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FORMATION OF SELECTED FISSION PRODUCTS IN POWER REACTORS

CFSTI PRICES

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FORMATION OF SELECTED FISSION PRODUCTS IN POWER REACTORS

With an increasing civilian power reactor economy and today's interests in the large scale use of certain isotopes, it is now pertinent to review the potential availability, formation, and composition of such materials. Such interests relate not only to the unique properties and potential uses for these materials, but also to the realistic possibility of value and credit to the fuel user as well as the fuel processor. For example, strontium-90 has potential large scale use as a radioisotopic heat source. In view of its long half life and rather impressive heat output per unit volume, it is uniquely suitable for such a specialized use. Such properties, therefore, make it far more valuable than conventional heat sources for certain specialized applications such as the power supply for remote, unmanned instrumentation on inaccessible land areas, beneath the sea and in space.

In the fission process, strontium-90 is produced along with other strontium isotopes, including some of the stable ones. Since there is no economical isotopic separation process applicable to highly radioactive materials, the use of strontium-90 must be satisfied by whatever isotopic composition results. The situation with reference to many other isotopes is essentially the same--applications for the immediate future will have to be satisfied with isotopes which are fairly heavily diluted with inert as well as with radioactive isotopes of widely differing characteristics.

Data in this report show the production of the various fission product isotopes as a function of fuel exposure for specific reactor conditions. Large scale uses are assumed only for those isotopes that are stable, or have reasonably long half lives (of about a year or more), and also have high fission yield. Table I lists typical isotopes and the potential large scale uses. These are very likely the only fission products that can be seriously considered in view of satisfactory yields, availability and useful properties. Essentially all other fission products: (1) are stable and already available at low cost from natural sources and at similar isotopic composition; (2) are formed at such low fission yields that little practical prospect exists to provide bases for justifying their recovery; or (3) have properties which are not sufficiently distinctive to appear to justify any specialized large scale uses. Table II gives calculated cross sections.

The fission product production was calculated on the IBM-7090 computer using the ALTHAEA-MELEAGER code as described in HW-77923. Two groups of reactor parameters were used. The first was based on a slightly enriched uranium PWR that is patterned after the PWR described in the Westinghouse report (WCAP-2385) titled "1000 MW_e

Closed-Cycle Water Reactor Study," and the second on a similar pressurized water reactor with natural uranium enriched with plutonium (76% Pu-239, 18% Pu-240, 5% Pu-241, 1% Pu-242).

Concurrently with this document, two others are being issued that complement it by describing in the same way the simulated production of the transuranium isotopes in power reactors. The first of these is BNWL-223, "Production and Indifference Pricing of Transuranium Isotopes," by D. E. Deonigi and E. A. Eschbach. It describes the methods used. The second document is BNWL-140 Rev. 1, "Formation of Transuranium Isotopes in Power Reactors," by D. E. Deonigi. It consists of over 700 pages of printout of computer calculations, and is available only on special distribution. It is suggested that the reader review the first of the two documents before requesting the extensive tables in the second.

The analysis of fission products has been divided into three groups, each group consisting of nine isotopes of two, three, or five elements. One may assume that adjacent fuel elements of proper enrichment will be available to absorb excess neutrons or provide needed neutrons as the situation warrants.

The cross sections are calculated with respect to the relative thermalized flux at slowing down fluxes with a formula originally developed by Westcott. As used here this takes on the form:

$$\sigma = \sigma_0 \left[g(T) + rs(T, N, \Sigma_s) \right] \qquad (1)$$

where σ_0 is the value of the cross section at 0.0253 eV, and g(T) is a factor which accounts for the averaging of the cross section over a Maxwellian distribution of neutron energies corresponding to a neutron temperature T, and includes thermal self-shielding. The s factor accounts for the averaging of the cross section over the slowing down distribution of neutron energies, with self-shielding of resonance levels accounted for in terms of the concentration N and a combined scattering cross section and geometry factor Σ_s. At low values of the ratio N/Σ_s these s factors reduce to the standard Westcott s factors.

Roughly, the g terms come from the thermal neutron cross sections data and the s terms from resonance integral data from the BNW Master library. This is accomplished by a Battelle-Northwest code named "GANDS," for g's and s's.

The treatment of resonance self-shielding used in the present study yields satisfactory results for isotopes of interest. The epithermal ratio r in Equation (1) is a measure of the relative

TABLE I

SELECTED ISOTOPES AND THEIR USES

Isotope	Use
Krypton-85 (mixed with other krypton isotopes which are stable)	Special light source phosphor.
Strontium-90 (plus other isotopes, including 50-day Sr-89)	Radioisotopic heat source.
Technetium-99 (very long half life - essentially stable)	New element, uses not yet developed. Has interesting properties under conditions of superconductivity and corrosion inhibition.
Rhodium (stable)	Valuable noble metal - industrial, electrical, ornamental.
Ruthenium (plus 40-day Ru-103 and 1-year Ru-106)	Radioisotopic heat source and energetic beta source; after several years of aging may be valuable as a noble metal.
Palladium (essentially stable including very long lived Pd-107)	Valuable noble metal - industrial, electrical, ornamental.
Xenon (stable)	Valuable rare gas, special light source, scintillation medium.
Cesium-137 (plus Cs-134 and stable isotopes including very long lived Cs-135)	Gamma source and radioisotopic heat source.
Cerium-144 (plus stable isotopes and 32-day Ce-141)	Radioisotopic heat source.
Promethium-147 (plus slight amount of 42-day Pm-148)	Radioisotopic heat source.

TABLE II

FISSION PRODUCT CROSS SECTIONS

Isotope		Sigma(1)	g(1)	s(1)
Kr	85	15.0	1.0	GANDS(3)
	86(2)	0.025	1.0	0.0
Sr	88	0.005	1.0	GANDS
	89	0.5	1.0	0.0
	90	1.0	1.0	0.0
Tc	99	22.0	1.1	GANDS
Ru	102(4)	0.5	1.0	GANDS
	103	30.0	1.0	0.0
	106	9.0	1.0	1.0(5)
Rh	103	149.0	GANDS	GANDS

(1) Sigma is the absorption cross section in barns for neutrons at 2,200 meter per second velocity, while g and s are constants in the Westcott formulation for the dilute cross section. The code applies further flux depression and resonance shielding corrections based on isotopic concentration.

(2) The data for Kr-86 represent the sum of the yields of Kr-84 and Kr-86. The cross section is used to compute the production of Kr-85 from stable Kr.

(3) A program to derive Westcott parameters from the RBU basic library, HW-81117 Rev. 1, July 10, 1964.

(4) The data for Ru-102 are the sum of the yields for Ru-99, Ru-100, Ru-101, and Ru-104. The cross section is used to compute the production of Ru-103 from stable Ru. A value of 0.5 barns was used to compute the yield of stable Pd from stable Ru.

(5) Estimate $s = 1.0 + 0.001\ T$.

TABLE II (Continued)

FISSION PRODUCT CROSS SECTIONS

Isotope		Sigma(1)	g(1)	s(1)
Pd	106(6)	12.2	1.0	0.0
	107	10.0	1.0	0.0
Xe(7)	131	120.0	1.0	GANDS
	132	0.2	1.0	0.0
	134	0.2	1.0	0.0
	135	2,425,800.0	GANDS	GANDS
	136	0.15	1.0	GANDS
Cs	133	29.0	1.0	GANDS
	134	134.0	1.0	0.0
	135	8.7	1.0	0.0
	137	0.11	1.0	0.0
Ce	141	30.0	1.0	0.0
	142(8)	0.33	1.0	0.0
	144	6.0	1.0	0.0
Pm	146	8,400.0	1.0	0.0
	147	132.0	GANDS	GANDS
	148	30,000.0	1.0	0.0

(6) The data for Pd-106 are the sum of yields for Pd-104, Pd-105, Pd-106, Pd-108, and Pd-110. The cross section is used to compute the yield of Pd-107 from stable Pd.

(7) Production of small amounts of Xe-128, Xe-129, and Xe-130 were ignored.

(8) The data for Ce-142 are the sum of the yields for Ce-140 and Ce-142. The cross section is used to compute the yield of Ce-141 from stable Ce.

strength of the slowing down portion of the spectrum, and is essentially the ratio of the loss rate of thermal neutrons (by asorption and leakage) to the production rate (by moderation). The neutron temperature T is determined from the moderator temperature and the r factor.

The dilute cross sections are calculated from the g, s, r, and 2200/m/sec cross section values as follows:

$$\sigma = \sigma_0(g + r\ s) \qquad (2)$$

The effective cross sections are obtained similarly by applying corrections for thermal flux depression and resonance shielding.

The spectral index r, or relative importance of epithermal-to-thermal neutrons, was calculated in each case for the reactor and fuel in use in order to obtain the proper fission cross sections. These cross sections were based on the values taken from the BNW Master library as updated by K. B. Stewart (BNWL-CC-325). Fission product cross sections were generally not as critical, so in the cases where g and s values were not available in the library or CRRP-960, estimated values were used.

It should be noted that the computations used the values in Table II, but that the generalized output data are recorded only to the nearest barn and include only the four numbers preceding the decimal point. Thus, Xe-135 and Pm-148 cross sections are not correctly reported in the Special Properties tables.

Isotopic production is given in several units to aid the user. The g/MWhr (which is based on electrical MWhr using 33% thermal efficiency) may be multiplied by megawatt hours of electrical energy to obtain production in grams or by $/g to obtain the economic effect in mills/kWhr.

Figure 1 shows a comparison of some of the calculated fission product concentrations of this report with measured data described in BNWL-45, Promethium-146, Fission Product, and Transuranium Isotope Content of Power Reactor Fuels, by F. P. Roberts and H. H. Van Tuyl. This document reviews a detailed analysis of isotope concentrations in spent fuel from Yankee and the VBWR for exposures as high as 30,000 MWd/T*. The low calculated results for Pm-147 are due to the low fission product yield for Pm-147 used in this report. The fission product yields employed are given in Table III. A more extensive description of the calibration may be found in BNWL-183, November 1965.

* MWd/T figures are based on the metric ton, and concentration figures are for conditions at the time of discharge unless indicated otherwise.

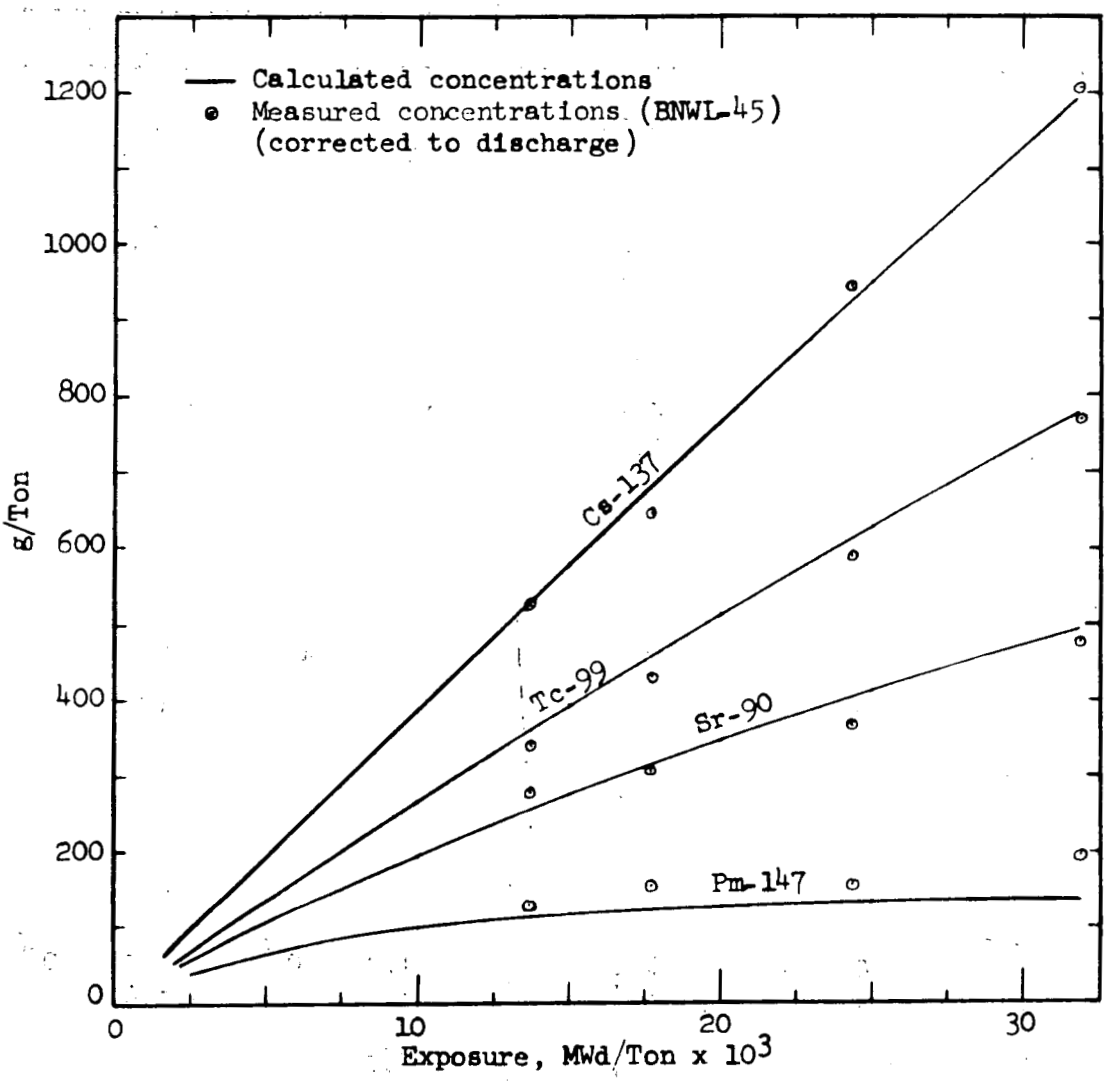


Figure 1

COMPARISON OF CALCULATED AND MEASURED CONCENTRATIONS OF FOUR FISSION PRODUCTS VERSUS EXPOSURE

TABLE III

PERCENT FISSION PRODUCT YIELDS*

Fission Product		Source			
		U^{235}	Pu^{239}	Pu^{241}	U^{238}
Kr	85	.293	0.09	0.05	0.153
	86	3.56	0.93	0.55	2.63
Sr	88	3.57	1.42	1.0	2.3
	89	4.79	1.71	1.5	2.9
	90	5.77	2.25	2.0	3.2
Tc	99	6.1	6.0	6.0	6.3
Ru	102	10.9	16.8	17.6	17.4
	103	3.0	5.6	5.9	6.7
	106	0.38	4.6	4.6	2.7
Rh	103				
Pd	106	0.97	6.7	6.7	54.4
	107	0.12	3.2	3.2	1.5
Xe	131	2.93	3.78	3.78	3.2
	132	4.38	5.26	5.26	4.7
	134	8.06	7.47	7.5	6.6
	135	6.3	7.0	7.0	5.9
	136	6.46	6.63	6.63	5.9
Cs	133	6.59	6.91	7.0	5.5
	134				
	135	1.0×10^{-6}	1.0×10^{-6}	1.0×10^{-6}	1.0×10^{-6}
	137	6.15	6.63	6.63	6.2
Ce	141	6.4	5.7	5.0	5.7
	142	12.45	15.61	10.0	11.40
	144	5.8	3.8	3.7	4.9
Pm	146	1.0×10^{-8}	1.0×10^{-8}	1.0×10^{-8}	1.0×10^{-8}
	147	2.3	1.9	1.9	3.2
	148	1.0×10^{-8}	1.0×10^{-8}	1.0×10^{-8}	1.0×10^{-8}

* Katcoff, Seymour, Nucleonics 18, No. 11, p 201-204, 1960 (Nov.).
* Yu. A. Zysin, et al, Fission Product Yields and Their Mass Distribution, New York, Consultants Bureau, 1964.

APPENDIX

PROPERTIES AND CONCENTRATIONS OF SPECIAL PRODUCTS

Case Number	Reactor*	Fuel Enrichment (wt%)	Fuel**	Fission Products Group	Exposure (MWd/T	Page
1000F	SPWR	2.92 (U^{235})	(1)	Ru, Rh, Pd, Tc, Kr	5000-25000	A2-A-6
				Plot of isotope concentrations		A7
1000F	SPWR	2.92 (U^{235})	(1)	Sr, Ce, Pm	5000-25000	A8-A12
				Plot of isotope concentrations		A13
1000F	SPWR	2.92 (U^{235})	(1)	Xe, Cs	5000-25000	A14-A18
				Plot of isotope concentrations		A19
3003F	SPWR with spectrum fixed at (r = 0.35)	3.47 (Pu + Natural U)	(2)	Ru, Rh, Pd, Tc, Kr	5000-25000	A20-A24
				Plot of isotope concentrations		A25
3003F	SPWR with spectrum fixed at (r = 0.35	3.47 (Pu + Natural U)	(2)	Sr, Ce, Pm	5000-25000	A26-A30
				Plot of isotope concentrations		A31
3003F	SPWR with spectrum fixed at (r = 0.35)	3.47 (Pu + Natural U)	(2)	Xe, Cs	5000-25000	A32-A36
				Plot of isotope concentrations		A37

*SPWR, simulated pressurized water reactor, specific power 20 MW/MT.
**(1) Slightly enriched uranium.
(2) Pu (76% Pu^{239}, 18% Pu^{240}, 5% Pu^{241}, 1% Pu^{242}) in natural uranium.

EXPOSURE 5000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 1000F

ISOTOPES	RU102	RU103	RU106	RH103	PD106	PD107	TC 99	KR 86	KR 85
HALF LIFE	STABLE	40 DAY	1.0 YR	STABLE	STABLE	7E6 YR	2E5 YR	STABLE	10.4YR
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	2	28	11	533	11	9	88	0	14
AVERAGE	2	28	11	553	11	9	91	0	14
FINAL	2	28	12	572	11	9	95	0	14
MACROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.	0.000
FINAL	0.000	0.000	0.000	0.002	0.000	0.000	0.001	0.	0.000
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	2.9348	0.2083	0.2269	0.6165	0.6123	0.1592	1.3934	0.6335	0.0496
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
FINAL	87.4	6.1	6.5	100.0	79.5	20.5	100.0	0.	0.
HEAT OUTPUT, WATTS/CC	0.	0.0135	0.0070	0.	0.	0.	0.0000	0.	0.0000
NET ISOTOPIC PRODUCTION									
GM/TON/YR	420.0	29.8	32.5	88.2	87.6	22.8	199.4	90.7	7.1
GM/MWE/YR	63.00	4.47	4.87	13.23	13.14	3.42	29.91	13.60	1.06
GM/MWH	0.0072	0.0005	0.0006	0.0015	0.0015	0.0004	0.0034	0.0016	0.0001
GM/TON	287.7	20.4	22.2	60.4	60.0	15.6	136.6	62.1	4.9
WATTS/MWE/YR	0.	290.6	151.0	0.	0.	0.	0.0	0.	0.8

EXPOSURE 10000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 1000F

ISOTOPES	RU102	RU103	RU106	RH103	PD106	PD107	TC 99	KR 86	KR 85
HALF LIFE	STABLE	40 DAY	1.0 YR	STABLE	STABLE	7E6 YR	2E5 YR	STABLE	10.4YR
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	2	28	11	533	11	9	88	0	14
AVERAGE	2	28	11	567	11	9	93	0	14
FINAL	3	28	12	588	11	9	97	0	14
MACROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.000	0.000	0.000	0.002	0.000	0.000	0.001	0.	0.000
FINAL	0.000	0.000	0.000	0.005	0.000	0.000	0.002	0.	0.000
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	6.1407	0.2319	0.5044	1.3749	1.7395	0.4523	2.7285	1.1718	0.0896
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
FINAL	89.6	3.3	7.1	100.0	79.5	20.5	100.0	0.	0.
HEAT OUTPUT, WATTS/CC	0.	0.0151	0.0156	0.	0.	0.	0.0000	0.	0.0001
NET ISOTOPIC PRODUCTION									
GM/TON/YR	439.4	16.6	36.1	98.4	124.5	32.4	195.2	83.8	6.4
GM/MWE/YR	65.91	2.49	5.41	14.76	18.67	4.85	29.28	12.58	0.96
GM/MWH	0.0075	0.0003	0.0006	0.0017	0.0021	0.0006	0.0033	0.0014	0.0001
GM/TON	601.9	22.7	49.4	134.8	170.5	44.3	267.4	114.9	8.8
WATTS/MWE/YR	0.	161.8	167.8	0.	0.	0.	0.0	0.	0.7

EXPOSURE 15000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 10006

ISOTOPES	RU102	RU103	RU106	RH103	PD106	PD107	TC 99	KR 86	KR 85
HALF LIFE	STABLE	40 DAY	1.0 YR	STABLE	STABLE	7E6 YR	2E5 YR	STABLE	10.4YR
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	2	28	11	533	11	9	88	0	14
AVERAGE	2	28	11	574	11	9	95	0	14
FINAL	3	28	12	592	11	9	98	0	14
MACROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.000	0.000	0.000	0.003	0.000	0.000	0.001	0.	0.000
FINAL	0.000	0.000	0.000	0.007	0.000	0.000	0.002	0.	0.000
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	9.5429	0.2473	0.7671	2.0590	3.3069	0.8364	4.0090	1.6463	0.1228
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
FINAL	90.7	2.3	7.0	100.0	80.0	20.0	100.0	0.	0.
HEAT OUTPUT, WATTS/CC	0.	0.0161	0.0238	0.	0.	0.	0.0000	0.	0.0001
NET ISOTOPIC PRODUCTION									
GM/TON/YR	455.2	11.8	36.6	98.2	157.7	39.9	191.2	78.5	5.9
GM/MWE/YR	66.28	1.77	5.49	14.73	23.66	5.98	28.69	11.78	0.88
GM/MWH	0.0078	0.0002	0.0006	0.0017	0.0027	0.0007	0.0033	0.0013	0.0001
GM/TON	935.4	24.2	75.2	201.8	324.1	82.0	392.9	161.4	12.0
WATTS/MWE/YR	0.	115.0	170.2	0.	0.	0.	0.0	0.	0.6

EXPOSURE 20000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 1000F

ISOTOPES	RU102	RU103	RU106	RH103	PD106	PD107	TC 99	KR 86	KR 85
HALF LIFE	STABLE	40 DAY	1.0 YR	STABLE	STABLE	7E6 YR	2E5 YR	STABLE	10.4YR
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	2	28	11	533	11	9	88	0	14
AVERAGE	2	28	11	579	11	9	95	0	14
FINAL	2	28	12	589	11	9	98	0	14
MACROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.000	0.000	0.000	0.004	0.000	0.000	0.002	0.	0.000
FINAL	0.000	0.000	0.000	0.009	0.000	0.000	0.003	0.	0.000
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	13.1078	0.2594	0.9996	2.6575	5.2586	1.2930	5.2352	2.0704	0.1506
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	1.	0.
FINAL	91.5	1.8	6.7	100.0	80.4	19.6	100.0	0.	0.
HEAT OUTPUT, WATTS/CC	0.	0.0169	0.0310	0.	0.	0.	0.0006	0.	0.0001
NET ISOTOPIC PRODUCTION									
GM/TON/YR	468.9	9.3	35.8	95.1	188.1	46.3	187.3	74.1	5.4
GM/MWE/YR	70.34	1.39	5.36	14.26	28.22	6.94	28.09	11.11	0.81
GM/MWH	0.0080	0.0002	0.0006	0.0016	0.0032	0.0008	0.0032	0.0013	0.0001
GM/TON	1284.8	25.4	98.0	260.5	515.4	126.7	513.1	202.9	14.8
WATTS/MWE/YR	0.	90.5	166.3	0.	0.	0.	0.0	0.	0.6

EXPOSURE 2500[illegible].0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 1000F

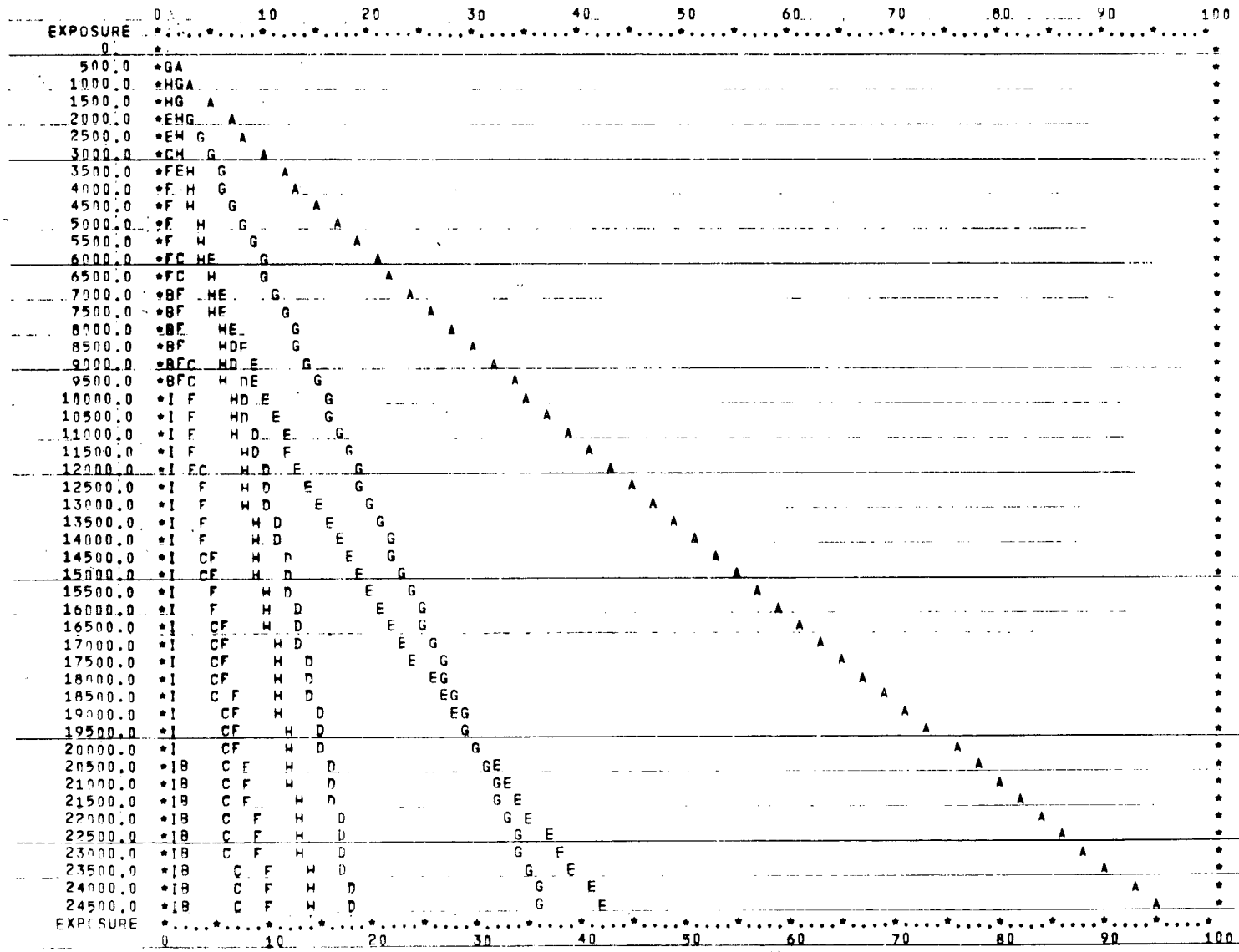
ISOTOPES	RU102	RU103	RU106	RH103	PD106	PD107	TC 99	KR 86	KR 85
HALF LIFE	STABLE	40 DAY	1.0 YR	STABLE	STABLE	7E6 YR	2E5 YR	STABLE	10.4YR
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	2	28	11	533	11	9	89	0	14
AVERAGE	2	28	11	580	11	9	96	0	14
FINAL	2	28	12	582	12	9	96	0	14
MACROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.000	0.000	0.000	0.006	0.000	0.000	0.002	0.	0.000
FINAL	0.000	0.000	0.000	0.011	0.001	0.000	0.004	0.	0.000
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	16.8148	0.2697	1.2001	3.1671	7.5430	1.8121	6.4055	2.4545	0.1739
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
FINAL	92.2	1.5	6.3	100.0	80.8	19.2	100.0	0.	0.
HEAT OUTPUT, WATTS/CC	0.	0.0175	0.0372	0.	0.	0.	0.0000	0.	0.0001
NET ISOTOPIC PRODUCTION									
GM/TON/YR	481.3	7.7	34.3	90.6	215.9	51.9	183.3	70.2	5.0
GM/MWE/YR	72.19	1.16	5.15	13.60	32.38	7.78	27.50	10.54	0.75
GM/MWH	0.0082	0.0001	0.0006	0.0016	0.0037	0.0009	0.0031	0.0012	0.0001
GM/TON	1648.1	26.4	117.6	310.4	739.3	177.6	627.8	240.6	17.0
WATTS/MWE/YR	0.	75.3	159.7	0.	0.	0.	0.0	0.	0.5

*** SPECIAL PRODUCT CONCENTRATIONS ***

FISSION PRODUCTS, RU, RH, PD, TC, AND KR. CASE NUMBER 1000F

A = RU102 B = RU103 C = RU106 D = RH103 E = PD106
F = PD107 G = TC 99 H = KR 86 I = KR 85

THE FULL SCALE VALUE FOR ALL ISOTOPES IS 1700.0 GRAMS/TON



EXPOSURE 500.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 10001

ISOTOPES	SR 88	SR 89	SR 90	CE142	CE141	CE144	PM146	PM147	PM148
HALF LIFE	STABLE	50 DAY	28 YR	STABLE	32 DAY	285DAY	1600 Y	2.5 YR	42 DAY
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	0	0	1	0	28	6	7901	773	8216
AVERAGE	0	0	1	0	28	6	7890	809	8181
FINAL	0	0	1	0	28	6	7886	842	8164
MACROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.	0.	0.000	0.	0.000	0.000	0.000	0.001	0.000
FINAL	0.	0.	0.000	0.	0.000	0.000	0.000	0.002	0.000
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	0.6578	0.2392	1.0683	4.2508	0.3762	1.3759	0.0000	0.6341	0.0125
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	33.9	12.2	53.9	71.0	6.3	22.7	100.0	98.1	1.9
HEAT OUTPUT, WATTS/CC	0.	0.0268	0.0010	0.	0.0188	0.0352	0.0000	0.0002	0.0019
NET ISOTOPIC PRODUCTION									
GM/TON/YR	94.1	34.2	152.9	608.3	53.8	196.9	0.0	90.7	1.8
GM/MWE/YR	14.12	5.14	22.93	91.25	8.08	29.54	0.00	13.61	0.27
GM/MWH	0.0016	0.0006	0.0026	0.0104	0.0009	0.0034	0.0000	0.0016	0.0000
GM/TON	64.5	23.4	104.7	416.6	36.9	134.9	0.0	62.2	1.2
WATTS/MWE/YR	0.	575.2	21.8	0.	403.8	756.1	0.0	5.0	40.9

EXPOSURE 10000.0 MWD/T ••• PROPERTIES OF SPECIAL PRODUCTS ••• CASE NUMBER 1000F

ISOTOPES	SR 88	SR 89	SR 90	CE142	CE141	CE144	PM146	PM147	PM148
HALF LIFE	STABLE	50 DAY	28 YR	STABLE	32 DAY	285DAY	1600CY	2.5 YR	42 DAY
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	0	0	1	0	28	6	7901	773	8216
AVERAGE	0	0	1	0	28	6	7888	832	8174
FINAL	0	0	1	0	28	6	7890	868	8178
MACROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.	0.	0.000	0.	0.000	0.000	0.000	0.002	0.000
FINAL	0.	0.	0.000	0.	0.000	0.000	0.000	0.004	0.001
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	1.2342	0.2183	1.9844	8.6171	0.3687	2.3317	0.0000	1.0019	0.0212
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	36.4	6.4	57.9	78.4	3.4	18.2	100.	97.9	2.1
HEAT OUTPUT, WATTS/CC	0.	0.0244	0.0019	0.	0.0184	0.0520	0.0000	0.0004	0.0032
NET ISOTOPIC PRODUCTION									
GM/TON/YR	88.3	15.6	142.0	616.6	26.4	145.4	0.0	71.7	1.5
GM/MWE/YR	13.25	2.34	21.30	92.49	3.96	21.81	0.00	10.75	0.23
GM/MWH	0.0015	0.0003	0.0024	0.0106	0.0005	0.0025	0.0000	0.0012	0.0000
GM/TON	121.0	21.4	194.5	844.6	36.1	199.1	0.0	98.2	2.1
WATTS/MWE/YR	0.	262.4	20.2	0.	197.9	558.2	0.0	4.0	34.7

EXPOSURE 15000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 1000F

ISOTOPES	SR 88	SR 89	SR 90	CE142	CE141	CE144	PM146	PM147	PM148
HALF LIFE	STABLE	50 DAY	28 YR	STABLE	32 DAY	285DAY	1600DY	2.5 YR	42 DAY
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	0	0	1	0	28	6	7901	773	8216
AVERAGE	0	0	1	0	28	6	7890	845	8180
FINAL	0	0	1	0	28	6	7898	873	8209
MACROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.	0.	0.000	0.	0.000	0.000	0.000	0.003	0.001
FINAL	0.	0.	0.000	0.	0.000	0.000	0.000	0.004	0.001
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	1.7547	0.1974	2.7973	13.0212	0.3615	2.3260	0.0000	1.2069	0.0263
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	37.5	4.2	58.4	83.0	2.3	14.6	100.0	97.9	2.1
HEAT OUTPUT, WATTS/CC	0.	0.0221	0.0027	0.	0.0181	0.0595	0.0000	0.0004	0.0040
NET ISOTOPIC PRODUCTION									
GM/TON/YR	83.7	9.4	133.4	621.1	17.2	111.0	0.0	57.6	1.3
GM/MWE/YR	12.56	1.41	20.02	93.17	2.59	16.64	0.00	8.64	0.19
GM/MWH	0.0014	0.0002	0.0023	0.0106	0.0003	0.0019	0.0000	0.0010	0.0000
GM/TON	172.0	19.4	274.2	1276.3	35.4	228.0	0.0	118.3	2.6
WATTS/MWE/YR	0.	158.2	19.0	0.	129.3	426.1	0.0	3.2	28.6

EXPOSURE 20000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 10008

ISOTOPES	SR 88	SR 89	SR 90	CE142	CE141	CE144	PM146	PM147	PM148
HALF LIFE	STABLE	50 DAY	28 YR	STABLE	32 DAY	285DAY	1600 Y	2.5 YR	42 DAY
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	0	0	1	0	28	6	7901	773	8216
AVERAGE	0	0	1	0	28	6	7893	851	8191
FINAL	0	0	1	0	28	6	7909	866	8248
MACROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.	0.	0.000	0.	0.000	0.000	0.000	0.003	0.001
FINAL	0.	0.	0.000	0.	0.000	0.000	0.000	0.005	0.001
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	2.2340	0.1809	3.5265	17.4347	0.3554	2.4387	0.0000	1.3123	0.0288
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	38.1	3.1	58.8	86.3	1.8	11.9	100.0	97.9	2.1
HEAT OUTPUT, WATTS/CC	0.	0.0203	0.0034	0.	0.0178	0.0624	0.0000	0.0005	0.0044
NET ISOTOPIC PRODUCTION									
GM/TON/YR	79.9	6.5	126.2	623.7	12.7	87.2	0.0	47.0	1.0
GM/MWE/YR	11.99	0.97	18.92	93.56	1.91	13.09	0.00	7.04	0.15
GM/MWH	0.0014	0.0001	0.0022	0.0107	0.0002	0.0015	0.0000	0.0008	0.0000
GM/TON	219.0	17.7	345.7	1708.9	34.8	239.0	0.0	128.6	2.8
WATTS/MWE/YR	0.	108.7	18.0	0.	95.4	335.0	0.0	2.6	23.5

EXPOSURE 25000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 1000F

ISOTOPES	SR 88	SR 89	SR 90	CE142	CE141	CE144	PM146	PM147	PM148
HALF LIFE	STABLE	50 DAY	28 YR	STABLE	32 DAY	285DAY	1600 Y	2.5 YR	42 DAY
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	0	0	1	0	28	6	7901	773	8216
AVERAGE	0	0	1	0	28	6	7897	853	8206
FINAL	0	0	1	0	28	6	7922	851	8293
MACROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.	0.	0.000	0.	0.000	0.000	0.000	0.003	0.001
FINAL	0.	0.	0.000	0.	0.000	0.000	0.000	0.005	0.001
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	2.6767	0.1673	4.1884	21.8505	0.3502	2.4578	0.0000	1.3570	0.0297
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	38.6	2.4	59.0	88.7	1.4	9.8	100.0	97.9	2.1
HEAT OUTPUT, WATTS/CC	0.	0.0187	0.0040	0.	0.0175	0.0629	0.0000	0.0005	0.0045
NET ISOTOPIC PRODUCTION									
GM/TON/YR	76.6	4.8	119.9	625.4	10.0	70.3	0.0	38.8	0.9
GM/MWE/YR	11.49	0.72	17.98	93.81	1.50	10.55	0.00	5.83	0.13
GM/MWH	0.0013	0.0001	0.0021	0.0107	0.0002	0.0012	0.0000	0.0007	0.0000
GM/TON	262.4	16.4	410.5	2141.7	34.3	240.9	0.0	133.0	2.9
WATTS/MWE/YR	0.	80.4	17.1	0.	75.2	270.1	0.0	2.2	19.4

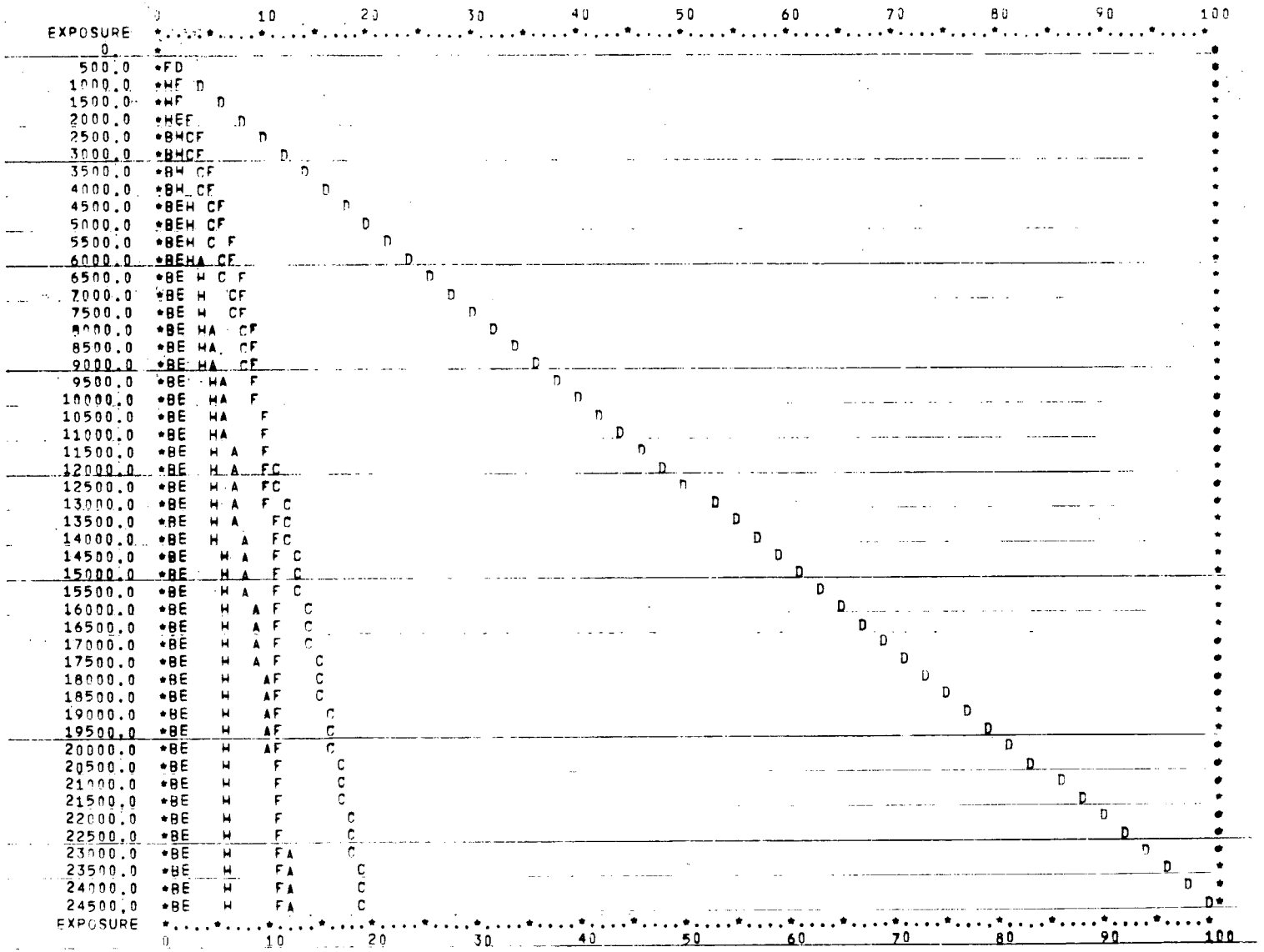
*** SPECIAL PRODUCT CONCENTRATIONS ***

SPWR WITH FISSION PRODUCTS, SR, CE, AND PM. CASE NUMBER 1000F

A = SR 88 B = SR 89 C = SR 90 D = CE142 E = CE141
F = CE144 G = PM146 H = PM147 I = PM148

THE FULL SCALE VALUE FOR ALL ISOTOPES IS 2100.0 GRAMS/TON

PERCENT OF FULL SCALE



EXPOSURE 5000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 1000F

ISOTOPES	XE131	XE132	XE134	XE136	XE135	CS133	CS134	CS135	CS137
HALF LIFE	STABLE	STABLE	STABLE	STABLE	9.2 HR	STABLE	2.1 YR	2E6 YR	30 YR
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	392	0	0	0	5301	165	126	8	0
AVERAGE	414	0	0	0	4546	176	126	8	0
FINAL	429	0	0	0	3103	184	126	8	0
MACROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.001	0.	0.	0.	0.000	0.001	0.000	0.000	0.
FINAL	0.002	0.	0.	0.	0.000	0.002	0.000	0.000	0.
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	0.8761	1.4646	2.4718	3.2877	0.0018	1.9794	0.0574	0.7856	1.9812
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	0.	18.4	30.5	40.0	0.0	41.8	1.2	16.4	40.6
HEAT OUTPUT, WATTS/CC	0.	0.	0.	0.	0.0217	0.	0.0004	0.0000	0.0008
NET ISOTOPIC PRODUCTION									
GM/TON/YR	125.4	209.6	353.7	470.5	0.3	283.3	8.2	112.4	283.5
GM/MWE/YR	18.81	31.44	53.05	70.57	0.04	42.49	1.23	16.86	42.53
GM/MWH	0.0021	0.0036	0.0061	0.0081	0.0000	0.0049	0.0001	0.0019	0.0049
GM/TON	85.9	143.6	242.3	322.2	0.2	194.0	5.6	77.0	194.2
WATTS/MWE/YR	0.	0.	0.	0.	465.4	0.	8.4	0.0	17.9

EXPOSURE 10000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 1000F

ISOTOPES	XE131	XE132	XE134	XE136	XE135	CS133	CS134	CS135	CS137
HALF LIFE	STABLE	STABLE	STABLE	STABLE	9.2 HR	STABLE	2.1 YR	2E6 YR	30 YR
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	392	0	0	0	5301	165	126	8	0
AVERAGE	425	0	0	0	4660	181	126	8	0
FINAL	440	0	0	0	9920	190	126	8	0
MACROSCOPIC CROSS SECTION									
ABSORBTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.002	0.	0.	0.	0.000	0.002	0.000	0.000	0.
FINAL	0.003	0.	0.	0.	0.000	0.003	0.000	0.000	0.
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	1.6669	3.0923	4.8946	6.5550	0.0017	3.8401	0.2101	1.6167	3.9442
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	0.	19.4	30.2	39.9	0.0	40.5	2.2	16.8	40.4
HEAT OUTPUT, WATTS/CC	0.	0.	0.	0.	0.0209	0.	0.0014	0.0000	0.0017
NET ISOTOPIC PRODUCTION									
GM/TON/YR	119.3	221.3	350.2	469.0	0.1	274.8	15.0	115.7	282.2
GM/MWE/YR	17.89	33.19	52.53	70.35	0.02	41.21	2.26	17.35	42.33
GM/MWH	0.0020	0.0038	0.0060	0.0080	0.0000	0.0047	0.0003	0.0020	0.0048
GM/TON	163.4	303.1	479.7	642.5	0.2	376.4	20.6	158.5	386.6
WATTS/MWE/YR	0.	0.	0.	0.	224.2	0.	15.3	0.0	17.8

EXPOSURE 15000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 1000F

ISOTOPES	XE131	XE132	XE134	XE136	XE135	CS133	CS134	CS135	CS137
HALF LIFE	STABLE	STABLE	STABLE	STABLE	9.2 HR	STABLE	2.1 YR	2E6 YR	30 YR
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	392	0	0	0	5301	165	126	8	0
AVERAGE	430	0	0	0	4188	184	126	8	0
FINAL	444	0	0	0	208	192	126	8	0
MACROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.002	0.	0.	0.	0.000	0.002	0.000	0.000	0.
FINAL	0.005	0.	0.	0.	0.000	0.005	0.000	0.000	0.
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	2.3664	4.8610	7.2840	9.8223	0.0018	5.5801	0.4349	2.4611	5.8867
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	0.	20.3	30.0	39.8	0.0	39.4	3.1	17.1	40.4
HEAT OUTPUT, WATTS/CC	0.	0.	0.	0.	0.0221	0.	0.0030	0.0000	0.0025
NET ISOTOPIC PRODUCTION									
GM/TON/YR	112.9	231.9	347.5	468.5	0.1	266.2	20.7	117.4	280.8
GM/MWE/YR	16.93	34.78	52.12	70.28	0.01	39.93	3.11	17.61	42.12
GM/MWH	0.0019	0.0040	0.0059	0.0080	0.0000	0.0046	0.0004	0.0020	0.0048
GM/TON	231.9	476.5	714.0	962.8	0.2	546.9	42.6	241.2	577.0
WATTS/MWE/YR	0.	0.	0.	0.	158.3	0.	21.2	0.0	17.7

EXPOSURE 20000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 1000F

ISOTOPES	XE131	XE132	XE134	XE136	XE135	CS133	CS134	CS135	CS137
HALF LIFE	STABLE	STABLE	STABLE	STABLE	9.2 HR	STABLE	2.1 YR	2E6 YR	30 YR
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	392	0	0	0	5301	165	126	8	0
AVERAGE	433	0	0	0	4013	186	126	8	0
FINAL	441	0	0	0	8319	191	126	8	0
MACROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.003	0.	0.	0.	0.000	0.003	0.000	0.000	0.
FINAL	0.006	0.	0.	0.	0.000	0.006	0.000	0.000	0.
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	2.9754	6.7567	9.6490	13.1100	0.0018	7.1987	0.7137	3.3083	7.8019
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	0.	21.1	29.7	39.8	0.0	38.4	3.8	17.4	40.4
HEAT OUTPUT, WATTS/CC	0.	0.	0.	0.	0.0217	0.	0.0049	0.0000	0.0033
NET ISOTOPIC PRODUCTION									
GM/TON/YR	106.4	241.7	345.2	469.0	0.1	257.5	25.5	118.4	279.1
GM/MWE/YR	15.97	36.26	51.78	70.35	0.01	38.63	3.83	17.75	41.87
GM/MWH	0.0018	0.0041	0.0059	0.0080	0.0000	0.0044	0.0004	0.0020	0.0048
GM/TON	291.6	662.3	945.8	1285.0	0.2	705.6	70.0	324.3	764.7
WATTS/MWE/YR	0.	0.	0.	0.	116.5	0.	26.0	0.0	17.6

EXPOSURE 25000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 1000F

ISOTOPES	XE131	XE132	XE134	XE136	XE135	CS133	CS134	CS135	CS137
HALF LIFE	STABLE	STABLE	STABLE	STABLE	9.2 HR	STABLE	2.1 YR	2E6 YR	30 YR
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	392	0	0	0	5301	165	126	8	0
AVERAGE	434	0	0	0	4187	187	126	8	0
FINAL	435	0	0	0	9514	188	126	8	0
MACROSCOPIC CROSS SECTION									
ABSORBTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.004	0.	0.	0.	0.000	0.004	0.000	0.000	0.
FINAL	0.007	0.	0.	0.	0.000	0.007	0.001	0.000	0.
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	3.4952	8.7686	11.9917	16.4203	0.0016	8.7003	1.0316	4.1466	9.6921
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	0.	21.9	29.5	39.8	0.0	37.5	4.4	17.6	40.5
HEAT OUTPUT, WATTS/CC	0.	0.	0.	0.	0.0193	0.	0.0070	0.0000	0.0041
NET ISOTOPIC PRODUCTION									
GM/TON/YR	100.0	251.0	343.2	470.0	0.0	249.0	29.5	118.7	277.4
GM/MWE/YR	15.01	37.64	51.48	70.49	0.01	37.35	4.43	17.80	41.61
GM/MWH	0.0017	0.0043	0.0059	0.0080	0.0000	0.0043	0.0005	0.0020	0.0047
GM/TON	342.6	859.5	1175.4	1609.5	0.2	852.8	101.1	406.4	950.0
WATTS/MWE/YR	0.	0.	0.	0.	83.0	0.	30.1	0.0	17.5

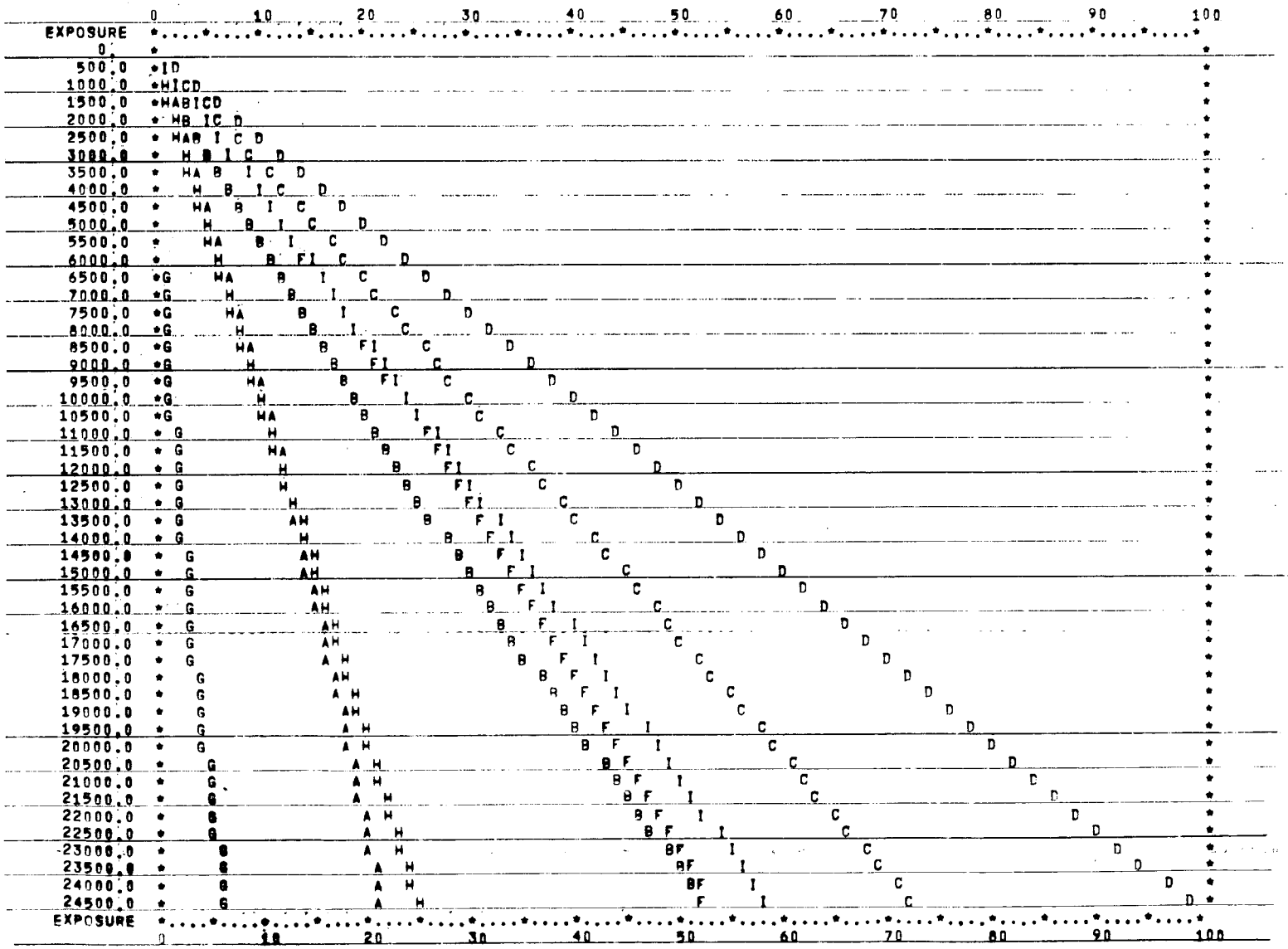
*** SPECIAL PRODUCT CONCENTRATIONS ***

FISSION PRODUCTS. XE AND CS. CASE NUMBER 1000F

A = XE131 B = XE132 C = XE134 D = XE136 E = XE135
F = CS133 G = CS134 H = CS135 I = CS137

THE FULL SCALE VALUE FOR ALL ISOTOPES IS 1600.0 GRAMS/TON

PERCENT OF FULL SCALE



EXPOSURE 5000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 3003F

ISOTOPES	RU102	RU103	RU106	RH103	PD106	PD107	TC 99	KR 86	KR 85
HALF LIFE	STABLE	40 DAY	1.0 YR	STABLE	STABLE	7E6 YR	2E5 YR	STABLE	10.4YR
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	2	26	11	541	11	9	90	0	13
AVERAGE	2	26	11	542	11	9	90	0	13
FINAL	2	26	11	543	11	9	90	0	13
MACROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.	0.000
FINAL	0.000	0.000	0.000	0.003	0.000	0.000	0.001	0.	0.000
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	3.8697	0.2989	0.8043	0.9669	1.7599	0.7021	1.3506	0.2355	0.0197
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
FINAL	78.3	6.0	15.7	100.0	71.7	28.3	100.0	0.	0.
HEAT OUTPUT, WATTS/CC	0.	0.0194	0.0249	0.	0.	0.	0.0000	0.	0.0000
NET ISOTOPIC PRODUCTION									
GM/TON/YR	553.8	42.8	115.1	138.4	251.9	100.5	193.3	33.7	2.8
GM/MWE/YR	83.06	6.42	17.26	20.75	37.78	15.07	28.99	5.05	0.42
GM/MWH	0.0095	0.0007	0.0020	0.0024	0.0043	0.0017	0.0033	0.0006	0.0000
GM/TON	379.3	29.3	78.8	94.8	172.5	68.8	132.4	23.1	1.9
WATTS/MWE/YR	0.	417.1	535.2	0.	0.	0.	0.0	0.	0.3

EXPOSURE 10000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 3003F

ISOTOPES	RU102	RU103	RU106	RH103	PD106	PD107	TC 99	KR 86	KR 85
HALF LIFE	STABLE	40 DAY	1.0 YR	STABLE	STABLE	7E6 YR	2E5 YR	STABLE	10.4YR
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	2	26	11	541	11	9	90	0	13
AVERAGE	2	26	11	542	11	9	90	0	13
FINAL	2	27	11	544	11	9	90	0	13
MACROSCOPIC CROSS SECTION									
ABSORBTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.000	0.000	0.000	0.003	0.000	0.000	0.001	0.	0.000
FINAL	0.000	0.000	0.000	0.007	0.000	0.000	0.001	0.	0.000
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	7.7715	0.3039	1.3032	2.0983	3.9581	1.4091	2.6743	0.4673	0.0380
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
FINAL	83.3	3.2	13.4	100.0	73.9	26.1	100.0	0.	0.
HEAT OUTPUT, WATTS/CC	0.	0.0198	0.0404	0.	0.	0.	0.0000	0.	0.0000
NET ISOTOPIC PRODUCTION									
GM/TON/YR	556.1	21.7	93.2	150.1	283.2	100.8	191.4	33.4	2.7
GM/MWE/YR	83.41	3.26	13.99	22.52	42.48	15.12	28.70	5.02	0.41
GM/MWH	0.0095	0.0004	0.0016	0.0026	0.0048	0.0017	0.0033	0.0006	0.0000
GM/TON	761.7	29.8	127.7	205.7	388.0	138.1	262.1	45.8	3.7
WATTS/MWE/YR	0.	212.0	433.6	0.	0.	0.	0.0	0.	0.3

EXPOSURE 15000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 3003F

ISOTOPES	RU102	RU103	RU106	RH103	PD106	PD107	TC 99	KR 86	KR 85
HALF LIFE	STABLE	40 DAY	1.0 YR	STABLE	STABLE	7E6 YR	2E5 YR	STABLE	10.4YR
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	2	26	11	541	11	9	90	0	13
AVERAGE	2	26	11	543	11	9	90	0	13
FINAL	2	27	11	545	11	9	90	0	14
MACROSCOPIC CROSS SECTION									
ABSORBTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.000	0.000	0.000	0.005	0.000	0.000	0.001	0.	0.000
FINAL	0.000	0.000	0.000	0.010	0.000	0.000	0.002	0.	0.000
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	11.7106	0.3049	1.6128	3.0850	6.4994	2.1229	3.9646	0.6951	0.0551
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
FINAL	86.3	2.2	11.4	100.0	75.6	24.4	100.0	0.	0.
HEAT OUTPUT, WATTS/CC	0.	0.0198	0.0500	0.	0.	0.	0.0000	0.	0.0000
NET ISOTOPIC PRODUCTION									
GM/TON/YR	558.6	14.5	76.9	147.2	310.0	101.3	189.1	33.2	2.6
GM/MWE/YR	83.79	2.18	11.54	22.07	46.50	15.19	28.37	4.97	0.39
GM/MWH	0.0096	0.0002	0.0013	0.0025	0.0053	0.0017	0.0032	0.0006	0.0000
GM/TON	1147.8	29.9	158.1	302.4	637.0	208.1	388.6	68.1	5.4
WATTS/MWE/YR	0.	141.8	357.7	0.	0.	0.	0.0	0.	0.3

EXPOSURE 20000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 3003F

ISOTOPES	RU102	RU103	RU106	RH103	PD106	PD107	TC 99	KR 86	KR 85
HALF LIFE	STABLE	40 DAY	1.0 YR	STABLE	STABLE	7E6 YR	2E5 YR	STABLE	10.4YR
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	2	26	11	541	11	9	90	0	13
AVERAGE	2	26	11	543	11	9	90	0	13
FINAL	2	27	11	546	11	9	90	0	14
MACROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.000	0.000	0.000	0.006	0.000	0.000	0.001	0.	0.000
FINAL	0.000	0.000	0.000	0.012	0.001	0.000	0.003	0.	0.000
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	15.6920	0.3061	1.8057	3.9127	9.3205	2.8460	5.2155	0.9181	0.0709
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
FINAL	88.5	1.7	9.8	100.0	76.8	23.2	100.0	0.	0.
HEAT OUTPUT, WATTS/CC	0.	0.0199	0.0560	0.	0.	0.	0.0000	0.	0.0001
NET ISOTOPIC PRODUCTION									
GM/TON/YR	561.4	11.0	64.6	140.0	333.5	101.8	186.6	32.8	2.5
GM/MWE/YR	84.21	1.64	9.69	21.00	50.02	15.27	27.99	4.93	0.38
GM/MWH	0.0096	0.0002	0.0011	0.0024	0.0057	0.0017	0.0032	0.0006	0.0000
GM/TON	1538.1	30.0	177.0	383.5	913.6	279.0	511.2	90.0	7.0
WATTS/MWE/YR	0.	106.8	300.4	0.	0.	0.	0.0	0.	0.3

EXPOSURE 25000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 3003F

ISOTOPES	RU102	RU103	RU106	RH103	PD106	PD107	TC 99	KR 86	KR 85
HALF LIFE	STABLE	40 DAY	1.0 YR	STABLE	STABLE	7E6 YR	2E5 YR	STABLE	10.4YR
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	2	26	11	541	11	9	90	0	13
AVERAGE	2	26	11	544	11	9	90	0	13
FINAL	2	28	11	547	11	9	90	0	14
MACROSCOPIC CROSS SECTION									
ABSORBTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.000	0.000	0.000	0.008	0.000	0.000	0.002	0.	0.000
FINAL	0.000	0.000	0.000	0.015	0.001	0.000	0.004	0.	0.000
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	19.7294	0.3076	1.9254	4.5728	12.3846	3.5815	6.4236	1.1363	0.0855
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
FINAL	90.1	1.4	8.5	100.0	77.7	22.3	100.0	0.	0.
HEAT OUTPUT, WATTS/CC	0.	0.0200	0.0597	0.	0.	0.	0.0000	0.	0.0001
NET ISOTOPIC PRODUCTION									
GM/TON/YR	564.7	8.8	55.1	130.9	354.5	102.5	183.8	32.5	2.4
GM/MWE/YR	84.70	1.32	8.27	19.63	53.17	15.38	27.58	4.88	0.37
GM/MWH	0.0097	0.0002	0.0009	0.0022	0.0061	0.0018	0.0031	0.0006	0.0000
GM/TON	1933.8	30.2	188.7	448.2	1213.9	351.0	629.6	111.4	8.4
WATTS/MWE/YR	0.	85.9	256.2	0.	0.	0.	0.0	0.	0.3

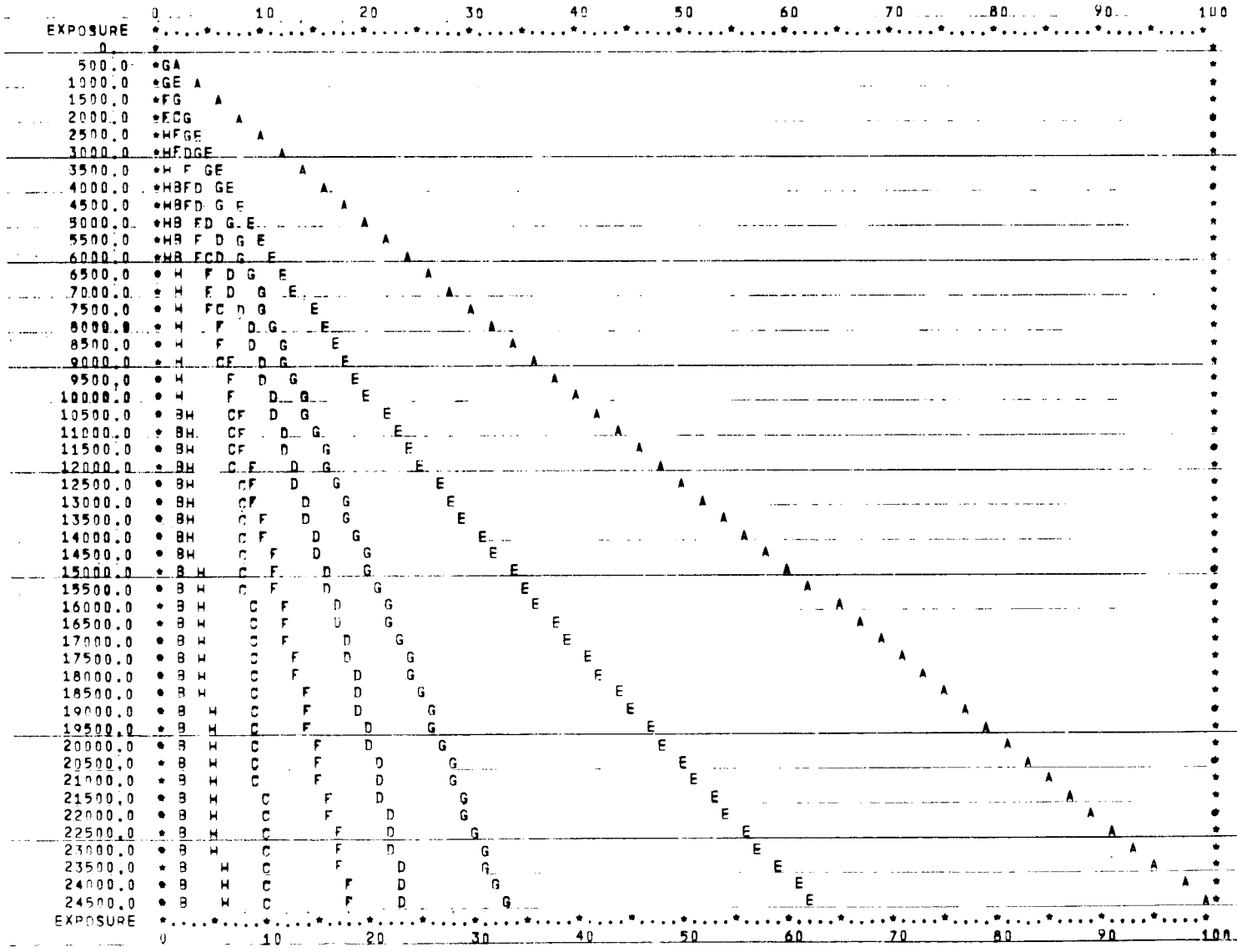
*** SPECIAL PRODUCT CONCENTRATIONS ***

FISSION PRODUCTS. RU, RH, PD, TC, AND KR. CASE NUMBER 3003F

A = RU102 B = RU103 C = RU106 D = RH103 E = PD106
F = PD107 G = TC 99 H = KR 86 I = KR 85

THE FULL SCALE VALUE FOR ALL ISOTOPES IS 1900.0 GRAMS/TON

PERCENT OF FULL SCALE



EXPOSURE 5000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 3003F

ISOTOPES	SR 88	SR 89	SR 90	CE142	CE141	CE144	PM146	PM147	PM148
HALF LIFE	STABLE	50 DAY	28 YR	STABLE	32 DAY	285DAY	1600DY	2.5 YR	42 DAY
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	0	0	1	0	26	5	7337	798	6204
AVERAGE	0	0	1	0	26	5	7379	798	6354
FINAL	0	0	1	0	27	5	7430	799	6536
MACROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.	0.	0.000	0.	0.000	0.000	0.000	0.001	0.000
FINAL	0.	0.	0.000	0.	0.000	0.000	0.000	0.002	0.000
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	0.3182	0.1129	0.5125	4.7082	0.3355	0.9857	0.0000	0.5784	0.0089
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	34.2	12.0	53.8	78.2	5.6	16.2	100.0	98.5	1.5
HEAT OUTPUT, WATTS/CC	0.	0.0126	0.0005	0.	0.0168	0.0252	0.0000	0.0002	0.0014
NET ISOTOPIC PRODUCTION									
GM/TON/YR	45.5	16.2	73.3	673.8	48.0	141.1	0.0	82.8	1.3
GM/MWE/YR	6.83	2.42	11.00	101.06	7.20	21.16	0.00	12.42	0.19
GM/MWH	0.0008	0.0003	0.0013	0.0115	0.0008	0.0024	0.0000	0.0014	0.0000
GM/TON	31.2	11.1	50.2	461.5	32.9	96.6	0.0	56.7	0.9
WATTS/MWE/YR	0.	271.4	10.5	0.	360.1	541.7	0.0	4.6	29.0

EXPOSURE 10000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 3003F

ISOTOPES	SR 88	SR 89	SR 90	CE142	CE141	CE144	PM146	PM147	PM148
HALF LIFE	STABLE	50 DAY	28 YR	STABLE	32 DAY	285DAY	1600CY	2.5 YR	42 DAY
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	0	0	1	0	26	5	7337	798	6204
AVERAGE	0	0	1	0	26	5	7424	798	6517
FINAL	0	0	1	0	27	5	7519	800	6853
MACROSCOPIC CROSS SECTION									
ABSORBTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.	0.	0.000	0.	0.000	0.000	0.000	0.002	0.000
FINAL	0.	0.	0.000	0.	0.000	0.000	0.001	0.003	0.000
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	0.6325	0.1158	1.0131	9.3386	0.3350	1.5201	0.0000	0.9782	0.0166
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	36.4	6.6	57.0	83.6	3.0	13.4	100.0	98.3	1.7
HEAT OUTPUT, WATTS/CC	0.	0.0130	0.0010	0.	0.0168	0.0389	0.0000	0.0004	0.0025
NET ISOTOPIC PRODUCTION									
GM/TON/YR	45.3	8.3	72.5	668.2	24.0	108.8	0.0	70.0	1.2
GM/MWE/YR	6.79	1.24	10.87	100.23	3.60	16.31	0.00	10.50	0.18
GM/MWH	0.0008	0.0001	0.0012	0.0114	0.0004	0.0019	0.0000	0.0012	0.0000
GM/TON	62.0	11.3	99.3	915.3	32.8	149.0	0.0	95.9	1.6
WATTS/MWE/YR	0.	139.2	10.3	0.	179.8	417.7	0.0	3.9	27.1

EXPOSURE 15000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 3003F

ISOTOPES	SR 88	SR 89	SR 90	CE142	CE141	CE144	PM146	PM147	PM148
HALF LIFE	STABLE	50 DAY	28 YR	STABLE	32 DAY	285DAY	1600DY	2.5 YR	42 DAY
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	0	0	1	0	26	5	7337	798	6204
AVERAGE	0	0	1	0	26	5	7466	799	6674
FINAL	0	0	1	0	27	5	7603	801	7152
MACROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.	0.	0.000	0.	0.000	0.000	0.000	0.002	0.000
FINAL	0.	0.	0.000	0.	0.000	0.000	0.000	0.004	0.001
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	0.9421	0.1149	1.5017	13.8864	0.3327	1.8082	0.0000	1.2403	0.0222
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	37.3	4.5	58.2	86.8	2.1	11.1	100.0	98.3	1.7
HEAT OUTPUT, WATTS/CC	0.	0.0129	0.0014	0.	0.0166	0.0463	0.0000	0.0005	0.0034
NET ISOTOPIC PRODUCTION									
GM/TON/YR	44.9	5.5	71.6	662.4	15.9	86.3	0.0	59.2	1.1
GM/MWE/YR	6.74	0.82	10.75	99.36	2.38	12.94	0.00	8.87	0.16
GM/MWH	0.0008	0.0001	0.0012	0.0113	0.0003	0.0015	0.0000	0.0010	0.0000
GM/TON	92.3	11.3	147.2	1361.1	32.6	177.2	0.0	121.6	2.2
WATTS/MWE/YR	0.	92.1	10.2	0.	119.0	331.2	0.0	3.3	24.2

EXPOSURE 20000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 3003F

ISOTOPES	SR 88	SR 89	SR 90	CE142	CE141	CE144	PM146	PM147	PM148
HALF LIFE	STABLE	50 DAY	28 YR	STABLE	32 DAY	285DAY	1600CY	2.5 YR	42 DAY
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	0	0	1	0	26	5	7337	798	6204
AVERAGE	0	0	1	0	26	5	7511	799	6825
FINAL	0	0	1	0	27	5	7679	801	7425
MACROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.	0.	0.000	0.	0.000	0.000	0.000	0.003	0.000
FINAL	0.	0.	0.000	0.	0.000	0.000	0.000	0.005	0.001
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	1.2467	0.1139	1.9769	18.3518	0.3306	1.9617	0.0000	1.3965	0.0261
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	37.9	3.4	58.7	89.0	1.6	9.4	100.0	98.2	1.8
HEAT OUTPUT, WATTS/CC	0.	0.0128	0.0019	0.	0.0165	0.0502	0.0000	0.0005	0.0040
NET ISOTOPIC PRODUCTION									
GM/TON/YR	44.6	4.1	70.7	656.6	11.8	70.2	0.0	50.0	0.9
GM/MWE/YR	6.69	0.61	10.61	98.48	1.77	10.53	0.00	7.49	0.14
GM/MWH	0.0008	0.0001	0.0012	0.0112	0.0002	0.0012	0.0000	0.0009	0.0000
GM/TON	122.2	11.2	193.8	1798.8	32.4	192.3	0.0	136.9	2.6
WATTS/MWE/YR	0.	68.4	10.1	0.	88.7	269.5	0.0	2.8	21.3

EXPOSURE 25000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 3003F

ISOTOPES	SR 88	SR 89	SR 90	CE142	CE141	CE144	PM146	PM147	PM148
HALF LIFE	STABLE	50 DAY	28 YR	STABLE	32 DAY	285DAY	1600DY	2.5 YR	42 DAY
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	0	0	1	0	26	5	7337	798	6204
AVERAGE	0	0	1	0	26	5	7550	800	6967
FINAL	0	0	1	0	28	6	7747	802	7668
MACROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.	0.	0.000	0.	0.000	0.000	0.000	0.003	0.001
FINAL	0.	0.	0.000	0.	0.000	0.000	0.000	0.005	0.001
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	1.5458	0.1126	2.4401	22.7370	0.3284	2.0413	0.0000	1.4732	0.0286
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	38.2	2.8	59.0	90.7	1.3	8.0	100.0	98.1	1.9
HEAT OUTPUT, WATTS/CC	0.	0.0126	0.0023	0.	0.0164	0.0523	0.0000	0.0005	0.0043
NET ISOTOPIC PRODUCTION									
GM/TON/YR	44.2	3.2	69.8	650.7	9.4	58.4	0.0	42.2	0.8
GM/MWE/YR	6.64	0.48	10.48	97.61	1.41	8.76	0.00	6.32	0.12
GM/MWH	0.0008	0.0001	0.0012	0.0111	0.0002	0.0010	0.0000	0.0007	0.0000
GM/TON	151.5	11.0	239.2	2228.6	32.2	200.1	0.0	144.4	2.8
WATTS/MWE/YR	0.	54.2	10.0	0.	70.5	224.3	0.0	2.3	18.6

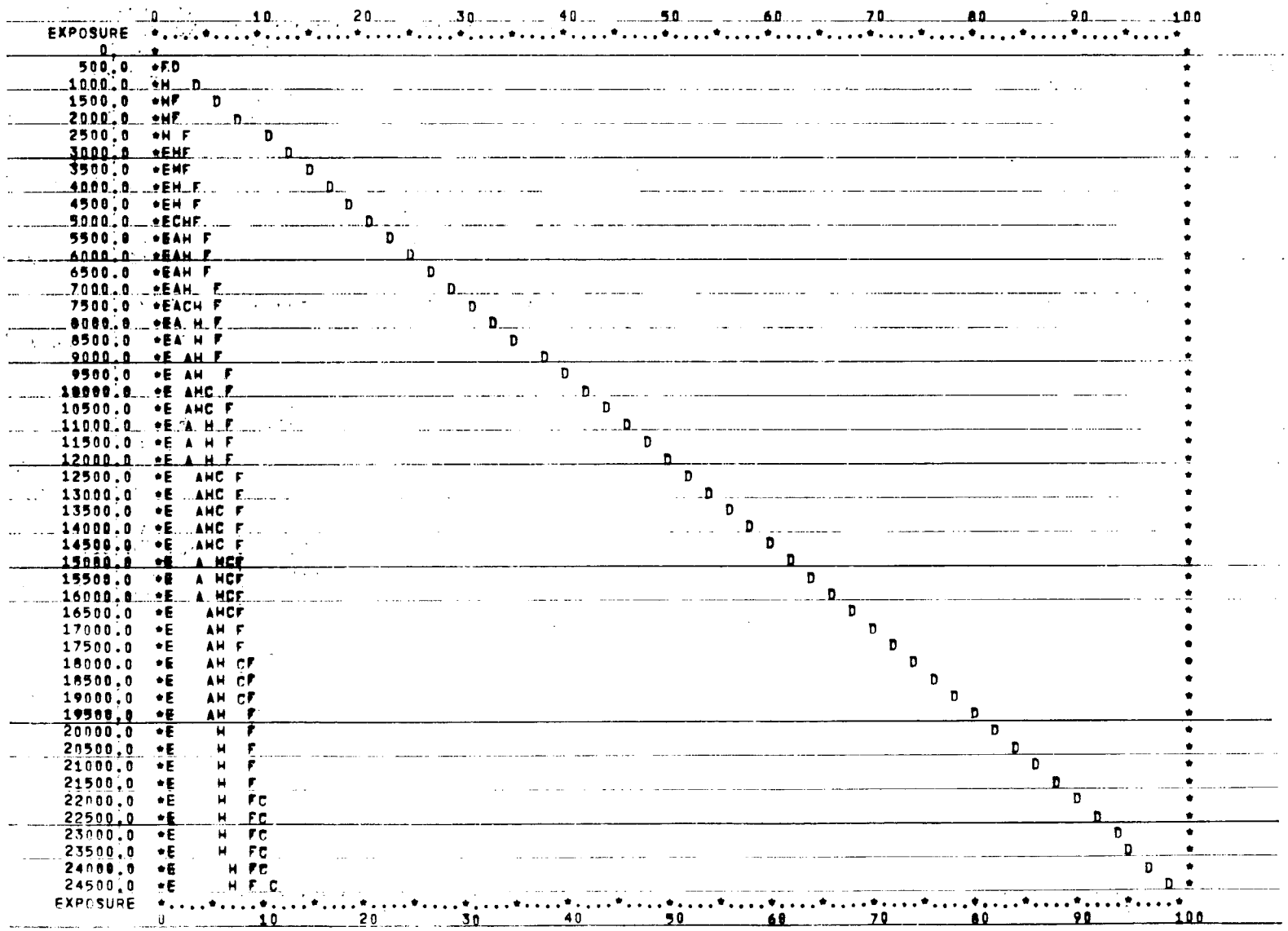
*** SPECIAL PRODUCT CONCENTRATIONS ***

SPWR WITH FISSION PRODUCTS, SR, CE, AND PM. CASE NUMBER 3003F

A = SR 88 B = SR 89 C = SR 90 D = CE142 E = CE141
F = CE144 G = PM146 H = PM147 I = PM148

THE FULL SCALE VALUE FOR ALL ISOTOPES IS 2200.0 GRAMS/TON

PERCENT OF FULL SCALE



EXPOSURE 500 .0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 3003F

ISOTOPES	XE131	XE132	XE134	XE136	XE135	CS133	CS134	CS135	CS137
HALF LIFE	STABLE	STABLE	STABLE	STABLE	9.2 HR	STABLE	2.1 YR	2E6 YR	30 YR
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	398	0	0	0	9319	170	117	8	0
AVERAGE	398	0	0	0	5918	170	117	8	0
FINAL	398	0	0	0	3057	170	118	8	0
MACROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.001	0.	0.	0.	0.000	0.001	0.000	0.000	0.
FINAL	0.002	0.	0.	0.	0.000	0.002	0.000	0.000	0.
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	1.0581	1.5948	2.2715	2.9648	0.0026	2.0221	0.0311	1.1850	2.0351
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	0.	20.5	28.8	37.0	0.0	38.9	0.6	22.5	38.0
HEAT OUTPUT, WATTS/CC	0.	0.	0.	0.	0.0307	0.	0.0002	0.0000	0.0009
NET ISOTOPIC PRODUCTION									
GM/TON/YR	151.4	228.2	325.1	424.3	0.4	289.4	4.4	169.6	291.2
GM/MWE/YR	22.71	34.23	48.76	63.64	0.05	43.40	0.67	25.44	43.68
GM/MWH	0.0026	0.0039	0.0056	0.0073	0.0000	0.0050	0.0001	0.0029	0.0050
GM/TON	103.7	156.3	222.6	290.6	0.3	198.2	3.0	116.2	199.5
WATTS/MWE/YR	0.	0.	0.	0.	659.3	0.	4.5	0.0	18.3

EXPOSURE 10000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 3003F

ISOTOPES	XE131	XE132	XE134	XE136	XE135	CS133	CS134	CS135	CS137
HALF LIFE	STABLE	STABLE	STABLE	STABLE	9.2 HR	STABLE	2.1 YR	2E6 YR	30 YR
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	398	0	0	0	9319	170	117	8	0
AVERAGE	397	0	0	0	4765	170	117	8	0
FINAL	397	0	0	0	6961	170	119	8	0
MACROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.002	0.	0.	0.	0.000	0.001	0.000	0.000	0.
FINAL	0.004	0.	0.	0.	0.000	0.003	0.000	0.000	0.
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	2.0269	3.2786	4.5408	5.9882	0.0024	3.9703	0.1215	2.3109	4.0374
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	0.	21.0	28.7	37.2	0.0	38.6	1.2	22.1	38.1
HEAT OUTPUT, WATTS/CC	0.	0.	0.	0.	0.0291	0.	0.0008	0.0000	0.0017
NET ISOTOPIC PRODUCTION									
GM/TON/YR	145.0	234.6	324.9	428.5	0.2	284.1	8.7	165.3	288.9
GM/MWE/YR	21.75	35.19	48.74	64.27	0.03	42.61	1.30	24.80	43.33
GM/MWH	0.0025	0.0040	0.0056	0.0073	0.0000	0.0049	0.0001	0.0028	0.0049
GM/TON	198.7	321.4	445.1	586.9	0.2	389.2	11.9	226.5	395.7
WATTS/MWE/YR	0.	0.	0.	0.	312.4	0.	8.9	0.0	18.2

EXPOSURE 15000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 3003F

ISOTOPES	XE131	XE132	XE134	XE136	XE135	CS133	CS134	CS135	CS137
HALF LIFE	STABLE	STABLE	STABLE	STABLE	9.2 HR	STABLE	2.1 YR	2E6 YR	30 YR
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	398	0	0	0	9319	170	117	8	0
AVERAGE	397	0	0	0	4701	170	118	8	0
FINAL	397	0	0	0	8751	170	121	8	0
MACROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.003	0.	0.	0.	0.000	0.002	0.000	0.000	0.
FINAL	0.005	0.	0.	0.	0.000	0.004	0.000	0.000	0.
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	2.8971	5.0582	6.8079	9.0727	0.0023	5.8297	0.2688	3.3756	6.0050
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	0.	21.5	28.5	37.5	0.0	38.2	1.7	21.8	38.2
HEAT OUTPUT, WATTS/CC	0.	0.	0.	0.	0.0272	0.	0.0018	0.0000	0.0025
NET ISOTOPIC PRODUCTION									
GM/TON/YR	138.2	241.3	324.7	432.8	0.1	278.1	12.8	161.0	286.4
GM/MWE/YR	20.73	36.19	48.71	64.92	0.02	41.71	1.92	24.15	42.97
GM/MWH	0.0024	0.0041	0.0056	0.0074	0.0000	0.0048	0.0002	0.0028	0.0049
GM/TON	284.0	495.8	667.3	889.3	0.2	571.4	26.3	330.9	588.6
WATTS/MWE/YR	0.	0.	0.	0.	194.8	0.	13.1	0.0	18.0

EXPOSURE 20001.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 3003F

ISOTOPES	XE131	XE132	XE134	XE136	XE135	CS133	CS134	CS135	CS137
HALF LIFE	STABLE	STABLE	STABLE	STABLE	9.2 HR	STABLE	2.1 YR	2E6 YR	30 YR
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	398	0	0	0	9319	170	117	8	0
AVERAGE	397	0	0	0	4834	170	119	8	0
FINAL	397	0	0	0	7686	170	122	8	0
MACROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.003	0.	0.	0.	0.000	0.003	0.000	0.000	0.
FINAL	0.007	0.	0.	0.	0.000	0.006	0.000	0.000	0.
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	3.6583	6.9474	9.0728	12.2181	0.0021	7.5896	0.4723	4.3797	7.9430
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	0.	22.1	28.4	37.7	0.0	37.8	2.3	21.5	38.4
HEAT OUTPUT, WATTS/CC	0.	0.	0.	0.	0.0256	0.	0.0032	0.0000	0.0033
NET ISOTOPIC PRODUCTION									
GM/TON/YR	130.9	248.5	324.6	437.1	0.1	271.5	16.9	156.7	284.2
GM/MWE/YR	19.63	37.28	48.69	65.57	0.01	40.73	2.53	23.50	42.63
GM/MWH	0.0022	0.0043	0.0056	0.0075	0.0000	0.0046	0.0003	0.0027	0.0049
GM/TON	358.6	681.0	889.3	1197.6	0.2	743.9	46.3	429.3	778.5
WATTS/MWE/YR	0.	0.	0.	0.	137.4	0.	17.2	0.0	17.9

EXPOSURE 25000.0 MWD/T *** PROPERTIES OF SPECIAL PRODUCTS *** CASE NUMBER 3003F

ISOTOPES	XE131	XE132	XE134	XE136	XE135	CS133	CS134	CS135	CS137
HALF LIFE	STABLE	STABLE	STABLE	STABLE	9.2 HR	STABLE	2.1 YR	2E6 YR	30 YR
MICROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	398	0	0	0	9319	170	117	8	0
AVERAGE	397	0	0	0	4783	170	120	8	0
FINAL	397	0	0	0	3512	171	123	8	0
MACROSCOPIC CROSS SECTION									
ABSORPTION-INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
AVERAGE	0.004	0.	0.	0.	0.000	0.004	0.000	0.000	0.
FINAL	0.008	0.	0.	0.	0.000	0.007	0.000	0.000	0.
ISOTOPIC DENSITY MILLIGRAM/CC									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	4.3021	8.9527	11.3354	15.4222	0.0020	9.2325	0.7311	5.3278	9.8468
PERCENT OF ELEMENT COMPOSITION									
INITIAL	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
FINAL	0.	22.7	28.3	38.0	0.0	37.3	2.9	21.2	38.6
HEAT OUTPUT, WATTS/CC	0.	0.	0.	0.	0.0236	0.	0.0050	0.0000	0.0041
NET ISOTOPIC PRODUCTION									
GM/TON/YR	123.1	256.2	324.4	441.4	0.1	264.2	20.9	152.5	281.8
GM/MWE/YR	18.47	38.43	48.66	66.21	0.01	39.64	3.14	22.87	42.27
GM/MWH	0.0021	0.0044	0.0056	0.0076	0.0000	0.0045	0.0004	0.0026	0.0048
GM/TON	421.7	877.5	1111.1	1511.6	0.2	904.9	71.7	522.2	965.1
WATTS/MWE/YR	0.	0.	0.	0.	101.2	0.	21.3	0.0	17.8

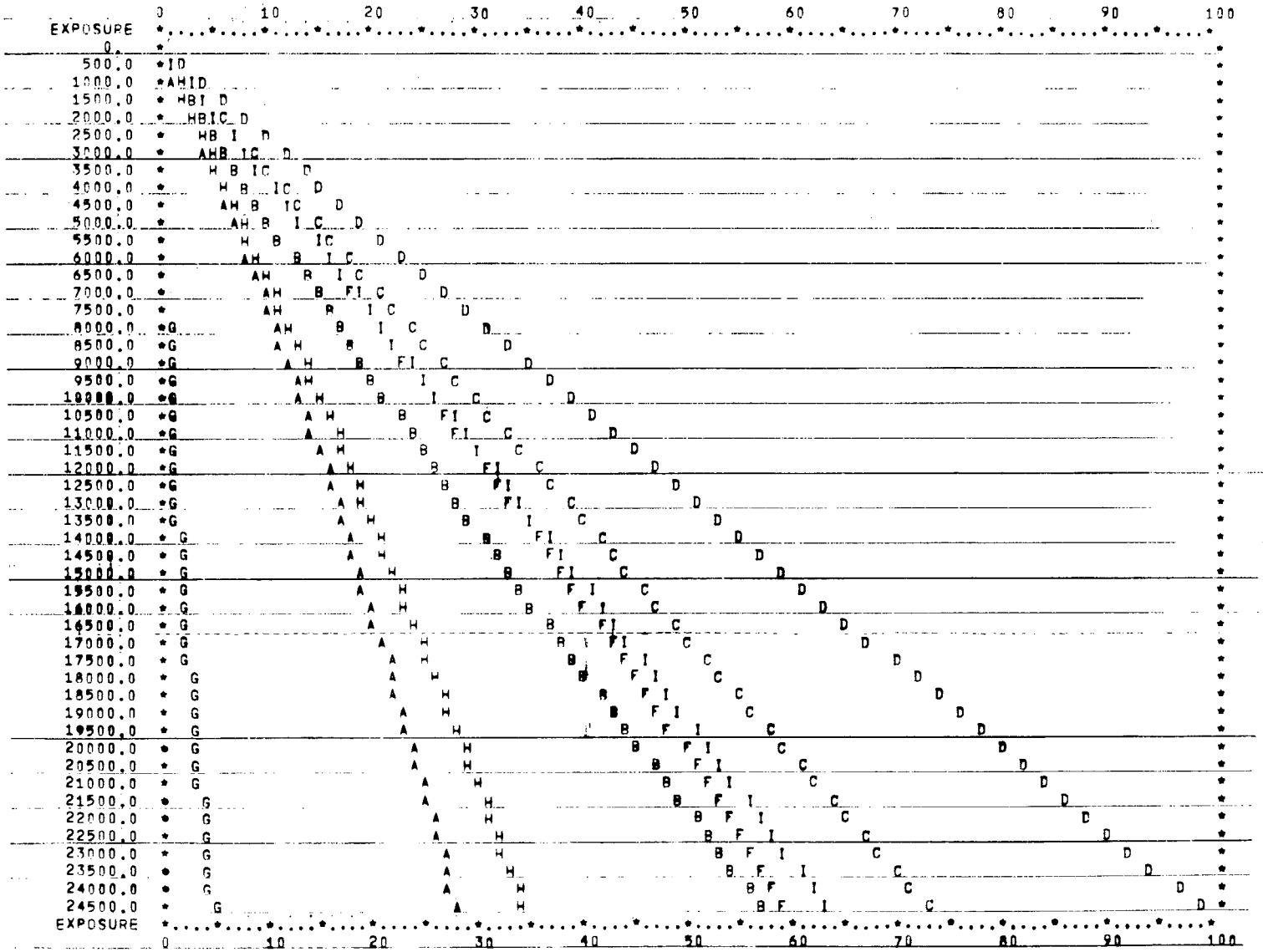
*** SPECIAL PRODUCT CONCENTRATIONS ***

FISSION PRODUCTS. XE AND CS. CASE NUMBER 3003F

A = XE131 B = XE132 C = XE134 D = XE136 E = XE135
F = CS133 G = CS134 H = CS135 I = CS137

THE FULL SCALE VALUE FOR ALL ISOTOPES IS 1500.0 GRAMS/TON

PERCENT OF FULL SCALE



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