NUREG/CR-2762
ORNL-5884

An ORIGEN2 Model and Results for the Clinch River Breeder Reactor

Prepared by A. G. Croff, M. A. Bjerke

Oak Ridge National Laboratory

Prepared for
U.S. Nuclear Regulatory
Commission

Available from

GPO Sales Program
Division of Technical Information and Document Control
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Printed copy price: $6.00

and

National Technical Information Service
Springfield, Virginia 22161

NUREG/CR-2762
ORNL-5884

An ORIGEN2 Model and Results for the Clinch River Breeder Reactor

Manuscript Completed: June 1982
Date Published: July 1982

Prepared by
A. G. Croff, M. A. Bjerke

Oak Ridge National Laboratory
Oak Ridge, TN 37830

Prepared for
Division of Fuel Cycle and Material Safety
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
NRC FIN B0009

ABSTRACT

Reactor physics calculations and literature information acquisition have led to the development of a Clinch River Breeder Reactor (CRBR) model for the ORIGEN2 computer code. The model is based on cross sections taken directly from physics codes. Details are presented concerning the physical description of the fuel assemblies, the fuel management scheme, irradiation parameters, and initial material compositions. The ORIGEN2 model for the CRBR has been implemented, resulting in the production of graphical and tabular characteristics (radioactivity, thermal power, and toxicity) of CRBR spent fuel, high-level waste, and fuel-assembly structural material waste as a function of decay time. Characteristics for pressurized water reactors (PWRs), commercial liquid-metal fast breeder reactors (LMFBRs), and the Fast Flux Test Facility (FFTF) have also been included in this report for comparison with the CRBR data.

CONTENTS

LIST OF TABLES

AN ORIGEN2 MODEL AND RESULTS FOR THE CLINCH RIVER BREEDER REACTOR

A. G. Croff
M. A. Bjerke

1. INTRODUCTION

The purpose of this document is to describe the development of an ORIGEN2[1,2] model for the Clinch River Breeder Reactor (CRBR). The model is being developed to support the work of the Nuclear Regulatory Commission (NRC) and its subcontractors concerning the licensing activities for the CRBR.

The development of a model for ORIGEN2 involves a series of computational and analytical tasks to provide the data libraries and input parameters required by ORIGEN2. The model development described herein follows the pattern and methods established during the development of models for a variety of thermal and fast reactors.[3-6] The first step is to acquire a general set of cross sections for the nuclides of interest and to process them into a format suitable for further, reactor-specific calculations. These cross sections are then used to calculate the neutron spectra characteristic of the various fuel zones within the reactor. These neutron spectra are a key result, and their further use as weighting functions for cross sections and fission product yields leads to the generation of CRBR cross-section and fission product yield libraries for use in ORIGEN2. These calculations are described in more detail in Sect. 2.

The model developer must simultaneously obtain information concerning (1) the physical description of the fuel elements and assemblies [used by the physics codes and by the ultimate model user], (2) the fuel management scheme for the CRBR [used principally as input to the physics calculations and ORIGEN2], (3) the initial composition of the fuels and fuel assembly structural materials [used as input to the physics codes and ORIGEN2], and (4) the relevant irradiation parameters from the reactor developer [used as input to ORIGEN2]. The result is a physical and compositional description of the materials going into the CRBR each cycle, the cross sections and half-lives (from prior work) of the nuclides while in the reactor, and the neutron flux exposure each material receives in the reactor. The details concerning this information and its sources are given in Sect. 3.

The information comprising the CRBR model is then used as input to the ORIGEN2 computer code to characterize the CRBR fuel cycle materials with respect to radioactivity, heat generation, and other characteristics. The CRBR model has been implemented through the ORIGEN2 code; the results of this implementation are described in Sect. 4 and are presented in the Appendixes. Detailed results are given for the CRBR materials as well as overall results comparing CRBR with other reactors.

2. DESCRIPTION OF REACTOR PHYSICS CALCULATIONS AND BASES

There are two basic steps involved in performing the reactor physics calculations necessary to provide the cross sections and flux parameters required by ORIGEN2. The first is to obtain and process system-independent cross sections into a form that is appropriate for the general type of reactor being considered. The second step involves using these cross sections to calculate the nuclear parameters characteristic of the specific reactor type and fuel composition of interest.

2.1 Sources and Processing of Cross Section Data

The sources of the system-independent cross sections used in the reactor physics calculations and the processing of these cross sections into a library that is generally applicable to LMFBRs are described in Ref. 7 and will be summarized here.

The cross sections for the fission product nuclides were obtained from ENDF/B-IV.[8] The cross sections for the actinides and structural material elements were obtained from ENDF/B-V.[9] All of these nuclides except ^{233}U and ^{241}Pu were processed with the NPTXS and XLACS2 modules of the AMPX system.[10] The ^{233}U and ^{241}Pu were processed with the NJOY code[11] because their cross sections were initially in a different format. The result was a 126-energy-group, cross-section library for the fission-product nuclides listed in Table 1 and the actinides and other materials listed in Table 2. This master library is appropriate for subsequent reactor physics calculations for LMFBRs.

2.2 CRBR Reactor Physics Calculations

For the reactor physics calculations, the master, multigroup, cross-section library described in Sect. 2.1 must first be processed into a situation-specific, cross-section library (working library) which is characteristic of a particular fuel composition and geometry. This is done by using the NITAWL module of the AMPX computer code system. When given information about the fuel region of a fuel element, such as the Doppler temperature, the coolant concentration, the dimensions, and the nuclide concentrations, the NITAWL module accounts for (1) the Doppler broadening of the resonances and (2) the fact that the effect of large resonances is diminished because there are relatively few neutrons at the resonance energy. The relevant dimensions and nuclide concentrations were obtained from Table 4.3-4 of Re. 12.

This working library is then used by the XSDRNPM module of AMPX, which accounts for the spatial and energy self-shielding effects within the fuel materials. To do this, the code performs a one-dimensional, static, S_8P_3, discrete-ordinates, neutron-spectrum calculation and then uses this spectrum as a weighting function for the input cross sections.

Table 1. ORIGEN2 fission-product nuclides[a]

^{72}Ge	^{73}Ge	^{74}Ge	^{75}As	^{76}Ge	^{76}Se	^{77}Se	^{78}Se
^{79}Br	^{80}Se	^{80}Kr	^{81}Br	^{82}Se	^{82}Kr	^{83}Kr	^{84}Kr
^{85}Kr	^{85}Rb	^{86}Kr	^{86}Rb	^{86}Sr	^{87}Rb	^{87}Sr	^{88}Sr
^{89}Sr	^{89}Y	^{90}Sr	^{90}Y	^{90}Zr	^{91}Y	^{91}Zr	^{92}Zr
^{93}Zr	^{93}Nb	^{94}Zr	^{94}Nb	^{94}Mo	^{95}Zr	^{95}Nb	^{95}Mo
^{96}Zr	^{96}Mo	^{97}Mo	^{98}Mo	^{99}Mo	^{99}Tc	^{99}Ru	^{100}Mo
^{100}Ru	^{101}Ru	^{102}Ru	^{103}Ru	^{103}Rh	^{104}Ru	^{104}Pd	^{105}Ru
^{105}Rh	^{105}Pd	^{106}Ru	^{106}Pd	^{107}Pd	^{107}Ag	^{108}Pd	^{108}Cd
^{109}Ag	^{110}Pd	^{110}Cd	^{111}Ag	^{111}Cd	^{112}Cd	^{113}Cd	^{113}In
^{114}Cd	^{115m}Cd	^{115}In	^{115}Sn	^{116}Cd	^{116}Sn	^{117}Sn	^{118}Sn
^{119}Sn	^{120}Sn	^{121}Sb	^{122}Sn	^{122}Te	^{123}Sn	^{123}Sb	^{123}Te
^{124}Sn	^{124}Sb	^{124}Te	^{125}Sn	^{125}Sb	^{125}Te	^{126}Sn	^{126}Sb
^{126}Te	^{127m}Te	^{127}I	^{128}Te	^{128}Xe	^{129m}Te	^{129}I	^{129}Xe
^{130}Te	^{130}I	^{130}Xe	^{131}I	^{131}Xe	^{132}Te	^{132}Xe	^{133}Xe
^{133}Cs	^{134}Xe	^{134}Cs	^{134}Ba	^{135}I	^{135}Xe	^{135}Cs	^{135}Ba
^{136}Xe	^{136}Cs	^{136}Ba	^{137}Cs	^{137}Ba	^{138}Ba	^{139}La	^{140}Ba
^{140}La	^{140}Ce	^{141}Ce	^{141}Pr	^{142}Ce	^{142}Pr	^{142}Nd	^{143}Ce
^{143}Pr	^{143}Nd	^{144}Ce	^{144}Nd	^{145}Nd	^{146}Nd	^{147}Nd	^{147}Pm
^{147}Sm	^{148}Nd	^{148}Pm	^{148m}Pm	^{148}Sm	^{149}Pm	^{149}Sm	^{150}Nd
^{150}Sm	^{151}Pm	^{151}Sm	^{151}Eu	^{152}Sm	^{152}Eu	^{153}Sm	^{153}Eu
^{154}Sm	^{154}Eu	^{154}Gd	^{155}Eu	^{155}Gd	^{156}Eu	^{156}Gd	^{157}Eu
^{157}Gd	^{158}Gd	^{159}Tb	^{160}Gd	^{160}Tb	^{160}Dy	^{161}Dy	^{162}Dy
^{163}Dy	^{164}Dy	^{165}Ho	^{166}Er	^{167}Er			

[a]All cross sections are taken from Ref. 8 and documented in Ref. 7.

Table 2. Non-fission-product nuclides included in reactor physics calculations[a]

^{1}H	^{231}Pa	^{241}Am
^{10}B	^{233}Pa	^{242}Am
^{11}B	^{232}U	^{242m}Am
^{12}C	^{233}U	^{243}Am
^{14}N	^{234}U	^{241}Cm
^{15}N	^{235}U	^{242}Cm
^{16}O	^{236}U	^{243}Cm
^{17}O	^{237}U	^{244}Cm
^{23}Na	^{238}Np	^{245}Cm
^{52}Cr	^{237}Np	^{246}Cm
^{55}Mn	^{238}Np	^{247}Cm
^{56}Fe	^{236}Pu	^{248}Cm
^{59}Co	^{237}Pu	^{249}Bk
^{58}Ni	^{238}Pu	^{249}Cf
^{92}Zr	^{239}Pu	^{250}Cf
^{93}Nb	^{240}Pu	^{251}Cf
^{98}Mo	^{241}Pu	^{252}Cf
^{120}Sn	^{242}Pu	^{253}Cf
^{230}Th	^{243}Pu	^{253}Es
^{232}Th	^{244}Pu	

[a]All cross sections are taken from Ref. 9 and documented in Ref. 7.

In the case of the CRBR, two one-dimensional traverses were calculated. The first was a radial traverse across the CRBR core, which was divided into 10 zones according to the type of fuel in each zone. The second traverse was an axial traverse, which was divided into 4 zones according to the type of fuel or the density of structural materials present in a particular area. The dimensions of these zones are given in Table 3.

2.3 Results of the Reactor Physics Calculations

2.3.1 Neutron spectrum

The central result of the reactor physics calculations is the multigroup neutron energy spectrum in each of the fuel zones of the CRBR description included in XSDRNPM. These spectra were calculated in a 126-energy-group structure corresponding to the structure of the cross-section library employed in the analysis. A listing of the multigroup neutron spectra, which have been averaged across similar fuel zones, is given in Appendix A, along with graphs of the neutron spectra.

As noted earlier, the XSDRNPM code has the capability to collapse the 126-energy-group spectra into a coarser group structure specified by the user. Calculations by XSDRNPM were performed in which the 126-group spectra were collapsed into two different 2-group spectra for each of the following fuel types: core [$(Pu,U)O_2$ fuel], inner blanket, radial blanket, and axial blanket. These 2-group spectra are, in turn, used to calculate the ORIGEN2 flux parameters THERM, RES, and FAST according to the method described in Ref. 1. The values of the ORIGEN2 flux parameters determined by this procedure are given in Table 4.

2.3.2 One-group cross sections

Another important result of the XSDRNPM calculations is the production of 1-energy-group cross sections by using the 126-group spectra as a weighting function for the 126-group cross sections in the working library mentioned earlier. The result is a single value for each nuclide in each of the fuel types that is suitable for input to ORIGEN2, but which nevertheless reflects the sophistication of the reactor physics codes underlying them. This type of calculation is possible only for nuclides for which multigroup, cross-section data is available, currently about 240 of the most important nuclides. These cross sections are listed in Appendix B.

Table 3. Layout and dimensions of CRBR core models for XSDRNPM calculations

Zone number	Radial traverse		Axial traverse	
	Description	Outer radius, cm	Description	Outer radius, cm
1	Inner blanket No. 1	16.5	Core fuel	46.0
2	Core fuel No. 1	27.2	Axial blanket	81.6
3	Inner blanket No. 2	37.9	Gas plenum	203.9
4	Core fuel No. 2	48.7	End pieces	233.9
5	Inner blanket No. 3	57.5		
6	Core fuel No. 3	68.6		
7	Inner blanket No. 4	76.6		
8	Core fuel No. 4	95.8		
9	Radial blanket	118.6		
10	Radial shield	143.2		

Table 4. ORIGEN2 flux parameters for the CRBR model

Fuel type	THERM	RES	FAST
Core	4.4637E-10	1.5935E-03	0.1511
Inner blanket	5.5863E-09	1.8448E-03	0.1073
Radial blanket	1.5628E-06	2.5831E-03	0.0778
Axial blanket	2.8291E-06	3.0646E-03	0.0558

2.3.3 End-piece activation ratios

The axial XSDRNPM calculations were also used to determine the activation rate of the stainless steel fuel-assembly structural material in the zones outside of the fuel zones (e.g., gas plenum) as compared to the activation rate in the axial blanket zone. These rates were then used to determine the equivalent fraction of the axial blanket flux to which the fuel-assembly structural material nuclides had been exposed. These fractions are 0.19 for the gas plenum and lower fuel-assembly shield and 0.015 for the end pieces for all nuclides except ^{59}Co, which has activation ratios that are 3.5 times those listed.

3. DESCRIPTION OF ORIGEN2 REACTOR MODEL

This section contains a summary description of the CRBR model for the ORIGEN2 computer code. Included are: a description of the sources of input data, such as cross sections and decay data, a discussion of the fuel management data upon which the CRBR model is based; a physical description of the CRBR fuel assemblies; a listing of the assumed initial material compositions; and a summary description of the CRBR model's irradiation characteristics and mass flows.

3.1 Sources of Input Data

The sources of the cross sections and ORIGEN2 flux parameters were described in the previous section and will not be repeated here. In addition to these cross sections, there are many nuclides for which some cross-section data have been measured, but have not been expressed as a multigroup cross section. This information is typically expressed as a

thermal (0.0253 eV) cross section and a resonance integral. For those nuclides without multigroup data, thermal cross sections and resonance integrals were obtained from Ref. 13, weighted with the appropriate ORIGEN2 flux parameters described in Sect. 2.3.1, and incorporated into the ORIGEN2 cross-section libraries.

The fission-product yields from neutron-induced, actinide fission were obtained from ENDF/B-IV, weighted using the neutron spectra described earlier, and incorporated into the ORIGEN2 libraries. Explicit yields are included for ^{232}Th, $^{233,235,236}U$, and $^{239,241}Pu$.

The decay and photon data were obtained from a variety of sources, depending on the data type of interest. A detailed description is given in Ref. 14.

3.2 Fuel Management Information

The CRBR fuel management scheme is somewhat complex because the fuel pattern for fuel ages and locations in the reactor does not repeat for many years. The details of the CRBR fuel management scheme, which are based on information from Sect. 4.3 of Ref. 12, are projected for cycles 5 through 10 in Appendix C, Table C.1; for reference, a schematic of the CRBR core layout is given in Fig. C.1.[12] The following summarizes the CRBR fuel management scheme after the first 2 cycles:[12]

1. Initially, the CRBR contains 156 core assemblies and 82 inner blanket assemblies (including their respective upper and lower axial blankets). These are irradiated for 1 cycle (275 full-power days). At that point 6 inner blanket assemblies are discharged and replaced by 6 core assemblies, resulting in 162 core assemblies and 76 inner blanket assemblies. These are irradiated for another cycle, after which all core and inner blanket assemblies are discharged.

2. The inner radial blanket ring is inserted and irradiated for 4 cycles, at which time it is discharged and replaced in its entirety.

3. The outer radial blanket ring is inserted and irradiated for 5 cycles, at which time it is discharged and replaced in its entirety.

4. No shuffling of fuel takes place except for the replacement of 6 inner blanket assemblies with 6 core assemblies noted above.

The detailed irradiation information that supports the values used in the ORIGEN2 calculations is given in Appendix C, Table C.2. This information is based on data given in Tables 4.3-7, 4.3-8, and 4.3-9 of Ref. 12.

3.3 Fuel Assembly Description

A physical description of the CRBR fuel assemblies is of interest in the design of hardware to handle and transport the assemblies and in the prediction of the amounts of fuel assembly structural material wastes that will be produced by reprocessing the fuel. This description, obtained from Refs. 12 and 15, is summarized in Table 5.

Also of interest is the composition of the fuel-assembly structural material, which is assumed to be comprised entirely of stainless steel 316. The metal's initial composition[16] is used as input data for ORIGEN2 and is shown in Table 6.

3.4 Initial Fuel Material Composition

The core fuel of the CRBR is comprised of an intimate mixture of uranium and plutonium dioxides, with the plutonium dioxide accounting for 33 wt % of the total $(Pu,U)O_2$ mass.[12] The other fuel zones (axial, inner, and radial blankets) are composed of ^{235}U-depleted uranium dioxide tails from the uranium enrichment process. The initial composition of a unit amount of the core and blanket heavy metal is given in Table 7.[12,17] Also given in this table is the composition of the core heavy metal after 4 yr of decay to simulate preirradiation delays in the fabrication and storage phases. The most important effect of this decay time is the production of ^{241}Am from ^{241}Pu, which has a 14.7-yr half-life.

The second aspect of the initial composition of the CRBR fuels concerns the nonactinide content of the fuel, which is given in Table 8.[18-22] All of these elements except oxygen are ppm-level impurities that result during the preparation of the fuel material and the fabrication process. The oxygen content represents the stoichiometric quantity for a heavy metal dioxide.

3.5 Summary Characterization of the CRBR

The information generated as a result of the calculations, analyses, and input data described in Sects. 2 and 3.1–3.4 were used by the ORIGEN2 computer code to calculate the discharge composition of the various fuel zones. A comparison of the discharge composition predicted by ORIGEN2 with that obtained from Ref. 12 is given in Table 9. The agreement is excellent, with the exception of ^{241}Pu, which differs by about 11%. This is attributed to differing assumptions concerning the preirradiation and refueling decays during the calculations.

The discharge composition of the various fuel zones, in concert with the information developed previously in support of the CRBR model for ORIGEN2, was combined to yield the summary characterization for the CRBR and its fuel cycle that is presented in Table 10. The average

Table 5. Physical characteristics of CRBR fuel assemblies[a]

	Core and axial blanket	Inner and radial blankets
Assembly component lengths, cm		
Upper end hardware	30.4	30.4
Gas plenum	124.5	124.5
Upper axial blanket	35.6	
Core or radial blanket	91.4	162.6
Lower axial blanket	35.6	
Lower end hardware	109.2	109.2
Overall total	426.7	426.7
Fuel element total	290.6	291.5
Assembly shape	hexagonal	hexagonal
Assembly flats, cm	11.62	11.62
Fuel element arrangement	triangular	triangular
Fuel elements per assembly	217	61
Fuel element OD, cm	0.584	1.285
Fuel pellet OD, cm		
Core	0.491	
Axial blanket	0.483	
Inner and radial blanket		1.194
Fuel pellet density, % of theoretical		
Core	91.3	
Axial blanket	96.0	
Inner and radial blanket		95.6
Fuel element pitch, cm	0.731	1.378
Cladding thickness, cm	0.038	0.038
Channel thickness, cm	0.305	0.305
Channel height, cm	314	314
Circumscribed volume/assembly, m^3	0.0607	0.0607
Heavy metal/assembly, kg	60.35	100.85
$(Pu,U)O_2$ per assembly, kg[b]	68.45	114.39
Stainless steel/assembly, kg	135.5	122.6
Assembly total weight, kg	204	237

[a]Based on data in Ref. 12.

[b]$(Pu,U)O_2$ in the core and UO_2 in the axial, inner, and radial blankets.

Table 6. Typical composition of stainless steel 316[a,b]

Element	Atomic number	Amount, g/10^6 g metal
B	5	5
C	6	610
N	7	320
Al	13	165
Si	14	5,700
P	15	204
S	16	150
Ti	22	150
Cr	24	170,500
Mn	25	18,500
Fe	26	643,726
Co	27	150
Ni	28	135,500
Cu	29	900
Nb	41	100
Mo	42	23,400
Sn	50	40
Pb	82	30

[a]Data from Ref. 16.

[b]Density = 8.02 g/cm^3.

Table 7. Initial composition of 1000 kg of CRBR heavy metal[a]

Nuclide	Material type		
	Fuel		Blankets
	No decay	4-yr decay	
^{234}U, g	0	6	
^{235}U, g	1,340	1,372	2,000
^{236}U, g	0	16	
^{238}U, g	668,660	668,660	998,000
Total uranium, g	670,000	670,054	1,000,000
^{237}Np, g	0	4	
^{236}Pu, g	0.005	0.002	
^{238}Pu, g	198	192	
^{239}Pu, g	283,932	283,900	
^{240}Pu, g	38,610	38,594	
^{241}Pu, g	6,600	5,444	
^{242}Pu, g	660	660	
Total plutonium, g	330,000	328,790	
^{241}Am, g	0	1,152	
Total heavy metal, g	1,000,000	1,000,000	1,000,000

[a]Based on Refs. 12 and 17.

Table 8. Assumed nonactinide composition of CRBR oxide fuels[a]

Element	Atomic number	Concentration (g/MTIHM)[b]	Element	Atomic Number	Concentration (g/MTIHM)[b]
Li	3	1.0	Mn	25	1.7
B	5	1.0	Fe	26	18.0
C	6	89.4	Co	27	1.0
N	7	25.0	Ni	28	24.0
O	8	134,454[c]	Cu	29	1.0
F	9	10.7	Zn	30	40.3
Na	11	15.0	Mo	42	10.0
Mg	12	2.0	Ag	47	0.1
Al	13	16.7	Cd	48	25.0
Si	14	12.1	In	49	2.0
P	15	35.0	Sn	50	4.0
Cl	17	5.3	Gd	64	2.5
Ca	20	2.0	W	74	2.0
Ti	22	1.0	Pb	82	1.0
V	23	3.0	Bi	83	0.4
Cr	24	4.0			

[a]Data obtained from Refs. 18 to 22.

[b]Parts of element per million parts of heavy metal.

[c]Stoichiometric quantity for $(Pu,U)O_2$ fuel.

Table 9. Comparison of core fuel-discharge composition predictions

Nuclide	Predicted discharge composition, g/MTIHM	
	ORIGEN2	CRBR[a]
^{235}U	952	1,002
^{238}U	635,800	635,274
^{239}Pu	226,900	223,570
^{240}Pu	50,420	50,910
^{241}Pu	6,746	6,067
^{242}Pu	1,011	965

[a]Based on Ref. 12, Table 4.3-4.

Table 10. Summary characteristics for the CRBR

Parameter	Fuel region[a]					
	Fuel	AB	Fuel + AB	IB	RB[b]	Fuel + AB + IB + RB
Electric power, MW(e) net	267.4	6.1	273.5	46.9	29.6	350.0
Thermal power, MW(t)	745.0	17.0	762.0	130.5	82.5	975.0
Average specific power,[c] MW(t)/MTIHM	140.9	3.95	79.4	16.4	6.49	32.21
Average fuel burnup, MWd/MTIHM	76,031	2133	42,870	8693	7977	22,600
Effective irradiation duration, full-power days	540	540	550	530	1229	
Refueling cycle length, full-power days	275	275	275	275	275	275
Average number of assemblies charged per cycle	81	81	81	41	28.2	
Average charge, kg/refueling cycle						
^{235}U	3.6	4.4	8.0	8.3	5.7	22.0
Total uranium	1805.5	2193.5	3999.0	4134.9	2843.9	10,978
Fissile plutonium[d]	783.0	0	783.0	0	0	783.0
Total plutonium	889.4	0	889.4	0	0	889.4
Total (U + Pu)	2694.9	2193.5	4888.4	4134.9	2843.9	11,867
Average discharge, kg/refueling cycle						
^{235}U	2.6	3.6	6.2	5.9	4.0	16.1
Total uranium	1715.8	2149.0	3864.8	3960.2	2726.9	10,552
Fissile plutonium[d]	627.2	38.5	665.7	131.6	89.1	886.4
Total plutonium	766.7	39.6	806.3	138.3	94.9	1039.5
Total (U + Pu)	2482.5	2188.6	4671.1	4098.5	2821.8	11,591

[a]Fuel = 36-in. $(Pu,U)O_2$ region; AB = UO_2 axial blankets associated with fuel, IB = entire inner blanket; RB = entire radial blanket.

[b]Weighted average of inner radial blanket (4-cycle residence) and outer radial blanket (5-cycle residence).

[c]Based on rated power level.

[d]$^{239}Pu + ^{241}Pu + ^{239}Np$.

burnup of the core fuel is about 76,000 MWd/MTIHM. However, when averaged over the entire core assembly, this value drops to about 43,000 MWd/MTIHM; when further averaged over the entire discharge batch of fuel, the reactor-average burnup is found to be 22,600 MWd/MTIHM, which is about three-fourths of the burnup in modern LWRs.

4. SUMMARY CHARACTERIZATION OF CRBR FUEL AND WASTES

This section describes the graphical and tabular characterization of CRBR fuel and wastes, compares the CRBR material characteristics with those of other reactors, and describes the calculational bases for the characteristics. The calculated results of the characterization of CRBR spent fuel, HLW, and SMW are presented in Appendix D. Appendix E graphically compares the characteristics of spent fuel, HLW, and SMW for four different reactor types: PWR, FFTF, CRBR, and LMFBR. Appendix F compares the characteristics of CRBR HLW with those of PWR spent fuel. In all cases, the PWR is assumed to be operating on a once-through, low-enrichment UO_2 fuel cycle.

4.1 Calculational Assumptions

The nuclear material characteristics were calculated based on ORIGEN2 reactor models for a commercial PWR,[3] a commercial LMFBR,[4] the FFTF,[4] and the CRBR model described by this document. The reader is referred to these documents for details concerning the models other than that for the CRBR. Three nuclear materials are characterized in this report: spent fuel, high-level waste, and fuel assembly structural material waste.

4.1.1 Spent fuel

The spent-fuel characteristics are for the specified spent-fuel material plus a commensurate amount of fuel-assembly structural material. Conservatively, all nuclides produced during the irradiation are assumed to be present with the spent fuel (e.g., no tritium loss through the cladding is assumed). The irradiation parameters and initial fuel compositions are as described in Refs. 3 and 4 and in this report.

4.1.2 High-level waste and structural material waste

The HLW and SMW are both assumed to be produced by chemical reprocessing of spent fuel to recover the economically valuable plutonium and uranium. The first part of the reprocessing sequence involves chopping the spent-fuel assembly with a heavy-duty shear, which cuts the fuel elements into segments a few centimeters in length. The segments are then immersed in concentrated nitric acid to dissolve

the oxide fuel matrix while leaving the fuel-assembly structural materials essentially intact. At this point, the volatile elements are freed to escape from the dissolver into the off-gas treatment system. After dissolution is complete, the structural materials are removed, becoming the SMW described below. The nitric acid solution containing the dissolved spent fuel is contacted with tributyl phosphate, which removes the uranium and plutonium for separation and purification further downstream in the plant. The residual nitric acid solution, containing the remaining fission products, traces of uranium and plutonium, and all of the actinides other than uranium and plutonium, constitutes the liquid HLW.

After its generation, the liquid HLW will most likely be concentrated by evaporation, heated to a high temperature to evaporate the nitric acid and convert the dissolved fission-product and actinide nitrates to oxides (i.e., calcined), and then incorporated into a monolithic solid matrix (e.g., vitrified in glass). The SMW may be compressed to reduce its volume. It should be noted that there are many alternative treatment technologies for the HLW and SMW; those mentioned above are only examples that are presently regarded as the most likely to be used and have been assumed for the CRBR fuel cycle assessment.

The HLW contains all of the contents of the spent fuel, decayed until the time of reprocessing, except for the following species that have been removed: 99.5% of the uranium and plutonium, 99.9% of the halogen elements (principally iodine), and 100% of the tritium, ^{14}C, and noble gases (krypton, xenon, and radon). In addition, because stainless steel is corroded slightly by the nitric acid, it is assumed that 0.69% of the LMFBR, FFTF, and CRBR fuel-assembly structural material is present in the HLW.[23]

The SMW is principally comprised of the hardware that constitutes the fuel assembly, but not the fuel material itself. For the PWR, this is predominantly Zircaloy with some stainless steel and Inconel. For the LMFBR, the CRBR, and the FFTF, it is virtually all stainless steel (with some Inconel from the reflector, in the case of the FFTF). In addition, it is assumed that 0.05% of the nonvolatile components of the spent-fuel oxide (i.e., the HLW plus the uranium and plutonium) are included in the SMW. This is a result of the shearing operation, which may pinch the ends of some of the cladding segments so that the fuel matrix is not readily accessible to the nitric acid in the dissolver. It is also assumed that 30% of the tritium produced in the PWR fuel is present in the SMW as a part of the Zircaloy cladding.

The time necessary for the spent fuel to be reprocessed, following its discharge from the reactor, is assumed to be 160 d for the PWR and FFTF, 90 d for the LMFBR, and 150 d for the CRBR.

4.1.3 Comparisons

In the recent past, a comparison has often been made of the ingestion toxicity of some fuel-cycle material with the ingestion toxicity of the uranium ore mined to produce that material. This has most often been done in studies involving LWRs (including the PWRs). If the total losses of uranium at the beginning of the fuel cycle are assumed to be 12% (10% during milling, 1% during conversion, and 1% during fabrication), and if the enrichment plant tails are assumed to be 0.25%, then 7.16 metric tons of uranium must be mined to produce 1.0 MTIHM of fresh fuel. This amount of uranium ore, when in equilibrium with its shorter-lived daughters (i.e., when it is most toxic), requires 1.1×10^8 m^3 of water to dilute it to the standards given in the Code of Federal Regulations.[24]

A comparison of the ingestion toxicity of uranium ore to that of a fuel-cycle material has also been made on a volumetric basis. The volumetric toxicity of carnotite ore, virtually the only source of uranium today, is about 10^5 m^3 of water/m^3 of ore. The toxicity of pitchblende, a very high-grade uranium ore, is about 10^8 m^3 of water/m^3 of ore.

These values are included for use as a comparison basis for the ingestion toxicity characteristic graphs given in the Appendixes to this report. The toxicity of the ore required to make 1.0 MTIHM of PWR fuel can simply be superimposed on the toxicity graphs in the Appendixes. The volumetric toxicities of uranium ores would require conversion of the graphs from a MTIHM basis to a volumetric basis (e.g., m^3 water per m^3 HLW) before superposition of the ore toxicities.

4.1.4 Conversions

The conversion factor that is most often of interest is the multiplicative factor used to convert "characteristic/MTIHM" to "characteristic/GWy(e)" where the GWy(e) represents the amount of electricity that was produced by the fuel or wastes. These factors, calculated for the CRBR and other comparison reactors, are given in Table 11. Two aspects of this table are worthy of special mention. First, the FFTF has been included, even though this test facility does not actually produce electricity, by employing the same conversion factors as those used for the commercial LMFBR. Secondly, the conversion factors for the commercial LMFBR are given for a range of thermal efficiencies. The 31.6% value was the design basis in the original documentation. This relatively conservative value was selected since the design was for the first full-sized commercial plant. However, the LMFBR technology has been developed sufficiently in the intervening years so that higher efficiencies would be likely. Thus, the conversion factor is also given at the 35.9% CRBR thermal efficiency and at an assumed maximum thermal efficiency of 40%, allowing the user to select the value most appropriate to the case at hand.

Table 11. Multiplicative factors for converting $MTIHM^{-1}$ to $GWy(e)^{-1}$

Reactor type	Thermal efficiency (%)	Multiplicative conversion factor, MTIHM/GWy(e)
CRBR	35.9	45.03
PWR	32.9	33.62
LMFBR	31.6[a]	25.52
	35.9	22.78
	40.0	20.16
FFTF[b]	31.6	25.67
	35.9	22.91
	40.0	20.28

[a]As-designed thermal efficiency.

[b]The FFTF does not produce electricity; the values are included for comparative purposes.

4.2 Graphical and Tabular Characterization of CRBR Spent Fuel and Wastes

This section briefly describes the detailed characterization of the spent fuel, HLW, and SMW associated with the CRBR fuel cycle. The characteristics examined for these materials are: radioactivity (Ci), thermal power (W), ingestion toxicity (m^3 water required to dilute material to 10 CFR 20 values[24]), inhalation toxicity (m^3 air required to dilute material to 10 CFR 20 values[24]). All characteristics are presented as a function of decay time after discharge from the reactor for times ranging from 0.1 yr to 1×10^6 yr and are calculated with the ORIGEN2 computer code. The summary graphical and tabular output that is presented in this report was generated by an auxiliary code, ORMANG, which accesses the ORIGEN2 output, extracts the desired results, and produces the graphs and tables.

The results of this exercise are presented in Appendix D, with the characteristics of the spent core/axial blanket fuel, HLW, and SMW given in Sects. D.1, D.2, and D.3, respectively. Both the graphs and tables present the total characteristics as a function of decay time. In addition, the graphs and tables list the nuclides that are the principal contributors to the total; the graphs include a maximum of 14 contributors, while the tables include the first 23 contributors.

4.3 Comparison of CRBR Spent Fuel and Waste with Other Reactors

In many instances, it is useful to compare the characteristics of the same type of material from various reactors to gain a perspective on a particular reactor. This has been accomplished using the previously generated characteristics for the PWR, the FFTF, and the commercial LMFBR[25,26] and adding the corresponding values generated for the CRBR as a result of the work reported here. A comparison of the total characteristics for each reactor type is presented as a function of decay time after discharge, with both graphical and tabular output given. Graphs and tables also show results for spent core/axial blanket fuel, HLW, and SMW and for the characteristics of radioactivity, thermal power, ingestion toxicity, and inhalation toxicity. These results are given for comparison in Appendix E, Sects. E.1, E.2, and E.3 for the spent fuel, HLW, and SMW, respectively.

It is also of interest to compare the CRBR HLW, a material that has not been extensively evaluated in a technical or licensing context, to the PWR spent fuel, which has received much greater attention. These data for comparison are presented graphically in Appendix F for the four characteristics mentioned above.

5. REFERENCES

1. A. G. Croff, ORIGEN2 — A Revised and Updated Version of the Oak Ridge Isotope Generation and Depletion Code, ORNL-5621 (July 1980).

2. A. G. Croff, A User's Manual for the ORIGEN2 Computer Code, ORNL/TM-7175 (July 1980).

3. A. G. Croff, M. A. Bjerke, G. W. Morrison, and L. M. Petrie, Revised Uranium-Plutonium Cycle PWR and BWR Models for the ORIGEN Computer Code, ORNL/TM-6051 (September 1978).

4. A. G. Croff, J. W. McAdoo, and M. A. Bjerke, LMFBR Models for the ORIGEN2 Computer Code, ORNL/TM-7176 (October 1981).

5. A. G. Croff and M. A. Bjerke, Alternative Fuel Cycle PWR Models for the ORIGEN Computer Code, ORNL/TM-7005 (February 1980).

6. A. G. Croff and M. A. Bjerke, Once-Through CANDU Reactor Models for the ORIGEN2 Computer Code, ORNL/TM-7177 (November 1980).

7. M. A. Bjerke and C. C. Webster, Neutron Cross-Section Libraries in the AMPX Master Interface Format for Thermal and Fast Reactors, ORNL/CSD/TM-164 (December 1981).

8. ENDF/B-IV Library Tapes 401-411 and 414-419, available from the National Neutron Cross Section Center, Brookhaven National Laboratory (December 1974).

9. ENDF/B-V Library Tapes 514, 521, and 522, available from the National Neutron Cross Section Center, Brookhaven National Laboratory (July 1979).

10. N. M. Greene et al., AMPX: A Modular Code System for Generating Coupled Multigroup Neutron-Gamma Libraries from ENDF/B, ORNL/TM-3706 (March 1976).

11. R. E. MacFarlane, R. J. Barrett, D. W. Muir, R. M. Boicourt, The NJOY Nuclear Data Processing System: User's Manual, LA-7484-M (ENDF-272), December 1978.

12. Project Management Corporation, Clinch River Breeder Reactor Project Preliminary Safety Analysis Report, updated through amendment 64 (January 1982).

13. S. G. Mughabghab and D. I. Garber, Neutron Cross Sections, Volume 1, Resonance Parameters, BNL-325, 3rd ed. (June 1973).

14. A. G. Croff, R. L. Haese, and N. B. Gove, Updated Decay and Photon Libraries for the ORIGEN Code, ORNL/TM-6051 (September 1978).

15. M. J. Haire and C. A. Rhodes, An Overview of ORNL Methods for Calculating Fuel Assembly Temperatures During Reprocessing (Applied Technology), ORNL/TM-7473 (November 1980).*

16. R. J. Beaver and W. R. Martin, Procurement of Type 316 Stainless Steel Reference Heat for LMFBR Research and Development Programs (Applied Technology), ORNL/TM-5196 (January 1976).*

17. R. C. Smith, L. G. Faust, and L. W. Brackenbush, "Plutonium Fuel Technology Part II: Radiation Exposure from Plutonium in LWR Fuel Manufacture," Nucl. Tech. 18, 97-108 (May 1973).

18. W. Davis, Jr., Carbon-14 Production in Nuclear Reactors, ORNL/NUREG/TM-12 (February 1977).

19. G. LaPier, Babcock and Wilcox Corp., Nuclear Materials Division, personal communication to A. G. Croff, Oak Ridge National Laboratory, May 9, 1978.

20. General Electric Corporation, Plutonium Utilization in Boiling Water Reactors: Phase II Semi-Annual Report, January-June 1971, NEDC-10586 (December 1971).

21. L. G. Wisnyi, LWB/LSBR Development Program: High Cross-Section Impurities in Reactor Core Materials, KAPL-3322 (June 1967).

22. Y. B. Katayama, Leaching of Irradiated LWR Fuel Pellets in Deionized and Typical Ground Water, BNWL-2057 (July 1976).

23. J. H. Goode and R. G. Stacy, Voloxidation of the UO_2 Axial Blankets from Irradiated $(U,Pu)O_2$ Fuel Rods (Applied Technology), ORNL/TM-6635 (January 1979).*

24. Code of Federal Regulations, Appendix B, Table II, Title 10, Part 20.

25. A. G. Croff, M. S. Liberman, and G. W. Morrison, Graphical and Tabular Summaries of Decay Characteristics for Once-Through PWR, LMFBR, and FFTF Fuel Cycle Materials, ORNL/TM-8061 (January 1982).

26. A. G. Croff and C. W. Alexander, Decay Characteristics of Once-Through LWR and LMFBR Spent Fuels, High-Level Wastes, and Fuel Assembly Structural Material Wastes, ORNL/TM-7431 (November 1980).

*This report contains Applied Technology information and has limited distribution. Information about its availability may be obtained from DOE's Technical Information Center, Oak Ridge, TN 37830.

APPENDIX A: 126-ENERGY-GROUP NEUTRON SPECTRA GRAPHS AND LISTINGS

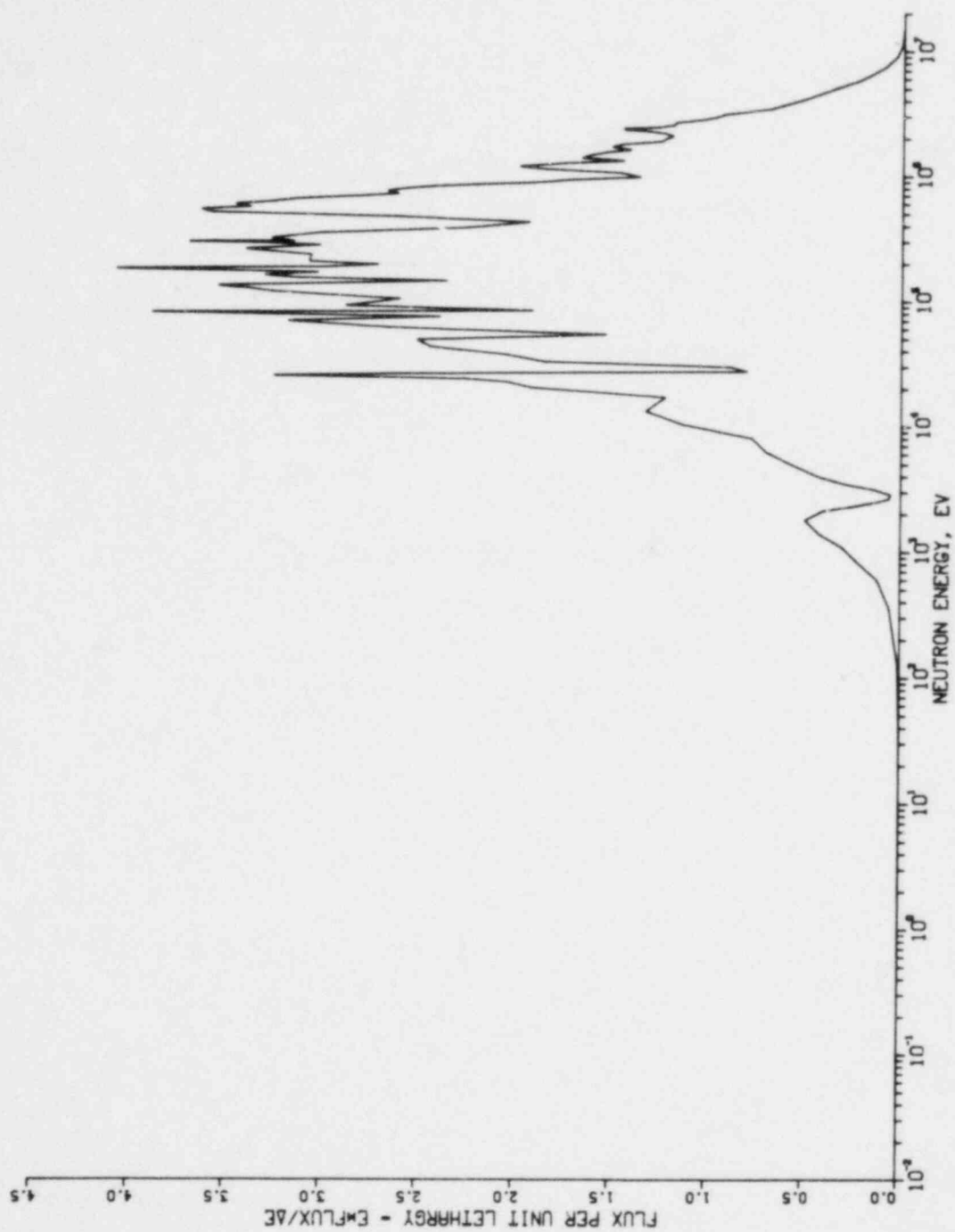

Fig. A.1. Neutron energy spectrum in CRBR core fuel.

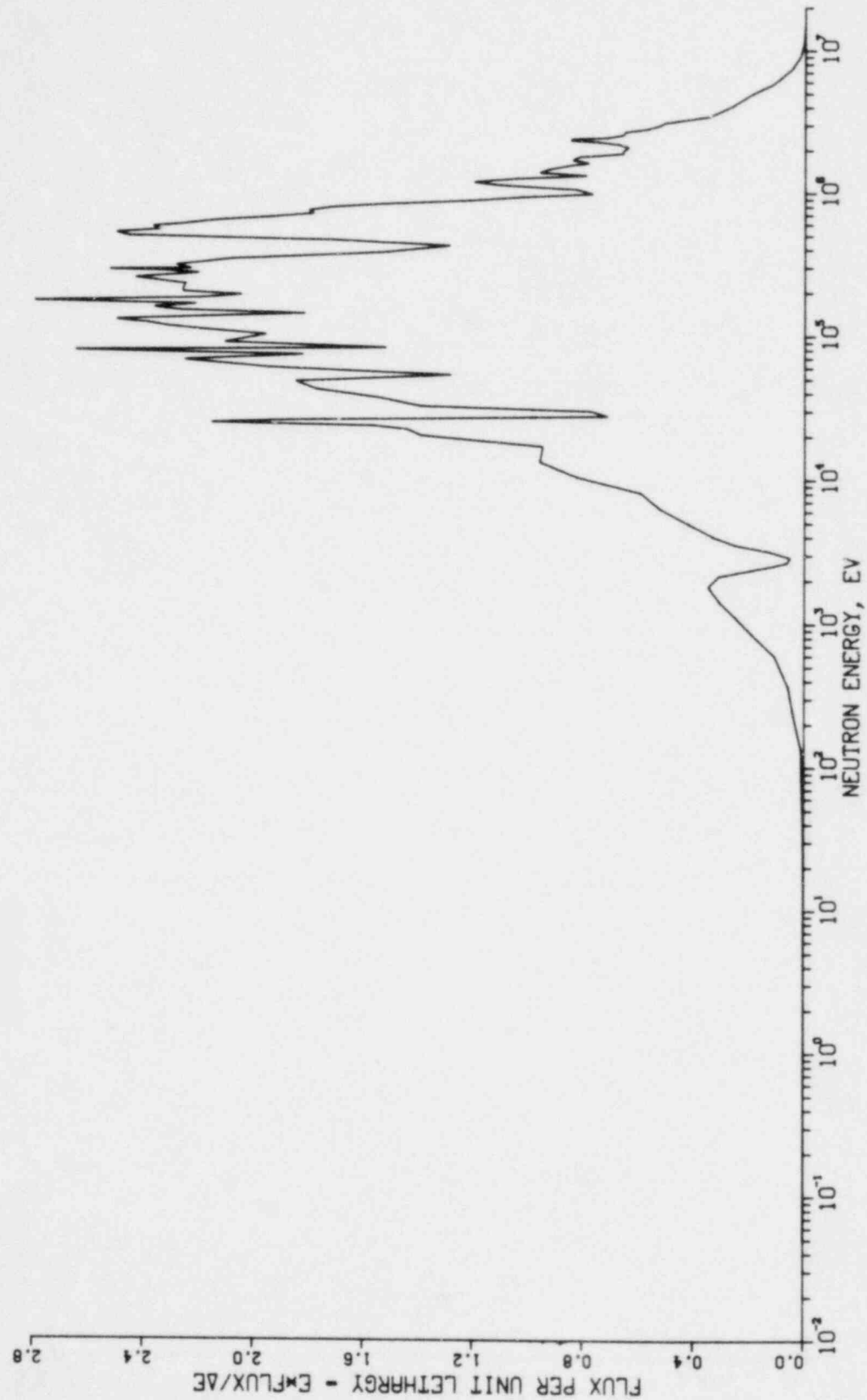

Fig. A.2. Neutron energy spectrum in CRBR inner blanket fuel.

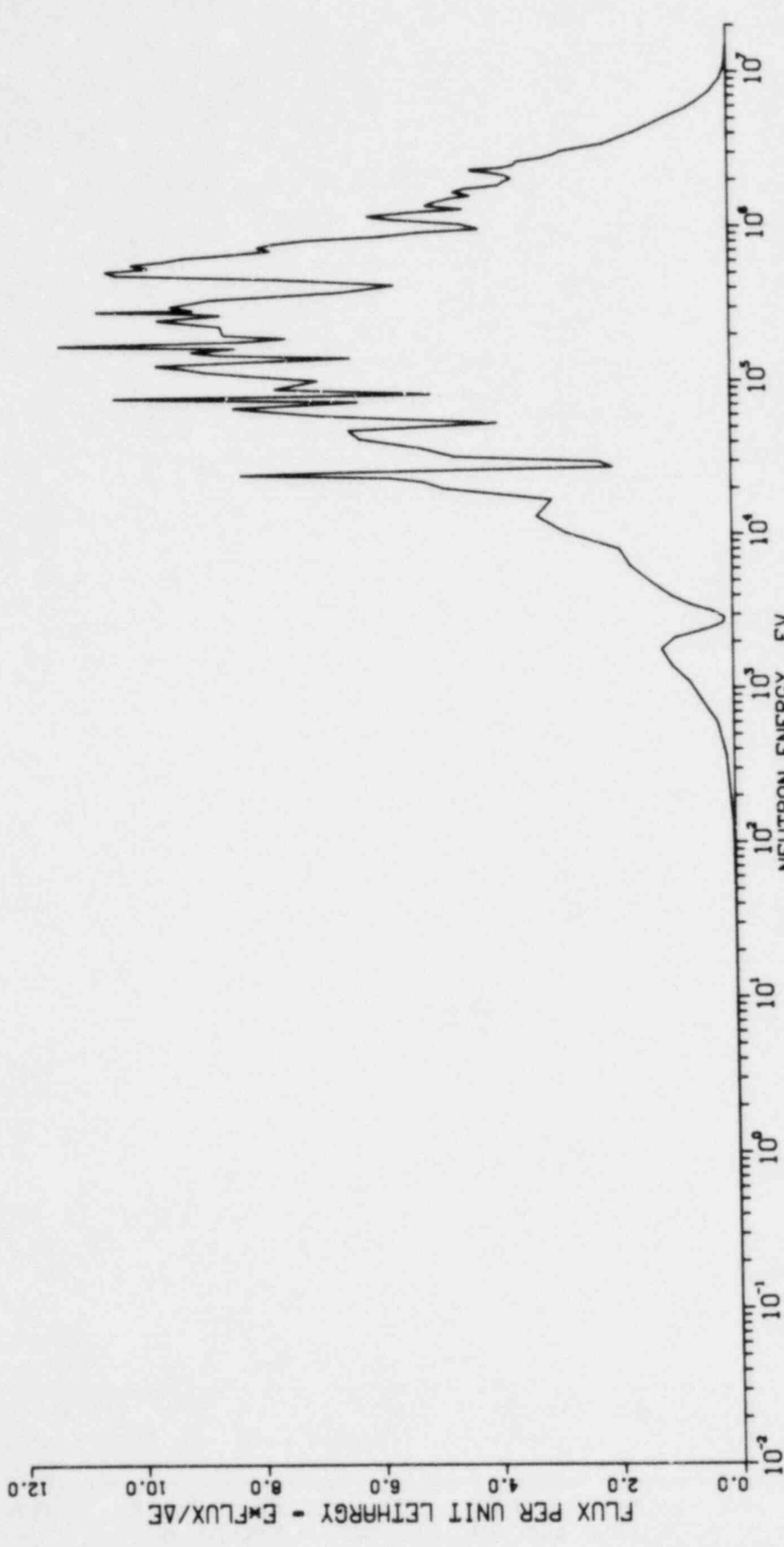

Fig. A.3. Neutron energy spectrum in CRBR radial blanket fuel.

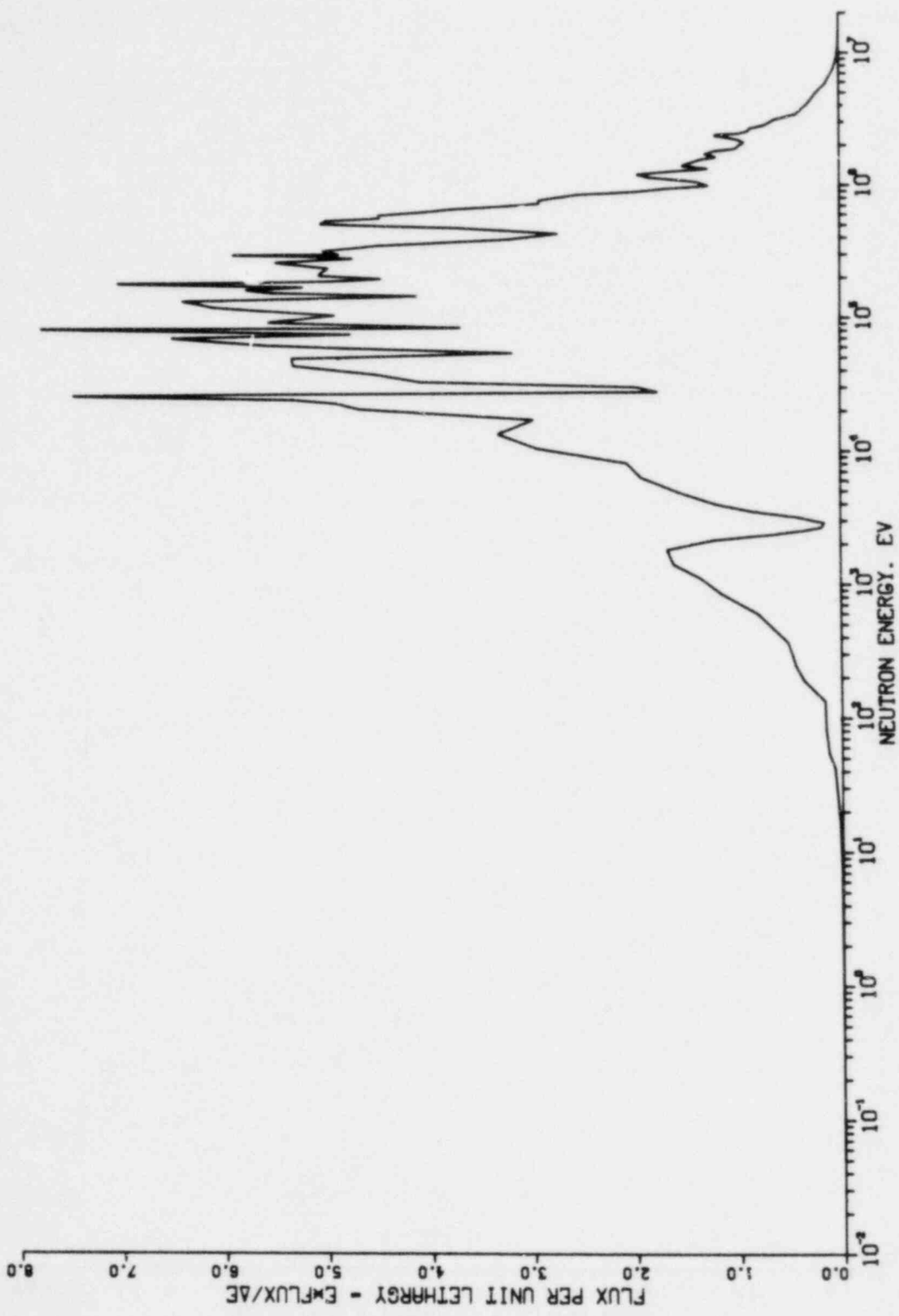

Fig. A.4. Neutron energy spectrum in CRBR axial blanket fuel.

Table A.1. Flux per unit lethargy for CRBR fuels

Energy group	Group energy boundaries, eV		Core	Inner blanket	Radial blanket	Axial blanket
	Upper	Lower				
1	1.733308 07	1.221408 07	1.239218-03	5.906498-04	3.795838-03	7.464248-04
2	1.221408 07	1.000008 07	9.725858-03	4.681408-03	2.970688-02	5.827768-03
3	1.000008 07	8.187308 06	3.509108-02	1.714418-02	1.068688-01	2.122268-02
4	8.187308 06	6.703208 06	9.477958-02	4.711668-02	2.875128-01	5.781118-02
5	6.703208 06	6.065308 06	1.731878-01	8.843228-02	5.227998-01	1.082148-01
6	6.065308 06	5.488108 06	2.328358-01	1.171978-01	7.047438-01	1.424378-01
7	5.488108 06	4.493308 06	3.622798-01	1.860448-01	1.094348 00	2.264848-01
8	4.493308 06	3.678808 06	5.179828-01	2.596728-01	1.574558 00	3.136638-01
9	3.678808 06	3.166408 06	6.884678-01	3.468638-01	2.101408 00	4.244528-01
10	3.166408 06	3.011908 06	9.274438-01	5.045218-01	2.810458 00	6.404948-01
11	3.011908 06	2.865008 06	9.697388-01	5.277748-01	2.932678 00	6.828408-01
12	2.865008 06	2.725308 06	1.037888 00	5.675078-01	3.140098 00	7.426178-01
13	2.725308 06	2.592408 06	1.173278 00	6.506268-01	3.550558 00	8.718978-01
14	2.592408 06	2.466008 06	1.185518 00	6.598658-01	3.584268 00	8.864188-01
15	2.466008 06	2.345208 06	1.265658 00	7.196298-01	3.814468 00	9.796538-01
16	2.345208 06	2.365308 06	1.445608 00	8.443758-01	4.337498 00	1.198228 00
17	2.365308 06	2.306908 06	1.442778 00	8.469088-01	4.315188 00	1.214538 00
18	2.306908 06	2.231308 06	1.325458 00	7.462558-01	4.001488 00	1.090148 00
19	2.231308 06	2.122508 06	1.234498 00	6.739348-01	3.755658 00	9.849438-01
20	2.122508 06	2.019008 06	1.188368 00	6.392058-01	3.630918 00	9.286688-01
21	2.019008 06	1.920508 06	1.227338 00	6.565778-01	3.769708 00	9.804918-01
22	1.920508 06	1.826808 06	1.247218 00	6.597258-01	3.852188 00	1.005588 00
23	1.826808 06	1.737708 06	1.488578 00	8.162528-01	4.436808 00	1.219558 00
24	1.737708 06	1.653008 06	1.504878 00	8.400578-01	4.626888 00	1.306918 00
25	1.653008 06	1.572408 06	1.409178 00	7.825728-01	4.333328 00	1.205688 00
26	1.572408 06	1.495708 06	1.535918 00	8.676028-01	4.724378 00	1.365068 00
27	1.495708 06	1.422708 06	1.615628 00	9.286158-01	4.955608 00	1.451068 00
28	1.422708 06	1.353408 06	1.659218 00	9.585388-01	5.093088 00	1.531038 00
29	1.353408 06	1.287308 06	1.443468 00	7.911838-01	4.465688 00	1.283398 00
30	1.287308 06	1.224608 06	1.762958 00	1.055718 00	5.400348 00	1.648648 00
31	1.224608 06	1.164808 06	1.995888 00	1.196568 00	6.078768 00	1.959878 00
32	1.164808 06	1.108008 06	1.848308 00	1.105238 00	5.661218 00	1.845948 00
33	1.108008 06	1.002608 06	1.457808 00	8.252228-01	4.[illegible]6648 00	1.399628 00
34	1.002608 06	9.616408 05	1.357848 00	7.677378-01	4.20[illegible]98 00	1.278578 00
35	9.616408 05	9.071808 05	1.698358 00	1.023378 00	5.222818 00	1.690268 00
36	9.071808 05	8.529408 05	1.929018 00	1.213228 00	5.874428 00	1.993138 00
37	8.629408 05	8.208508 05	2.363428 00	1.531298 00	7.138868 00	2.531648 00
38	8.208508 05	7.808208 05	2.559778 00	1.716688 00	7.655368 00	2.738108 00
39	7.808208 05	7.427408 05	2.662298 00	1.798648 00	7.918078 00	2.922038 00
40	7.427408 05	7.065108 05	2.609738 00	1.780938 00	7.710568 00	2.915928 00
41	7.065108 05	6.720608 05	2.835178 00	1.930468 00	8.346758 00	3.262378 00
42	6.720608 05	6.392808 05	3.130418 00	2.127688 00	9.179688 00	3.778848 00
43	6.392808 05	6.081008 05	3.258738 00	2.229288 00	9.608838 00	4.080538 00
44	6.081008 05	5.784408 05	3.454838 00	2.363808 00	1.005038 01	4.482558 00
45	5.784408 05	5.502308 05	3.376638 00	2.340328 00	9.767118 00	4.477378 00
46	5.502308 05	5.234008 05	3.632018 00	2.497428 00	1.049018 01	4.991808 00
47	5.234008 05	4.978708 05	3.576448 00	2.450778 00	1.032228 01	5.046488 00
48	4.978708 05	4.504908 05	2.595168 00	1.704678 00	7.567708 00	3.688478 00
49	4.504908 05	4.076208 05	1.928178 00	1.286088 00	5.632538 00	2.737278 00
50	4.076208 05	3.688308 05	2.239628 00	1.515108 00	6.536868 00	3.239518 00
51	3.688308 05	3.337308 05	3.012268 00	2.082518 00	8.732978 00	4.486118 00
52	3.337308 05	3.019708 05	3.264158 00	2.280068 00	9.405418 00	5.019828 00
53	3.019708 05	2.985008 05	3.144818 00	2.226068 00	9.027468 00	4.863718 00
54	2.985008 05	2.972008 05	3.561238 00	2.444458 00	1.026118 01	5.601648 00

Table A.1 (continued)

Energy group	Group energy boundaries, eV Upper	Lower	Core	Inner blanket	Radial blanket	Axial blanket
55	2.97200E 05	2.94520E 05	3.69417E 00	2.52203E 00	1.06546E 01	5.90420E 00
56	2.94520E 05	2.87250E 05	3.26163E 00	2.31961E 00	9.32820E 00	5.16051E 00
57	2.87250E 05	2.73240E 05	3.01204E 00	2.19717E 00	8.55047E 00	4.73377E 00
58	2.73240E 05	2.47240E 05	3.40098E 00	2.42813E 00	9.62845E 00	5.49643E 00
59	2.47240E 05	2.23710E 05	3.05714E 00	2.24485E 00	8.55158E 00	4.97139E 00
60	2.23710E 05	2.12800E 05	3.06729E 00	2.25503E 00	8.52944E 00	5.04129E 00
61	2.12800E 05	2.02420E 05	3.06783E 00	2.25521E 00	8.50515E 00	5.06468E 00
62	2.02420E 05	1.92550E 05	2.71103E 00	2.04234E 00	7.46433E 00	4.46506E 00
63	1.92550E 05	1.83160E 05	2.99890E 00	2.19782E 00	8.24939E 00	4.98226E 00
64	1.83160E 05	1.74220E 05	4.07239E 00	2.79730E 00	1.13028E 01	7.03679E 00
65	1.74220E 05	1.65730E 05	3.02309E 00	2.20819E 00	8.30671E 00	5.22386E 00
66	1.65730E 05	1.57640E 05	3.29821E 00	2.35910E 00	9.05965E 00	5.77751E 00
67	1.57640E 05	1.49960E 05	3.12446E 00	2.25920E 00	8.54958E 00	5.52214E 00
68	1.49960E 05	1.42640E 05	2.35481E 00	1.80982E 00	6.38475E 00	4.11409E 00
69	1.42640E 05	1.35690E 05	2.98275E 00	2.18169E 00	8.09458E 00	5.25615E 00
70	1.35690E 05	1.29070E 05	3.54330E 00	2.49780E 00	9.65462E 00	6.40027E 00
71	1.29070E 05	1.22770E 05	3.37114E 00	2.38237E 00	9.17537E 00	6.23496E 00
72	1.22770E 05	1.16790E 05	3.25605E 00	2.31225E 00	8.84437E 00	6.11028E 00
73	1.16790E 05	1.11090E 05	3.02848E 00	2.19212E 00	8.18517E 00	5.72866E 00
74	1.11090E 05	9.80370E 04	2.59661E 00	1.95176E 00	6.92943E 00	4.90629E 00
75	9.80370E 04	8.65170E 04	2.88110E 00	2.10100E 00	7.65948E 00	5.56908E 00
76	8.65170E 04	8.25000E 04	1.91024E 00	1.51576E 00	5.02437E 00	3.69020E 00
77	8.25000E 04	7.95000E 04	3.88843E 00	2.64797E 00	1.03752E 01	7.78866E 00
78	7.95000E 04	7.20000E 04	2.38864E 00	1.81804E 00	6.25707E 00	4.75915E 00
79	7.20000E 04	6.73790E 04	3.17424E 00	2.24855E 00	8.36120E 00	6.50953E 00
80	6.73790E 04	5.65620E 04	2.65228E 00	1.94675E 00	6.90721E 00	5.58032E 00
81	5.65620E 04	5.24750E 04	1.52649E 00	1.28158E 00	3.90100E 00	3.18580E 00
82	5.24750E 04	4.63090E 04	2.50702E 00	1.84195E 00	6.42398E 00	5.33759E 00
83	4.63090E 04	4.08680E 04	2.43879E 00	1.76857E 00	6.24012E 00	5.32481E 00
84	4.08680E 04	3.43070E 04	2.04281E 00	1.52666E 00	5.17144E 00	4.51789E 00
85	3.43070E 04	3.18280E 04	1.84101E 00	1.38954E 00	4.63528E 00	4.09577E 00
86	3.18280E 04	2.85000E 04	8.85571E-01	7.72373E-01	2.20397E 00	1.97047E 00
87	2.85000E 04	2.70000E 04	7.97513E-01	7.10938E-01	1.97883E 00	1.77328E 00
88	2.70000E 04	2.60580E 04	2.55478E 00	1.86438E 00	6.36772E 00	5.64716E 00
89	2.60580E 04	2.47880E 04	3.24794E 00	2.15016E 00	8.23973E 00	7.47834E 00
90	2.47880E 04	2.35790E 04	2.25318E 00	1.55917E 00	5.72045E 00	5.33095E 00
91	2.35790E 04	2.18750E 04	2.03453E 00	1.43547E 00	5.15685E 00	4.89343E 00
92	2.18750E 04	1.93050E 04	1.91497E 00	1.38826E 00	4.82323E 00	4.67902E 00
93	1.93050E 04	1.50340E 04	1.21706E 00	9.44877E-01	3.00691E 00	2.97875E 00
94	1.50340E 04	1.17090E 04	1.31874E 00	9.55429E-01	3.26053E 00	3.32613E 00
95	1.17090E 04	9.11880E 03	1.12716E 00	8.17467E-01	2.78030E 00	2.94668E 00
96	9.11880E 03	7.10170E 03	7.70806E-01	5.88778E-01	1.88212E 00	2.06675E 00
97	7.10170E 03	5.53080E 03	6.99848E-01	5.20421E-01	1.70235E 00	1.92997E 00
98	5.53080E 03	4.30740E 03	5.56159E-01	4.17806E-01	1.34570E 00	1.58249E 00
99	4.30740E 03	3.70740E 03	4.20747E-01	3.28125E-01	1.01242E 00	1.22021E 00
100	3.70740E 03	3.35460E 03	2.94786E-01	2.47112E-01	7.05064E-01	8.66298E-01
101	3.35460E 03	3.03540E 03	1.37750E-01	1.26430E-01	3.28515E-01	4.07724E-01
102	3.03540E 03	2.74650E 03	5.11727E-02	5.08293E-02	1.22018E-01	1.52772E-01
103	2.74650E 03	2.61260E 03	6.29787E-02	6.16952E-02	1.49994E-01	1.87998E-01
104	2.61260E 03	2.48520E 03	1.13431E-01	1.08080E-01	2.69579E-01	3.39428E-01
105	2.48520E 03	2.24870E 03	2.22285E-01	1.87897E-01	5.27769E-01	6.64232E-01
106	2.24870E 03	2.03470E 03	4.04605E-01	3.09588E-01	9.61528E-01	1.23734E 00
107	2.03470E 03	1.58460E 03	4.95122E-01	3.47162E-01	1.18869E 00	1.68011E 00
108	1.58460E 03	1.23410E 03	4.20839E-01	3.03948E-01	1.01099E 00	1.62146E 00

Table A.1 (continued)

Energy group	Group energy boundaries, eV		Core	Inner blanket	Radial blanket	Axial blanket
	Upper	Lower				
109	1.23410E 03	9.61120E 02	2.99586E-01	2.43364E-01	7.04395E-01	1.34872E 00
110	9.61120E 02	7.48520E 02	2.28014E-01	1.88417E-01	5.24620E-01	1.16162E 00
111	7.48520E 02	4.54000E 02	1.16630E-01	1.05295E-01	2.57926E-01	8.04580E-01
112	4.54000E 02	2.75360E 02	5.47730E-02	5.63779E-02	1.16408E-01	5.11209E-01
113	2.75360E 02	2.14450E 02	3.75079E-02	3.96956E-02	7.78329E-02	4.40785E-01
114	2.14450E 02	1.67020E 02	2.61922E-02	2.76410E-02	5.36917E-02	3.64315E-01
115	1.67020E 02	1.01300E 02	9.08149E-03	9.14473E-03	1.87054E-02	1.61065E-01
116	1.01300E 02	6.14420E 01	4.81715E-03	6.71605E-03	9.84588E-03	1.50624E-01
117	6.14420E 01	4.78510E 01	2.48608E-03	3.98935E-03	5.22187E-03	1.23338E-01
118	4.78510E 01	3.72670E 01	1.14277E-03	1.79420E-03	2.45928E-03	6.69359E-02
119	3.72670E 01	2.26030E 01	8.45604E-04	1.08793E-03	2.08124E-03	5.01095E-02
120	2.26030E 01	1.06770E 01	1.78883E-04	2.68736E-04	4.92288E-04	2.09356E-02
121	1.06770E 01	5.04350E 00	4.49850E-05	6.33600E-05	1.44285E-04	7.11245E-03
122	5.04350E 00	2.37239E 00	2.19349E-05	2.88075E-05	1.23710E-04	5.30583E-03
123	2.37239E 00	1.12540E 00	5.44760E-06	1.11819E-05	5.17922E-05	3.50477E-03
124	1.12540E 00	4.13990E-01	3.08484E-07	1.69124E-06	4.17877E-06	1.15353E-03
125	4.13990E-01	1.00000E-01	5.16986E-09	7.19801E-08	8.33189E-08	1.16015E-04
126	1.00000E-01	1.00000E-05	2.12047E-10	2.49279E-09	3.59253E-09	1.04563E-05

APPENDIX B: ONE-GROUP, SPECTRUM-AVERAGED CROSS SECTIONS FOR THE CRBR

Table B.1. One-group, spectrum-averaged cross sections for CRBR fuels

Nuclide	Cross section type[a]	Cross section (barns)			
		Core	Inner blanket	Radial blanket	Axial blanket
H - 1	N,G	1.99E-04	2.35E-04	3.46E-04	4.19E-04
B - 10	N,A	2.61E 00	3.05E 00	4.33E 00	5.16E 00
B - 11	N,G	3.95E-05	4.33E-05	4.99E-05	5.43E-05
C - 12	N,G	3.16E-06	3.09E-06	3.94E-06	4.51E-06
N - 14	N,P	1.40E-02	1.22E-02	1.07E-02	9.82E-03
N - 15	N,G	1.22E-05	1.15E-05	1.04E-05	9.81E-06
O - 16	N,A	1.16E-03	7.69E-04	5.47E-04	3.79E-04
O - 17	N,G	6.53E-05	5.49E-05	4.61E-05	4.11E-05
NA- 23	N,G	1.48E-03	1.80E-03	2.27E-03	2.40E-03
CR- 52	N,G	1.95E-02	2.10E-02	2.42E-02	2.66E-02
MN- 55	N,G	6.57E-02	9.28E-02	1.58E-01	2.13E-01
FE- 56	N,G	1.16E-02	1.31E-02	1.58E-02	1.82E-02
CO- 59	N,G	6.20E-02	9.28E-02	2.50E-01	3.89E-01
NI- 58	N,G	2.09E-02	2.29E-02	2.61E-02	2.75E-02
GE- 72	N,G	5.15E-02	5.47E-02	1E-02	5.88E-02
GE- 73	N,G	3.42E-01	4.47E-01	4E-01	1.01E 00
GE- 74	N,G	3.03E-02	3.25E-02	5E-02	3.47E-02
GE- 76	N,G	1.92E-02	2.43E-02	9E-02	4.64E-02
AS- 75	N,G	3.66E-01	4.51E-01	8E-01	8.59E-01
SE- 76	N,G	1.57E-01	1.89E-01	.66E-01	3.25E-01
SE- 77	N,G	3.62E-01	4.27E-01	.72E-01	6.87E-01
SE- 78	N,G	6.27E-02	7.66E-02	1.07E-01	1.31E-01
SE- 80	N,G	5.45E-02	5.89E-02	6.63E-02	7.20E-02
SE- 82	N,G	9.10E-03	9.42E-03	9.57E-03	9.55E-03
BR- 79	N,G	6.44E-01	7.85E-01	1.20E 00	1.51E 00
BR- 81	N,G	3.48E-01	4.11E-01	5.95E-01	7.35E-01
KR- 80	N,G	1.94E-01	2.39E-01	4.10E-01	5.61E-01
KR- 82	N,G	1.47E-01	1.84E-01	4.31E-01	6.02E-01
KR- 83	N,G	5.02E-01	5.77E-01	8.54E-01	1.03E 00
KR- 84	N,G	5.17E-02	6.54E-02	9.83E-02	1.28E-01
KR- 85	N,G	3.84E-02	4.37E-02	5.33E-02	6.08E-02
KR- 86	N,G	3.35E-03	3.69E-03	3.94E-03	3.81E-03
RB- 85	N,G	2.08E-01	2.38E-01	2.92E-01	3.32E-01
RB- 86	N,G	1.69E-01	2.23E-01	3.65E-01	4.84E-01
RB- 87	N,G	1.50E-02	2.08E-02	3.47E-02	4.60E-02
SR- 86	N,G	7.03E-02	8.61E-02	1.22E-01	1.54E-01
SR- 87	N,G	9.99E-02	1.16E-01	1.68E-01	1.92E-01
SR- 88	N,G	1.14E-03	1.12E-03	1.08E-03	1.05E-03
SR- 89	N,G	2.10E-02	2.29E-02	2.58E-02	2.73E-02
SR- 90	N,G	1.30E-02	1.36E-02	1.44E-02	1.47E-02
Y - 89	N,G	2.25E-02	2.47E-02	2.72E-02	2.73E-02
Y - 90	N,G	1.27E-01	1.44E-01	1.74E-01	1.95E-01
Y - 91	N,G	4.11E-02	4.67E-02	5.68E-02	6.48E-02
ZR- 90	N,G	2.29E-02	2.44E-02	2.65E-02	2.67E-02
ZR- 91	N,G	8.23E-02	1.00E-01	1.40E-01	1.72E-01
ZR- 92	N,G	3.93E-02	4.29E-02	4.89E-02	5.26E-02
ZR- 93	N,G	9.21E-02	1.22E-01	2.25E-01	3.14E-01
ZR- 94	N,G	2.08E-02	2.28E-02	2.54E-02	2.61E-02
ZR- 95	N,G	1.52E-01	1.75E-01	2.19E-01	2.55E-01

Table B.1 (continued)

Nuclide	Cross section type[a]	Cross section (barns) Core	Inner blanket	Radial blanket	Axial blanket
ZR- 96	N,G	4.46E-02	5.87E-02	9.35E-02	1.22E-01
NB- 93	N,G	2.09E-01	2.44E-01	3.12E-01	3.67E-01
NB- 94	N,G	2.36E-01	2.87E-01	4.49E-01	5.64E-01
NB- 95	N,G	3.45E-01	4.08E-01	5.50E-01	6.64E-01
MO- 94	N,G	4.87E-02	5.28E-02	5.99E-02	6.52E-02
MO- 95	N,G	2.88E-01	3.43E-01	5.52E-01	7.02E-01
MO- 96	N,G	5.89E-02	7.18E-02	1.24E-01	1.68E-01
MO- 97	N,G	2.71E-01	3.14E-01	4.10E-01	4.82E-01
MO- 98	N,G	2.46E-01	2.93E-01	4.18E-01	5.18E-01
MO- 99	N,G	4.62E-01	5.27E-01	6.61E-01	7.58E-01
MO-100	N,G	7.82E-02	9.21E-02	1.21E-01	1.45E-01
TC- 99	N,G	4.69E-01	5.53E-01	8.12E-01	9.75E-01
RU- 99	N,G	4.76E-01	5.70E-01	8.44E-01	1.05E 00
RU-100	N,G	1.60E-01	1.89E-01	2.52E-01	3.05E-01
RU-101	N,G	5.11E-01	5.90E-01	8.00E-01	9.43E-01
RU-102	N,G	1.82E-01	1.98E-01	2.26E-01	2.47E-01
RU-103	N,G	4.20E-01	4.91E-01	6.99E-01	8.45E-01
RU-104	N,G	1.35E-01	1.58E-01	2.07E-01	2.46E-01
RU-105	N,G	3.34E-01	3.75E-01	4.36E-01	4.75E-01
RU-106	N,G	7.94E-02	8.92E-02	1.0[illegible]E-01	1.15E-01
RH-103	N,G	6.69E-01	7.72E-01	1.10E 00	1.24E 00
RH-105	N,G	5.50E-01	6.29E-01	2.04E 00	2.11E 00
PD-104	N,G	2.67E-01	3.11E-01	4.25E-01	5.15E-01
PD-105	N,G	7.94E-01	9.04E-01	1.16E 00	1.33E 00
PD-106	N,G	1.57E-01	1.82E-01	2.34E-01	2.75E-01
PD-107	N,G	5.44E-01	6.20E-01	8.12E-01	9.47E-01
PD-108	N,G	1.71E-01	2.22E-01	5.54E-01	7.57E-01
PD-110	N,G	1.48E-01	1.76E-01	2.39E-01	2.99E-01
AG-107	N,G	6.75E-01	7.79E-01	1.05E 00	1.24E 00
AG-109	N,G	4.80E-01	5.87E-01	1.16E 00	1.43E 00
AG-111	N,G	6.48E-01	8.28E-01	1.34E 00	1.77E 00
CD-108	N,G	1.94E-01	2.10E-01	2.39E-01	2.58E-01
CD-110	N,G	2.59E-01	2.98E-01	4.34E-01	5.29E-01
CD-111	N,G	4.01E-01	4.67E-01	6.35E-01	7.64E-01
CD-112	N,G	2.28E-01	2.57E-01	3.24E-01	3.74E-01
CD-113	N,G	3.83E-01	4.64E-01	8.13E-01	1.07E 00
CD-114	N,G	2.85E-01	3.27E-01	4.28E-01	5.15E-01
CD-115	N,G	6.60E-01	8.91E-01	1.63E 00	2.24E 00
CD-116	N,G	1.09E-01	1.19E-01	1.37E-01	1.52E-01
IN-113	N,G	5.83E-01	6.47E-01	8.72E-01	1.01E 00
IN-115	N,G	4.34E-01	4.96E-01	1.08E 00	1.15E 00
SN-115	N,G	4.70E-02	5.74E-02	8.53E-02	1.06E-01
SN-116	N,G	6.00E-02	6.93E-02	1.05E-01	1.37E-01
SN-117	N,G	1.99E-01	2.29E-01	3.00E-01	3.54E-01
SN-118	N,G	1.13E-01	1.28E-01	1.63E-01	1.91E-01
SN-119	N,G	5.49E-02	6.44E-02	8.50E-02	1.02E-01
SN-120	N,G	4.34E-02	4.85E-02	5.93E-02	6.86E-02
SN-122	N,G	2.27E-02	2.40E-02	2.75E-02	3.06E-02
SN-123	N,G	1.10E-01	1.23E-01	1.47E-01	1.65E-01
SN-124	N,G	2.86E-02	3.36E-02	5.46E-02	6.71E-02

Table B.1 (continued)

Nuclide	Cross section type[a]	Cross section (barns) Core	Inner blanket	Radial blanket	Axial blanket
SN-125	N,G	2.87E-01	3.52E-01	4.96E-01	6.30E-01
SN-126	N,G	7.02E-03	7.10E-03	7.11E-03	7.04E-03
SB-121	N,G	4.58E-01	5.22E-01	7.21E-01	8.47E-01
SB-123	N,G	2.60E-01	3.02E-01	4.48E-01	5.48E-01
SB-124	N,G	6.52E-01	7.39E-01	8.90E-01	9.89E-01
SB-125	N,G	2.82E-01	3.28E-01	4.37E-01	5.27E-01
SB-126	N,G	4.11E-01	4.93E-01	7.03E-01	8.67E-01
TE-122	N,G	3.35E-01	4.07E-01	6.68E-01	8.55E-01
TE-123	N,G	4.80E-01	5.80E-01	1.72E 00	1.89E 00
TE-124	N,G	2.33E-01	2.55E-01	2.99E-01	3.35E-01
TE-125	N,G	3.46E-01	4.14E-01	5.61E-01	6.81E-01
TE-126	N,G	1.03E-01	1.22E-01	1.79E-01	2.25E-01
TE-127	N,G	3.59E-01	4.27E-01	6.10E-01	7.53E-01
TE-128	N,G	9.35E-02	1.01E-01	1.17E-01	1.29E-01
TE-129	N,G	1.17E-01	1.40E-01	1.87E-01	2.25E-01
TE-130	N,G	1.49E-02	1.63E-02	1.86E-02	2.01E-02
TE-132	N,G	3.99E-04	3.68E-04	3.21E-04	2.95E-04
I -127	N,G	5.35E-01	6.51E-01	1.04E 00	1.33E 00
I -129	N,G	3.69E-01	4.33E-01	5.81E-01	6.99E-01
I -130	N,G	5.48E-01	7.19E-01	1.29E 00	1.75E 00
I -131	N,G	1.39E-01	1.70E-01	2.35E-01	2.92E-01
I -135	N,G	5.98E-04	6.20E-04	6.45E-04	6.46E-04
XE-128	N,G	1.67E-01	1.96E-01	2.66E-01	3.25E-01
XE-129	N,G	4.07E-01	4.94E-01	7.76E-01	9.74E-01
XE-130	N,G	1.07E-01	1.15E-01	1.25E-01	1.30E-01
XE-131	N,G	2.15E-01	2.67E-01	7.42E-01	1.01E 00
XE-132	N,G	6.50E-02	7.19E-02	8.41E-02	9.30E-02
XE-133	N,G	1.24E-01	1.93E-01	6.29E-01	9.17E-01
XE-134	N,G	3.23E-02	3.47E-02	3.76E-02	3.85E-02
XE-135	N,G	7.56E-03	2.17E-02	3.60E 00	6.41E 00
XE-136	N,G	2.82E-03	3.07E-03	3.53E-03	3.88E-03
CS-133	N,G	4.76E-01	5.68E-01	8.79E-01	1.08E 00
CS-134	N,G	5.25E-01	6.45E-01	1.01E 00	1.28E 00
CS-135	N,G	7.12E-02	9.56E-02	2.07E-01	2.85E-01
CS-136	N,G	2.60E-01	3.24E-01	5.06E-01	6.52E-01
CS-137	N,G	1.31E-02	1.50E-02	1.85E-02	2.06E-02
BA-134	N,G	1.09E-01	1.28E-01	1.98E-01	2.58E-01
BA-135	N,G	3.38E-01	4.25E-01	7.25E-01	9.49E-01
BA-136	N,G	4.54E-02	5.26E-02	6.81E-02	8.12E-02
BA-137	N,G	5.44E-02	6.51E-02	8.80E-02	1.07E-01
BA-138	N,G	5.71E-03	5.39E-03	4.96E-03	4.72E-03
BA-140	N,G	4.81E-02	7.96E-02	1.62E-01	2.32E-01
LA-139	N,G	3.97E-02	4.84E-02	7.95E-02	1.00E-01
LA-140	N,G	3.06E-01	4.05E-01	7.10E-01	9.64E-01
CE-140	N,G	1.73E-02	1.77E-02	1.84E-02	1.84E-02
CE-141	N,G	1.36E-01	1.59E-01	2.20E-01	2.67E-01
CE-142	N,G	3.24E-02	3.44E-02	3.68E-02	3.77E-02
CE-143	N,G	2.63E-01	3.47E-01	5.76E-01	7.78E-01
CE-144	N,G	5.16E-02	6.01E-02	7.74E-02	9.51E-02
PR-141	N,G	1.55E-01	1.95E-01	2.94E-01	3.76E-01

Table B.1 (continued)

Nuclide	Cross section type[a]	Cross section (barns) Core	Inner blanket	Radial blanket	Axial blanket
PR-142	N,G	4.02E-01	5.05E-01	8.49E-01	1.10E 00
PR-143	N,G	3.55E-01	4.49E-01	8.10E-01	1.07E 00
ND-142	N,G	3.83E-02	4.15E-02	5.02E-02	5.59E-02
ND-143	N,G	3.05E-01	3.83E-01	6.37E-01	8.36E-01
ND-144	N,G	9.41E-02	1.06E-01	1.35E-01	1.61E-01
ND-145	N,G	3.41E-01	4.26E-01	7.21E-01	9.40E-01
ND-146	N,G	1.23E-01	1.33E-01	1.53E-01	1.68E-01
ND-147	N,G	6.84E-01	8.73E-01	1.63E 00	2.16E 00
ND-148	N,G	1.79E-01	2.04E-01	2.82E-01	3.47E-01
ND-150	N,G	2.21E-01	2.57E-01	3.42E-01	4.07E-01
PM-147	N,G	1.26E 00	1.55E 00	2.80E 00	3.54E 00
PM-148	N,G	7.09E 00	8.41E 00	1.57E 01	1.83E 01
PM-149	N,G	3.08E 00	3.68E 00	5.38E 00	6.70E 00
PM-151	N,G	4.19E-02	6.60E-02	6.09E-01	7.81E-01
SM-147	N,G	8.15E-01	1.02E 00	1.93E 00	2.55E 00
SM-148	N,G	3.36E-01	3.79E-01	5.01E-01	6.01E-01
SM-149	N,G	1.43E 00	1.79E 00	3.30E 00	4.33E 00
SM-150	N,G	4.04E-01	4.81E-01	8.10E-01	1.04E 00
SM-151	N,G	2.22E 00	2.76E 00	4.79E 00	6.12E 00
SM-152	N,G	4.14E-01	5.15E-01	1.38E 00	1.69E 00
SM-153	N,G	6.92E-02	1.34E-01	1.12E 00	1.54E 00
SM-154	N,G	2.11E-01	2.55E-01	3.91E-01	4.95E-01
EU-151	N,G	3.60E 00	4.36E 00	6.91E 00	8.65E 00
EU-152	N,G	4.50E 00	5.40E 00	8.19E 00	1.01E 01
EU-153	N,G	2.28E 00	2.76E 00	4.34E 00	5.41E 00
EU-154	N,G	2.71E 00	3.28E 00	5.18E 00	6.44E 00
EU-155	N,G	2.53E 00	3.05E 00	4.72E 00	5.92E 00
EU-156	N,G	6.49E-02	8.95E-02	4.80E-01	5.99E-01
EU-157	N,G	4.26E-02	5.90E-02	3.89E-01	4.82E-01
GD-154	N,G	9.73E-01	1.17E 00	1.76E 00	2.24E 00
GD-155	N,G	1.96E 00	2.35E 00	3.69E 00	4.52E 00
GD-156	N,G	4.51E-01	5.44E-01	8.69E-01	1.11E 00
GD-157	N,G	3.67E 00	4.89E 00	8.17E 00	1.11E 01
GD-158	N,G	2.79E-01	3.33E-01	4.73E-01	5.87E-01
GD-160	N,G	2.00E-01	2.28E-01	2.90E-01	3.41E-01
TB-159	N,G	1.40E 00	1.75E 00	2.79E 00	3.61E 00
TB-160	N,G	1.46E-01	1.90E-01	5.55E-01	7.03E-01
DY-160	N,G	1.95E 00	2.37E 00	4.04E 00	5.20E 00
DY-161	N,G	2.16E 00	2.72E 00	4.51E 00	5.82E 00
DY-162	N,G	8.48E-01	1.04E 00	2.20E 00	2.77E 00
DY-163	N,G	9.49E-01	1.19E 00	2.10E 00	2.67E 00
DY-164	N,G	2.48E-01	2.85E-01	4.16E-01	5.10E-01
HO-165	N,G	1.52E 00	1.90E 00	3.10E 00	3.99E 00
ER-166	N,G	4.45E-01	5.38E-01	8.31E-01	1.05E 00
ER-167	N,G	1.44E 00	1.82E 00	3.32E 00	4.30E 00
TH-230	N,G	1.94E-01	2.61E-01	6.90E-01	9.19E-01
TH-230	N,F	3.61E-02	2.65E-02	1.98E-02	1.59E-02
TH-232	N,G	3.76E-01	4.46E-01	6.69E-01	8.35E-01
TH-232	N,F	1.25E-02	8.87E-03	6.51E-03	4.97E-03
PA-231	N,G	2.91E 00	3.32E 00	4.30E 00	4.95E 00

Table B.1 (continued)

Nuclide	Cross section type[a]	Cross section (barns) Core	Inner blanket	Radial blanket	Axial blanket
PA-231	N,F	2.84E-01	2.28E-01	1.80E-01	1.53E-01
PA-233	N,G	5.22E-01	6.18E-01	9.32E-01	1.13E 00
PA-233	N,F	8.04E-02	5.74E-02	4.22E-02	3.25E-02
PA-233	N,GX	5.22E-01	6.18E-01	9.32E-01	1.13E 00
U -232	N,G	6.46E-01	7.42E-01	1.01E 00	1.18E 00
U -232	N,F	2.30E 00	2.39E 00	2.91E 00	3.33E 00
U -233	N,G	2.65E-01	2.98E-01	3.93E-01	4.51E-01
U -233	N,F	2.71E 00	2.89E 00	3.47E 00	3.85E 00
U -234	N,G	6.03E-01	7.09E-01	1.14E 00	1.41E 00
U -234	N,F	3.81E-01	3.13E-01	2.53E-01	2.18E-01
U -235	N,G	5.48E-01	6.35E-01	8.73E-01	1.05E 00
U -235	N,F	1.90E 00	2.07E 00	2.53E 00	2.88E 00
U -236	N,G	5.44E-01	6.27E-01	9.26E-01	1.12E 00
U -236	N,F	1.24E-01	9.45E-02	7.69E-02	6.70E-02
U -237	N,G	4.82E-01	5.99E-01	1.02E 00	1.34E 00
U -237	N,F	6.19E-01	6.08E-01	5.90E-01	5.76E-01
U -238	N,G	2.97E-01	3.14E-01	3.65E-01	4.10E-01
U -238	N,F	5.25E-02	3.75E-02	2.76E-02	2.13E-02
NP-237	N,G	1.49E 00	1.76E 00	2.56E 00	3.11E 00
NP-237	N,F	3.89E-01	3.14E-01	2.49E-01	2.12E-01
NP-238	N,G	8.76E-02	1.15E-01	2.05E-01	2.70E-01
NP-238	N,F	5.83E-01	7.62E-01	1.41E 00	1.84E 00
PU-236	N,G	3.84E-01	4.65E-01	7.52E-01	9.39E-01
PU-236	N,F	1.53E 00	1.52E 00	1.71E 00	1.83E 00
PU-237	N,G	1.93E-01	2.25E-01	3.26E-01	3.88E-01
PU-237	N,F	3.69E 00	3.90E 00	4.65E 00	5.17E 00
PU-238	N,G	7.19E-01	8.40E-01	1.15E 00	1.39E 00
PU-238	N,F	1.19E 00	1.15E 00	1.16E 00	1.19E 00
PU-239	N,G	4.90E-01	6.14E-01	9.34E-01	1.23E 00
PU-239	N,F	1.84E 00	1.93E 00	2.26E 00	2.55E 00
PU-240	N,G	5.24E-01	6.77E-01	1.25E 00	1.67E 00
PU-240	N,F	4.24E-01	3.54E-01	2.95E-01	2.63E-01
PU-241	N,G	4.54E-01	5.28E-01	7.49E-01	8.98E-01
PU-241	N,F	2.49E 00	2.70E 00	3.37E 00	3.83E 00
PU-242	N,G	4.31E-01	5.12E-01	9.54E-01	1.09E 00
PU-242	N,F	3.07E-01	2.43E-01	1.92E-01	1.63E-01
PU-243	N,G	3.72E-01	4.40E-01	6.58E-01	7.96E-01
PU-243	N,F	8.66E-01	9.21E-01	1.26E 00	1.47E 00
PU-244	N,G	2.26E-01	2.95E-01	5.45E-01	7.35E-01
PU-244	N,F	2.58E-01	2.02E-01	1.57E-01	1.31E-01
AM-241	N,G	1.37E 00	1.58E 00	2.22E 00	2.62E 00
AM-241	N,F	3.46E-01	2.68E-01	2.13E-01	1.82E-01
AM-241	N,GX	3.41E-01	3.95E-01	5.55E-01	6.56E-01
AM-242	N,G	7.83E-02	1.03E-01	1.81E-01	2.39E-01
AM-242	N,F	5.22E-01	6.82E-01	1.23E 00	1.62E 00
AM-242	N,G	3.86E-01	4.69E-01	7.24E-01	8.99E-01
AM-242	N,F	4.00E 00	4.44E 00	5.90E 00	6.90E 00
AM-243	N,G	5.29E-02	6.39E-02	1.05E-01	1.27E-01
AM-243	N,F	2.72E-01	2.08E-01	1.60E-01	1.32E-01
AM-243	N,GX	1.00E 00	1.21E 00	2.00E 00	2.42E 00

Table B.1 (continued)

Nuclide	Cross section type[a]	Cross section (barns) Core	Inner blanket	Radial blanket	Axial blanket
CM-241	N,G	1.93E-01	2.23E-01	3.07E-01	3.61E-01
CM-241	N,F	3.17E 00	3.35E 00	4.07E 00	4.56E 00
CM-242	N,G	3.28E-01	4.19E-01	7.44E-01	9.89E-01
CM-242	N,F	1.99E-01	1.47E-01	1.11E-01	8.93E-02
CM-243	N,G	2.40E-01	2.90E-01	4.63E-01	5.68E-01
CM-243	N,F	2.66E 00	2.89E 00	3.91E 00	4.50E 00
CM-244	N,G	8.22E-01	9.53E-01	1.36E 00	1.60E 00
CM-244	N,F	4.86E-01	4.00E-01	3.34E-01	2.95E-01
CM-245	N,G	3.08E-01	3.49E-01	4.51E-01	5.11E-01
CM-245	N,F	2.63E 00	2.80E 00	3.37E 00	3.74E 00
CM-246	N,G	2.30E-01	2.75E-01	4.09E-01	5.02E-01
CM-246	N,F	3.20E-01	2.45E-01	1.89E-01	1.57E-01
CM-247	N,G	3.02E-01	3.45E-01	4.79E-01	5.57E-01
CM-247	N,F	1.93E 00	1.93E 00	2.01E 00	2.05E 00
CM-248	N,G	2.45E-01	3.02E-01	5.74E-01	7.37E-01
CM-248	N,F	3.56E-01	2.82E-01	2.34E-01	2.06E-01
BK-249	N,G	9.47E-01	1.26E 00	2.70E 00	3.59E 00
BK-249	N,F	1.90E-01	1.44E-01	1.11E-01	9.14E-02
CF-249	N,G	3.58E-01	4.21E-01	6.41E-01	7.82E-01
CF-249	N,F	2.62E 00	2.85E 00	3.56E 00	4.06E 00
CF-250	N,G	4.12E-01	5.14E-01	1.24E 00	1.56E 00
CF-250	N,F	1.11E 00	1.01E 00	8.87E-01	8.17E-01
CF-251	N,G	3.08E-01	3.56E-01	5.71E-01	6.79E-01
CF-251	N,F	2.30E 00	2.42E 00	3.01E 00	3.30E 00
CF-252	N,G	2.87E-01	3.31E-01	4.44E-01	5.25E-01
CF-252	N,F	7.72E-01	7.35E-01	8.82E-01	1.01E 00
CF-253	N,G	1.91E-01	2.59E-01	5.22E-01	7.01E-01
CF-253	N,F	6.81E-01	8.89E-01	1.68E 00	2.18E 00
ES-253	N,G	1.47E-01	2.16E-01	6.86E-01	9.24E-01
ES-253	N,GX	1.02E-01	1.50E-01	4.77E-01	6.42E-01
1/V	N,G	7.17E-04	8.30E-04	1.16E-03	1.38E-03

[a] N,G = (n,gamma) to a ground state
N,F = (n,fission)
N,GX = (n,gamma) to an excited state
N,A = (n,alpha)
N,P = (n,proton)

APPENDIX C: FUEL MANAGEMENT DETAILS FOR THE CRBR

Table C.1. Details of the CRBR fuel cycle management for cycles 5-10

Cycle[a]	Parameter	Fuel management schedule, kg heavy metal (fuel assemblies)											
		Core			Inner blanket			Inner radial blanket			Outer radial blanket		
		Fuel[b]	AB[c]	Fuel + AB	"Fuel"[d]	AB	"Fuel" + AB	"Fuel"	AB	"Fuel" + AB	"Fuel"	AB	"Fuel" + AB
EOC4	Inventory	0	0	0 (0)	0	0	0 (0)	0	0	0 (0)	3744.0	2912.0	6656.0 (66)
BOC5	+ Charge	5190.2	4224.6	9414.8 (156)	4651.7	3618.0	8269.7 (82)	3403.6	2647.3	6050.9 (60)	0	0	0 (0)
	= Inventory	5190.2	4224.6	9414.8 (156)	4651.7	3618.0	8269.7 (82)	3403.6	2647.3	6050.9 (60)	3744.0	2912.0	6656.0 (66)
EOC5	- Discharge	0	0	0 (0)	340.4	264.7	605.1 (6)	0	0	0 (0)	3744.0	2912.0	6656.0 (66)
	= Inventory	5190.2	4224.6	9414.8 (156)	4311.3	3353.3	7664.6 (76)	3403.6	2647.3	6050.9 (60)	0	0	0 (0)
BOC6	+ Charge	199.6	162.5	362.1 (6)	0	0	0 (0)	0	0	0 (0)	3744.0	2912.0	6656.0 (66)
	= Inventory	5389.8	4387.1	9766.9 (162)	4311.3	3353.3	7664.6 (76)	3403.6	2647.3	6050.9 (60)	3744.0	2912.0	6656.0 (66)
EOC6	- Discharge	5389.8	4387.1	9766.9 (162)	4311.3	3353.3	7664.6 (76)	0	0	0 (0)	0	0	0 (0)
	= Inventory	0	0	0 (0)	0	0	0 (0)	3403.6	2647.3	6050.9 (60)	3744.0	2912.0	6656.0 (66)
BOC7	+ Charge	5190.2	4224.6	9414.8 (156)	4651.7	3618.0	8269.7 (82)	0	0	0 (0)	0	0	0 (0)
	= Inventory	5190.2	4224.6	9414.8 (156)	4651.7	3618.0	8269.7 (82)	3403.6	2647.3	6050.9 (60)	3744.0	2912.0	6656.0 (66)
EOC7	- Discharge	0	0	0 (0)	340.4	264.7	605.1 (6)	0	0	0 (0)	0	0	0 (0)
	= Inventory	5190.2	4224.6	9414.8 (156)	4311.3	3353.3	7664.6 (76)	3403.6	2647.3	6050.9 (60)	3744.0	2912.0	6656.0 (66)
BOC8	+ Charge	199.6	162.5	362.1 (6)	0	0	0 (0)	0	0	0 (0)	0	0	0 (0)
	= Inventory	5389.8	4387.1	9776.9 (162)	4311.3	3353.3	7664.6 (76)	3403.6	2647.3	6050.9 (60)	3744.0	2912.0	6656.0 (66)
EOC8	- Discharge	5389.8	4387.1	9776.9 (162)	4311.3	3353.3	7664.6 (76)	3403.6	2647.3	6050.9 (60)	0	0	0 (0)
	= Inventory	0	0	0 (0)	0	0	0 (0)	0	0	0 (0)	3744.0	2912.0	6656.0 (66)
BOC9	+ Charge	5190.2	4224.6	9414.8 (156)	4651.7	3618.0	8269.7 (82)	3403.6	2647.3	6050.9 (60)	0	0	0 (0)
	= Inventory	5190.2	4224.6	9414.8 (156)	4651.7	3618.0	8269.7 (82)	3403.6	2647.3	6050.9 (60)	3744.0	2912.0	6656.0 (66)
EOC9	- Discharge	0	0	0 (0)	340.4	264.7	605.1 (6)	0	0	0 (0)	0	0	0 (0)
	= Inventory	5190.2	4224.6	9414.8 (156)	4311.3	3353.3	7664.6 (76)	3403.6	2647.3	6050.9 (60)	3744.0	2912.0	6656.0 (66)
BOC10	+ Charge	199.6	162.5	362.1 (6)	0	0	0 (0)	0	0	0 (0)			
	= Inventory	5389.8	4387.1	9776.9 (162)	4311.3	3353.3	7664.6 (76)	3403.6	2647.3	6050.9 (60)	3744.0	2912.0	6656.0 (66)
EOC10	- Discharge	5389.8	4387.1	9776.9 (162)	4311.3	3353.3	7664.6 (76)	0	0	0 (0)	3744.0	2912.0	6656.0 (66)
	= Inventory	0	0	0 (0)	0	0	0 (0)	3403.6	2647.3	6050.9 (60)	0	0	0 (0)

[a] EOCx = end of cycle x; BOCy = beginning of cycle y.

[b] 36-in. $(Pu,U)O_2$ region.

[c] Composite of upper (14-in.) and lower (14-in.) UO_2 axial blankets.

[d] 36-in. UO_2 region at the same axial elevation as the core fuel.

Table C.2. Details of CRBR irradiation characteristics

Material type	Parameter													
	Charge rate, kg/cycle			Inventory, kg			Power, MW(t)			Specific power, MW(t)/MTIHM			Effective irradiation duration, full-power days	Discharge burnup, MWd/MTIHM
	Cycle N	Cycle N + 1	Average	Cycle N	Cycle N + 1	Average	Cycle N	Cycle N + 1	Average	Cycle N	Cycle N + 1	Average		
Core														
Two-cycle residence														
Fuel[a]	5190.2		2595.1	5190.2	5190.2	5190.2	773.6	689.9	731.7	149.1	132.9	141.0	550	77,550
AB[b]	4224.6		2112.3	4224.6	4224.6	4224.6	14.0	19.3	16.7	3.31	4.57	3.94	550	2,167
Fuel + AB	9414.8		4707.4	9414.8	9414.8	9414.8	787.6	709.2	748.4	83.7	75.3	79.5	550	43,725
One-cycle residence														
Fuel		199.6	99.8		199.6	99.8		26.5	13.3		132.9	132.9	275	36,548
AB		162.5	81.3		162.5	81.3		0.741	0.371		4.57	4.57	275	1,257
Fuel + AB		362.1	181.1		362.1	181.1		27.2	13.6		75.1	75.1	275	20,653
Total														
Fuel	5190.2	199.6	2694.9	5190.2	5389.8	5290.0	773.6	716.4	745.0	149.1	132.9	140.9	539.8	76,031
AB	4224.6	162.5	2193.6	4224.6	4387.1	4305.9	14.0	20.0	17.0	3.31	4.57	3.95	539.8	2,133
Fuel + AB	9414.8	362.1	4888.5	9414.8	9776.9	9595.9	787.6	736.4	762.0	83.7	75.1	79.4	539.8	42,870
Inner blanket														
Two-cycle residence														
"Fuel"[c]	4311.3		2155.7	4311.3	4311.3	4311.3	86.0	138.2	112.1	19.9	32.1	26.0	550	14,300
AB	3353.3		1676.7	3353.3	3353.3	3353.3	11.2	17.9	14.6	3.34	5.34	4.34	550	2,387
"Fuel" + AB	7664.6		3832.3	7664.6	7664.6	7664.6	97.2	156.1		12.7	20.4	16.6	550	9,103
One-cycle residence														
"Fuel"	340.4		170.2	340.4		170.2	6.79		3.40	19.9		19.9	275	5,473
AB	264.7		132.4	264.7		132.4	0.885		0.443	3.34		3.34	275	919
"Fuel" + AB	605.1		302.6	605.1		302.6	7.68		3.84	12.7		12.7	275	3,493
Total														
"Fuel"	4651.7		2325.9	4651.7	4311.3	4481.5	92.8	138.2	115.5	19.9	32.1	25.8	529.9	13,654
AB	3618.0		1809.0	3618.0	3353.3	3485.7	12.1	17.9	15.0	3.34	5.34	4.30	529.9	2,280
"Fuel" + AB	8269.7		4134.9	8269.7	7664.6	7967.2	104.9	156.1	130.5	12.7	20.4	16.4	529.9	8,693
Radial blankets														
Inner radial blanket														
"Fuel"			850.9	3403.6	3403.6	3403.6	46.6	46.6	46.6	13.7	13.7	13.7	1100	15,070
AB			661.8	2647.3	2647.3	2647.3	5.1	5.1	5.1	1.93	1.93	1.93	1100	2,123
"Fuel" + AB			1512.7	6050.9	6050.9	6050.9	51.7	51.7	51.7	8.54	8.54	8.54	1100	9,394
Outer radial blanket														
"Fuel"			748.8	3744.0	3744.0	3744.0	27.7	27.7	27.7	7.40	7.40	7.40	1375	10,175
AB			582.4	2912.0	2912.0	2912.0	3.1	3.1	3.1	1.06	1.06	1.06	1375	1,458
"Fuel" + AB			1331.2	6656.0	6656.0	6656.0	30.8	30.8	30.8	4.63	4.63	4.63	1375	6,366
Total radial blanket														
"Fuel"			1599.7	7147.6	7147.6	7147.6	74.3	74.3	74.3	10.4	10.4	10.4	1229	12,779
AB			1244.2	5559.3	5559.3	5559.3	8.2	8.2	8.2	1.48	1.48	1.48	1229	1,819
"Fuel" + AB			2843.9	12,706.9	12,706.9	12,706.9	82.5	82.5	82.5	6.49	6.49	6.49	1229	7,977
Reactor total			11,867.3	30,391.4	30,148.4	30,270	975	975	975	32.10	32.28	32.2.		22,600

[a] 36-in. $(Pu,U)O_2$ region.

[b] Composite of upper (14-in.) and lower (14-in.) UO_2 axial blankets.

[c] 36-in. UO_2 region at the same axial elevation as the core fuel.

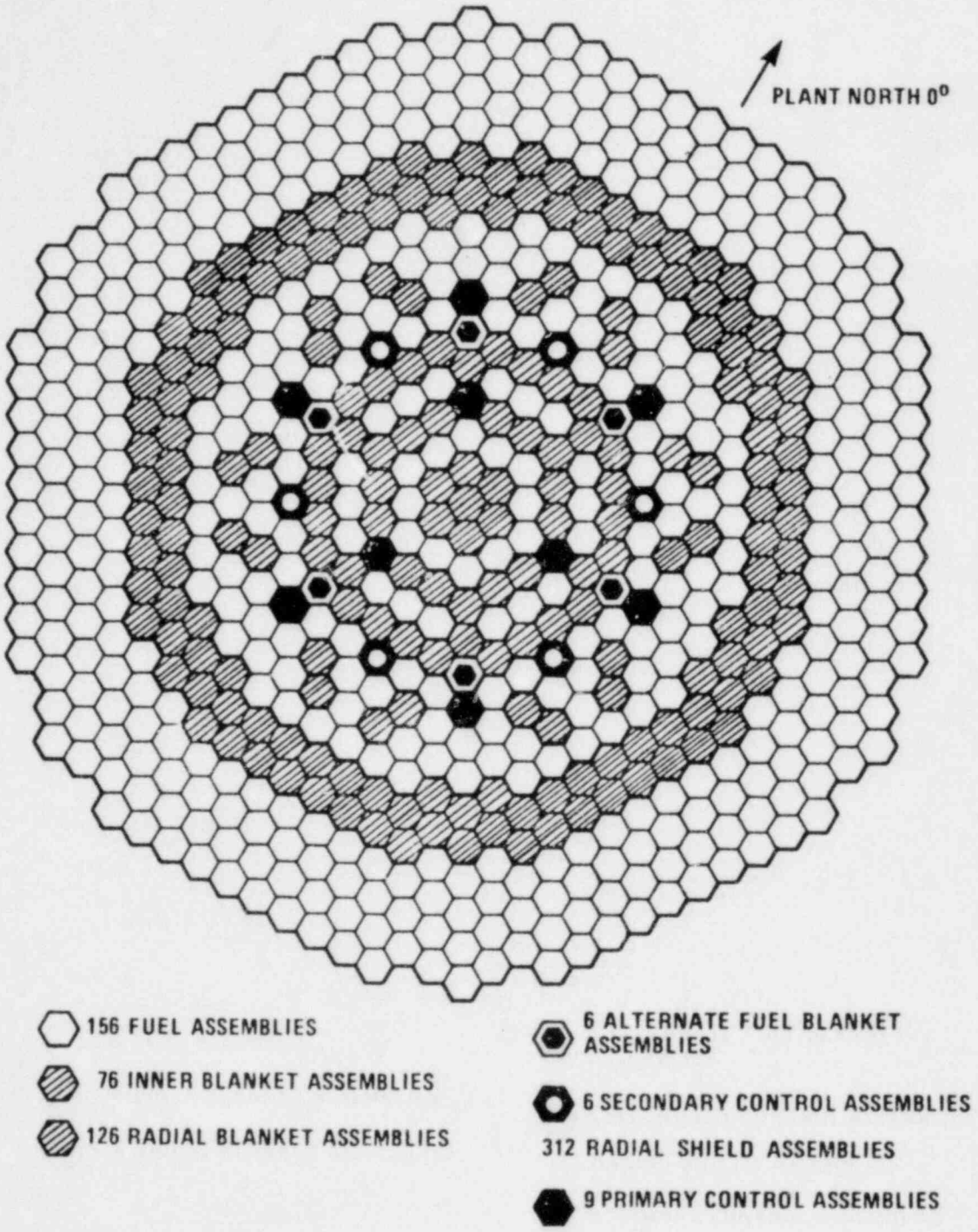

Fig. C.1. Clinch River Breeder Reactor core layout.

APPENDIX D: CHARACTERISTICS OF CRBR SPENT FUEL, HIGH-LEVEL WASTE, AND FUEL-ASSEMBLY STRUCTURAL MATERIAL WASTES

D.1: Characteristics of CRBR Spent Core Fuel Assemblies

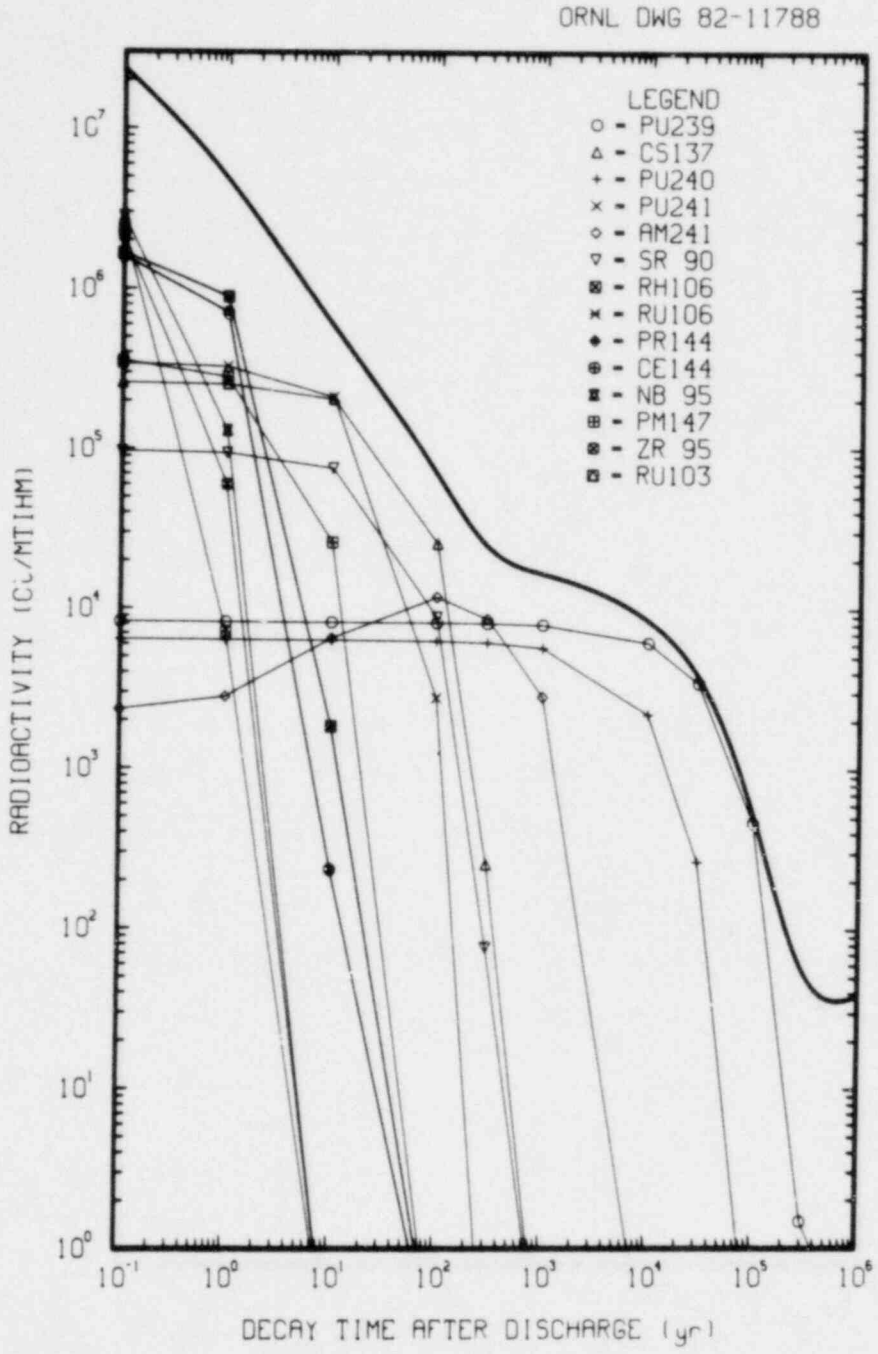

Fig. D.1. Radioactivity of CRBR spent core/axial blanket fuel as a function of decay time.

Table D.1. Radioactivity of CRBR spent core/axial blanket fuel as a function of decay time

Time (yr)	Radioactivity (Ci/MTIHM)											
	TOTAL	PU239	CS137	PU240	PU241	AM241	SR 90	RH106	FI106	PR144	CE144	NB 95
1.000E-01	2.360E+07	8.270E+03	2.603E+05	6.396E+03	3.428E+05	2.331E+03	9.659E+04	1.664E+06	1.664E+06	1.593E+06	1.593E+06	2.812E+06
1.000E+00	4.729E+06	8.270E+03	2.550E+05	6.396E+03	3.283E+05	2.812E+03	9.453E+04	8.961E+05	8.961E+05	7.148E+05	7.148E+05	1.307E+05
1.000E+01	5.823E+05	8.267E+03	2.071E+05	6.389E+03	2.128E+05	6.587E+03	7.630E+04	1.839E+03	1.839E+03	2.361E+02	2.341E+02	4.567E-11
1.000E+02	6.896E+04	8.245E+03	2.589E+04	6.330E+03	2.795E+03	1.195E+04	8.959E+03	2.437E-24	2.437E-24	0.0	0.0	0.0
3.000E+02	2.467E+04	8.199E+03	2.548E+02	6.196E+03	1.952E-01	8.744E+03	7.669E+01	0.0	0.0	0.0	0.0	0.0
1.000E+03	1.672E+04	8.035E+03	2.409E-05	5.753E+03	1.034E-02	2.845E+03	4.452E-06	0.0	0.0	0.0	0.0	0.0
1.000E+04	8.482E+03	6.200E+03	0.0	2.215E+03	4.963E-03	6.497E-03	0.0	0.0	0.0	0.0	0.0	0.0
3.000E+04	3.813E+03	3.486E+03	0.0	2.658E+02	9.712E-04	9.712E-04	0.0	0.0	0.0	0.0	0.0	0.0
1.000E+05	5.226E+02	4.641E+02	0.0	1.589E-01	3.225E-06	3.223E-06	0.0	0.0	0.0	0.0	0.0	0.0
3.000E+05	5.432E+01	1.472E+00	0.0	2.794E-08	2.656E-13	2.799E-13	0.0	0.0	0.0	0.0	0.0	0.0
1.000E+06	3.841E+01	3.007E-09	0.0	2.767E-08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Time (yr)	Radioactivity (Ci/MTIHM)											
	PM147	ZR 95	RU103	RH103M	CE141	ZR 93	NP237	PA233	U233	TH229	AC225	RA225
1.000E-01	3.553E+05	2.119E+06	2.358E+06	2.126E+06	1.579E+06	1.732E+00	7.521E-02	7.223E-02	2.756E-06	1.048E-06	1.136E-06	1.089E-06
1.000E+00	2.815E+05	6.018E+04	7.137E+03	6.434E+03	1.518E+03	1.799E+00	7.601E-02	7.591E-02	3.052E-06	1.049E-06	1.048E-06	1.048E-06
1.000E+01	2.610E+04	2.056E-11	4.598E-22	4.146E-22	0.0	2.323E+00	9.014E-02	9.014E-02	6.318E-06	1.052E-06	1.052E-06	1.052E-06
1.000E+02	1.230E-06	0.0	0.0	0.0	0.0	3.214E+00	4.194E-01	4.194E-01	1.029E-04	1.411E-06	1.411E-06	1.411E-06
3.000E+02	0.0	0.0	0.0	0.0	0.0	3.223E+00	1.087E+00	1.087E+00	7.766E-04	8.729E-06	8.729E-06	8.729E-06
1.000E+03	0.0	0.0	0.0	0.0	0.0	3.222E+00	2.278E+00	2.278E+00	6.252E-03	2.161E-04	2.161E-04	2.161E-04
1.000E+04	0.0	0.0	0.0	0.0	0.0	3.209E+00	2.845E+00	2.845E+00	1.145E-01	3.889E-02	3.889E-02	3.889E-02
3.000E+04	0.0	0.0	0.0	0.0	0.0	3.180E+00	2.827E+00	2.827E+00	3.423E-01	2.300E-01	2.300E-01	2.300E-01
1.000E+05	0.0	0.0	0.0	0.0	0.0	3.081E+00	2.762E+00	2.762E+00	9.886E-01	9.019E-01	9.019E-01	9.019E-01
3.000E+05	0.0	0.0	0.0	0.0	0.0	2.814E+00	2.590E+00	2.590E+00	1.965E+00	1.985E+00	1.985E+00	1.985E+00
1.000E+06	0.0	0.0	0.0	0.0	0.0	2.049E+00	2.065E+00	2.065E+00	2.191E+00	2.196E+00	2.196E+00	2.196E+00

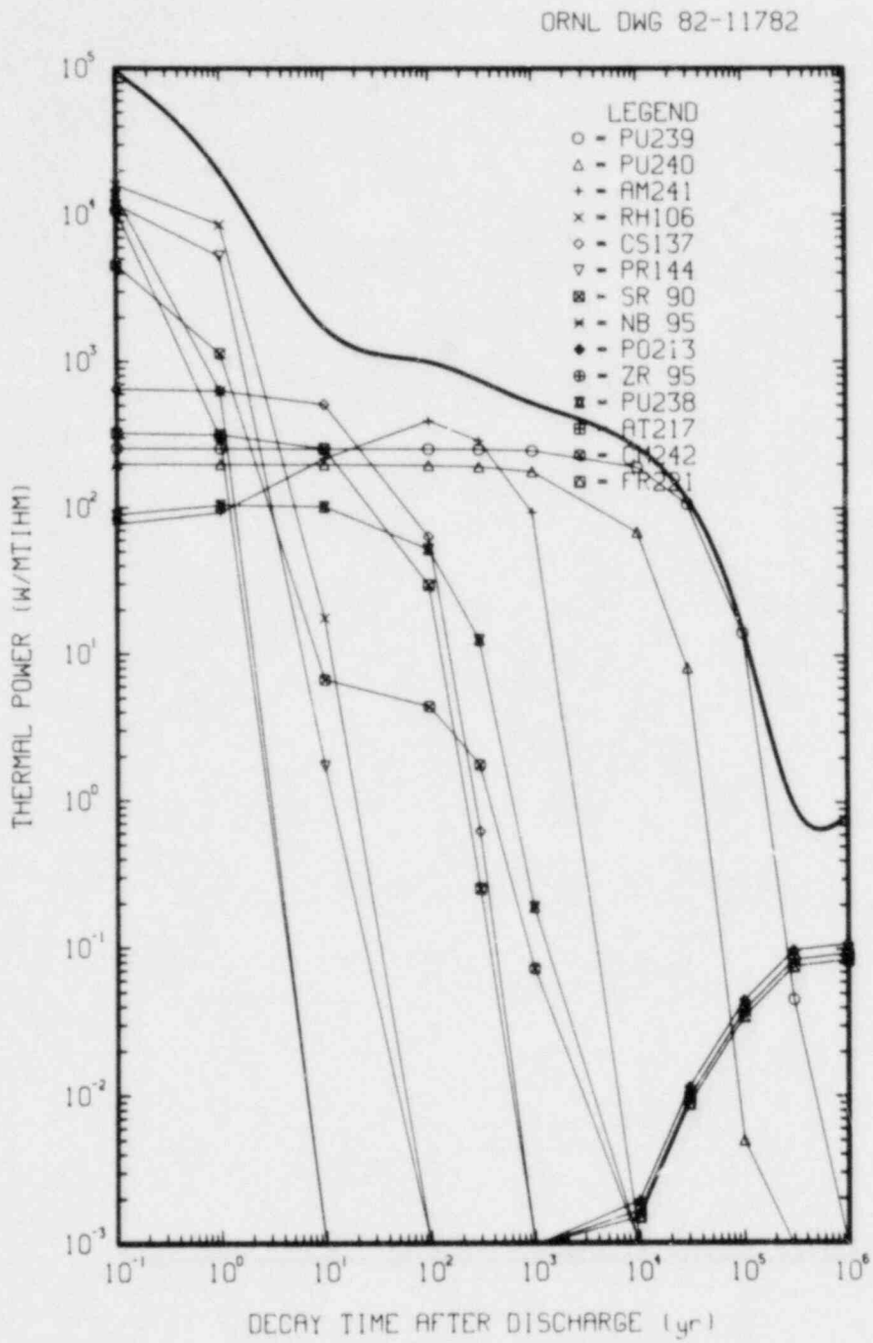

Fig. D.2. Thermal power of CRBR spent core/axial blanket fuel as a function of decay time.

Table D.2. Thermal power of CRBR spent core/axial blanket fuel as a function of decay time

Thermal power (W/MTIHM)

Time (yr)	TOTAL	PU239	PU240	AM241	RH106	CS137	PR144	SR 90	NB 95	PO213	ZR 95	PU238
1.000E-01	9.524E+04	2.548E+02	1.992E+02	7.743E+01	1.596E+04	6.449E+02	1.171E+04	3.238E+02	1.349E+04	5.624E-08	1.073E+04	8.923E+01
1.000E+00	1.964E+04	2.548E+02	1.992E+02	9.339E+01	8.595E+03	6.316E+02	5.254E+03	3.168E+02	6.268E+02	5.191E-08	3.049E+02	1.043E+02
1.000E+01	1.722E+03	2.548E+02	1.990E+02	2.187E+02	1.765E+01	5.131E+02	1.735E+00	2.557E+02	2.191E-13	5.206E-08	1.042E-13	1.024E+02
1.000E+02	1.001E+03	2.542E+02	1.970E+02	3.970E+02	2.338E-26	6.413E+01	0.0	3.002E+01	0.0	6.988E-08	0.0	5.276E+01
3.000E+02	7.521E+02	2.527E+02	1.929E+02	2.905E+02	0.0	6.311E-01	0.0	2.571E-01	0.0	4.321E-07	0.0	1.274E+01
1.000E+03	5.221E+02	2.476E+02	1.791E+02	9.452E+01	0.0	5.968E-09	0.0	1.492E-08	0.0	1.069E-05	0.0	1.932E-01
1.000E+04	2.606E+02	1.911E+02	6.898E+01	2.159E-04	0.0	0.0	0.0	0.0	0.0	1.925E-03	0.0	2.376E-19
3.000E+04	1.162E+02	1.074E+02	8.275E+00	3.226E-05	0.0	0.0	0.0	0.0	0.0	1.139E-02	0.0	0.0
1.000E+05	1.504E+01	1.430E+01	4.948E-03	1.071E-07	0.0	0.0	0.0	0.0	0.0	4.466E-02	0.0	0.0
3.000E+05	9.778E-01	4.535E-02	8.696E-10	9.296E-15	0.0	0.0	0.0	0.0	0.0	9.826E-02	0.0	0.0
1.000E+06	8.071E-01	9.266E-11	8.615E-10	0.0	0.0	0.0	0.0	0.0	0.0	1.087E-01	0.0	0.0

Thermal power (W/MTIHM)

Time (yr)	AT217	CM242	PR221	LA140	AC225	TH229	NP237	RU103	U233	U236	CO 60	CS134
1.000E-01	4.847E-09	4.562E+03	4.384E-08	9.415E+03	3.969E-08	3.206E-08	2.298E-03	7.889E+03	8.010E-08	1.756E-04	2.335E+02	6.714E+02
1.000E+00	4.474E-08	1.135E+03	4.046E-08	1.723E-04	3.662E-08	3.208E-08	2.323E-03	2.388E+01	8.872E-08	1.803E-04	2.075E+02	4.961E+02
1.000E+01	4.487E-08	6.729E+00	4.058E-08	0.0	3.674E-08	3.216E-08	2.756E-03	1.538E-24	1.836E-07	2.263E-04	6.350E+01	2.408E+01
1.000E+02	6.023E-08	4.464E+00	5.447E-08	0.0	4.930E-08	4.318E-08	1.282E-02	0.0	2.991E-06	6.853E-04	4.587E-04	1.780E-12
3.000E+02	3.725E-07	1.793E+00	3.369E-07	0.0	3.049E-07	2.669E-07	3.322E-02	0.0	2.258E-05	1.690E-03	1.725E-15	0.0
1.000E+03	9.218E-06	7.369E-02	8.336E-06	0.0	7.546E-06	6.608E-06	6.963E-02	0.0	1.818E-04	5.042E-03	0.0	0.0
1.000E+04	1.659E-03	1.110E-19	1.501E-03	0.0	1.358E-03	1.190E-03	8.694E-02	0.0	3.329E-03	3.180E-02	0.0	0.0
3.000E+04	9.813E-03	0.0	8.875E-03	0.0	8.033E-03	7.036E-03	8.638E-02	0.0	9.952E-03	4.651E-02	0.0	0.0
1.000E+05	3.849E-02	0.0	3.481E-02	0.0	3.150E-02	2.759E-02	8.444E-02	0.0	2.873E-02	4.842E-02	0.0	0.0
3.000E+05	8.469E-02	0.0	7.659E-02	0.0	6.933E-02	6.071E-02	7.914E-02	0.0	5.710E-02	4.814E-02	0.0	0.0
1.000E+06	9.365E-02	0.0	8.471E-02	0.0	7.667E-02	6.714E-02	6.308E-02	0.0	6.366E-02	4.716E-02	0.0	0.0

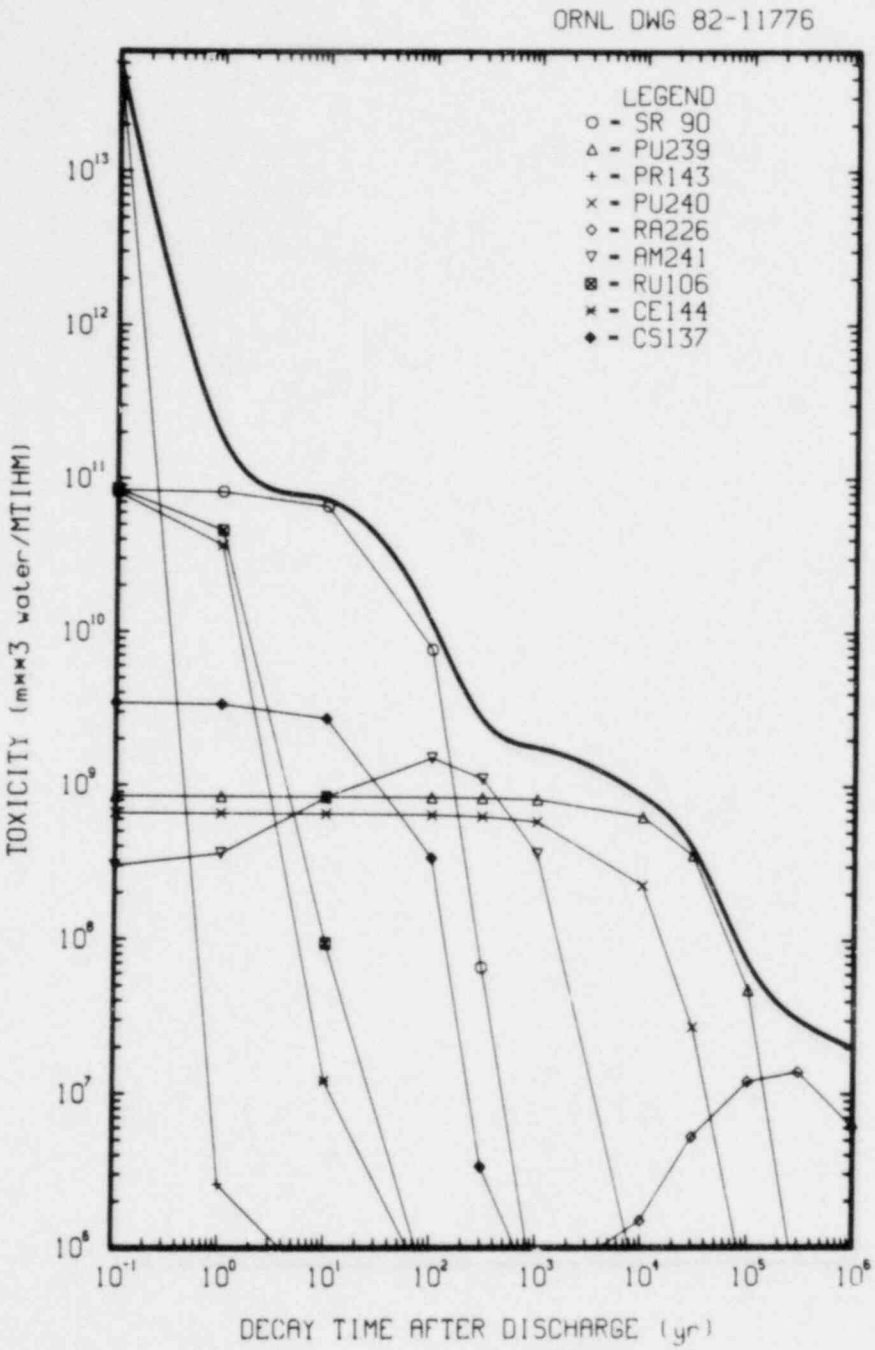

Fig. D.3. Ingestion toxicity of CRBR spent core/axial blanket fuel as a function of decay time.

Table D.3. Ingestion toxicity of CRBR spent core/axial blanket fuel as a function of decay time

Time (yr)	Ingestion toxicity (m^3 water/MTIHM)											
	TOTAL	SR 90	PU239	PR143	PU240	RA226	AM241	RN219	RU106	CE144	TH229	PB210
1.000E-01	5.126E+13	8.381E+10	8.484E+08	5.053E+13	6.562E+08	9.698E-03	2.989E+08	7.101E-01	8.534E+10	8.173E+10	1.345E+00	2.533E-01
1.000E+00	1.800E+11	8.203E+10	8.494E+08	2.561E+06	6.561E+08	1.526E-02	3.606E+08	7.120E-01	4.597E+10	3.667E+10	1.345E+00	2.510E-01
1.000E+01	7.269E+10	6.622E+10	8.482E+08	0.0	6.555E+08	2.482E-01	8.446E+08	3.417E+00	9.435E+07	1.201E+07	1.348E+00	1.972E-01
1.000E+02	1.135E+10	7.773E+09	8.460E+08	0.0	6.493E+08	9.588E+01	1.533E+09	8.395E+01	1.250E-19	0.0	1.810E+00	1.394E+01
3.000E+02	2.721E+09	6.651E+07	8.412E+08	0.0	6.357E+08	1.778E+03	1.121E+09	3.820E+02	0.0	0.0	1.119E+01	4.096E+02
1.000E+03	1.783E+09	3.863E+00	8.243E+08	0.0	5.902E+08	2.973E+04	3.649E+08	2.449E+03	0.0	0.0	2.770E+02	8.517E+03
1.000E+04	8.678E+08	0.0	6.361E+08	0.0	2.273E+08	1.493E+06	8.333E+02	1.340E+05	0.0	0.0	4.986E+04	4.476E+05
3.000E+04	3.953E+08	0.0	3.576E+08	0.0	2.727E+07	5.247E+06	1.245E+02	8.407E+05	0.0	0.0	2.950E+05	1.573E+06
1.000E+05	7.148E+07	0.0	4.762E+07	0.0	1.630E+04	1.204E+07	4.134E-01	3.432E+06	0.0	0.0	1.157E+06	3.610E+06
3.000E+05	3.046E+07	0.0	1.510E+05	0.0	2.965E-03	1.393E+07	3.589E-08	4.853E+06	0.0	0.0	2.545E+06	4.178E+06
1.000E+06	1.996E+07	0.0	3.085E-04	0.0	2.839E-03	6.116E+06	0.0	4.879E+06	0.0	0.0	2.814E+06	1.833E+06

Time (yr)	Ingestion toxicity (m^3 water/MTIHM)											
	RA225	CS137	I129	NP237	PU238	PO210	CS134	PU241	AC225	RA223	SR 89	PA231
1.000E-01	1.118E+00	3.432E+09	4.950E+05	1.286E+04	2.762E+08	2.377E-02	3.760E+09	8.789E+08	1.165E-01	3.043E-02	1.283E+11	1.951E-01
1.000E+00	1.075E+00	3.361E+09	4.984E+05	1.303E+04	3.227E+08	3.340E-02	2.778E+09	8.418E+08	1.075E-01	3.051E-02	1.408E+09	2.255E-01
1.000E+01	1.079E+00	2.730E+09	4.984E+05	1.541E+04	3.169E+08	2.819E-02	1.348E+08	5.459E+08	1.079E-01	1.465E-01	3.568E-11	5.319E-01
1.000E+02	1.448E+00	3.412E+08	4.984E+05	7.171E+04	1.634E+08	1.992E+00	9.962E-06	7.170E+06	1.448E-01	3.597E+00	0.0	4.026E+00
3.000E+02	8.959E+00	3.358E+06	4.984E+05	1.859E+05	3.944E+07	5.851E+01	0.0	5.005E+02	8.959E-01	1.637E+01	0.0	1.460E+01
1.000E+03	2.216E+02	3.176E-01	4.983E+05	3.895E+05	5.981E+05	1.273E+03	0.0	2.652E+01	2.216E+01	1.050E+02	0.0	8.161E+01
1.000E+04	3.989E+04	0.0	4.981E+05	4.864E+05	7.357E-13	6.395E+04	0.0	1.273E+01	3.989E+03	5.743E+03	0.0	4.467E+03
3.000E+04	2.360E+05	0.0	4.977E+05	4.832E+05	0.0	2.247E+05	0.0	2.491E+00	2.360E+04	3.603E+04	0.0	2.802E+04
1.000E+05	9.257E+05	0.0	4.961E+05	4.724E+05	0.0	5.157E+05	0.0	8.269E-03	9.257E+04	1.471E+05	0.0	1.144E+05
3.000E+05	2.036E+06	0.0	4.918E+05	4.428E+05	0.0	5.969E+05	0.0	6.813E-10	2.036E+05	2.080E+05	0.0	1.618E+05
1.000E+06	2.252E+06	0.0	4.768E+05	3.529E+05	0.0	2.620E+05	0.0	0.0	2.252E+05	2.091E+05	0.0	1.626E+05

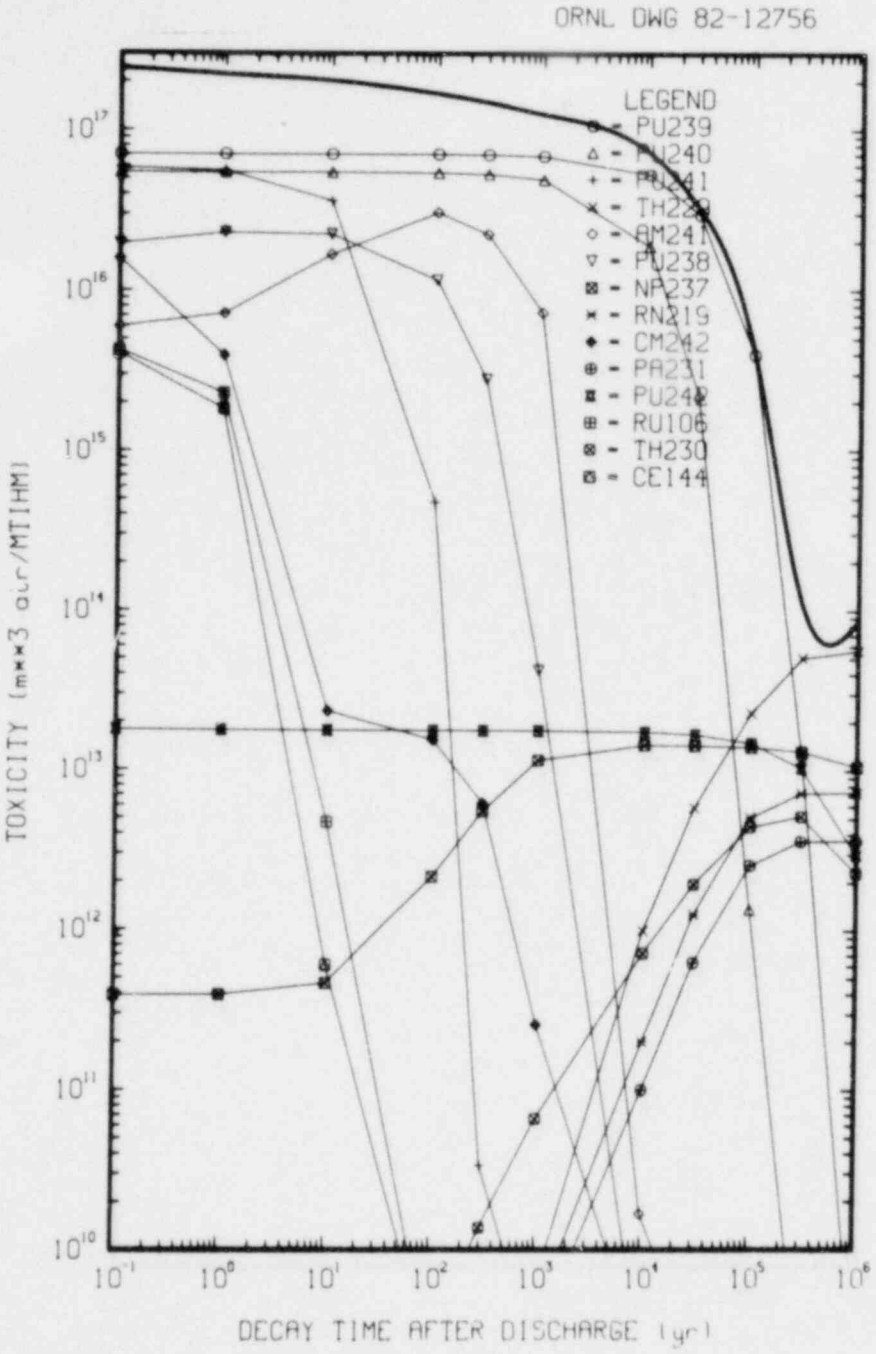

Fig. D.4. Inhalation toxicity of CRBR spent core/axial blanket fuel as a function of decay time.

Table D.4. Inhalation toxicity of CRBR spent core/axial blanket fuel as a function of decay time

Time (yr)	Inhalation toxicity (m^3 air/MTIHM)											
	TOTAL	PU239	PU240	PU241	TH229	AM241	PU238	NP237	RN219	CM242	PA231	PU242
1.000E-01	2.428E+17	7.070E+16	5.468E+16	5.861E+16	2.689E+07	5.979E+15	1.973E+16	3.858E+11	1.065E+06	1.588E+16	4.389E+06	1.779E+13
1.000E+00	2.222E+17	7.070E+16	5.468E+16	5.613E+16	2.689E+07	7.211E+15	2.305E+16	3.899E+11	1.068E+06	3.949E+15	5.075E+06	1.779E+13
1.000E+01	2.030E+17	7.068E+16	5.463E+16	3.639E+16	2.697E+07	1.689E+16	2.264E+16	4.624E+11	5.126E+06	2.343E+13	1.197E+07	1.779E+13
1.000E+02	1.680E+17	7.050E+16	5.411E+16	4.780E+14	3.620E+07	3.066E+16	1.167E+16	2.151E+12	1.259E+08	1.554E+13	9.061E+07	1.783E+13
3.000E+02	1.485E+17	7.009E+16	5.297E+16	3.336E+10	2.239E+08	2.242E+16	2.817E+15	5.577E+12	5.730E+08	6.242E+12	3.285E+08	1.788E+13
1.000E+03	1.253E+17	6.870E+16	4.918E+16	1.768E+09	5.540E+09	7.298E+15	4.273E+13	1.169E+13	3.673E+09	2.564E+11	1.836E+09	1.789E+13
1.000E+04	7.199E+16	5.301E+16	1.894E+16	8.486E+08	9.970E+11	1.667E+10	5.255E-05	1.459E+13	2.010E+11	3.864E-07	1.005E+11	1.760E+13
3.000E+04	3.212E+16	2.980E+16	2.272E+15	1.661E+08	5.898E+12	2.491E+09	0.0	1.450E+13	1.261E+12	0.0	6.305E+11	1.698E+13
1.000E+05	4.037E+15	3.969E+15	1.358E+12	5.512E+05	2.314E+13	8.268E+06	0.0	1.417E+13	5.148E+12	0.0	2.574E+12	1.499E+13
3.000E+05	1.064E+14	1.258E+13	2.388E+05	4.542E-02	5.090E+13	7.177E-01	0.0	1.329E+13	7.279E+12	0.0	3.640E+12	1.047E+13
1.000E+06	8.593E+13	2.570E+04	2.366E+05	0.0	5.630E+13	0.0	0.0	1.059E+13	7.318E+12	0.0	3.659E+12	2.988E+12

Time (yr)	Inhalation toxicity (m^3 air/MTIHM)											
	RU106	TH230	CE144	AC227	SR 90	AM242M	SR 89	ZR 95	U233	CM244	U236	I131
1.000E-01	4.268E+15	4.571E+06	4.087E+15	2.054E+05	8.339E+14	5.955E+14	1.283E+15	1.087E+15	3.533E+05	2.486E+14	8.316E+08	5.851E+14
1.000E+00	2.298E+15	6.195E+06	1.833E+15	2.665E+05	8.163E+14	5.930E+14	1.408E+13	3.087E+13	3.913E+05	2.402E+14	8.534E+08	2.885E+02
1.000E+01	4.717E+12	4.573E+07	6.007E+11	1.280E+06	6.589E+14	5.692E+14	3.568E-07	1.055E-02	8.102E+05	1.702E+14	1.072E+09	0.0
1.000E+02	6.251E-15	2.309E+08	0.0	3.148E+07	7.735E+13	3.776E+14	0.0	0.0	1.319E+07	5.432E+12	3.244E+09	0.0
3.000E+02	0.0	1.368E+10	0.0	1.432E+08	6.618E+11	1.517E+14	0.0	0.0	9.962E+07	2.573E+09	7.999E+09	0.0
1.000E+03	0.0	6.592E+10	0.0	9.180E+08	3.844E+04	6.233E+12	0.0	0.0	8.016E+08	4.786E+00	2.387E+10	0.0
1.000E+04	0.0	7.211E+11	0.0	5.025E+10	0.0	9.367E-06	0.0	0.0	1.468E+10	4.780E+00	1.505E+11	0.0
3.000E+04	0.0	1.955E+12	0.0	3.153E+11	0.0	0.0	0.0	0.0	4.390E+10	4.779E+00	2.202E+11	0.0
1.000E+05	0.0	4.492E+12	0.0	1.287E+12	0.0	0.0	0.0	0.0	1.267E+11	4.776E+00	2.292E+11	0.0
3.000E+05	0.0	5.209E+12	0.0	1.820E+12	0.0	0.0	0.0	0.0	2.519E+11	4.768E+00	2.279E+11	0.0
1.000E+06	0.0	2.293E+12	0.0	1.829E+12	0.0	0.0	0.0	0.0	2.809E+11	4.740E+00	2.232E+11	0.0

D.2: Characteristics of Blended CRBR High-Level Waste

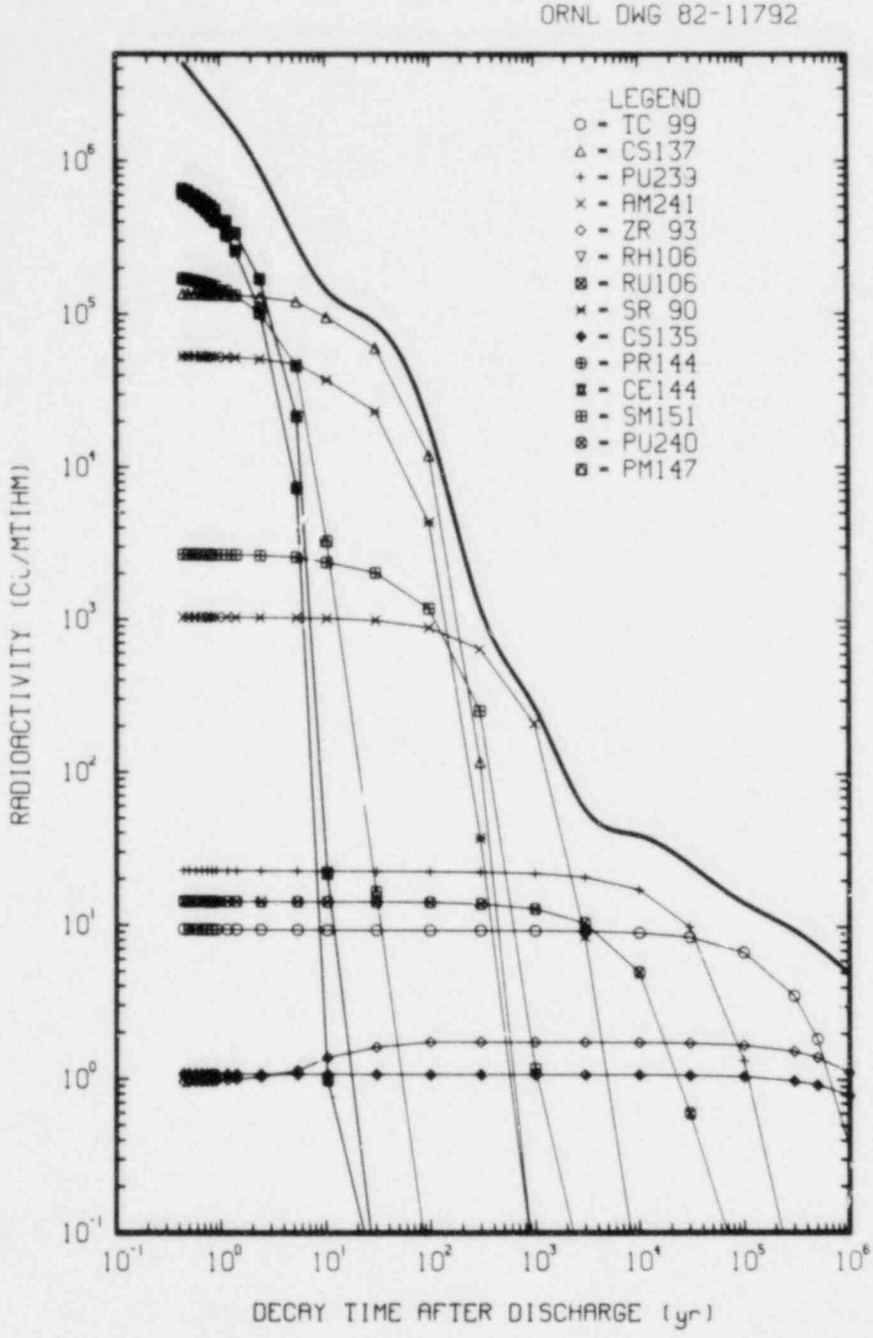

Fig. D.5. Radioactivity of CRBR blended high-level waste as a function of decay time.

Table D.5. Radioactivity of CRBR blended high-level waste as a function of decay time

Time (yr)	Radioactivity (Ci/MTIHM)											
	TOTAL	TC 99	CS137	PU239	AM241	ZR 93	RH106	RU106	SR 90	CS135	PR144	CE144
4.384E-01	4.429E+06	9.400E+00	1.358E+05	2.277E+01	1.037E+03	9.598E-01	6.581E+05	6.581E+05	5.337E+04	1.076E+00	6.127E+05	6.127E+05
4.931E-01	4.010E+06	9.400E+00	1.356E+05	2.277E+01	1.037E+03	9.620E-01	6.338E+05	6.338E+05	5.331E+04	1.076E+00	5.835E+05	5.835E+05
5.753E-01	3.515E+06	9.400E+00	1.354E+05	2.277E+01	1.037E+03	9.653E-01	5.990E+05	5.990E+05	5.321E+04	1.076E+00	5.424E+05	5.424E+05
6.574E-01	3.134E+06	9.400E+00	1.351E+05	2.277E+01	1.037E+03	9.687E-01	5.661E+05	5.661E+05	5.310E+04	1.076E+00	5.041E+05	5.041E+05
7.395E-01	2.833E+06	9.400E+00	1.349E+05	2.277E+01	1.037E+03	9.719E-01	5.350E+05	5.350E+05	5.300E+04	1.076E+00	4.686E+05	4.685E+05
8.217E-01	2.588E+06	9.400E+00	1.346E+05	2.277E+01	1.037E+03	9.752E-01	5.056E+05	5.056E+05	5.290E+04	1.076E+00	4.355E+05	4.355E+05
9.038E-01	2.386E+06	9.400E+00	1.343E+05	2.277E+01	1.037E+03	9.785E-01	4.779E+05	4.779E+05	5.280E+04	1.076E+00	4.048E+05	4.048E+05
1.150E+00	1.935E+06	9.400E+00	1.336E+05	2.277E+01	1.037E+03	9.882E-01	4.034E+05	4.034E+05	5.247E+04	1.076E+00	3.250E+05	3.250E+05
1.411E+00	1.603E+06	9.400E+00	1.328E+05	2.277E+01	1.037E+03	9.983E-01	3.372E+05	3.372E+05	5.215E+04	1.076E+00	2.577E+05	2.576E+05
2.411E+00	8.841E+05	9.400E+00	1.297E+05	2.277E+01	1.036E+03	1.036E+00	1.695E+05	1.695E+05	5.093E+04	1.076E+00	1.057E+05	1.057E+05
5.411E+00	2.975E+05	9.400E+00	1.211E+05	2.277E+01	1.034E+03	1.138E+00	2.154E+04	2.154E+04	4.741E+04	1.076E+00	7.309E+03	7.309E+03
1.041E+01	1.439E+05	9.399E+00	9.608E+04	2.277E+01	1.025E+03	1.385E+00	2.223E+01	2.192E+01	3.737E+04	1.076E+00	9.905E-01	9.905E-01
3.041E+01	8.764E+04	9.399E+00	6.052E+04	2.277E+01	9.995E+02	1.622E+00	2.334E-05	2.334E-05	2.322E+04	1.076E+00	1.819E-08	1.819E-08
1.004E+02	1.883E+04	9.397E+00	1.201E+04	2.274E+01	8.973E+02	1.752E+00	2.905E-26	2.905E-26	4.387E+03	1.076E+00	0.0	0.0
3.004E+02	1.232E+03	9.391E+00	1.182E+02	2.262E+01	6.512E+02	1.756E+00	0.0	0.0	3.757E+01	1.076E+00	0.0	0.0
1.000E+03	2.725E+02	9.369E+00	1.118E-05	2.221E+01	2.119E+02	1.755E+00	0.0	0.0	2.182E-06	1.076E+00	0.0	0.0
3.000E+03	5.899E+01	9.308E+00	9.534E-26	2.106E+01	8.579E+00	1.754E+00	0.0	0.0	4.620E-27	1.075E+00	0.0	0.0
1.000E+04	3.944E+01	9.099E+00	0.0	1.743E+01	2.158E-03	1.748E+00	0.0	0.0	0.0	1.073E+00	0.0	0.0
3.000E+04	2.554E+01	8.525E+00	0.0	9.950E+00	4.000E-04	1.732E+00	0.0	0.0	0.0	1.066E+00	0.0	0.0
1.000E+05	1.430E+01	6.789E+00	0.0	1.332E+00	1.326E-06	1.678E+00	0.0	0.0	0.0	1.044E+00	0.0	0.0
3.000E+05	9.478E+00	3.541E+00	0.0	4.219E-03	1.151E-13	1.533E+00	0.0	0.0	0.0	9.830E-01	0.0	0.0
5.000E+05	7.400E+00	1.847E+00	0.0	1.331E-05	9.487E-21	1.400E+00	0.0	0.0	0.0	9.255E-01	0.0	0.0
1.000E+06	4.957E+00	3.630E-01	0.0	1.844E-10	1.849E-38	1.116E+00	0.0	0.0	0.0	7.960E-01	0.0	0.0

Time (yr)	Radioactivity (Ci/MTIHM)										
	SM151	PU240	PM147	NB 93	NP237	PA233	U233	TH229	AC225	RA225	FR221	AT217
4.384E-01	2.686E+03	1.433E+01	1.719E+05	5.538E+05	7.307E-02	7.295E-02	1.740E-08	2.184E-09	3.893E-07	2.746E-07	3.894E-07	3.894E-07
4.931E-01	2.685E+03	1.433E+01	1.694E+05	4.572E+05	7.309E-02	7.300E-02	3.487E-08	2.184E-09	2.182E-07	1.090E-07	2.182E-07	2.182E-07
5.753E-01	2.684E+03	1.433E+01	1.658E+05	3.402E+05	7.311E-02	7.305E-02	6.110E-08	2.185E-09	6.882E-08	2.840E-08	6.883E-08	6.883E-08
6.574E-01	2.682E+03	1.433E+01	1.622E+05	2.512E+05	7.314E-02	7.309E-02	8.735E-08	2.185E-09	2.024E-08	8.618E-09	2.025E-08	2.025E-08
7.395E-01	2.680E+03	1.433E+01	1.588E+05	1.845E+05	7.317E-02	7.313E-02	1.136E-07	2.185E-09	6.830E-09	3.764E-09	6.831E-09	6.831E-09
8.217E-01	2.678E+03	1.433E+01	1.554E+05	1.350E+05	7.320E-02	7.316E-02	1.399E-07	2.187E-09	3.353E-09	2.574E-09	3.353E-09	3.353E-09
9.038E-01	2.677E+03	1.433E+01	1.520E+05	9.844E+04	7.322E-02	7.319E-02	1.662E-07	2.188E-09	2.477E-09	2.282E-09	2.477E-09	2.477E-09
1.150E+00	2.672E+03	1.433E+01	1.424E+05	3.775E+04	7.331E-02	7.327E-02	2.451E-07	2.193E-09	2.195E-09	2.193E-09	2.195E-09	2.195E-09
1.411E+00	2.666E+03	1.433E+01	1.330E+05	1.355E+04	7.339E-02	7.336E-02	3.287E-07	2.200E-09	2.197E-09	2.198E-09	2.197E-09	2.197E-09
2.411E+00	2.646E+03	1.434E+01	1.021E+05	2.698E+02	7.373E-02	7.374E-02	6.846E-07	2.249E-09	2.249E-09	2.249E-09	2.249E-09	2.249E-09
5.411E+00	2.585E+03	1.435E+01	4.621E+04	1.823E-03	7.474E-02	7.473E-02	1.693E-06	2.590E-09	2.590E-09	2.590E-09	2.590E-09	2.590E-09
1.041E+01	2.394E+03	1.438E+01	3.291E+03	1.191E-20	7.807E-02	7.807E-02	5.033E-06	5.767E-09	5.767E-09	5.767E-09	5.767E-09	5.767E-09
3.041E+01	2.052E+03	1.440E+01	1.670E+01	0.0	8.463E-02	8.463E-02	1.215E-05	2.191E-08	2.191E-08	2.191E-08	2.191E-08	2.191E-08
1.004E+02	1.197E+03	1.433E+01	1.551E-07	0.0	1.061E-01	1.061E-01	4.139E-05	1.948E-07	1.948E-07	1.948E-07	1.948E-07	1.948E-07
3.004E+02	2.565E+02	1.403E+01	0.0	0.0	1.559E-01	1.559E-01	1.570E-04	1.984E-06	1.984E-06	1.984E-06	1.984E-06	1.984E-06
1.000E+03	1.169E+00	1.303E+01	0.0	0.0	2.445E-01	2.445E-01	7.933E-04	3.108E-05	3.108E-05	3.108E-05	3.108E-05	3.108E-05
3.000E+03	2.386E-07	1.054E+01	0.0	0.0	2.854E-01	2.854E-01	3.177E-03	3.698E-04	3.698E-04	3.698E-04	3.698E-04	3.698E-04
1.000E+04	0.0	5.017E+00	0.0	0.0	2.865E-01	2.865E-01	1.173E-02	4.033E-03	4.033E-03	4.033E-03	4.033E-03	4.033E-03
3.000E+04	0.0	6.019E-01	0.0	0.0	2.847E-01	2.847E-01	3.466E-02	2.334E-02	2.334E-02	2.334E-02	2.334E-02	2.334E-02
1.000E+05	0.0	3.598E-04	0.0	0.0	2.783E-01	2.783E-01	9.970E-02	9.099E-02	9.099E-02	9.099E-02	9.099E-02	9.099E-02
3.000E+05	0.0	5.770E-11	0.0	0.0	2.608E-01	2.608E-01	1.979E-01	2.000E-01	2.000E-01	2.000E-01	2.000E-01	2.000E-01
5.000E+05	0.0	5.742E-11	0.0	0.0	2.445E-01	2.445E-01	2.291E-01	2.331E-01	2.331E-01	2.331E-01	2.331E-01	2.331E-01
1.000E+06	0.0	5.724E-11	0.0	0.0	2.079E-01	2.079E-01	2.206E-01	2.219E-01	2.219E-01	2.219E-01	2.219E-01	2.219E-01

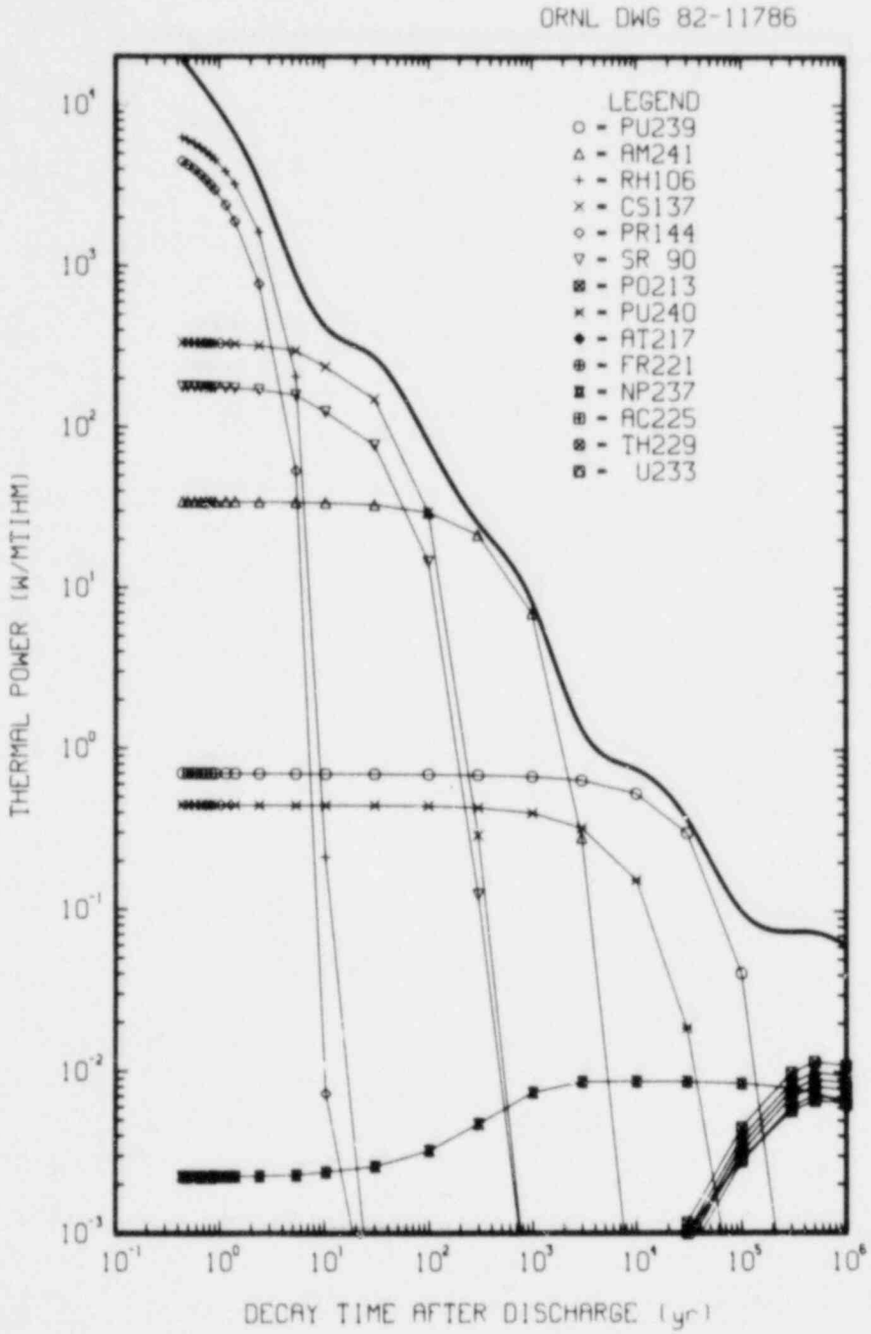

Fig. D.6. Thermal power of CRBR blended high-level waste as a function of decay time.

Table D.6. Thermal power of CRBR blended high-level waste as a function of decay time

Time (yr)	Thermal power (W/MTIHM)											
	TOTAL	PU239	AM241	RH106	CS137	PR144	SR 90	PO213	PU240	AT217	FR221	NP237
4.384E-01	1.904E+04	7.018E-01	3.446E+01	6.312E+03	3.364E+02	4.504E+03	1.789E+02	1.928E-08	4.462E-01	1.662E-08	1.503E-08	2.233E-03
4.931E-01	1.735E+04	7.018E-01	3.446E+01	6.079E+03	3.360E+02	4.289E+03	1.786E+02	1.080E-08	4.462E-01	9.312E-09	8.422E-09	2.234E-03
5.753E-01	1.527E+04	7.019E-01	3.445E+01	5.745E+03	3.353E+02	3.987E+03	1.784E+02	3.408E-09	4.462E-01	2.937E-09	2.657E-09	2.235E-03
6.574E-01	1.362E+04	7.018E-01	3.445E+01	5.430E+03	3.347E+02	3.705E+03	1.780E+02	1.002E-09	4.462E-01	8.640E-10	7.814E-10	2.235E-03
7.395E-01	1.228E+04	7.018E-01	3.445E+01	5.131E+03	3.340E+02	3.444E+03	1.776E+02	3.382E-10	4.462E-01	2.915E-10	2.636E-10	2.236E-03
8.217E-01	1.117E+04	7.018E-01	3.445E+01	4.850E+03	3.334E+02	3.201E+03	1.773E+02	1.660E-10	4.462E-01	1.431E-10	1.294E-10	2.237E-03
9.038E-01	1.024E+04	7.018E-01	3.445E+01	4.583E+03	3.328E+02	2.975E+03	1.770E+02	1.226E-10	4.462E-01	1.057E-10	9.559E-11	2.238E-03
1.150E+00	8.144E+03	7.018E-01	3.444E+01	3.869E+03	3.309E+02	2.389E+03	1.758E+02	1.087E-10	4.463E-01	9.367E-11	8.472E-11	2.240E-03
1.411E+00	6.605E+03	7.018E-01	3.444E+01	3.234E+03	3.299E+02	1.894E+03	1.748E+02	1.088E-10	4.463E-01	9.376E-11	8.480E-11	2.243E-03
2.411E+00	3.353E+03	7.018E-01	3.442E+01	1.626E+03	3.213E+02	7.772E+02	1.706E+02	1.114E-10	4.464E-01	9.598E-11	8.681E-11	2.253E-03
5.411E+00	8.883E+02	7.018E-01	3.435E+01	2.066E+02	2.999E+02	5.372E+01	1.589E+02	1.282E-10	4.468E-01	1.105E-10	9.995E-11	2.284E-03
1.041E+01	4.210E+02	7.018E-01	3.404E+01	2.132E-01	2.380E+02	7.281E-03	1.253E+02	2.855E-10	4.477E-01	2.461E-10	2.226E-10	2.366E-03
3.041E+01	2.721E+02	7.016E-01	3.320E+01	2.238E-07	1.499E+02	1.337E-10	7.782E+01	1.085E-09	4.483E-01	9.351E-10	8.458E-10	2.587E-03
1.004E+02	8.122E+01	7.007E-01	2.981E+01	2.786E-28	2.975E+01	0.0	1.471E+01	9.645E-09	4.462E-01	8.313E-09	7.518E-09	3.244E-03
3.004E+02	2.556E+01	6.971E-01	2.163E+01	0.0	2.929E-01	0.0	1.259E-01	9.823E-08	4.369E-01	8.466E-08	7.657E-08	4.764E-03
1.000E+03	8.327E+00	6.844E-01	7.040E+00	0.0	2.770E-08	0.0	7.313E-09	1.539E-06	4.057E-01	1.326E-06	1.199E-06	7.474E-03
3.000E+03	1.355E+00	6.491E-01	2.850E-01	0.0	2.362E-28	0.0	1.549E-29	1.831E-05	3.282E-01	1.578E-05	1.427E-05	8.724E-03
1.000E+04	7.603E-01	5.372E-01	7.170E-05	0.0	0.0	0.0	0.0	1.997E-04	1.562E-01	1.721E-04	1.557E-04	8.757E-03
3.000E+04	3.734E-01	3.066E-01	1.329E-05	0.0	0.0	0.0	0.0	1.156E-03	1.874E-02	9.959E-04	9.007E-04	8.701E-03
1.000E+05	9.996E-02	4.106E-02	4.406E-08	0.0	0.0	0.0	0.0	4.505E-03	1.120E-05	3.883E-03	3.512E-03	8.506E-03
3.000E+05	7.449E-02	1.300E-04	3.825E-15	0.0	0.0	0.0	0.0	9.900E-03	1.797E-12	8.533E-03	7.718E-03	7.972E-03
5.000E+05	7.375E-02	4.103E-07	3.151E-22	0.0	0.0	0.0	0.0	1.154E-02	1.788E-12	9.948E-03	8.997E-03	7.472E-03
1.000E+06	6.190E-02	5.684E-12	6.141E-40	0.0	0.0	0.0	0.0	1.099E-02	1.782E-12	9.468E-03	8.564E-03	6.355E-03

Time (yr)	Thermal power (W/MTIHM)											
	AC225	TH229	U233	NB 95	CM242	PU238	ZR 95	SB126M	CS134	AM243	CE144	PO214
4.384E-01	1.360E-08	6.682E-11	5.057E-10	2.657E+03	1.115E+03	4.464E-01	1.460E+03	1.325E-02	3.249E+02	6.883E-02	4.064E+02	1.142E-11
4.931E-01	7.622E-09	6.682E-11	1.014E-09	2.193E+03	1.024E+03	8.620E-01	1.176E+03	1.325E-02	3.190E+02	6.883E-02	3.871E+02	1.319E-11
5.753E-01	2.404E-09	6.684E-11	1.776E-09	1.632E+03	9.020E+02	1.423E+00	8.494E+02	1.325E-02	3.103E+02	6.883E-02	3.597E+02	1.306E-11
6.574E-01	7.071E-10	6.685E-11	2.539E-09	1.205E+03	7.944E+02	1.916E+00	6.137E+02	1.325E-02	3.019E+02	6.883E-02	3.344E+02	1.300E-11
7.395E-01	2.386E-10	6.688E-11	3.302E-09	8.850E+02	6.997E+02	2.350E+00	4.434E+02	1.325E-02	2.937E+02	6.883E-02	3.108E+02	1.298E-11
8.217E-01	1.171E-10	6.691E-11	4.066E-09	6.474E+02	6.163E+02	2.732E+00	3.204E+02	1.325E-02	2.857E+02	6.883E-02	2.889E+02	1.297E-11
9.038E-01	8.651E-11	6.693E-11	4.830E-09	4.722E+02	5.430E+02	3.068E+00	2.315E+02	1.325E-02	2.779E+02	6.883E-02	2.685E+02	1.297E-11
1.150E+00	7.668E-11	6.709E-11	7.124E-09	1.811E+02	3.714E+02	3.852E+00	8.731E+01	1.325E-02	2.558E+02	6.882E-02	2.156E+02	1.298E-11
1.411E+00	7.675E-11	6.730E-11	9.554E-09	6.501E+01	2.488E+02	4.410E+00	3.111E+01	1.325E-02	2.343E+02	6.882E-02	1.709E+02	1.299E-11
2.411E+00	7.857E-11	6.881E-11	1.990E-08	1.294E+00	5.499E+01	5.279E+00	5.948E-01	1.325E-02	1.674E+02	6.882E-02	7.014E+01	1.309E-11
5.411E+00	9.047E-11	7.923E-11	4.921E-08	8.742E-06	3.335E+00	5.448E+00	4.158E-06	1.325E-02	6.107E+01	6.880E-02	4.848E+00	1.451E-11
1.041E+01	2.015E-10	1.764E-10	1.463E-07	5.712E-23	2.707E+00	5.227E+00	2.717E-23	1.325E-02	2.118E+00	6.873E-02	6.570E-04	5.689E-11
3.041E+01	7.655E-10	6.704E-10	3.531E-07	0.0	2.471E+00	4.805E+00	0.0	1.324E-02	2.631E-03	6.860E-02	1.207E-11	5.820E-10
1.004E+02	6.805E-09	5.959E-09	1.203E-06	0.0	1.796E+00	3.566E+00	0.0	1.324E-02	1.587E-13	6.815E-02	0.0	1.458E-08
3.004E+02	6.930E-08	6.069E-08	4.565E-06	0.0	7.214E-01	1.487E+00	0.0	1.322E-02	0.0	6.689E-02	0.0	2.916E-07
1.000E+03	1.086E-06	9.508E-07	2.306E-05	0.0	2.964E-02	6.323E-02	0.0	1.315E-02	0.0	6.263E-02	0.0	5.733E-06
3.000E+03	1.292E-05	1.131E-05	9.234E-05	0.0	3.254E-06	6.966E-06	0.0	1.297E-02	0.0	5.190E-02	0.0	5.275E-05
1.000E+04	1.409E-04	1.234E-04	3.409E-04	0.0	4.466E-20	9.560E-20	0.0	1.236E-02	0.0	2.690E-02	0.0	3.270E-04
3.000E+04	8.153E-04	7.140E-04	1.008E-03	0.0	0.0	0.0	0.0	1.076E-02	0.0	4.110E-03	0.0	1.151E-03
1.000E+05	3.178E-03	2.784E-03	2.898E-03	0.0	0.0	0.0	0.0	6.623E-03	0.0	5.661E-06	0.0	2.585E-03
3.000E+05	6.985E-03	6.117E-03	5.754E-03	0.0	0.0	0.0	0.0	1.656E-03	0.0	5.910E-12	0.0	2.706E-03
5.000E+05	8.143E-03	7.132E-03	6.560E-03	0.0	0.0	0.0	0.0	4.141E-04	0.0	5.819E-12	0.0	1.769E-03
1.000E+06	7.751E-03	6.788E-03	6.404E-03	0.0	0.0	0.0	0.0	1.294E-05	0.0	5.691E-12	0.0	4.983E-04

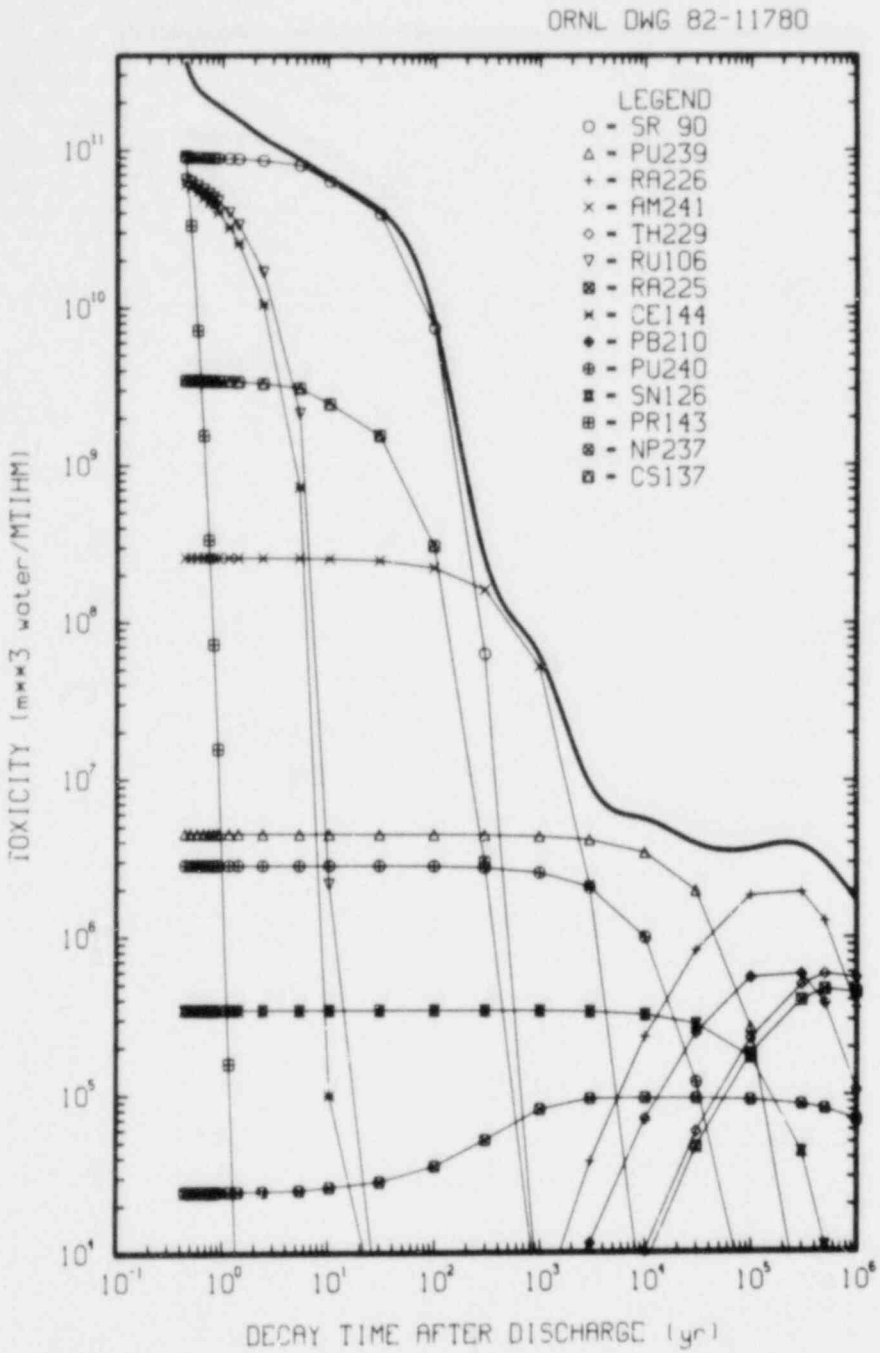

Fig. D.7. Ingestion toxicity of CRBR blended high-level waste as a function of decay time.

Table D.7. Ingestion toxicity of CRBR blended high-level waste as a function of decay time

Time (yr)	Ingestion toxicity (m^3 water/MTIHM)											
	TOTAL	SR 90	PU239	RA226	AM241	TE229	RU106	RA225	CE144	PB210	PU240	SN126
4.384E-01	3.667E+11	9.027E+10	4.554E+06	9.303E-03	2.593E+08	5.461E-03	6.581E+10	5.492E-01	6.127E+10	2.087E-01	2.866E+06	3.468E+05
4.931E-01	2.912E+11	9.016E+10	4.554E+06	9.304E-03	2.593E+08	5.461E-03	6.338E+10	2.180E-01	5.835E+10	2.083E-01	2.866E+06	3.468E+05
5.753E-01	2.456E+11	8.999E+10	4.554E+06	9.305E-03	2.593E+08	5.462E-03	5.990E+10	5.679E-02	5.424E+10	2.078E-01	2.866E+06	3.468E+05
6.574E-01	2.247E+11	8.981E+10	4.554E+06	9.307E-03	2.593E+08	5.463E-03	5.661E+10	1.724E-02	5.041E+10	2.073E-01	2.866E+06	3.468E+05
7.395E-01	2.112E+11	8.964E+10	4.554E+06	9.309E-03	2.593E+08	5.465E-03	5.350E+10	7.529E-03	4.685E+10	2.068E-01	2.866E+06	3.468E+05
8.217E-01	2.007E+11	8.946E+10	4.554E+06	9.311E-03	2.593E+08	5.467E-03	5.056E+10	5.148E-03	4.355E+10	2.062E-01	2.866E+06	3.468E+05
9.038E-01	1.920E+11	8.928E+10	4.554E+06	9.313E-03	2.593E+08	5.470E-03	4.779E+10	4.565E-03	4.048E+10	2.057E-01	2.866E+06	3.468E+05
1.150E+00	1.718E+11	8.876E+10	4.554E+06	9.320E-03	2.592E+08	5.482E-03	4.034E+10	4.386E-03	3.250E+10	2.042E-01	2.866E+06	3.468E+05
1.411E+00	1.561E+11	8.821E+10	4.554E+06	9.330E-03	2.592E+08	5.500E-03	3.372E+10	4.396E-03	2.576E+10	2.026E-01	2.867E+06	3.468E+05
2.411E+00	1.201E+11	8.613E+10	4.554E+06	9.400E-03	2.590E+08	5.623E-03	1.695E+10	4.498E-03	1.057E+10	1.964E-01	2.868E+06	3.468E+05
5.411E+00	8.764E+10	8.021E+10	4.554E+06	1.042E-02	2.585E+08	6.475E-03	2.154E+09	5.180E-03	7.309E+08	1.792E-01	2.870E+06	3.468E+05
1.041E+01	6.612E+10	6.321E+10	4.554E+06	4.086E-02	2.562E+08	1.442E-02	2.192E+06	1.153E-02	9.905E+04	1.331E-01	2.876E+06	3.468E+05
3.041E+01	4.116E+10	3.927E+10	4.553E+06	4.180E-01	2.499E+08	5.478E-02	2.334E+00	4.383E-02	1.819E-03	9.936E-02	2.879E+06	3.467E+05
1.004E+02	8.006E+09	7.421E+09	4.547E+06	1.047E+01	2.243E+08	4.870E-01	2.905E-21	3.896E-01	0.0	1.530E+00	2.866E+06	3.465E+05
3.004E+02	2.547E+08	6.358E+07	4.524E+06	2.094E+02	1.628E+08	4.960E+00	0.0	3.968E+00	0.0	4.779E+01	2.806E+06	3.461E+05
1.000E+03	6.190E+07	3.691E+00	4.442E+06	4.118E+03	5.298E+07	7.770E+01	0.0	6.216E+01	0.0	1.235E+03	2.606E+06	3.444E+05
3.000E+03	9.627E+06	7.814E-21	4.213E+06	3.789E+04	2.145E+06	9.245E+02	0.0	7.396E+02	0.0	1.136E+04	2.108E+06	3.396E+05
1.000E+04	5.709E+06	0.0	3.486E+06	2.349E+05	5.396E+02	1.008E+04	0.0	8.067E+03	0.0	7.044E+04	1.003E+06	3.236E+05
3.000E+04	3.976E+06	0.0	1.990E+06	8.266E+05	1.000E+02	5.835E+04	0.0	4.668E+04	0.0	2.479E+05	1.204E+05	2.817E+05
1.000E+05	3.666E+06	0.0	2.664E+05	1.857E+06	3.316E-01	2.275E+05	0.0	1.820E+05	0.0	5.568E+05	7.197E+01	1.734E+05
3.000E+05	3.843E+06	0.0	8.438E+02	1.944E+06	2.878E-08	4.999E+05	0.0	3.999E+05	0.0	5.829E+05	1.154E-05	4.335E+04
5.000E+05	3.028E+06	0.0	2.662E+00	1.271E+06	2.372E-15	5.828E+05	0.0	4.662E+05	0.0	3.810E+05	1.148E-05	1.084E+04
1.000E+06	1.697E+06	0.0	3.689E-05	3.579E+05	4.621E-33	5.547E+05	0.0	4.438E+05	0.0	1.073E+05	1.145E-05	3.388E+02

Time (yr)	Ingestion toxicity (m^3 water/MTIHM)										
	PR143	NP237	CS137	SR 89	PD107	AM243	PO210	AC225	PU238	CS134	SE 79	BN219
4.384E-01	9.264E+10	2.436E+04	3.489E+09	2.446E+10	4.943E+04	5.353E+05	2.397E-02	7.786E-02	2.694E+06	3.547E+09	8.360E+04	1.632E+00
4.931E-01	3.334E+10	2.436E+04	3.485E+09	1.859E+10	4.943E+04	5.353E+05	2.453E-02	4.364E-02	5.202E+06	3.483E+09	8.360E+04	1.501E+00
5.753E-01	7.197E+09	2.437E+04	3.478E+09	1.232E+10	4.943E+04	5.353E+05	2.526E-02	1.376E-02	8.585E+06	3.388E+09	8.359E+04	2.078E+00
6.574E-01	1.554E+09	2.438E+04	3.471E+09	8.159E+09	4.943E+04	5.353E+05	2.587E-02	4.049E-03	1.156E+07	3.296E+09	8.359E+04	2.439E+00
7.395E-01	3.355E+08	2.439E+04	3.465E+09	5.405E+09	4.943E+04	5.353E+05	2.639E-02	1.366E-03	1.418E+07	3.206E+09	8.359E+04	2.606E+00
8.217E-01	7.243E+07	2.440E+04	3.458E+09	3.580E+09	4.943E+04	5.353E+05	2.683E-02	6.705E-04	1.649E+07	3.119E+09	8.359E+04	2.689E+00
9.038E-01	1.564E+07	2.441E+04	3.452E+09	2.372E+09	4.943E+04	5.353E+05	2.719E-02	4.953E-04	1.851E+07	3.034E+09	8.359E+04	2.741E+00
1.150E+00	1.575E+05	2.444E+04	3.432E+09	6.896E+08	4.943E+04	5.353E+05	2.780E-02	4.390E-04	2.324E+07	2.792E+09	8.359E+04	2.855E+00
1.411E+00	1.211E+03	2.446E+04	3.411E+09	1.865E+08	4.943E+04	5.352E+05	2.812E-02	4.394E-04	2.661E+07	2.558E+09	8.359E+04	2.967E+00
2.411E+00	9.499E-06	2.458E+04	3.334E+09	1.240E+06	4.943E+04	5.352E+05	2.804E-02	4.498E-04	3.186E+07	1.828E+09	8.359E+04	3.443E+00
5.411E+00	0.0	2.491E+04	3.110E+09	3.643E-01	4.943E+04	5.350E+05	2.588E-02	5.180E-04	3.288E+07	6.667E+08	8.359E+04	4.626E+00
1.041E+01	0.0	2.602E+04	2.469E+09	0.0	4.943E+04	5.345E+05	1.902E-02	1.153E-03	3.154E+07	2.312E+07	8.358E+04	7.862E+00
3.041E+01	0.0	2.821E+04	1.555E+09	0.0	4.943E+04	5.335E+05	1.420E-02	4.383E-03	2.900E+07	2.873E+04	8.356E+04	1.201E+01
1.004E+02	0.0	3.538E+04	3.086E+08	0.0	4.943E+04	5.300E+05	2.186E-01	3.896E-02	2.152E+07	1.733E-06	8.350E+04	1.670E+01
3.004E+02	0.0	5.195E+04	3.038E+06	0.0	4.943E+04	5.202E+05	6.827E+00	3.968E-01	8.974E+06	0.0	8.332E+04	1.972E+01
1.000E+03	0.0	8.151E+04	2.873E-01	0.0	4.943E+04	4.871E+05	1.764E+02	6.216E+00	3.816E+05	0.0	8.270E+04	3.427E+01
3.000E+03	0.0	9.515E+04	2.450E-21	0.0	4.941E+04	4.037E+05	1.623E+03	7.396E+01	4.204E+01	0.0	8.096E+04	1.139E+02
1.000E+04	0.0	9.551E+04	0.0	0.0	4.938E+04	2.092E+05	1.006E+04	8.067E+02	5.769E-13	0.0	7.513E+04	7.843E+02
3.000E+04	0.0	9.489E+04	0.0	0.0	4.927E+04	3.197E+04	3.541E+04	4.668E+03	0.0	0.0	6.069E+04	4.712E+03
1.000E+05	0.0	9.277E+04	0.0	0.0	4.891E+04	4.402E+01	7.955E+04	1.820E+04	0.0	0.0	2.876E+04	1.913E+04
3.000E+05	0.0	8.695E+04	0.0	0.0	4.787E+04	4.596E-05	8.327E+04	3.999E+04	0.0	0.0	3.404E+03	2.705E+04
5.000E+05	0.0	8.149E+04	0.0	0.0	4.686E+04	4.525E-05	5.443E+04	4.662E+04	0.0	0.0	4.028E+02	2.721E+04
1.000E+06	0.0	6.931E+04	0.0	0.0	4.443E+04	4.026E-05	1.533E+04	4.438E+04	0.0	0.0	1.938E+00	2.720E+04

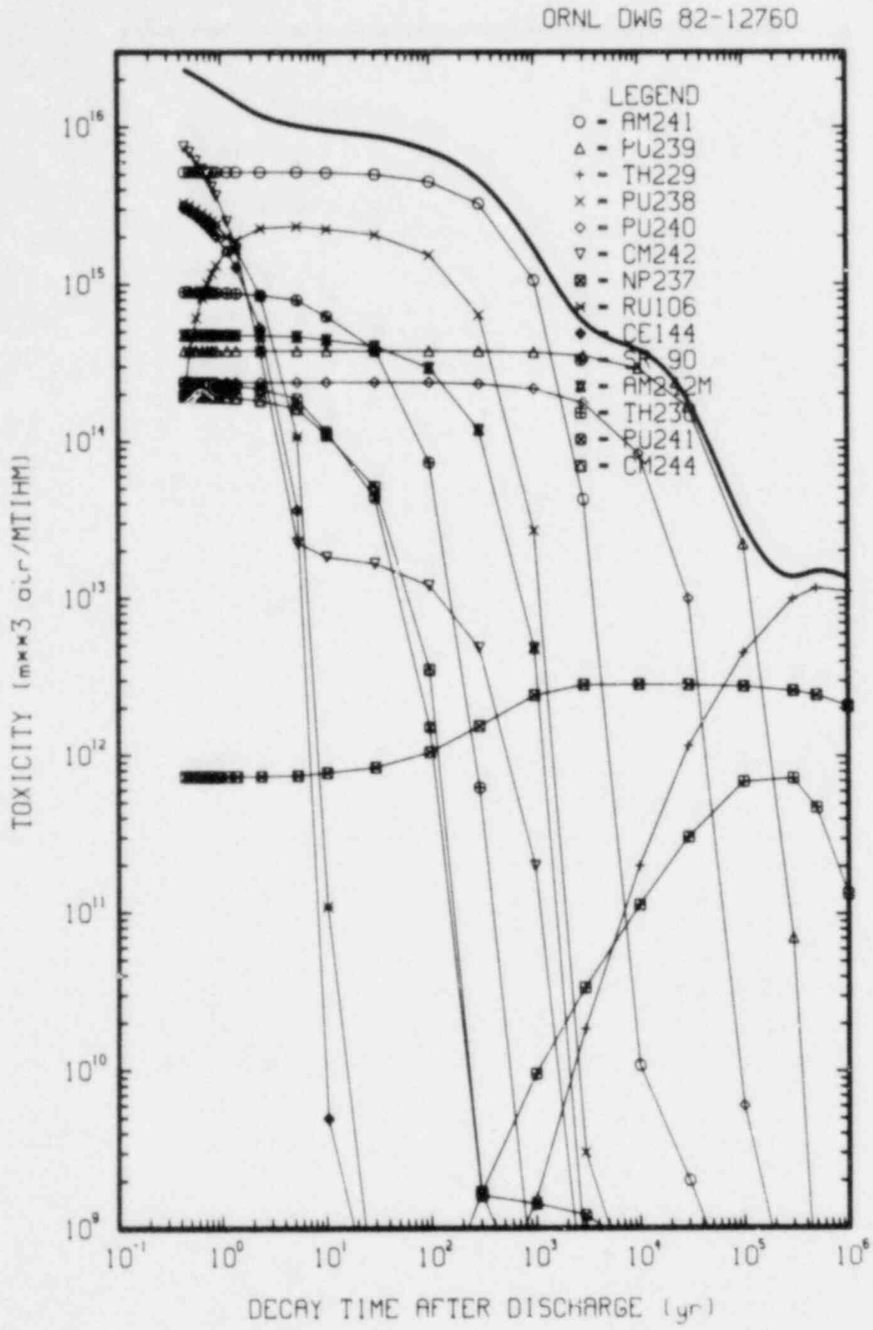

Fig. D.8. Inhalation toxicity of CRBR blended high-level waste as a function of decay time.

Table D.8. Inhalation toxicity of CRBR blended high-level waste as a function of decay time

Time (yr)	Inhalation toxicity (m^3 air/MTIHM)											
	TOTAL	AM241	PU239	TH229	PU238	PU240	CM242	NP237	RU106	CE144	SR 90	AM242M
4.384E-01	2.332E+16	5.186E+15	3.795E+14	1.092E+05	1.924E+14	2.388E+14	7.563E+15	7.307E+11	3.294E+15	3.063E+15	8.983E+14	4.780E+14
4.931E-01	2.239E+16	5.186E+15	3.795E+14	1.092E+05	3.716E+14	2.388E+14	6.949E+15	7.309E+11	3.169E+15	2.918E+15	8.972E+14	4.778E+14
5.753E-01	2.116E+16	5.186E+15	3.795E+14	1.092E+05	6.132E+14	2.388E+14	6.120E+15	7.311E+11	2.995E+15	2.712E+15	8.954E+14	4.777E+14
6.574E-01	2.010E+16	5.186E+15	3.795E+14	1.093E+05	8.258E+14	2.388E+14	5.390E+15	7.314E+11	2.831E+15	2.520E+15	8.937E+14	4.775E+14
7.395E-01	1.918E+16	5.186E+15	3.795E+14	1.093E+05	1.013E+15	2.388E+14	4.747E+15	7.317E+11	2.675E+15	2.343E+15	8.919E+14	4.773E+14
8.217E-01	1.838E+16	5.185E+15	3.795E+14	1.093E+05	1.178E+15	2.388E+14	4.182E+15	7.320E+11	2.528E+15	2.177E+15	8.902E+14	4.771E+14
9.038E-01	1.766E+16	5.185E+15	3.795E+14	1.094E+05	1.322E+15	2.389E+14	3.684E+15	7.322E+11	2.389E+15	2.024E+15	8.884E+14	4.769E+14
1.150E+00	1.594E+16	5.184E+15	3.795E+14	1.096E+05	1.660E+15	2.389E+14	2.520E+15	7.331E+11	2.017E+15	1.625E+15	8.832E+14	4.764E+14
1.411E+00	1.462E+16	5.184E+15	3.795E+14	1.100E+05	1.901E+15	2.389E+14	1.688E+15	7.339E+11	1.686E+15	1.288E+15	8.778E+14	4.758E+14
2.411E+00	1.196E+16	5.181E+15	3.795E+14	1.125E+05	2.276E+15	2.390E+14	3.731E+14	7.373E+11	8.476E+14	5.287E+14	8.571E+14	4.737E+14
5.411E+00	1.023E+16	5.170E+15	3.795E+14	1.295E+05	2.348E+15	2.392E+14	2.263E+13	7.474E+11	1.077E+14	3.654E+13	7.981E+14	4.672E+14
1.041E+01	9.523E+15	5.124E+15	3.795E+14	2.884E+05	2.253E+15	2.396E+14	1.837E+13	7.807E+11	1.096E+11	4.952E+09	6.290E+14	4.464E+14
3.041E+01	8.727E+15	4.997E+15	3.795E+14	1.096E+06	2.071E+15	2.399E+14	1.677E+13	8.463E+11	1.167E+05	9.096E+01	3.908E+14	4.075E+14
1.004E+02	7.063E+15	4.486E+15	3.789E+14	9.740E+06	1.537E+15	2.388E+14	1.218E+13	1.061E+12	1.452E-16	0.0	7.384E+13	2.961E+14
3.004E+02	4.645E+15	3.256E+15	3.770E+14	9.920E+07	6.410E+14	2.339E+14	4.895E+12	1.559E+12	0.0	0.0	6.323E+11	1.190E+14
1.000E+03	1.692E+15	1.060E+15	3.701E+14	1.554E+09	2.726E+13	2.171E+14	2.011E+11	2.445E+12	0.0	0.0	3.672E+04	4.888E+12
3.000E+03	5.808E+14	4.290E+13	3.511E+14	1.849E+10	3.003E+09	1.756E+14	2.208E+07	2.854E+12	0.0	0.0	7.776E-17	5.351E+08
1.000E+04	3.818E+14	1.079E+10	2.905E+14	2.017E+11	4.121E-05	8.362E+13	3.030E-07	2.865E+12	0.0	0.0	0.0	7.344E-06
3.000E+04	1.811E+14	2.000E+09	1.658E+14	1.167E+12	0.0	1.003E+13	0.0	2.847E+12	0.0	0.0	0.0	0.0
1.000E+05	3.056E+13	6.632E+06	2.220E+13	4.549E+12	0.0	5.997E+09	0.0	2.783E+12	0.0	0.0	0.0	0.0
3.000E+05	1.373E+13	5.757E-01	7.032E+10	9.998E+12	0.0	9.617E+02	0.0	2.608E+12	0.0	0.0	0.0	0.0
5.000E+05	1.485E+13	4.743E-08	2.219E+08	1.166E+13	0.0	9.571E+02	0.0	2.445E+12	0.0	0.0	0.0	0.0
1.000E+06	1.351E+13	9.243E-26	3.074E+03	1.109E+13	0.0	9.540E+02	0.0	2.079E+12	0.0	0.0	0.0	0.0

Time (yr)	Inhalation toxicity (m^3 air/MTIHM)											
	TH230	PU241	CM244	CS137	AM243	CM243	PU242	ZR 95	SR 89	PM147	U233	CS134
4.384E-01	2.119E+04	2.388E+14	1.972E+14	1.418E+14	1.071E+13	1.185E+14	7.174E+10	2.882E+14	2.446E+14	8.596E+13	4.349E+03	7.982E+13
4.931E-01	2.162E+04	2.382E+14	1.968E+14	1.416E+14	1.071E+13	1.183E+14	7.176E+10	2.321E+14	1.859E+14	8.472E+13	8.718E+03	7.836E+13
5.753E-01	2.230E+04	2.373E+14	1.962E+14	1.413E+14	1.071E+13	1.181E+14	7.180E+10	1.677E+14	1.232E+14	8.290E+13	1.528E+04	7.623E+13
6.574E-01	2.307E+04	2.363E+14	1.956E+14	1.411E+14	1.071E+13	1.178E+14	7.184E+10	1.212E+14	8.159E+13	8.112E+13	2.184E+04	7.415E+13
7.395E-01	2.397E+04	2.354E+14	1.950E+14	1.408E+14	1.071E+13	1.176E+14	7.188E+10	8.754E+13	5.405E+13	7.938E+13	2.840E+04	7.213E+13
8.217E-01	2.502E+04	2.345E+14	1.944E+14	1.405E+14	1.071E+13	1.174E+14	7.192E+10	6.325E+13	3.580E+13	7.768E+13	3.497E+04	7.017E+13
9.038E-01	2.625E+04	2.335E+14	1.938E+14	1.403E+14	1.071E+13	1.171E+14	7.196E+10	4.570E+13	2.372E+13	7.601E+13	4.154E+04	6.826E+13
1.150E+00	3.120E+04	2.308E+14	1.919E+14	1.395E+14	1.071E+13	1.164E+14	7.209E+10	1.724E+13	6.896E+12	7.122E+13	6.127E+04	6.283E+13
1.411E+00	3.889E+04	2.279E+14	1.900E+14	1.387E+14	1.070E+13	1.157E+14	7.221E+10	6.142E+12	1.865E+12	6.648E+13	8.217E+04	5.756E+13
2.411E+00	9.686E+04	2.172E+14	1.829E+14	1.354E+14	1.070E+13	1.129E+14	7.270E+10	1.174E+11	1.240E+10	5.104E+13	1.711E+05	4.112E+13
5.411E+00	5.789E+05	1.880E+14	1.631E+14	1.264E+14	1.070E+13	1.050E+14	7.415E+10	8.209E+05	3.643E+03	2.310E+13	4.232E+05	1.500E+13
1.041E+01	5.563E+06	1.162E+14	1.112E+14	1.003E+14	1.069E+13	8.232E+13	7.884E+10	5.364E-12	0.0	1.645E+12	1.258E+06	5.202E+11
3.041E+01	3.044E+07	4.436E+13	5.172E+13	6.318E+13	1.067E+13	5.061E+13	8.761E+10	0.0	0.0	8.349E+09	3.037E+06	6.463E+08
1.004E+02	2.538E+08	1.527E+12	3.549E+12	1.253E+13	1.060E+13	9.223E+12	1.127E+11	0.0	0.0	7.753E+01	1.035E+07	3.899E-02
3.004E+02	1.682E+09	1.604E+09	1.681E+09	1.234E+11	1.040E+13	7.121E+10	1.526E+11	0.0	0.0	0.0	3.926E+07	0.0
1.000E+03	9.575E+09	1.420E+09	2.310E-02	1.167E+04	9.742E+12	2.877E+03	1.781E+11	0.0	0.0	0.0	1.983E+08	0.0
3.000E+03	3.368E+10	1.206E+09	1.921E-02	9.952E-17	8.073E+12	2.159E-18	1.786E+11	0.0	0.0	0.0	7.941E+08	0.0
1.000E+04	1.137E+11	6.814E+08	1.921E-02	0.0	4.183E+12	0.0	1.763E+11	0.0	0.0	0.0	2.932E+09	0.0
3.000E+04	3.079E+11	1.333E+08	1.921E-02	0.0	6.394E+11	0.0	1.701E+11	0.0	0.0	0.0	8.666E+09	0.0
1.000E+05	6.928E+11	4.421E+05	1.921E-02	0.0	8.805E+08	0.0	1.501E+11	0.0	0.0	0.0	2.493E+10	0.0
3.000E+05	7.265E+11	3.643E-02	1.920E-02	0.0	9.192E+02	0.0	1.049E+11	0.0	0.0	0.0	4.949E+10	0.0
5.000E+05	4.739E+11	3.001E-09	1.918E-02	0.0	9.050E+02	0.0	7.331E+10	0.0	0.0	0.0	5.728E+10	0.0
1.000E+06	1.341E+11	5.849E-27	1.912E-02	0.0	8.851E+02	0.0	2.993E+10	0.0	0.0	0.0	5.516E+10	0.0

D.3: Characteristics of Blended CRBR Fuel-Assembly Structural Material Waste

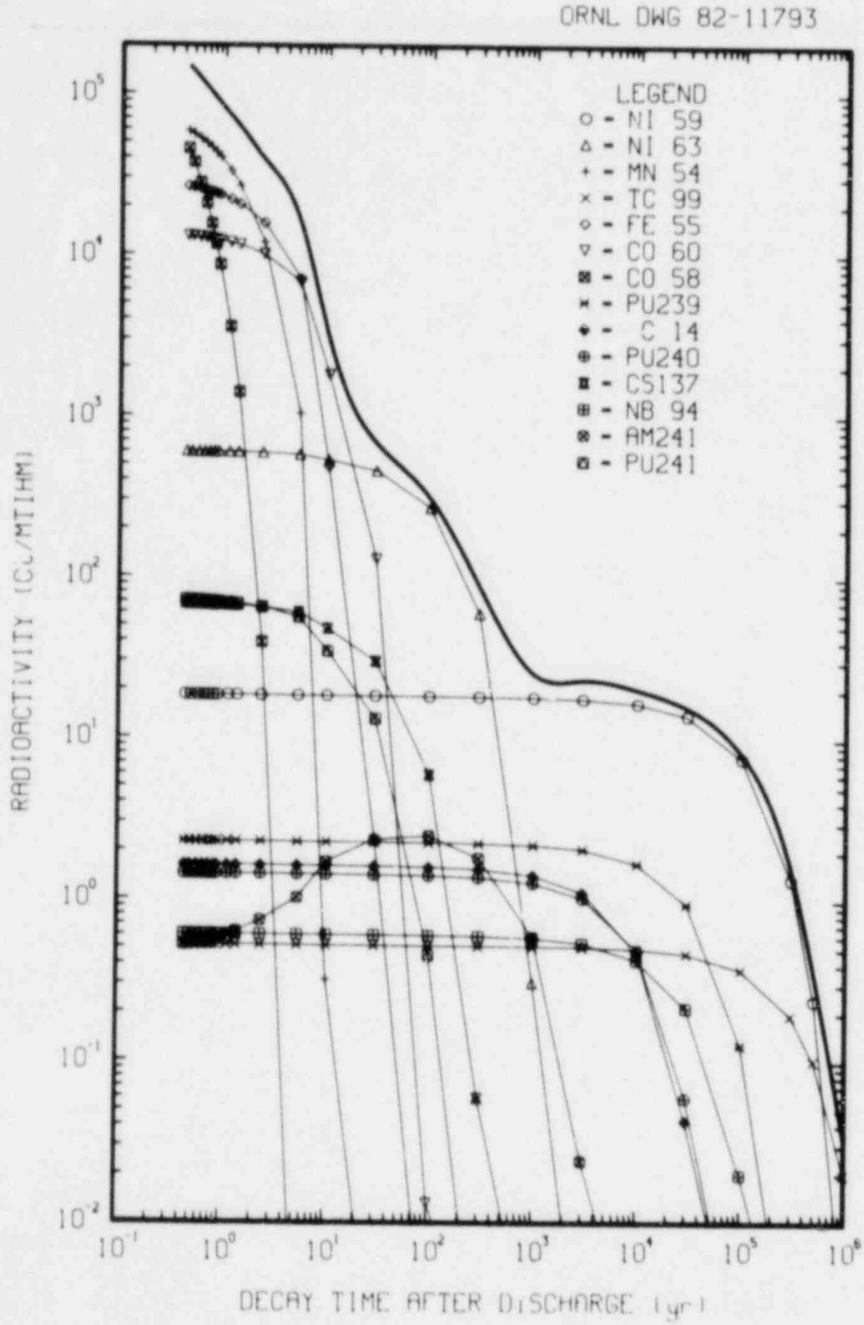

Fig. D.9. Radioactivity of blended fuel-assembly structural material waste as a function of decay time.

Table D.9. Radioactivity of blended fuel-assembly structural material waste as a function of decay time

Time (yr)	Radioactivity (Ci/MTIHM)											
	TOTAL	NI 59	NI 63	MN 54	TC 99	FE 55	CO 60	CO 58	PU239	C 14	PU240	CS137
4.384E-01	1.491E+05	1.842E+01	6.017E+02	5.880E+04	5.203E-01	2.657E+04	1.301E+04	4.555E+04	2.278E+00	1.623E+00	1.434E+00	6.793E+01
4.931E-01	1.369E+05	1.842E+01	6.015E+02	5.625E+04	5.203E-01	2.618E+04	1.292E+04	3.744E+04	2.278E+00	1.623E+00	1.434E+00	6.784E+01
5.753E-01	1.221E+05	1.842E+01	6.011E+02	5.263E+04	5.203E-01	2.561E+04	1.278E+04	2.791E+04	2.278E+00	1.623E+00	1.434E+00	6.772E+01
6.574E-01	1.104E+05	1.842E+01	6.007E+02	4.924E+04	5.203E-01	2.506E+04	1.264E+04	2.081E+04	2.278E+00	1.623E+00	1.434E+00	6.759E+01
7.395E-01	1.009E+05	1.842E+01	6.003E+02	4.607E+04	5.203E-01	2.452E+04	1.251E+04	1.551E+04	2.278E+00	1.622E+00	1.434E+00	6.746E+01
8.217E-01	9.314E+04	1.842E+01	6.000E+02	4.310E+04	5.203E-01	2.399E+04	1.237E+04	1.156E+04	2.278E+00	1.622E+00	1.434E+00	6.733E+01
9.038E-01	8.662E+04	1.842E+01	5.996E+02	4.033E+04	5.203E-01	2.347E+04	1.224E+04	8.618E+03	2.278E+00	1.622E+00	1.434E+00	6.720E+01
1.150E+00	7.212E+04	1.842E+01	5.985E+02	3.303E+04	5.203E-01	2.197E+04	1.185E+04	3.569E+03	2.278E+00	1.622E+00	1.433E+00	6.682E+01
1.411E+00	6.161E+04	1.842E+01	5.973E+02	2.674E+04	5.203E-01	2.050E+04	1.145E+04	1.404E+03	2.278E+00	1.622E+00	1.433E+00	6.642E+01
2.411E+00	3.881E+04	1.842E+01	5.928E+02	1.189E+04	5.203E-01	1.570E+04	1.004E+04	3.926E+01	2.278E+00	1.622E+00	1.433E+00	6.490E+01
5.411E+00	1.568E+04	1.842E+01	5.796E+02	1.047E+03	5.203E-01	7.057E+03	6.765E+03	8.578E-04	2.278E+00	1.622E+00	1.433E+00	6.056E+01
1.041E+01	2.978E+03	1.842E+01	5.375E+02	3.172E-61	5.202E-01	4.907E+02	1.816E+03	2.502E-19	2.277E+00	1.620E+00	1.431E+00	4.806E+01
3.041E+01	6.803E+02	1.842E+01	4.623E+02	2.914E-08	5.202E-01	2.372E+00	1.308E+02	0.0	2.276E+00	1.616E+00	1.428E+00	3.028E+01
1.004E+02	3.104E+02	1.841E+01	2.728E+02	0.0	5.201E-01	1.864E-08	1.312E-02	0.0	2.271E+00	1.602E+00	1.418E+00	6.007E+00
3.004E+02	8.784E+01	1.837E+01	6.046E+01	0.0	5.197E-01	0.0	4.931E-14	0.0	2.258E+00	1.564E+00	1.388E+00	5.912E-02
1.000E+03	2.566E+01	1.826E+01	3.096E-01	0.0	5.186E-01	0.0	0.0	0.0	2.213E+00	1.437E+00	1.289E+00	5.591E-09
3.000E+03	2.360E+01	1.795E+01	8.844E-08	0.0	5.152E-01	0.0	0.0	0.0	2.089E+00	1.128E+00	1.042E+00	4.767E-29
1.000E+04	2.060E+01	1.689E+01	0.0	0.0	5.036E-01	0.0	0.0	0.0	1.708E+00	4.836E-01	8.963E-01	0.0
3.000E+04	1.597E+01	1.420E+01	0.0	0.0	4.719E-01	0.0	0.0	0.0	9.602E-01	4.302E-02	5.953E-02	0.0
1.000E+05	8.281E+00	7.745E+00	0.0	0.0	3.757E-01	0.0	0.0	0.0	1.278E-01	9.029E-06	3.559E-05	0.0
3.000E+05	1.578E+00	1.369E+00	0.0	0.0	1.960E-01	0.0	0.0	0.0	4.044E-04	2.799E-16	5.762E-12	0.0
5.000E+05	3.562E-01	2.420E-01	0.0	0.0	1.022E-01	0.0	0.0	0.0	1.278E-06	8.678E-27	5.730E-12	0.0
1.000E+06	3.332E-02	3.179E-03	0.0	0.0	2.009E-02	0.0	0.0	0.0	7.992E-13	0.0	5.706E-12	0.0

Time (yr)	Radioactivity (Ci/MTIHM)											
	NB 94	AM241	PU241	MO 93	SR 90	ZR 93	TH229	AC225	RA225	FR221	AT217	BI213
4.384E-01	6.051E-01	5.220E-01	7.168E+01	5.340E-01	2.670E+01	4.802E-04	2.185E-10	2.190E-10	2.187E-10	2.190E-10	2.190E-10	2.190E-10
4.931E-01	6.051E-01	5.283E-01	7.149E+01	5.340E-01	2.666E+01	4.813E-04	2.185E-10	2.187E-10	2.186E-10	2.187E-10	2.187E-10	2.187E-10
5.753E-01	6.051E-01	5.376E-01	7.121E+01	5.340E-01	2.661E+01	4.829E-04	2.185E-10	2.186E-10	2.185E-10	2.186E-10	2.186E-10	2.186E-10
6.574E-01	6.051E-01	5.469E-01	7.093E+01	5.340E-01	2.657E+01	4.846E-04	2.185E-10	2.185E-10	2.185E-10	2.185E-10	2.185E-10	2.185E-10
7.395E-01	6.051E-01	5.561E-01	7.065E+01	5.340E-01	2.651E+01	4.862E-04	2.185E-10	2.185E-10	2.185E-10	2.185E-10	2.185E-10	2.185E-10
8.217E-01	6.051E-01	5.654E-01	7.037E+01	5.340E-01	2.647E+01	4.879E-04	2.185E-10	2.185E-10	2.185E-10	2.185E-10	2.185E-10	2.185E-10
9.038E-01	6.051E-01	5.745E-01	7.009E+01	5.340E-01	2.641E+01	4.895E-04	2.186E-10	2.185E-10	2.185E-10	2.186E-10	2.186E-10	2.186E-10
1.150E+00	6.051E-01	6.018E-01	6.927E+01	5.339E-01	2.625E+01	4.944E-04	2.186E-10	2.186E-10	2.186E-10	2.186E-10	2.186E-10	2.186E-10
1.411E+00	6.051E-01	6.304E-01	6.840E+01	5.339E-01	2.609E+01	4.994E-04	2.186E-10	2.186E-10	2.186E-10	2.186E-10	2.186E-10	2.186E-10
2.411E+00	6.051E-01	7.364E-01	6.519E+01	5.338E-01	2.548E+01	5.183E-04	2.187E-10	2.187E-10	2.187E-10	2.187E-10	2.187E-10	2.187E-10
5.411E+00	6.050E-01	1.024E+00	5.642E+01	5.335E-01	2.372E+01	5.693E-04	2.190E-10	2.190E-10	2.190E-10	2.190E-10	2.190E-10	2.190E-10
1.041E+01	6.048E-01	1.720E+00	3.487E+01	5.324E-01	1.870E+01	6.928E-04	2.213E-10	2.213E-10	2.213E-10	2.213E-10	2.213E-10	2.213E-10
3.041E+01	6.044E-01	2.370E+00	1.331E+01	5.303E-01	1.161E+01	8.114E-04	2.312E-10	2.312E-10	2.312E-10	2.312E-10	2.312E-10	2.312E-10
1.004E+02	6.029E-01	2.513E+00	4.580E-01	5.230E-01	2.195E+00	8.765E-04	3.564E-10	3.564E-10	3.564E-10	3.564E-10	3.564E-10	3.564E-10
3.004E+02	5.988E-01	1.835E+00	3.243E-05	5.027E-01	1.879E-02	8.783E-04	2.327E-09	2.327E-09	2.327E-09	2.327E-09	2.327E-09	2.327E-09
1.000E+03	5.847E-01	5.971E-01	2.131E-06	4.376E-01	1.091E-09	8.781E-04	5.054E-08	5.054E-08	5.054E-08	5.054E-08	5.054E-08	5.054E-08
3.000E+03	5.461E-01	2.416E-02	1.810E-06	2.944E-01	2.311E-30	8.773E-04	7.289E-07	7.289E-07	7.289E-07	7.289E-07	7.289E-07	7.289E-07
1.000E+04	4.300E-01	1.345E-06	1.023E-06	7.356E-02	0.0	8.744E-04	8.550E-06	8.550E-06	8.550E-06	8.550E-06	8.550E-06	8.550E-06
3.000E+04	2.172E-01	2.001E-07	2.001E-07	1.398E-03	0.0	8.666E-04	5.039E-05	5.039E-05	5.039E-05	5.039E-05	5.039E-05	5.039E-05
1.000E+05	1.990E-02	6.640E-10	6.640E-10	1.325E-09	0.0	8.395E-04	1.974E-04	1.974E-04	1.974E-04	1.974E-04	1.974E-04	1.974E-04
3.000E+05	2.251E-05	5.764E-17	5.471E-17	8.174E-27	0.0	7.668E-04	4.344E-04	4.344E-04	4.344E-04	4.344E-04	4.344E-04	4.344E-04
5.000E+05	2.521E-08	4.749E-24	4.508E-24	5.043E-48	0.0	7.004E-04	5.064E-04	5.064E-04	5.064E-04	5.064E-04	5.064E-04	5.064E-04
1.000E+06	9.702E-16	9.255E-42	8.784E-42	0.0	0.0	5.584E-04	4.821E-04	4.821E-04	4.821E-04	4.821E-04	4.821E-04	4.821E-04

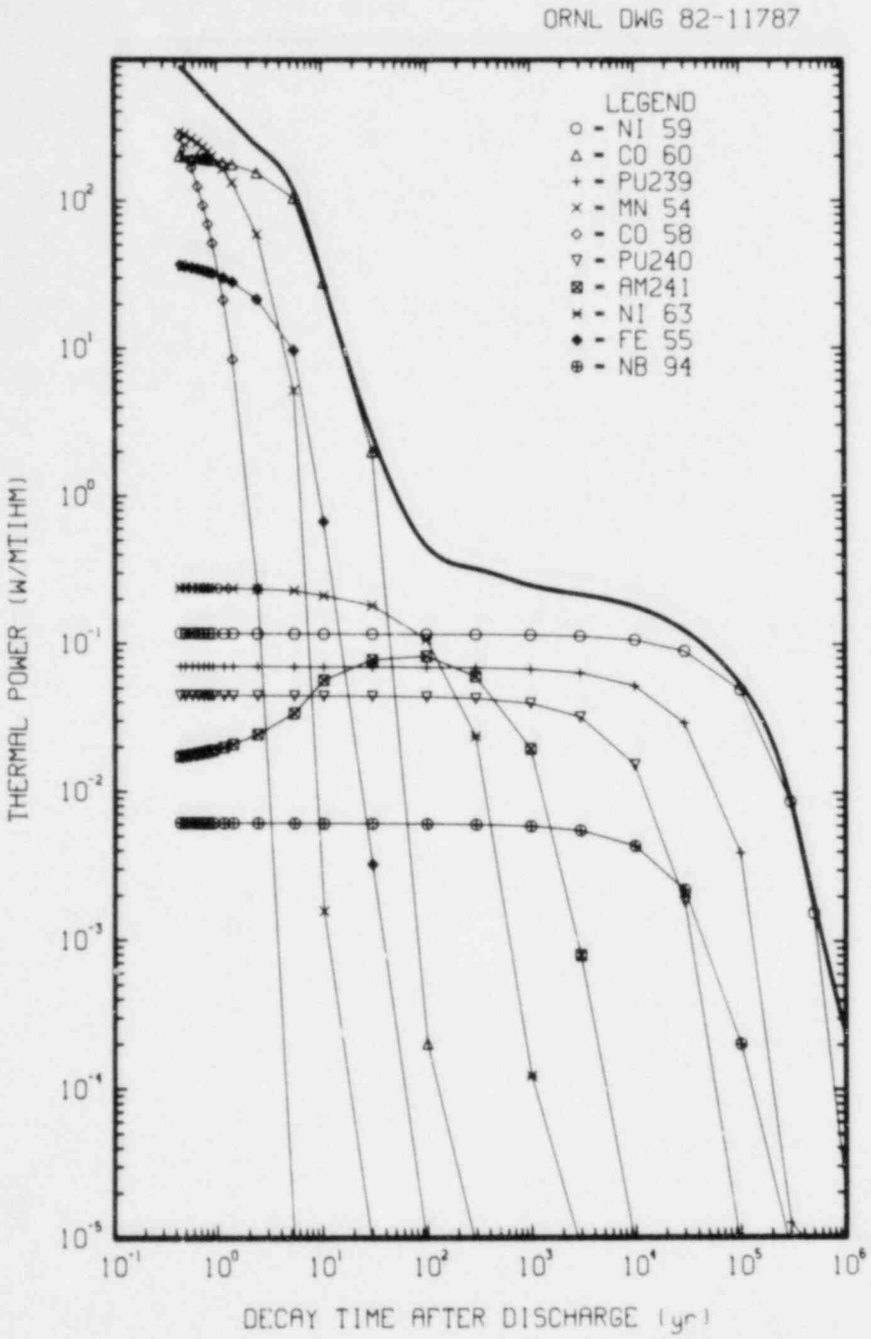

Fig. D.10. Thermal power of blended fuel-assembly structural material waste as a function of decay time.

Table D.10. Thermal power of blended fuel-assembly structural material waste as a function of decay time

Thermal power (W/MTIHM)

Time (yr)	TOTAL	NI 59	CO 60	PO239	MN 54	CO 58	PU240	AM241	NI 63	FE 55	PO213	AT217
4.384E-01	8.161E+02	1.173E-01	2.006E+02	7.021E-02	2.928E+02	2.727E+02	4.464E-02	1.734E-02	2.390E-01	3.654E+01	1.084E-11	9.346E-12
4.931E-01	7.511E+02	1.173E-01	1.992E+02	7.021E-02	2.801E+02	2.242E+02	4.464E-02	1.755E-02	2.389E-01	3.601E+01	1.083E-11	9.333E-12
5.753E-01	6.711E+02	1.173E-01	1.970E+02	7.021E-02	2.620E+02	1.671E+02	4.464E-02	1.786E-02	2.387E-01	3.523E+01	1.082E-11	9.327E-12
6.574E-01	6.074E+02	1.173E-01	1.949E+02	7.021E-02	2.452E+02	1.246E+02	4.464E-02	1.817E-02	2.386E-01	3.446E+01	1.082E-11	9.326E-12
7.395E-01	5.561E+02	1.173E-01	1.928E+02	7.021E-02	2.294E+02	9.285E+01	4.464E-02	1.847E-02	2.384E-01	3.372E+01	1.082E-11	9.326E-12
8.217E-01	5.141E+02	1.173E-01	1.907E+02	7.021E-02	2.146E+02	6.921E+01	4.464E-02	1.878E-02	2.383E-01	3.299E+01	1.082E-11	9.326E-12
9.038E-01	4.793E+02	1.173E-01	1.887E+02	7.021E-02	2.008E+02	5.159E+01	4.464E-02	1.908E-02	2.381E-01	3.227E+01	1.082E-11	9.326E-12
1.150E+00	4.034E+02	1.173E-01	1.827E+02	7.021E-02	1.685E+02	2.137E+01	4.464E-02	1.999E-02	2.377E-01	3.022E+01	1.082E-11	9.327E-12
1.411E+00	3.501E+02	1.173E-01	1.765E+02	7.021E-02	1.331E+02	8.408E+00	4.463E-02	2.094E-02	2.372E-01	2.819E+01	1.082E-11	9.328E-12
2.411E+00	2.380E+02	1.173E-01	1.548E+02	7.021E-02	5.922E+01	2.351E-01	4.463E-02	2.446E-02	2.354E-01	2.159E+01	1.083E-11	9.332E-12
5.411E+00	1.202E+02	1.173E-01	1.043E+02	7.020E-02	5.211E+00	5.136E-06	4.462E-02	3.402E-02	2.302E-01	9.705E+00	1.084E-11	9.347E-12
1.041E+01	2.939E+01	1.173E-01	2.799E+01	7.018E-02	1.579E-03	1.498E-21	4.457E-02	5.713E-02	2.135E-01	6.748E-01	1.095E-11	9.442E-12
3.041E+01	2.657E+00	1.172E-01	2.016E+00	7.014E-02	1.451E-10	0.0	4.448E-02	7.874E-02	1.836E-01	3.262E-03	1.145E-11	9.867E-12
1.004E+02	4.652E-01	1.172E-01	2.022E-04	7.000E-02	0.0	0.0	4.415E-02	8.347E-02	1.084E-01	2.563E-11	1.764E-11	1.521E-11
3.004E+02	3.251E-01	1.170E-01	7.603E-16	6.960E-02	0.0	0.0	4.322E-02	6.095E-02	2.401E-02	0.0	1.152E-10	9.930E-11
1.000E+03	2.514E-01	1.163E-01	0.0	6.821E-02	0.0	0.0	4.013E-02	1.984E-02	1.230E-04	0.0	2.502E-09	2.157E-09
3.000E+03	2.182E-01	1.143E-01	0.0	6.439E-02	0.0	0.0	3.246E-02	8.027E-04	3.512E-11	0.0	3.609E-08	3.111E-08
1.000E+04	1.805E-01	1.075E-01	0.0	5.264E-02	0.0	0.0	1.545E-02	4.467E-08	0.0	0.0	4.233E-07	3.649E-07
3.000E+04	1.244E-01	9.043E-02	0.0	2.959E-02	0.0	0.0	1.854E-03	6.648E-09	0.0	0.0	2.495E-06	2.150E-06
1.000E+05	5.380E-02	4.931E-02	0.0	3.940E-03	0.0	0.0	1.108E-06	2.206E-11	0.0	0.0	9.776E-06	8.425E-06
3.000E+05	9.048E-03	8.717E-03	0.0	1.246E-05	0.0	0.0	1.794E-13	1.915E-18	0.0	0.0	2.151E-05	1.854E-05
5.000E+05	1.819E-03	1.541E-03	0.0	3.938E-08	0.0	0.0	1.784E-13	1.578E-25	0.0	0.0	2.507E-05	2.161E-05
1.000E+06	2.361E-04	2.024E-05	0.0	2.463E-14	0.0	0.0	1.777E-13	3.074E-43	0.0	0.0	2.387E-05	2.057E-05

Thermal power (W/MTIHM)

Time (yr)	FR221	AC225	NB 94	TH229	NP237	U233	TC 99	U236	PO214	CS137	PO218	RN222
4.384E-01	8.453E-12	7.649E-12	6.166E-03	6.685E-12	1.117E-06	2.532E-11	2.609E-04	1.073E-07	6.321E-14	1.683E-01	4.272E-15	3.906E-15
4.931E-01	8.441E-12	7.639E-12	6.166E-03	6.685E-12	1.117E-06	2.558E-11	2.609E-04	1.074E-07	3.633E-14	1.681E-01	5.216E-15	4.769E-15
5.753E-01	8.436E-12	7.635E-12	6.166E-03	6.685E-12	1.118E-06	2.596E-11	2.609E-04	1.075E-07	1.791E-14	1.678E-01	5.462E-15	4.995E-15
6.574E-01	8.435E-12	7.634E-12	6.166E-03	6.686E-12	1.118E-06	2.634E-11	2.609E-04	1.075E-07	1.131E-14	1.674E-01	5.694E-15	5.207E-15
7.395E-01	8.435E-12	7.634E-12	6.166E-03	6.686E-12	1.119E-06	2.672E-11	2.609E-04	1.076E-07	9.075E-15	1.671E-01	5.932E-15	5.424E-15
8.217E-01	8.435E-12	7.634E-12	6.166E-03	6.686E-12	1.119E-06	2.711E-11	2.609E-04	1.077E-07	8.455E-15	1.668E-01	6.177E-15	5.649E-15
9.038E-01	8.435E-12	7.634E-12	6.166E-03	6.686E-12	1.120E-06	2.749E-11	2.609E-04	1.078E-07	8.435E-15	1.665E-01	6.429E-15	5.879E-15
1.150E+00	8.435E-12	7.635E-12	6.166E-03	6.687E-12	1.121E-06	2.864E-11	2.609E-04	1.081E-07	9.335E-15	1.655E-01	7.281E-15	6.658E-15
1.411E+00	8.436E-12	7.635E-12	6.166E-03	6.687E-12	1.123E-06	2.985E-11	2.609E-04	1.084E-07	1.051E-14	1.645E-01	8.208E-15	7.506E-15
2.411E+00	8.440E-12	7.639E-12	6.165E-03	6.690E-12	1.129E-06	3.503E-11	2.609E-04	1.096E-07	1.611E-14	1.608E-01	1.258E-14	1.150E-14
5.411E+00	8.453E-12	7.651E-12	6.165E-03	6.701E-12	1.156E-06	4.978E-11	2.609E-04	1.130E-07	4.610E-14	1.500E-01	3.599E-14	3.291E-14
1.041E+01	8.539E-12	7.729E-12	6.163E-03	6.769E-12	1.295E-06	1.005E-10	2.609E-04	1.245E-07	4.018E-13	1.191E-01	3.137E-13	2.869E-13
3.041E+01	8.924E-12	8.077E-12	6.158E-03	7.074E-12	1.711E-06	2.245E-10	2.609E-04	1.474E-07	3.442E-12	7.500E-02	2.688E-12	2.458E-12
1.004E+02	1.375E-11	1.245E-11	6.144E-03	1.090E-11	3.475E-06	9.776E-10	2.608E-04	2.273E-07	6.852E-11	1.488E-02	5.349E-11	4.892E-11
3.004E+02	8.981E-11	8.128E-11	6.102E-03	7.119E-11	7.757E-06	5.741E-09	2.606E-04	4.523E-07	1.152E-09	1.465E-04	8.991E-10	8.222E-10
1.000E+03	1.950E-09	1.765E-09	5.958E-03	1.546E-09	1.540E-05	4.142E-08	2.601E-04	1.203E-06	1.857E-08	1.385E-11	1.450E-08	1.326E-08
3.000E+03	2.813E-08	2.546E-08	5.564E-03	2.230E-08	1.892E-05	1.899E-07	2.584E-04	3.066E-06	1.538E-07	1.181E-31	1.201E-07	1.098E-07
1.000E+04	3.300E-07	2.987E-07	4.381E-03	2.616E-07	1.903E-05	7.304E-07	2.525E-04	7.196E-06	9.232E-07	0.0	7.208E-07	6.591E-07
3.000E+04	1.945E-06	1.760E-06	2.213E-03	1.542E-06	1.890E-05	2.180E-06	2.366E-04	1.049E-05	3.273E-06	0.0	2.556E-06	2.337E-06
1.000E+05	7.620E-06	6.897E-06	2.027E-04	6.040E-06	1.848E-05	6.290E-06	1.884E-04	1.092E-05	7.774E-06	0.0	6.070E-06	5.550E-06
3.000E+05	1.676E-05	1.517E-05	2.293E-07	1.329E-05	1.732E-05	1.250E-05	9.829E-05	1.086E-05	1.026E-05	0.0	8.011E-06	7.326E-06
5.000E+05	1.955E-05	1.769E-05	2.569E-10	1.549E-05	1.623E-05	1.447E-05	5.127E-05	1.079E-05	9.309E-06	0.0	7.268E-06	6.646E-06
1.000E+06	1.861E-05	1.684E-05	9.886E-18	1.475E-05	1.381E-05	1.393E-05	1.007E-05	1.063E-05	7.542E-06	0.0	5.888E-06	5.385E-06

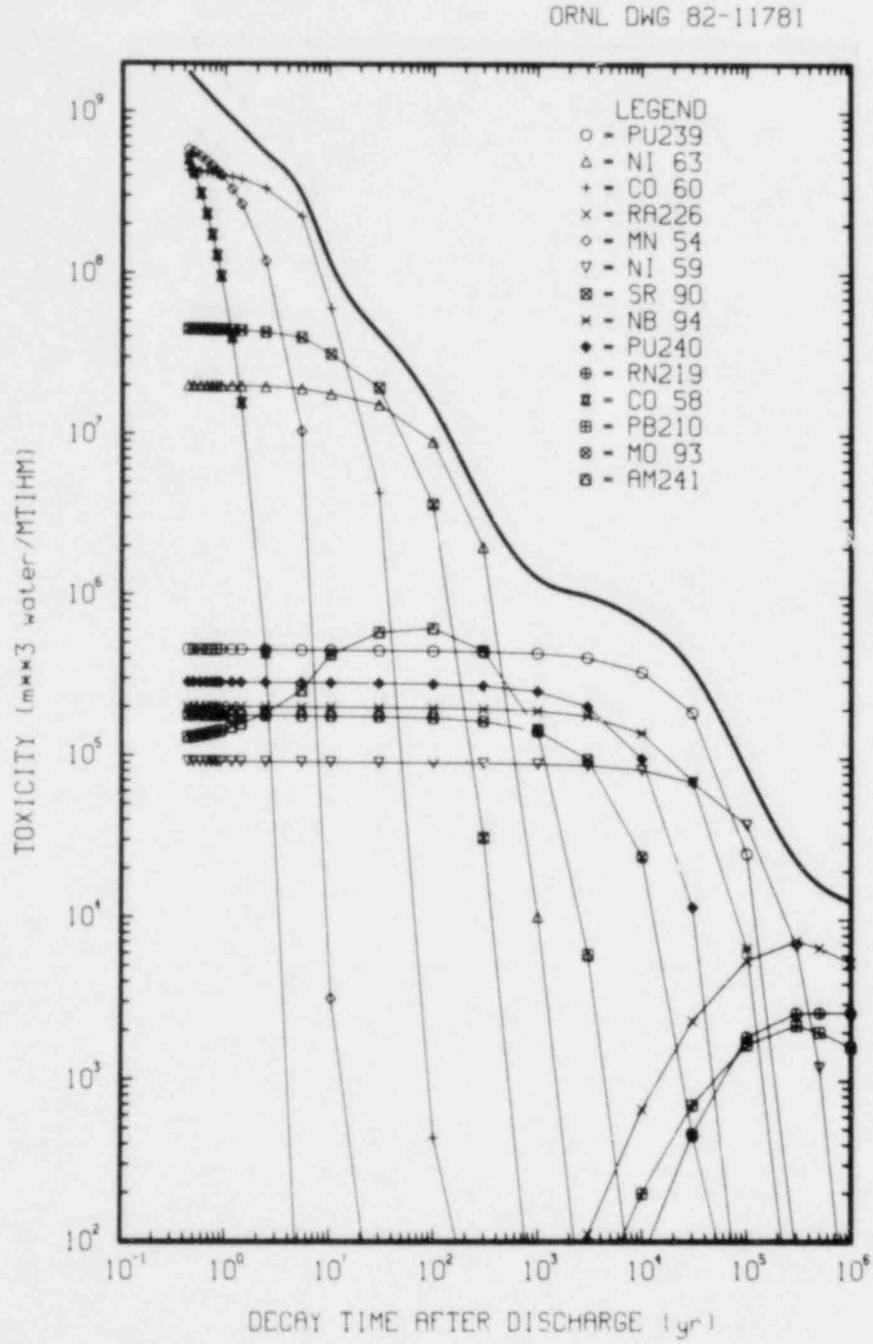

Fig. D.11. Ingestion toxicity of blended fuel-assembly structural material waste as a function of decay time.

Table D.11. Ingestion toxicity of blended fuel-assembly structural material waste as a function of decay time

Ingestion toxicity (m^3 water/MTIHM)

Time (yr)	TOTAL	PU239	NI 63	CO 60	RA226	MN 54	NI 59	SR 90	NB 94	PU240	PA231	CO 58
4.384E-01	1.784E+09	4.557E+05	2.006E+07	4.337E+08	4.720E-06	5.880E+08	9.211E+04	4.516E+07	2.017E+05	2.867E+05	1.284E-03	5.061E+08
4.931E-01	1.624E+09	4.557E+05	2.005E+07	4.306E+08	4.855E-06	5.625E+08	9.211E+04	4.511E+07	2.017E+05	2.867E+05	1.289E-03	4.161E+08
5.753E-01	1.451E+09	4.557E+05	2.004E+07	4.260E+08	5.063E-06	5.263E+08	9.211E+04	4.502E+07	2.017E+05	2.867E+05	1.304E-03	3.101E+08
6.574E-01	1.320E+09	4.557E+05	2.002E+07	4.214E+08	5.277E-06	4.924E+08	9.211E+04	4.492E+07	2.017E+05	2.867E+05	1.322E-03	2.312E+08
7.395E-01	1.216E+09	4.557E+05	2.001E+07	4.169E+08	5.498E-06	4.607E+08	9.211E+04	4.484E+07	2.017E+05	2.867E+05	1.340E-03	1.723E+08
8.217E-01	1.131E+09	4.557E+05	2.000E+07	4.124E+08	5.724E-06	4.310E+08	9.211E+04	4.475E+07	2.017E+05	2.867E+05	1.359E-03	1.285E+08
9.038E-01	1.060E+09	4.557E+05	1.999E+07	4.080E+08	5.957E-06	4.033E+08	9.211E+04	4.466E+07	2.017E+05	2.867E+05	1.378E-03	9.575E+07
1.150E+00	9.045E+08	4.557E+05	1.995E+07	3.949E+08	6.697E-06	3.303E+08	9.211E+04	4.441E+07	2.017E+05	2.867E+05	1.435E-03	3.966E+07
1.411E+00	7.933E+08	4.556E+05	1.991E+07	3.816E+08	7.550E-06	2.674E+08	9.211E+04	4.413E+07	2.017E+05	2.867E+05	1.498E-03	1.560E+07
2.411E+00	5.563E+08	4.556E+05	1.976E+07	3.346E+08	1.157E-05	1.189E+08	9.211E+04	4.309E+07	2.017E+05	2.867E+05	1.789E-03	4.362E+05
5.411E+00	3.098E+08	4.556E+05	1.932E+07	2.255E+08	3.311E-05	1.047E+07	9.211E+04	4.012E+07	2.017E+05	2.866E+05	2.712E-03	9.532E+00
1.041E+01	1.139E+08	4.555E+05	1.792E+07	6.052E+07	2.886E-04	3.172E+03	9.210E+04	3.163E+07	2.016E+05	2.863E+05	7.159E-03	2.779E-15
3.041E+01	4.221E+07	4.552E+05	1.541E+07	8.359E+06	2.472E-03	2.914E-04	9.208E+04	1.964E+07	2.015E+05	2.857E+05	2.071E-02	0.0
1.004E+02	1.488E+07	4.543E+05	9.095E+06	4.372E+02	4.921E-02	0.0	9.203E+04	3.713E+06	2.010E+05	2.836E+05	9.069E-02	0.0
3.004E+02	3.722E+06	4.517E+05	2.015E+06	1.644E-09	8.271E-01	0.0	9.187E+04	3.178E+04	1.996E+05	2.776E+05	3.519E-01	0.0
1.000E+03	1.298E+06	4.427E+05	1.032E+04	0.0	1.334E+01	0.0	9.131E+04	1.846E-03	1.949E+05	2.577E+05	1.829E+00	0.0
3.000E+03	1.007E+06	4.179E+05	2.948E-03	0.0	1.105E+02	0.0	8.974E+04	3.909E-24	1.820E+05	2.085E+05	9.836E+00	0.0
1.000E+04	6.980E+05	3.416E+05	0.0	0.0	6.630E+02	0.0	8.446E+04	0.0	1.433E+05	9.926E+04	7.657E+01	0.0
3.000E+04	3.548E+05	1.920E+05	0.0	0.0	2.351E+03	0.0	7.102E+04	0.0	7.240E+04	1.191E+04	4.628E+02	0.0
1.000E+05	8.385E+04	2.557E+04	0.0	0.0	5.583E+03	0.0	3.873E+04	0.0	6.633E+03	7.119E+00	1.864E+03	0.0
3.000E+05	2.321E+04	8.088E+01	0.0	0.0	7.370E+03	0.0	6.846E+03	0.0	7.502E+00	1.152E-06	2.630E+03	0.0
5.000E+05	1.639E+04	2.556E-01	0.0	0.0	6.686E+03	0.0	1.210E+03	0.0	8.404E-03	1.146E-06	2.645E+03	0.0
1.000E+06	1.288E+04	1.598E-07	0.0	0.0	5.417E+03	0.0	1.590E+01	0.0	3.234E-10	1.141E-06	2.644E+03	0.0

Ingestion toxicity (m^3 water/MTIHM)

Time (yr)	PB210	MO 93	AM241	TH229	RA225	TC 99	FE 55	RU106	CE144	PO210	CS137	NP237
4.384E-01	1.044E-04	1.780E+05	1.305E+05	5.463E-04	4.373E-04	2.601E+03	3.321E+07	3.292E+07	3.065E+07	1.199E-05	1.745E+06	1.218E+01
4.931E-01	1.042E-04	1.780E+05	1.321E+05	5.463E-04	4.372E-04	2.601E+03	3.273E+07	3.171E+07	2.919E+07	1.227E-05	1.743E+06	1.219E+01
5.753E-01	1.040E-04	1.780E+05	1.344E+05	5.463E-04	4.371E-04	2.601E+03	3.202E+07	2.997E+07	2.713E+07	1.264E-05	1.740E+06	1.219E+01
6.574E-01	1.037E-04	1.780E+05	1.367E+05	5.463E-04	4.371E-04	2.601E+03	3.133E+07	2.832E+07	2.522E+07	1.294E-05	1.737E+06	1.220E+01
7.395E-01	1.035E-04	1.780E+05	1.390E+05	5.464E-04	4.371E-04	2.601E+03	3.065E+07	2.676E+07	2.344E+07	1.320E-05	1.733E+06	1.220E+01
8.217E-01	1.032E-04	1.780E+05	1.413E+05	5.464E-04	4.371E-04	2.601E+03	2.998E+07	2.529E+07	2.179E+07	1.342E-05	1.730E+06	1.221E+01
9.038E-01	1.030E-04	1.780E+05	1.436E+05	5.464E-04	4.371E-04	2.601E+03	2.933E+07	2.391E+07	2.025E+07	1.361E-05	1.727E+06	1.221E+01
1.150E+00	1.022E-04	1.780E+05	1.505E+05	5.464E-04	4.371E-04	2.601E+03	2.747E+07	2.018E+07	1.626E+07	1.391E-05	1.717E+06	1.223E+01
1.411E+00	1.014E-04	1.780E+05	1.576E+05	5.465E-04	4.372E-04	2.601E+03	2.562E+07	1.687E+07	1.289E+07	1.407E-05	1.707E+06	1.224E+01
2.411E+00	9.837E-05	1.779E+05	1.841E+05	5.467E-04	4.373E-04	2.601E+03	1.963E+07	8.480E+06	5.289E+06	1.404E-05	1.668E+06	1.232E+01
5.411E+00	9.017E-05	1.778E+05	2.560E+05	5.476E-04	4.391E-04	2.601E+03	8.821E+06	1.078E+06	3.656E+05	1.300E-05	1.556E+06	1.261E+01
1.041E+01	7.712E-05	1.775E+05	4.299E+05	5.531E-04	4.425E-04	2.601E+03	6.134E+05	1.130E+03	4.955E+01	1.102E-05	1.235E+06	1.412E+01
3.041E+01	2.154E-04	1.768E+05	5.926E+05	5.780E-04	4.624E-04	2.601E+03	2.965E+03	1.203E-03	9.100E-07	3.077E-05	7.779E+05	1.866E+01
1.004E+02	7.365E-03	1.743E+05	6.282E+05	8.909E-04	7.127E-04	2.600E+03	2.330E-05	1.498E-24	0.0	1.052E-03	1.544E+05	3.790E+01
3.004E+02	1.915E-01	1.676E+05	4.587E+05	5.817E-03	4.654E-03	2.599E+03	0.0	0.0	0.0	2.736E-02	1.519E+03	8.461E+01
1.000E+03	4.000E+00	1.459E+05	1.493E+05	1.263E-01	1.011E-01	2.593E+03	0.0	0.0	0.0	5.715E-01	1.437E-04	1.679E+02
3.000E+03	3.312E+01	9.818E+04	6.041E+03	1.822E+00	1.458E+00	2.576E+03	0.0	0.0	0.0	4.732E+00	1.225E-24	2.064E+02
1.000E+04	1.988E+02	2.452E+04	3.362E-01	2.138E+01	1.710E+01	2.518E+03	0.0	0.0	0.0	2.840E+01	0.0	2.075E+02
3.000E+04	7.050E+02	4.661E+02	5.003E-02	1.260E+02	1.008E+02	2.359E+03	0.0	0.0	0.0	1.007E+02	0.0	2.062E+02
1.000E+05	1.674E+03	4.416E-04	1.660E-04	4.936E+02	3.949E+02	1.879E+03	0.0	0.0	0.0	2.392E+02	0.0	2.016E+02
3.000E+05	2.210E+03	2.725E-21	1.441E-11	1.086E+03	8.687E+02	9.800E+02	0.0	0.0	0.0	3.157E+02	0.0	1.889E+02
5.000E+05	2.005E+03	1.681E-38	1.187E-18	1.266E+03	1.013E+03	5.112E+02	0.0	0.0	0.0	2.864E+02	0.0	1.771E+02
1.000E+06	1.624E+03	0.0	2.314E-36	1.205E+03	9.642E+02	1.004E+02	0.0	0.0	0.0	2.321E+02	0.0	1.506E+02

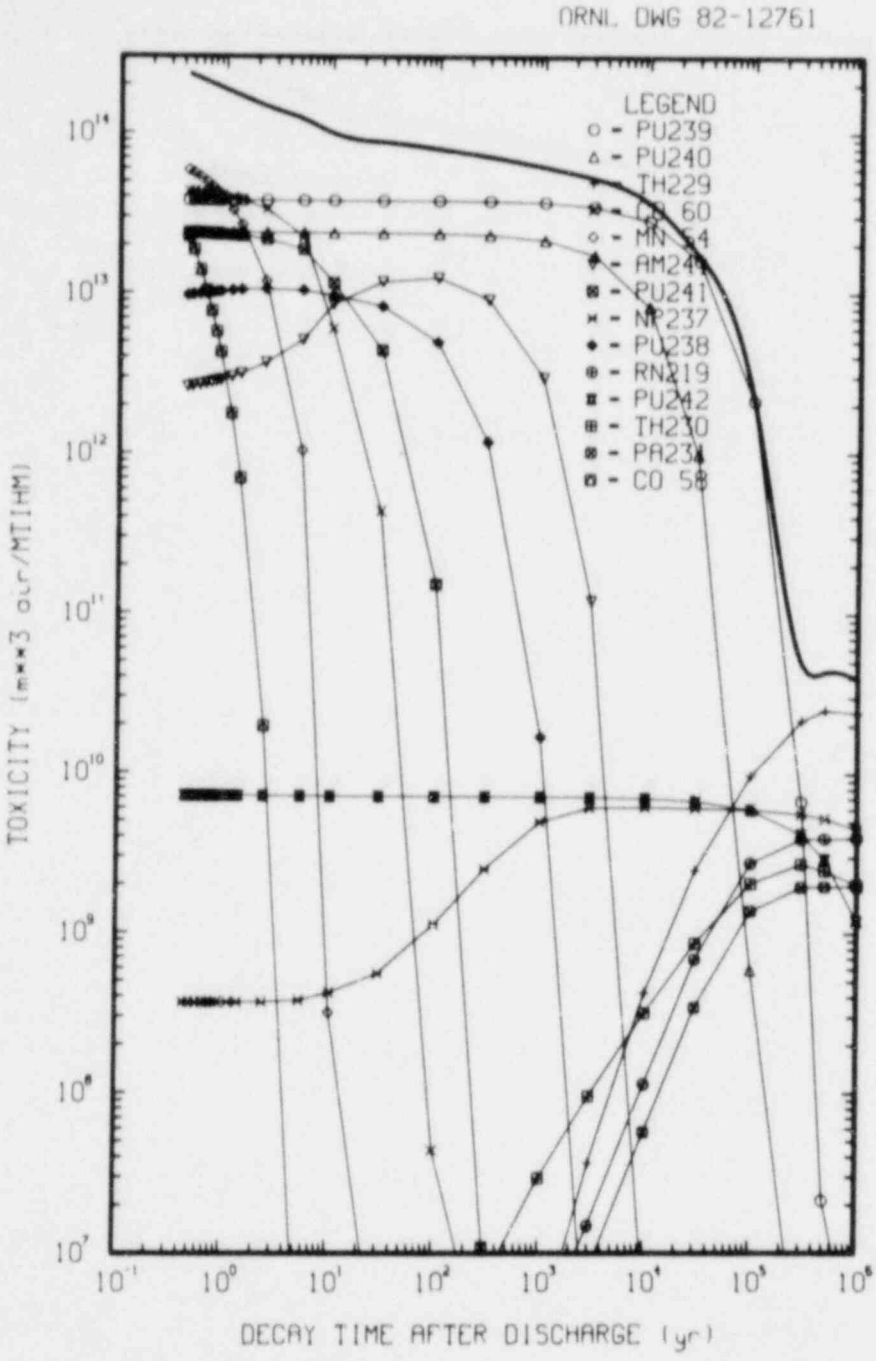

Fig. D.12. Inhalation toxicity of blended fuel-assembly structural material waste as a function of decay time.

Table D.12. Inhalation toxicity of blended fuel-assembly structural material waste as a function of decay time

Inhalation toxicity (m^3 air/MTIHM)

Time (yr)	TOTAL	PU239	PU240	TH229	CO 60	MN 54	AM241	PU241	NP237	PU238	PB219	PU242
4.384E-01	2.334E+14	3.797E+13	2.389E+13	1.093E+04	4.337E+13	5.880E+13	2.610E+12	2.389E+13	3.655E+08	9.749E+12	1.926E+03	7.176E+09
4.931E-01	2.258E+14	3.797E+13	2.389E+13	1.093E+04	4.306E+13	5.625E+13	2.641E+12	2.383E+13	3.656E+08	9.834E+12	1.933E+03	7.176E+09
5.753E-01	2.162E+14	3.797E+13	2.389E+13	1.093E+04	4.250E+13	5.263E+13	2.688E+12	2.374E+13	3.658E+08	9.949E+12	1.956E+03	7.176E+09
6.574E-01	2.082E+14	3.797E+13	2.389E+13	1.093E+04	4.214E+13	4.924E+13	2.734E+12	2.364E+13	3.659E+08	1.005E+13	1.983E+03	7.176E+09
7.395E-01	2.013E+14	3.797E+13	2.389E+13	1.093E+04	4.169E+13	4.607E+13	2.781E+12	2.355E+13	3.660E+08	1.014E+13	2.010E+03	7.176E+09
8.217E-01	1.954E+14	3.797E+13	2.389E+13	1.093E+04	4.124E+13	4.310E+13	2.827E+12	2.346E+13	3.662E+08	1.021E+13	2.038E+03	7.176E+09
9.038E-01	1.903E+14	3.797E+13	2.389E+13	1.093E+04	4.080E+13	4.033E+13	2.873E+12	2.336E+13	3.663E+08	1.028E+13	2.066E+03	7.176E+09
1.150E+00	1.780E+14	3.797E+13	2.389E+13	1.093E+04	3.949E+13	3.303E+13	3.009E+12	2.309E+13	3.668E+08	1.043E+13	2.153E+03	7.176E+09
1.411E+00	1.684E+14	3.797E+13	2.389E+13	1.093E+04	3.816E+13	2.674E+13	3.152E+12	2.280E+13	3.673E+08	1.053E+13	2.247E+03	7.176E+09
2.411E+00	1.460E+14	3.797E+13	2.389E+13	1.093E+04	3.346E+13	1.189E+13	3.682E+12	2.173E+13	3.696E+08	1.064E+13	2.684E+03	7.176E+09
5.411E+00	1.213E+14	3.797E+13	2.388E+13	1.095E+04	2.255E+13	1.047E+12	5.121E+12	1.881E+13	3.782E+08	1.046E+13	4.058E+03	7.177E+09
1.041E+01	9.880E+13	3.796E+13	2.386E+13	1.106E+04	6.052E+12	3.172E+08	8.599E+12	1.162E+13	4.236E+08	9.703E+12	1.074E+04	7.179E+09
3.041E+01	8.757E+13	3.793E+13	2.381E+13	1.156E+04	4.359E+11	2.914E+01	1.185E+13	4.438E+12	5.599E+08	8.359E+12	3.107E+04	7.183E+09
1.004E+02	7.955E+13	3.786E+13	2.363E+13	1.782E+04	4.372E+07	0.0	1.256E+13	1.527E+11	1.137E+09	4.981E+12	1.360E+05	7.195E+09
3.004E+02	7.126E+13	3.764E+13	2.313E+13	1.163E+05	1.644E-04	0.0	9.174E+12	1.081E+07	2.538E+09	1.188E+12	5.278E+05	7.212E+09
1.000E+03	6.180E+13	3.689E+13	2.148E+13	2.527E+06	0.0	0.0	2.986E+12	7.102E+05	5.037E+09	1.708E+10	2.744E+06	7.216E+09
3.000E+03	5.235E+13	3.482E+13	1.737E+13	3.645E+07	0.0	0.0	1.20[illegible]+11	6.033E+05	6.191E+09	1.503E+06	1.475E+07	7.191E+09
1.000E+04	3.676E+13	2.847E+13	8.271E+12	4.275E+08	0.0	0.0	6.723E+06	3.409E+05	6.225E+09	2.061E-08	1.148E+08	7.101E+09
3.000E+04	1.702E+13	1.600E+13	9.922E+11	2.520E+09	0.0	0.0	1.001E+06	6.671E+04	6.185E+09	0.0	6.942E+08	6.851E+09
1.000E+05	2.162E+12	2.131E+12	5.932E+08	9.872E+09	0.0	0.0	3.320E+03	2.213E+02	6.047E+09	0.0	2.796E+09	6.044E+09
3.000E+05	4.878E+10	6.740E+09	9.603E+01	2.172E+10	0.0	0.0	2.882E-04	1.824E-05	5.667E+09	0.0	3.945E+09	4.224E+09
5.000E+05	4.371E+10	2.130E+07	9.550E+01	2.532E+10	0.0	0.0	2.375E-11	1.503E-12	5.312E+09	0.0	3.967E+09	2.952E+09
1.000E+06	3.936E+10	1.332E+01	9.510E+01	2.410E+10	0.0	0.0	4.627E-29	2.928E-30	4.518E+09	0.0	3.966E+09	1.205E+09

Inhalation toxicity (m^3 air/MTIHM)

Time (yr)	TH230	PA231	CO 58	AC227	CM242	RU106	CE144	FE 55	SR 90	NI 63	AM242M	U233
4.384E-01	2.120E+03	6.167E+03	2.277E+13	4.872E+02	3.783E+12	1.646E+12	1.532E+12	8.856E+11	4.494E+11	3.009E+11	2.391E+11	2.178E+02
4.931E-01	2.162E+03	6.213E+03	1.872E+13	4.917E+02	3.476E+12	1.585E+12	1.460E+12	8.727E+11	4.488E+11	3.007E+11	2.390E+11	2.200E+02
5.753E-01	2.225E+03	6.280E+03	1.396E+13	4.986E+02	3.061E+12	1.498E+12	1.357E+12	8.538E+11	4.479E+11	3.005E+11	2.389E+11	2.233E+02
6.574E-01	2.290E+03	6.348E+03	1.040E+13	5.056E+02	2.696E+12	1.416E+12	1.261E+12	8.353E+11	4.470E+11	3.004E+11	2.389E+11	2.265E+02
7.395E-01	2.357E+03	6.415E+03	7.755E+12	5.126E+02	2.375E+12	1.338E+12	1.172E+12	8.172E+11	4.462E+11	3.002E+11	2.388E+11	2.298E+02
8.217E-01	2.425E+03	6.483E+03	5.780E+12	5.197E+02	2.092E+12	1.265E+12	1.089E+12	7.995E+11	4.453E+11	3.000E+11	2.387E+11	2.331E+02
9.038E-01	2.498E+03	6.550E+03	4.309E+12	5.268E+02	1.843E+12	1.195E+12	1.012E+12	7.822E+11	4.444E+11	2.998E+11	2.386E+11	2.364E+02
1.150E+00	2.712E+03	6.746E+03	1.785E+12	5.487E+02	1.261E+12	1.009E+12	8.129E+11	7.325E+11	4.419E+11	2.992E+11	2.383E+11	2.463E+02
1.411E+00	2.958E+03	6.953E+03	7.022E+11	5.725E+02	8.444E+11	8.433E+11	6.444E+11	6.833E+11	4.391E+11	2.987E+11	2.380E+11	2.567E+02
2.411E+00	4.051E+03	7.739E+03	1.963E+10	6.697E+02	1.867E+11	4.240E+11	2.645E+11	5.234E+11	4.287E+11	2.964E+11	2.370E+11	3.013E+02
5.411E+00	8.748E+03	1.010E+04	4.289E+05	1.016E+03	1.132E+10	5.388E+10	1.828E+10	2.352E+11	3.993E+11	2.898E+11	2.337E+11	4.281E+02
1.041E+01	3.933E+04	1.802E+04	1.251E-10	2.683E+03	9.188E+09	5.651E+07	2.477E+06	1.636E+10	3.147E+11	2.688E+11	2.233E+11	8.641E+02
3.041E+01	1.640E+05	3.422E+04	0.0	7.763E+03	8.387E+09	6.016E+01	4.550E-02	7.906E+07	1.954E+11	2.312E+11	2.039E+11	1.931E+03
1.004E+02	1.125E+06	9.459E+04	0.0	3.401E+04	6.095E+09	7.489E-20	0.0	6.213E-01	3.695E+10	1.364E+11	1.481E+11	8.408E+03
3.004E+02	6.243E+06	2.984E+05	0.0	1.320E+05	2.449E+09	0.0	0.0	0.0	3.162E+08	3.023E+10	5.951E+10	4.937E+04
1.000E+03	2.940E+07	1.372E+06	0.0	6.860E+05	1.306E+08	0.0	0.0	0.0	1.837E+01	1.548E+08	2.445E+09	3.562E+05
3.000E+03	9.648E+07	7.376E+06	0.0	3.689E+06	1.105E+04	0.0	0.0	0.0	3.890E-20	4.422E+01	2.677E+05	1.633E+06
1.000E+04	3.204E+08	5.742E+07	0.0	2.871E+07	1.516E-10	0.0	0.0	0.0	0.0	0.0	3.674E-09	6.282E+06
3.000E+04	8.759E+08	3.471E+08	0.0	1.735E+08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.875E+07
1.000E+05	2.084E+09	1.398E+09	0.0	6.991E+08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.410E+07
3.000E+05	2.756E+09	1.972E+09	0.0	9.861E+08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.075E+08
5.000E+05	2.498E+09	1.984E+09	0.0	9.918E+08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.244E+08
1.000E+06	2.031E+09	1.983E+09	0.0	9.914E+08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.198E+08

APPENDIX E: COMPARISON OF THE CHARACTERISTICS OF FUEL-CYCLE MATERIALS FROM THE CRBR, A PWR-U, THE FFTF, AND A COMMERCIAL LMFBR

E.1: Characteristics of Spent-Fuel Assemblies

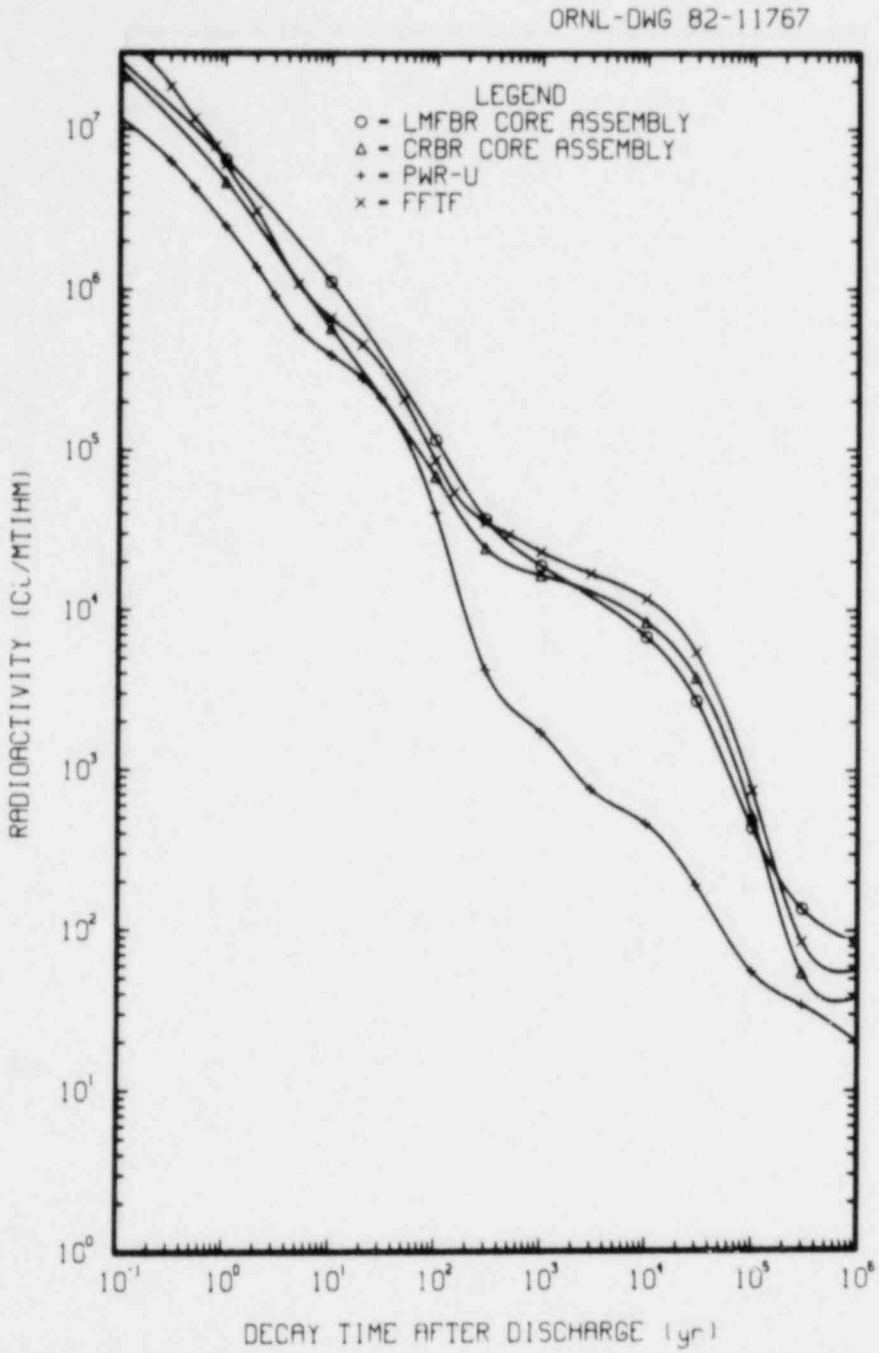

Fig. E.1. Spent-fuel assembly radioactivity.

Table E.1. Spent-fuel assembly radioactivity

CRBR core		PWR-U		FFTF		Commercial LMFBR	
Time (yr)	Radioactivity (Ci/MTIHM)	Time (yr)	Radioactivity (Ci/MTIHM)	Time (yr)	Radioactivity (Ci/MTIHM)	Time (yr)	Radioactivity (Ci/MTIHM)
1.000E-01	2.360E+07	1.000E-01	1.173E+07	1.000E-01	3.849E+07	1.000E-01	2.661E+07
1.000E+00	4.729E+06	3.000E-01	6.334E+06	3.000E-01	1.867E+07	1.000E+00	6.516E+06
1.000E+01	5.823E+05	5.000E-01	4.336E+06	5.000E-01	1.175E+07	1.000E+01	1.128E+06
1.000E+02	6.896E+04	1.000E+00	2.507E+06	8.000E-01	7.937E+06	1.000E+02	1.165E+05
3.000E+02	2.467E+04	2.000E+00	1.386E+06	1.000E+00	6.069E+06	3.000E+02	3.738E+04
1.000E+03	1.672E+04	3.000E+00	9.221E+05	2.000E+00	3.114E+06	1.000E+03	1.916E+04
1.000E+04	8.482E+03	5.000E+00	5.775E+05	5.000E+00	1.090E+06	1.000E+04	6.856E+03
3.000E+04	3.813E+03	1.000E+01	3.935E+05	1.000E+01	6.714E+05	3.000E+04	2.733E+03
1.000E+05	5.226E+02	2.000E+01	2.808E+05	2.000E+01	4.596E+05	1.000E+05	4.394E+02
3.000E+05	5.432E+01	3.000E+01	2.129E+05	5.000E+01	2.079E+05	3.000E+05	1.368E+02
1.000E+06	3.841E+01	1.000E+02	4.096E+04	1.000E+02	8.708E+04	1.000E+06	8.282E+01
		3.000E+02	4.280E+03	1.500E+02	5.476E+04		
		1.000E+03	1.742E+03	3.000E+02	3.575E+04		
		3.000E+03	7.697E+02	5.000E+02	2.996E+04		
		1.000E+04	4.676E+02	1.000E+03	2.340E+04		
		3.000E+04	1.933E+02	3.000E+03	1.707E+04		
		1.000E+05	5.524E+01	1.000E+04	1.186E+04		
		3.000E+05	3.433E+01	3.000E+04	5.488E+03		
		1.000E+06	2.013E+01	1.000E+05	7.563E+02		
				3.000E+05	8.500E+01		
				1.000E+06	5.690E+01		

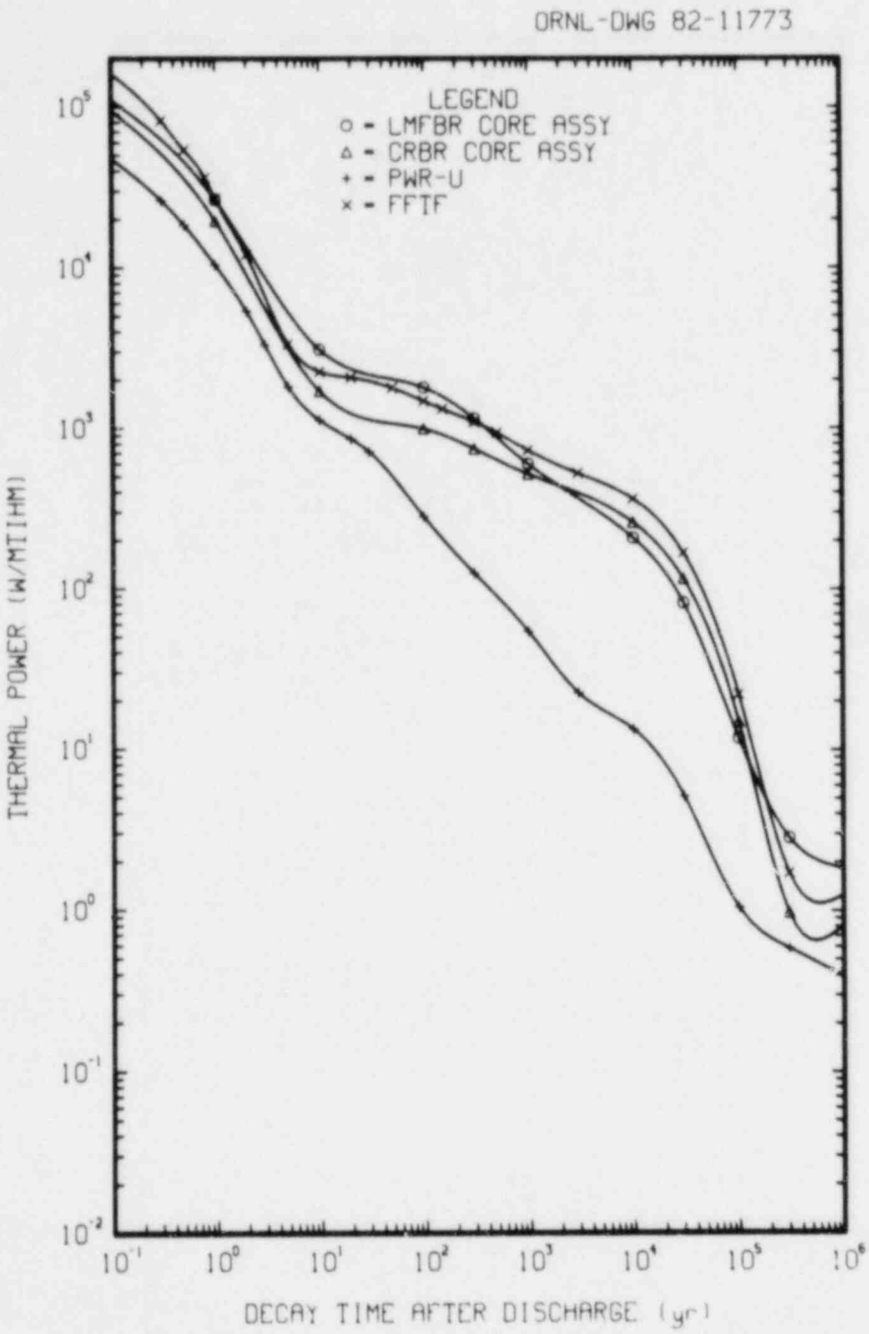

Fig. E.2. Spent-fuel assembly thermal power.

Table E.2. Spent-fuel assembly thermal power

CRBR core		PWR-U		FFTF		Commercial LMFBR	
Time (yr)	Thermal power (W/MTIHM)	Time (yr)	Thermal power (W/MTIHM)	Time (yr)	Thermal power (W/MTIHM)	Time (yr)	Thermal power (W/MTIHM)
1.000E-01	9.524E+04	1.000E-01	4.778E+04	1.000E-01	1.611E+05	1.000E-01	1.110E+05
1.000E+00	1.964E+04	3.000E-01	2.631E+04	3.000E-01	8.250E+04	1.000E+00	2.666E+04
1.000E+01	1.722E+03	5.000E-01	1.843E+04	5.000E-01	5.410E+04	1.000E+01	3.119E+03
1.000E+02	1.001E+03	1.000E+00	1.046E+04	8.000E-01	3.638E+04	1.000E+02	1.809E+03
3.000E+02	7.521E+02	2.000E+00	5.389E+03	1.000E+00	2.699E+04	3.000E+02	1.160E+03
1.000E+03	5.221E+02	3.000E+00	3.329E+03	2.000E+00	1.210E+04	1.000E+03	6.032E+02
1.000E+04	2.606E+02	5.000E+00	1.826E+03	5.000E+00	3.355E+03	1.000E+04	2.089E+02
3.000E+04	1.162E+02	1.000E+01	1.132E+03	1.000E+01	2.264E+03	3.000E+04	8.242E+01
1.000E+05	1.504E+01	2.000E+01	8.644E+02	2.000E+01	2.087E+03	1.000E+05	1.189E+01
3.000E+05	9.778E-01	3.000E+01	7.190E+02	5.000E+01	1.796E+03	3.000E+05	2.850E+00
1.000E+06	8.071E-01	1.000E+02	2.843E+02	1.000E+02	1.492E+03	1.000E+06	1.833E+00
		3.000E+02	1.261E+02	1.500E+02	1.330E+03		
		1.000E+03	5.474E+01	3.000E+02	1.102E+03		
		3.000E+03	2.278E+01	5.000E+02	9.416E+02		
		1.000E+04	1.352E+01	1.000E+03	7.325E+02		
		3.000E+04	5.205E+00	3.000E+03	5.271E+02		
		1.000E+05	1.053E+00	1.000E+04	3.651E+02		
		3.000E+05	5.853E-01	3.000E+04	1.682E+02		
		1.000E+06	3.907E-01	1.000E+05	2.223E+01		
				3.000E+05	1.720E+00		
				1.000E+06	1.249E+00		

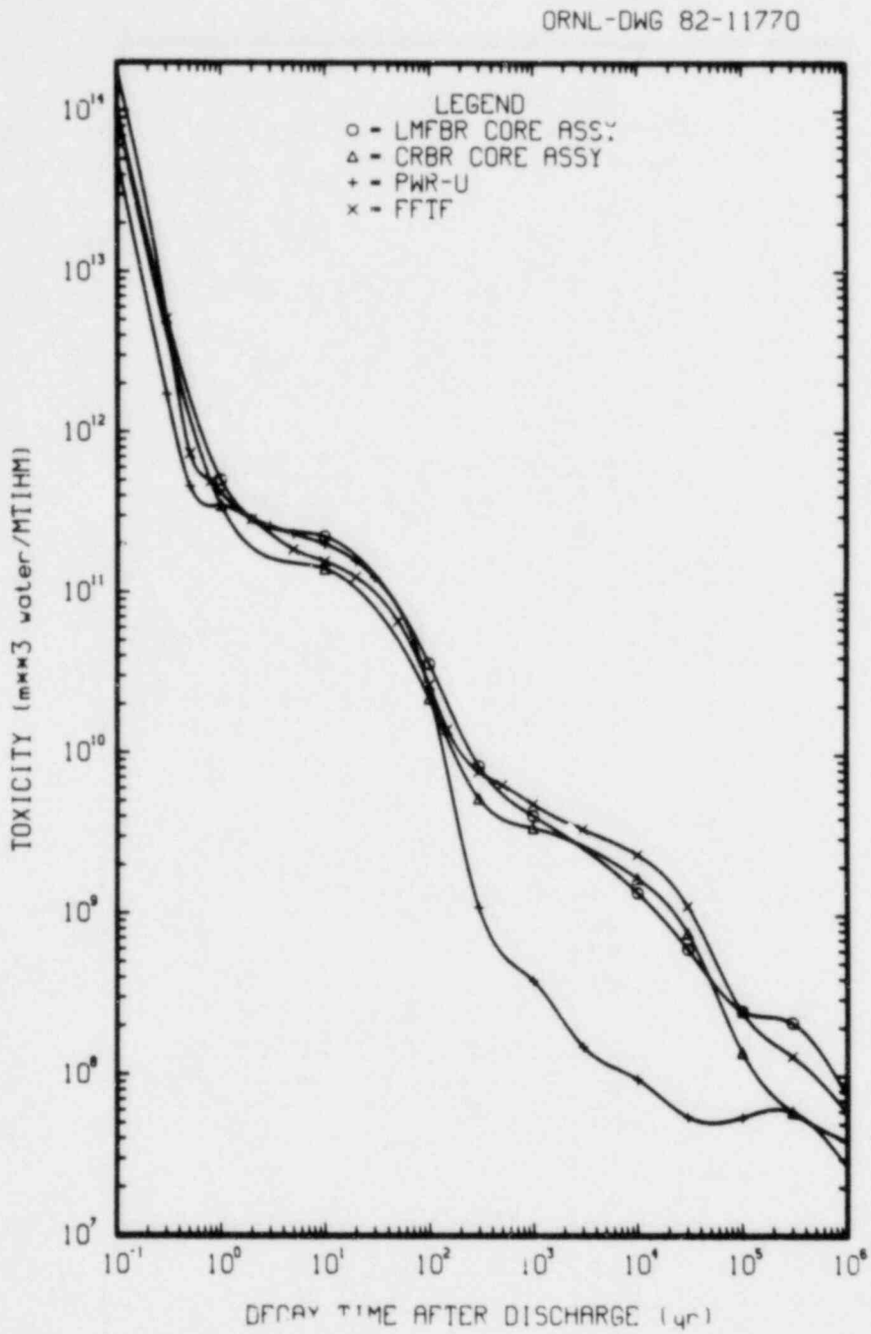

Fig. E.3. Spent-fuel assembly ingestion toxicity.

Table E.3. Spent-fuel assembly ingestion toxicity

CRBR core		PWR-U		FFTF		Commercial LMFBR	
Time (yr)	Ingestion toxicity (m^3 water/MTIHM)	Time (yr)	Ingestion toxicity (m^3 water/MTIHM)	Time (yr)	Ingestion toxicity (m^3 water/MTIHM)	Time (yr)	Ingestion toxicity (m^3 water/MTIHM)
1.000E-01	9.993E+13	1.000E-01	5.160E+13	1.000E-01	1.787E+14	1.000E-01	1.033E+14
1.000E+00	3.510E+11	3.000E-01	1.732E+12	3.000E-01	5.105E+12	1.000E+00	5.061E+11
1.000E+01	1.417E+11	5.000E-01	8.605E+11	5.000E-01	7.361E+11	1.000E+01	2.247E+11
1.000E+02	2.212E+10	1.000E+00	3.482E+11	8.000E-01	8.955E+11	1.000E+02	3.635E+10
3.000E+02	5.304E+09	2.000E+00	2.889E+11	1.000E+00	8.205E+11	3.000E+02	9.434E+09
1.000E+03	3.476E+09	3.000E+00	2.605E+11	2.000E+00	2.874E+11	1.000E+03	8.145E+09
1.000E+04	1.692E+09	5.000E+00	2.336E+11	5.000E+00	1.864E+11	1.000E+04	1.376E+09
3.000E+04	7.707E+09	1.000E+01	2.018E+11	1.000E+01	1.572E+11	3.000E+04	6.114E+08
1.000E+05	1.394E+08	2.000E+01	1.588E+11	2.000E+01	1.258E+11	1.000E+05	2.522E+08
3.000E+05	5.939E+07	3.000E+01	1.254E+11	5.000E+01	6.681E+10	3.000E+05	2.136E+08
1.000E+06	3.891E+07	1.000E+02	2.477E+10	1.000E+02	2.685E+10	1.000E+06	7.513E+07
		3.000E+02	1.107E+09	1.500E+02	1.424E+10		
		1.000E+03	3.866E+08	3.000E+02	7.753E+09		
		3.000E+03	1.506E+08	5.000E+02	6.443E+09		
		1.000E+04	9.431E+07	1.000E+03	8.898E+09		
		3.000E+04	5.502E+07	3.000E+03	3.419E+09		
		1.000E+05	5.485E+07	1.000E+04	2.378E+09		
		3.000E+05	5.955E+07	3.000E+04	1.135E+09		
		1.000E+06	2.713E+07	1.000E+05	2.485E+08		
				3.000E+05	1.318E+08		
				1.000E+06	5.943E+07		

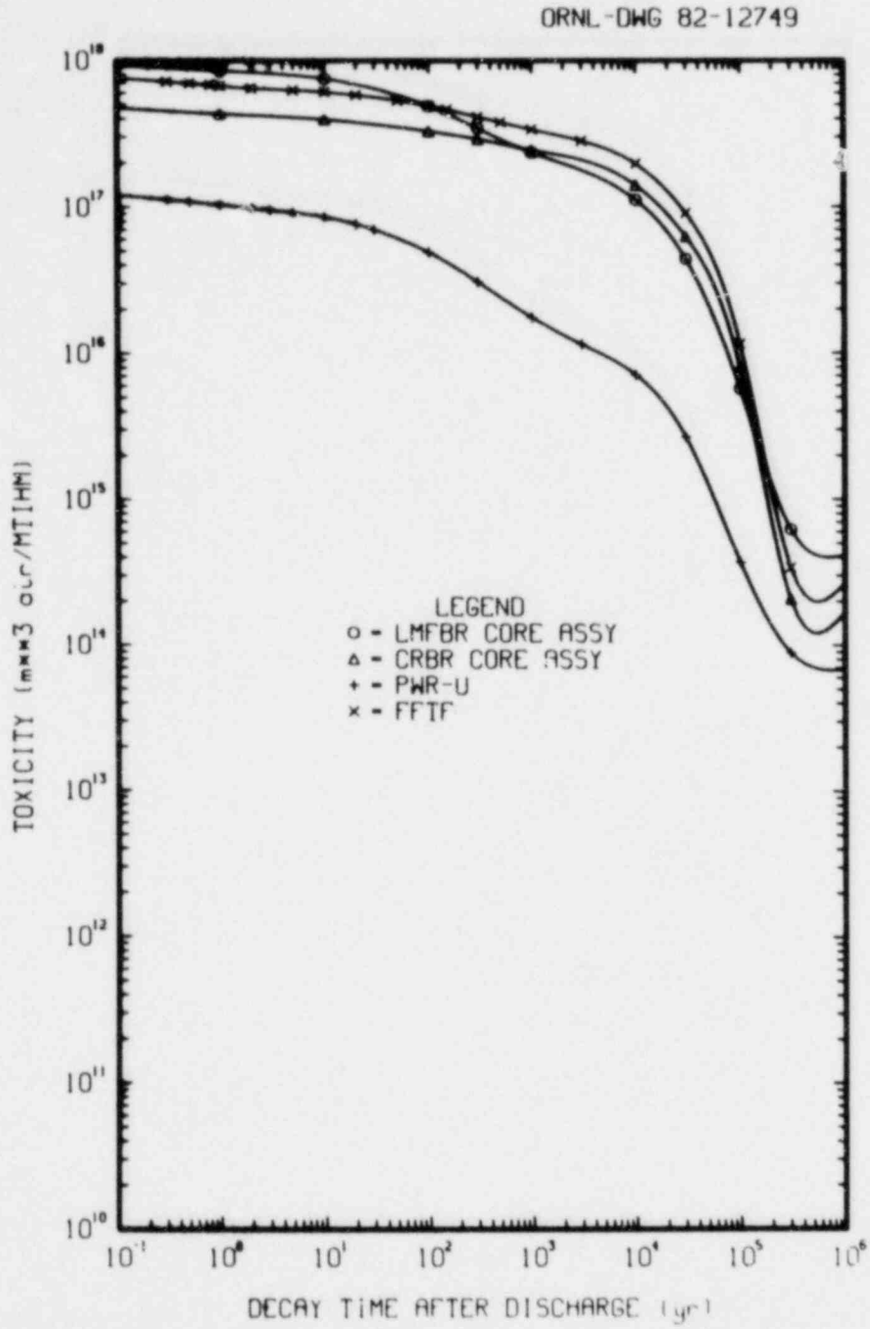

Fig. E.4. Spent-fuel assembly inhalation toxicity.

Table E.4. Spent-fuel assembly inhalation toxicity

CRBR core		PWR-U		FFTF		Commercial LMFBR	
Time (yr)	Inhalation toxicity (m^3 air/MTIHM)	Time (yr)	Inhalation toxicity (m^3 air/MTIHM)	Time (yr)	Inhalation toxicity (m^3 air/MTIHM)	Time (yr)	Inhalation toxicity (m^3 air/MTIHM)
1.000E-01	4.732E+17	1.000E-01	1.200E+17	1.000E-01	7.545E+17	1.000E-01	9.197E+17
1.000E+00	4.331E+17	3.000E-01	1.127E+17	3.000E-01	7.175E+17	1.000E+00	8.508E+17
1.000E+01	3.957E+17	5.000E-01	1.088E+17	5.000E-01	6.970E+17	1.000E+01	7.509E+17
1.000E+02	3.274E+17	1.000E+00	1.035E+17	8.000E-01	6.804E+17	1.000E+02	4.878E+17
3.000E+02	2.895E+17	2.000E+00	9.840E+16	1.000E+00	6.690E+17	3.000E+02	3.431E+17
1.000E+03	2.442E+17	3.000E+00	9.567E+16	2.000E+00	6.467E+17	1.000E+03	2.343E+17
1.000E+04	1.403E+17	5.000E+00	9.221E+16	5.000E+00	6.268E+17	1.000E+04	1.114E+17
3.000E+04	6.262E+16	1.000E+01	8.605E+16	1.000E+01	6.087E+17	3.000E+04	4.395E+16
1.000E+05	7.869E+15	2.000E+01	7.691E+16	2.000E+01	5.813E+17	1.000E+05	5.680E+15
3.000E+05	2.075E+14	3.000E+01	7.023E+16	5.000E+01	5.319E+17	3.000E+05	6.232E+14
1.000E+06	1.675E+14	1.000E+02	4.917E+16	1.000E+02	4.891E+17	1.000E+06	4.117E+14
		3.000E+02	3.084E+16	1.500E+02	4.611E+17		
		1.000E+03	1.763E+16	3.000E+02	4.108E+17		
		3.000E+03	1.152E+16	5.000E+02	3.771E+17		
		1.000E+04	7.097E+15	1.000E+03	3.367E+17		
		3.000E+04	2.670E+15	3.000E+03	2.815E+17		
		1.000E+05	3.714E+14	1.000E+04	1.968E+17		
		3.000E+05	8.887E+13	3.000E+04	9.060E+16		
		1.000E+06	6.815E+13	1.000E+05	1.154E+16		
				3.000E+05	3.410E+14		
				1.000E+06	2.647E+14		

E.2: Characteristics of Blended High-Level Waste

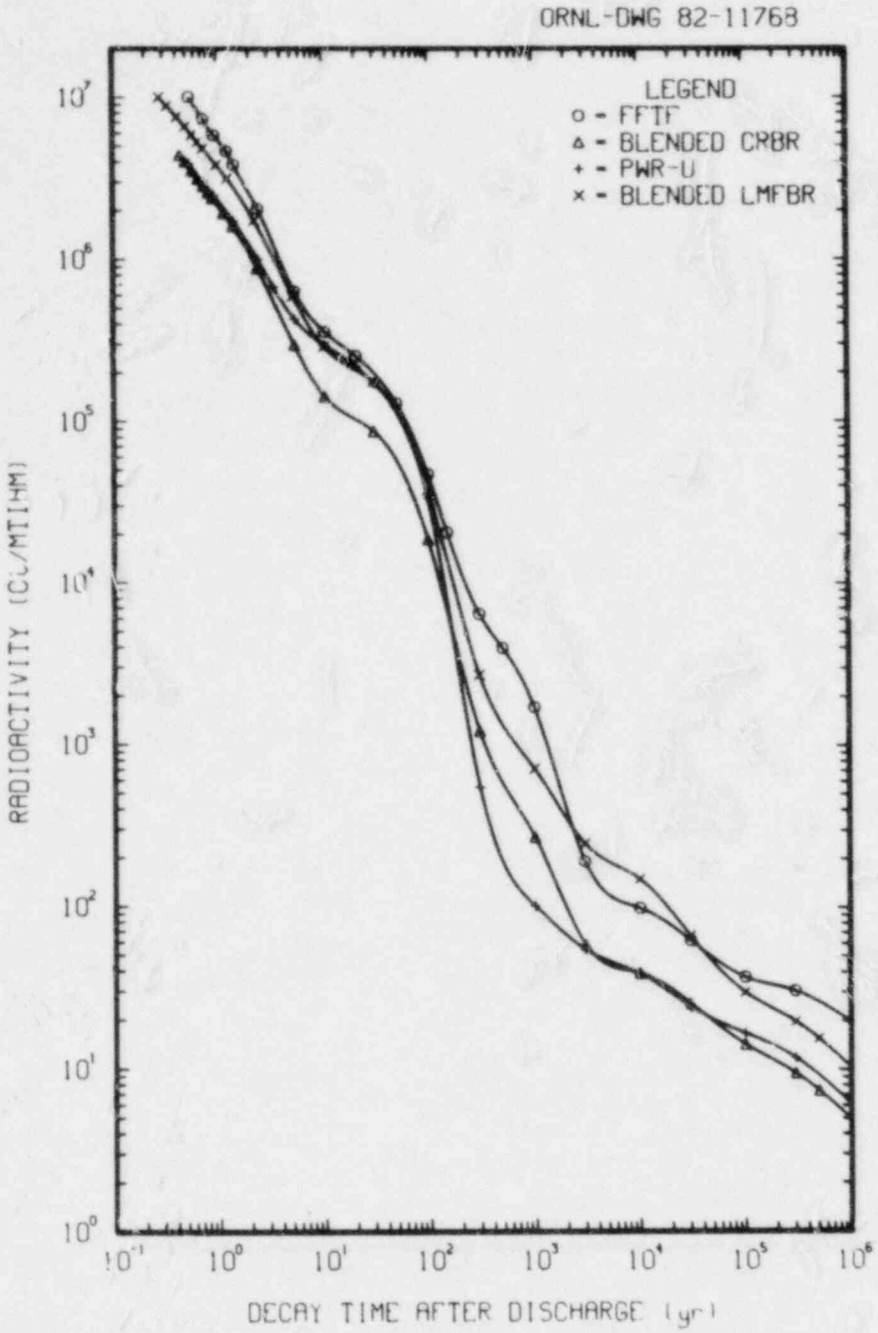

Fig. E.5. High-level waste radioactivity.

Table E.5. High-level waste radioactivity

Blended CRBR		PWR-U		FFTF		Blended commercial LMFBR	
Time (yr)	Radioactivity (Ci/MTIHM)	Time (yr)	Radioactivity (Ci/MTIHM)	Time (yr)	Radioactivity (Ci/MTIHM)	Time (yr)	Radioactivity (Ci/MTIHM)
4.384E-01	4.429E+06	5.380E-01	3.922E+06	5.380E-01	1.008E+07	2.774E-01	1.007E+07
4.931E-01	4.010E+06	7.380E-01	3.027E+06	7.380E-01	7.372E+06	3.321E-01	8.895E+06
5.753E-01	3.515E+06	9.380E-01	2.485E+06	9.380E-01	5.842E+06	4.143E-01	7.568E+06
6.574E-01	3.134E+06	1.438E+00	1.723E+06	1.238E+00	4.652E+06	4.964E-01	6.594E+06
7.395E-01	2.833E+06	2.438E+00	1.005E+06	1.438E+00	3.843E+06	5.785E-01	5.856E+06
8.217E-01	2.588E+06	3.438E+00	6.777E+05	2.438E+00	2.053E+06	6.607E-01	5.279E+06
9.038E-01	2.386E+06	5.438E+00	4.300E+05	5.438E+00	6.364E+05	7.428E-01	4.816E+06
1.150E+00	1.935E+06	1.044E+01	2.975E+05	1.044E+01	3.593E+05	9.892E-01	3.837E+06
1.411E+00	1.603E+06	2.044E+01	2.213E+05	2.044E+01	2.557E+05	1.250E+00	3.156E+06
2.411E+00	8.841E+05	3.044E+01	1.736E+05	5.044E+01	1.306E+05	2.250E+00	1.739E+06
5.411E+00	2.975E+05	1.004E+02	3.382E+04	1.004E+02	4.761E+04	5.250E+00	5.946E+05
1.041E+01	1.439E+05	3.004E+02	5.531E+02	1.504E+02	2.076E+04	1.025E+01	2.909E+05
3.041E+01	8.764E+04	1.000E+03	1.020E+02	3.004E+02	6.514E+03	3.025E+01	1.766E+05
1.004E+02	1.883E+04	3.000E+03	5.490E+01	5.004E+02	4.014E+03	1.002E+02	3.792E+04
3.004E+02	1.232E+03	1.000E+04	3.903E+01	1.000E+03	1.732E+03	3.002E+02	2.727E+03
1.000E+03	2.725E+02	3.000E+04	2.431E+01	3.000E+03	1.924E+02	1.000E+03	7.210E+02
3.000E+03	5.899E+01	1.000E+05	1.675E+01	1.000E+04	9.915E+01	3.000E+03	2.480E+02
1.000E+04	3.944E+01	3.000E+05	1.181E+01	3.000E+04	6.260E+01	1.000E+04	1.493E+02
3.000E+04	2.554E+01	1.000E+06	6.140E+00	1.000E+05	3.717E+01	3.000E+04	6.676E+01
1.000E+05	1.430E+01			3.000E+05	3.055E+01	1.000E+05	2.996E+01
3.000E+05	9.478E+00			1.000E+06	1.982E+01	3.000E+05	1.979E+01
5.000E+05	7.400E+00					5.000E+05	1.550E+01
1.000E+06	4.957E+00					1.000E+06	1.032E+01

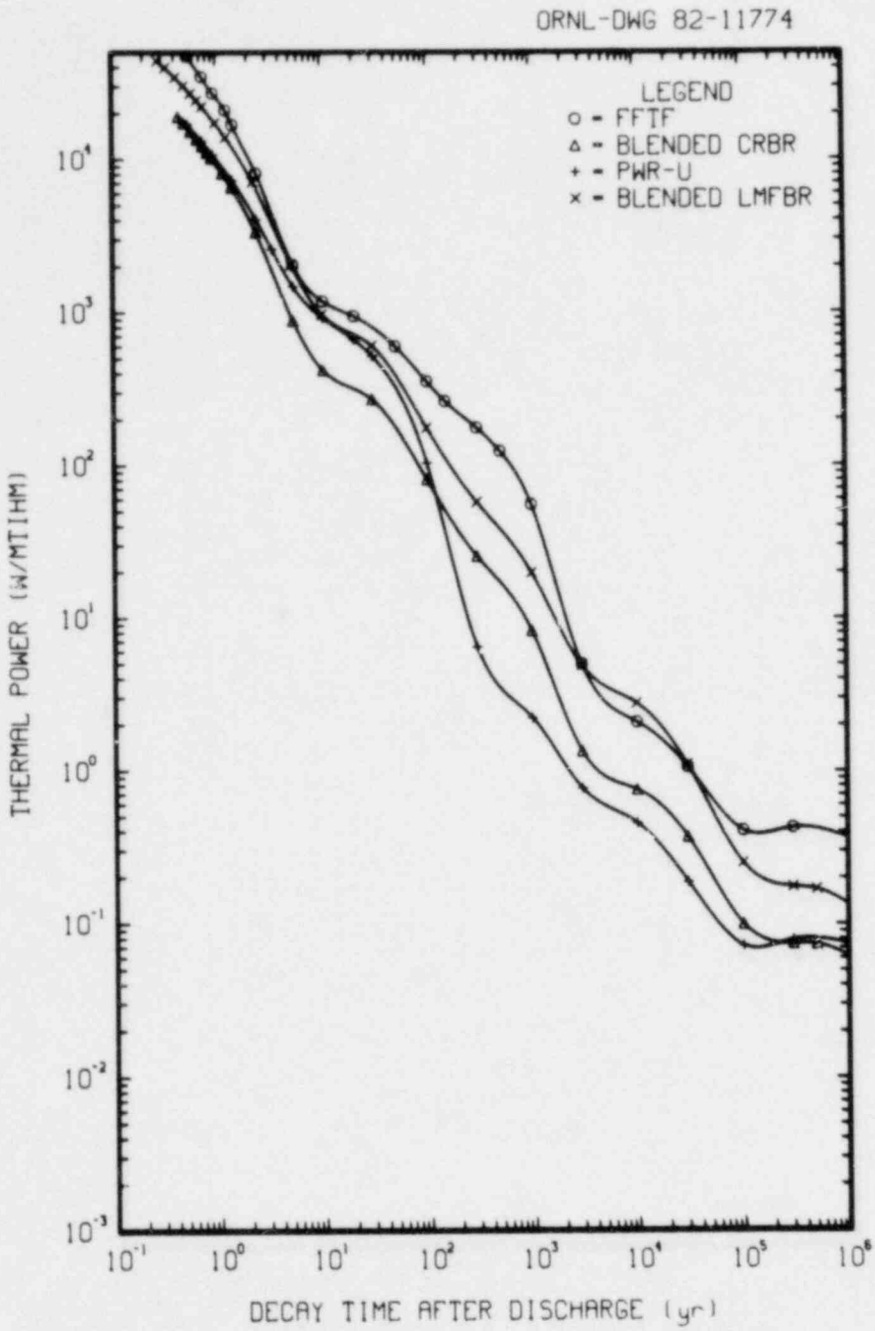

Fig. E.6. High-level waste thermal power.

Table E.6. High-level waste thermal power

Blended CRBR		PWR-U		FFTF		Blended commercial LMFBR	
Time (yr)	Thermal power (W/MTIHM)	Time (yr)	Thermal power (W/MTIHM)	Time (yr)	Thermal power (W/MTIHM)	Time (yr)	Thermal power (W/MTIHM)
4.384E-01	1.904E+04	5.380E-01	1.710E+04	5.380E-01	4.723E+04	2.774E-01	4.428E+04
4.931E-01	1.735E+04	7.380E-01	1.323E+04	7.380E-01	3.474E+04	3.321E-01	3.971E+04
5.753E-01	1.527E+04	9.380E-01	1.080E+04	9.380E-01	2.714E+04	4.143E-01	3.435E+04
6.574E-01	1.362E+04	1.438E+00	7.325E+03	1.238E+00	2.104E+04	4.964E-01	3.021E+04
7.395E-01	1.228E+04	2.438E+00	4.075E+03	1.438E+00	1.688E+04	5.785E-01	2.693E+04
8.217E-01	1.117E+04	3.438E+00	2.600E+03	2.438E+00	8.144E+03	6.607E-01	2.427E+04
9.038E-01	1.024E+04	5.438E+00	1.486E+03	5.438E+00	2.054E+03	7.428E-01	2.208E+04
1.150E+00	8.144E+03	1.044E+01	9.257E+02	1.044E+01	1.189E+03	9.892E-01	1.731E+04
1.411E+00	6.605E+03	2.044E+01	6.707E+02	2.044E+01	9.533E+02	1.250E+00	1.395E+04
2.411E+00	3.353E+03	3.044E+01	5.218E+02	5.044E+01	6.039E+02	2.250E+00	7.137E+03
5.411E+00	8.883E+02	1.004E+02	1.041E+02	1.004E+02	3.563E+02	5.250E+00	2.058E+03
1.041E+01	4.210E+02	3.004E+02	6.495E+00	1.504E+02	2.640E+02	1.025E+01	9.775E+02
3.041E+01	2.721E+02	1.000E+03	2.240E+00	3.004E+02	1.772E+02	3.025E+01	6.104E+02
1.004E+02	8.122E+01	3.000E+03	7.739E-01	5.004E+02	1.244E+02	1.002E+02	1.769E+02
3.004E+02	2.556E+01	1.000E+04	4.594E-01	1.000E+03	5.571E+01	3.002E+02	5.766E+01
1.000E+03	8.327E+00	3.000E+04	1.888E-01	3.000E+03	5.046E+00	1.000E+03	1.993E+01
3.000E+03	1.355E+00	1.000E+05	7.230E-02	1.000E+04	2.101E+00	3.000E+03	4.920E+00
1.000E+04	7.603E-01	3.000E+05	7.918E-02	3.000E+04	1.071E+00	1.000E+04	2.786E+00
3.000E+04	3.734E-01	1.000E+06	7.394E-02	1.000E+05	4.101E-01	3.000E+04	1.104E+00
1.000E+05	9.996E-02			3.000E+05	8.266E-01	1.000E+05	2.516E-01
3.000E+05	7.449E-02			1.300E+06	3.642E-01	3.000E+05	1.751E-01
5.000E+05	7.375E-02					5.000E+05	1.680E-01
1.000E+06	6.190E-02					1.000E+06	1.350E-01

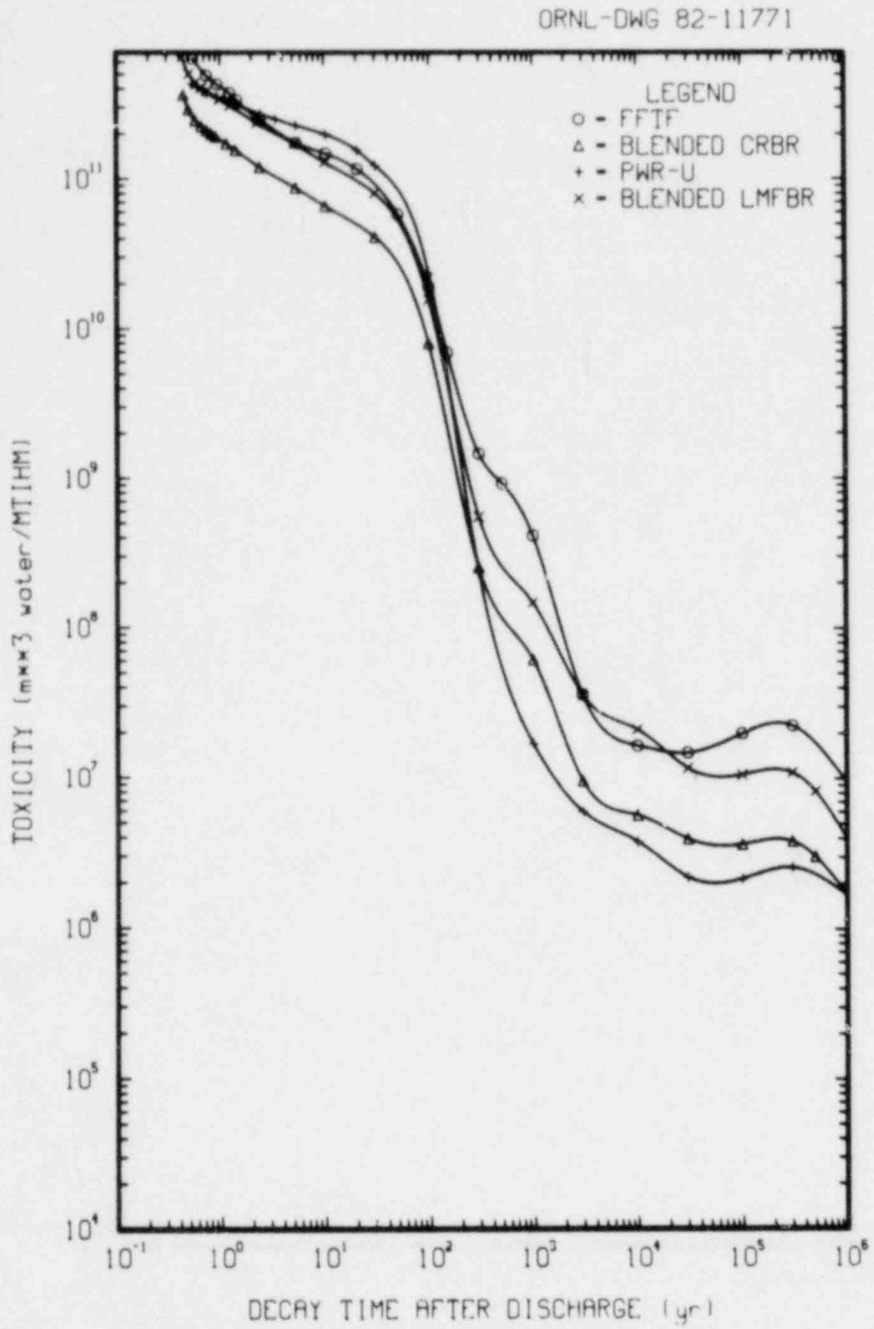

Fig. E.7. High-level waste ingestion toxicity.

Table E.7. High-level waste ingestion toxicity

Blended CRBR		PWR-U		FFTF		Blended commercial LMFBR	
Time (yr)	Ingestion toxicity (m^3 water/MTIHM)	Time (yr)	Ingestion toxicity (m^3 water/MTIHM)	Time (yr)	Ingestion toxicity (m^3 water/MTIHM)	Time (yr)	Ingestion toxicity (m^3 water/MTIHM)
4.384E-01	3.667E+11	5.380E-01	4.319E+11	5.380E-01	6.447E+11	2.774E-01	3.408E+12
4.931E-01	2.912E+11	7.380E-01	3.777E+11	7.380E-01	4.910E+11	3.321E-01	1.562E+12
5.753E-01	2.456E+11	9.380E-01	3.521E+11	9.380E-01	4.272E+11	4.143E-01	7.160E+11
6.574E-01	2.247E+11	1.438E+00	3.137E+11	1.238E+00	3.753E+11	4.964E-01	5.055E+11
7.395E-01	2.112E+11	2.438E+00	2.725E+11	1.438E+00	3.378E+11	5.785E-01	4.383E+11
8.217E-01	2.007E+11	3.438E+00	2.506E+11	2.438E+00	2.498E+11	6.607E-01	4.063E+11
9.038E-01	1.920E+11	5.438E+00	2.279E+11	5.438E+00	1.743E+11	7.428E-01	3.848E+11
1.150E+00	1.718E+11	1.044E+01	1.981E+11	1.044E+01	1.479E+11	9.892E-01	3.410E+11
1.411E+00	1.561E+11	2.044E+01	1.556E+11	2.044E+01	1.166E+11	1.250E+00	3.089E+11
2.411E+00	1.201E+11	3.044E+01	1.226E+11	5.044E+01	5.814E+10	2.250E+00	2.372E+11
5.411E+00	8.764E+10	1.004E+02	2.323E+10	1.004E+02	1.898E+10	5.250E+00	1.721E+11
1.041E+01	6.612E+10	3.004E+02	2.410E+08	1.504E+02	6.941E+09	1.025E+01	1.290E+11
3.041E+01	4.116E+10	1.000E+03	1.700E+07	3.004E+02	1.467E+09	3.025E+01	8.021E+10
1.004E+02	8.006E+09	3.000E+03	6.003E+06	5.004E+02	9.333E+08	1.002E+02	1.565E+10
3.004E+02	2.547E+08	1.000E+04	3.795E+06	1.000E+03	4.168E+08	3.002E+02	5.536E+08
1.000E+03	6.190E+07	3.000E+04	2.208E+06	3.000E+03	3.633E+07	1.000E+03	1.487E+08
3.000E+03	9.627E+06	1.000E+05	2.161E+06	1.000E+04	1.660E+07	3.000E+03	3.612E+07
1.000E+04	5.709E+06	3.000E+05	2.577E+06	3.000E+04	1.491E+07	1.000E+04	2.127E+07
3.000E+04	3.976E+06	1.000E+06	1.688E+06	1.000E+05	2.001E+07	3.000E+04	1.179E+07
1.000E+05	3.666E+06			3.000E+05	2.260E+07	1.000E+05	1.065E+07
3.000E+05	3.843E+06			1.000E+06	9.544E+06	3.000E+05	1.099E+07
5.000E+05	3.028E+06					5.000E+05	8.232E+06
1.000E+06	1.697E+06					1.000E+06	4.019E+06

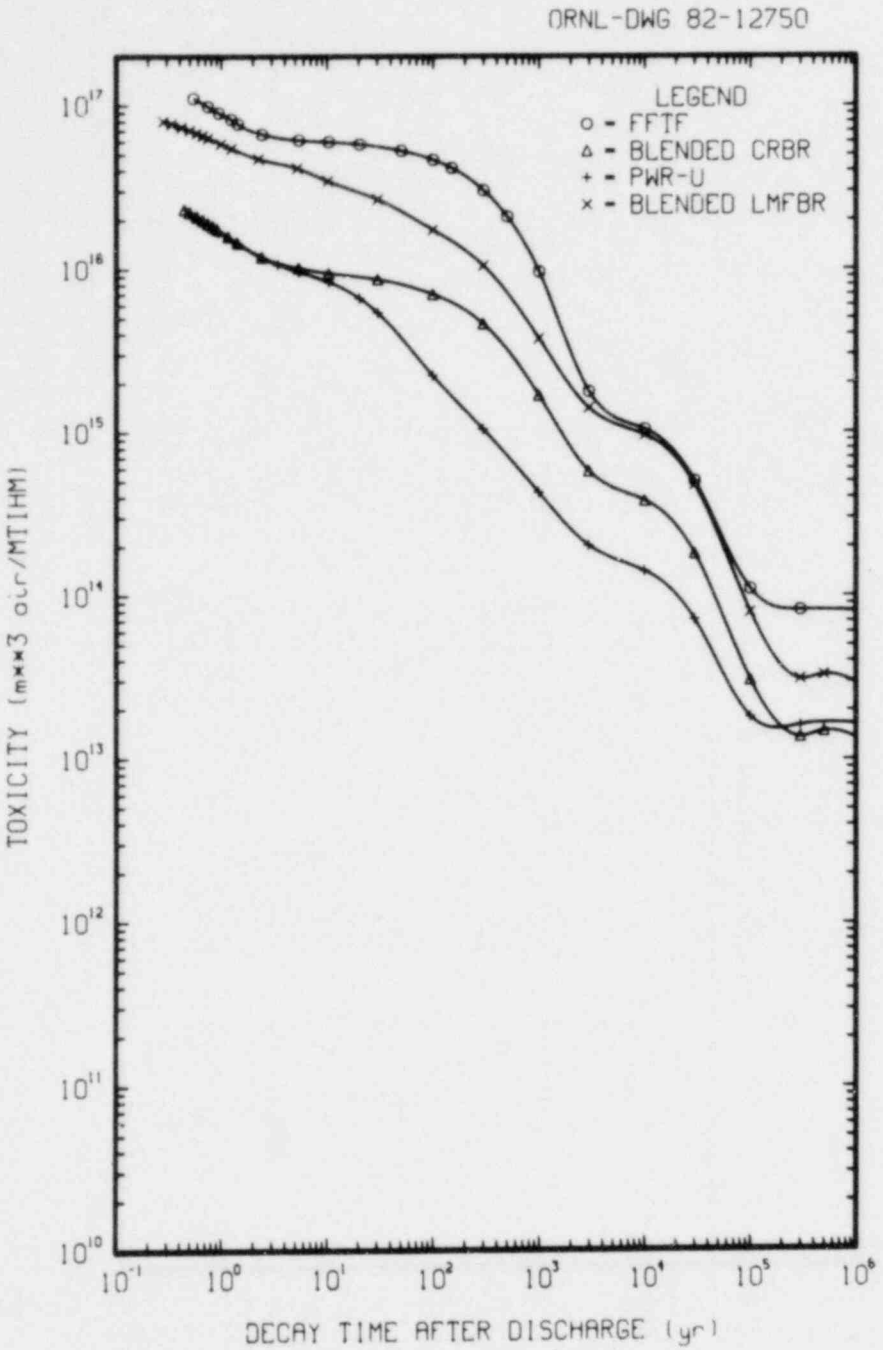

Fig. E.8. High-level waste inhalation toxicity.

Table E.8. High-level waste inhalation toxicity

Blended CRBR		PWR-U		FFTF		Blended commercial LMFBR	
Time (yr)	Inhalation toxicity (m^3 air/MTIHM)	Time (yr)	Inhalation toxicity (m^3 air/MTIHM)	Time (yr)	Inhalation toxicity (m^3 air/MTIHM)	Time (yr)	Inhalation toxicity (m^3 air/MTIHM)
4.384E-01	2.332E+16	5.380E-01	2.079E+16	5.380E-01	1.110E+17	2.778E-01	8.030E+16
4.931E-01	2.239E+16	7.380E-01	1.860E+16	7.380E-01	9.909E+16	3.321E-01	7.785E+16
5.753E-01	2.116E+16	9.380E-01	1.700E+16	9.380E-01	9.052E+16	4.143E-01	7.377E+16
6.574E-01	2.010E+16	1.438E+00	1.440E+16	1.238E+00	8.284E+16	4.964E-01	7.063E+16
7.395E-01	1.918E+16	2.438E+00	1.187E+16	1.438E+00	7.741E+16	5.785E-01	6.793E+16
8.217E-01	1.838E+16	3.438E+00	1.073E+16	2.438E+00	6.699E+16	6.607E-01	6.557E+16
9.038E-01	1.766E+16	5.438E+00	9.677E+15	5.438E+00	6.151E+16	7.428E-01	6.350E+16
1.150E+00	1.594E+16	1.044E+01	8.406E+15	1.044E+01	5.999E+16	9.892E-01	5.857E+16
1.411E+00	1.462E+16	2.044E+01	6.688E+15	2.044E+01	5.797E+16	1.250E+00	5.483E+16
2.411E+00	1.196E+16	3.044E+01	5.456E+15	5.044E+01	5.299E+16	2.250E+00	4.741E+16
5.411E+00	1.023E+16	1.004E+02	2.248E+15	1.004E+02	4.659E+16	5.250E+00	4.158E+16
1.041E+01	9.523E+15	3.004E+02	1.052E+15	1.504E+02	4.148E+16	1.025E+01	3.477E+16
3.041E+01	8.727E+15	1.000E+03	4.310E+14	3.004E+02	3.028E+16	3.025E+01	2.683E+16
1.004E+02	7.063E+15	3.000E+03	2.041E+14	5.004E+02	2.092E+16	1.002E+02	1.743E+16
3.004E+02	4.685E+15	1.000E+04	1.417E+14	1.000E+03	9.628E+15	3.002E+02	1.053E+16
1.000E+03	1.692E+15	3.000E+04	7.176E+13	3.000E+03	1.782E+15	1.000E+03	3.761E+15
3.000E+03	5.808E+14	1.000E+05	1.815E+13	1.000E+04	1.042E+15	3.000E+03	1.410E+15
1.000E+04	3.818E+14	3.000E+05	1.616E+13	3.000E+04	5.029E+14	1.000E+04	9.601E+14
3.000E+04	1.811E+14	1.000E+06	1.644E+13	1.000E+05	1.095E+14	3.000E+04	4.757E+14
1.000E+05	3.056E+13			3.000E+05	8.162E+13	1.000E+05	7.938E+13
3.000E+05	1.373E+13			1.000E+06	8.025E+13	3.000E+05	3.096E+13
5.000E+05	1.485E+13					5.000E+05	3.284E+13
1.000E+06	1.351E+13					1.000E+06	2.927E+13

E.3: Characteristics of Blended Fuel Assembly Structural Material Waste

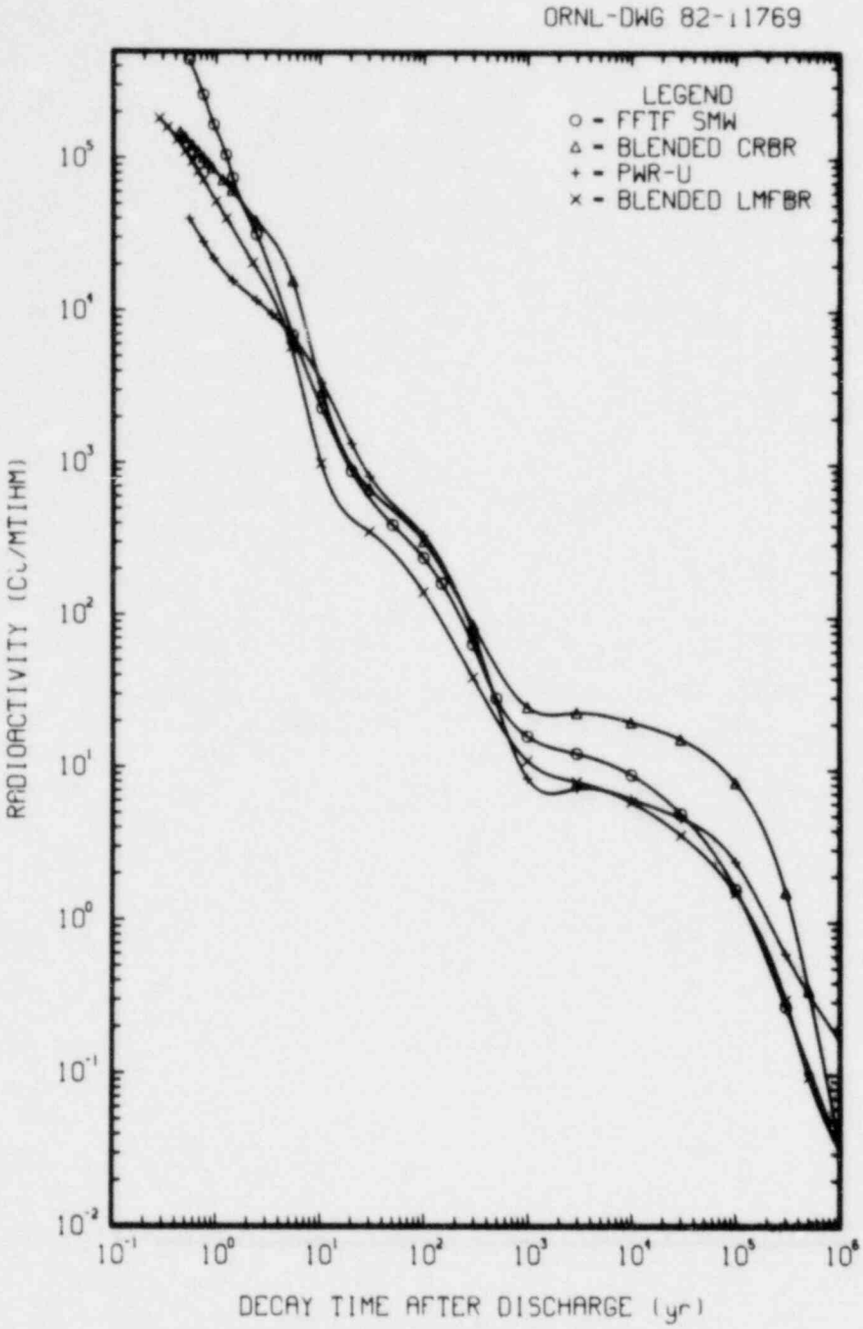

Fig. E.9. Fuel-assembly structural material waste radioactivity.

Table E.9. Fuel-assembly structural material waste radioactivity

Blended CRBR		PWR-U		FFTF		Blended commercial LMFBR	
Time (yr)	Radioactivity (Ci/MTIHM)	Time (yr)	Radioactivity (Ci/MTIHM)	Time (yr)	Radioactivity (Ci/MTIHM)	Time (yr)	Radioactivity (Ci/MTIHM)
4.384E-01	1.491E+05	5.380E-01	4.009E+04	5.380E-01	4.485E+05	2.774E-01	1.830E+05
4.931E-01	1.369E+05	7.380E-01	2.811E+04	7.380E-01	2.610E+05	3.321E-01	1.596E+05
5.753E-01	1.221E+05	9.380E-01	2.189E+04	9.380E-01	1.656E+05	4.143E-01	1.319E+05
6.574E-01	1.104E+05	1.438E+00	1.566E+04	1.238E+00	1.050E+05	4.964E-01	1.108E+05
7.395E-01	1.009E+05	2.438E+00	1.165E+04	1.438E+00	7.426E+04	5.785E-01	9.454E+04
8.217E-01	9.314E+04	3.438E+00	9.476E+03	2.438E+00	3.160E+04	6.607E-01	8.188E+04
9.038E-01	8.662E+04	5.438E+00	6.740E+03	5.438E+00	6.943E+03	7.428E-01	7.182E+04
1.150E+00	7.212E+04	1.044E+01	3.405E+03	1.044E+01	2.313E+03	9.892E-01	5.201E+04
1.411E+00	6.161E+04	2.044E+01	1.352E+03	2.044E+01	8.983E+02	1.250E+00	4.014E+04
2.411E+00	3.881E+04	3.044E+01	8.258E+02	5.044E+01	3.971E+02	2.250E+00	2.051E+04
5.411E+00	1.568E+04	1.004E+02	3.388E+02	1.004E+02	2.413E+02	5.250E+00	5.800E+03
1.041E+01	2.978E+03	3.004E+02	7.844E+01	1.504E+02	1.645E+02	1.025E+01	1.003E+03
3.041E+01	6.803E+02	1.000E+03	8.709E+00	3.004E+02	6.538E+01	3.025E+01	3.571E+02
1.004E+02	3.104E+02	3.000E+03	7.513E+00	5.004E+02	2.916E+01	1.002E+02	1.433E+02
3.004E+02	8.784E+01	1.000E+04	6.429E+00	1.000E+03	1.651E+01	3.002E+02	3.984E+01
1.000E+03	2.566E+01	3.000E+04	4.821E+00	3.000E+03	1.274E+01	1.000E+03	1.137E+01
3.000E+03	2.360E+01	1.000E+05	2.484E+00	1.000E+04	9.265E+00	3.000E+03	8.292E+00
1.000E+04	2.060E+01	3.000E+05	6.183E-01	3.000E+04	5.185E+00	1.000E+04	6.116E+00
3.000E+04	1.597E+01	1.000E+06	1.682E-01	1.000E+05	1.638E+00	3.000E+04	3.719E+00
1.000E+05	8.281E+00			3.000E+05	2.797E-01	1.000E+05	1.555E+00
3.000E+05	1.578E+00			1.000E+06	3.153E-02	3.000E+05	3.078E-01
5.000E+05	3.562E-01					5.000E+05	9.556E-02
1.000E+06	3.332E-02					1.000E+06	3.129E-02

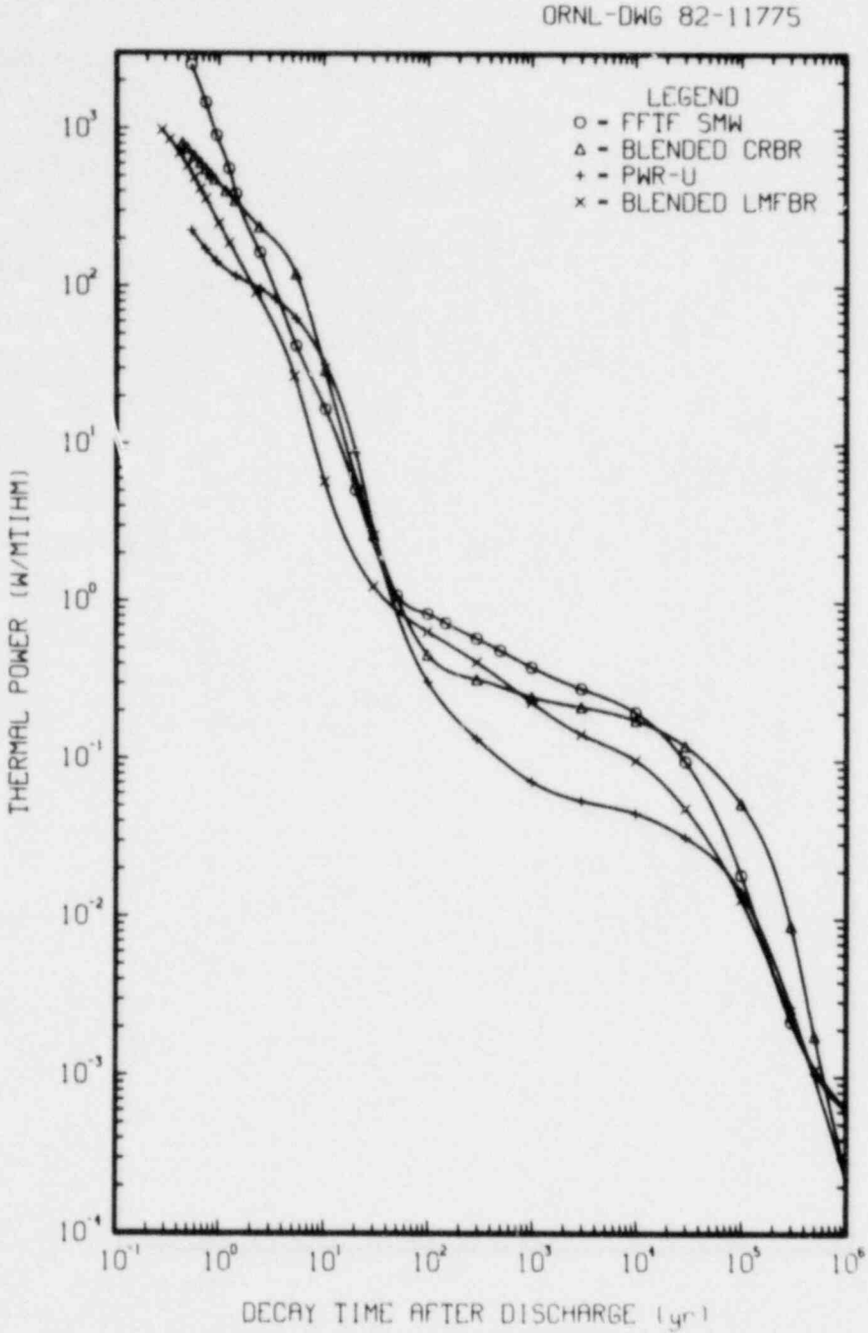

Fig. E.10. Fuel-assembly structural material waste thermal power.

Table E.10. Fuel-assembly structural material waste thermal power

Blended CRBR		PWR-U		FFTF		Blended commercial LMFBR	
Time (yr)	Thermal power (W/MTIHM)	Time (yr)	Thermal power (W/MTIHM)	Time (yr)	Thermal power (W/MTIHM)	Time (yr)	Thermal power (W/MTIHM)
4.384E-01	8.161E+02	5.380E-01	2.268E+02	5.380E-01	2.540E+03	2.774E-01	9.851E+02
4.931E-01	7.511E+02	7.380E-01	1.720E+02	7.380E-01	1.462E+03	3.321E-01	8.547E+02
5.753E-01	6.711E+02	9.380E-01	1.437E+02	9.380E-01	9.058E+02	4.143E-01	6.987E+02
6.574E-01	6.074E+02	1.438E+00	1.160E+02	1.238E+00	5.585E+02	4.964E-01	5.792E+02
7.395E-01	5.561E+02	2.438E+00	9.664E+01	1.438E+00	3.871E+02	5.785E-01	4.870E+02
8.217E-01	5.141E+02	3.438E+00	8.331E+01	2.438E+00	1.638E+02	6.607E-01	4.153E+02
9.038E-01	4.793E+02	5.438E+00	6.286E+01	5.438E+00	4.229E+01	7.428E-01	3.592E+02
1.150E+00	4.034E+02	1.044E+01	3.203E+01	1.044E+01	1.678E+01	9.892E-01	2.503E+02
1.411E+00	3.501E+02	2.044E+01	9.901E+00	2.044E+01	5.141E+00	1.250E+00	1.877E+02
2.411E+00	2.380E+02	3.044E+01	2.801E+00	5.044E+01	1.107E+00	2.250E+00	9.190E+01
5.411E+00	1.202E+02	1.004E+02	3.115E-01	1.004E+02	8.450E-01	5.250E+00	2.702E+01
1.041E+01	2.939E+01	3.004E+02	1.364E-01	1.504E+02	7.403E-01	1.025E+01	5.819E+00
3.041E+01	2.657E+00	1.000E+03	7.310E-02	3.004E+02	5.906E-01	3.025E+01	1.256E+00
1.004E+02	4.652E-01	3.000E+03	5.554E-02	5.004E+02	4.969E-01	1.002E+02	6.498E-01
3.004E+02	3.251E-01	1.000E+04	8.640E-02	1.000E+03	3.882E-01	3.002E+02	4.176E-01
1.000E+03	2.514E-01	3.000E+04	3.276E-02	3.000E+03	2.847E-01	1.000E+03	2.329E-01
3.000E+03	2.182E-01	1.000E+05	1.485E-02	1.000E+04	2.018E-01	3.000E+03	1.464E-01
1.000E+04	1.805E-01	3.000E+05	2.775E-03	3.000E+04	9.932E-02	1.000E+04	1.005E-01
3.000E+04	1.244E-01	1.000E+06	2.240E-04	1.000E+05	1.892E-02	3.000E+04	4.993E-02
1.000E+05	5.380E-02			3.000E+05	2.230E-03	1.000E+05	1.325E-02
3.000E+05	9.048E-03			1.000E+06	6.308E-04	3.000E+05	2.421E-03
5.000E+05	1.819E-03					5.000E+05	1.094E-03
1.000E+06	2.361E-04					1.000E+06	6.121E-04

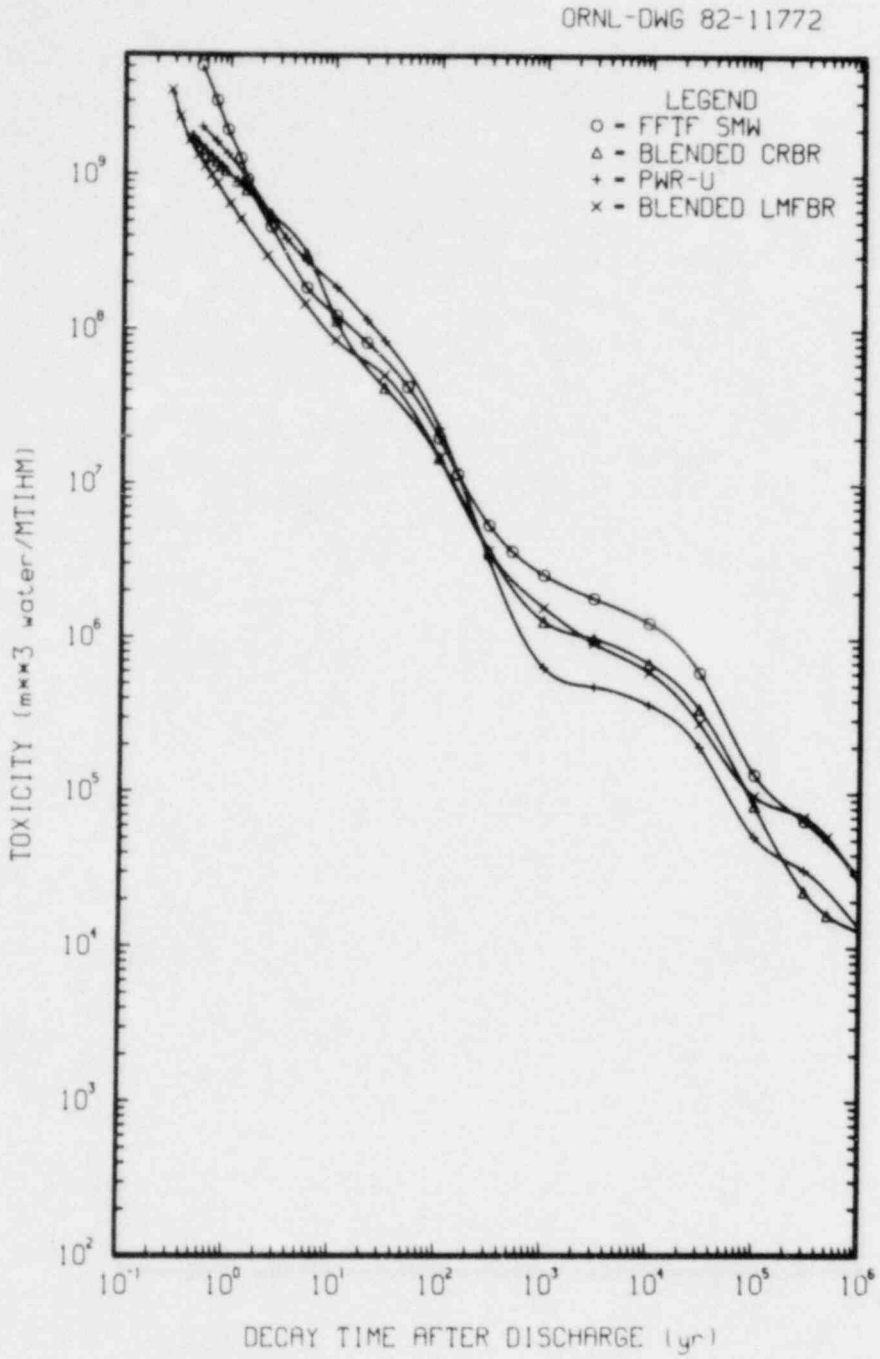

Fig. E.11. Fuel-assembly structural material waste ingestion toxicity.

Table E.11. Fuel-assembly structural material waste ingestion toxicity

Blended CRBR		PWR-U		FFTF		Blended commercial LMFBR	
Time (yr)	Ingestion toxicity (m^3 water/MTIHM)	Time (yr)	Ingestion toxicity (m^3 water/MTIHM)	Time (yr)	Ingestion toxicity (m^3 water/MTIHM)	Time (yr)	Ingestion toxicity (m^3 water/MTIHM)
4.384E-01	1.784E+09	5.380E-01	2.056E+09	5.380E-01	5.096E+09	2.774E-01	3.544E+09
4.931E-01	1.624E+09	7.380E-01	1.642E+09	7.380E-01	3.017E+09	3.321E-01	2.380E+09
5.753E-01	1.451E+09	9.380E-01	1.359E+09	9.380E-01	1.950E+09	4.143E-01	1.669E+09
6.574E-01	1.320E+09	1.438E+00	9.280E+08	1.238E+00	1.275E+09	4.964E-01	1.343E+09
7.395E-01	1.216E+09	2.438E+0	5.409E+08	1.438E+00	9.328E+08	5.785E-01	1.139E+09
8.217E-01	1.131E+09	3.438E+	3.877E+08	2.438E+00	4.609E+08	6.607E-01	9.900E+08
9.038E-01	1.060E+09	5.439E	2.779E+08	5.438E+00	1.869E+08	7.428E-01	8.751E+08
1.150E+00	9.045E+08	1.044E+01	1.883E+08	1.044E+01	1.232E+08	9.892E-01	6.503E+08
1.411E+00	7.933E+08	2.044E+01	1.158E+08	2.044E+01	8.282E+07	1.250E+00	5.169E+08
2.411E+00	5.563E+08	3.044E+01	8.491E+07	5.044E+01	4.289E+07	2.250E+00	3.002E+08
5.411E+00	3.098E+08	1.004E+02	2.310E+07	1.004E+02	1.995E+07	5.250E+00	1.464E+08
1.041E+01	1.139E+08	3.004E+02	3.303E+06	1.504E+02	1.167E+07	1.025E+01	8.516E+07
3.041E+01	4.221E+07	1.000E+03	6.518E+05	3.004E+02	5.457E+06	3.025E+01	5.069E+07
1.004E+02	1.488E+07	3.000E+03	4.920E+05	5.004E+02	3.690E+06	1.002E+02	1.489E+07
3.004E+02	3.722E+06	1.000E+04	3.764E+05	1.000E+03	2.600E+06	3.002E+02	3.709E+06
1.000E+03	1.298E+06	3.000E+04	2.012E+05	3.000E+03	1.832E+06	1.000E+03	1.597E+06
3.000E+03	1.007E+06	1.000E+05	5.256E+04	1.000E+04	1.271E+06	3.000E+03	9.420E+05
1.000E+04	6.980E+05	3.000E+05	3.187E+04	3.000E+04	6.091E+05	1.000E+04	6.138E+05
3.000E+04	3.548E+05	1.000E+06	1.362E+04	1.000E+05	1.330E+05	3.000E+04	2.864E+05
1.000E+05	8.385E+04			3.000E+05	6.678E+04	1.000E+05	9.660E+04
3.000E+05	2.321E+04			1.000E+06	2.933E+04	3.000E+05	7.066E+04
5.000E+05	1.639E+04					5.000E+05	5.247E+04
1.000E+06	1.288E+04					1.000E+06	2.665E+04

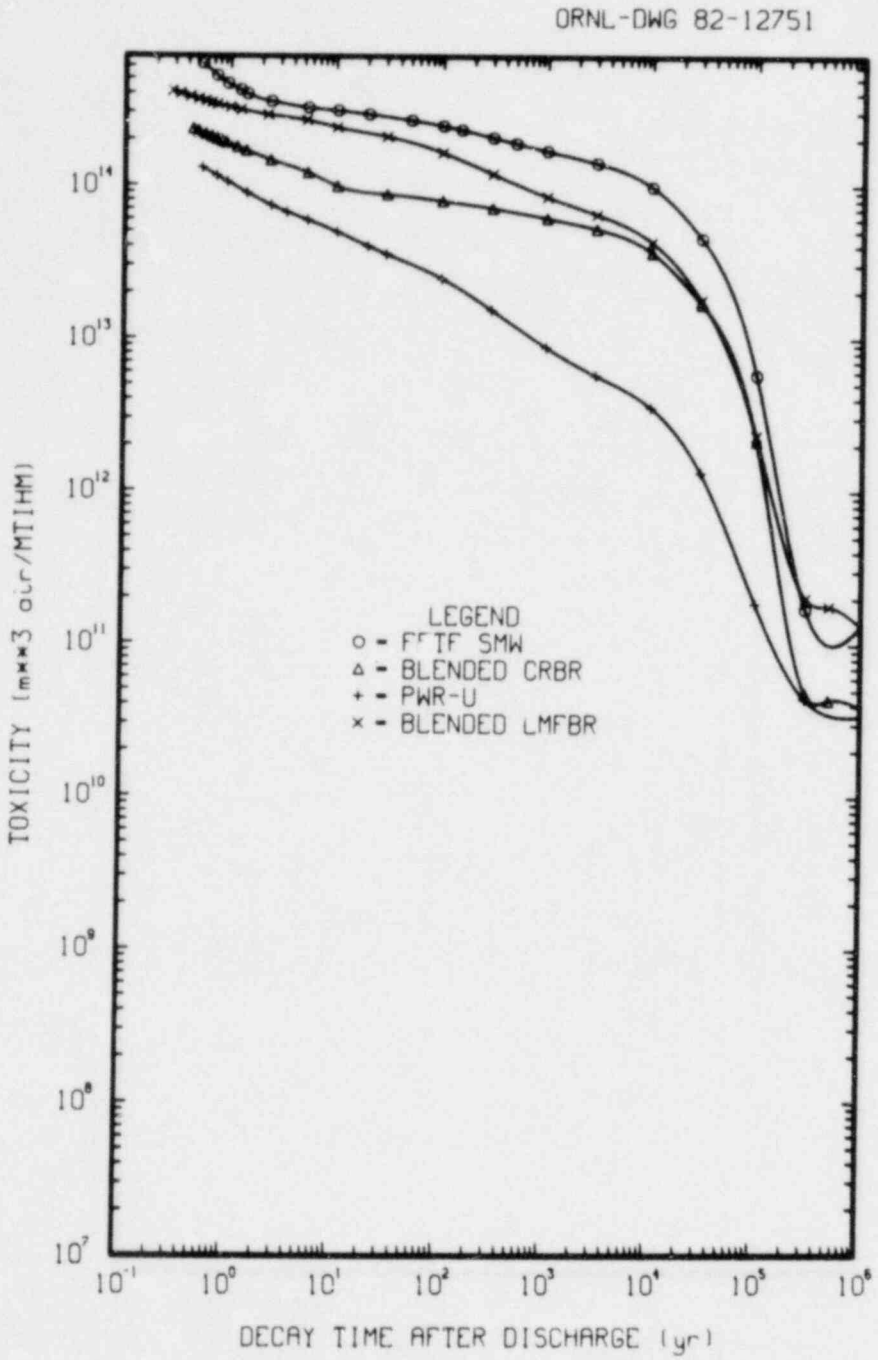

Fig. E.12. Fuel-assembly structural material waste inhalation toxicity.

Table E.12. Fuel-assembly structural material waste inhalation toxicity

Blended CRBR		PWR-U		FFTF		Blended commercial LMFBR	
Time (yr)	Inhalation toxicity (m^3 air/MTIHM)	Time (yr)	Inhalation toxicity (m^3 air/MTIHM)	Time (yr)	Inhalation toxicity (m^3 air/MTIHM)	Time (yr)	Inhalation toxicity (m^3 air/MTIHM)
4.384E-01	2.334E+14	5.380E-01	1.305E+14	5.380E-01	6.241E+14	2.774E-01	4.101E+14
4.931E-01	2.258E+14	7.380E-01	1.153E+14	7.380E-01	5.191E+14	3.321E-01	3.963E+14
5.753E-01	2.162E+14	9.380E-01	1.049E+14	9.380E-01	4.605E+14	4.143E-01	3.792E+14
6.574E-01	2.082E+14	1.438E+00	8.917E+13	1.238E+00	4.193E+14	4.964E-01	3.657E+14
7.395E-01	2.013E+14	2.438E+00	7.416E+13	1.438E+00	3.953E+14	5.785E-01	3.547E+14
8.217E-01	1.954E+14	3.438E+00	6.698E+13	2.438E+00	3.532E+14	6.607E-01	3.458E+14
9.038E-01	1.903E+14	5.438E+00	5.956E+13	5.438E+00	3.217E+14	7.428E-01	3.384E+14
1.150E+00	1.780E+14	1.044E+01	4.983E+13	1.044E+01	3.080E+14	9.892E-01	3.224E+14
1.411E+00	1.684E+14	2.044E+01	4.036E+13	2.044E+01	2.920E+14	1.250E+00	3.113E+14
2.411E+00	1.460E+14	3.044E+01	3.575E+13	5.044E+01	2.667E+14	2.250E+00	2.889E+14
5.411E+00	1.213E+14	1.004E+02	2.473E+13	1.004E+02	2.452E+14	5.250E+00	2.666E+14
1.041E+01	9.880E+13	3.004E+02	1.546E+13	1.504E+02	2.312E+14	1.025E+01	2.391E+14
3.041E+01	8.757E+13	1.000E+03	9.828E+12	3.004E+02	2.060E+14	3.025E+01	2.084E+14
1.004E+02	7.955E+13	3.000E+03	5.775E+12	5.004E+02	1.891E+14	1.002E+02	1.636E+14
3.004E+02	7.126E+13	1.000E+04	3.558E+12	1.000E+03	1.688E+14	3.002E+02	1.190E+14
1.000E+03	6.140E+13	3.000E+04	1.340E+12	3.000E+03	1.412E+14	1.000E+03	8.466E+13
3.000E+03	5.235E+13	1.000E+05	1.863E+11	1.000E+04	9.870E+13	3.000E+03	6.520E+13
1.000E+04	3.676E+13	3.000E+05	4.451E+10	3.000E+04	4.544E+13	1.000E+04	4.287E+13
3.000E+04	1.702E+13	1.000E+06	3.412E+10	1.000E+05	5.791E+12	3.000E+04	1.795E+13
1.000E+05	2.162E+12			3.000E+05	1.713E+11	1.000E+05	2.328E+12
3.000E+05	4.878E+10			1.000E+06	1.328E+11	3.000E+05	2.020E+11
5.000E+05	4.371E+10					5.000E+05	1.791E+11
1.000E+06	3.936E+10					1.000E+06	1.341E+11

APPENDIX F: CHARACTERISTICS OF CRBR HIGH-LEVEL WASTE AND PWR-U SPENT FUEL

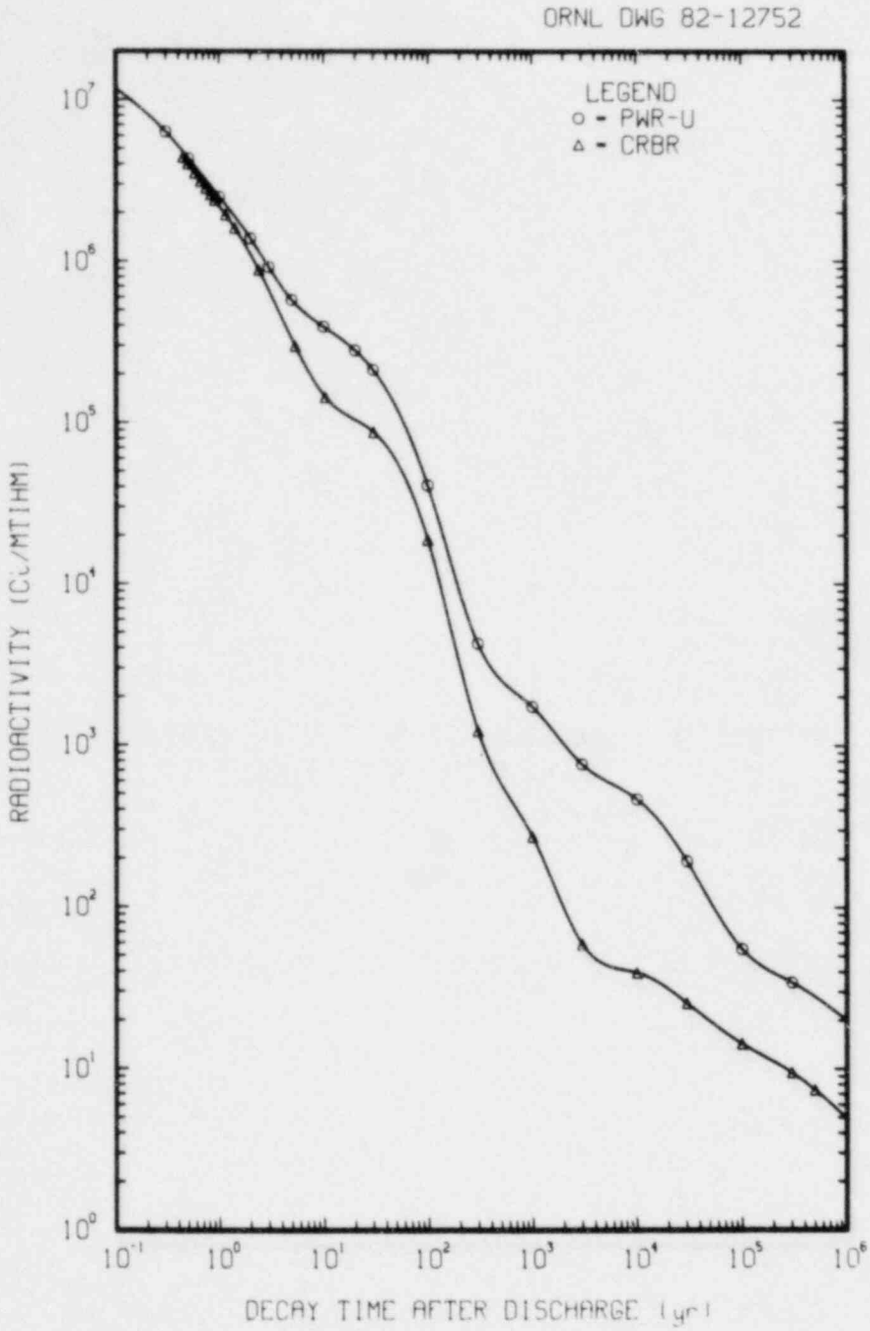

Fig. F.1. Radioactivity of blended CRBR high-level waste and PWR-U spent fuel as a function of decay time.

Table F.1. Radioactivity of blended CRBR high-level waste and PWR-U spent fuel as a function of decay time

Blended CRBR HLW		PWR-U spent fuel	
Time (yr)	Radioactivity (Ci/MTIHM)	Time (yr)	Radioactivity (Ci/MTIHM)
4.384E-01	4.429E+06	1.000E-01	1.173E+07
4.931E-01	4.010E+06	3.000E-01	6.334E+06
5.753E-01	3.515E+06	5.000E-01	4.336E+06
6.574E-01	3.134E+06	1.000E+00	2.507E+06
7.395E-01	2.833E+06	2.000E+00	1.386E+06
8.217E-01	2.588E+06	3.000E+00	9.221E+05
9.038E-01	2.386E+06	5.000E+00	5.775E+05
1.150E+00	1.935E+06	1.000E+01	3.935E+05
1.411E+00	1.603E+06	2.000E+01	2.808E+05
2.411E+00	8.841E+05	3.000E+01	2.129E+05
5.411E+00	2.975E+05	1.000E+02	4.096E+04
1.041E+01	1.439E+05	3.000E+02	4.280E+03
3.041E+01	8.764E+04	1.000E+03	1.742E+03
1.004E+02	1.883E+04	3.000E+03	7.697E+02
3.004E+02	1.232E+03	1.000E+04	4.676E+02
1.000E+03	2.725E+02	3.000E+04	1.933E+02
3.000E+03	5.899E+01	1.000E+05	5.524E+01
1.000E+04	3.944E+01	3.000E+05	3.433E+01
3.000E+04	2.554E+01	1.000E+06	2.013E+01
1.000E+05	1.430E+01		
3.000E+05	9.478E+00		
5.000E+05	7.400E+00		
1.000E+06	4.957E+00		

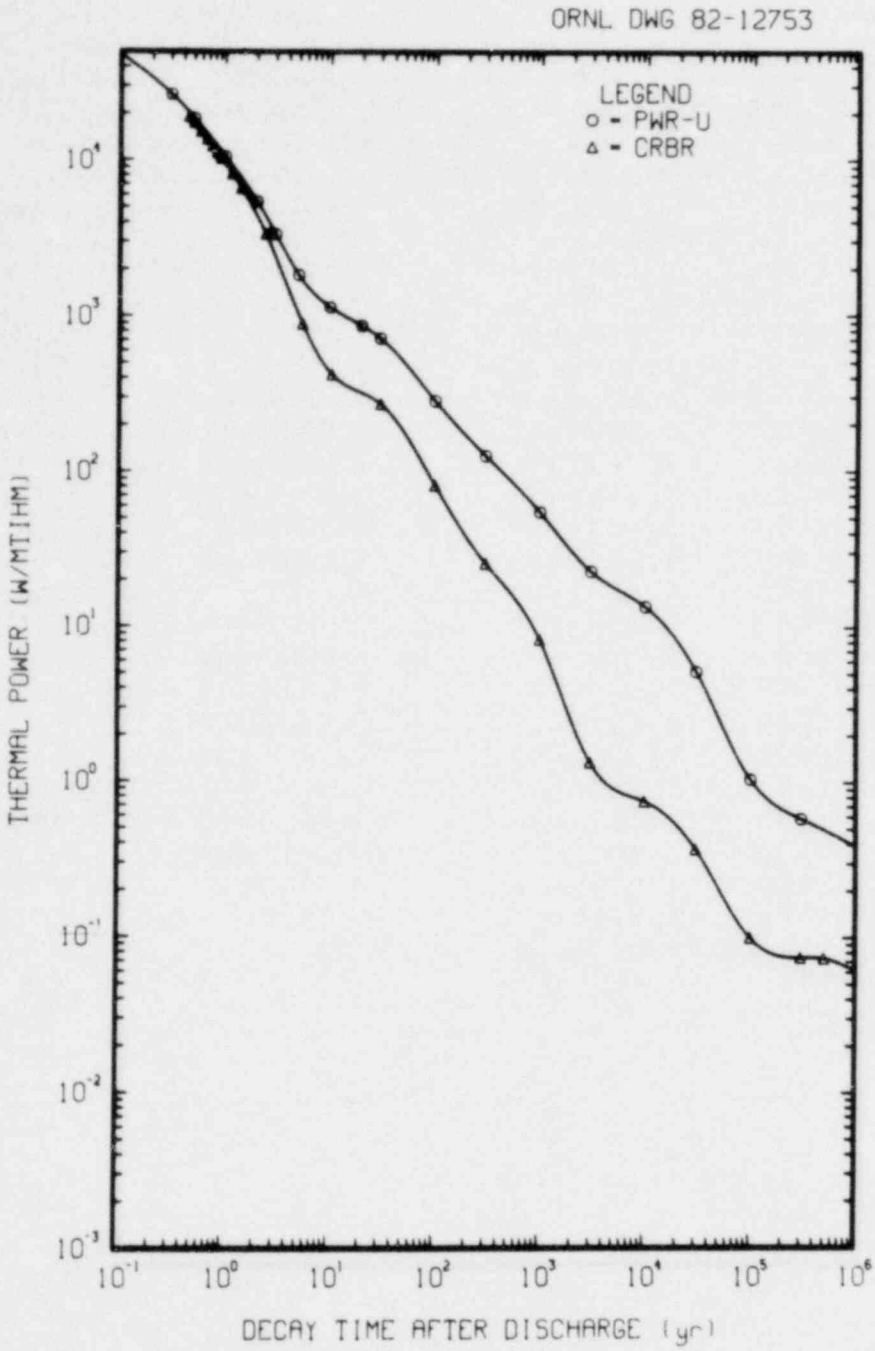

Fig. F.2. Thermal power of blended CRBR high-level waste and PWR-U spent fuel as a function of decay time.

Table F.2. Thermal power of blended CRBR high-level waste and PWR-U spent fuel as a function of decay time

Blended CRBR HLW		PWR-U spent fuel	
Time (yr)	Thermal power (W/MTIHM)	Time (yr)	Thermal power (W/MTIHM)
4.384E-01	1.904E+04	1.000E-01	4.778E+04
4.931E-01	1.735E+04	3.000E-01	2.631E+04
5.753E-01	1.527E+04	5.000E-01	1.843E+04
6.574E-01	1.362E+04	1.000E+00	1.046E+04
7.395E-01	1.228E+04	2.000E+00	5.389E+03
8.217E-01	1.117E+04	3.000E+00	3.329E+03
9.038E-01	1.024E+04	5.000E+00	1.826E+03
1.150E+00	8.144E+03	1.000E+01	1.132E+03
1.411E+00	6.605E+03	2.000E+01	8.644E+02
2.411E+00	3.353E+03	3.000E+01	7.190E+02
5.411E+00	8.883E+02	1.000E+02	2.843E+02
1.041E+01	4.210E+02	3.000E+02	1.261E+02
3.041E+01	2.721E+02	1.000E+03	5.474E+01
1.004E+02	8.122E+01	3.000E+03	2.278E+01
3.004E+02	2.556E+01	1.000E+04	1.352E+01
1.000E+03	8.327E+00	3.000E+04	5.205E+00
3.000E+03	1.355E+00	1.000E+05	1.053E+00
1.000E+04	7.603E-01	3.000E+05	5.853E-01
3.000E+04	3.734E-01	1.000E+06	3.907E-01
1.000E+05	9.996E-02		
3.000E+05	7.449E-02		
5.000E+05	7.375E-02		
1.000E+06	6.190E-02		

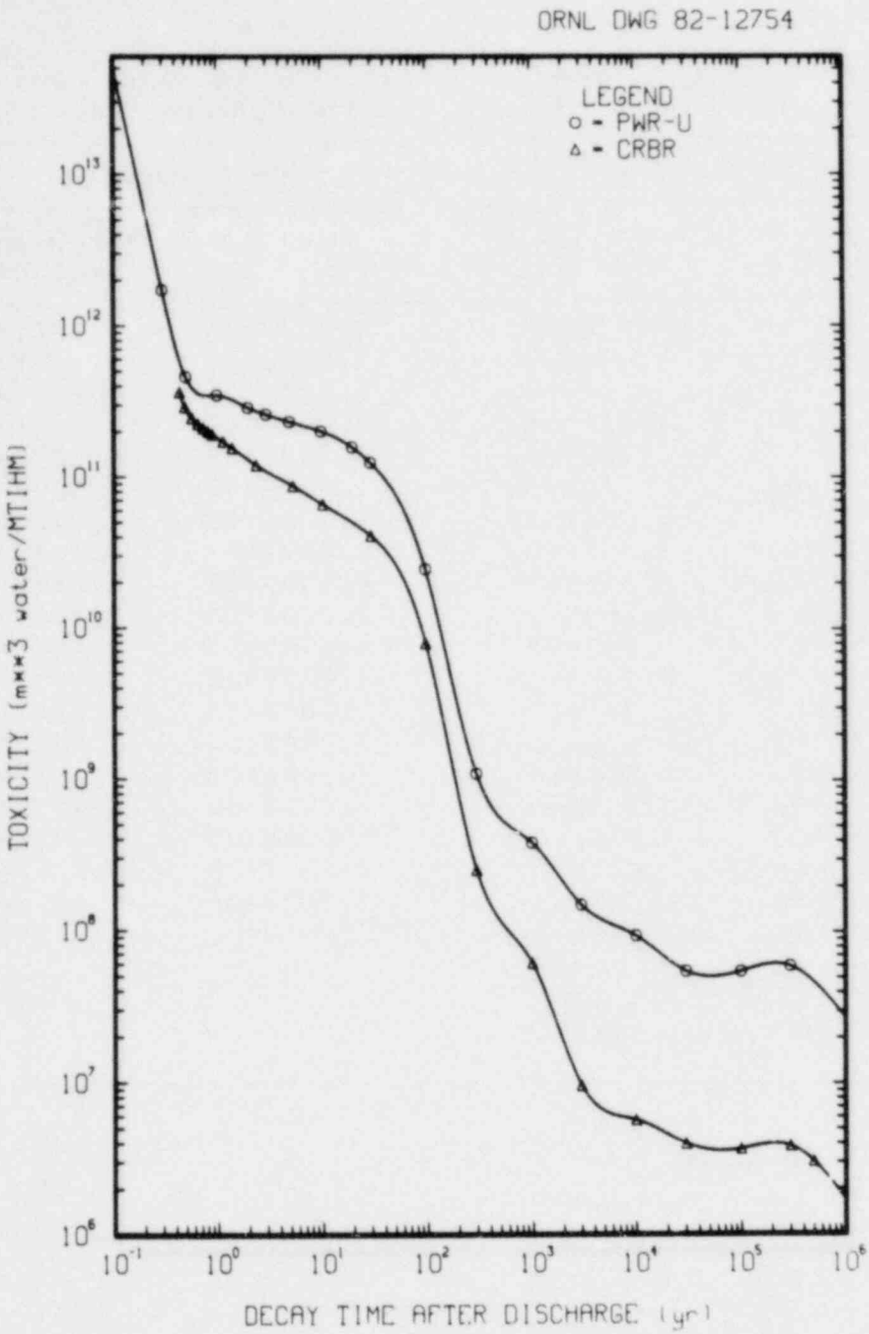

Fig. F.3. Ingestion toxicity of blended CRBR high-level waste and PWR-U spent fuel as a function of decay time.

Table F.3. Ingestion toxicity of blended CRBR high-level waste and PWR-U spent fuel as a function of decay time

Blended CRBR HLW		PWR-U spent fuel	
Time (yr)	Ingestion toxicity (m^3 water/MTIHM)	Time (yr)	Ingestion toxicity (m^3 water/MTIHM)
4.384E-01	3.667E+11	1.000E-01	5.160E+13
4.931E-01	2.912E+11	3.000E-01	1.732E+12
5.753E-01	2.456E+11	5.000E-01	4.605E+11
6.574E-01	2.247E+11	1.000E+00	3.482E+11
7.395E-01	2.112E+11	2.000E+00	2.889E+11
8.217E-01	2.007E+11	3.000E+00	2.605E+11
9.038E-01	1.920E+11	5.000E+00	2.332E+11
1.150E+00	1.718E+11	1.000E+01	2.018E+11
1.411E+00	1.561E+11	2.000E+01	1.588E+11
2.411E+00	1.201E+11	3.000E+01	1.254E+11
5.411E+00	8.764E+10	1.000E+02	2.477E+10
1.041E+01	6.612E+10	3.000E+02	1.107E+09
3.041E+01	4.116E+10	1.000E+03	3.866E+08
1.004E+02	8.006E+09	3.000E+03	1.506E+08
3.004E+02	2.547E+08	1.000E+04	9.431E+07
1.000E+03	6.190E+07	3.000E+04	5.502E+07
3.000E+03	9.627E+06	1.000E+05	5.485E+07
1.000E+04	5.709E+06	3.000E+05	5.955E+07
3.000E+04	3.976E+06	1.000E+06	2.713E+07
1.000E+05	3.666E+06		
3.000E+05	3.843E+06		
5.000E+05	3.028E+06		
1.000E+06	1.697E+06		

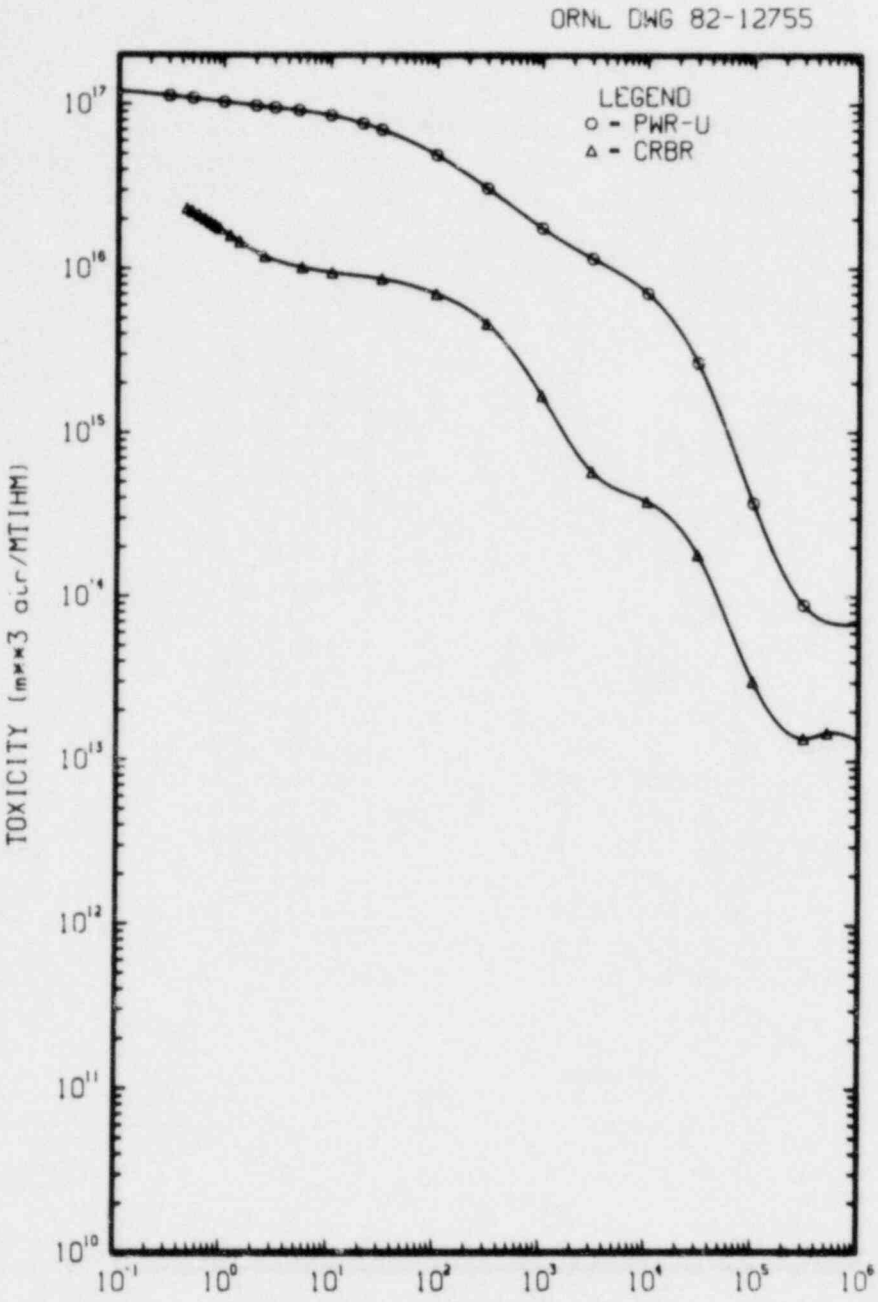

Fig. F.4. Inhalation toxicity of blended CRBR high-level waste and PWR-U spent fuel as a function of decay time.

Table F.4. Inhalation toxicity of blended CRBR high-level waste and PWR-U spent fuel as a function of decay time

Blended CRBR HLW		PWR-U spent fuel	
Time (yr)	Inhalation toxicity (m^3 air/MTIHM)	Time (yr)	Inhalation toxicity (m^3 air/MTIHM)
4.384E-01	2.332E+16	1.000E-01	1.200E+17
4.931E-01	2.239E+16	3.000E-01	1.127E+17
5.753E-01	2.116E+16	5.000E-01	1.088E+17
6.574E-01	2.010E+16	1.000E+00	1.035E+17
7.395E-01	1.918E+16	2.000E+00	9.840E+16
8.217E-01	1.838E+16	3.000E+00	9.567E+16
9.038E-01	1.766E+16	5.000E+00	9.221E+16
1.150E+00	1.594E+16	1.000E+01	8.605E+16
1.411E+00	1.462E+16	2.000E+01	7.691E+16
2.411E+00	1.196E+16	3.000E+01	7.023E+16
5.411E+00	1.023E+16	1.000E+02	4.917E+16
1.041E+01	9.523E+15	3.000E+02	3.084E+16
3.041E+01	8.727E+15	1.000E+03	1.763E+16
1.004E+02	7.063E+15	3.000E+03	1.152E+16
3.004E+02	4.645E+15	1.000E+04	7.097E+15
1.000E+03	1.692E+15	3.000E+04	2.670E+15
3.000E+03	5.808E+14	1.000E+05	3.714E+14
1.000E+04	3.818E+14	3.000E+05	8.887E+13
3.000E+04	1.811E+14	1.000E+06	6.815E+13
1.000E+05	3.056E+13		
3.000E+05	1.373E+13		
5.000E+05	1.485E+13		
1.000E+06	1.351E+13		

GLOSSARY

GWd	Gigawatt-days = 10^9 watt-days
MWd	Megawatt-days = 10^6 watt-days
MTIHM	Metric tons (10^6 g) of initial heavy metal
Fuel element	The smallest structurally discrete part of a fuel assembly that has nuclear fuel as the principal constituent; also called a fuel pin or a fuel rod
Fuel assembly	A grouping of fuel elements that remains intact during the charging and discharging of a reactor core
Pin cell	A cylindrical model of a fuel element used in a reactor physics calculation
Fuel channel	Hexagonal, sheet-metal can surrounding each fuel assembly to prevent cross-flow of coolant between assemblies
LMFBR	Liquid-metal (cooled), fast breeder reactor. "Fast" refers to the fact that the neutron spectrum is high-energy, i.e., not thermal.
FFTF	Fast-Flux Test Facility in Richland, Washington
HLW	High-level waste
LWR	Light-water reactor
ORIGEN2	A computer code for calculating the radionuclide composition and characteristics (radioactivity, thermal power, etc.) of nuclear materials such as spent fuel and wastes
ORMANG	A computer program that processes ORIGEN2 output to produce publication-quality graphs and tables
PWR-U	Pressurized-water reactor fueled with low-enrichment UO_2
SMW	Fuel assembly structural material (cladding) waste
CRBR	Clinch River Breeder Reactor to be located in Oak Ridge, Tennessee

NRC FORM 335 (7-77)

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

1. REPORT NUMBER *(Assigned by DDC)*
NUREG/CR-2762
ORNL-5884

4. TITLE AND SUBTITLE *(Add Volume No., if appropriate)*
An ORIGEN2 Model and Results for the Clinch River Breeder Reactor

2. *(Leave blank)*

3. RECIPIENT'S ACCESSION NO.

7. AUTHOR(S)
A.G. Croff, M.A. Bjerke

5. DATE REPORT COMPLETED
MONTH: June YEAR: 1982

9. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS *(Include Zip Code)*
Oak Ridge National Laboratory
Oak Ridge, TN 37830

DATE REPORT ISSUED
MONTH: July YEAR: 1982

6. *(Leave blank)*

8. *(Leave blank)*

12. SPONSORING ORGANIZATION NAME AND MAILING ADDRESS *(Include Zip Code)*
Division of Fuel Cycle and Material Safety
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555

10. PROJECT/TASK/WORK UNIT NO.

11. CONTRACT NO.
FIN B0009

13. TYPE OF REPORT
Technical Report

PERIOD COVERED *(Inclusive dates)*

15. SUPPLEMENTARY NOTES

14. *(Leave blank)*

16. ABSTRACT *(200 words or less)*

Reactor physics calculations and literature information acquisition have led to the development of a Clinch River Breeder Reactor (CRBR) model for the ORIGEN2 computer code. The model is based on cross sections taken directly from physics codes. Details are presented concerning the physical description of the fuel assemblies, the fuel management scheme, irradiation parameters, and initial material compositions. The ORIGEN2 model for the CRBR has been implemented, resulting in the production of graphical and tabular characteristics (radioactivity, thermal power, and toxicity) of CRBR spent fuel, high-level waste, and fuel-assembly structural material waste as a function of decay time. Characteristics for pressurized water reactors (PWRs), commercial liquid-metal fast breeder reactors (LMFBRs), and the Fast Flux Test Facility (FFTF) have also been included in this report for comparison with the CRBR data.

17. KEY WORDS AND DOCUMENT ANALYSIS

CRBR
neutron spectra
fission products
computer code
cross sections

17a. DESCRIPTORS

radionuclide inventory
spent fuel toxicity
spent fuel radioactivity

17b. IDENTIFIERS/OPEN-ENDED TERMS

18. AVAILABILITY STATEMENT
Unlimited

19. SECURITY CLASS *(This report)*
Unclassified

21. NO. OF PAGES

20. SECURITY CLASS *(This page)*
Unclassified

22. PRICE
$

NRC FORM 335 (7-77)

*U.S. GOVERNMENT PRINTING OFFICE : 1982 0-361-297/2307

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

FOURTH CLASS MAIL
POSTAGE & FEES PAID
USNRC
WASH D C
PERMIT No G 67