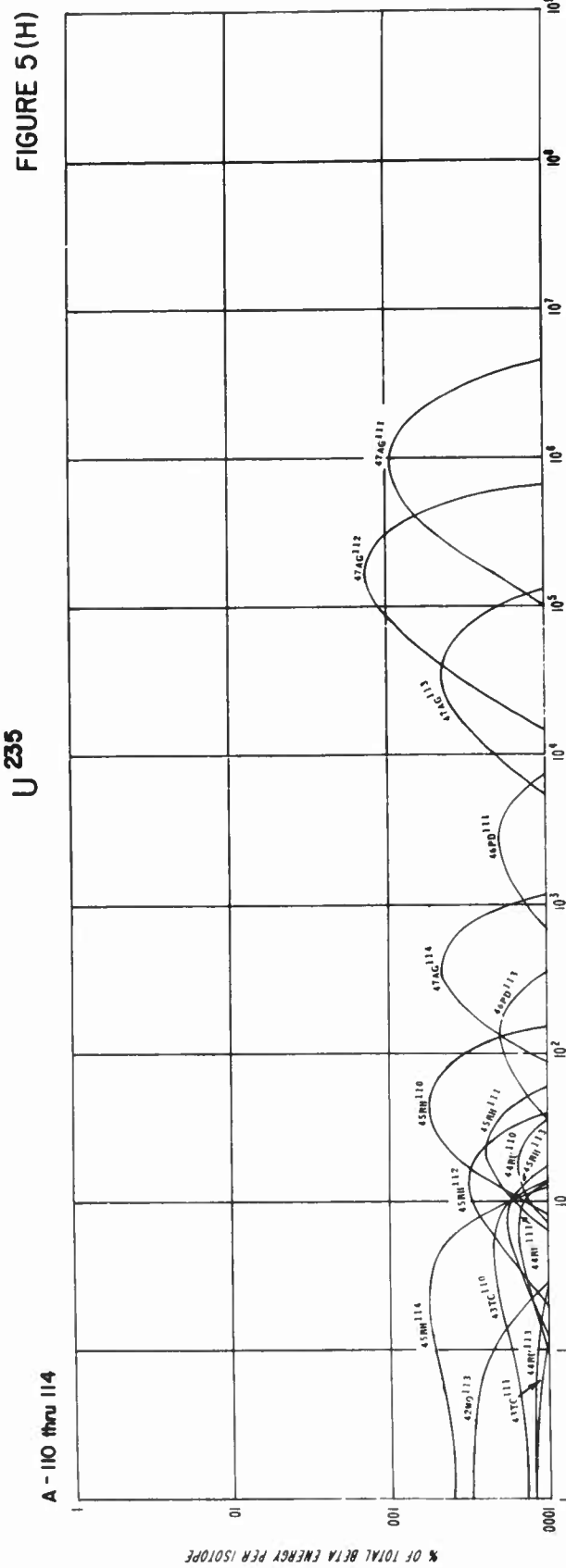


U 235



8-22-60-4

U 235

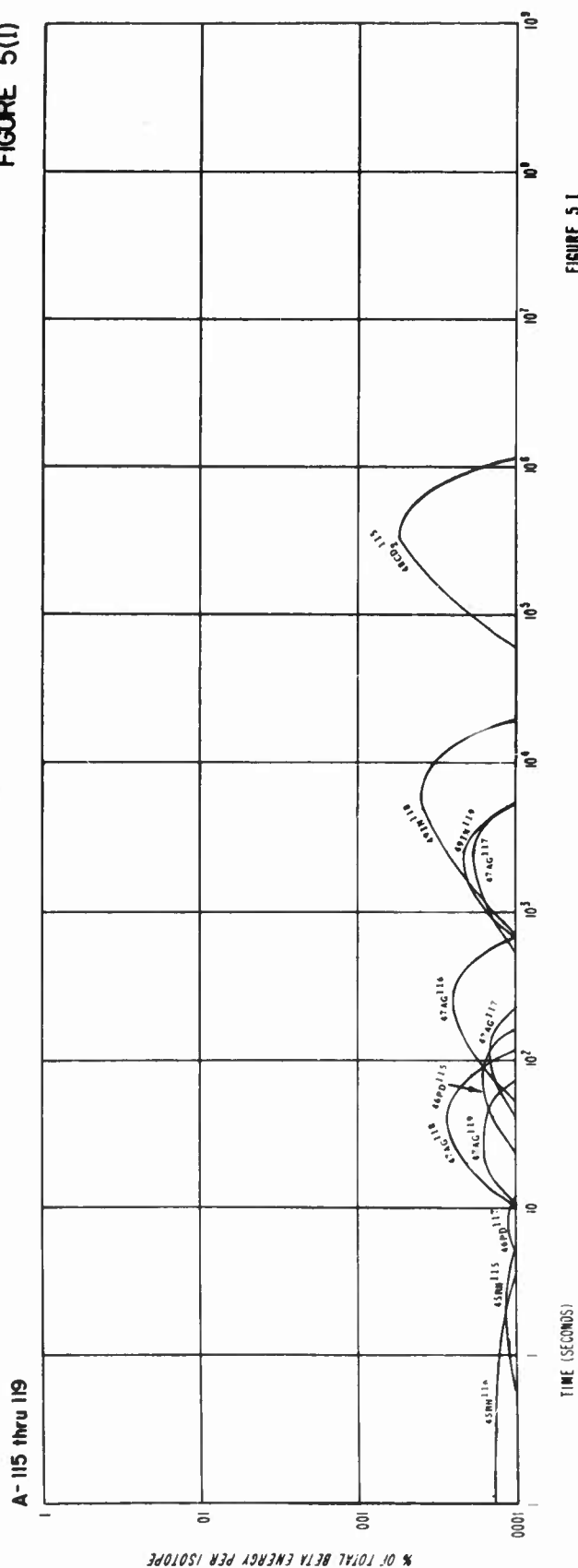


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FIGURES 5(G) & 5(H)
WSEG RM 19

U 235

FIGURE 5(I)

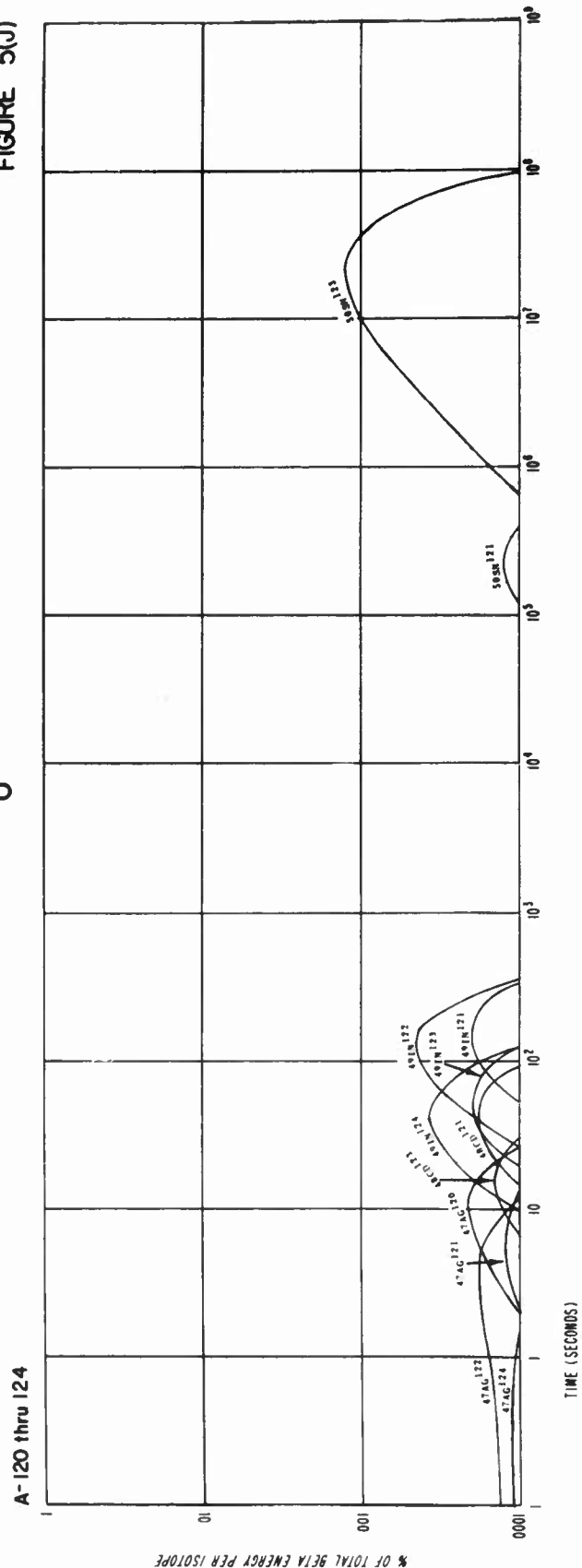


TIME (SECONDS)

FIGURE 5 I

U 235

FIGURE 5(J)



TIME (SECONDS)

U 235

FIGURE 5(K)

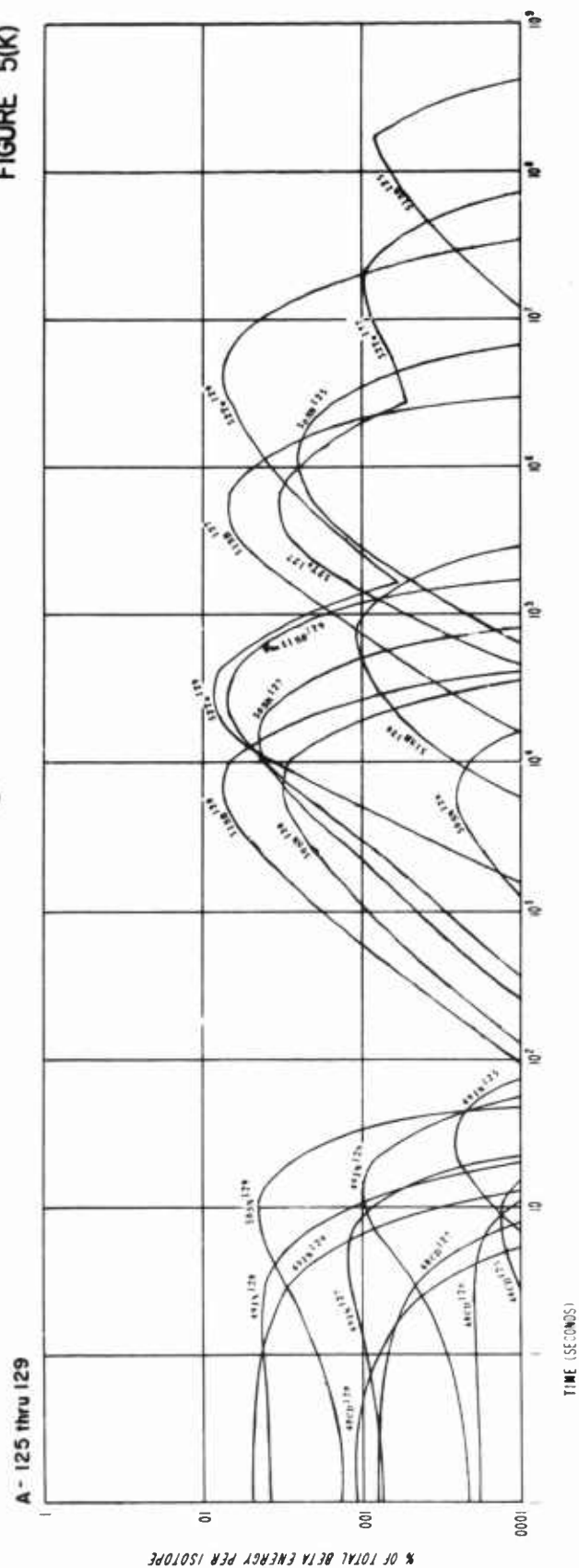
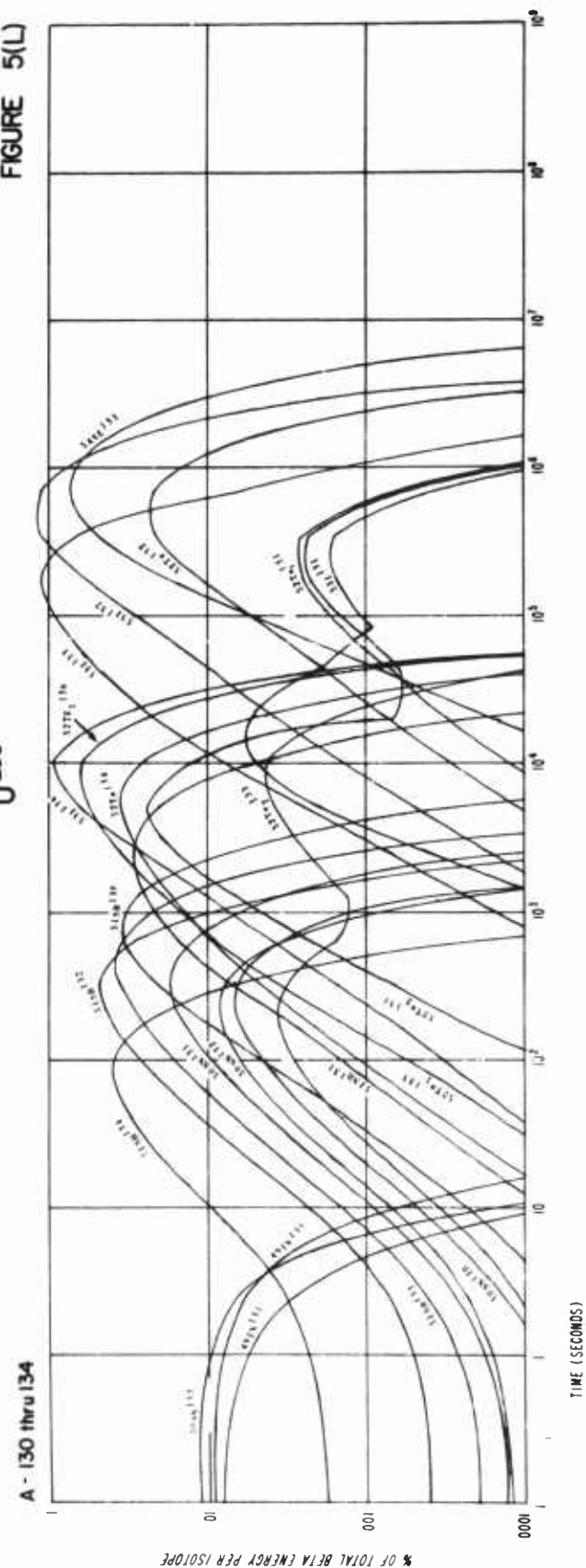
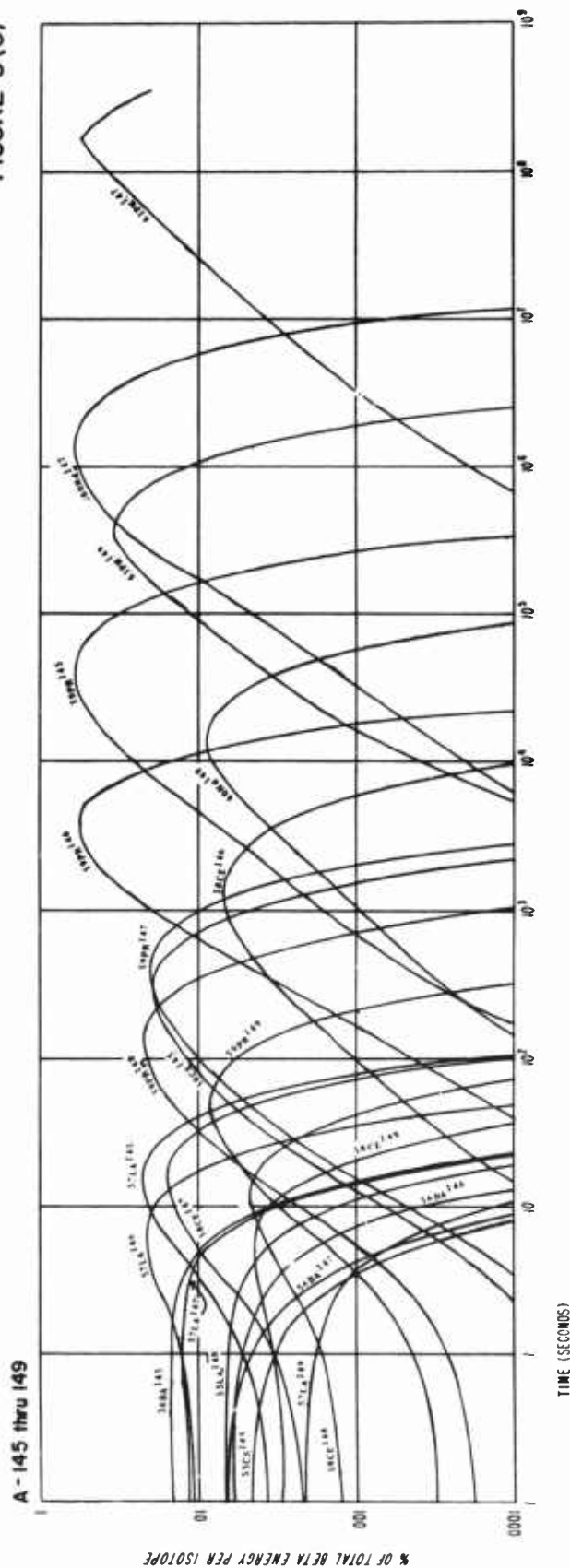
U²³⁵

FIGURE 5(L)



U 235

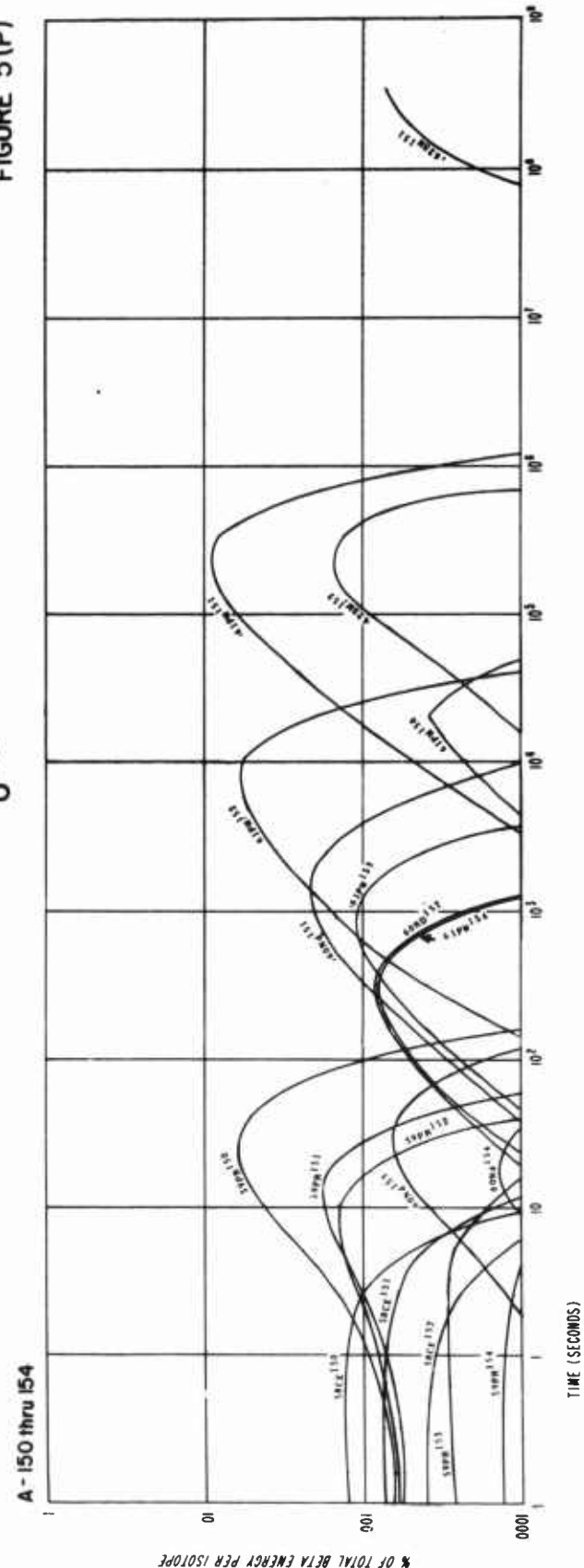
FIGURE 5(O)



8-22-60-8

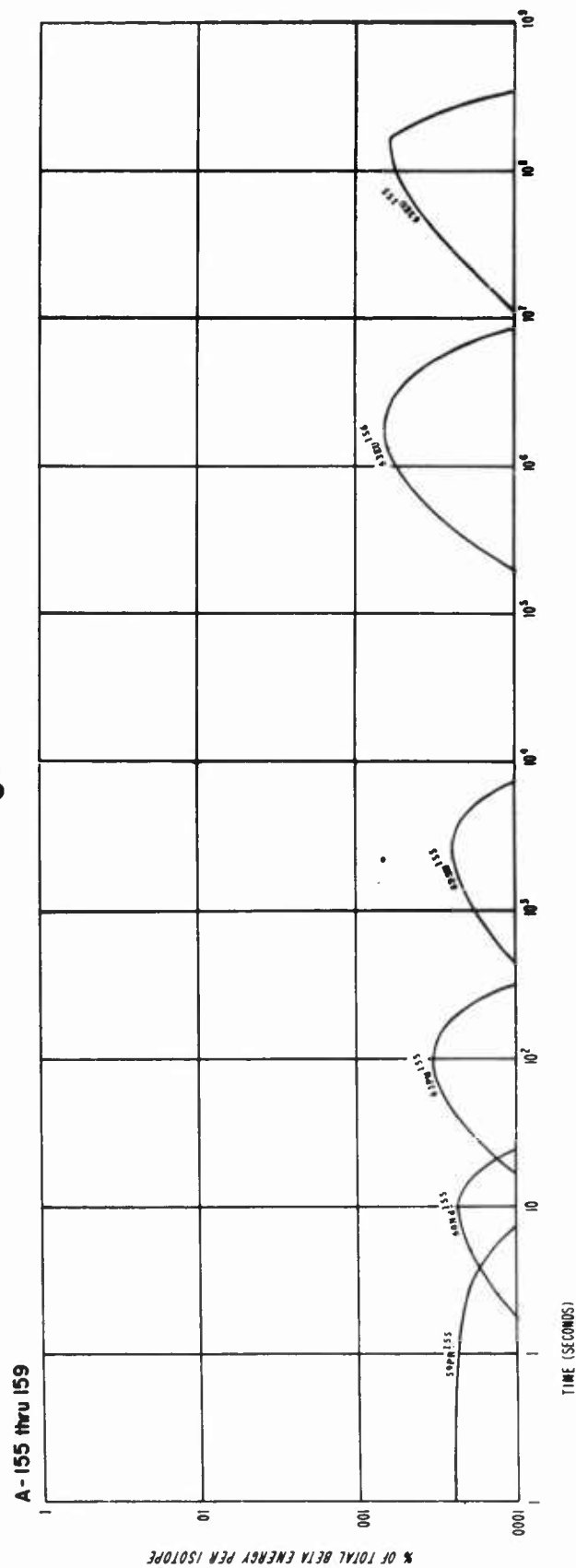
U 236

FIGURE 5(P)



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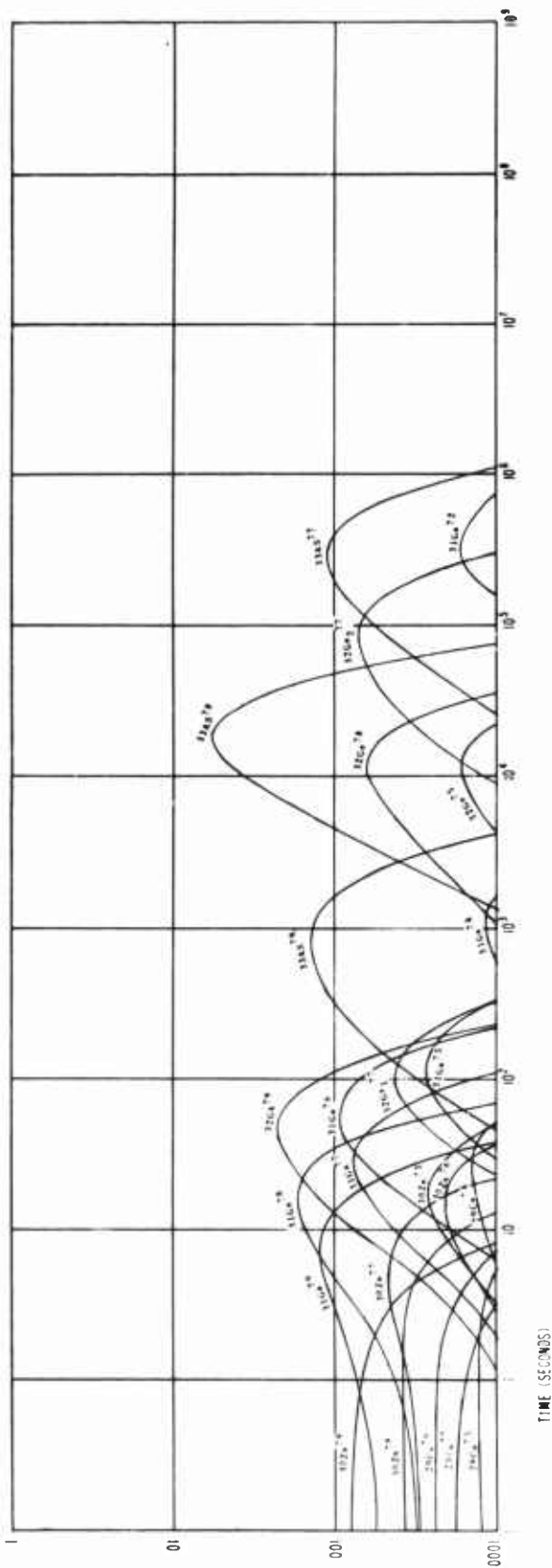
FIGURES 5(O) & (P)
WSEG RM 19

U²³⁵

U²³⁸

FIGURE 6(A)

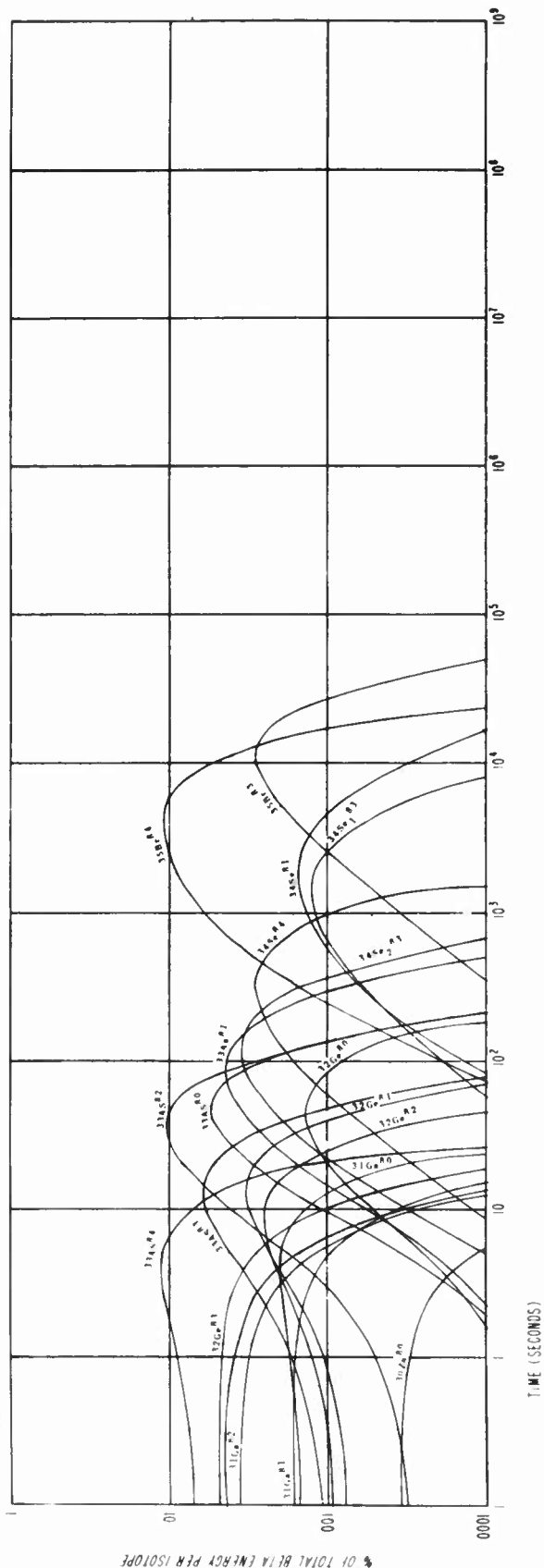
A - 72 thru 79



U²³⁸

FIGURE 6(B)

A - 80 thru 84

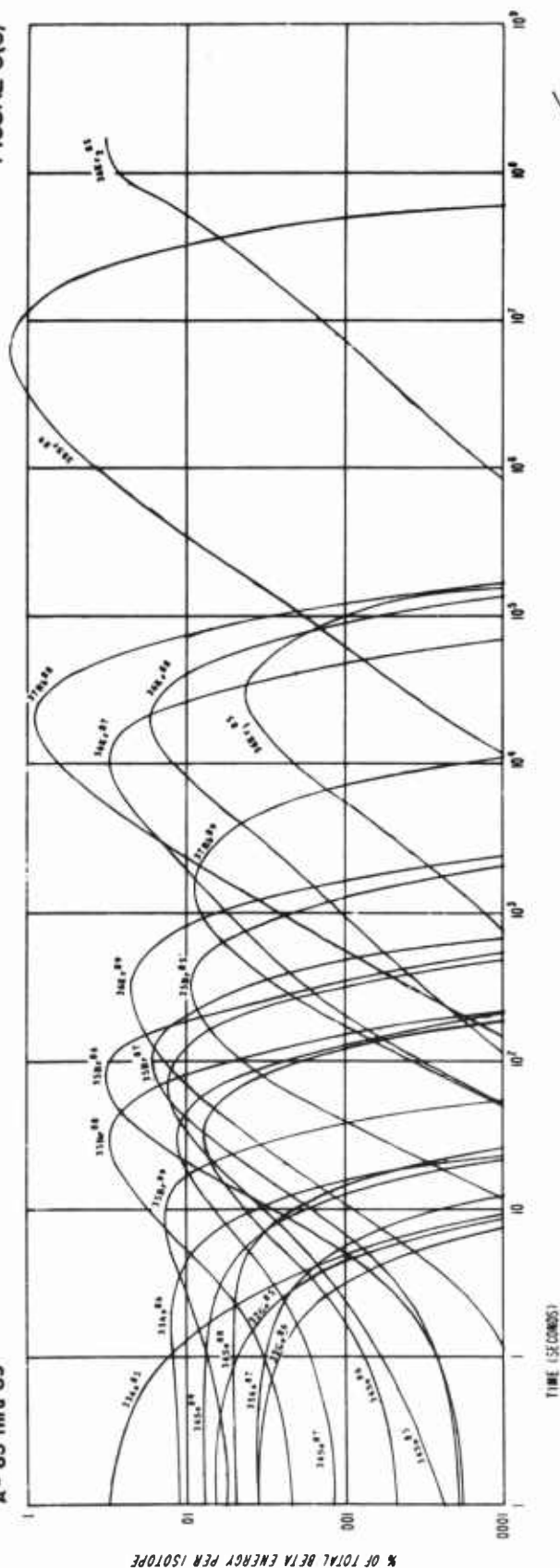


8-22-60-10

U 238

A - 85 thru 89

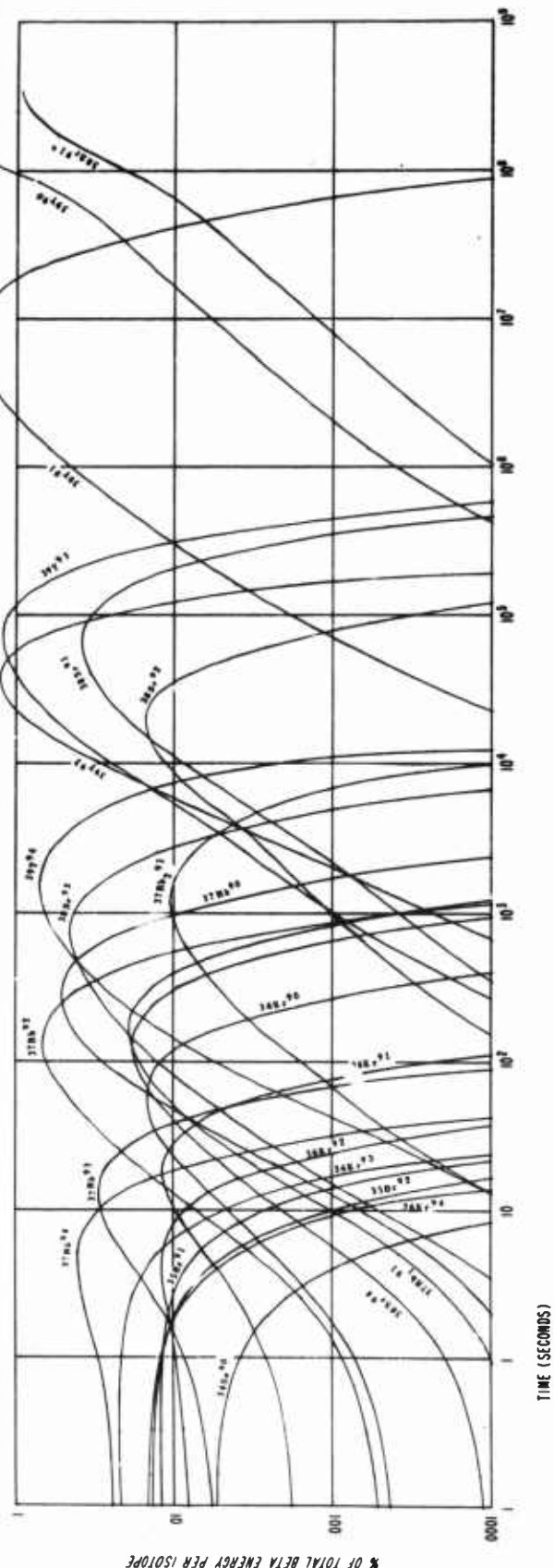
FIGURE 6(C)

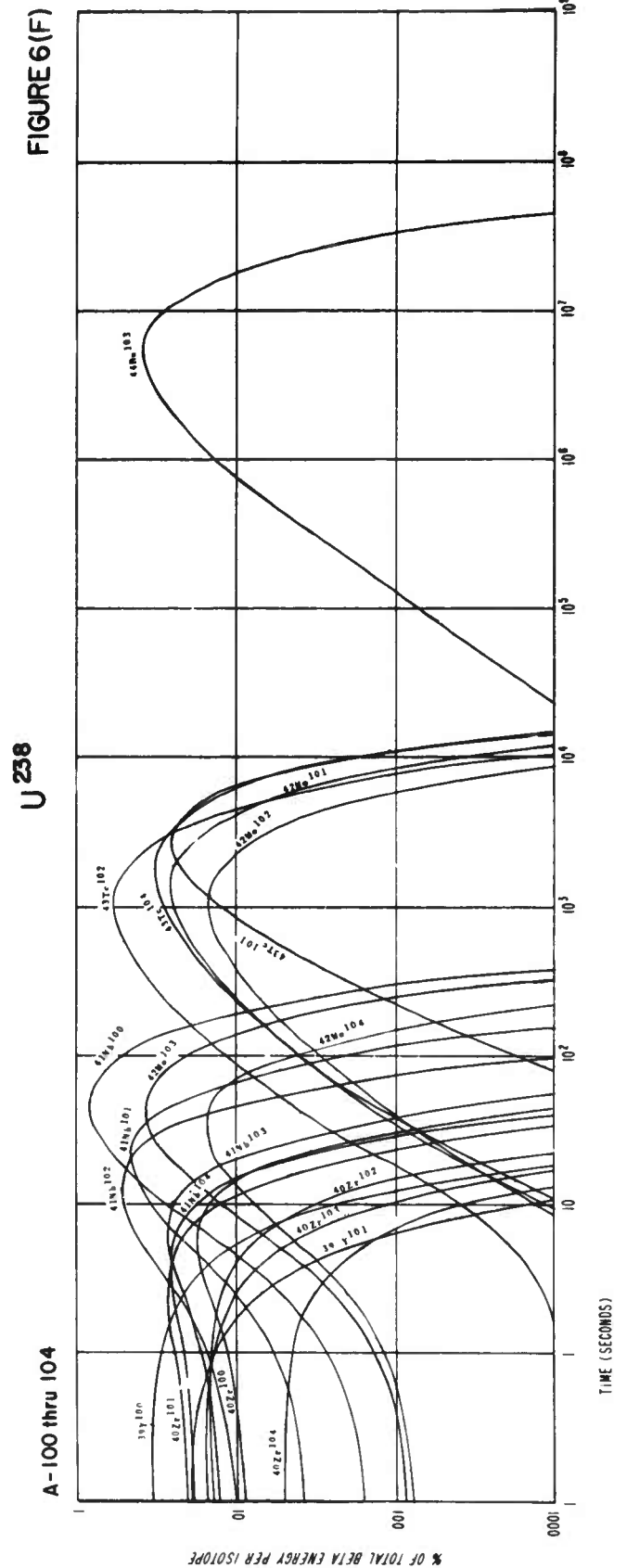
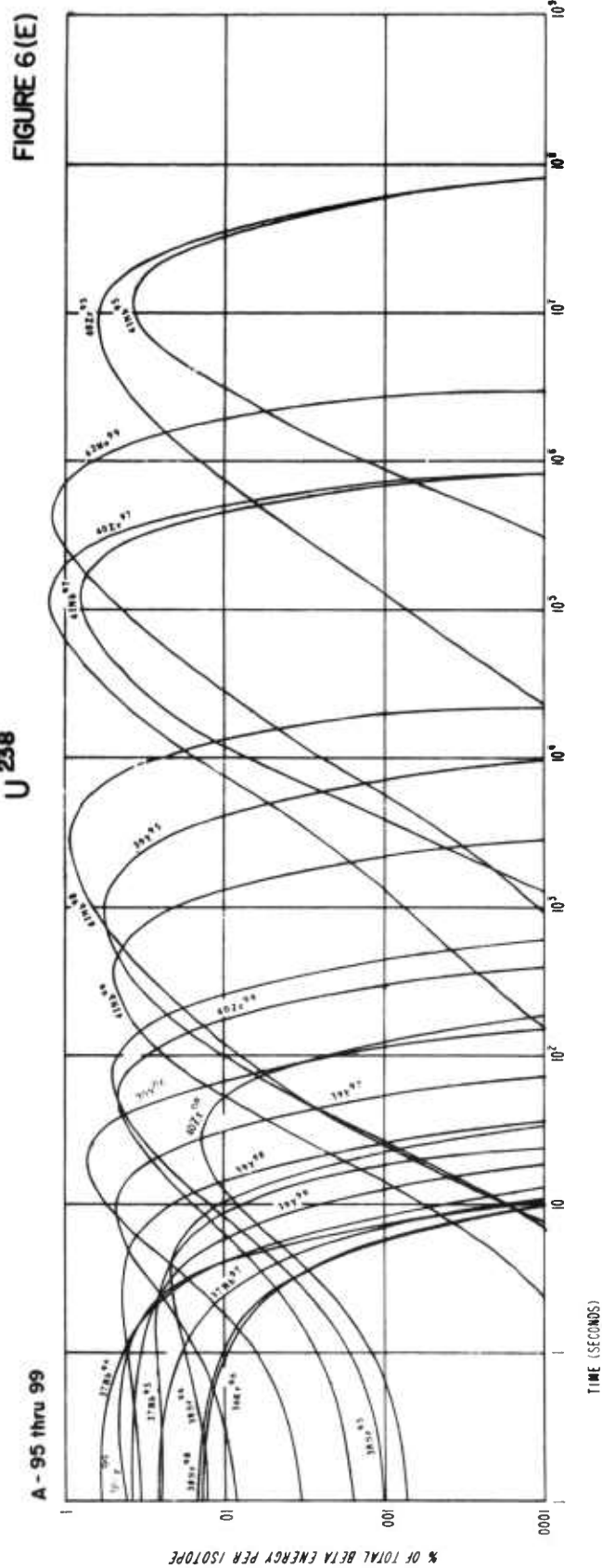


U 238

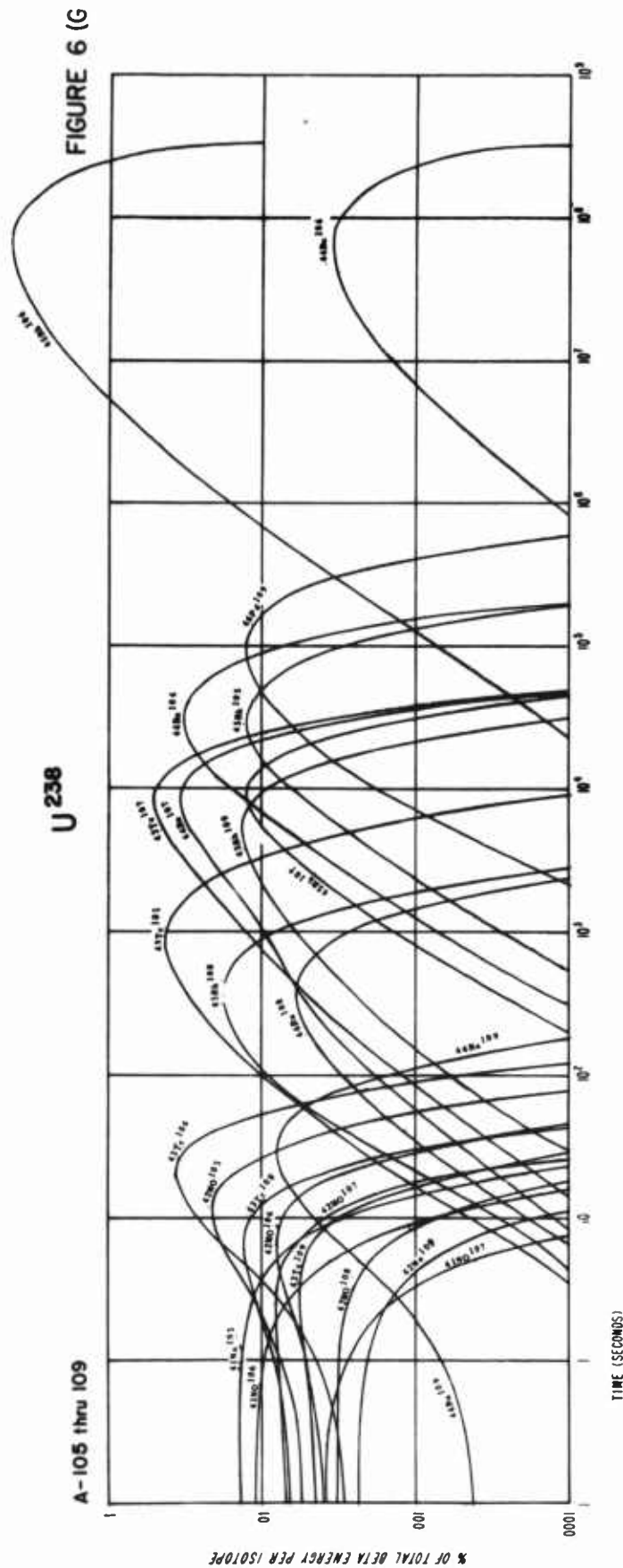
A - 90 thru 94

FIGURE 6(D)

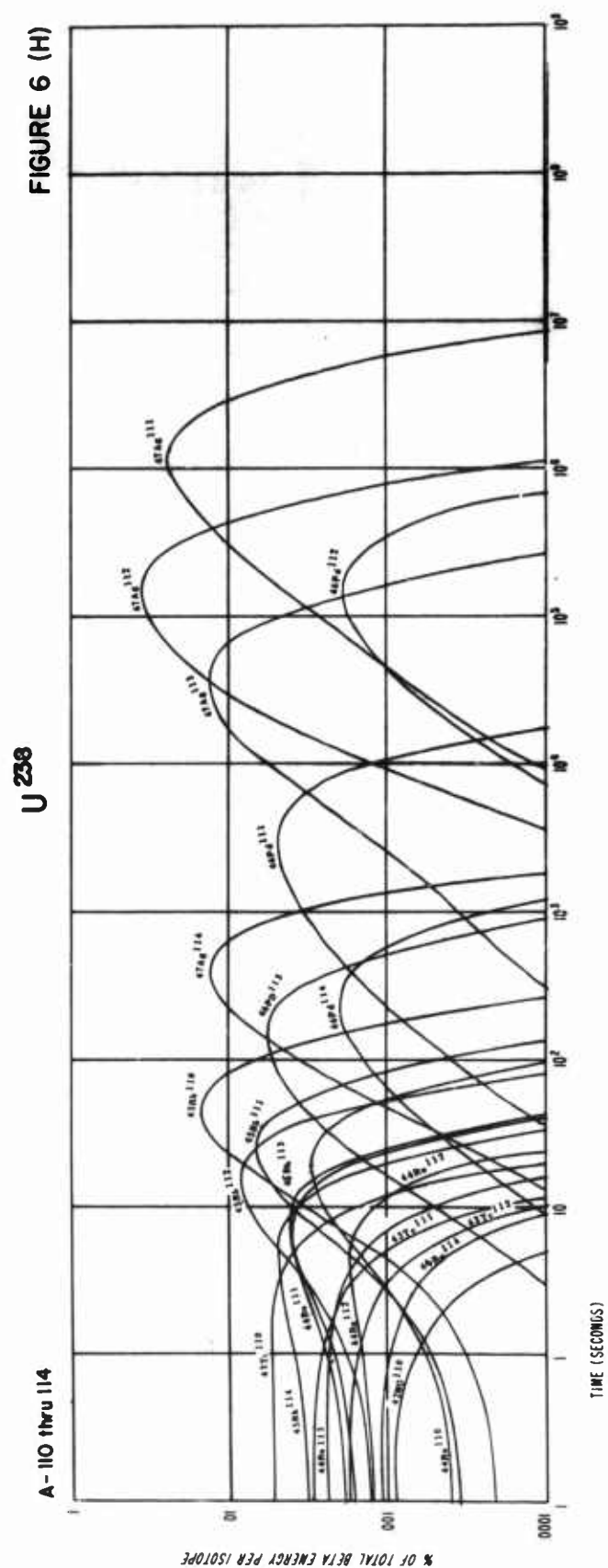




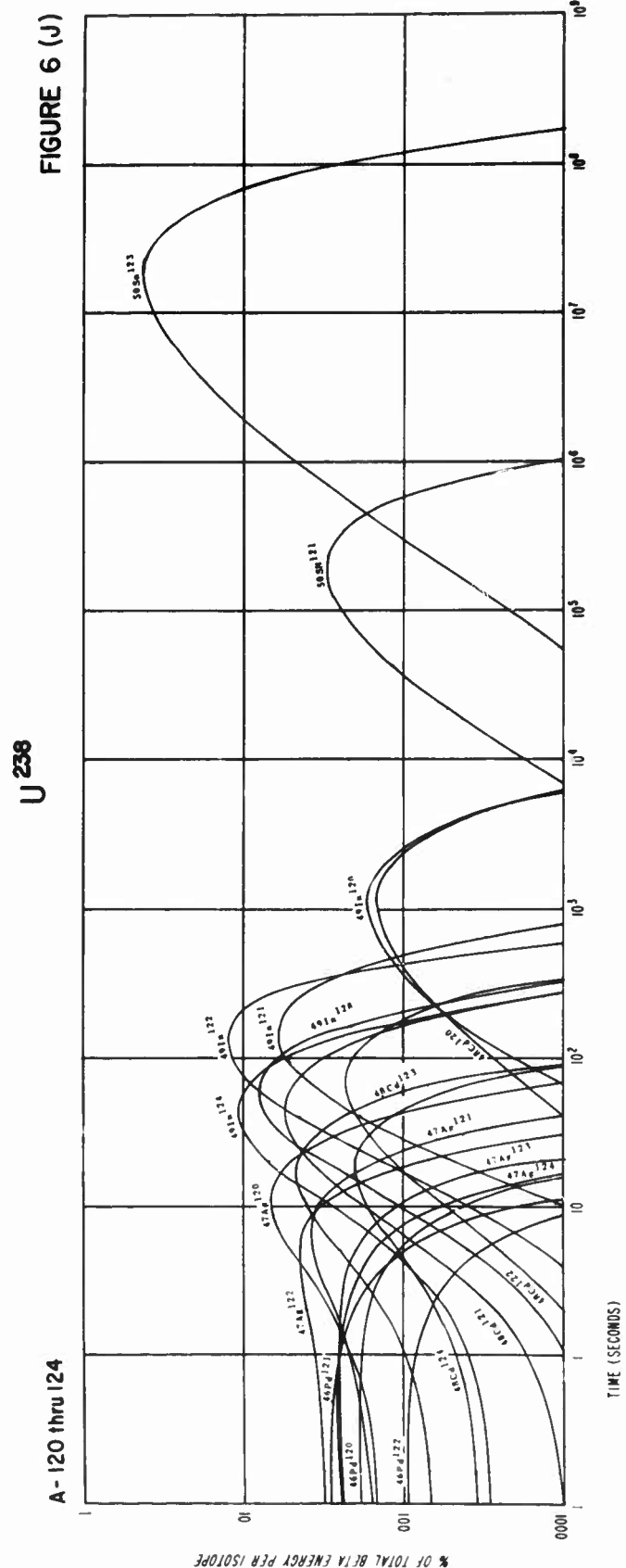
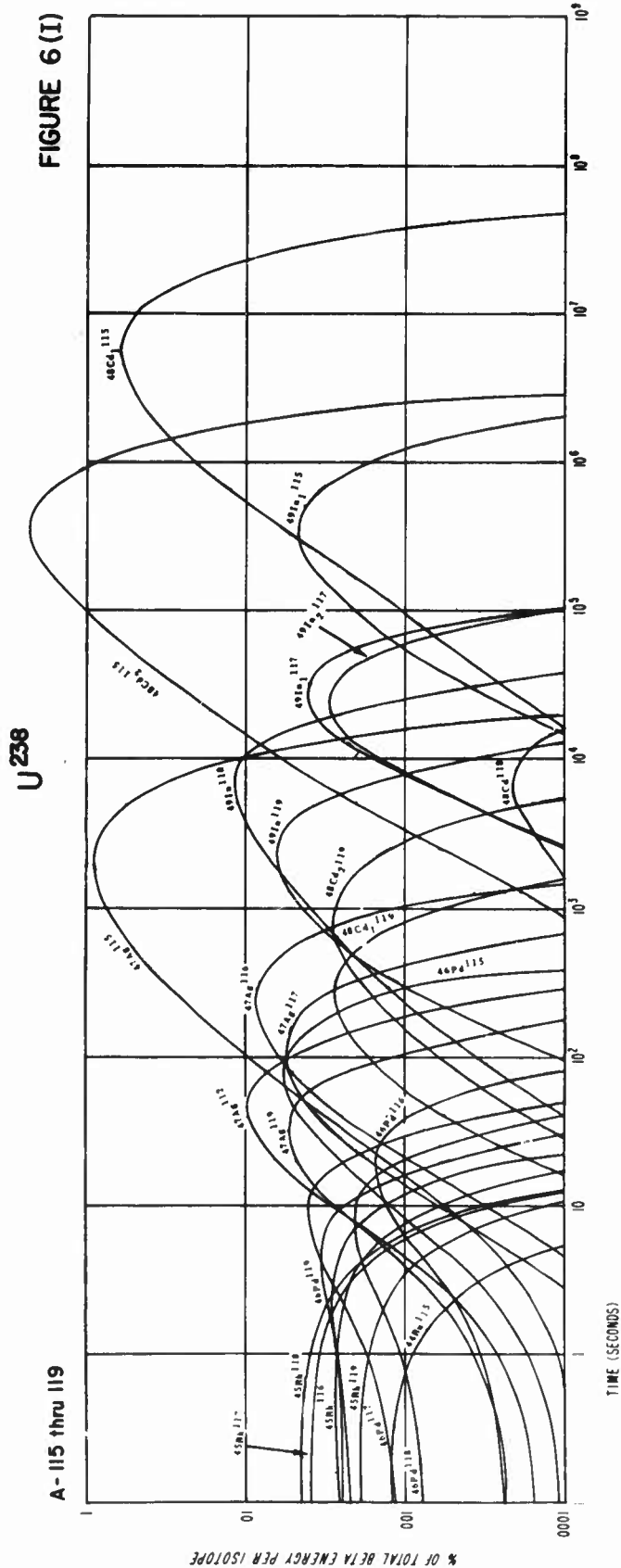
8-22-60-13



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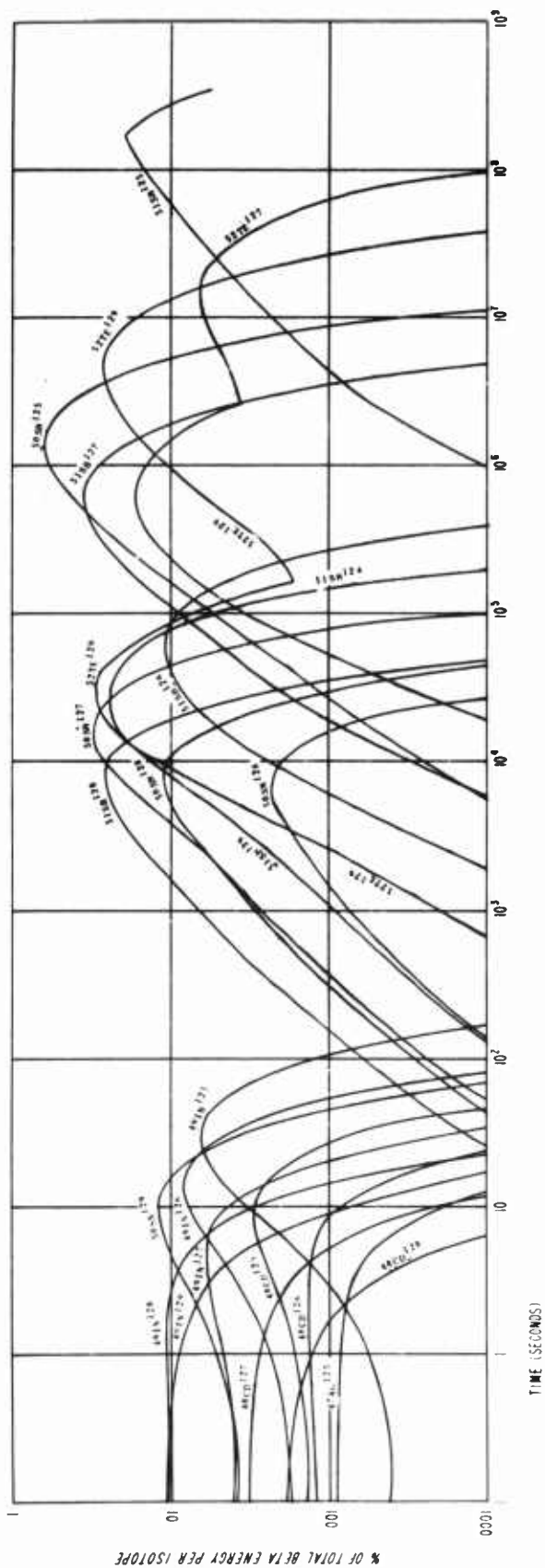
FIGURES 6 (G) & 6 (H)
WSEG RM 19



A - 125 thru 129

U²³⁸

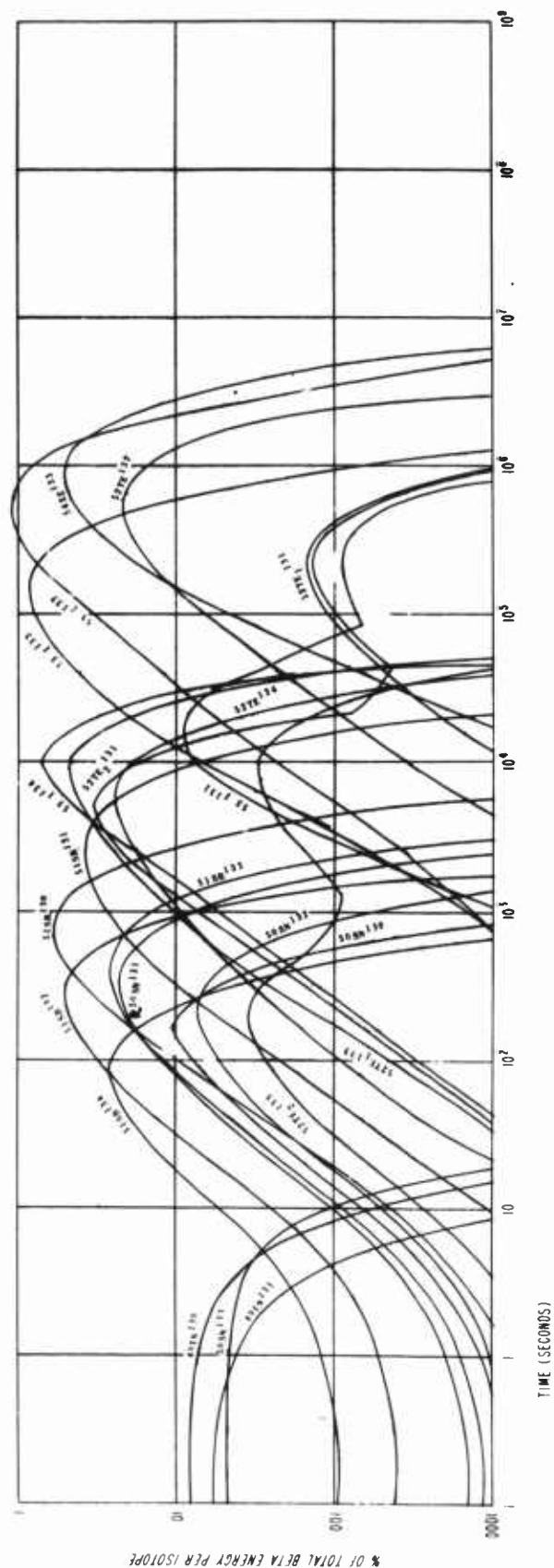
FIGURE 6 (K)

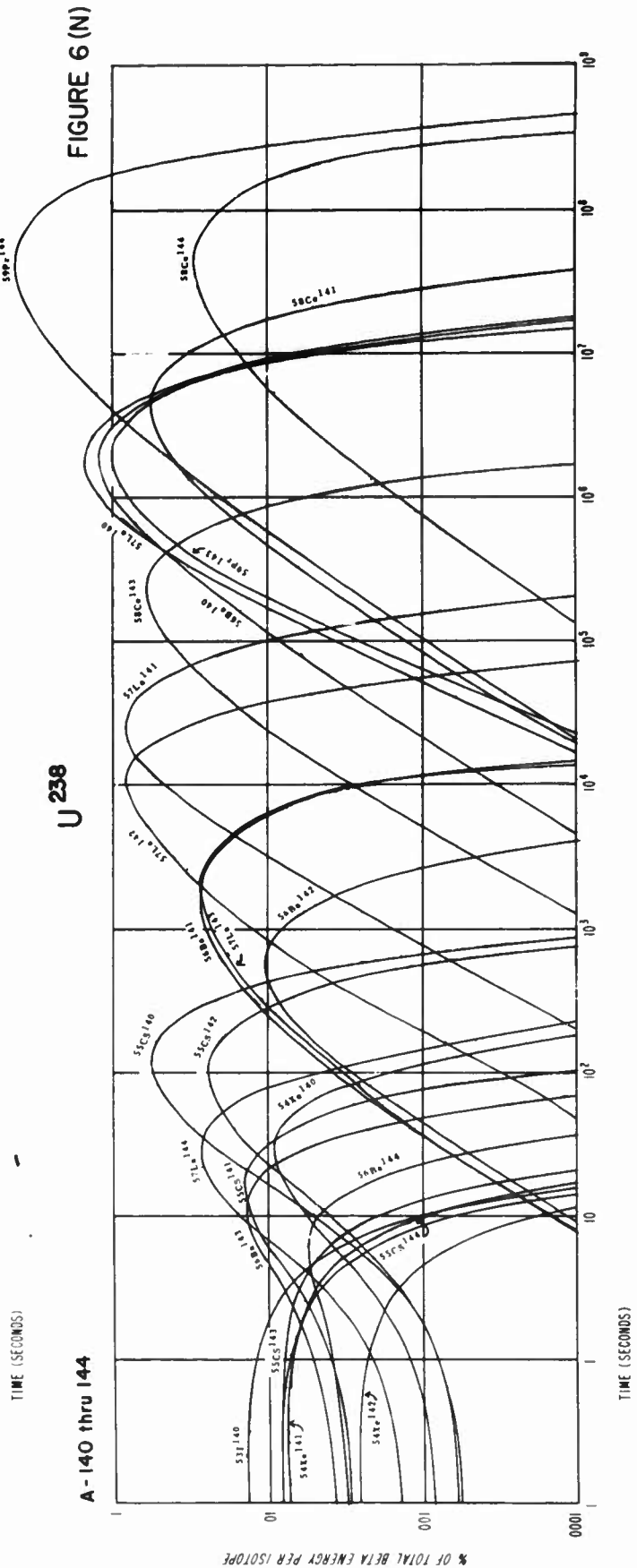
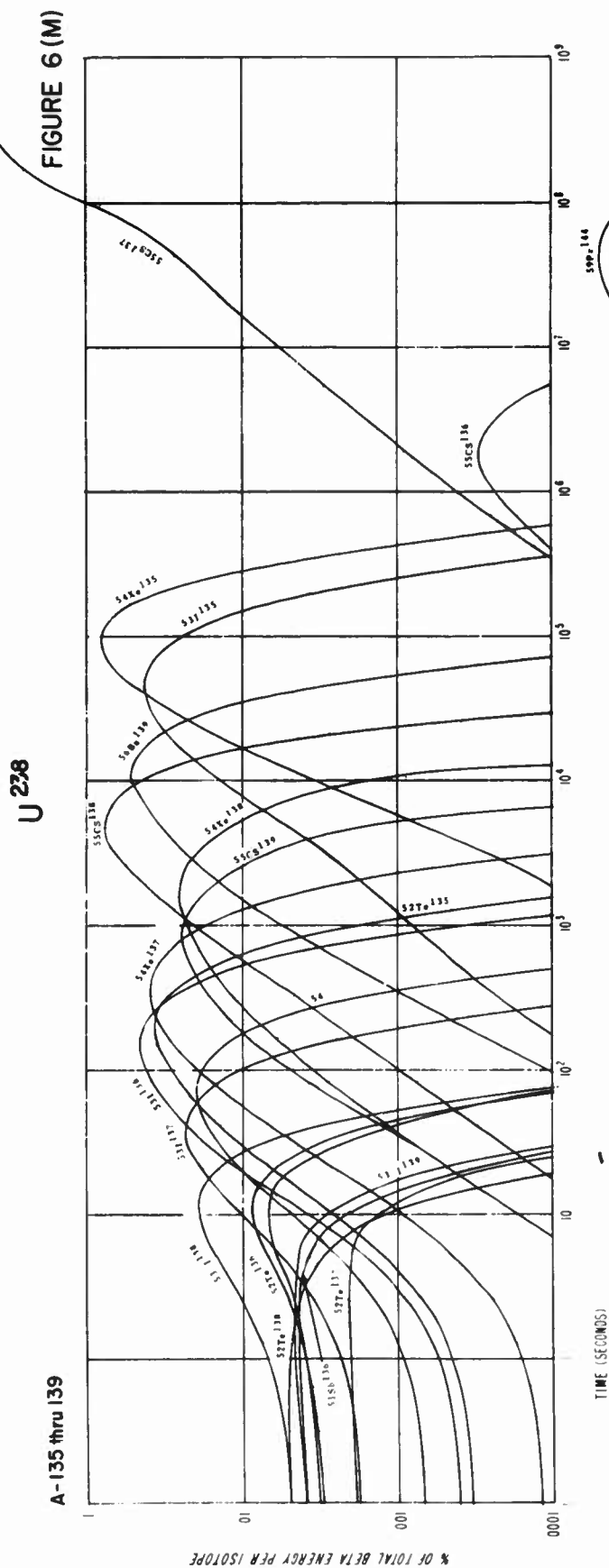


A - 130 thru 134

U²³⁸

FIGURE 6 (L)





U
238

FIGURE 6(0)

U
238

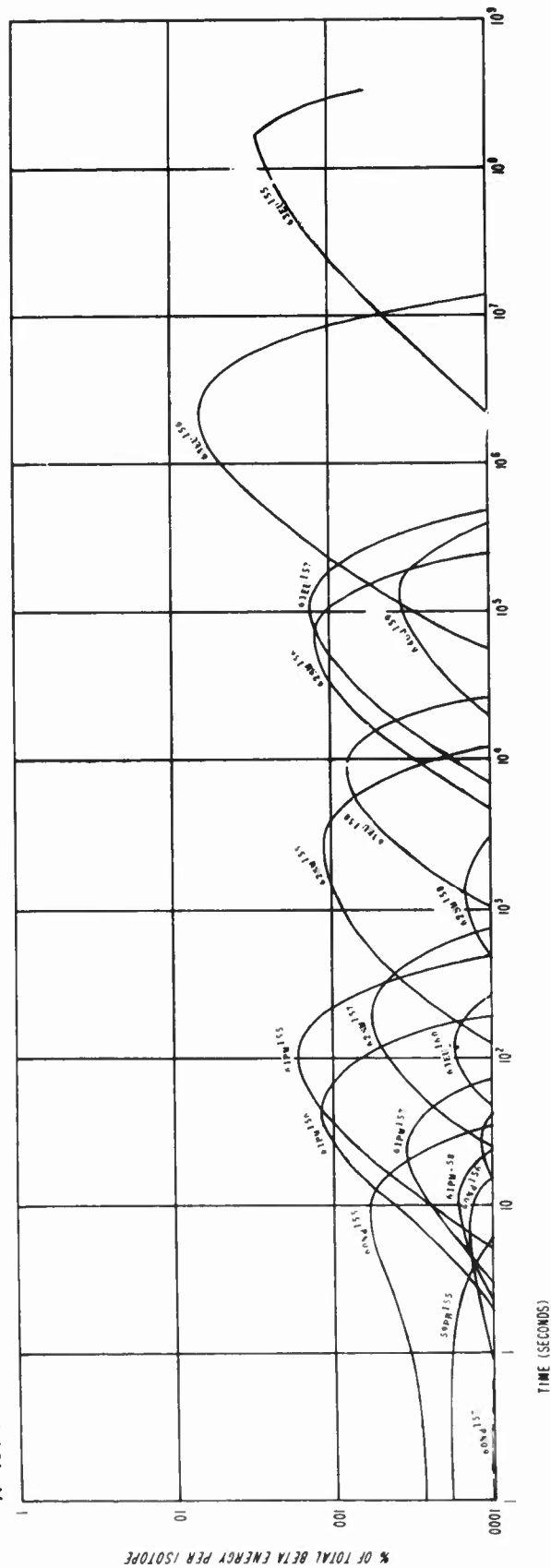
FIGURE 6 (P)



FIGURES 6 (O) & 6 (P)
WSEG RM 19

U^{238}

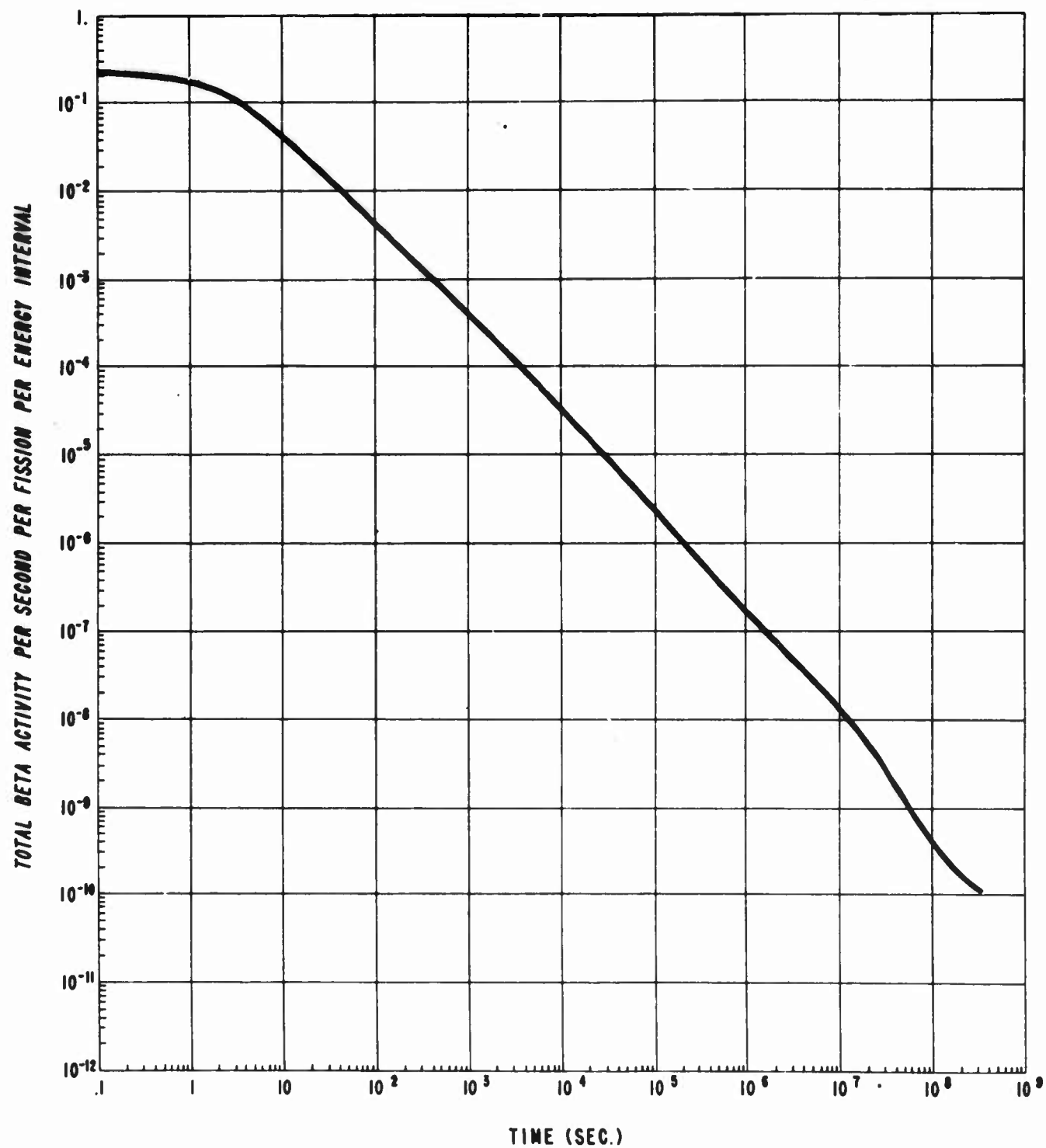
A - 155 thru 160



8-22-60-18

FIGURE 6 (Q)
WSEG RM 19

U²³⁵

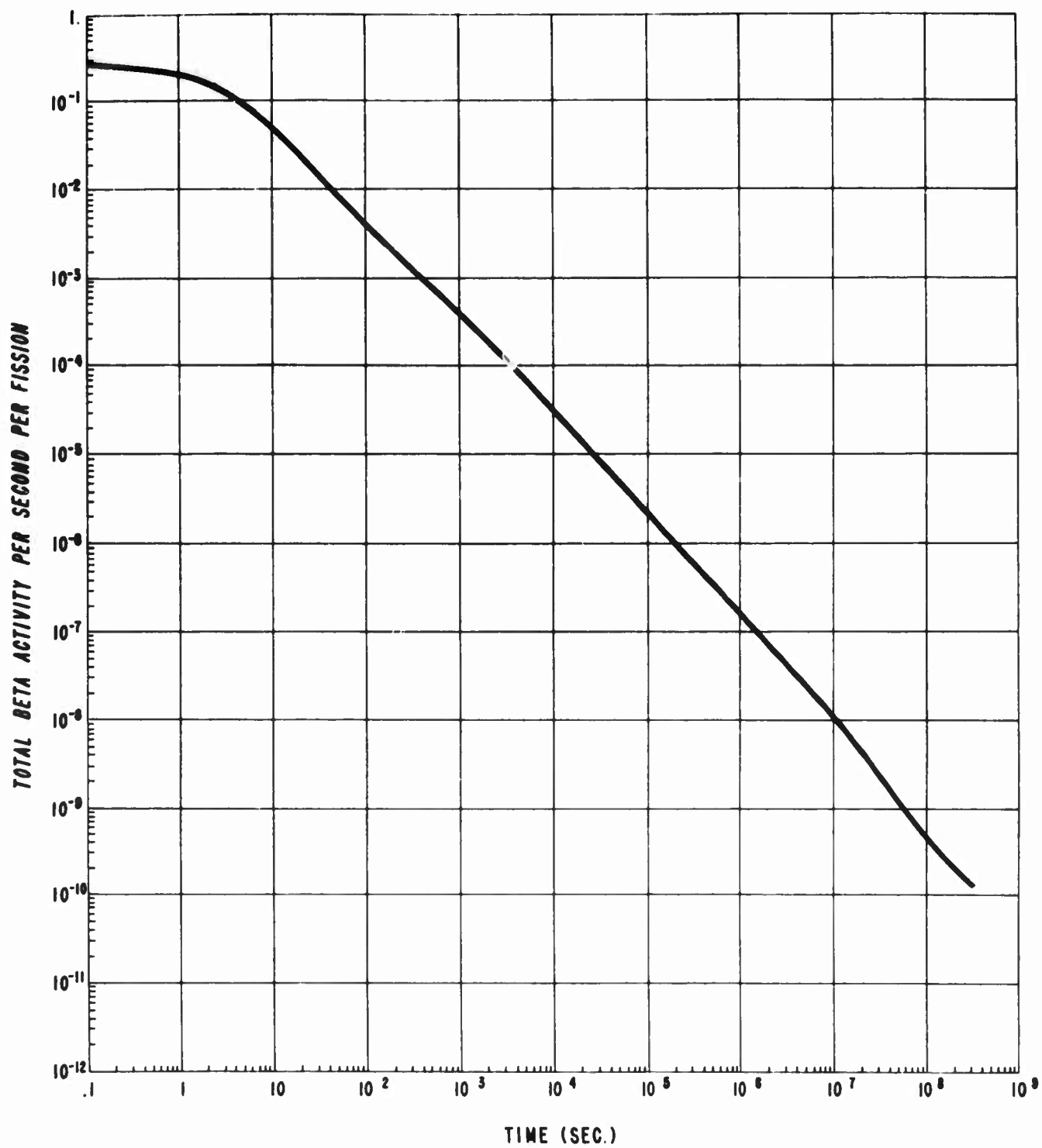


8-22-60-19

- 48 -

FIGURE 7
WSEG RM 19

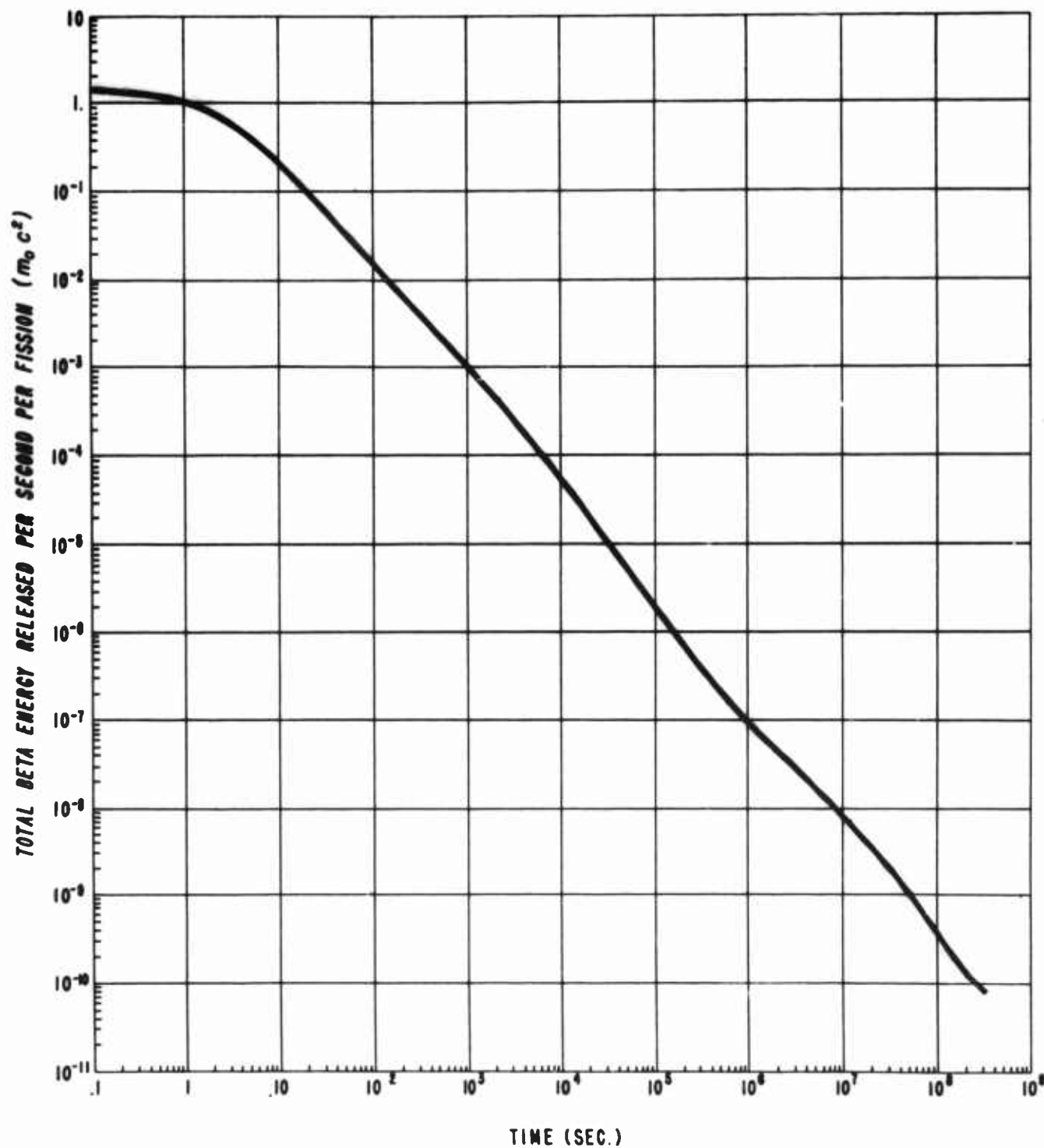
U^{238}



8-22-60-20

FIGURE 8
WSEG RM 19

U^{235}

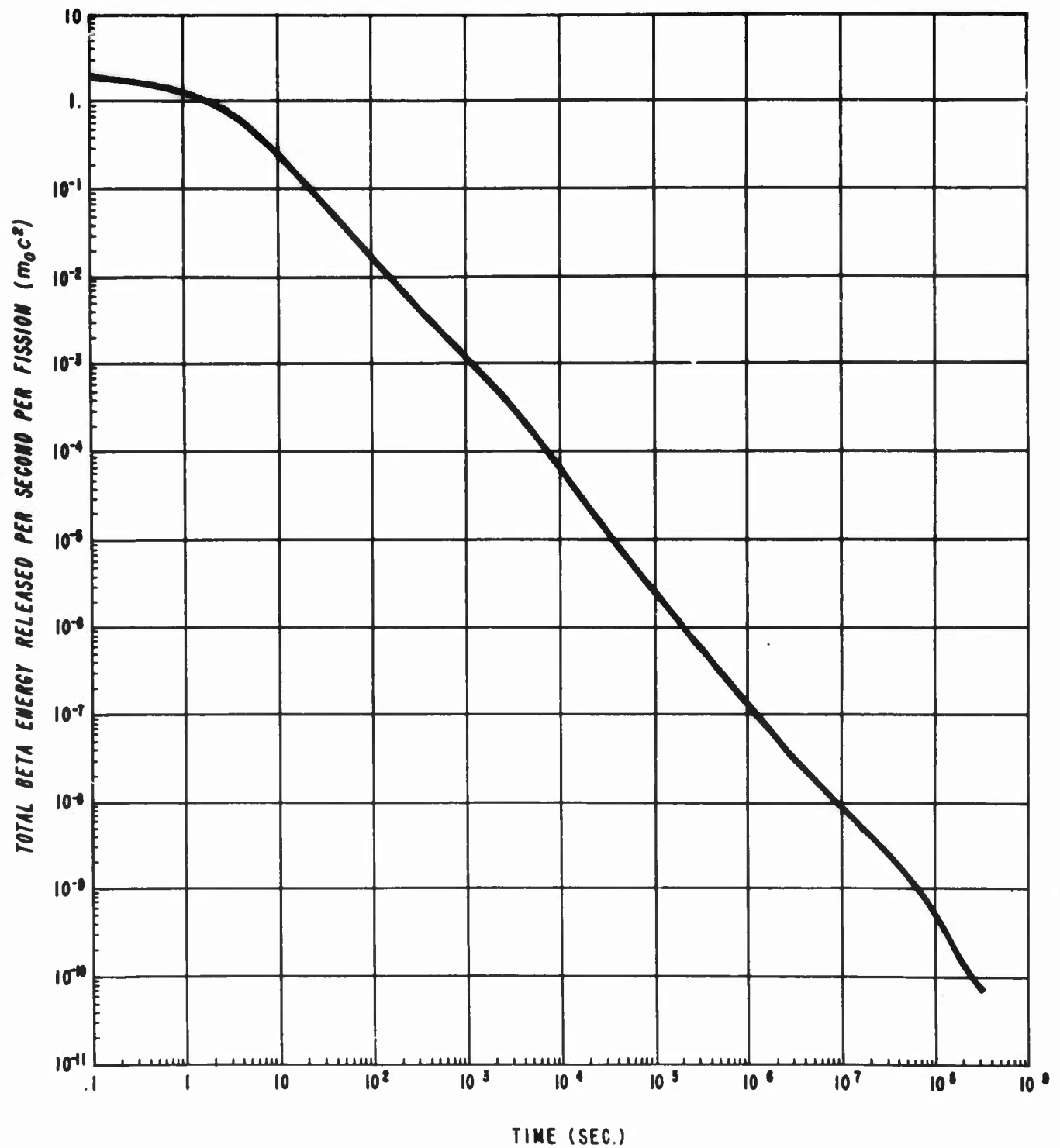


8-22-60-21

- 50 -

FIGURE 9
WSEG RM 19

U^{238}

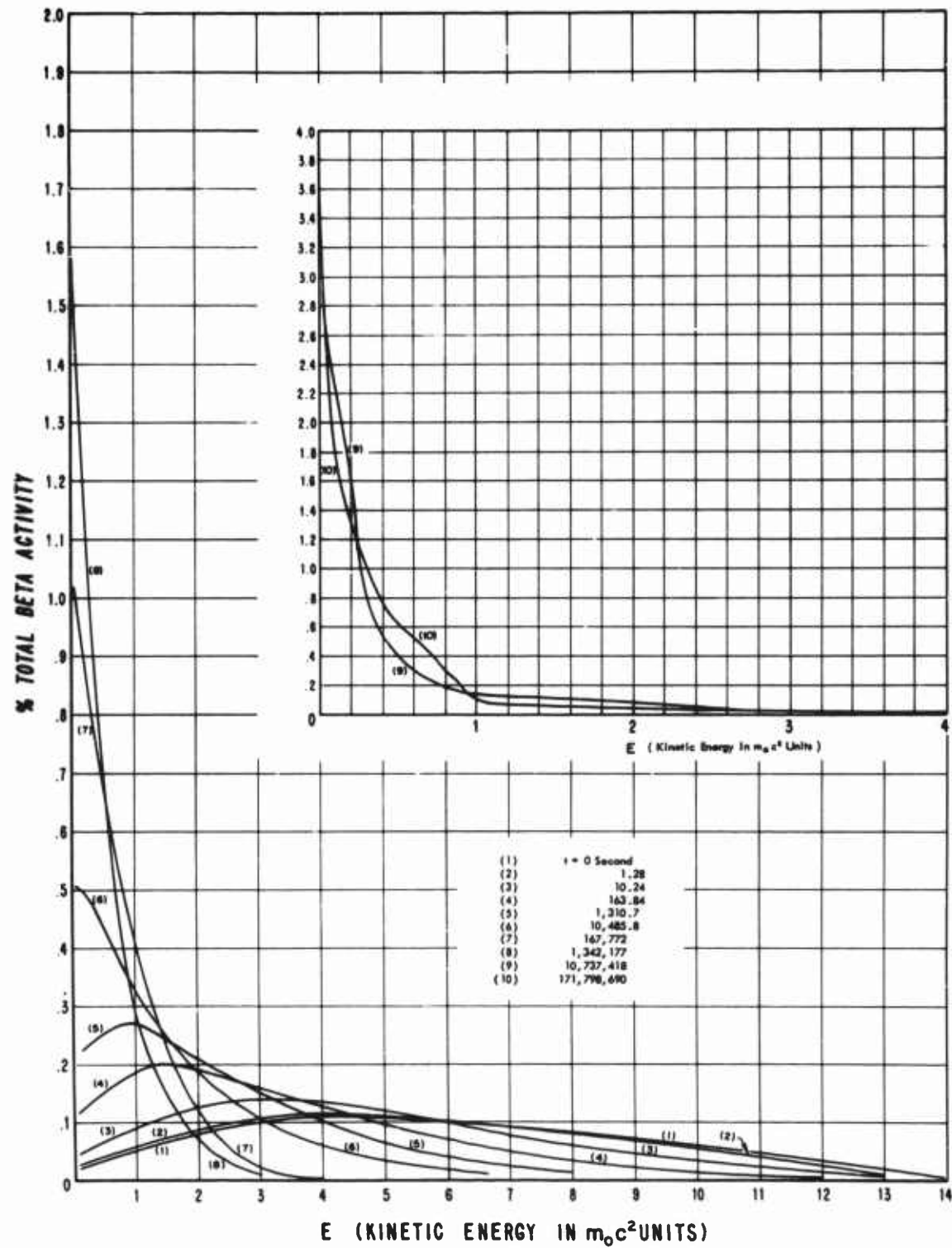


8-22-60-22

- 51 -

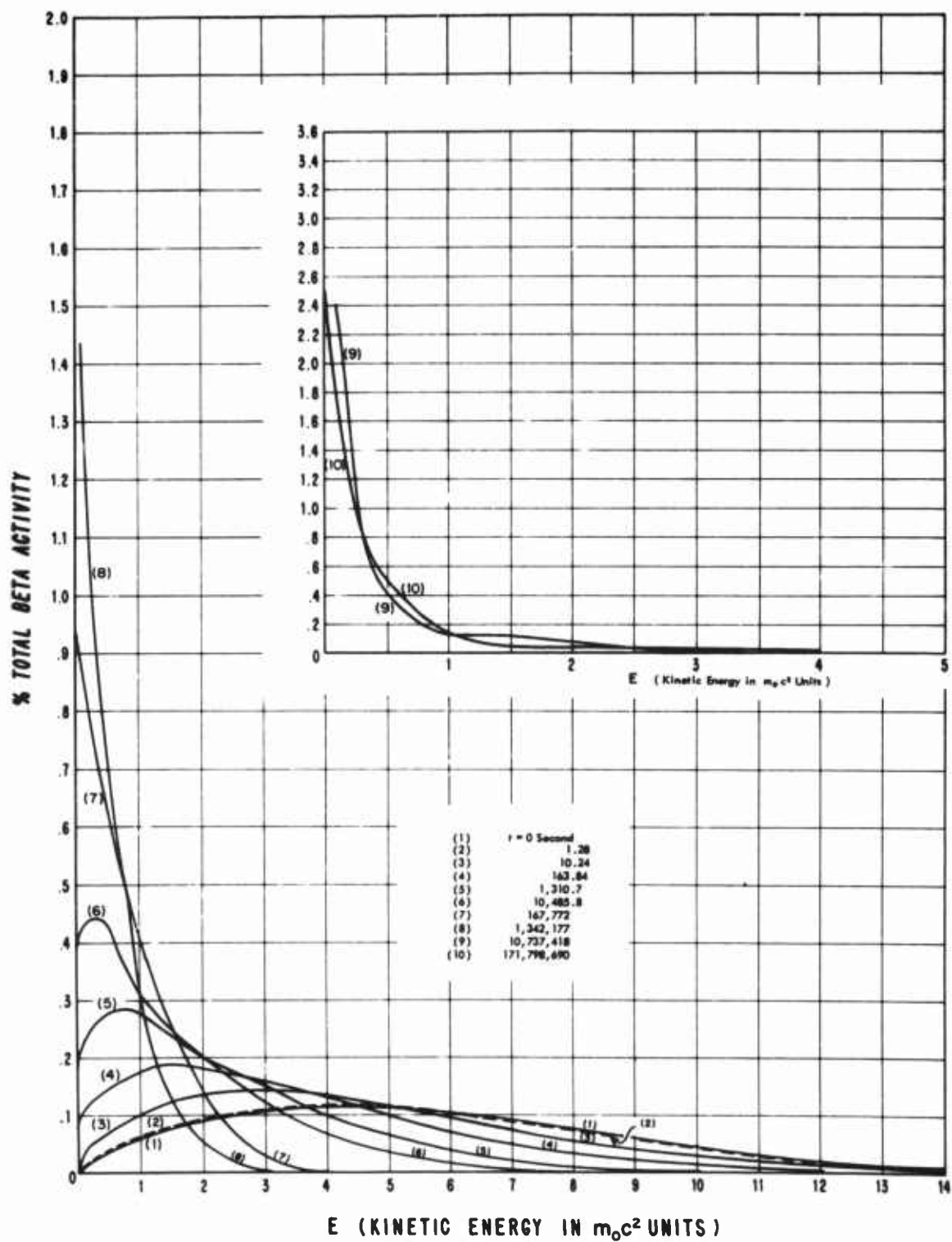
FIGURE 10
WSEG RM 19

U 238

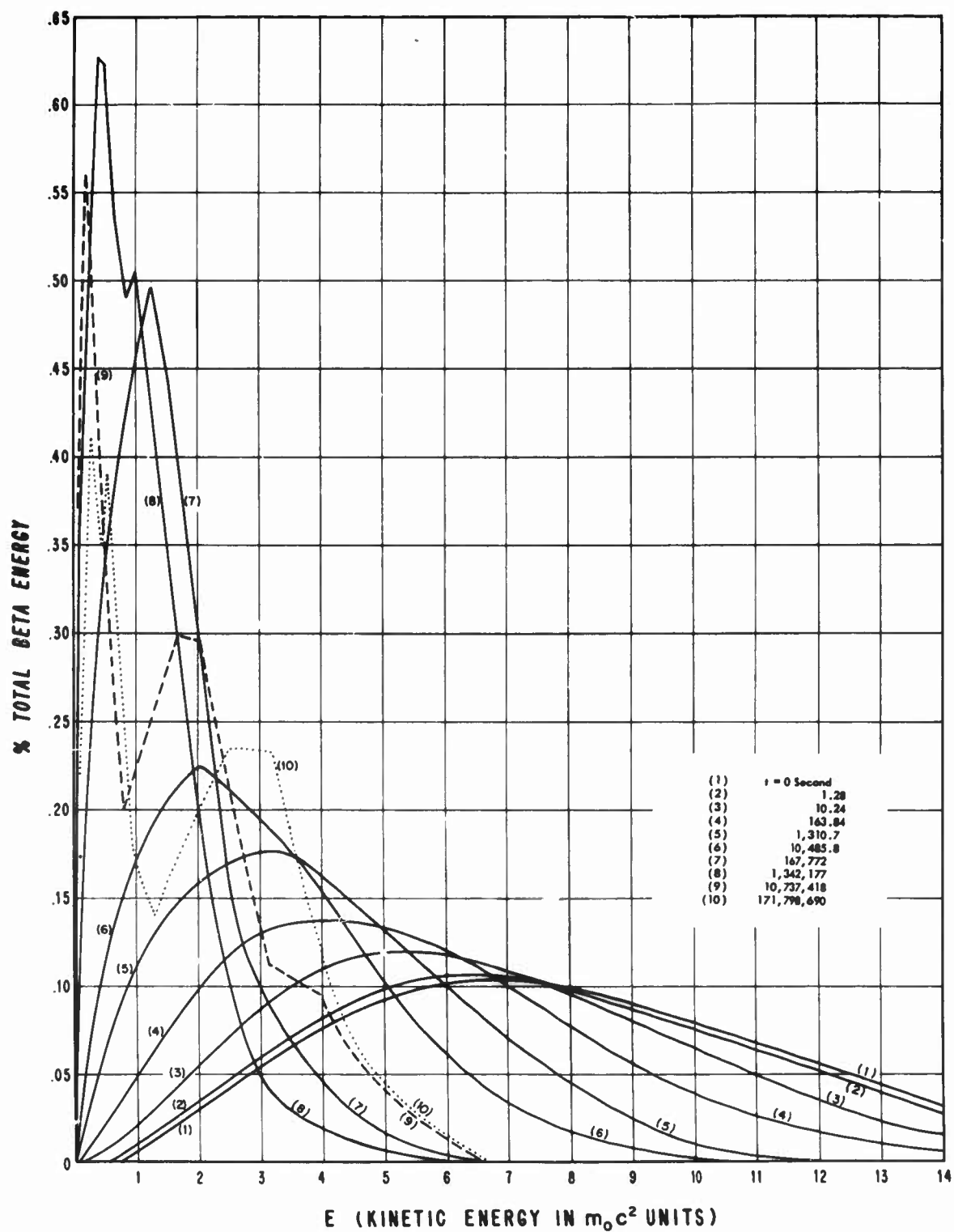


8-22-60-23

FIGURE 11
WSEG RM 19



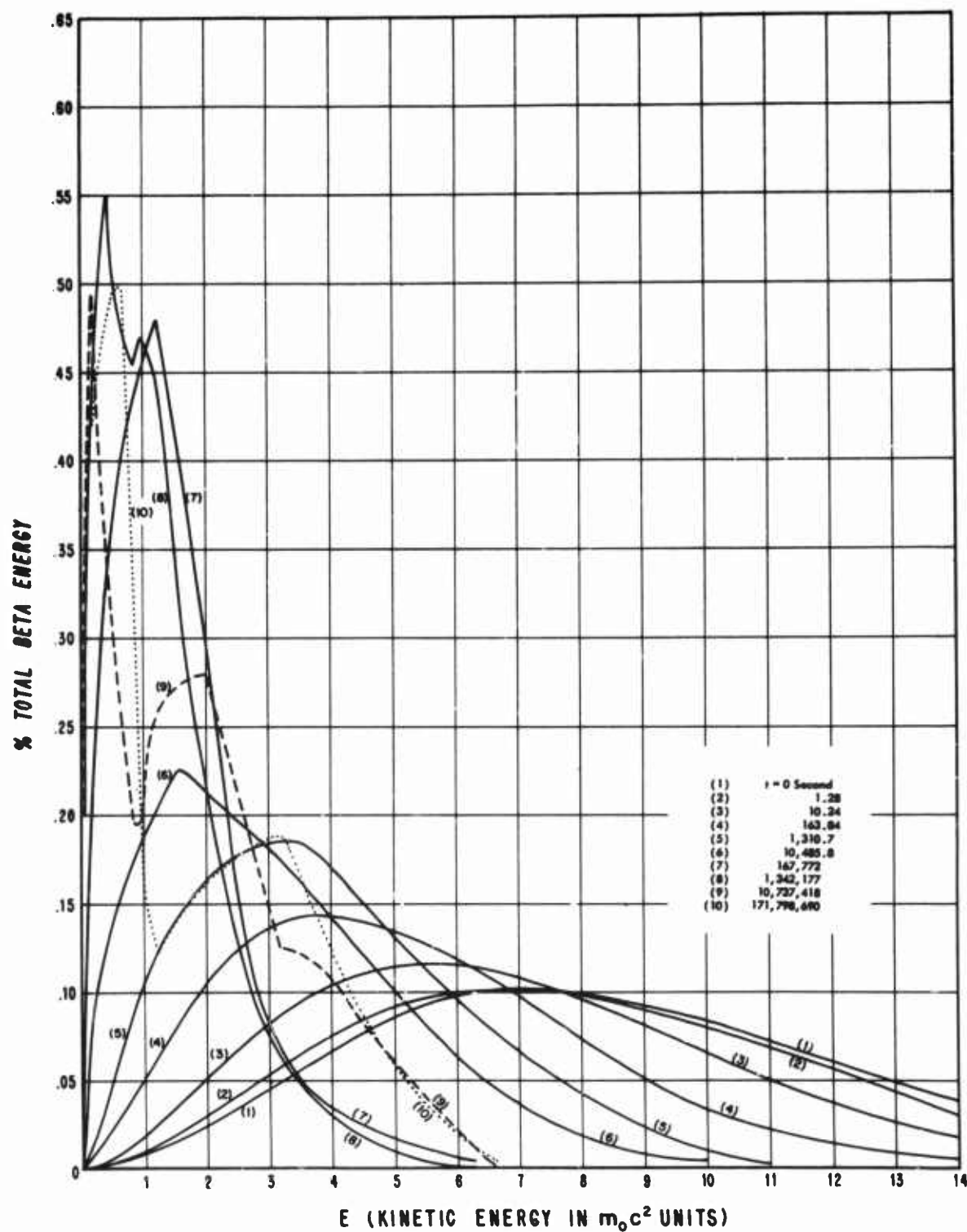
U^{235}



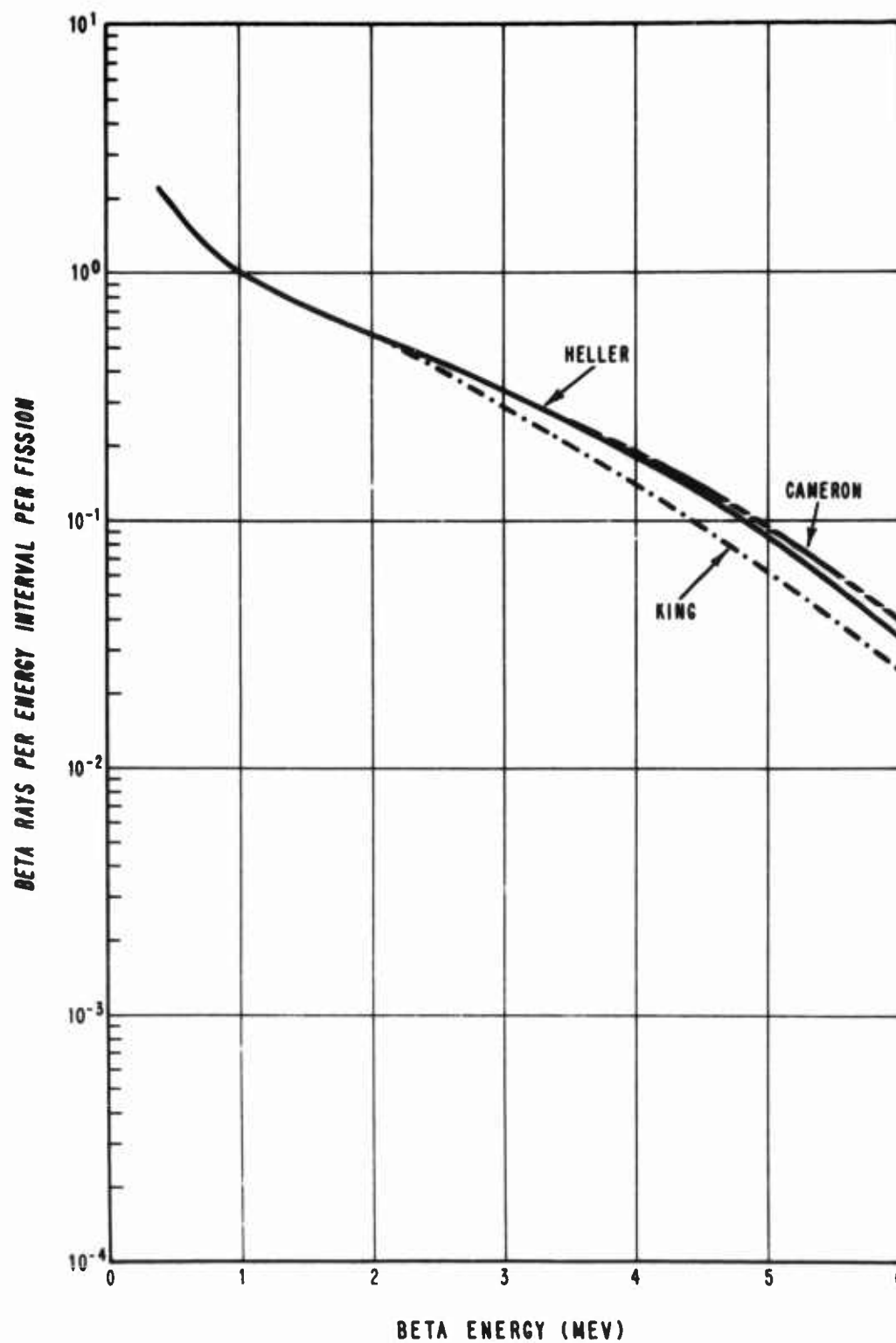
8-22-60-25

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FIGURE 13
WSEG RM 19



NUMBER OF BETA RAYS PER FISSION PER ENERGY INTERVAL U^{235}



UNCLASSIFIED

UNCLASSIFIED