SAND76-0740
NUREG 76-6521
Unlimited Release

Distribution
Category NRC-1

Radiation Signature Following the Hypothesized LOCA

Lloyd L. Bonzon

Prepared by Sandia Laboratories, Albuquerque, New Mexico 87115
and Livermore, California 94550 for the United States Nuclear
Regulatory Commission under DOE Contract AT(29-1)-789.

Revised October 1977

Sandia Laboratories

SF 2900 Q(7-73)

When printing a copy of any digitized SAND Report, you are required to update the markings to current standards.

Issued by Sandia Laboratories, operated for the United States Energy Research & Development Administration by Sandia Corporation

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor the United States Nuclear Regulatory Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Printed in the United States of America

Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

Price: Printed Copy $5.50; Microfiche $3.00

SAND76-0740
NUREG 76-6521
Unlimited Release
Printed September 1977
Revised October 1977

Manuscript Completed December 1976

RADIATION SIGNATURE FOLLOWING THE HYPOTHESIZED LOCA

Lloyd L. Bonzon
Systems Safety Technology Division, 5432
Sandia Laboratories, Albuquerque, New Mexico 87115

ABSTRACT

This study establishes the radiation source profile following the hypothesized Loss of Coolant Accident (LOCA) as suggested by the applicable Regulatory Guides. The source is specified as time-dependent gamma and beta energy release rates and energy spectra with dose and dose rate values presented for a generic containment structure.

The results of this study will provide a basis for a comparison of radiation simulators used in (radiation) qualification testing of Class I components and an evaluation of simulator "adequacy" in duplicating the LOCA radiation environments and resultant component damage.

CONTENTS

		Page
Chapter 1.	Introduction	7
	1.1 Background	7
	1.2 Objectives of Study	9
	1.3 Presentation of Information	10
Chapter 2.	LOCA Gamma Radiation Signature	13
	2.1 Methodology	13
	2.2 Comparison with Other Codes	13
	2.2.1 Magnitude	13
	2.2.2 Spectra	13
	2.3 Gamma Energy Release	14
	2.3.1 Waterborne Source	14
	2.3.2 Airborne Source	14
	2.3.3 Plate-Out Source	14
	2.3.4 Selected Nuclide Fractionations	15
	2.4 Gamma Spectra	15
Chapter 3.	LOCA Beta Radiation Signature	23
	3.1 Methodology	23
	3.2 Comparison with Other Codes	25
	3.3 Beta Energy Release	25
	3.3.1 Waterborne Source	26
	3.3.2 Airborne Source	26
	3.3.3 Plate-Out Source	26
	3.3.4 Selected Nuclide Fractionations	26
	3.4 Beta Spectra	27
Chapter 4.	Doses and Dose Rates for a Generic Containment	35
	4.1 Methodology	35
	4.2 Gamma Doses and Rates	37
	4.3 Beta Doses and Rates	38
Chapter 5.	Radiation Simulator Adequacy Methodology	46
Chapter 6.	Discussion and Suggested Topics	51
	6.1 Summary	51
	6.2 Suggested Topics	52
References		53
APPENDIX A - GAMMA DECAY SCHEMES		55
APPENDIX B - BETA DECAY SCHEMES		79
APPENDIX C - GAMMA PARTICLE/ENERGY SPECTRA		103
APPENDIX D - BETA PARTICLE/ENERGY SPECTRA		113

ILLUSTRATIONS

Figures		Page
2.2.1	Gamma energy release rate after 100% release of fission products, compared with ORIGEN calculations; 5000-day power operation.	16
2.2.2	Gamma energy release rate, compared with CINDER calculations; 5000-day power operation with FISSP-GAM, 833-day power operation with CINDER.	17
2.2.3	Gamma energy spectra for 100% release of fission products, compared with ORIGEN calculations; 5000-day power operation.	17
2.2.4	Gamma energy spectra for 100% release of fission products, compared with ORIGEN calculations; 5000-day power operation.	17
2.3.1	Waterborne gamma energy release rate source; 50% halogens, 1% solids.	18
2.3.2	Airborne gamma energy release rate source; 100% noble gases, 25% iodines. Halogens contribution is also illustrated.	18
2.3.3	Plate-out gamma energy release rate source; 25% iodines. Halogens contribution is also illustrated.	19
2.3.4	Gamma energy release rate source for noble gases, iodines, and solids.	19
2.3.5	Gamma energy release rate source for the WASH-1400 specified percentage releases from the fuel-clad gap.	19
2.3.6	Gamma energy release rate source for the WASH-1400 specified percentage releases from the fuel-clad gap.	20
2.4.1	Gamma energy spectra for the waterborne source; 50% halogens, 1% solids.	20
2.4.2	Gamma energy spectra for the airborne source; 100% noble gases, 25% iodines.	21
2.4.3	Gamma energy spectra for the plate-out source, 25% iodines.	21
2.4.4	Measures of the gamma energy spectra for the waterborne source; 50% halogens, 1% solids.	22
2.4.5	Measures of the gamma energy spectra for the airborne source; 100% noble gases, 25% iodines.	22
2.4.6	Measures of the gamma energy spectra for the plate-out source; 25% iodines.	22
3.2.1	Beta energy release rate after 100% release of fission products, compared with ORIGEN calculations; 5000-day power operation.	28
3.2.2	Beta energy release rate, compared with CINDER calculations; 5000-day power operation with FISSP-BETA, 833-day power operation with CINDER.	29
3.3.1	Waterborne beta energy release rate source; 50% halogens, 1% solids.	29
3.3.2	Airborne beta energy release rate source; 100% noble gases, 25% iodines. Halogens contribution is also illustrated.	30
3.3.3	Plate-out beta energy release rate source; 25% iodines. Halogens contribution is also illustrated.	30
3.3.4	Beta energy release rate source for noble gases, iodines, and solids.	31
3.3.5	Beta energy release rate source for the WASH-1400 specified percentage releases from the fuel-clad gap.	31
3.3.6	Beta energy release rate source for the WASH-1400 specified percentage releases from the fuel-clad gap.	32
3.4.1	Beta energy spectra for the waterborne source; 50% halogens, 1% solids.	32

ILLUSTRATIONS (cont.)

Figure		Page
3.4.2	Beta energy spectra for the airborne source; 100% noble gases, 25% iodines.	33
3.4.3	Beta energy spectra for the plate-out source; 25% iodines.	33
3.4.4.	Measures of the beta energy spectra for the waterborne source; 50% halogens, 1% solids.	34
3.4.5	Measures of the beta energy spectra for the airborne source; 100% noble gases, 25% iodines.	34
3.4.6	Measures of the beta energy spectra for the plate-out source; 25% iodines.	34
4.2.1	Rate and dose to air from the airborne gamma source uniformly distributed in the containment volume.	39
4.2.2	Dose rate to air at mid-axis from the airborne source as a function of containment volume.	40
4.2.3	Rate and dose to air from the plate-out gamma source uniformly distributed on the containment sidewall surface.	40
4.2.4	Dose rate to air from the plate-out gamma source as a function of containment volume (or sidewall surface area).	40
4.2.5	Rate and dose to air from the waterborne gamma source assumed uniformly distributed in the containment volume.	41
4.2.6	Dose rate along centerline from the 1-minute waterborne gamma source uniformly distributed in a 5-m deep pool at the bottom of the containment structure.	41
4.2.7	Rate and dose to air from the combined gamma source; airborne source uniformly distributed in the containment volume, plate-out source uniformly distributed on the containment sidewall surface, 1/10 of the waterborne source assumed to be uniformly distributed in the containment volume.	41
4.3.1	Rate and dose to air from the airborne beta source uniformly distributed in a normalized containment volume.	42
4.3.2	Rate and dose to air from the airborne beta source uniformly distributed in the containment volume.	42
4.3.3	Dose rate to air from the waterborne beta source assumed uniformly distributed in a normalized containment volume.	43
4.3.4	Rate and dose to air from the waterborne beta source assumed uniformly distributed in the containment volume.	43
4.3.5	Dose rate along centerline from the 1-minute waterborne beta source uniformly distributed in a 5-m deep pool at the bottom of the containment structure.	44
4.3.6	Dose rate from the plate-out beta source uniformly distributed on the containment sidewall surface, as a function of distance and time after release.	44
4.3.7	Dose rate from the plate-out beta source uniformly distributed on the containment sidewall surface, as a function of distance and time after release.	45
4.3.8	Rate and dose to air from the combined beta sources; airborne source uniformly distributed in the containment volume, plate-out source uniformly distributed on the containment sidewall surface, 1/10 of the waterborne source assumed to be uniformly distributed in the containment volume.	45

RADIATION SIGNATURE FOLLOWING THE HYPOTHESIZED LOCA*

Chapter 1. Introduction

The primary purpose of this program is to determine the adequacy of radiation simulators in duplicating the effects that the hypothesized Loss of Coolant Accident (LOCA) radiation signature would produce in Class I components.

1.1 Background

Nuclear power reactors are designed, constructed, and operated to extremely high standards to achieve maximum safety and reliability during normal operation. Plant design features emphasize quality, redundancy, inspectability, and testability of components in order to assure maximum tolerance to system malfunctions; reliable protection systems ensure that system failures or operator errors will be accommodated safely. Additional engineered safety features are included to protect the operators and the public even in the event of accidents due to unforeseen or extremely unlikely circumstances.

IEEE-323,[1] "IEEE Standard for Qualifying Class IE Equipment for Nuclear Power Generating Stations," defines the equipment that provides engineered safety features as Class IE: ". . . the safety classification of the electric equipment and systems that are essential to emergency reactor shutdown, containment isolation, reactor core cooling, and containment and reactor heat removal, or are otherwise essential in preventing significant release of radioactive material to the environment." A simple extrapolation to include nonelectric equipment can be made by extension of this definition.

IEEE-323 is also the parent document for describing the qualification of Class IE equipment and includes the principles, procedures, and methods of qualification; these requirements, when met, will confirm the adequacy of the equipment design under normal, abnormal, design basis event, post-design basis event, and containment test conditions. IEEE-323 recognizes that qualification may be accomplished in several ways, i.e., type-testing, operating experience, or analyses. In type-testing, it is expected that equipment will be subjected to the environments and operating conditions for which it was designed and its performance measured. In a test program, however, it is usually practical only to simulate environments and operating conditions. The limitation in such simulations must be evaluated on a case-by-case basis.

---

*This program was authorized by the Nuclear Regulatory Commission, Office of Standards Development, by letter dated August 4, 1975, from R. B. Minogue (NRC/OSD) to H. C. Donnelly (ERDA/ALO).

Both operating experience and analysis are recognized as methods of only limited value, whereas, type-testing of actual equipment in simulated service conditions is the preferred method. However, it was recognized that a type-test alone satisfies qualification only if the equipment to be tested is aged, subjected to all environmental influences, and operated under post-event conditions to provide assurance that the equipment will be able to perform its intended function for at least the required operating time. When size or other practical requirements limit or preclude type-tests, this method of qualification is suspect. A further practical limitation in qualification testing has been that it is difficult to apply all test environments simultaneously. In particular, radiation testing is usually done sequentially and separately from the other environments.

A principal controversy in qualification testing has been in the definition of the radiation environment. The most widely accepted standard is contained in IEEE-323; unfortunately, the specified radiation environments are relegated to an Appendix, which means they are not officially a part of the standard. Two separate radiation profiles are presented: one for the pressurized water reactor and one for the boiling water reactor. For the pressurized water reactor, it is specified that the radiation dose to the containment atmosphere is 4 MR after one hour, 20 MR after twelve hours, etc., to a total of 150 MR after one year. The boiling water reactor profile is even less specific in that the radiation environment is specified as 26 MR integrated over the accident. It was recognized that the values would vary from plant to plant and they may or may not contain adequate margin. However, a footnote to that table indicates that the values are a ". . . conservative calculation of radiation dose to the containment atmosphere resulting from beta and gamma radiation emitters released from the primary system and at a location within the primary containment."

More recently, Regulatory Guide 1.89[2] was drafted to define the radiation source to be used in qualification testing. Although the Guide relied primarily on IEEE-323, in the area of the applicable radiation source, it endorsed a source based on Regulatory Guides 1.3,[3] 1.4,[4] and 1.7.[5] Implicit in that definition are the associated dose rates, the radiation types (i.e., gammas or betas), and the total dose. To determine the impact on industry of Regulatory Guide 1.89, should it be adopted, a study[6] was performed by staff of the U.S. Nuclear Regulatory Commission to see if typical Class I equipment had been tested successfully to environments consistent with Regulatory Guide 1.89. A few of the typical findings were:

> Differential pressure transmitters, tested to radiation exposures of greater than 2×10^8 rads and also subjected to other LOCA environments of temperature, pressure, and humidity, performed satisfactorily.
>
> Valve motor operators, tested to a radiation level of 2×10^8 rads and subjected to all other qualification requirements, passed the tests.
>
> Electrical cables of various ratings and construction, subjected to all expected environments of aging, LOCA, and post-LOCA, including nuclear radiation exposure exceeding 2×10^8 rads, performed satisfactorily.

As suggested in the preceeding discussion, the primary commonality in radiation testing is the total dose of about 2×10^8 rads.

However, Regulatory Guide 1.89 is not specific in such a dose value, nor is it specific in dose rate and the type of radiation; rather, it specifies the radiation source in terms of the fraction of nuclides released from the core. Three specific source terms are implied. First, for equipment exposed to a water environment or within the radiation fields of sources transported by water, it assumes that 50 percent of the halogens and 1 percent of the solids originally present in the core are intimately mixed with the coolant water. Second, for equipment normally exposed to containment atmosphere or within the radiation fields of sources associated with containment atmosphere, it assumes that 100 percent of the noble gases and 25 percent of the iodines are uniformly dispersed in the containment atmosphere. Third, an additional 25 percent of the iodines are assumed to be plated out on surfaces exposed to the containment atmosphere. These values in turn must be translated to dose and dose rates, and, of course, are plant specific, primarily because of plant geometry.

In an effort to evaluate the qualification testing of Class I equipment which is currently being performed, a program was begun at Sandia Laboratories in July 1974 entitled "Synergistic Effects of Simultaneous Environmental Exposures of Protective System Components for Water-Cooled Nuclear Power Plants." The objective of that study was to determine, qualitatively and quantitatively, the synergisms which exist when radiation was sequentially and simultaneously applied during the qualification testing. As the study proceeded, certain additional areas in the general field of qualification testing were identified as important. The concept of accelerated aging and the validity of existing techniques is currently being investigated at Sandia Laboratories; the ultimate objective of the program is to devise models which can account for the accelerated aging of Class I components subjected to combined environment stresses. Secondly, it was determined that the radiation source must be more specifically established and, in particular, the adequacy of laboratory simulators in duplicating component damage from the specified LOCA radiation signature must be addressed.

This report summarizes the activities to date in specifying the radiation source as dictated by Regulatory Guide 1.89 and, by reference, Regulatory Guides 1.3, 1.4 and 1.7.

1.2 Objectives of Study

This study will ultimately establish the "adequacy" of existing radiation simulators in duplicating the radiation environments resulting from the LOCA, as hypothesized in the Regulatory Guides. The adequacy of simulators can only be judged relative to the measurables inherent for any radiation environment, i.e., dose rate, dose, energy spectra, particle type, etc. However, ignoring the scaling factors implied by the dose rate and dose, the most reliable indicator of radiation environment equivalence is the depth-dose profile, which results from the environment, in a component or material. Depth-dose accounts for the energy dependence and particle type dependence of the radiation signature; equivalent component damage is insured by equivalent depth-dose profiles.

Before simulators can be compared, the LOCA radiation environment must be adequately defined. The prime objective of the portion of the study reported here has been in defining the LOCA radiation signature. That environment was synthesized from the specified nuclide fractionation as described in Section 1.3; specifically, the energy release rate and energy spectra for the emitted gamma and beta have been defined as a function of time.

An additional subtask of the LOCA source definition was the translation of the energy release rate/spectra into dose rate and dose for a generic containment structure. These scoping values are particularly pertinent to the qualification testing "industry" since they impact the conduct of the experiment and even the capability to perform the test; however, these magnitude considerations are independent of the question of simulator adequacy in terms of depth-dose.

1.3 Presentation of Information

The assumptions required to specify the hypothetical LOCA radiation environment are contained in certain of the Regulatory Guides. Regulatory Guide 1.89 (Revision 1, Draft 3),[2] not yet officially endorsed, implies the existence of three separate LOCA radiation sources which can be characterized by their spatial location within the containment structure and by their assumed nuclide fractionation. These can be summarized as:

Water Environment:

1. 50% Halogens, 1% Solids — Intimately mixed with coolant water.

Air Environment:

2. 100% Noble Gases, 25% Iodines — Uniformly dispersed in the containment atmosphere.
3. 25% Iodines — Plated out on surfaces exposed to the containment atmosphere.

The water-environment source is defined by reference to Regulatory Guide 1.7;[5] the air-environment sources are defined by reference to Regulatory Guides 1.3[3] and 1.4.[4] The nuclide fractions refer to the percentages released from the equilibrium full-power core. These three source definitions serve as the bases for the presentation in this report.

Certain additional assumptions are also contained in the referenced Regulatory Guides and affect the source definition. These are shown in Table 1.I, along with the disposition of each as assumed in this report. Items 1, 2, 4, and 5 are readily interpreted and require only brief comment.

TABLE 1.I

Basic Assumptions

	Regulatory Guide Assumptions	Calculational Assumptions
1.	". . . equilibrium . . . inventory from maximum full power operation of the core . . ."	1 watt - 5000 day operation
2.	". . . immediately available for leakage . . ."	Instantaneous, uniform release or deposition
3.	". . . radiological decay . . . should be taken into account."	As specified Fractions released at time = 0, but all subsequent daughters followed whether or not included in original specification.
4.	". . . reduction of . . . material for leakage by . . . engineered safety features may be taken into account."	Neglected
5.	". . . containment should be assumed to leak at the leak rate . . . in the technical specifications . . ."	Neglected

Five thousand-day reactor operation (Item 1) is significantly longer than any reactor could operate without a complete fuel change; the difference between equilibrium and 5000-day operation is only reflected in a few, very long-lived, radioactive nuclides. Similarly, the calculations were done for 1-watt operation, so that the power level was considered a scaling factor; this also has significance to only a few nuclides, having large neutron cross sections, where nuclide transmutation is determined by neutron absorption rather than radioactive decay. The implicit error for the majority of the calculations is estimated as less than a few percent.

Item 2, while nonrealistic, is a conservative assumption and was included, as specified, in these calculations.

Items 4 and 5 are plant specific and beyond the scope and intent of this work. With the information presented, however, it should be possible to account for the engineered safety features functioning and containment leakage by selectively "removing" a portion of the nuclides.

Accounting for radiological decay (Item 3) is easily accommodated and was included in these calculations. The code used allows the nuclides to be selected and then followed in time as they subsequently decay. For example, for the 100% noble gas - 25% iodine source the sequence is:

1. Power operation for 5000 days at 1 watt.
2. The resultant nuclide population is then fractioned,
   a. 100% noble gas
   b. 25% iodines
   c. all others are zeroed.
3. The remaining nuclides are then allowed to radioactively decay.

Radiological decay, however, implies buildup of daughters. This is illustrated in Table 1.II where a typical decay chain is shown. BR-89, KR-89, and RB-89 are formed directly in fission and decay to SR-89 and Y-89 and, through neutron absorption, to Y-90. Suppose, as in the sequence above, the KR-89 was followed and all others zeroed. As the KR-89 decays, RB-89, SR-89, and Y-89 would be formed. While the Regulatory Guides are not specific about accounting for daughters, these calculations include all daughters with the originally specified nuclide fractions, i.e., all would be counted as noble gases. The "error" depends upon the original nuclide fractionation but, for the majority of the calculations, it is estimated as less than a few percent.

TABLE 1.II

Typical Decay Scheme

Nuclide	Half-Life	Thermal Cross Section (Barns)	Yield Fraction Per Fission
BR-89	4.5 sec	-	0.028
KR-89	3.2 min	-	0.014
RB-89	15.0 min	-	0.0014
SR-89	50.0 day	0.5	-
Y-89	Infinite	1.3	-
Y-90	2.67 day	-	-

The report is organized so as to present each topic independently. Chapters 2 and 3 present the plant-independent gamma and beta energy release rates and energy spectra. The reader can use these data to derive the dose and rate for a specific plant and geometry. These data depend only on the yield fractions and subsequent radioactive decay of the fission products (from U-235 thermal fission).

Chapter 4 presents the doses and dose rates for a generic containment structure. The containment is modeled as an empty cylinder having an inside radius of 1768 cm, inside height of 6355 cm, and concrete walls 114 cm thick; total free volume is 6.24×10^{10} cm^3 (2.2×10^6 ft^3). Volume scaling factors are presented where appropriate.

Doses and rates are presented for air at standard temperature and pressure (STP). Admittedly, the post-LOCA containment environment will contain saturated steam, chemical spray, etc.; however, calculating air dose and rate is a recognized and reproducible method for communicating the data. In addition, radiation qualification testing usually requires a pretest radiation map of the test chamber. These maps are most often made when the chamber is dry and empty (filled with air); the later imposed environments may affect the radiation environment but these combined environments merely duplicate the post-LOCA containment environments.

Chapter 5 presents a discussion of the methodology to be used in the follow-on radiation simulator adequacy task. Generally, the radiation signatures described in Chapters 2 and 3 will be compared with simulators' signatures using calculated "damage" to typical Class I components as the comparative basis; for example, the depth-dose and charged-particle distribution profiles in electrical cable insulations and jackets are such "damage" indicators.

Chapter 2. LOCA Gamma Radiation Signature

2.1 Methodology

The calculation of the gamma radiation signature relies on the accurate description of the core curie activity for the specified core power histories. The FISSP code[7] was used in these calculations because of its coding uniqueness; it allows the user to specify "released" fractions of nuclides by type (e.g., noble gas, halogen, solid) and then follows the released nuclides through their decay and the formation of daughters. A total of 326 fission product nuclides and metastable states are included in the FISSP library.

The conversion of the curie activity to gamma energy release rate and spectra used the gamma decay scheme data taken from Reference 8. These data are included in Appendix A for the 205 nuclides, with gamma decay schemes, used in these calculations. For each nuclide, the discrete gamma energies and percents of emission per disintegration are given as well as the gamma energy per disintegration; the latter quantity is the cumulative sum of the energy and emission percentage product and is the average gamma energy released per disintegration. The combined code for calculating gamma energy release and spectra is referred to as FISSP-GAM.

2.2 Comparison with Other Codes

2.2.1 Magnitude -- Prior to the presentation of the LOCA gamma radiation source, several comparisons with other codes are appropriate. Figure 2.2.1 shows the resultant gamma energy release rate from all fission product nuclides subsequent to 5000 days of power operation. The ORIGEN code[9] results are in good agreement, particularly to about 30 days after release.

Another comparison, shown in Figure 2.2.2, is with the CINDER code[10] which incorporates the latest ENDF/B-IV data files. The comparison is specified in units of MeV/sec-fission, and the agreement is very good except for a very early time (< 100-second) discrepancy; at 1 minute the error is less than 15 percent, but is 60 percent at 1 second. That discrepancy is not apparent in the ORIGEN results and will be additionally evaluated as discussed later in Chapter 6.

2.2.2 Spectra -- The FISSP-GAM energy spectra is compared with the ORIGEN code in Figures 2.2.3 and 2.2.4. Assuming release of all fission products, Figure 2.2.3 shows the fraction of energy below the given energy versus energy. Three separate time cuts are shown: inventory; 2-day decay; 30-day decay.

An alternate display of the same information is given in Figure 2.2.4. Here the percent cumulative difference in the energy spectrum is plotted versus time after 5000-day operation at

0.4, 0.9, 1.35, and 1.8 MeV energy levels. The agreement is quite good, usually well within 15 percent for the given energy levels. In general, ORIGEN predicts slightly softer energy spectra than does FISSP-GAM. Similar comparisons with CINDER have not been made because of the only very recent availability of applicable data.

2.3 Gamma Energy Release

This section presents the plant-independent gamma energy release rate profiles as described in Section 1.3. Sections 2.3.1, 2.3.2, and 2.3.3 define the three post-LOCA sources defined from the Regulatory Guides. These are energy release rates only; specific dose and rates, which account for the spatial placement of these sources, are shown in Chapter 4.

Section 2.3.4 is included to allow the reader to select different nuclide fractionations that may be useful. A new "source" can be calculated by selectively mixing the proportionate nuclide types; an example is given in the section.

Section 2.3.4 also includes an estimate of the gamma energy release rate from the gap release fraction specified in WASH-1400. This is included as an example of a "realistic" LOCA assuming all Emergency Core Cooling Systems (ECCS) and Engineered Safety Features (ESF) function properly during the course of the LOCA.

2.3.1 Waterborne Source -- Immediately following the LOCA, 50 percent of the halogens and 1 percent of the solids in the equilibrium core are assumed to be intimately mixed with the coolant water. Figure 2.3.1 shows the gamma radiation from this environment as a function of time after release.

2.3.2 Airborne Source -- Immediately following the LOCA, 100 percent of the noble gases and 25 percent of the iodines in the equilibrium core are assumed to be uniformly dispersed in the containment atmosphere. Figure 2.3.2 shows the gamma radiation from this environment as a function of time after release.

It is not entirely clear that a distinction should be made between "halogens" and "iodines" as in Reference 2. (However, the referenced Guides 1.3 and 1.4 are only concerned with downwind dose calculations, so the specification of "iodine" is entirely appropriate in that context.) Figure 2.3.2 indicates that the inclusion of the halogens does not substantially affect the gamma energy release rate.

2.3.3 Plate-Out Source -- Immediately following the LOCA, 25 percent of the iodines in the equilibrium core are assumed to be plated out on surfaces exposed to the containment atmosphere. Figure 2.3.3 shows the gamma radiation from this environment as a function of time after release. As in Figure 2.3.2, the corresponding halogen source is shown to have minimal effect on the magnitude of the calculated source.

2.3.4 Selected Nuclide Fractionations -- Figure 2.3.4 shows the gamma radiation for the three nuclide types. Suppose it is assumed that a source of interest is composed of 35 percent of the noble gases, 5 percent of the iodines, and 10 percent of the solids. To a first approximation, the individual components can be summed; for example, at 1 day following release:

35% - Noble Gases	$\equiv 4.9 \times 10^7$ MeV/sec
5% - Iodines	$\equiv 6.6 \times 10^7$ MeV/sec
10% - Solids	$\equiv 1.5 \times 10^9$ MeV/sec
Combined Source	$\equiv 1.6 \times 10^9$ MeV/sec

Some interest in a "realistic" LOCA has led to the suggestion that the inventory in the fuel/clad gap (gap release fraction) be adopted as the definition of the resultant radiation source. The gap release fraction, as defined in WASH-1400, Appendix VII,[11] and given as a percentage of the total core inventory, is:

Xe, Kr	- 3.0%
I, Br	- 1.7%
Cs, Rb	- 5.0%
Te, Se, Sb	- 0.01%
Sr, Ba	- 0.0001%

The gamma radiation from this environment is shown in Figures 2.3.5 and 2.3.6. As in the previous discussion, a further stipulation must be made; that is, the spatial location of these nuclides must be defined. To convert the gamma energy release rates to dose and rate, the results presented in this chapter and in Chapter 4 can be approximately ratioed by the corresponding energy release rates.

2.4 Gamma Spectra

This section presents the gamma spectra profiles as described in Section 1.3. Additional information is contained in Appendix C which presents the tabulated data for these sources plus several additional nuclide fractionations.

Figure 2.4.1 shows the energy spectra for the waterborne source with the time after release as a parameter. Initially the spectrum is hard, softens in time, and then rehardens. Figure 2.4.2 shows the energy spectra for the airborne source and Figure 2.4.3 for the plate-out source with similar information plotted.

Figures 2.4.4, 2.4.5, and 2.4.6 present the same information, respectively, but are perhaps easier visualizations of the data. For each of the three sources, the median energy of the energy spectra, the average energy per particle, and the median energy of the particle spectra is displayed as a function of time after release. For gammas, the average energy per particle may be the best indicator; although, as the figures indicate, all three measures of the spectra are qualitatively similar.

The changing spectra hardness is not unexpected since it is generally true that radioactive emissions from short-lived nuclides are higher in energy than those from long-lived nuclides. However, the reality of the spectral shape has potential impact on the radiation qualification testing of components; at least, the implications of a changing spectra hardness must be addressed, as suggested in Chapter 6. This is particularly true when radiation simulators which have fixed or mono-energetic spectra, like Cobalt-60, are used in qualification testing.

The second phenomenon illustrated in Figures 2.4.4 - 2.4.6 is that the spectral shift is a (sensitive) function of the choice of the nuclide fractionation. Iodines only, Figure 2.4.6, shows "no" rehardening of the spectrum; however, the combination of 25 percent of the iodines and 100 percent of the noble gases, Figure 2.4.5, shows a definite rehardening. Certainly, the combination of 50 percent of the halogens and 1 percent of the solids, Figure 2.4.4, shows a marked rehardening for all three measures of the spectrum. Should the fractionation ever be reselected, a spectral shift would occur and must be considered; to a first approximation, the data of Appendix C could be applied to derive a new spectrum for the ensemble of nuclides.

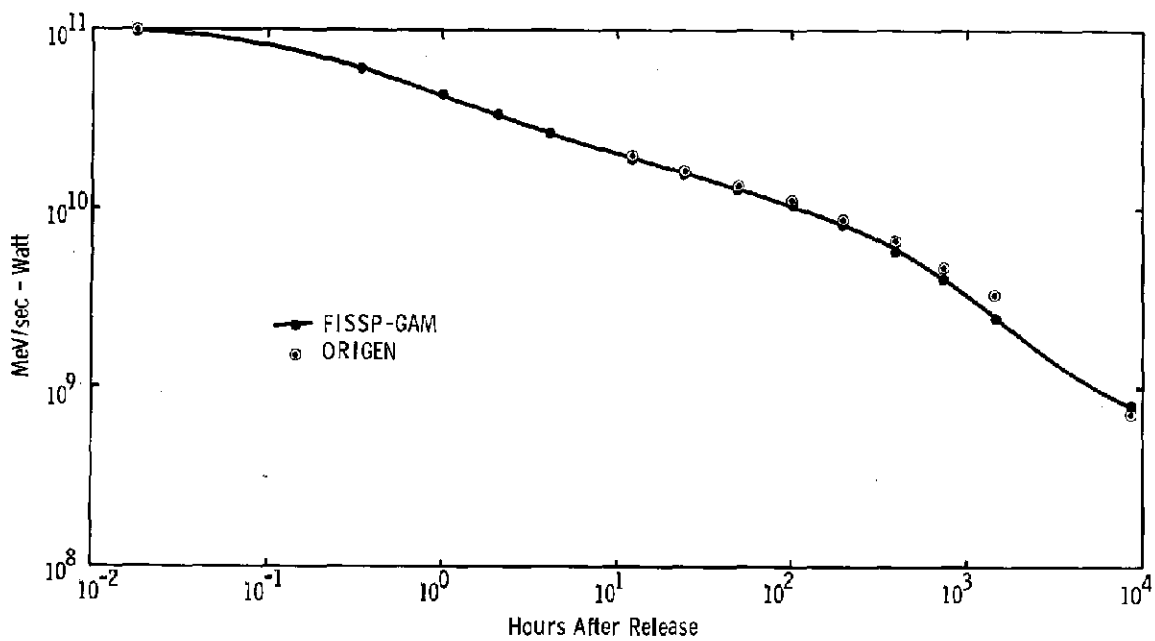

Figure 2.2.1. Gamma energy release rate after 100% release of fission products, compared with ORIGEN calculations; 5000-day power operation.

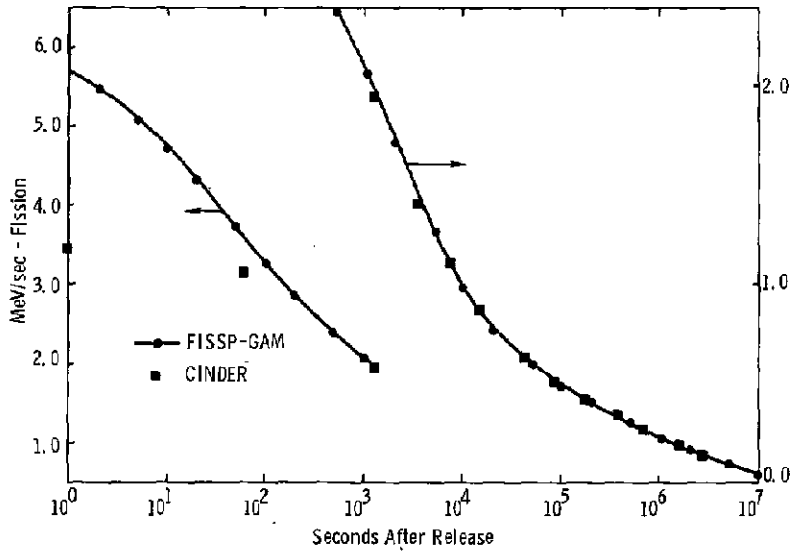

Figure 2.2.2. Gamma energy release rate, compared with CINDER calculations; 5000-day power operation with FISSP-GAM, 833-day power operation with CINDER.

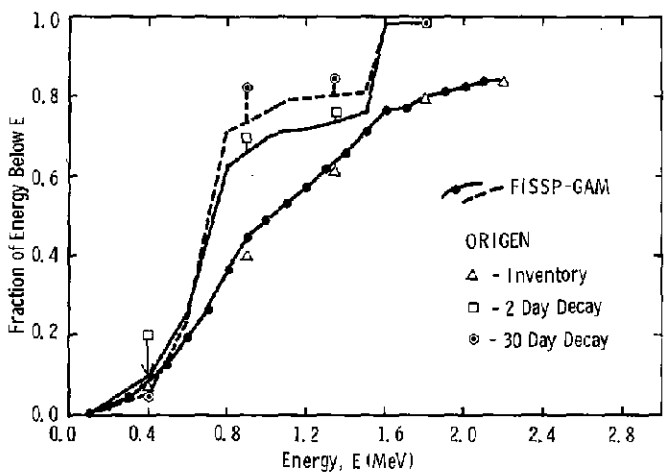

Figure 2.2.3. Gamma energy spectra for 100% release of fission products, compared with ORIGEN calculations; 5000-day power operation.

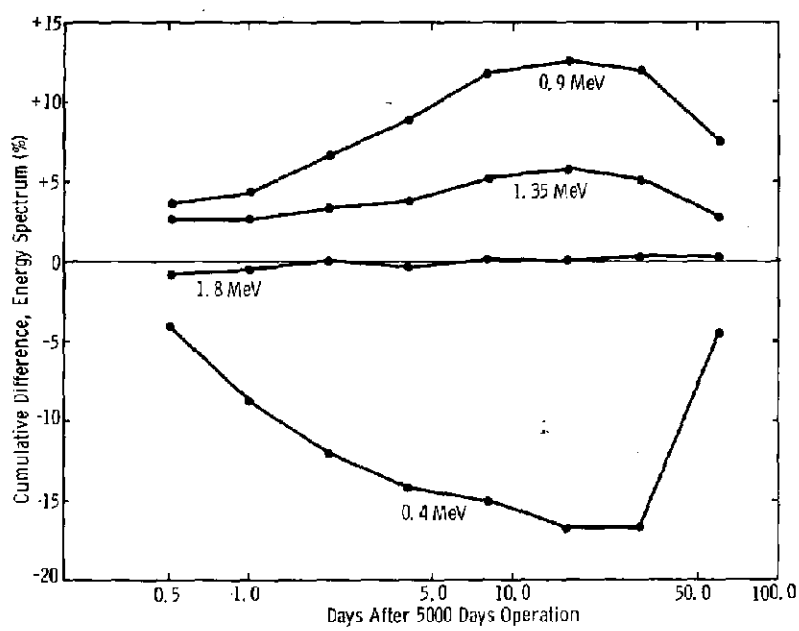

Figure 2.2.4. Gamma energy spectra for 100% release of fission products, compared with ORIGEN calculations; 5000-day power operation. The ORIGEN less FISSP-GAM results relative to FISSP-GAM are plotted.

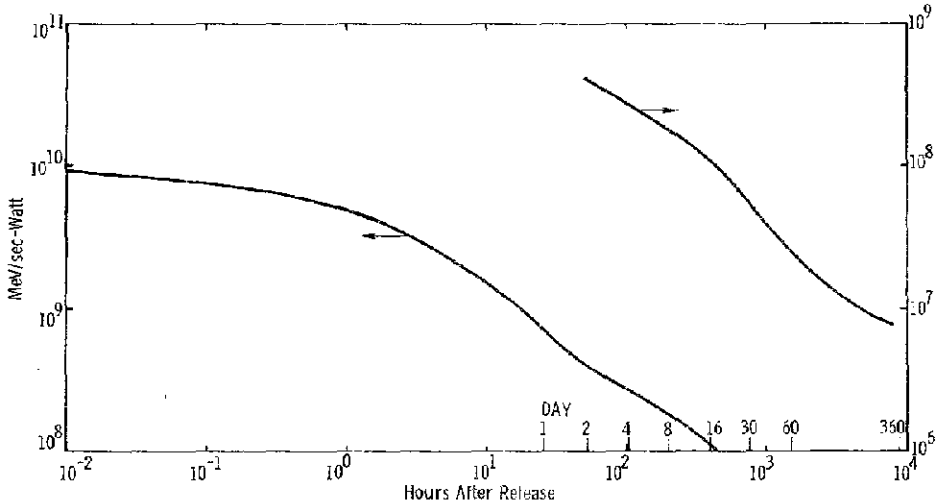

Figure 2.3.1. Waterborne gamma energy release rate source; 50% halogens, 1% solids.

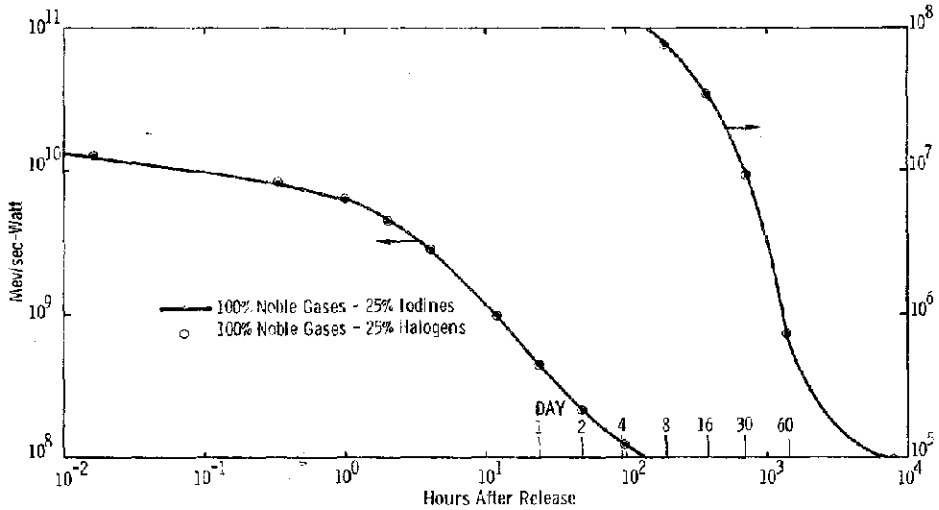

Figure 2.3.2. Airborne gamma energy release rate source; 100% noble gases, 25% iodines. Halogens contribution is also illustrated.

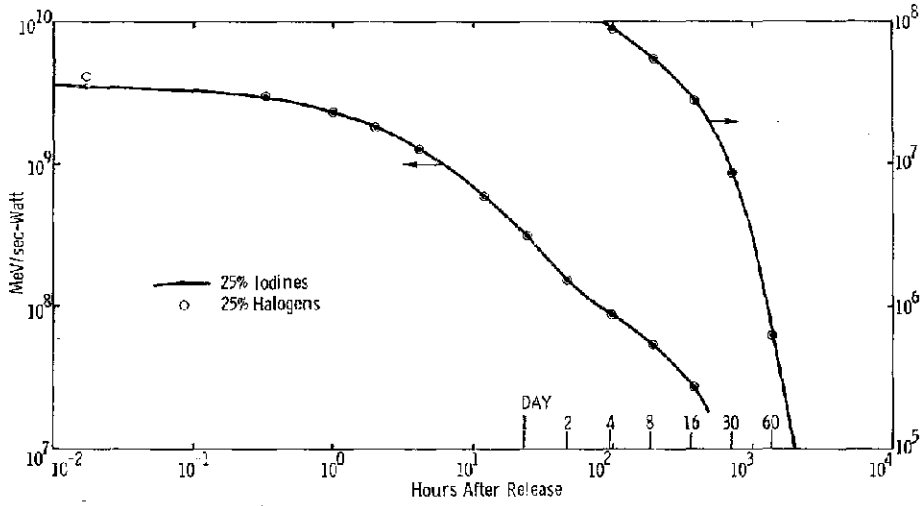

Figure 2.3.3. Plate-out gamma energy release rate source; 25% iodines. Halogens contribution is also illustrated.

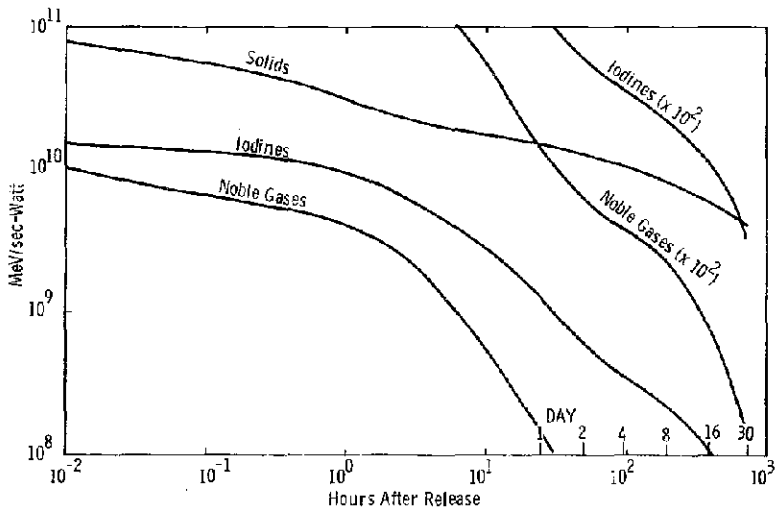

Figure 2.3.4. Gamma energy release rate source for noble gases, iodines, and solids.

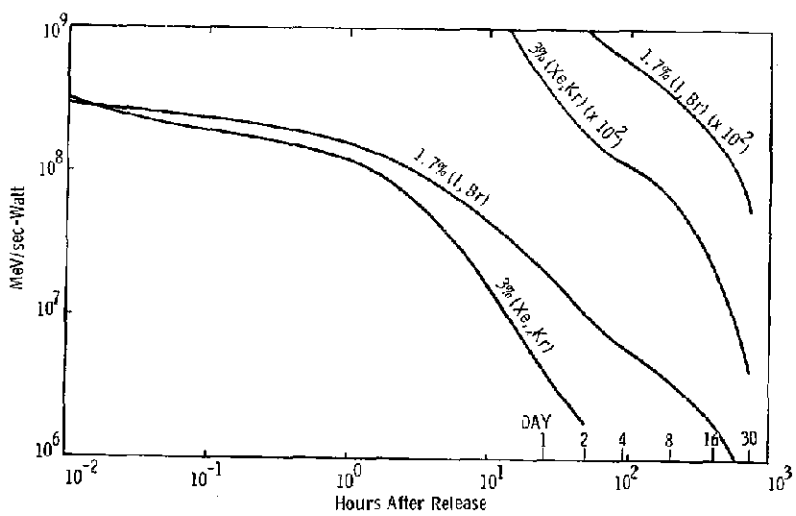

Figure 2.3.5. Gamma energy release rate source for the WASH-1400 specified percentage releases from the fuel-clad gap.

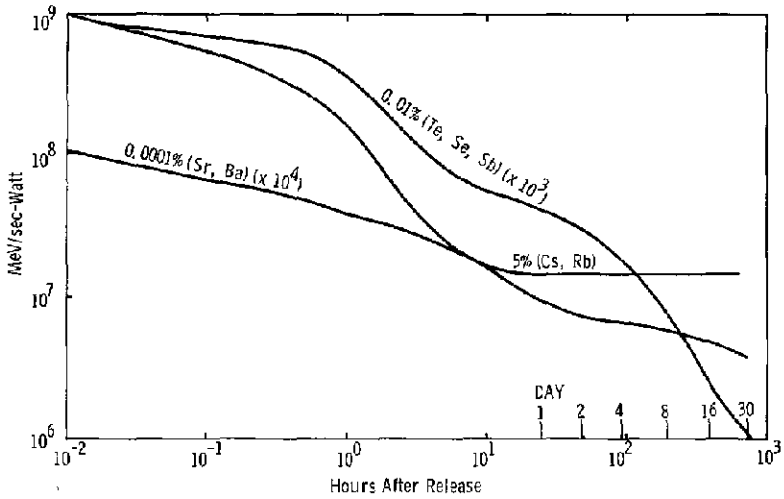

Figure 2.3.6. Gamma energy release rate source for the WASH-1400 specified percentage releases from the fuel-clad gap.

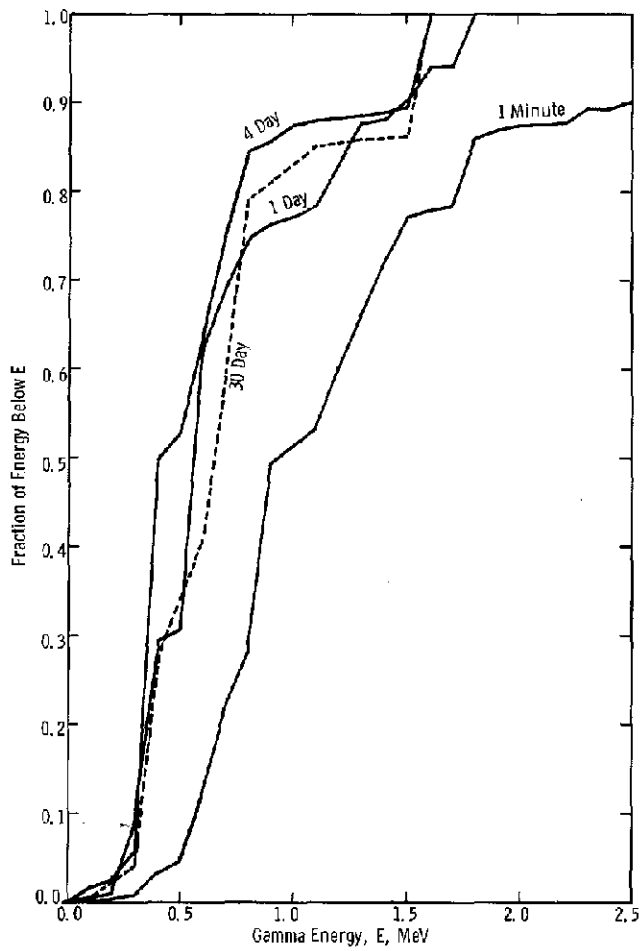

Figure 2.4.1. Gamma energy spectra for the waterborne source; 50% halogens, 1% solids.

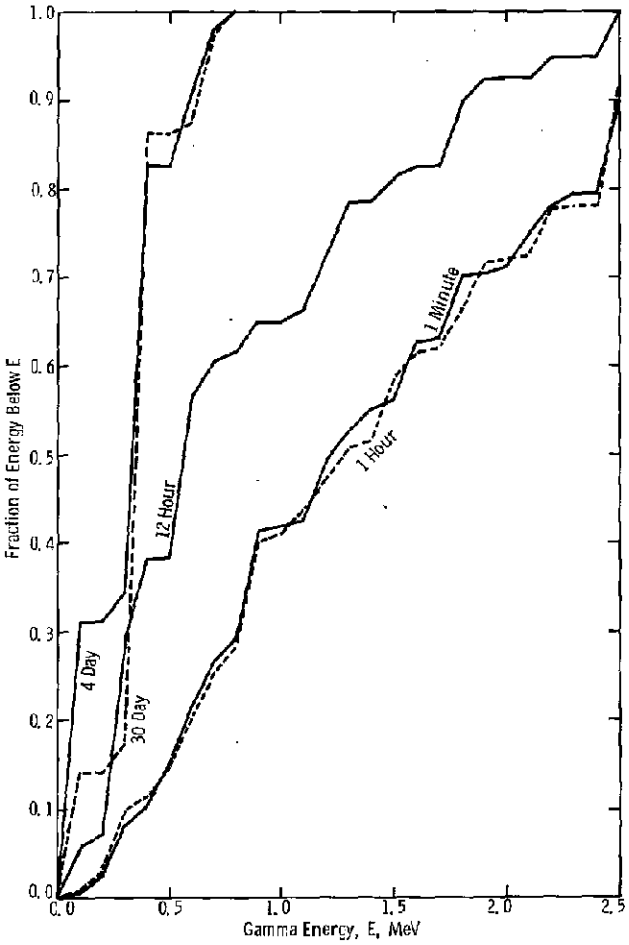

Figure 2.4.2. Gamma energy spectra for the airborne source; 100% noble gases, 25% iodines.

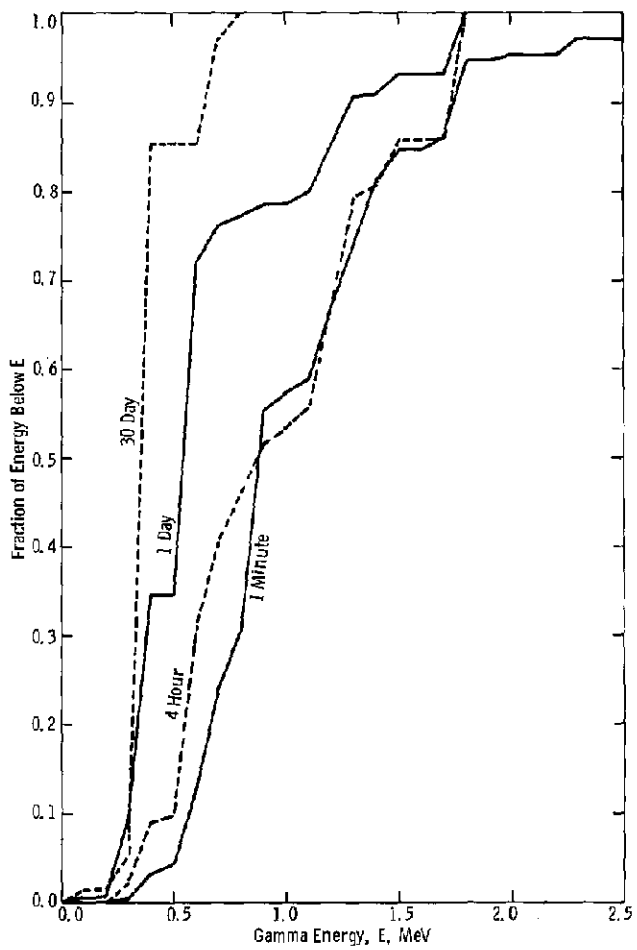

Figure 2.4.3. Gamma energy spectra for the plate-out source; 25% iodines.

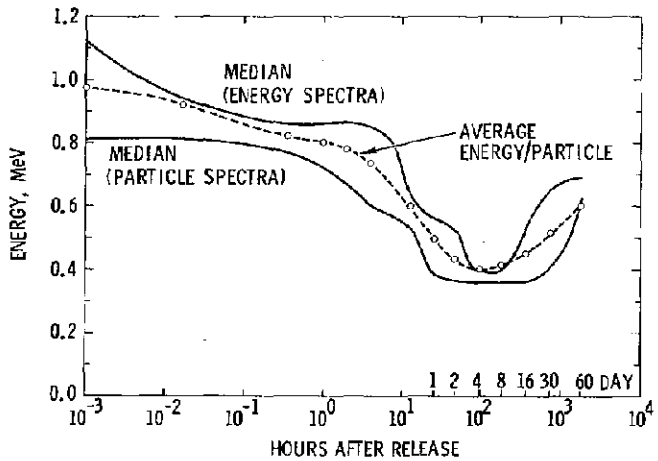

Figure 2.4.4. Measures of the gamma energy spectra for the waterborne source; 50% halogens, 1% solids.

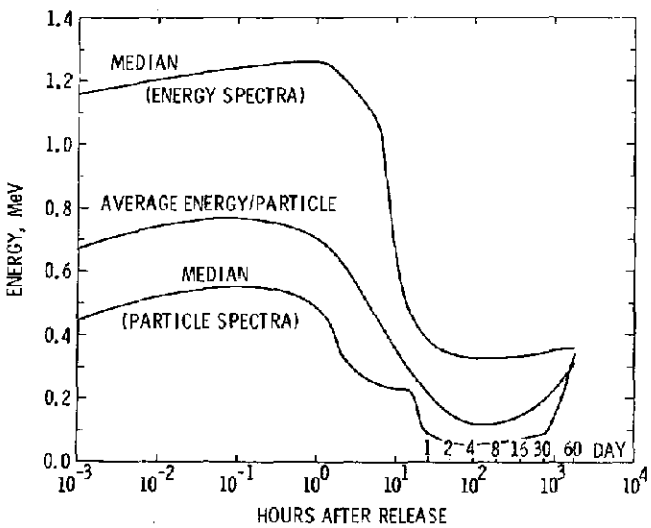

Figure 2.4.5. Measures of the gamma energy spectra for the airborne source; 100% noble gases, 25% iodines.

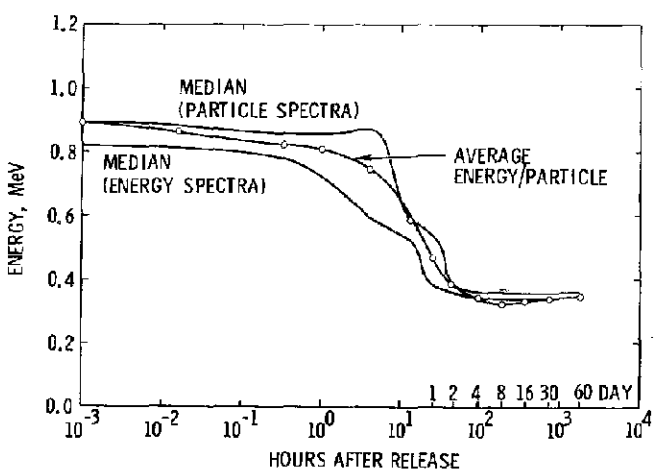

Figure 2.4.6. Measures of the gamma energy spectra for the plate-out source; 25% iodines.

Chapter 3. LOCA Beta Radiation Signature

3.1 Methodology

The calculation of the beta radiation signature relies on the accurate description of the core curie activity for the specified core power histories. As discussed in Section 2.1, the FISSP code was used in these calculations because of its coding uniqueness.

The conversion of the curie activity to beta energy release rate and spectra used beta decay scheme data taken from Reference 8. These data are included in Appendix B for the 281 nuclides, with beta decay schemes, used in these calculations. For each nuclide, the discrete beta endpoint energy of each spectrum is given as well as the percents of spectrum emission per disintegration. The percentages should sum to 1 beta emission per disintegration; in some cases, where data were given as relative intensity rather than percentage, the conversion was made to percentage assuming 1 beta emission. The tabulated data also include the average beta energy per disintegration for each spectrum group and the average beta energy per disintegration of the nuclide (i.e., the cumulative sum of the average energy of each spectrum group and group emission percentage product).

To adequately describe the beta spectra based on the group endpoint energy and emission percentage, it is necessary to establish the shape of the beta emission curve for each group (i.e., number of particles versus energy). Once established for each group, the spectrum for an ensemble of nuclides can be obtained by selectively summing the beta emission curves according to the group emission percentage and the relative occurrence of each nuclide in the ensemble. The combined code for calculating beta energy release and spectra is referred to as FISSP-BETA.

The shape of the beta emission curve was established using the techniques suggested in Reference 12 for allowed beta transitions. For allowed beta transitions, and neglecting screening by atomic electrons, the emission shape is given as

$$N(W)\,dW = C\Big|_{W_o, Z} F(Z,W)\,(W^2 - 1)^{1/2}\,(W_o - W)^2\,W\,dW$$

where

$N(W)\,dW$, number of beta particles in the energy range W to $W + dW$

$C\Big|_{W_o, Z}$, a constant depending on W_o and Z, but not a function of W_o and Z

$F(Z,W)$, the nuclear coulomb factor, the Fermi function

$W = \dfrac{E + m_o c^2}{m_o c^2}$, energy of the beta particle

$$W_o = \frac{E_o + m_o c^2}{m_o c^2}$$, endpoint energy of the spectrum

Z, atomic number.

The constant $C\big|_{W_o, Z}$ can be determined, since the total number of beta particles is proportional to

$$\int_1^{W_o} N(W)\, dW \quad .$$

Assuming one particle per disintegration, $C\big|_{W_o, Z}$ is given as

$$C\big|_{W_o, Z} = \frac{1}{\int_1^{W_o} F(Z, W)(W^2 - 1)^{1/2} (W_o - W)^2 W\, dW}$$

with $C\big|_{W_o, Z}$ determined, the beta energy in a band of energy between W_1 and W_2 is

$$E_{W_1, W_2} = m_o c^2 \int_{W_1}^{W_2} (W - 1)\, N(W)\, dW \quad .$$

This latter equation is used in FISSP-BETA to determine the spectrum resulting from the ensemble of nuclides for the given fractionation.

The additional complication of the nuclear coulomb factor can be addressed by three appro imations.

1. $F(Z, W) \simeq 1$

2. $F(Z, W) \sim \dfrac{2\pi y}{1 - e^{-2\pi y}}$

$$y \equiv \frac{Z}{137} \frac{W}{\sqrt{W^2 - 1}}$$

3. $$F(Z, \eta) = \left\{ \frac{4\left(1 + \frac{s}{2}\right)}{\left[\Gamma(3 + 2s)\right]^2} \left(\frac{2R}{\frac{\hbar}{m_o c}} \right)^{2s} \right\} \left\{ \eta^{2s} e^{\pi y} \left| \Gamma(1 + s + iy) \right|^2 \right\}$$

$$s \equiv \left[1 - \left(\frac{Z}{137} \right)^2 \right]^{1/2} - 1 \quad .$$

$F(Z,W) \sim 1$ is applicable for allowed shape and small Z ($F = 1$ for $Z = 0$). Approximation 2 is appropriate for nonrelativistic beta particles. Equation 3 is the relativistic nuclear coulomb factor expressed in momentum space (η). According to Evans,[12] approximation 2 is within 5 percent of approximation 3 for $Z \leq 30$ and $0.08 < E < 2.1$ MeV. Further, for the ensemble of nuclides as presented in the remaining sections of Chapter 3, Equations 1 and 2 gave almost indistinguishable results (some comparisons are presented later). $F(Z,W) = 1$ is used in the majority of these calculations.

3.2 Comparison with Other Codes

Prior to the presentation of the LOCA beta radiation source, comparisons with other codes are appropriate. Figure 3.2.1 shows the resultant beta energy release rate from all fission product nuclides subsequent to 5000 days of power operation. The ORIGEN code results are in excellent agreement over the entire time span.

Also shown is the nonrelativistic nuclear coulomb factor effect (approximation 2 of Section 3.1) compared with the effect of assuming $F(Z,W) = 1$. Assuming that $F = 1$ is apparently conservative; compared with the nonrelativistic factor, the results for $F = 1$ are 6 to 10 percent greater in magnitude. In terms of the effect on spectra, it will be shown later that the resultant energy spectra is only slightly affected for $F = 1$.

Some very recent data is compared in Figure 3.2.2 as computed with the CINDER code and the latest ENDF/B-IV data files. The comparison is specified in units of MeV/sec-fission, with the FISSP-BETA results ~ 30 percent smaller than the CINDER results. Since only preliminary results are available from CINDER and since ORIGEN does not indicate a similar error, the discrepancy needs to be evaluated further as discussed in Chapter 6.

Comparisons of beta spectra are not currently available. Beta spectra are not normally calculated, since the general interest in beta emission is the absorption in, and subsequent heating of, materials which are not strong functions of spectra. As discussed in Chapter 6, it is intended that spectral comparisons will be made, particularly with the CINDER code.

3.3 Beta Energy Release

This section presents the plant independent beta release rate profiles as described in Section 1.3. Sections 3.3.1, 3.3.2, and 3.3.3 define the three post-LOCA sources derived from the Regulatory Guides. These are energy release rates only; specific dose rates, which account for the spatial placement of these sources, are shown in Chapter 4.

Section 3.3.4 is included to allow the reader to select different nuclide fractionations that may be useful. A new "source" can be calculated by selectively mixing the proportionate nuclide types; an example is given in the section.

Section 3.3.4 also includes an estimate of the beta energy release rate from the gap release fraction specified in WASH-1400. This is included as an example of a "realistic" LOCA assuming all Emergency Core Cooling Systems and Engineered Safety Features function properly during the course of the LOCA.

3.3.1 Waterborne Source -- Immediately following the LOCA, 50 percent of the halogens and 1 percent of the solids in the equilibrium core are assumed to be intimately mixed with the coolant water. Figure 3.3.1 shows the beta radiation from this environment as a function of time after release.

Also shown in the figure is the resultant profile using the nonrelativistic coulomb factor; the difference is only ~ 10 percent.

3.3.2 Airborne Source -- Immediately following the LOCA, 100 percent of the noble gases and 25 percent of the iodines in the equilibrium core are assumed to be uniformly dispersed in the containment atmosphere. Figure 3.3.2 shows the beta radiation from this environment as a function of time after release.

3.3.3 Plate-Out Source -- Immediately following the LOCA, 25 percent of the iodines in the equilibrium core are assumed to be plated out on surfaces exposed to the containment atmosphere. Figure 3.3.3 shows the beta radiation from this environment as a function of time after release.

As previously discussed, in Section 2.3.2, it is not entirely clear that a distinction between "halogen" and "iodine" is appropriate. But as shown in Figure 3.3.3., the inclusion of the halogens does not substantially affect the beta energy release rate, except at very early times; beyond 1 hour, there is less than a ~ 1-percent difference.

Also shown in the figure are the profiles for iodines and halogens resulting from including the nonrelativistic coulomb factor; the difference is only ~ 10 percent at early times and ~ 20 percent at 30 days. Where data is not shown separately for iodines and halogens, there is no significant difference.

3.3.4 Selected Nuclide Fractionations -- Figure 3.3.4 shows the beta radiation for the three nuclide types. Suppose it is assumed that a source of interest is composed of 35 percent of the noble gases, 5 percent of the iodines, and 10 percent of the solids. To a first approximation, the individual components can be summed; for example, at 1 day following release:

35% -	Noble Gases	$\equiv 1.3 \times 10^8$ MeV/sec
5% -	Iodines	$\equiv 4.7 \times 10^7$ MeV/sec
10% -	Solids	$\equiv 1.42 \times 10^9$ MeV/sec
Combined Source		$\equiv 1.60 \times 10^9$ MeV/sec

Some interest in a "realistic" LOCA has led to the suggestion that the gap release fraction be adapted as the definition of the resultant radiation source. The gap release fraction, as defined in WASH-1400, Appendix VII, and given as a percentage of the total core inventory, is:

Xe, Kr	- 3.0%
I, Br	- 1.7%
Cs, Rb	- 5.0%
Te, Se, Sb	- 0.01%
Sr, Ba	- 0.0001%

The beta radiation from this environment is shown in Figure 3.3.5 and 3.3.6. As in the previous discussion, a further stipulation must be made; that is, the spatial location of these nuclides must be defined.

3.4 Beta Spectra

This section presents the beta spectra profiles as described in Section 1.3. Additional information is contained in Appendix D which presents the tabulated data for these sources plus several additional nuclide fractionations.

Figure 3.4.1 shows the energy spectra for the waterborne source with time after release as a parameter. Initially the spectrum is hard, softens in time, and then rehardens. Figure 3.4.2 shows the energy spectra for the airborne source and Figure 3.4.3 for the plate-out source with similar information plotted.

The effect of including the nonrelativistic coulomb factor is also shown in these figures. Apparently for the ensemble of nuclides, the spectral shift is not pronounced; for individual nuclides, however, it is certainly more important. While there is essentially no difference, for the very softest spectra (Figure 3.4.2 and 3.4.3), assuming that F = 1 results in a slightly harder spectra. However, for the majority of the spectra, the assumption, F = 1, results in a slightly softer spectra.

Figures 3.4.4, 3.4.5, and 3.4.6 present the same information, respectively, but are perhaps easier visualizations of the data. For each of the three sources the median energy of the energy spectra, the average energy per particle, and the median energy of the particle spectra is displayed as a function of time after release. Since betas result from a continuum spectra, the best indicator is the median energy of the energy spectra. In fact, the particle spectra were derived by assuming that the particles had energy equivalent to the mid-energy of specific energy

bins. Similarly, the average energy per particle requires the estimation of the total number of particles, which was calculated by summing the number of particles in each energy bin. In a sense, and assuming the formulation as presented in Section 3.1, the median energy of the energy spectra is the pure indicator without additional assumptions.

The changing spectra is similar to that noted in Section 2.4 for the gamma spectra and must be explained in a similar manner; radioactive emissions from short-lived nuclides are generally higher in energy than those from long-lived nuclides. Certainly, as for gammas, the implications of a changing spectra must be addressed for the radiation qualification testing of components. But unlike gammas, the charged beta particles present added problems in duplicating component damage with radiation simulators, the majority of which are gamma emitters.

As for gammas, the beta spectral shift is a (sensitive) function of the choice of the nuclide fractionation. Iodines (Figure 3.4.6) show "no" rehardening, but when selectively combined with noble gases (Figure 3.4.5) the resulting spectra shows a definite rehardening. The rehardening, in Figure 3.4.4, is even more pronounced for the combination of 50 percent of the halogens and 1 percent of the solids. Should the fractionation ever be reselected, a spectral shift would occur and must be considered; to a first approximation, the data of Appendix D could be applied to derive a new spectrum for the ensemble of nuclides.

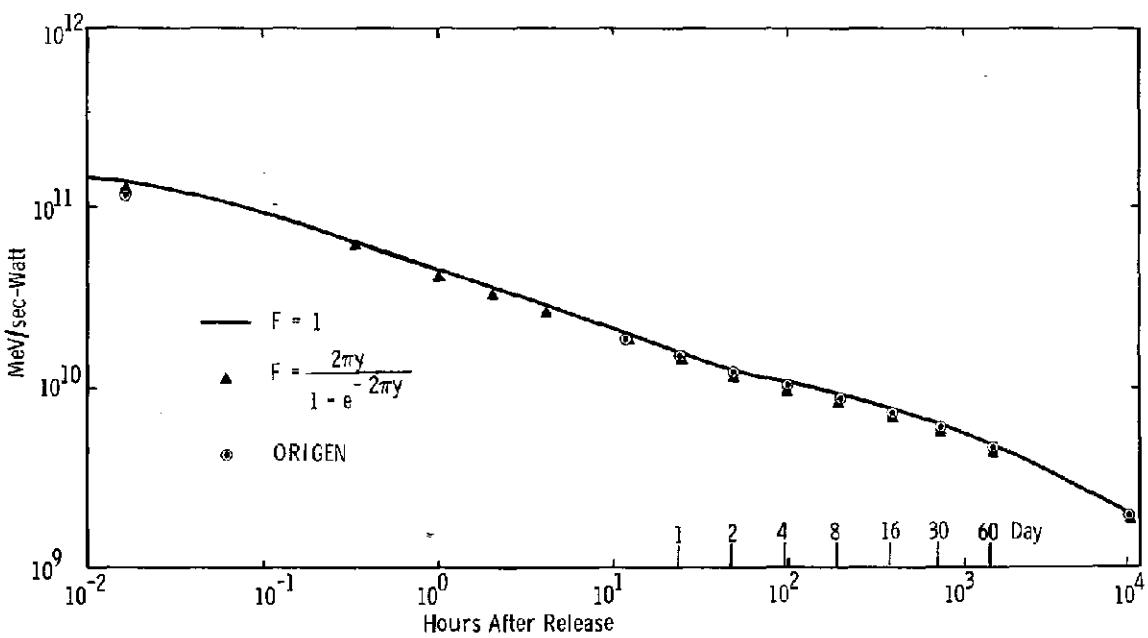

Figure 3.2.1. Beta energy release rate after 100% release of fission products, compared with ORIGEN calculations; 5000-day power operation.

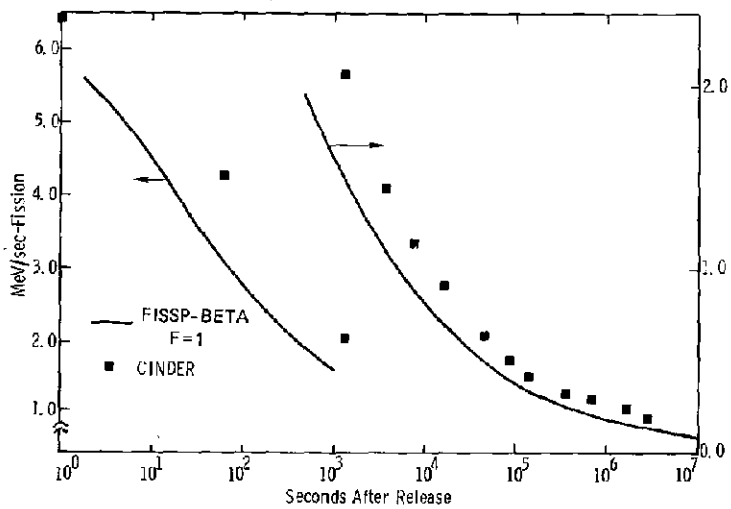

Figure 3.2.2. Beta energy release rate, compared with CINDER calculations; 5000-day power operation with FISSP-BETA, 833-day power operation with CINDER.

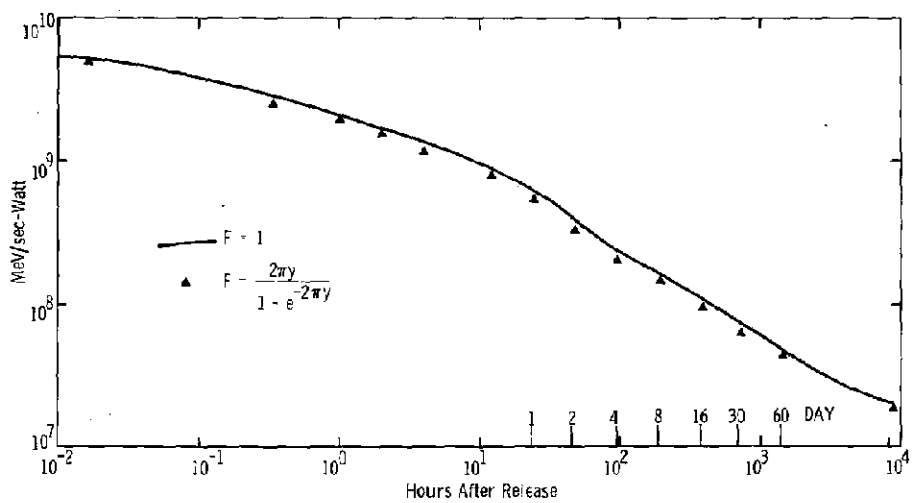

Figure 3.3.1. Waterborne beta energy release rate source; 50% halogens, 1% solids.

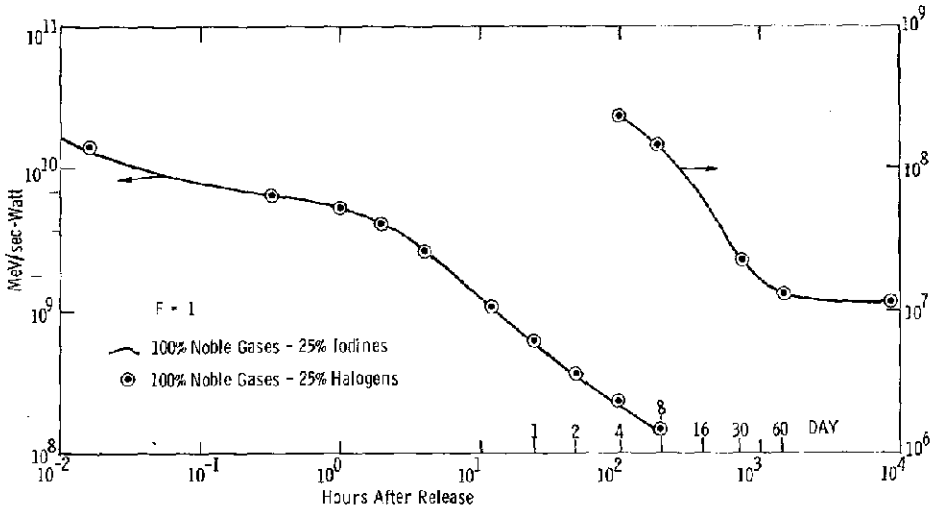

Figure 3.3.2. Airborne beta energy release rate source; 100% noble gases, 25% iodines. Halogens contribution is also illustrated.

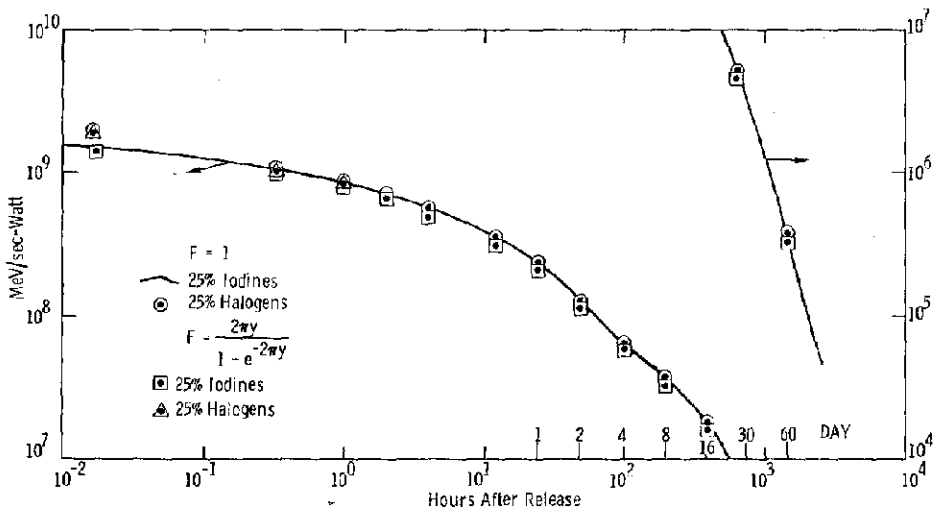

Figure 3.3.3. Plate-out beta energy release rate source; 25% iodines. Halogens contribution is also illustrated.

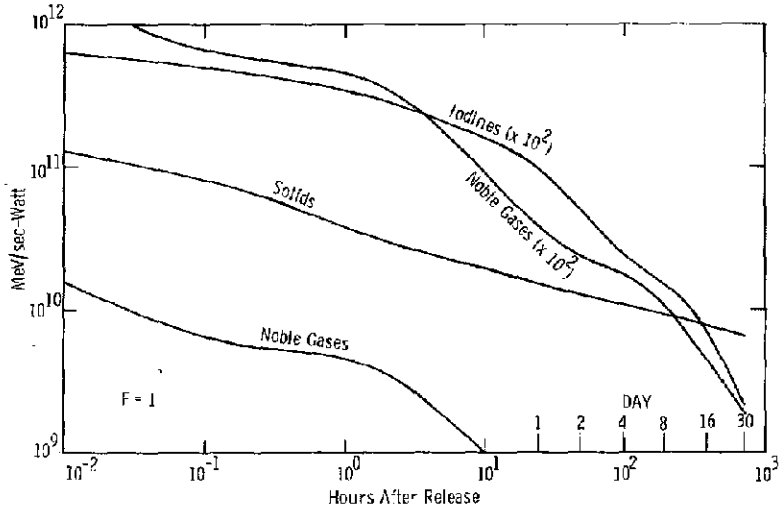

Figure 3.3.4. Beta energy release rate source for noble gases, iodines, and solids.

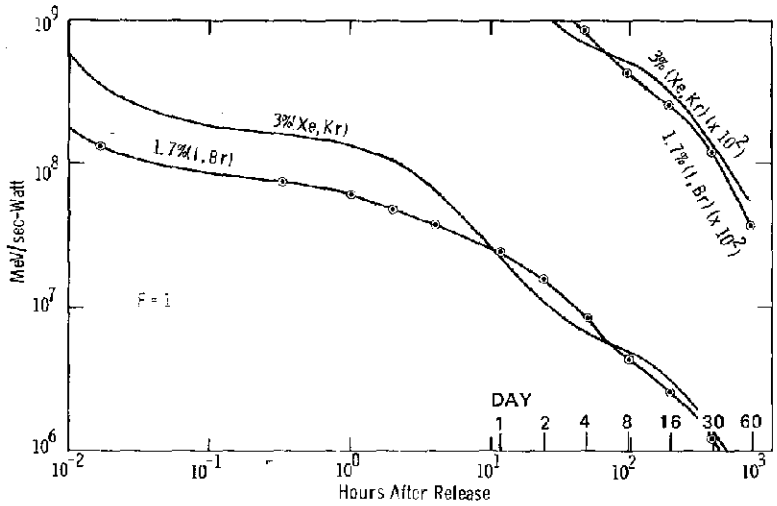

Figure 3.3.5. Beta energy release rate source for the WASH-1400 specified percentage releases from the fuel-clad gap.

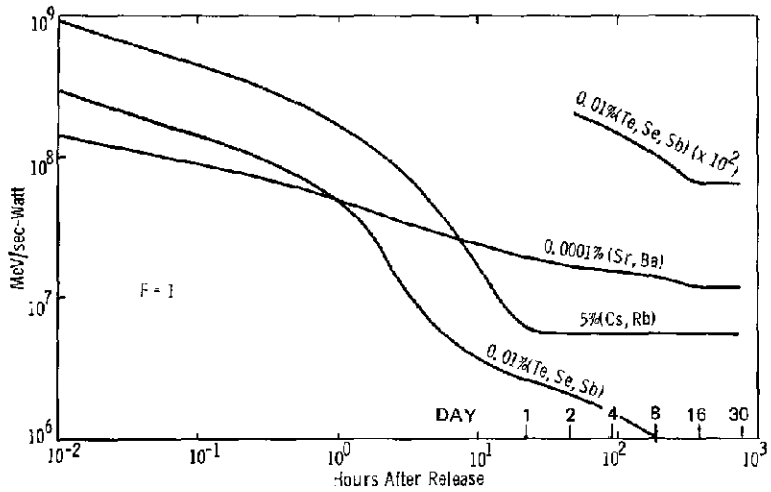

Figure 3.3.6. Beta energy release rate source for the WASH-1400 specified percentage releases from the fuel-clad gap.

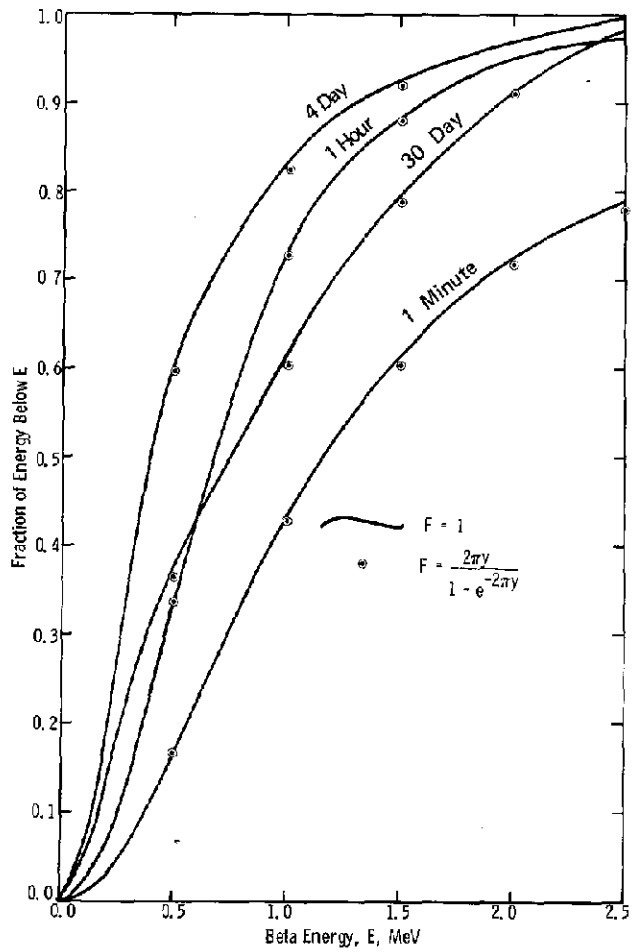

Figure 3.4.1. Beta energy spectra for the waterborne source; 50% halogens, 1% solids.

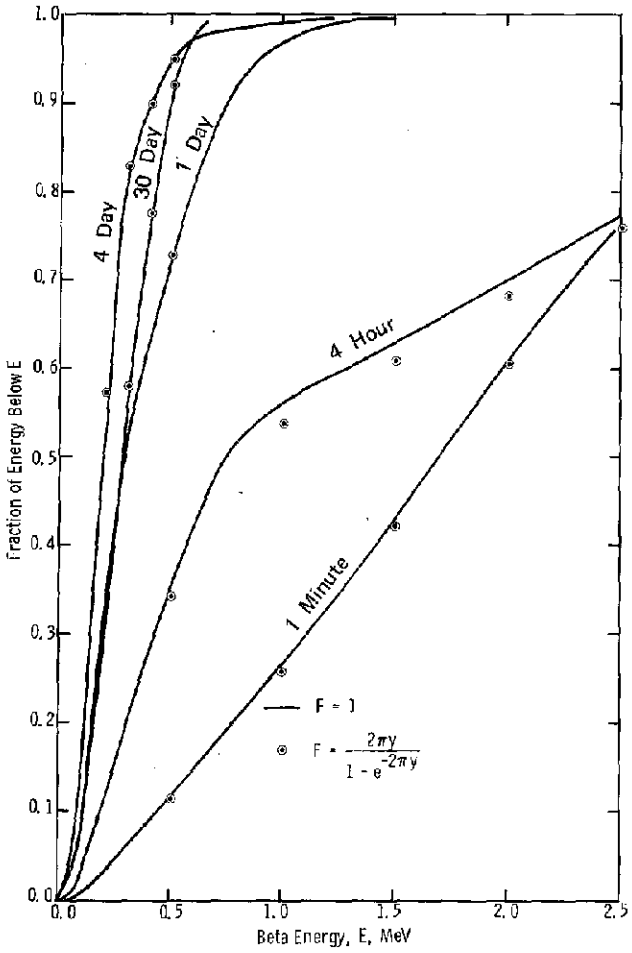

Figure 3.4.2. Beta energy spectra for the airborne source; 100% noble gases, 25% iodines.

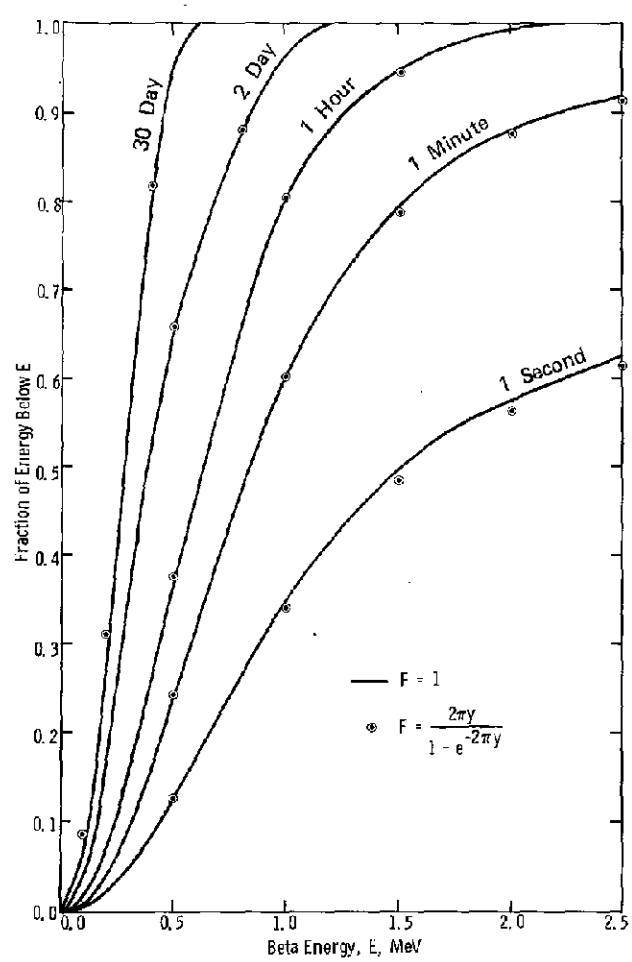

Figure 3.4.3. Beta energy spectra for the plate-out source; 25% iodines.

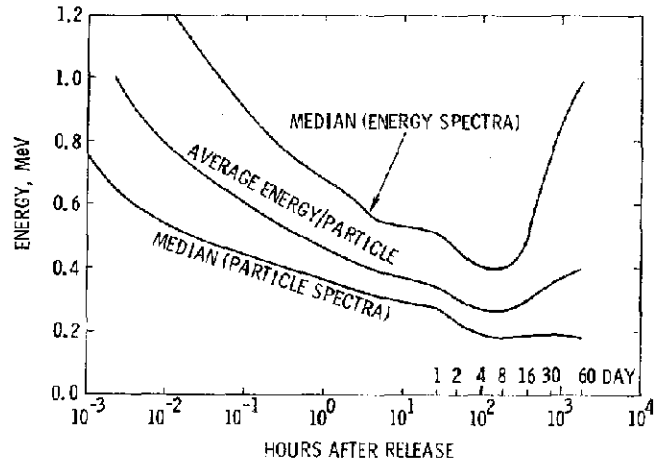

Figure 3.4.4. Measures of the beta energy spectra for the water-borne source; 50% halogens, 1% solids.

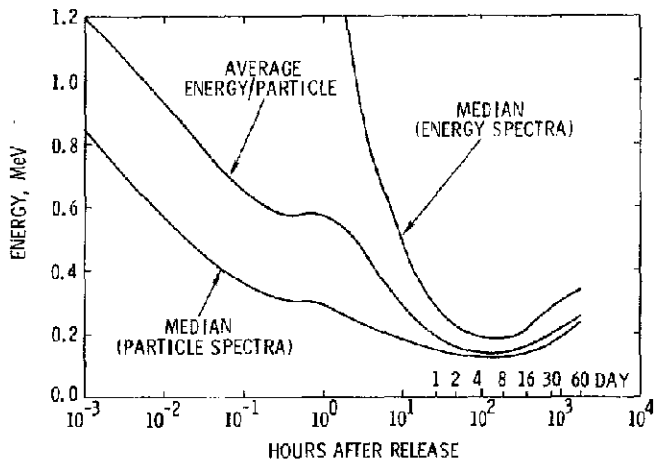

Figure 3.4.5. Measures of the beta energy spectra for the airborne source; 100% noble gases, 25% iodines.

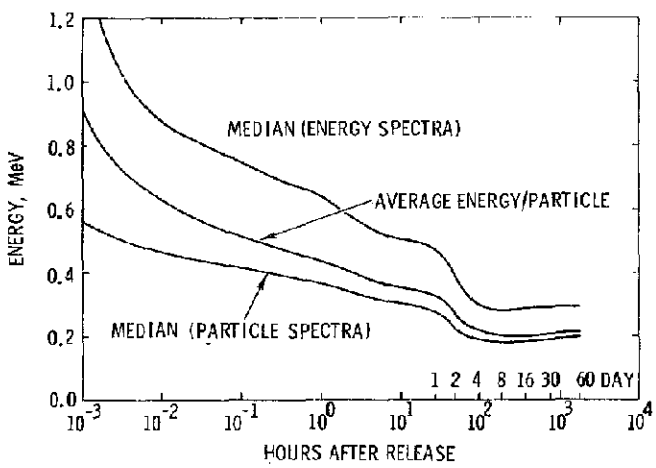

Figure 3.4.6. Measures of the beta energy spectra for the plate-out source; 25% iodines.

4.1 Methodology

A summary of the information in Chapters 2 and 3 is presented in Table 4.1. The feature of the energy release rates is that for each of the three sources, the gamma and beta releases are generally within a factor of 2 of each other over the time span indicated. Yet the conversion to dose and dose rate must account for the transport of the radiation inside the containment with its complement of internal structure. Since this calculation is completely plant specific, further simplifying assumptions were made to calculate the data in Sections 4.2 and 4.3.

TABLE 4.I

The Energy Release Rate Following the Hypothetical LOCA

Time After LOCA	MeV/Sec-Watt					
	50% Halogens 1% Solids		100% Noble Gases 25% Iodines		25% Iodines	
	Gamma	Beta	Gamma	Beta	Gamma	Beta
1 sec	1.06 + 10*	1.37 + 10	1.48 + 10	2.57 + 10	3.81 + 9	2.97 + 9
1 min	8.90 + 9	5.07 + 9	1.26	1.36	3.56	1.47
20 min	6.29	2.73	8.08 + 9	6.14 + 9	2.84	1.02
1 hr	4.98	2.12	6.34	5.24	2.30	8.40 + 8
2 hr	3.82	1.68	4.54	4.03	1.78	6.79
4 hr	2.69	1.31	2.82	2.66	1.24	5.29
12 hr	1.34	8.80 + 8	9.91 + 8	1.07	5.87 + 8	3.51
1 day	7.67 + 8	6.08	4.53	5.96 + 8	3.10	2.32
2 day	4.29	3.66	2.14	3.53	1.53	1.22
4 day	2.75	2.28	1.24	2.29	8.67 + 7	6.24 + 7
8 day	1.89	1.61	7.64 + 7	1.40	5.44	3.65
16 day	1.13	1.08	3.49	6.21 + 7	2.71	1.75
30 day	5.67 + 7	7.04 + 7	9.46 + 6	2.27	8.12 + 6	5.06 + 6

*read as 1.06×10^{10}

The containment structure was modeled as an empty cylinder[13] having an inside radius of 1768 cm, inside height of 6355 cm, and concrete walls, 114 cm thick; total free volume is approximately 6.25×10^{10} cm^3 (2.2 million cubic feet). The internal structure was not modeled at all, since that detail was considered to be beyond the scope of this project. However, the calculations

are useful as scoping values for the dose and rate. Certainly for betas, and to a first approximation for gammas, free volume is a pertinent scaling factor. Volume scaling factors are presented and discussed where appropriate in the following sections; while the modeled structure is most typical of a PWR containment, the scaling factors should allow approximate application to BWR structures as well.

Except in a few cases, doses and rates are presented for air at standard temperature and pressure (STP), with a density of 0.001293 gm/cm^3. The justification for computing air dose and rate was discussed in Section 1.3, but suffice to say that such calculations are a recognized and reproducible method for communicating the data.

An additional factor is the reactor power assumed prior to the LOCA. While merely a scaling factor, which can be adjusted for a specific plant, the full impact of these environments is more graphically illustrated when a "typical" power level is assumed. The calculations are presented for a 4000-MW(t) plant, approximately the 1300-MW(e) class of nuclear power plant.

Certain assumptions, listed and discussed in Section 1.3, are important in the calculation of dose and rate, but do not affect the energy release rates of Chapters 2 and 3. These three are reiterated here:

(a) Instantaneous, uniform release or deposition.

(b) Engineered safety features are neglected.

(c) Containment leakage is neglected.

The first assumption is particularly important in establishing the initial dose rate; the latter two may affect the total integrated dose, although typical containment leak rates are on the order of 0.1 to 0.5 volume percent per day and thus would change the total dose by ~ 3 to 15 percent over a 30-day period.

Gamma transport was done using the DTF69 code,[14] which utilizes the method of discrete ordinates. The cylindrical containment was assumed infinite in the axial dimension. However, corrections were made to account for the truly finite dimensions by correcting the dose and rate for the correct source volume. The error is not considered significant in any case since dose and dose rate were recorded at the mid-axis (i.e., 31.775 m from either end of the finite cylinder), but is conservatively high. Complementary unpublished calculations for an equivalent volume sphere, compared with the infinite (but corrected) cylinder, shows the dose rates to be within ~10 percent.

Beta volumetric sources were assumed to be deposited locally because of the short beta range in air (e.g., a 2-MeV beta has a maximum range of ~ 7.5 m in air); this is referred to as the infinite volume assumption. Certain calculations required that betas be transported as well. For these calculations, the CYLTRAN Monte Carlo code[15] was used. For one or two gamma transport calculations, CYLTRAN was also used.

4.2 Gamma Doses and Rates

The gamma dose and rate from the airborne volumetric source is shown in Figure 4.2.1, as a function of time after release. The initial centerline dose rate is ~ 3.5 MR/hr and the dose to 30 days is ~ 28 MR. The edge and mid-radius dose rates are also shown; because of the air penetrability of the gamma radiation, the edge dose and rate are similar in magnitude, e.g., ~ 2.5 MR/hr initial dose rate. Figure 4.2.2 shows the dose rate (implicitly, dose) dependence on containment volume for the airborne source, with time after release a parameter. Volume changes were made by proportionally changing the cylinder radius and height.

Figure 4.2.3 shows the dose and rate from the plated-out iodines as a function of time after release. It was assumed that the 25 percent of the iodines were plated on the containment walls (no floor or ceiling plate-out) with a surface area of 7.06×10^7 cm^2; surface area is a normalizing factor. (Since the DTF69 code requires a volumetric source, the plate-out was approximated by a 5-cm thick annulus volume at the containment wall.) The initial centerline dose rate is ~ 0.5 MR/hr initially and ~16 MR to 30 days. Figure 4.2.4 shows the dose rate (implicitly, dose) dependence on containment volume for the plate-out source, with time after release a parameter. Volume changes were made by proportionally changing the cylinder radius and height.

Immediately following the LOCA, 50 percent of the halogens and 1 percent of the solids in the equilibrium core are assumed to be intimately mixed with the coolant water. But where is the coolant water? Figures 4.2.5 and 4.2.6 show extreme models for the coolant water spatial location. In Figure 4.2.5 it is assumed that the source is airborne in the containment as was assumed in Figure 4.2.1. Clearly, the assumption does not model the realities of the LOCA; of course, it could be postulated that a portion of the source was sprayed in the containment. Figure 4.2.5 does serve to illustrate the magnitude of the source, an initial dose rate of ~2.5 MR/hr and a dose to 30 days of ~45 MR.

A more reasonable assumption may be that the coolant water is collected somewhere. Figure 4.2.6 shows one such case assuming that the water pool is 500 cm deep at the bottom of the containment (1768 cm radius). The dose rate resulting from the gamma environment at one minute following the LOCA is shown; the infinite volume assumption is appropriate in the water. The dose rate in the air above the water decreases rapidly with distance; since the one minute energy spectrum is "hard," the dose rates at later times will fall off even more rapidly. Further, compared to the dose rates from the airborne source (Figure 4.2.1) and the plate-out source (Figure 4.2.3), the additional contribution from the waterborne source is not significant.

The dose and rate to a particular area of the containment is a combination of the three sources. Clearly, the airborne source and the plate-out source are additive (spatially). But the waterborne source is less spatially defined. However, Figure 4.2.7 assumes that 1/10 of the waterborne source is added to the airborne and plate-out sources. The resultant initial centerline dose rate is ~4.5 MR/hr and the dose to 30 days is ~45 MR. While the airborne source is the principal dose and rate contributor everywhere in containment, the plate-out source adds significantly to the edge dose so that dose and rate are almost uniform throughout the containment in this model. The doses and rates are severe, but are a result of the assumptions, which must be critically examined for specific plant applicability.

4.3 Beta Doses and Rates

The beta dose and rate from the airborne volumetric source is shown in Figure 4.3.1, as a function of time after release. Since the infinite volume assumption is appropriate (see Section 4.1), the dose and rate are presented normalized to reactor power and containment volume. That is, the beta dose and rate are directly proportional to power and inversely proportional to volume. An example may be appropriate; assuming 4000 MW(t) power and 6.25×10^{10} cm^3 volume, the dose rate is ~15 MR/hr at 1 hour and ~0.07 MR/hr at 30 days. Total dose to 30 days is ~320 MR. These can be compared with the gamma dose and rate in Section 4.2 (~1.7 MR/hr at 1 hour, 28 MR to 30 days).

While Figure 4.3.1 demonstrates the volumetric dependence of the airborne source, Figure 4.3.2 translates the data to dose and rate for the typical containment. The initial centerline rate is greater than 50 MR/hr (~75 MR/hr at 1 second) and the dose to 30 days is ~320 MR. The early time decay is very rapid, so that at 1 hour the dose rate is ~15 MR/hr and at 1 day ~1.7 MR/hr. The edge dose and rate are also shown; a reasonable assumption is that the edge dose and rate are ~1/2 the centerline values since a receptor at the edge is exposed to essentially a semi-infinite volume.

Figure 4.3.3 shows the dose rate assuming the waterborne source is somehow made airborne; section 4.2 discussed this assumption at some length. Figure 4.3.4 translates the normalized dose rate to dose and rate for the typical containment. The initial centerline dose rate is in excess of 15 MR/hr and the dose to 30 days is ~ 350 MR.

A more realistic model for the waterborne source is that the coolant water is collected somewhere. Figure 4.3.5 shows this case assuming that the water pool is 500 cm deep at the bottom of the containment, 1768-cm radius. As would be expected, the (1-minute) beta radiation essentially cannot escape the water, so that the dose rate in the air above the water is insignificant (compared to the airborne source); the infinite volume assumption is appropriate for betas in the water.

Figure 4.3.6 shows the dose rate from the plated-out iodines as a function of distance from the wall, with time after release a parameter. Even at 1 hour the edge dose rate exceeds ~40 MR/hr; however, at ~180 cm from the wall, the rate is ~1 MR/hr. The 25 percent of the iodines were assumed to be plated on the containment walls with a surface area of 7.06×10^7 cm^2; surface area is a normalizing factor.

The dose rate as a function of time after release, for the plate-out source, is shown in Figure 4.3.7, with distance from the wall a parameter. Under the assumptions, the rate very close to the wall (~5 cm) remains above 1 MR/hr until ~18 days after the hypothetical LOCA. However, when compared to the airborne source, the dose rates from the two sources are approximately equivalent at ~50 cm from the wall, so the dominant source is the airborne source. Similarly, the total plate-out surface should be expected to be much greater than the assumed 7.06×10^7 cm^2, since the (neglected) internal structure would add significantly to the surface area; this would almost proportionately lower the dose and rate from the plate-out source for the bulk of the containment, but could result in "hot spots" where surfaces are in close proximity to each other.

The dose and rate to a particular area of the containment is a combination of the three sources. Clearly the airborne source and the plate-out source are additive (spatially); the waterborne source is less spatially defined. However, as was done in Section 4.2, Figure 4.3.8 combines the three sources by assuming 1/10 of the waterborne source is added to the airborne and plate-out source. The resultant initial centerline dose rate is greater than 50 MR/hr and the dose to 30 days is ~370 MR. The edge (~5 cm) dose and rate are even more significant because of the plate-out source; the initial rate exceeds 80 MR/hr and the dose to 30 days is 5 to 6 times the centerline dose. While these are very significant doses and rates, the assumptions must be critically examined for specific plant applicability.

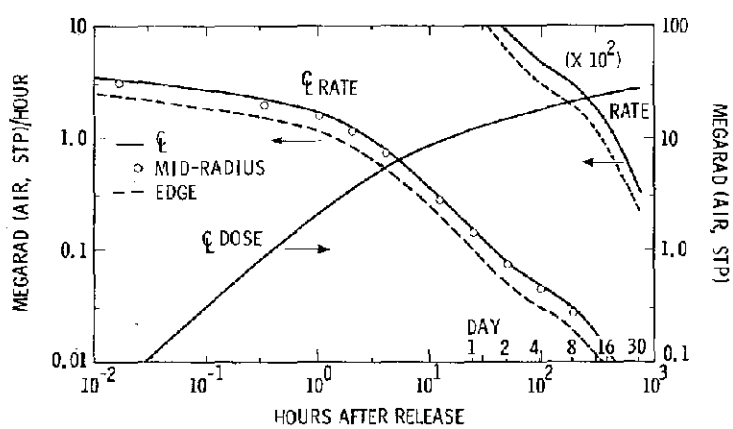

Figure 4.2.1. Rate and dose to air from the airborne gamma source uniformly distributed in the containment volume.

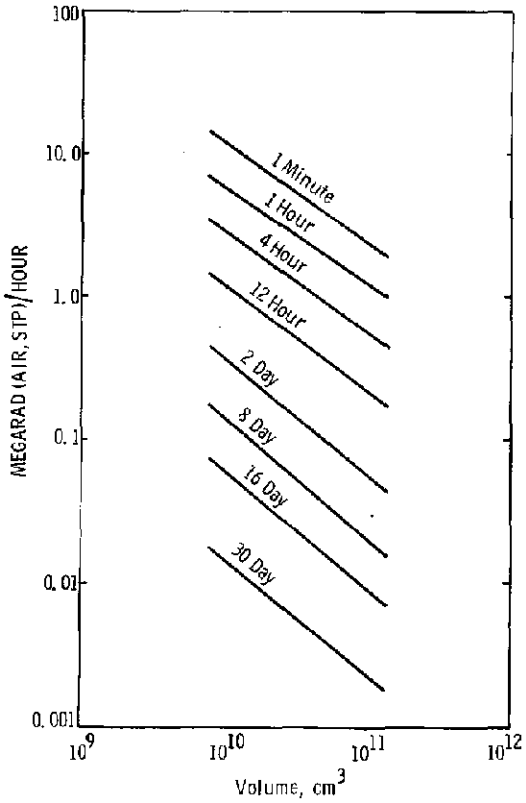

Figure 4.2.2. Dose rate to air at mid-axis from the airborne source as a function of containment volume.

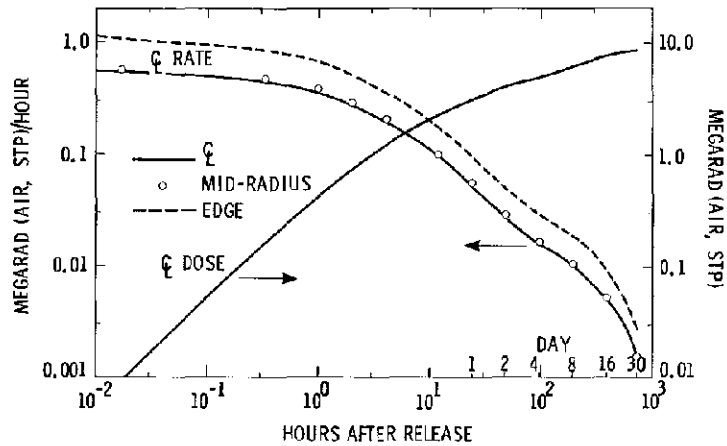

Figure 4.2.3. Rate and dose to air from the plate-out gamma source uniformly distributed on the containment sidewall surface.

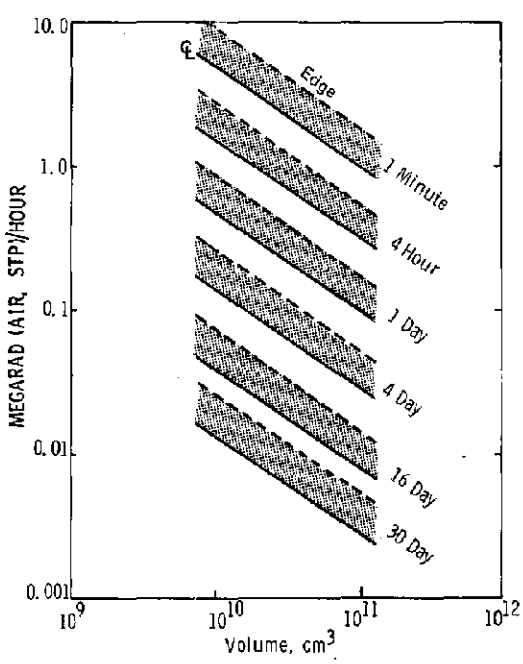

Figure 4.2.4. Dose rate to air from the plate-out gamma source as a function of containment volume (or sidewall surface area).

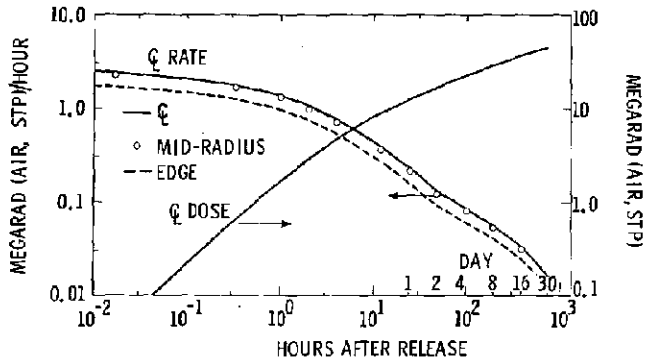

Figure 4.2.5. Rate and dose to air from the waterborne gamma source assumed uniformly distributed in the containment volume.

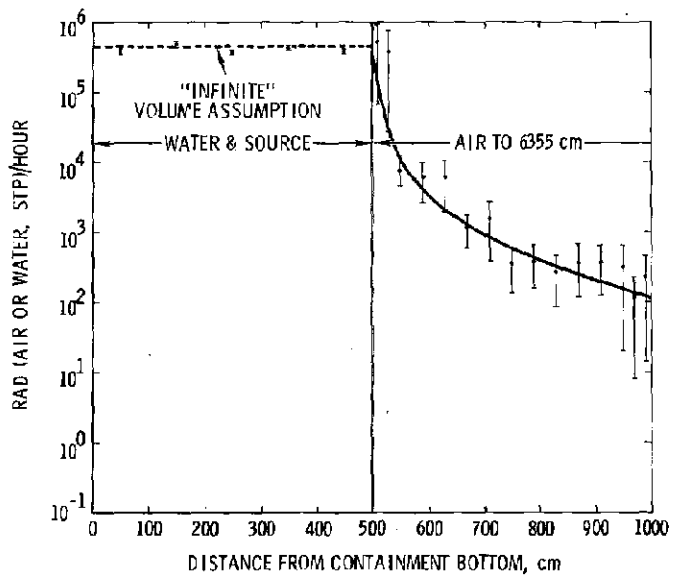

Figure 4.2.6. Dose rate along centerline from the 1-minute waterborne gamma source uniformly distributed in a 5-m deep pool at the bottom of the containment structure.

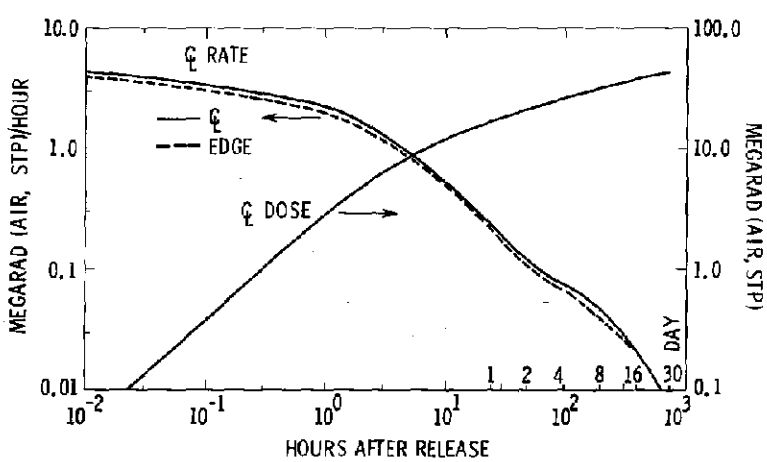

Figure 4.2.7. Rate and dose to air from the combined gamma sources; airborne source uniformly distributed in the containment volume, plate-out source uniformly distributed on the containment sidewall surface, 1/10 of the waterborne source assumed to be uniformly distributed in the containment volume.

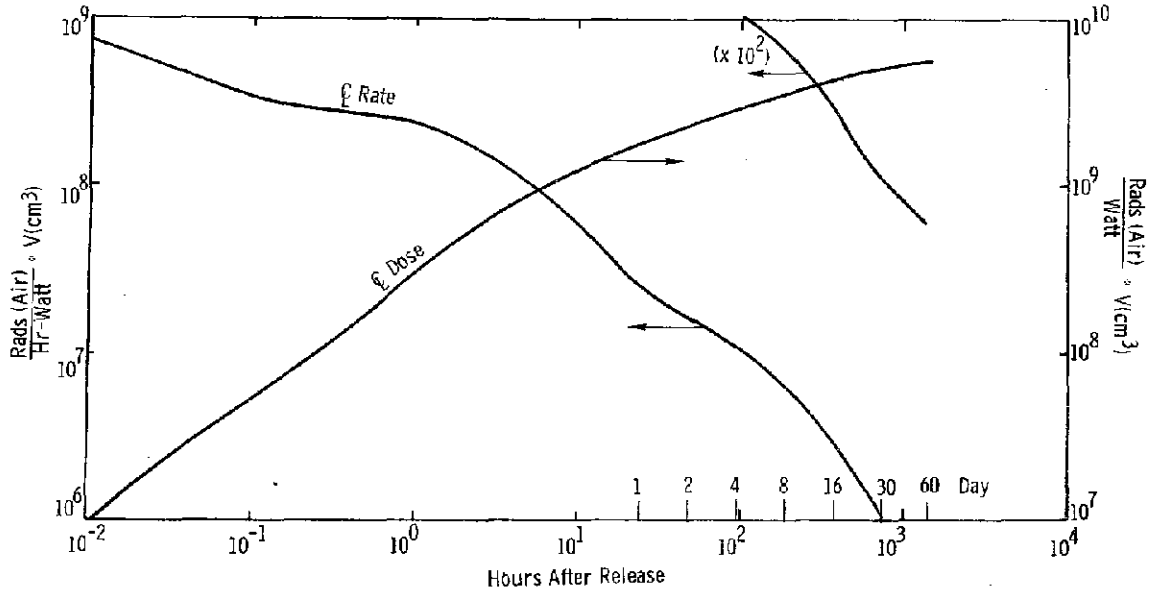

Figure 4.3.1. Rate and dose to air from the airborne beta source uniformly distributed in a normalized containment volume.

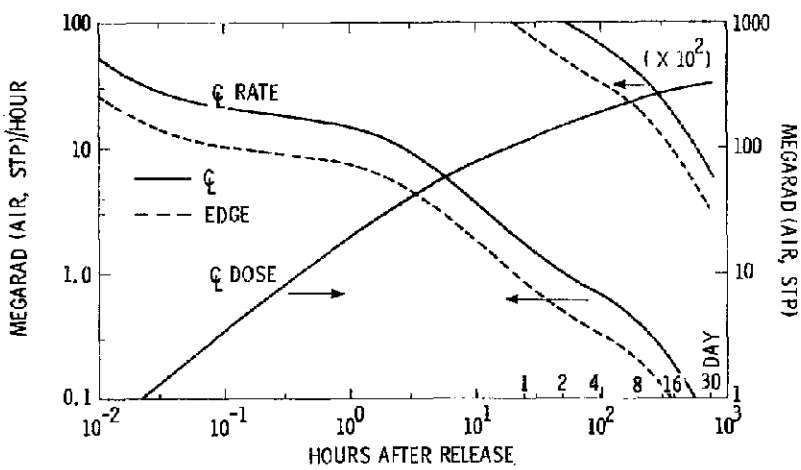

Figure 4.3.2. Rate and dose to air from the airborne beta source uniformly distributed in the containment volume.

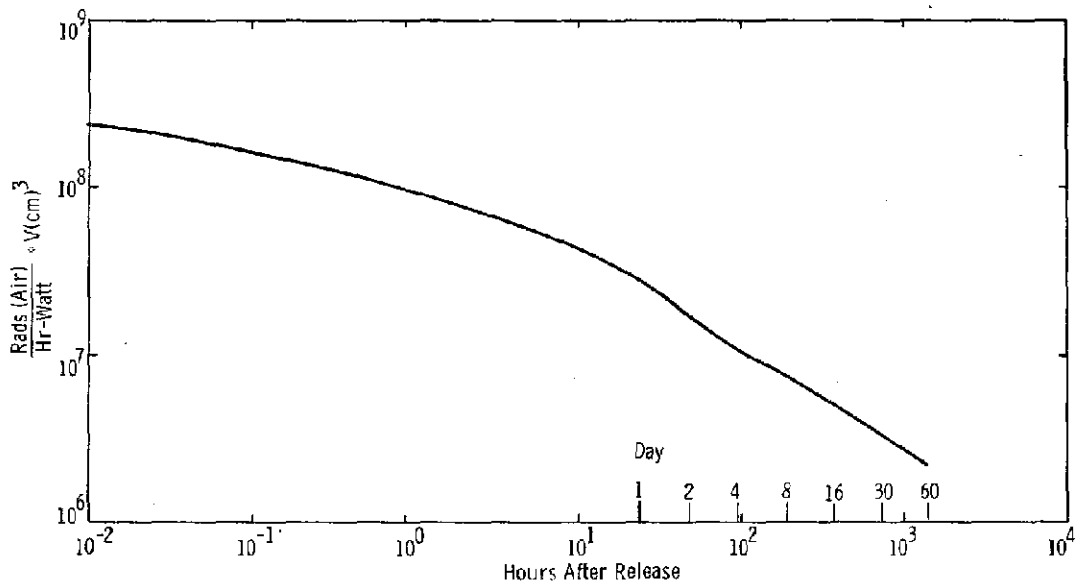

Figure 4.3.3. Dose rate to air from the waterborne beta source assumed uniformly distributed in a normalized containment volume.

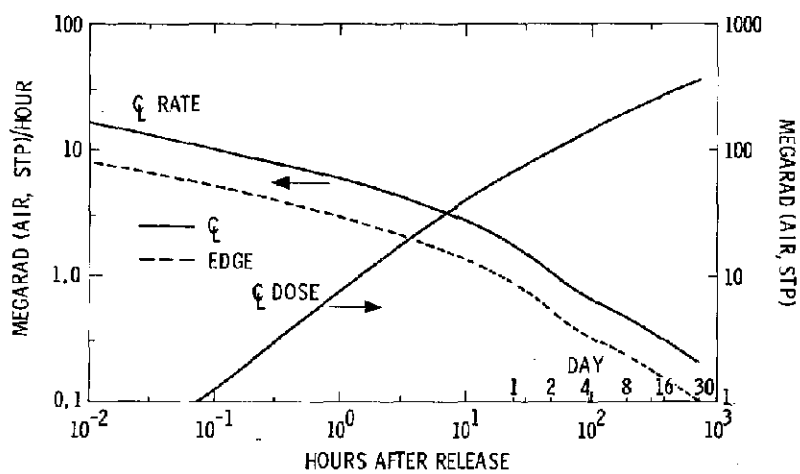

Figure 4.3.4. Rate and dose to air from the waterborne beta source assumed uniformly distributed in the containment volume.

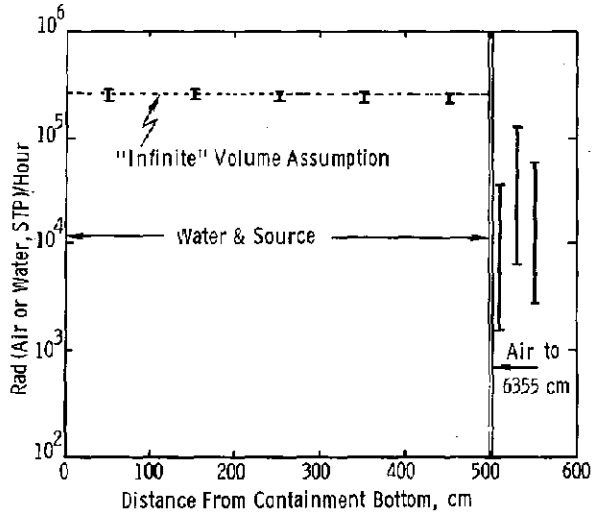

Figure 4.3.5. Dose rate along centerline from the 1-minute waterborne beta source uniformly distributed in a 5-m deep pool at the bottom of the containment structure.

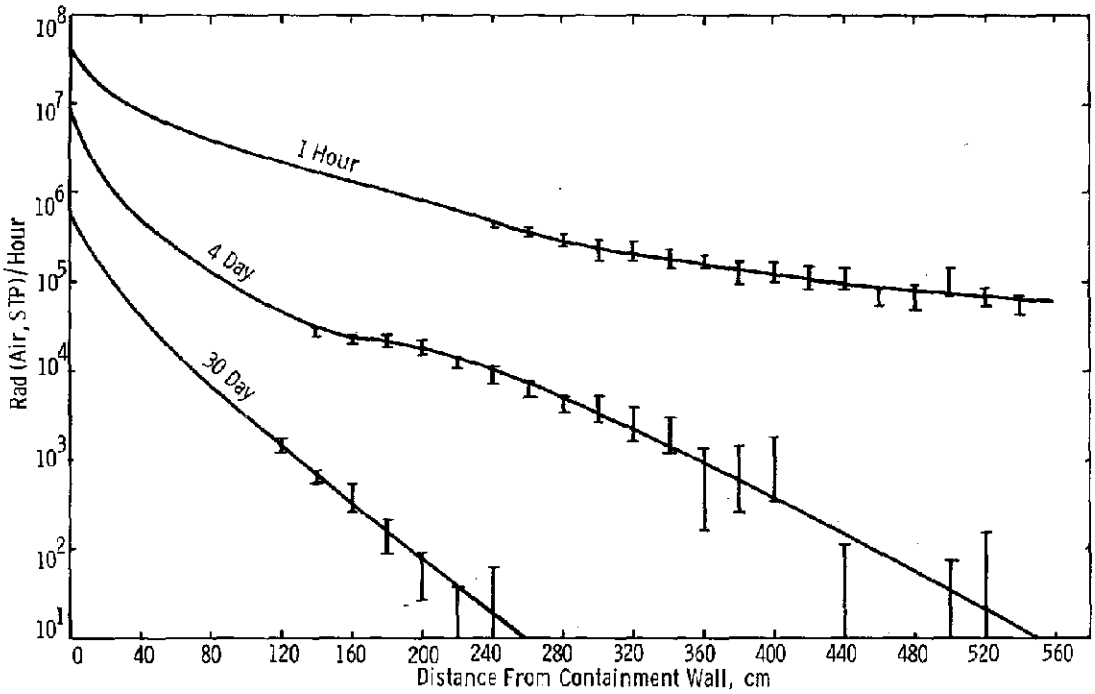

Figure 4.3.6. Dose rate from the plate-out beta source uniformly distributed on the containment sidewall surface, as a function of distance and time after release.

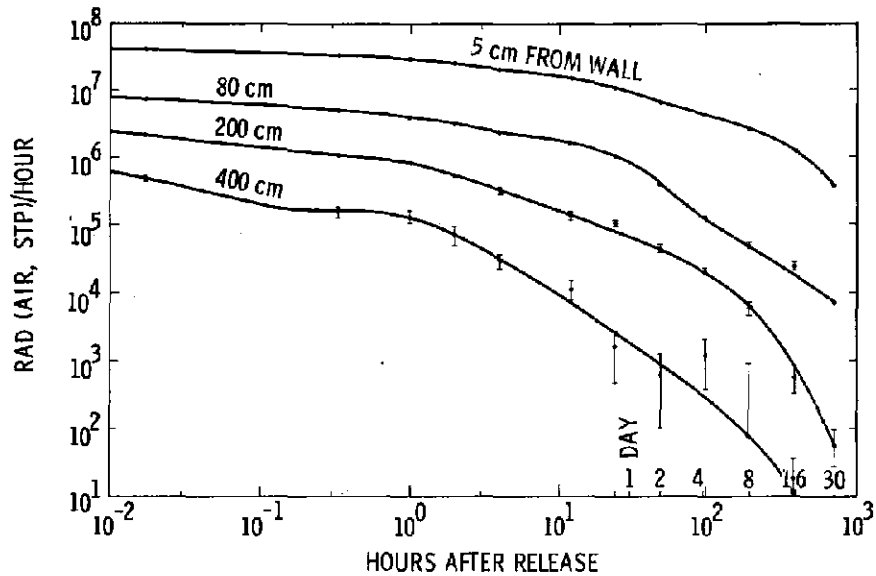

Figure 4.3.7. Dose rate from the plate-out beta source uniformly distributed on the containment sidewall surface, as a function of distance and time after release.

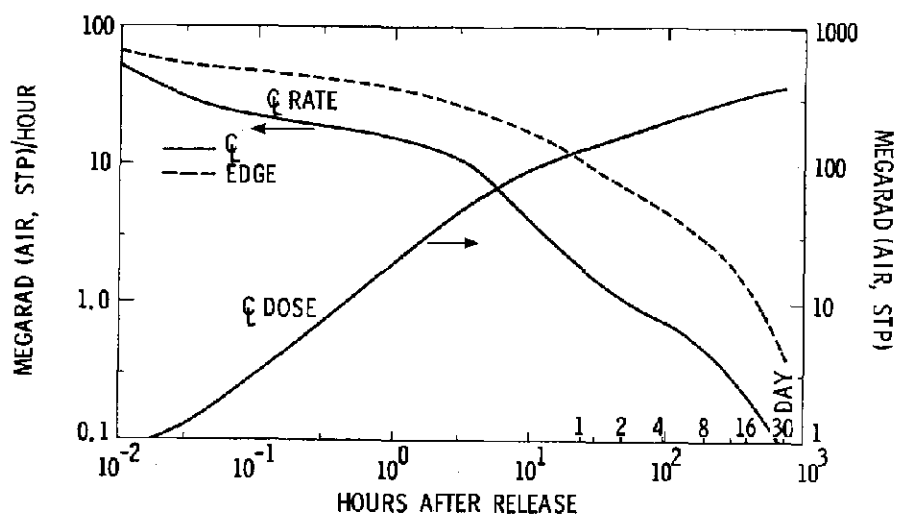

Figure 4.3.8. Rate and dose to air from the combined beta sources; airborne source uniformly distributed in the containment volume, plate-out source uniformly distributed on the containment sidewall surface, 1/10 of the waterborne source assumed to be uniformly distributed in the containment volume.

Chapter 5. Radiation Simulator Adequacy Methodology

Ultimately, the objective of this study is to determine the adequacy of existing radiation simulators in duplicating the effects that the hypothesized LOCA radiation signature would produce in Class I components. With the LOCA signature defined preliminarily in Chapters 2, 3, and 4, the comparison with simulators can be initiated.

Simulator adequacy cannot be judged on the basis of a direct comparison of the simulator radiation signature with the LOCA signature. Simulators, in general, do not produce time-dependent energy spectra; nor does a single simulator produce both usable gamma rays and beta particles. Instead, radiation qualification of Class I components is assured if the "correct" damage and damage mechanisms can be accomplished with simulators. While these are influenced by the differences in LOCA and simulator spectra and particle type, the simulator(s) may be "sufficiently" adequate with respect to component damage. The typical damage mechanisms for that adequacy evaluation include dose-rate effects, total dose effects, depth-dose effects, heating, and induced electrical conductivity. Ignoring the scaling factors implied by the specific dose rate and total dose, the most reliable indicator of radiation-environments damage equivalence is the equivalence of the resultant depth-dose profiles in the component; depth-dose profiles account for the energy-spectra and particle-type dependence of a radiation signature.

The assessment of simulator adequacy will initially proceed by calculating and evaluating damage in the simplest Class IE components to reduce the problems in computer modeling of these components. For example, such a simple component is an electrical cable which has a symmetrical cylindrical geometry. A common cable type would be a #12 AWG tinned copper wire (0.6543-cm diameter), with a 0.2286-cm ethylene propyline rubber (EPR) insulation, and a hypalon jacket, 0.1905-cm thick. EPR is basically $(CH_2)_n$ with a density of about 0.92 gm/cm^3; a hypalon material is $C_{85}H_{157}Cl_{13}SO_2$ with a density of about 1.29 gm/cm^3.

To further simplify the calculational geometry, it would be assumed that the cable is uniformly surrounded by the specific LOCA or simulator radiation sources. For the LOCA sources, this includes the airborne, plate-out, and waterborne sources. An assumption of uniformity avoids the reality of a cable located in cable trays, next to walls, etc., which affect the actual spatial source geometry. But these perturbations can be estimated, approximated, or further calculated as may be required. For the case of simulators, spatial and even cylindrical source symmetry is a good assumption since many irradiations are conducted with the source surrounding the component at some (equivalent) radial position.

Other modeling problems remain to be solved. Early, unpublished but similar calculations using a discrete-ordinates transport code produced unrealistic depth-dose profiles for the case of a Cobalt-60 simulator surrounding the cable at a fixed radius. These distorted profiles resulted

from the nature of the discrete-ordinates method in which the angular distribution of the gamma flux is represented by ordinates in a small number of discrete directions. In reality, the gammas are emitted isotropically. But because of the discrete propagation directions assumed in the calculation, the gammas did not uniformly "illuminate" the cable and the deposition profiles were severely distorted. An additional, but related, problem is that the cable dimensions are small relative to the source dimensions. For example, compare the cable diameter (1.49525 cm) with the dimension of the airborne gamma source which is effectively the containment dimensions (typically 35-m diameter and 60-m height). Only a very small number of particles will strike the cable because of its vanishingly small solid intercept angle with respect to the sources at a distance. This is difficult to model and it is difficult to "force" sufficient particle interactions with the cable to obtain reasonable computational statistical accuracy; this is particularly relevant for standard Monte Carlo transport calculations. In fact, more sophisticated calculational techniques may be appropriate, particularly the use of adjoint transport techniques.

In summary, the simulator adequacy assessment will proceed by calculating the depth-dose and charged-particle distribution profiles in simple Class I components. These calculations will be done for the several LOCA radiation sources and at several times during the LOCA since the energy spectra are a function of time. Similar calculations will be done for the most common simulators, e.g., Cobalt-60, Cesium-137, mixed fission products, electron and bremsstrahlung accelerators. These profiles can then be compared and evaluated against the available material data base and "adequacy" can be preliminarily assessed.

Chapter 6. Discussion and Suggested Topics

6.1 Summary

As discussed in Section 1.2, the ultimate objective of this study is to establish the "adequacy" of existing radiation simulators in duplicating the radiation environments resulting from the LOCA, as hypothesized in the Regulatory Guides. To date two subtasks have been completed, subject to incorporation of new data. These are the definition of the LOCA radiation environment (Chapters 2 and 3) and the scoping of the expected and resultant dose and rates in a typical containment (Chapter 4). Very preliminary discussion on evaluating simulator(s) adequacy has been included in Chapter 5, but this is so preliminary that it merely serves to outline the method to be used in evaluating simulators.

Three significant features of this study are:

1. A (formal) definition of expectable magnitudes of the gamma and beta dose and rate for a typical containment, using the applicable Regulatory Guides. These values are further segregated according to their spatial dependence as waterborne, airborne, and plate-out sources. The implications of the spatial dependence may be significant in radiation qualification testing, and should at least be a consideration.

2. A (formal) recognition that the beta dose and rate is significantly greater than the corresponding gamma values. Apparently, the bulk of the testing to date considers only the gamma contribution, but betas have been shown, in this report, to contribute perhaps seven times more dose (to 30 days) and to have significantly greater dose rates; e.g., initial rates of ~ 70 MR/hr. Both measures of radiation are very significant in radiation qualification testing. (The importance of the particle type is a consideration in evaluating the adequacy of simulators, and may prove to be very significant.)

3. A definition of the LOCA radiation sources energy spectra as a function of time following the hypothesized releases. Both the gamma and beta spectra exhibit a changing energy dependence with time. For mono- or fixed-energy simulators, the changing spectra cannot be followed. While not a clearly important test parameter, this must be a consideration in testing and will be a consideration in evaluating the adequacy of simulators. The resolved energy spectra also demonstrates an apparent sensitivity to the assumed nuclide fractionation. This could be an important feature if a new LOCA source term were hypothesized.

6.2 Suggested Topics

The effort to date has suggested several topics which should be considered for further investigation as this study proceeds. These are listed in a general priority ranking.

1. The gamma and beta signatures should be further compared with other code results. This is particularly true of the beta profiles where an apparent discrepancy was noted (Section 3.2); arrangements are currently being made to have additional CINDER runs made for comparison. A corollary to this task is to update the existing gamma and beta decay scheme library as new data become available.

2. The evaluation of simulators should proceed as quickly as possible; only the common and existing simulators will be considered. The comparison should be made on the basis of depth-dose calculations for several typical Class I-level components (e.g., cable, paint, seals), to assure a comprehensive comparison.

3. The sensitivity of the energy spectra should be evaluated to determine the effect of varying the nuclide fractionation.

4. A more realistic representation of the LOCA radiation source could be constructed based on a prescribed accident sequencing, as suggested in WASH-1400 and supported by ongoing experimental programs. The sequencing would account for the time-dependence and the magnitude of the releases. WASH-1400 provides estimates for the four categories of release (gap, meltdown, vaporization, and steam explosion fractions) and for the time (given as a range) of each release occurrence.

5. An evaluation of dose-rate damage phenomena should be initiated with the intent of allowing lowered testing rates than would be dictated by the hypothesized LOCA. A determination of the range of dose rates where rate effects are not significant would be made for typical Class I components.

6. Based on the calculated depth-dose profiles from the hypothesized LOCA and simulator sources, an evaluation of damage and damage mechanisms could be attempted; the necessity for duplicating the depth-dose could be judged.

7. Depending on the results of these studies, some effort should be directed at tailoring/designing radiation simulators to achieve better duplication of the actual damage profiles.

References

1. "IEEE Standard for Qualifying Class IE Equipment for Nuclear Power Generating Stations," IEEE Std 323-1974, the Institute of Electrical and Electronics Engineers, Inc., 1974.

2. "Qualification of Class IE Equipment for Nuclear Power Plants," Regulatory Guide 1.89, Rev 1, Draft 3, December 1, 1975.

3. "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Boiling Water Reactors," Regulatory Guide 1.3, Rev. 1, June 1973.

4. "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Pressurized Water Reactors," Regulatory Guide 1.4, Rev. 1, June 1973.

5. "Control of Combustible Gas Concentrations in Containment Following a Loss of Coolant Accident," Safety Guide 7, March 10, 1971.

6. "Response to Request for Additional Information Concerning Regulatory Guide 1.89 on Qualification of Class IE Equipment," Note for Raymond F. Fraley (ACRS/USNRC) from Robert B. Minogue, dated December 11, 1975.

7. "Computational Methods for Calculation of Radiological Dose Resulting from Hypothetical Fission Product Release," L. L. Bonzon and J. B. Rivard, Sandia Laboratories, SC-RR-70-338, July 1970.

8. Table of Isotopes, Sixth Edition, C. M. Lederer, J. M. Hollander, and I. Perlman, John Wiley & Sons, Inc., 1967.

9. "ORIGEN - the ORNL Isotope Generation and Depletion Code," M. J. Bell, ORNL-4628, Oak Ridge National Laboratory, May 1973.

10. "CINDER-7: An Interim Users Report," T. R. England, R. Wilczynski, and N. L. Whittemore, LA-5885-MS, Los Alamos Scientific Laboratory, 1975.

11. "Reactor Safety Study: An Assessment of Accident Risks in U. S. Commercial Nuclear Power Plants; Appendix VII, Release of Radioactivity in Reactor Accidents," WASH-1400, NUREG 75/014, U. S. Nuclear Regulatory Commission, October 1975.

12. The Atomic Nucleus, R. D. Evans, McGraw-Hill Book Co., New York, 1955.

13. The Oconee Power Station structure was used as a typical-sized containment.

14. James H. Renken, Kenneth G. Adams, "An Improved Capability for Solution of Photon Transport Problems by the Method of Discrete Ordinates," Sandia Laboratories, SC-RR-69-739, December 1969.

15. "CYLTRAN: A Cylindrical-Geometry Multi-Material Electron/Photon Monte Carlo Transport Code," J. A. Halbleib and W. H. Vandevender, Sandia Laboratories, SAND74-0030, March 1975.

APPENDIX A

GAMMA DECAY SCHEMES

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	NUCLIDE MEV/DIS
ZN-72	.015	8.00	.1514
	.046	1.00	
	.145	90.00	
	.192	10.00	
GA-72	.631	8.00	2.4792
	.630	27.00	
	.835	96.00	
	.894	10.00	
	1.050	7.00	
	1.465	3.50	
	1.600	5.00	
	1.860	5.00	
	2.201	26.00	
	2.500	20.00	
GA-73	.054	9.00	.3266
	.295	94.00	
	.740	6.00	
GA-74	.500	11.00	2.2488
	.600	100.00	
	.870	9.00	
	1.110	5.00	
	1.200	8.00	
	1.330	5.00	
	1.460	8.00	
	1.760	7.00	
	2.350	45.00	
GE-75M	.139	34.00	.0473
GE-75	.066	.30	.0355
	.199	1.40	
	.265	11.00	
	.427	.30	
	.477	.30	
	.628	.10	
GE-77M	.159	12.00	.0642
	.215	21.00	
GE-77	.210	61.00	.8389
	.263	45.00	
	.368	15.00	
	.417	25.00	
	.563	18.00	
	.632	11.00	
	.730	14.00	
	.800	6.00	
	.930	5.00	
	1.090	6.00	
GE-78	.277	94.00	.2604

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	NUCLIDE MEV/DIS
AS-76	.559	43.00	.3751
	.657	6.00	
	1.220	5.00	
	1.440	.70	
	1.789	.30	
	2.100	.50	
AS-77	.086	.10	.0102
	.239	2.50	
	.522	.80	
AS-78	.614	66.60	.9407
	.700	24.30	
	.830	16.30	
	1.310	16.90	
AS-79	.350	2.00	.0310
	.430	2.00	
	.540	.50	
	.730	.50	
	.890	1.00	
AS-80	.666	42.00	.4354
	.800	1.40	
	1.220	4.00	
	1.640	4.00	
	1.770	1.70	
SE-79M	.096	9.30	.0086
SE-81M	.103	8.00	.0082
SE-81	.030	.06	.0059
	.280	.90	
	.560	.30	
	.830	.20	
SE-83M	.350	9.00	1.1433
	.650	11.00	
	1.010	57.00	
	2.020	23.00	
SE-83	.220	44.00	2.1738
	.360	69.00	
	.520	59.00	
	.710	25.00	
	.830	41.00	
	1.060	16.00	
	1.310	25.00	
	1.880	16.00	
	2.290	9.00	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	NUCLIDE MEV/DIS
BR-82	.554	66.00	2.5557
	.619	41.00	
	.698	27.00	
	.777	83.00	
	.828	25.00	
	1.044	29.00	
	1.317	26.00	
	1.475	17.00	
BR-83	.530	1.40	.0074
BR-84A	.810	9.00	1.7216
	.880	51.00	
	1.010	10.00	
	1.210	4.00	
	1.900	18.00	
	2.470	8.00	
	3.930	13.00	
BR-84B	.440	68.00	2.3566
	.880	75.00	
	1.460	75.00	
	1.890	16.00	
BR-86	1.290	5.00	1.8100
	1.360	17.00	
	1.560	44.00	
	1.970	9.00	
	2.340	9.00	
	2.750	16.00	
BR-87	1.440	51.00	3.8220
	1.850	9.00	
	2.480	9.00	
	2.640	8.00	
	2.980	13.00	
	3.180	8.00	
	3.800	5.00	
	4.190	11.00	
	4.800	9.00	
	5.000	9.00	
	5.200	6.00	
BR-88	.760	100.00	.7600
KR-83M	.009	9.00	.0008
KR-85M	.150	74.00	.1506
	.305	13.00	
KR-85	.514	.41	.0021

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	NUCLIDE MEV/DIS
KR-87	.403	84.00	1.3740
	.850	16.00	
	2.570	35.00	
KR-88	.028	1.00	1.7434
	.166	7.00	
	.191	35.00	
	.360	5.00	
	.850	23.00	
	1.550	14.00	
	2.190	18.00	
	2.400	35.00	
KR-89	.230	25.00	1.8044
	.360	8.00	
	.430	9.00	
	.510	13.00	
	.600	30.00	
	.740	6.00	
	.880	19.00	
	1.120	13.00	
	1.290	9.00	
	1.510	26.00	
	1.710	10.00	
	1.930	3.00	
	2.040	5.00	
	2.230	3.00	
	2.420	7.00	
KR-90	.105	15.00	1.5389
	.120	65.00	
	.236	16.00	
	.495	12.00	
	.536	48.00	
	1.110	48.00	
	1.540	17.00	
	1.790	11.00	
	2.480	4.00	
RB-86	1.078	8.80	.0949
RB-88	.898	13.00	.5696
	1.863	21.00	
	2.680	2.30	
RB-89	.650	17.00	2.2248
	1.050	75.00	
	1.260	54.00	
	2.200	14.00	
	2.590	13.00	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	NUCLIDE MEV/DIS
RB-90	.530	4.00	3.2827
	.830	61.00	
	1.030	5.00	
	1.110	7.00	
	1.400	5.00	
	1.700	3.00	
	3.070	5.00	
	3.340	15.00	
	3.540	5.00	
	4.130	11.00	
	4.340	18.00	
	4.600	5.00	
	5.200	4.00	
SR-89	.910	.01	.0001
SR-91	.645	15.00	.7048
	.748	27.00	
	.930	3.00	
	1.025	30.00	
	1.413	5.00	
SR-92	.230	3.00	1.2575
	.440	4.00	
	1.370	90.00	
SR-93	.600	50.00	1.3000
	.800	50.00	
	1.200	50.00	
SR-94	1.420	100.00	1.4200
Y-91M	.551	95.00	.5234
Y-91	1.210	.30	.0036
Y-92	.448	2.30	.2287
	.560	2.60	
	.934	14.00	
	1.400	4.70	
	1.830	.40	
Y-93	.267	6.00	.0930
	.670	.70	
	.940	2.30	
	1.420	.70	
	1.900	1.30	
	2.180	.30	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	NUCLIDE MEV/DIS
Y-94	.560	6.00	.7240
	.920	43.00	
	1.130	5.00	
	1.650	2.40	
	1.900	1.60	
	2.130	2.40	
	2.570	1.50	
	3.060	1.30	
	3.530	1.10	
Y-95	1.300	35.00	1.0850
	1.800	35.00	
ZR-95	.724	49.00	.7252
	.756	49.00	
ZR-97	.747	92.00	.6872
NB-95M	.235	100.00	.2350
NB-95	.765	100.00	.7650
NB-97M	.747	98.00	.7321
NB-97	.665	98.00	.6517
NB-98	.330	9.00	2.3071
	.720	75.00	
	.787	100.00	
	1.160	30.00	
	1.440	10.00	
	1.520	4.00	
	1.680	10.00	
	1.880	4.00	
	1.930	8.00	
NB-100	.140	25.00	2.2695
	.360	135.00	
	.450	100.00	
	.530	245.00	
MO-99	.041	2.00	.1372
	.181	7.00	
	.372	1.00	
	.740	12.00	
	.780	4.00	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	NUCLIDE MEV/DIS
MO-101	.191	25.00	1.4720
	.510	15.00	
	.590	21.00	
	.700	11.00	
	.890	15.00	
	1.020	25.00	
	1.180	11.00	
	1.380	9.00	
	1.560	11.00	
	2.080	16.00	
MO-104	.070	100.00	.0700
TC-99M	.140	90.00	.1260
TC-100	.540	50.00	.6700
	.600	50.00	
	1.000	10.00	
TC-101	.130	3.00	.3323
	.307	91.00	
	.545	9.00	
TC-102	.470	100.00	.4700
TC-103	.135	23.00	.0702
	.210	12.00	
	.350	4.00	
TC-104	.360	150.00	2.8350
	.530	150.00	
	1.000	150.00	
TC-105	.110	100.00	.1100
RU-103	.497	88.00	.4740
	.610	5.00	
RU-105	.263	6.00	.6253
	.317	11.00	
	.400	6.00	
	.475	20.00	
	.670	15.00	
	.726	48.00	
RU-107	.195	14.00	.2175
	.860	7.00	
	.930	4.00	
	1.030	4.00	
	1.290	4.00	
RU-108	.165	28.00	.0462
RH-103M	.040	.40	.0002

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	NUCLIDE MEV/DIS
RH-104M	.051	47.00	.0313
	.078	2.50	
	.097	2.60	
	.560	.18	
	.770	.24	
RH-104	.560	2.00	.0128
	1.240	.13	
RH-105M	.129	100.00	.1290
RH-105	.306	5.00	.0759
	.319	19.00	
RH-106A	.512	21.00	.1982
	.622	11.00	
	1.050	1.50	
	1.130	.30	
	1.550	.20	
RH-106B	.220	18.00	2.3736
	.406	18.00	
	.451	35.00	
	.512	88.00	
	.616	29.00	
	.735	41.00	
	.820	35.00	
	1.046	25.00	
	1.128	12.00	
	1.223	17.00	
	1.560	18.00	
RH-107	.305	73.00	.2859
	.390	11.00	
	.680	3.00	
RH-108	.434	43.00	.3740
	.510	10.00	
	.620	22.00	
PD-109M	.188	58.00	.1090
PD-109	.088	5.00	.0047
	.129	.01	
	.310	.01	
	.410	.01	
	.600	.03	
	.640	.01	
PD-111M	.170	100.00	.1700

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	NUCLIDE MEV/DIS
PD-111	.380	2.00	.0828
	.600	5.00	
	.810	.40	
	1.400	3.00	
PD-112	.019	20.00	.0038
AG-109M	.088	5.00	.0044
AG-110M	.658	96.00	2.5002
	.680	16.00	
	.706	19.00	
	.764	23.00	
	.818	8.00	
	.885	71.00	
	.937	32.00	
	1.384	21.00	
	1.505	11.00	
AG-110	.658	4.50	.0296
AG-111M	.065	100.00	.0650
AG-111	.247	1.00	.0230
	.342	6.00	
AG-112	.617	41.00	.4862
	1.400	5.00	
	1.630	3.00	
	2.110	3.00	
	2.550	2.00	
AG-113M	.140	20.00	.4180
	.300	20.00	
	.390	20.00	
	.560	20.00	
	.700	20.00	
AG-113	.120	10.20	.5912
	.300	100.80	
	.580	4.40	
	.670	17.50	
	.880	4.40	
	.980	4.40	
	1.180	4.40	
AG-114	.570	100.00	.5700

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	NUCLIDE MEV/DIS.
AG-115	.140	12.00	1.0628
	.220	49.00	
	.280	13.00	
	.360	11.00	
	.420	7.00	
	.470	10.00	
	.640	4.00	
	1.480	11.00	
	1.660	8.00	
	1.890	10.00	
	2.120	13.00	
AG-116	.520	50.00	.6100
	.700	50.00	
CD-115M	.485	.31	.0309
	.935	1.90	
	1.290	.90	
CD-115	.230	.60	.1934
	.262	2.00	
	.490	10.00	
	.530	26.00	
CD-117	.089	7.00	.9256
	.273	31.00	
	.314	16.00	
	.345	18.00	
	.434	13.00	
	.832	4.00	
	.880	3.00	
	.950	4.00	
	1.052	5.00	
	1.303	19.00	
	1.577	17.00	
IN-115M	.335	50.00	.1675
IN-116	.434	.12	.0170
	.950	.10	
	1.293	1.20	
IN-117M	.158	14.00	.1195
	.314	31.00	
IN-117	.158	37.00	.7025
	.565	100.00	
IN-118A	1.230	15.00	.1845
IN-118B	.690	41.00	2.3772
	1.050	80.00	
	1.230	97.00	
	2.040	3.00	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	NUCLIDE MEV/DIS
IN-119M	.024	5.00	.0617
	.300	5.00	
	.910	5.00	
IN-119	.820	95.00	.7790
IN-120	.090	12.00	2.8311
	.198	9.00	
	.710	12.00	
	.860	34.00	
	.940	12.00	
	1.020	61.00	
	1.171	100.00	
	1.280	14.00	
	1.470	6.00	
	1.870	7.00	
	2.010	6.00	
IN-121	.940	100.00	.9400
IN-123	1.100	100.00	1.1000
SN-119M	.024	16.00	.0038
SN-123	1.080	2.00	.0216
SN-125M	.325	97.00	.3152
SN-125	.342	.30	.0870
	.468	.40	
	.811	1.50	
	.904	1.40	
	1.068	4.00	
	1.170	.14	
	1.410	.14	
	1.970	.60	
	2.230	.05	
SN-127	.440	40.00	.7720
	.490	40.00	
	1.000	40.00	
SN-128	.044	7.00	.4472
	.072	19.00	
	.500	61.00	
	.570	22.00	
SB-122M	.061	50.00	.0432
	.075	17.00	
SB-122	.564	66.00	.4124
	.686	3.40	
	1.140	.70	
	1.260	.70	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	NUCLIDE MEV/DIS
SB-124M	.505	20.00	.3504
	.603	20.00	
	.644	20.00	
SB-124	.603	97.00	1.9081
	.644	7.00	
	.720	14.00	
	.967	2.40	
	1.048	2.40	
	1.310	3.00	
	1.370	5.00	
	1.450	2.00	
	1.692	50.00	
	2.088	7.00	
SB-125	.176	6.00	.4225
	.427	31.00	
	.463	10.00	
	.599	24.00	
	.634	11.00	
	.660	3.00	
SB-126A	.410	50.00	1.4125
	.690	175.00	
SB-126B	.410	50.00	1.2100
	.670	150.00	
SB-127	.060	40.00	.5240
	.250	40.00	
	1.000	40.00	
SB-128A	.320	83.00	1.8084
	.750	200.00	
	1.070	4.00	
SB-128B	.314	74.00	1.6532
	.530	74.00	
	.640	74.00	
	.750	74.00	
SB-129	.073	72.00	1.0174
	.340	72.00	
	1.000	72.00	
SB-130A	.190	100.00	2.2800
	.330	100.00	
	.820	100.00	
	.940	100.00	
SB-130B	.200	63.00	2.0223
	.820	63.00	
	1.030	63.00	
	1.160	63.00	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	NUCLIDE MEV/DIS
SB-131	.640	37.00	.6928
	.950	48.00	
TE-125M	.035	7.00	.0028
	.110	.30	
TE-127M	.059	.19	.0002
	.089	.08	
	.670	.00	
TE-127	.058	.01	.0015
	.210	.03	
	.360	.05	
	.417	.30	
TE-129M	.690	6.00	.0414
TE-129	.027	19.00	.0983
	.275	1.70	
	.455	15.00	
	.810	.50	
	1.080	1.50	
TE-131M	.081	2.00	1.1897
	.102	5.00	
	.200	8.00	
	.241	8.00	
	.336	9.00	
	.780	60.00	
	.850	31.00	
	1.127	13.00	
	1.206	11.00	
	1.629	3.00	
	1.860	1.00	
	1.965	2.00	
TE-131	.150	68.00	.3606
	.453	16.00	
	.493	5.00	
	.603	4.00	
	.950	3.00	
	1.000	4.00	
	1.147	6.00	
TE-132	.053	17.00	.2160
	.230	90.00	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	NUCLIDE MEV/DIS
TE-133M	.310	22.00	2.1245
	.432	50.00	
	.470	22.00	
	.557	35.00	
	.630	18.00	
	.700	24.00	
	.754	85.00	
	.910	57.00	
	1.010	10.00	
TE-133	.150	120.00	1.7520
	.310	120.00	
	1.000	120.00	
TE-134	.080	13.00	.1302
	.170	16.00	
	.204	21.00	
	.262	19.00	
I-128	.441	14.00	.0735
	.528	1.40	
	.743	.20	
	.969	.30	
I-129	.040	9.00	.0036
I-130	.419	35.00	2.1327
	.538	99.00	
	.669	100.00	
	.743	87.00	
	1.150	12.00	
I-131	.080	2.60	.3708
	.284	5.40	
	.364	82.00	
	.637	6.80	
	.723	1.50	
I-132	.240	1.00	2.3885
	.520	20.00	
	.670	144.00	
	.773	89.00	
	.955	22.00	
	1.140	6.00	
	1.280	7.00	
	1.400	14.00	
	1.450	1.00	
	1.910	1.30	
	1.990	1.30	
I-133	.530	90.00	.4770

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	NUCLIDE MEV/DIS
I-134	.135	3.00	1.9355
	.410	8.00	
	.550	8.00	
	.610	18.00	
	.850	95.00	
	.890	65.00	
	1.070	1.40	
	1.150	10.00	
	1.460	4.00	
	1.620	5.00	
	1.790	5.00	
I-135	.420	7.00	1.7746
	.860	11.00	
	1.040	9.00	
	1.140	37.00	
	1.280	34.00	
	1.460	12.00	
	1.720	19.00	
	1.800	11.00	
I-135	.200	12.00	2.4847
	.270	18.00	
	.390	19.00	
	1.320	95.00	
	2.300	19.00	
	2.830	10.00	
	2.800	8.00	
	3.200	5.00	
XE-131M	.164	2.00	.0033
XE-133M	.233	14.00	.0326
XE-133	.081	37.00	.0300
XE-135M	.527	80.00	.4216
XE-135	.250	91.00	.2458
	.610	3.00	
XE-137	.455	33.00	.1502
XE-138	.160	10.00	.4950
	.260	16.00	
	.420	7.00	
	.510	2.00	
	1.790	11.00	
	2.020	10.00	
XE-139	.180	38.00	.6524
	.220	90.00	
	.300	52.00	
	1.150	20.00	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	NUCLIDE MEV/DIS.
XE-140	.130	100.00	.1300
CS-134M	.126	14.00	.0179
CS-134	.570	23.00	1.5910
	.605	98.00	
	.796	99.00	
	1.038	1.00	
	1.168	1.90	
	1.365	3.40	
CS-136	.067	11.00	2.2285
	.086	6.00	
	.160	36.00	
	.273	18.00	
	.340	53.00	
	.818	100.00	
	1.050	82.00	
	1.250	20.00	
CS-137	.662	85.00	.5627
CS-138	.463	23.00	2.0785
	.550	8.00	
	1.010	25.00	
	1.428	73.00	
	2.210	18.00	
	2.630	9.00	
CS-139	.500	15.00	.7590
	1.280	30.00	
	2.000	15.00	
CS-140	.590	40.00	1.5880
	.880	40.00	
	2.500	40.00	
BA-137M	.662	89.00	.5892
BA-139	.166	23.00	.0439
	1.430	.40	
BA-140	.030	11.00	.2359
	.163	6.00	
	.305	6.00	
	.438	5.00	
	.537	34.00	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	NUCLIDE MEV/DIS
BA-141	.118	7.50	.9797
	.193	75.00	
	.280	38.00	
	.310	45.00	
	.350	15.00	
	.460	23.00	
	.640	15.00	
	.730	6.00	
	.860	5.00	
	.930	2.50	
	1.190	6.00	
	1.290	2.50	
	1.420	5.00	
	1.650	2.50	
BA-142	.080	13.00	.5713
	.260	43.50	
	.890	17.40	
	.970	6.50	
	1.080	4.40	
	1.200	15.20	
LA-140	.329	20.00	2.1158
	.487	40.00	
	.815	19.00	
	.923	10.00	
	1.596	96.00	
	2.530	3.00	
LA-141	1.370	2.00	.0274
LA-142	.650	48.00	1.8842
	.900	9.00	
	1.010	5.00	
	1.060	4.00	
	1.550	5.00	
	1.740	5.00	
	1.910	9.00	
	2.060	6.00	
	2.410	15.00	
	2.550	11.00	
	2.990	5.00	
	3.310	1.90	
	3.650	2.30	
LA-143	.620	22.00	.8651
	.800	10.00	
	1.070	6.00	
	1.170	13.00	
	1.580	6.00	
	1.980	8.00	
	2.560	7.00	
CE-141	.145	48.00	.0696

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	NUCLIDE MEV/DIS
CE-143	.057	11.00	.2766
	.293	46.00	
	.493	2.40	
	.668	7.00	
	.725	8.00	
	.880	1.40	
	1.100	.60	
CE-144	.080	2.00	.0163
	.134	11.00	
CE-146	.110	12.00	.3075
	.142	24.00	
	.220	28.00	
	.270	6.00	
	.320	57.00	
PR-142	1.570	3.70	.0581
PR-144	.695	1.50	.0300
	1.487	.29	
	2.186	.70	
PR-145	.072	3.20	.0561
	.680	3.20	
	1.000	3.20	
PR-146	.455	77.00	1.4070
	.740	16.00	
	.780	15.00	
	.920	6.00	
	1.370	6.00	
	1.510	27.00	
	1.720	4.00	
	2.230	4.00	
	2.390	3.00	
	2.730	1.70	
PR-148	.300	100.00	.3000
ND-147	.091	28.00	.1215
	.319	3.00	
	.430	4.00	
	.533	13.00	
ND-149	.114	18.00	.3211
	.156	4.00	
	.210	27.00	
	.270	26.00	
	.327	5.00	
	.424	9.00	
	.541	10.00	
	.654	9.00	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	NUCLIDE MEV/DIS
ND-151	.086	5.00	.3160
	.118	40.00	
	.138	6.00	
	.174	10.00	
	.256	11.00	
	.425	5.00	
	.737	5.00	
	.797	3.00	
	1.122	2.00	
	1.180	9.00	
PM-148M	.289	13.00	1.8364
	.413	17.00	
	.551	95.00	
	.630	87.00	
	.727	36.00	
	.916	21.00	
	1.015	20.00	
PM-148	.551	27.00	.6228
	.914	15.00	
	1.465	23.00	
PM-149	.286	2.00	.0080
	.580	.10	
	.850	.20	
PM-151	.070	5.00	.2265
	.100	7.00	
	.170	18.00	
	.240	5.00	
	.275	6.00	
	.340	21.00	
	.450	5.00	
	.660	3.00	
	.720	6.00	
PM-152	.122	350.00	1.2845
	.245	350.00	
SM-151	.022	4.00	.0009
SM-153	.070	5.40	.0356
	.103	28.00	
	.500	.60	
SM-155	.104	73.00	.0858
	.246	4.00	
SM-156	.088	30.00	.1050
	.166	10.00	
	.204	20.00	
	.250	5.00	
	.291	3.00	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	NUCLIDE MEV/DIS.
EU-154	.123	38.00	1.1776
	.248	7.00	
	.593	6.00	
	.724	21.00	
	.759	5.00	
	.876	12.00	
	1.000	31.00	
	1.278	37.00	
EU-155	.087	32.00	.0488
	.105	20.00	
EU-156	.089	8.00	.9562
	.646	7.00	
	.723	6.00	
	.812	9.00	
	1.070	11.00	
	1.150	14.00	
	1.240	16.00	
	1.970	7.00	
	2.098	3.00	
	2.190	5.00	
EU-157	.055	5.00	.2606
	.064	27.00	
	.320	5.00	
	.370	14.00	
	.413	27.00	
	.477	5.00	
	.623	6.00	
EU-158	.080	111.00	1.7330
	.182	27.00	
	.520	27.00	
	.610	18.00	
	.950	105.00	
	1.110	12.00	
	1.190	18.00	
EU-159	.070	42.00	.5753
	.090	18.00	
	.150	14.00	
	.220	5.00	
	.670	21.00	
	.730	10.00	
	.900	11.00	
	1.100	11.00	
	1.500	5.00	
GD-159	.058	3.00	.0344
	.363	9.00	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	NUCLIDE MEV/DIS
GD-151	.102	11.00	.3509
	.284	8.00	
	.315	25.00	
	.361	66.00	
TB-160	.087	12.00	.9496
	.197	6.00	
	.299	30.00	
	.879	31.00	
	.966	31.00	
	1.178	15.00	
	1.272	7.00	
TB-151	.026	21.00	.0251
	.049	19.00	
	.057	5.00	
	.075	10.00	

APPENDIX B

BETA DECAY SCHEMES

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	GROUP MEV/DIS	NUCLIDE MEV/DIS
ZN-72	.300	90.00	.1076	.1057
	.250	10.00	.0887	
GA-72	3.150	8.00	1.3984	.5319
	2.520	8.00	1.0966	
	2.260	4.00	.9733	
	1.920	5.00	.8138	
	1.470	8.00	.6063	
	.950	30.00	.3747	
	.660	22.00	.2514	
	.640	19.00	.2431	
GA-73	1.485	5.00	.6132	.4373
	1.190	93.00	.4803	
	.452	5.00	.1668	
GA-74	3.800	55.00	1.7132	1.4314
	2.600	45.00	1.0870	
GE-75 M	.139	100.00	.0481	.0481
GE-75	1.140	87.00	.4580	.4431
	.940	1.40	.3704	
	.830	11.00	.3445	
	.670	.30	.2555	
	.510	.40	.1900	
GE-77 M	2.900	55.00	1.2781	.9645
	2.730	21.00	1.1824	
	.159	24.00	.0593	
GE-77	2.200	15.00	.9450	.6012
	2.040	24.00	.8698	
	1.480	22.00	.6109	
	1.210	5.00	.4892	
	1.110	13.00	.4448	
	.670	8.00	.2555	
	.590	2.00	.2225	
	.320	3.00	.1152	
	.200	8.00	.0702	
GE-79	.710	94.00	.2723	.2718
	.693	6.00	.2651	
AS-76	2.970	53.00	1.3117	1.1265
	2.410	35.00	1.0443	
	1.750	6.90	.7348	
	1.180	2.10	.4758	
	.870	.20	.3402	
	.860	.30	.3359	
	.540	1.00	.2021	
	.310	1.20	.1114	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	GROUP MEV/DIS	NUCLIDE MEV/DIS
AS-77	.680	97.00	.2597	.2566
	.440	2.30	.1620	
	.430	.30	.1580	
	.150	.80	.0556	
AS-78	4.100	70.00	1.8593	1.4739
	1.400	30.00	.5746	
AS-79	2.150	95.00	.9215	.9093
	1.700	1.50	.7117	
	1.620	2.00	.6749	
	1.330	.50	.5429	
	1.150	1.50	.4669	
AS-80	6.000	56.00	2.7921	2.5579
	5.330	32.00	2.4620	
	4.520	1.00	2.0645	
	4.230	1.70	1.9227	
	4.140	4.00	1.8788	
	3.680	4.00	1.6548	
	3.500	.50	1.5675	
	2.970	.30	1.3117	
AS-81	3.800	100.00	1.7132	1.7132
SE-79 M	.096	100.00	.0329	.0329
SE-79	.160	100.00	.0556	.0556
SE-81	1.560	99.00	.6474	.6444
	1.000	.60	.3965	
	.730	.40	.2807	
SE-83 M	3.800	50.00	1.7132	1.2309
	1.780	50.00	.7487	
SE-83	3.300	2.00	1.4708	.5626
	1.800	40.00	.7580	
	1.000	58.00	.3965	
SE-84	3.200	100.00	1.4225	1.4225
SE-85	8.000	100.00	3.7817	3.7817
SE-87	4.400	100.00	2.0058	2.0058
BR-82	.444	100.00	.1636	.1636
BR-83	.920	98.60	.3617	.3586
	.390	1.40	.1423	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	GROUP MEV/DIS	NUCLIDE MEV/DIS
BR-84 A	4.680	32.00	2.1429	1.2620
	3.800	14.00	1.7132	
	2.790	15.00	1.2200	
	1.770	1.00	.7441	
	1.330	14.00	.5429	
	.980	2.00	.3878	
	.770	19.00	.2975	
	.500	3.00	.1859	
BR-84 B	3.200	8.00	1.4225	.7550
	1.900	72.00	.8044	
	.800	20.00	.3103	
BR-85	2.500	100.00	1.0870	1.0870
BR-85	7.100	100.00	3.3357	3.3357
BR-87	8.000	30.00	3.7817	1.9288
	2.600	70.00	1.1346	
BR-88	10.000	100.00	4.7750	4.7750
BR-89	8.000	100.00	3.7817	3.7817
BR-90	5.000	100.00	2.2998	2.2998
KR-83 M	.032	100.00	.0108	.0108
KR-85 M	.820	77.00	.3188	.2706
	.305	23.00	.1095	
KR-85	.690	99.60	.2639	.2630
	.150	.41	.0520	
KR-87	3.800	70.00	1.7132	1.4051
	3.300	5.00	1.4708	
	1.300	25.00	.5294	
KR-88	2.800	20.00	1.2302	.4203
	.900	12.00	.3531	
	.520	68.00	.1940	
KR-89	4.200	100.00	1.8105	1.8105
KR-90	2.800	7.00	1.2302	1.0125
	2.650	47.00	1.1585	
	2.410	10.00	1.0443	
	2.150	13.00	.9215	
	2.020	7.00	.8605	
	1.950	4.00	.8278	
	1.730	5.00	.7256	
	1.240	3.00	.5026	
	.830	4.00	.3230	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	GROUP MEV/DIS	NUCLIDE MEV/DIS
KR-91	3.600	100.00	1.6160	1.6160
KR-92	5.600	100.00	2.5949	2.5949
KR-93	9.000	100.00	4.2780	4.2780
KR-94	7.500	100.00	3.5338	3.5338
KR-95	5.000	100.00	2.2998	2.2998
KR-97	5.000	100.00	2.2998	2.2998
RB-86	1.730	91.20	.7487	.7068
	.710	8.80	.2723	
RB-87	.272	100.00	.0970	.0970
RB-88	5.300	76.00	2.4473	2.1068
	3.460	4.00	1.5482	
	2.570	14.00	1.1204	
	2.060	1.70	.8792	
	1.790	.30	.7487	
	1.620	.08	.6749	
	.780	2.50	.3018	
	.450	1.70	.1660	
RB-89	3.920	7.00	1.7715	.6421
	2.870	5.00	1.2637	
	1.810	53.00	.6703	
	1.330	2.00	.5429	
	1.170	3.00	.4714	
	.670	28.00	.2555	
	.420	2.00	.1541	
RB-90	6.600	6.00	3.0884	1.5013
	5.770	10.00	2.6787	
	4.910	8.00	2.2557	
	4.660	5.00	2.1331	
	4.370	5.00	1.9911	
	3.530	6.00	1.5821	
	3.250	7.00	1.4514	
	2.450	23.00	1.0633	
	2.260	17.00	.9733	
	2.000	5.00	.8511	
	1.520	2.00	.6291	
	1.370	8.00	.5610	
RB-91	4.600	100.00	2.1037	2.1037
RB-92	8.800	100.00	4.1787	4.1787
RB-93	7.000	100.00	3.2862	3.2862
RB-94	10.000	100.00	4.7750	4.7750

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	GROUP MEV/DIS	NUCLIDE MEV/DIS
RB-95	8.500	100.00	4.0297	4.0297
RB-97	4.500	100.00	2.0547	2.0547
SR-89	1.460	99.50	.6018	.5988
	.550	.01	.2062	
SR-90	.546	100.00	.2045	.2045
SR-91	2.670	27.00	1.1680	.6717
	2.030	4.00	.8652	
	1.360	29.00	.5565	
	1.090	33.00	.4360	
	.620	7.00	.2348	
SR-92	1.500	10.00	.6200	.2475
	.550	90.00	.2062	
SR-93	2.900	65.00	1.2781	1.2090
	2.600	25.00	1.1346	
	2.200	10.00	.9450	
SR-94	2.100	100.00	.8980	.8980
SR-95	6.000	100.00	2.7921	2.7921
SR-97	4.500	100.00	2.0547	2.0547
Y- 90	2.268	99.00	.9771	.9674
	.518	.02	.1932	
Y- 91 M	.551	100.00	.2066	.2066
Y- 91	1.545	99.70	.6405	.6390
	.330	.30	.1191	
Y- 92	3.640	86.00	1.6354	1.5196
	2.710	3.10	1.1872	
	2.260	2.30	.9733	
	2.150	1.50	.9215	
	1.810	.80	.7626	
	1.590	.30	.6611	
	1.310	6.00	.5339	
Y- 93	2.890	90.00	1.2733	1.2278
	2.620	4.00	1.1442	
	1.950	3.00	.8278	
	1.470	.90	.6063	
	1.000	.15	.3965	
	.710	1.80	.2723	
	.450	.15	.1660	
Y- 94	5.000	50.00	2.2998	1.8130
	3.000	50.00	1.3262	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	GROUP MEV/DIS	NUCLIDE MEV/DIS
Y- 95	4.000	100.00	1.8105	1.8105
Y- 97	5.500	100.00	2.5457	2.5457
ZR-93	.060	5.00	.0283	.0332
	.090	95.00	.0308	
ZR-95	.890	2.00	.3488	.1419
	.398	49.00	.1447	
	.360	49.00	.1336	
ZR-97	1.910	93.00	.8091	.7644
	.460	7.00	.1639	
ZR-98	1.400	100.00	.5746	.5746
ZR-99	1.800	100.00	.7580	.7580
NB-95 M	.235	100.00	.0831	.0831
NB-95	.924	.08	.3634	.0558
	.160	100.00	.0555	
NB-97 M	.747	100.00	.2878	.2878
NB-97	1.270	98.00	.5160	.5129
	.915	2.00	.3596	
NB-98 M	5.000	100.00	2.2998	2.2998
NB-98	3.100	100.00	1.3743	1.3743
NB-99	3.200	100.00	1.4225	1.4225
NB-100	4.200	10.00	1.9081	1.5146
	3.500	45.00	1.5675	
	3.100	45.00	1.3743	
NB-101	3.000	100.00	1.3262	1.3262
MO-99	1.234	82.00	.4999	.5002
	1.604	1.00	.6676	
	1.200	17.00	.4847	
	1.010	.30	.4038	
MO-101	2.230	10.00	.9592	.4766
	1.610	25.00	.6703	
	1.230	11.00	.4981	
	.840	13.00	.3273	
	.740	38.00	.2849	
	.660	3.00	.2514	
MO-102	1.200	100.00	.4847	.4847

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	GROUP MEV/DIS	NUCLIDE MEV/DIS
MO-104	4.800	50.00	2.2017	1.5734
	2.200	50.00	.9450	
MO-105	5.500	100.00	2.5457	2.5457
TC-99 M	.143	100.00	.0494	.0494
TC-99	.292	100.00	.1046	.1046
TC-100	3.380	100.00	1.5094	1.5094
TC-101	1.320	90.00	.5384	.5262
	1.080	8.00	.4315	
	.960	2.00	.3531	
TC-102M	2.000	100.00	.8511	.8511
TC-102	4.400	100.00	2.0058	2.0058
TC-103	2.200	100.00	.9450	.9450
TC-104	5.300	20.00	2.4473	1.5638
	4.600	20.00	2.1037	
	3.300	20.00	1.4708	
	2.400	20.00	1.0396	
	1.800	20.00	.7580	
TC-105	3.400	100.00	1.5191	1.5191
TC-107	2.000	100.00	1.3262	1.3262
RU-103	.690	3.00	.2639	.0730
	.432	1.00	.1588	
	.370	1.00	.1345	
	.193	89.00	.0676	
	.080	7.00	.0273	
RU-105	1.870	11.00	.7905	.5344
	1.740	10.00	.7302	
	1.480	2.00	.6109	
	1.140	44.00	.4580	
	1.080	13.00	.4315	
	1.060	14.00	.4227	
	.930	4.00	.3660	
	.910	3.00	.3574	
	.850	.90	.3316	
	.520	3.00	.1940	
	.490	5.00	.1819	
	.290	2.00	.1038	
	.140	.10	.0485	
RU-106	.039	100.00	.0132	.0132

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	GROUP MEV/DIS	NUCLIDE MEV/DIS
RU-107	3.200	74.00	1.4225	1.3610
	3.010	5.00	1.3310	
	2.630	6.00	1.1490	
	2.270	4.00	.9780	
	2.150	11.00	.9215	
	1.910	4.00	.8091	
RU-108	1.300	72.00	.5294	.5088
	1.135	28.00	.4558	
RH-103M	.040	100.00	.0135	.0135
RH-104M	.500	.15	.1859	.0444
	.250	.03	.0887	
	.129	99.00	.0445	
RH-104	2.500	98.00	1.0870	1.0809
	1.900	1.90	.8044	
	.700	.13	.2681	
RH-105	.568	75.00	.2135	.1825
	.262	5.00	.0932	
	.249	20.00	.0884	
	.125	.04	.0431	
RH-106M	1.620	11.00	.6749	.3914
	1.180	11.00	.4758	
	.950	38.00	.3747	
	.790	40.00	.3060	
RH-106	3.530	79.00	1.5821	1.4835
	3.020	8.00	1.3358	
	2.400	11.00	1.0396	
	1.970	1.00	.8371	
	1.530	.40	.6337	
	1.260	.10	.5115	
	1.090	.10	.4360	
	.900	.10	.3531	
	.650	.10	.2472	
RH-107	1.200	17.00	.4847	.3747
	.893	71.00	.3501	
	.810	8.00	.3145	
	.630	2.00	.2390	
	.530	7.00	.1981	
RH-108	4.500	51.00	2.0547	1.7809
	4.070	17.00	1.8446	
	3.560	5.00	1.5966	
	3.450	22.00	1.5433	
RH-109	1.800	100.00	.7580	.7580
PD-107	.040	100.00	.0135	.0135

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	GROUP MEV/DIS	NUCLIDE MEV/DIS
PD-109M	.188	100.00	.0658	.0658
PD-109	1.028	99.97	.4087	.4086
	.396	.01	.1447	
	.256	.02	.0910	
PD-111M	2.200	25.00	.9450	.2807
	.170	75.00	.0593	
PD-111	1.200	100.00	.4847	.4941
	1.100	1.00	.4404	
	.700	1.00	.2681	
	.600	1.00	.2266	
PD-112	.250	100.00	.1000	.1000
PD-113	3.000	100.00	1.3262	1.3262
PD-114	3.000	100.00	1.3262	1.3262
PD-115	5.000	100.00	2.2998	2.2998
AG-109M	.088	100.00	.0299	.0299
AG-110M	1.500	.60	.6200	.0960
	.563	31.00	.2115	
	.116	67.00	.0399	
AG-110	2.870	95.50	1.2637	1.2499
	2.210	4.50	.9497	
	1.390	.05	.5700	
AG-111M	.070	100.00	.0238	.0238
AG-111	1.040	93.00	.4140	.4041
	.793	1.00	.3073	
	.700	6.00	.2681	
AG-112	3.940	54.00	1.7813	1.4295
	3.350	22.00	1.4949	
	1.960	10.00	.8324	
	1.000	14.00	.3965	
AG-113M	2.000	100.00	.8511	.8511
AG-113	2.000	15.00	.8511	.5107
	1.700	15.00	.7117	
	1.420	15.00	.5836	
	1.320	15.00	.5384	
	1.010	15.00	.4008	
	.820	15.00	.3188	
AG-114	4.600	100.00	2.1037	2.1037

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	GROUP MEV/DIS	NUCLIDE MEV/DIS
AG-115M	3.500	100.00	1.5675	1.5675
AG-115	3.200	17.00	1.4225	.7348
	2.970	8.00	1.3117	
	2.820	1.00	1.2398	
	2.720	5.00	1.1919	
	2.550	9.00	1.1108	
	2.100	3.00	.8980	
	1.070	38.00	.4271	
	.700	10.00	.2681	
AG-116	5.000	100.00	2.2998	2.2998
AG-117	3.000	100.00	1.3262	1.3262
CD-115M	1.620	97.00	.6749	.6603
	.685	1.60	.2618	
	.490	.07	.1819	
	.330	.90	.1191	
	.200	.40	.0702	
CD-115	1.110	62.00	.4448	.3632
	.848	1.40	.3307	
	.615	10.00	.2328	
	.595	27.00	.2204	
CD-117B	1.929	3.00	.8180	.2786
	1.612	4.00	.6712	
	1.444	1.00	.5945	
	1.429	8.00	.5877	
	.995	4.00	.3943	
	.738	3.00	.2840	
	.679	34.00	.2593	
	.582	8.00	.2192	
	.356	26.00	.1330	
	.358	3.00	.1299	
	.283	1.00	.1012	
	.270	5.00	.0962	
CD-117	2.230	12.00	.9592	.5355
	1.955	7.00	.8301	
	1.835	9.00	.7975	
	1.796	16.00	.7561	
	1.664	.40	.6951	
	1.492	6.00	.6163	
	.849	2.00	.3312	
	.833	7.00	.3243	
	.654	38.00	.2489	
	.522	3.00	.1948	
CD-118	.600	100.00	.2266	.2266
CD-119M	3.500	100.00	1.5675	1.5675

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	GROUP MEV/DIS	NUCLIDE MEV/DIS
IN-115M	.830	5.00	.3230	.1311
	.335	95.00	.1210	
IN-115	.480	100.00	.1779	.1779
IN-116	3.300	99.00	1.4708	1.4553
	2.010	1.00	.8558	
	1.580	.10	.6566	
IN-117M	1.770	37.00	.7441	.4358
	1.612	16.00	.6712	
	.314	47.00	.1129	
IN-117	.740	100.00	.2849	.2849
IN-118B	4.200	85.00	1.9081	1.8186
	2.970	15.00	1.3117	
IN-118	2.000	32.00	.8511	.6585
	1.798	13.00	.7570	
	1.548	2.00	.6419	
	1.318	53.00	.5375	
IN-119M	2.700	40.00	1.1824	1.1022
	2.680	50.00	1.1728	
	1.780	5.00	.7487	
	.300	5.00	.1076	
IN-119	1.600	100.00	.6657	.6657
IN-120	3.100	27.00	1.3743	.9843
	2.630	6.00	1.1490	
	2.220	41.00	.9544	
	2.110	6.00	.9027	
	1.890	3.00	.7998	
	1.710	1.00	.7163	
	1.470	2.00	.6063	
	1.000	14.00	.3965	
IN-121	3.700	100.00	1.6646	1.6646
IN-123	4.600	100.00	2.1037	2.1037
SN-119M	.089	100.00	.0304	.0304
SN-121	.383	100.00	.1396	.1396
SN-123	1.420	100.00	.5836	.5850
	.380	1.00	.1384	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	GROUP MEV/DIS	NUCLIDE MEV/DIS
SN-125M	2.040	98.00	.8698	.8607
	1.730	.15	.7256	
	1.460	.60	.6018	
	.896	.17	.3609	
	.645	1.00	.2452	
	.429	.30	.1561	
SN-125	2.330	95.10	1.0064	.9666
	1.260	.80	.5115	
	.922	.25	.3617	
	.457	1.90	.1660	
	.340	1.90	.1229	
	.100	.20	.0343	
SN-126	.250	100.00	.0887	.0887
SN-127	1.500	100.00	.6200	.6200
SN-128	.800	100.00	.3103	.3103
SN-129	2.000	100.00	.8511	.8511
SN-130	2.850	100.00	1.2302	1.2302
SN-132	5.300	100.00	2.2998	2.2998
SB-122M	.162	100.00	.0564	.0564
SB-122	1.970	30.00	.8371	.6259
	1.400	63.00	.5773	
	.725	4.00	.2764	
SB-124A	.025	100.00	.0084	.0084
SB-124M	1.700	20.00	.7117	.1460
	.010	80.00	.0033	
SB-124	2.317	22.00	1.0063	.4268
	1.675	3.00	.6979	
	1.590	5.00	.6611	
	1.025	1.50	.4052	
	.558	5.00	.3782	
	.625	50.00	.2369	
	.229	11.00	.0839	
	.060	2.00	.0203	
SB-125	.612	13.00	.2315	.1013
	.438	6.00	.1634	
	.295	43.00	.1057	
	.233	1.00	.0824	
	.123	28.00	.0424	
	.117	7.00	.0403	
	.089	2.00	.0304	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	GROUP MEV/DIS	NUCLIDE MEV/DIS
SB-126M	1.900	100.00	.8044	.8044
SB-126	1.900	100.00	.8044	.8044
SB-127	1.570	30.00	.6520	.4525
	1.110	20.00	.4448	
	.860	50.00	.3359	
SB-128B	2.400	100.00	1.0396	1.0396
SB-128	1.250	100.00	.5070	.5070
SB-129	1.870	20.00	.7905	.4753
	1.600	80.00	.3965	
SB-130A	3.600	100.00	1.3262	1.3262
SB-130B	3.100	100.00	1.3262	1.3262
SB-131	2.250	100.00	.9686	.9686
SB-132	8.000	100.00	3.7817	3.7817
SB-133	7.000	100.00	3.2862	3.2862
SB-134	9.000	100.00	4.2780	4.2780
SB-135	3.800	100.00	1.7132	1.7132
TE-127M	.731	.80	.2811	.0323
	.140	.00	.0485	
	.074	.00	.0251	
	.089	99.20	.0303	
TE-127	.700	99.70	.2681	.2676
	.497	.01	.1847	
	.283	.32	.1012	
TE-129M	1.600	30.00	.6657	.2443
	.933	6.00	.3544	
	.106	64.00	.0364	
TE-129	1.450	81.00	.5972	.5529
	1.200	1.00	.4847	
	.990	16.00	.3921	
	.395	1.00	.1443	
	.216	.20	.0761	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	GROUP MEV/DIS	NUCLIDE MEV/DIS
TE-131M	2.460	5.00	1.0680	.2570
	1.395	5.00	.5723	
	.831	16.00	.3235	
	.631	7.00	.2394	
	.558	13.00	.2094	
	.529	3.00	.1976	
	.495	12.00	.1839	
	.479	11.00	.1775	
	.448	10.00	.1652	
	.330	.50	.1191	
	.217	4.00	.0765	
	.130	.30	.0449	
	.182	18.00	.0635	
TE-131	2.140	62.00	.9168	.7656
	1.797	1.40	.7566	
	1.687	20.00	.7057	
	1.192	2.40	.4811	
	1.143	1.00	.4594	
	.864	1.50	.3376	
	.845	1.60	.3295	
	.790	1.40	.3060	
	.500	7.90	.1859	
TE-132	.220	100.00	.0776	.0776
TE-133M	2.400	87.00	1.0396	.9201
	.334	13.00	.1206	
TE-133	2.400	30.00	1.0396	.6825
	1.300	70.00	.5294	
TE-134	7.000	100.00	3.2862	3.2862
TE-135	6.500	100.00	3.0390	3.0390
I- 128	2.120	79.00	.9074	.3154
	1.680	13.00	.7025	
	1.130	1.60	.4536	
I- 129	.150	100.00	.0520	.0520
I- 130	1.700	.40	.7117	.2959
	.957	52.00	.3777	
	.538	48.00	.2013	
I- 131	.810	.60	.3145	.2211
	.610	90.40	.2307	
	.471	.50	.1743	
	.337	6.90	.1218	
	.251	1.60	.0891	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	GROUP MEV/DIS	NUCLIDE MEV/DIS
I- 132	2.160	18.00	.9262	.5352
	1.790	6.00	.7533	
	1.640	9.00	.6841	
	1.200	20.00	.4847	
	1.020	18.00	.4052	
	.943	5.00	.3717	
	.839	8.00	.3269	
	.762	16.00	.2941	
I- 133	1.270	91.00	.5160	.4974
	.940	1.00	.3704	
	.700	9.00	.2681	
I- 134	2.430	25.00	1.0538	.7411
	2.250	12.00	.9686	
	1.830	9.00	.7719	
	1.690	4.00	.7071	
	1.530	15.00	.6337	
	1.290	23.00	.5250	
	1.060	1.00	.4227	
	1.000	11.00	.3965	
I- 135	1.400	25.00	.5746	.3673
	1.000	40.00	.3965	
	.500	35.00	.1859	
I- 136	7.000	6.00	3.2862	1.5561
	5.680	15.00	2.6343	
	4.360	23.00	1.9862	
	2.800	8.00	1.2302	
	2.000	48.00	.8511	
I- 137N	2.000	100.00	.8511	.8511
I- 138N	8.000	100.00	3.7817	3.7817
I- 139N	5.000	100.00	2.2998	2.2998
XE-133M	.233	100.00	.0823	.0823
XE-133	.348	99.30	.1252	.1250
	.268	.70	.0955	
	.046	.01	.0155	
XE-135M	.527	100.00	.1968	.1968
XE-135	.910	97.00	.3574	.3529
	.550	3.00	.2062	
XE-137	4.190	33.00	1.8593	1.6963
	3.600	67.00	1.6160	
XE-138	2.400	100.00	1.0396	1.0396

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	GROUP MEV/DIS	NUCLIDE MEV/DIS
XE-139	5.000	100.00	2.2998	2.2998
XE-140	4.500	100.00	2.0547	2.0547
XE-141	6.500	100.00	3.0390	3.0390
XE-142	7.500	100.00	3.5338	3.5338
XE-143	7.500	100.00	3.5338	3.5338
XE-144	2.000	100.00	.8511	.8511
CS-134M	.138	100.00	.0477	.0477
CS-134	.662	71.00	.2522	.1915
	.419	2.50	.1537	
	.093	27.00	.0317	
CS-135	.210	100.00	.0739	.0739
CS-136	.657	7.00	.2501	.1248
	.467	2.00	.1727	
	.317	91.00	.1141	
CS-137	1.176	6.50	.4740	.2099
	.514	93.50	.1916	
CS-138	3.400	21.00	1.5191	1.2006
	2.940	12.00	1.2973	
	2.820	16.00	1.1442	
	2.530	5.00	1.1013	
	2.470	36.00	1.0728	
	2.280	10.00	.9828	
	1.570	.50	.6520	
CS-139	3.000	100.00	1.3262	1.3262
CS-140	4.500	100.00	2.0547	2.0547
CS-141	5.000	100.00	2.2998	2.2998
CS-142	7.500	100.00	3.5338	3.5338
CS-143	6.000	100.00	2.7921	2.7921
CS-144	3.500	100.00	1.5675	1.5675
BA-137M	.662	100.00	.2521	.2521
BA-139	2.380	72.00	1.0301	1.0000
	2.210	27.00	.9497	
	.950	.50	.3747	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	GROUP MEV/DIS	NUCLIDE MEV/DIS
BA-140	1.020	19.00	.4052	.3028
	1.010	33.00	.4008	
	.887	3.00	.3475	
	.582	11.00	.2192	
	.469	34.00	.1735	
BA-141	3.000	10.00	1.3262	1.0230
	2.857	10.00	1.2336	
	2.690	10.00	1.1776	
	2.530	10.00	1.1013	
	2.350	10.00	1.0159	
	2.070	10.00	.8839	
	1.900	10.00	.8044	
	1.810	10.00	.7626	
	1.710	10.00	.7163	
	1.580	10.00	.6566	
	1.350	10.00	.5520	
BA-142	1.700	100.00	.7117	.7117
BA-143	4.500	100.00	2.0547	2.0547
BA-144	.800	100.00	.3103	.3103
LA-140	3.800	.00	1.7132	.6741
	2.175	27.00	.9332	
	1.870	.04	.7905	
	1.690	18.00	.7071	
	1.420	4.00	.5836	
	1.360	35.00	.5565	
	1.250	15.00	.5070	
	.871	.08	.3406	
	.641	.04	.2435	
	.371	.00	.1349	
	.361	.00	.1310	
LA-141	2.430	98.00	1.0538	1.0398
	.900	2.00	.3531	
LA-142	4.520	13.00	2.0645	.3544
	3.870	2.40	1.7472	
	2.980	1.70	1.3166	
	2.500	1.00	1.0870	
	2.330	6.00	1.0064	
	2.110	24.00	.9027	
	1.970	19.00	.8371	
	1.810	11.00	.7626	
	1.210	5.00	.4892	
	1.070	6.00	.4271	
	.870	12.00	.3402	
LA-143	3.300	100.00	1.4708	1.4708
LA-144	6.000	100.00	2.7921	2.7921

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	GROUP MEV/DIS	NUCLIDE MEV/DIS
CE-141	.582	30.00	.2192	.1803
	.444	70.00	.1636	
CE-143	1.390	38.00	.5700	.4527
	1.100	42.00	.4404	
	.723	16.00	.2777	
	.506	3.00	.1884	
	.288	1.00	.1030	
CE-144	.309	78.00	.1110	.1003
	.250	.40	.0887	
	.229	4.50	.0809	
	.209	.30	.0735	
	.176	19.00	.0614	
CE-145	2.000	100.00	.8511	.8511
CE-146	.700	100.00	.2681	.2681
CE-148	5.000	100.00	2.2998	2.2998
PR-142	2.150	96.30	.9215	.8964
	.640	3.70	.2431	
PR-143	.933	100.00	.3673	.3673
PR-144	2.996	97.70	1.3242	1.3098
	2.301	1.30	.9927	
	.812	1.00	.3154	
PR-145	1.800	95.00	.7580	.7399
	1.000	5.00	.3965	
PR-146	3.700	21.00	1.6646	1.0581
	2.780	3.00	1.2236	
	2.430	6.00	1.0538	
	2.160	52.00	.9262	
	1.910	12.00	.8091	
	1.410	7.00	.5791	
PR-148	4.200	100.00	1.9081	1.9081
ND-147	.800	77.00	.3133	.2658
	.402	1.00	.1470	
	.360	17.00	.1306	
	.205	4.00	.0720	
	.171	.60	.0596	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	GROUP MEV/DIS	NUCLIDE MEV/DIS
ND-149	1.550	11.00	.6428	.5231
	1.476	3.00	.6091	
	1.454	23.00	.5991	
	1.424	4.00	.5854	
	1.395	19.00	.5723	
	1.278	.30	.5196	
	1.126	19.00	.4519	
	1.010	18.00	.4008	
	.897	1.30	.3518	
ND-151	2.100	25.00	.8980	.7016
	1.800	25.00	.7580	
	1.600	25.00	.6657	
	1.200	25.00	.4847	
PM-147	.224	100.00	.0791	.0791
PM-148M	1.027	1.00	.4083	.1390
	.584	24.00	.2200	
	.395	18.00	.1443	
	.295	50.00	.1057	
	.137	7.00	.0474	
PM-148	2.480	50.00	1.0775	.7827
	1.930	10.00	.8184	
	1.020	40.00	.4052	
PM-149	1.072	97.00	.4280	.4248
	.780	3.00	.3043	
	.506	.15	.1834	
	.232	.06	.0820	
	.192	.18	.0673	
PM-151	1.190	10.00	.4803	.3251
	1.121	8.00	.4492	
	1.090	5.00	.4360	
	1.020	7.00	.4052	
	.931	2.00	.3882	
	.866	3.00	.3385	
	.845	41.00	.3295	
	.794	1.00	.3077	
	.744	7.00	.2865	
	.448	3.00	.1652	
	.415	1.60	.1521	
	.367	5.00	.1334	
	.236	1.00	.0835	
PM-152	2.200	100.00	.9450	.9450
PM-154	2.500	100.00	1.0870	1.0870
SM-151	.076	98.00	.0259	.0257
	.054	1.70	.0184	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	GROUP MEV/DIS	NUCLIDE MEV/DIS
SM-153	.810	20.00	.3145	.2745
	.727	.40	.2794	
	.713	1.00	.2735	
	.707	48.00	.2710	
	.659	.00	.2510	
	.638	32.00	.2423	
	.177	.07	.0618	
	.175	.07	.0611	
	.117	.11	.0403	
	.083	.02	.0283	
	.010	.02	.0033	
SM-155	1.700	92.00	.7117	.7038
	1.560	6.00	.6474	
	1.490	.60	.6154	
	1.040	.60	.4140	
	.890	.10	.3496	
	.672	.10	.2564	
	.492	.20	.1827	
SM-156	.700	51.00	.2681	.2107
	.430	44.00	.1580	
	.250	5.00	.0887	
EU-154	1.860	10.00	.7858	.3599
	1.415	3.00	.5814	
	1.232	2.00	.4990	
	1.100	17.00	.4404	
	.830	37.00	.3230	
	.610	1.90	.2307	
	.510	29.00	.1900	
EU-155	.252	16.00	.0895	.0614
	.192	10.00	.0673	
	.165	40.00	.0574	
	.147	34.00	.0510	
EU-156	2.430	31.00	1.0538	.4579
	1.260	6.00	.5115	
	1.190	1.30	.4603	
	1.060	2.30	.4227	
	.464	33.00	.1715	
	.404	8.00	.1478	
	.250	2.20	.0887	
	.244	9.00	.0865	
	.227	8.00	.0802	
EU-157	1.350	3.00	.5520	.3815
	1.286	30.00	.5232	
	.913	15.00	.3587	
	.872	35.00	.3410	
	.662	10.00	.2522	
	.558	2.00	.2094	
	.300	5.00	.1076	

NUCLIDE	ENERGY	PERCENT OF DISINTEGRATIONS	GROUP MEV/DIS	NUCLIDE MEV/DIS
EU-158	2.500	35.00	1.0870	.8161
	1.900	35.00	.8044	
	1.100	35.00	.4434	
EU-159	2.570	25.00	1.1204	.8510
	2.350	21.00	1.0159	
	1.900	21.00	.8044	
	1.750	11.00	.7348	
	1.500	11.00	.6200	
	1.000	10.00	.3965	
GD-159	.950	63.00	.3747	.3498
	.892	24.00	.3496	
	.602	.40	.2274	
	.587	13.00	.2213	
	.371	.08	.1349	
	.181	.06	.0633	
GD-161	1.600	90.00	.6657	.6614
	1.536	7.00	.6364	
	1.431	3.00	.5886	
TB-160	1.740	.34	.7302	.2484
	1.543	.12	.6396	
	.860	29.00	.3359	
	.777	7.00	.3005	
	.562	44.00	.2110	
	.539	4.00	.2017	
	.468	10.00	.1731	
	.440	.40	.1620	
	.427	5.00	.1569	
TB-161	.580	10.00	.2184	.1852
	.505	64.00	.1880	
	.448	26.00	.1652	
	.208	.11	.0731	
	.168	.02	.0585	
	.038	.07	.0128	

APPENDIX C

GAMMA PARTICLE/ENERGY SPECTRA

TABLE C-1

Gamma Release Rates Per Watt of Reactor Power

Time After LOCA	50 % Halogens 1% Solids		100 % Noble Gases 25% Iodines		25% Iodines		100% Noble Gases		100% Solids		100% Release	
	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle
1 sec	1.06+10*	1.09+10†	1.48+10	2.21+10	3.81+9	4.30+9	1.10+10	1.78+10	7.66+10	9.96+10	1.07+11	1.37+11
1 min	8.90+9	9.69+9	1.26	1.68	3.56	4.11	9.08+9	1.27	7.18	9.42	9.72+10	1.24
20 min	6.29	7.62	8.08+9	1.09	2.84	3.45	5.24	7.42+9	4.35	5.99	6.05	8.14+10
1 hr	4.98	6.18	6.34	8.96+9	2.30	2.85	4.04	6.12	3.03	4.31	4.37	6.07
2 hr	3.82	4.89	4.54	7.16	1.78	2.26	2.77	4.90	2.43	3.57	3.42	4.97
4 hr	2.69	3.66	2.82	5.36	1.24	1.67	1.59	3.69	2.05	3.12	2.71	4.16
12 hr	1.34	2.24	9.91+8	3.06	5.87+8	9.90+8	4.04+8	2.07	1.69	2.64	1.97	3.25
1 day	7.67+8	1.55	4.53	2.06	3.10	6.59	1.43	1.40	1.47	2.29	1.60	2.69
2 day	4.29	9.93+8	2.14	1.40	1.53	4.01	6.11+7	9.98+8	1.23	1.90	1.30	2.16
4 day	2.75	6.76	1.24	9.95+8	8.67+7	2.61	3.75	7.34	1.02	1.54	1.06	1.71
8 day	1.89	4.59	7.64+7	6.06	5.44	1.70	2.20	4.36	8.03+9	1.18	8.27+9	1.30
16 day	1.13	2.51	3.49	2.36	2.71	8.23+7	7.80+6	1.54	5.85	8.68+9	5.96	9.17+9
30 day	5.67+7	1.10	9.46+6	4.86+7	8.12+6	2.38	1.34	2.48+7	4.05	6.25	4.08	6.37

*Read as 1.06×10^{10} MeV/sec

†Read as 1.09×10^{10} particles/sec

TABLE C-2

Gamma - 100% Release

Time After LOCA / Energy (Mev)	Fraction Below Given Energy																									
	1 Second		1 Minute		20 Minute		1 Hour		2 Hour		4 Hour		12 Hour		1 Day		2 Day		4 Day		8 Day		16 Day		30 Day	
	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle
5.20	1.000	1.000	1.000	1.000																						
5.00	.994	.999	.995	.999																						
4.50	.983	.997	.986	.997																						
4.00	.959	.993	.964	.993	1.000		1.000																			
3.70	.957	.992	.961	.993	.997	1.000	.999	1.000	1.000		1.000															
3.60	.955	.992	.960	.992	.995	.999	.996	.999	.997		.999															
3.50	.952	.991	.956	.992	.994	.999	.995	.999	.997		.999															
3.40	.952	.991	.956	.992	.994	.999	.996	.999	.997	1.000	.999															
3.30	.942	.989	.947	.989	.992	.998	.994	.998	.996	.999	.998															
3.20	.941	.988	.946	.989	.992	.998	.994	.998	.996	.999	.998															
3.10	.939	.988	.945	.989	.992	.998	.994	.998	.996	.999	.998															
3.00	.936	.987	.941	.988	.992	.998	.994	.998	.996	.999	.998	1.000														
2.90	.930	.986	.937	.987	.988	.997	.990	.997	.992	.998	.996	.999														
2.80	.930	.986	.937	.987	.988	.997	.990	.997	.992	.998	.996	.999														
2.70	.928	.985	.935	.986	.987	.997	.989	.997	.992	.998	.996	.999														
2.60	.918	.982	.926	.984	.979	.994	.983	.995	.989	.997	.995	.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2.50	.898	.976	.903	.977	.952	.987	.960	.989	.971	.992	.984	.996	.992	.998	.990	.997	.989	.997	.987	.996	.986	.996	.987	.996	.991	.997
2.40	.861	.964	.871	.967	.927	.979	.933	.981	.946	.985	.967	.991	.989	.997	.990	.997	.989	.997	.987	.996	.986	.996	.987	.996	.991	.997
2.30	.860	.964	.871	.966	.927	.979	.933	.981	.946	.985	.967	.991	.989	.997	.990	.997	.989	.997	.987	.996	.986	.996	.987	.996	.991	.997
2.20	.841	.957	.852	.960	.909	.973	.922	.976	.943	.984	.967	.991	.989	.997	.990	.997	.989	.997	.987	.996	.986	.996	.987	.996	.991	.997
2.10	.836	.955	.845	.958	.901	.970	.913	.975	.934	.981	.959	.989	.986	.996	.988	.997	.986	.996	.985	.996	.983	.995	.983	.995	.985	.996
2.00	.824	.951	.834	.953	.892	.967	.900	.973	.931	.980	.958	.988	.986	.996	.988	.997	.986	.996	.984	.996	.983	.995	.983	.995	.985	.996
1.90	.809	.945	.818	.947	.870	.962	.900	.970	.924	.978	.953	.987	.983	.995	.984	.996	.983	.995	.981	.995	.981	.995	.983	.995	.985	.996
1.80	.800	.941	.809	.943	.868	.957	.888	.965	.913	.974	.944	.984	.980	.994	.983	.995	.982	.995	.981	.995	.981	.995	.983	.995	.985	.996
1.70	.769	.927	.778	.929	.838	.945	.859	.953	.884	.962	.918	.974	.965	.989	.978	.994	.982	.995	.981	.995	.981	.995	.983	.995	.985	.996
1.60	.763	.924	.771	.926	.831	.942	.854	.951	.881	.961	.916	.973	.965	.989	.978	.993	.982	.995	.981	.995	.981	.995	.983	.995	.985	.996
1.50	.714	.900	.721	.901	.766	.911	.775	.914	.786	.919	.801	.925	.812	.929	.792	.922	.758	.908	.726	.893	.711	.883	.734	.891	.809	.923
1.40	.657	.869	.669	.872	.716	.885	.731	.893	.755	.904	.778	.914	.791	.920	.774	.915	.742	.902	.710	.887	.698	.878	.726	.887	.804	.920
1.30	.619	.847	.631	.851	.675	.863	.685	.868	.708	.880	.738	.895	.773	.912	.760	.908	.728	.895	.699	.882	.692	.875	.724	.886	.804	.920
1.20	.572	.818	.582	.820	.639	.841	.661	.854	.683	.866	.711	.881	.752	.902	.747	.902	.718	.891	.691	.877	.685	.871	.718	.883	.796	.917
1.10	.530	.789	.544	.794	.603	.818	.628	.834	.653	.849	.684	.866	.734	.892	.735	.893	.711	.887	.685	.874	.681	.869	.715	.881	.792	.914
1.00	.491	.760	.502	.763	.557	.785	.592	.809	.622	.828	.655	.848	.709	.878	.718	.888	.697	.879	.670	.865	.663	.858	.693	.867	.765	.898
.90	.441	.718	.447	.718	.500	.741	.543	.772	.576	.795	.610	.817	.667	.851	.675	.859	.652	.850	.625	.836	.622	.830	.657	.843	.734	.877
.80	.361	.645	.365	.642	.714	.688	.459	.701	.506	.738	.569	.786	.644	.835	.651	.842	.625	.831	.596	.815	.591	.807	.627	.820	.709	.858
.70	.262	.542	.264	.537	.278	.530	.303	.551	.333	.580	.372	.615	.420	.654	.430	.667	.421	.668	.407	.659	.400	.645	.411	.633	.447	.634
.60	.197	.463	.193	.451	.183	.422	.190	.426	.205	.443	.228	.470	.255	.500	.259	.510	.256	.515	.252	.513	.250	.498	.247	.468	.235	.424
.50	.125	.362	.124	.353	.118	.334	.113	.326	.116	.332	.127	.351	.148	.382	.160	.402	.167	.418	.170	.421	.168	.402	.162	.368	.149	.325
.40	.080	.284	.077	.272	.072	.258	.071	.257	.076	.270	.086	.291	.100	.317	.108	.327	.099	.328	.092	.313	.080	.277	.066	.229	.054	.189
.30	.044	.203	.042	.192	.045	.200	.049	.213	.055	.229	.063	.248	.072	.268	.071	.272	.063	.266	.054	.246	.043	.211	.038	.176	.038	.160
.20	.020	.127	.018	.120	.019	.123	.019	.128	.021	.135	.023	.144	.026	.158	.030	.175	.032	.190	.031	.189	.027	.169	.025	.143	.024	.125
.10	.002	.031	.002	.033	.002	.040	.003	.049	.004	.057	.005	.065	.006	.075	.007	.083	.007	.092	.007	.092	.006	.078	.004	.051	.002	.028

TABLE C-3

Gamma - 100% Noble Gases

Time After LOCA / Energy (MeV)	Fraction Below Given Energy																									
	1 Second		1 Minute		20 Minutes		1 Hour		2 Hours		4 Hours		12 Hours		1 Day		2 Days		4 Days		8 Days		16 Days		30 Days	
	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle
5.20			1.000	1.000																						
5.00			.995	.999																						
4.50	1.000		.991	.998	1.000																					
4.00	.999		.966	.994	.999																					
3.50	.998		.962	.993	.998																					
3.00	.998		.949	.990	.998																					
2.90	.998		.949	.990	.998																					
2.80	.998		.948	.990	.998																					
2.70	.998		.949	.990	.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000											
2.60	.998	1.000	.948	.990	.974	.993	.966	.991	.972	.994	.980	.996	.990	.999	.998											
2.50	.925	.984	.870	.968	.854	.960	.864	.985	.886	.975	.928	.988	.987	.999	.998	1.000										
2.40	.814	.953	.725	.926	.689	.912	.684	.916	.681	.927	.710	.949	.869	.989	.981	.999										
2.30	.814	.953	.725	.926	.689	.912	.684	.916	.681	.927	.710	.949	.869	.989	.981	.999										
2.20	.806	.951	.713	.922	.652	.900	.648	.906	.668	.923	.708	.949	.869	.989	.981	.999										
2.10	.766	.940	.665	.908	.575	.875	.564	.880	.536	.898	.605	.928	.813	.984	.973	.998										
2.00	.723	.927	.617	.890	.547	.865	.557	.877	.568	.897	.605	.928	.813	.984	.973	.998										
1.90	.716	.924	.607	.886	.545	.865	.557	.877	.566	.897	.605	.928	.813	.984	.973	.998										
1.80	.716	.924	.606	.885	.502	.849	.475	.848	.460	.865	.492	.902	.752	.978	.964	.998										
1.70	.638	.897	.540	.859	.475	.837	.468	.846	.459	.866	.492	.902	.752	.978	.964	.998										
1.60	.638	.897	.540	.859	.475	.837	.468	.846	.459	.865	.492	.902	.752	.978	.964	.998					1.000		1.000		1.000	
1.50	.529	.853	.451	.818	.431	.818	.421	.826	.406	.846	.435	.886	.721	.974	.960	.998					.999		.998		.995	
1.40	.529	.853	.447	.815	.355	.781	.333	.785	.360	.828	.429	.884	.721	.974	.960	.998					.999		.998		.995	
1.30	.529	.853	.446	.815	.355	.781	.333	.785	.360	.828	.429	.884	.721	.974	.960	.998					.999		.998		.995	
1.20	.514	.845	.423	.802	.333	.768	.329	.783	.360	.827	.429	.884	.721	.974	.960	.998					.999		.998		.995	
1.10	.389	.778	.363	.765	.333	.768	.329	.783	.350	.827	.429	.884	.721	.974	.960	.998	1.000				.999		.998		.995	
1.00	.388	.778	.356	.760	.292	.741	.302	.767	.348	.821	.427	.884	.721	.974	.959	.998	.999				.999		.998		.995	
.90	.388	.778	.356	.760	.292	.741	.302	.767	.348	.821	.427	.884	.721	.974	.958	.998	.999		1.000		.999		.998		.995	
.80	.337	.740	.283	.698	.224	.684	.221	.703	.256	.760	.334	.837	.674	.963	.953	.997	.999		.999		.999		.998		.995	
.70	.331	.736	.277	.693	.223	.684	.221	.703	.256	.760	.334	.837	.674	.963	.953	.997	.999	1.000	.999		.999		.998		.995	
.60	.305	.710	.249	.663	.213	.672	.212	.694	.244	.750	.317	.826	.638	.952	.911	.990	.983	.998	.998		.999		.998	1.000	.994	1.000
.50	.239	.637	.199	.597	.190	.643	.204	.684	.242	.747	.317	.825	.637	.952	.910	.990	.982	.998	.996		.994		.985	.998	.919	.992
.40	.173	.545	.131	.489	.135	.556	.156	.614	.204	.700	.297	.806	.686	.952	.910	.990	.981	.998	.995		.994		.984	.998	.919	.992
.30	.143	.492	.113	.453	.128	.543	.148	.600	.195	.687	.287	.794	.628	.947	.907	.989	.981	.998	.995	1.000	.994	1.000	.984	.998	.918	.992
.20	.054	.272	.034	.226	.087	.285	.141	.317	.052	.364	.073	.425	.169	.589	.384	.775	.773	.947	.974	.995	.987	.998	.983	.998	.918	.992
.10	.005	.069	.006	.096	.011	.165	.015	.199	.021	.247	.037	.324	.141	.553	.375	.769	.772	.946	.974	.995	.987	.997	.982	.997	.915	.991

TABLE C-4

Gamma - 100% Solids

Time After LOCA / Energy (MeV)	Fraction Below Given Energy																									
	1 Second		1 Minute		20 Minutes		1 Hour		2 Hours		4 Hours		12 Hours		1 Day		2 Days		4 Days		8 Days		16 Days		30 Days	
	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle
5.20	1.000	1.000	1.000	1.000																						
5.00	.995	.998	.995	.999																						
4.50	.989	.998	.989	.998	1.000																					
4.00	.960	.993	.954	.993	.999																					
3.90	.960	.993	.954	.993	.999																					
3.80	.960	.993	.954	.993	.999																					
3.70	.960	.993	.954	.993	.998	1.000	1.000	1.000	1.000	1.000	1.000															
3.60	.950	.992	.962	.993	.996	.999	.996	.999	.997	.999	.998															
3.50	.953	.991	.957	.992	.995	.999	.996	.999	.997	.999	.998															
3.40	.953	.991	.957	.992	.995	.999	.996	.999	.997	.999	.998															
3.30	.940	.988	.946	.989	.992	.998	.993	.998	.995	.999	.997															
3.20	.940	.988	.946	.989	.992	.998	.993	.998	.995	.999	.997															
3.10	.940	.988	.946	.989	.992	.998	.993	.998	.995	.999	.997															
3.00	.936	.987	.942	.986	.991	.998	.993	.998	.995	.999	.997	1.000														
2.90	.932	.986	.937	.987	.986	.996	.987	.997	.990	.997	.995	.999														
2.80	.932	.986	.937	.987	.986	.996	.987	.997	.990	.997	.995	.999														
2.70	.932	.986	.937	.987	.985	.996	.986	.997	.990	.997	.995	.999														
2.60	.924	.984	.928	.985	.976	.994	.981	.995	.988	.997	.995	.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2.50	.904	.978	.908	.978	.954	.987	.963	.990	.973	.993	.984	.996	.991	.997	.990	.997	.988	.997	.987	.996	.986	.996	.987	.996	.991	.997
2.40	.873	.968	.885	.971	.940	.983	.948	.986	.962	.990	.979	.994	.991	.997	.990	.997	.988	.997	.987	.996	.986	.996	.987	.996	.991	.997
2.30	.872	.968	.884	.971	.939	.983	.947	.986	.962	.990	.979	.994	.991	.997	.990	.997	.988	.997	.987	.996	.986	.996	.987	.996	.991	.997
2.20	.853	.961	.884	.964	.919	.977	.937	.983	.958	.989	.979	.994	.991	.997	.990	.997	.988	.997	.987	.996	.986	.996	.987	.996	.991	.997
2.10	.851	.960	.863	.964	.918	.976	.935	.982	.957	.988	.977	.994	.989	.997	.988	.996	.986	.996	.984	.995	.983	.995	.983	.995	.985	.996
2.00	.841	.957	.852	.960	.908	.973	.929	.980	.953	.987	.975	.993	.989	.997	.988	.996	.986	.996	.984	.995	.983	.995	.983	.995	.985	.996
1.90	.822	.949	.833	.952	.892	.967	.918	.976	.945	.984	.970	.991	.984	.995	.983	.995	.982	.995	.981	.994	.981	.994	.982	.995	.985	.996
1.80	.812	.945	.823	.948	.882	.963	.913	.974	.942	.983	.967	.990	.983	.995	.982	.995	.981	.994	.981	.994	.981	.994	.982	.995	.985	.996
1.70	.796	.938	.806	.941	.871	.958	.906	.971	.937	.981	.965	.990	.982	.995	.982	.995	.981	.994	.981	.994	.981	.994	.982	.995	.985	.996
1.60	.790	.935	.800	.938	.854	.955	.902	.969	.934	.980	.964	.989	.982	.994	.982	.995	.981	.994	.981	.994	.981	.994	.982	.995	.985	.996
1.50	.738	.909	.744	.911	.780	.916	.794	.920	.807	.924	.816	.927	.805	.921	.779	.911	.746	.896	.715	.881	.702	.872	.729	.885	.807	.921
1.40	.672	.874	.684	.879	.729	.890	.755	.902	.781	.912	.797	.918	.787	.913	.761	.903	.729	.888	.700	.873	.689	.866	.720	.881	.802	.919
1.30	.638	.855	.648	.859	.679	.863	.685	.870	.731	.882	.748	.894	.766	.903	.746	.896	.714	.881	.688	.858	.683	.863	.719	.880	.802	.919
1.20	.538	.824	.598	.828	.653	.848	.689	.867	.717	.879	.742	.891	.757	.898	.736	.890	.704	.876	.679	.863	.676	.859	.713	.877	.795	.915
1.10	.562	.807	.571	.810	.627	.832	.673	.857	.707	.874	.735	.887	.749	.894	.728	.886	.697	.872	.673	.860	.672	.857	.709	.875	.791	.913
1.00	.511	.770	.518	.772	.573	.795	.630	.828	.670	.850	.702	.866	.724	.879	.709	.875	.682	.863	.658	.850	.653	.845	.687	.860	.763	.899
.90	.444	.715	.448	.716	.500	.739	.566	.781	.612	.808	.648	.828	.675	.846	.663	.843	.635	.831	.611	.817	.611	.814	.650	.834	.732	.875
.80	.389	.665	.396	.669	.458	.703	.513	.737	.559	.766	.614	.802	.652	.820	.638	.824	.607	.809	.580	.793	.578	.789	.619	.810	.707	.855
.70	.273	.547	.274	.545	.285	.535	.311	.548	.338	.565	.368	.587	.395	.609	.396	.618	.392	.624	.385	.621	.383	.612	.400	.613	.442	.627
.60	.207	.468	.204	.463	.188	.427	.188	.414	.192	.412	.201	.418	.209	.426	.214	.439	.222	.455	.228	.461	.232	.455	.235	.441	.329	.414
.50	.132	.365	.134	.366	.130	.350	.120	.328	.117	.319	.119	.320	.128	.331	.135	.348	.145	.364	.147	.363	.147	.350	.148	.335	.144	.313
.40	.081	.277	.082	.278	.075	.262	.068	.247	.066	.243	.069	.246	.072	.252	.074	.260	.073	.261	.066	.243	.056	.213	.050	.189	.047	.174
.30	.040	.186	.041	.189	.046	.201	.049	.208	.052	.214	.055	.220	.059	.228	.060	.234	.058	.233	.050	.213	.010	.182	.036	.162	.038	.157
.20	.020	.125	.021	.126	.022	.130	.022	.133	.023	.136	.024	.139	.026	.144	.028	.152	.029	.157	.027	.153	.024	.139	.023	.128	.024	.122
.10	.002	.031	.001	.030	.002	.034	.002	.040	.003	.044	.003	.046	.003	.045	.003	.045	.003	.046	.003	.044	.002	.040	.002	.032	.001	.023

TABLE C-5

Gamma - 100% Iodines

Time After LOCA / Energy (MeV)	Fraction Below Given Energy																									
	1 Second		1 Minute		20 Minutes		1 Hour		2 Hours		4 Hours		12 Hours		1 Day		2 Days		4 Days		8 Days		16 Days		30 Days	
	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle
3.30	1.000	1.000	1.000	1.000																						
3.00	.989	.997	.992	.998																						
2.50	.957	.986	.971	.991																						
2.00	.928	.975	.952	.983	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000													
1.90	.923	.973	.947	.981	.994	.997	.994	.997	.994	.997	.995	.998	.999													
1.80	.923	.973	.947	.981	.994	.997	.994	.997	.994	.997	.995	.998	.999	1.000	1.000	1.000	1.000	1.000								
1.70	.843	.932	.861	.939	.893	.950	.884	.946	.872	.942	.858	.940	.874	.957	.931	.981	.988	.997								
1.60	.830	.925	.847	.931	.880	.943	.874	.942	.866	.940	.857	.939	.874	.957	.931	.981	.988	.997								
1.50	.830	.925	.847	.931	.880	.943	.874	.942	.866	.940	.857	.939	.874	.957	.931	.981	.988	.997								
1.40	.797	.905	.813	.911	.840	.920	.832	.918	.822	.916	.809	.915	.832	.940	.909	.974	.984	.996								
1.30	.687	.839	.739	.863	.819	.908	.811	.906	.801	.904	.793	.906	.829	.939	.908	.974	.984	.996								
1.20	.634	.794	.672	.817	.738	.854	.719	.846	.696	.837	.674	.835	.725	.889	.852	.952	.975	.993								
1.10	.556	.734	.589	.754	.642	.786	.618	.775	.587	.763	.557	.760	.624	.837	.797	.930	.965	.990								
1.00	.542	.722	.573	.742	.624	.772	.598	.760	.566	.747	.533	.743	.602	.824	.785	.925	.963	.989								
.90	.523	.705	.554	.724	.602	.752	.576	.741	.544	.729	.515	.729	.598	.822	.785	.924	.963	.989								
.80	.391	.463	.309	.474	.359	.517	.391	.566	.425	.619	.462	.682	.576	.806	.772	.918	.961	.988	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
.70	.329	.389	.242	.398	.284	.435	.315	.484	.351	.542	.403	.624	.560	.794	.762	.911	.943	.979	.972	.988	.969	.987	.969	.986	.969	.985
.60	.123	.244	.129	.247	.157	.274	.191	.329	.235	.401	.310	.518	.520	.758	.719	.880	.872	.938	.872	.936	.856	.931	.854	.928	.853	.924
.50	.043	.115	.043	.111	.043	.104	.052	.125	.066	.161	.098	.232	.212	.425	.349	.563	.543	.710	.754	.865	.848	.926	.854	.928	.853	.924
.40	.034	.097	.032	.091	.033	.085	.042	.108	.058	.146	.090	.219	.205	.416	.345	.559	.543	.710	.754	.865	.848	.926	.854	.928	.853	.924
.30	.007	.029	.005	.024	.003	.015	.005	.023	.010	.040	.022	.076	.067	.182	.095	.223	.076	.203	.062	.209	.065	.211	.060	.132	.054	.145
.20	.001	.006	.001	.007	.001	.007	.001	.007	.001	.008	.001	.010	.002	.027	.005	.054	.014	.108	.023	.158	.024	.159	.019	.128	.013	.089
.10	.000	.002	.000	.002	.000	.003	.000	.004	.000	.006	.000	.010	.002	.027	.005	.054	.014	.108	.023	.158	.024	.159	.019	.128	.013	.089

TABLE C-6

Gamma - 100% Noble Gases, 25% Iodines

Time After LOCA / Energy (MeV)	Fraction Below Given Energy																									
	1 Second		1 Minute		20 Minutes		1 Hour		2 Hours		4 Hours		12 Hours		1 Day		2 Days		4 Days		8 Days		16 Days		30 Days	
	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle
5.20			1.000																							
5.00			.996																							
4.60			.996	1.000																						
4.50			.993	.999																						
4.20	1.000		.982	.997	1.000																					
4.00	.999		.975	.995	.999																					
3.90	.999		.975	.995	.999																					
3.80	.999		.975	.995	.999																					
3.70	.999		.975	.995	.999																					
3.60	.999		.975	.995	.999																					
3.50	.999		.973	.995	.999																					
3.40	.999		.973	.995	.999																					
3.30	.999	1.000	.965	.993	.999																					
3.20	.996	.999	.964	.993	.999																					
3.10	.996	.999	.964	.993	.999																					
3.00	.996	.999	.961	.992	.999																					
2.90	.996	.999	.961	.992	.999																					
2.80	.996	.999	.961	.992	.999																					
2.70	.992	.998	.959	.981	.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000													
2.60	.987	.997	.954	.990	.983	.995	.978	.994	.983	.996	.989	.997	.996	1.000												
2.50	.941	.984	.898	.974	.905	.972	.913	.976	.930	.982	.959	.991	.994	.999	1.000	1.000										
2.40	.851	.960	.794	.942	.798	.940	.798	.943	.805	.950	.837	.965	.946	.993	.994	.999										
2.30	.851	.960	.794	.942	.798	.940	.798	.943	.805	.950	.837	.965	.946	.993	.994	.999										
2.20	.837	.956	.780	.937	.774	.932	.776	.935	.794	.947	.836	.965	.946	.993	.994	.999										
2.10	.808	.946	.746	.925	.724	.915	.722	.918	.736	.930	.778	.951	.924	.989	.991	.999										
2.00	.776	.936	.711	.913	.706	.908	.717	.916	.735	.930	.778	.951	.924	.989	.991	.999										
1.90	.769	.934	.703	.909	.703	.907	.715	.915	.733	.929	.776	.950	.923	.989	.991	.999										
1.80	.769	.934	.702	.909	.675	.896	.663	.896	.669	.907	.712	.932	.898	.985	.988	.998	1.000	1.000								
1.70	.698	.903	.630	.878	.622	.878	.619	.878	.621	.889	.652	.914	.824	.971	.942	.993	.991	.999								
1.60	.687	.902	.626	.876	.617	.871	.615	.876	.618	.889	.652	.914	.824	.971	.942	.993	.991	.999							1.000	
1.50	.606	.867	.563	.845	.569	.857	.586	.863	.585	.875	.620	.903	.812	.968	.940	.992	.991	.999							.999	
1.40	.598	.863	.551	.839	.526	.825	.514	.820	.541	.855	.595	.894	.787	.963	.925	.990	.988	.998							.999	
1.30	.572	.850	.520	.827	.518	.821	.505	.824	.532	.852	.588	.881	.785	.962	.925	.990	.988	.998							.999	
1.20	.545	.836	.493	.806	.475	.795	.470	.803	.491	.831	.538	.869	.723	.946	.885	.983	.982	.998							.999	
1.10	.432	.769	.426	.762	.442	.744	.434	.781	.449	.807	.485	.846	.663	.929	.848	.976	.975	.997							.999	
1.00	.428	.767	.417	.755	.409	.751	.410	.765	.433	.798	.473	.840	.663	.925	.848	.974	.973	.997							.999	
.90	.423	.764	.411	.751	.401	.744	.401	.758	.424	.792	.466	.836	.648	.925	.840	.974	.973	.997							.999	
.80	.325	.686	.290	.644	.271	.631	.288	.660	.322	.715	.390	.789	.616	.912	.829	.971	.972	.996	1.000	1.000	1.000	1.000	1.000	1.000	.999	1.000
.70	.305	.668	.267	.621	.245	.605	.255	.633	.293	.691	.364	.771	.606	.968	.822	.969	.959	.994	.980	.996	.978	.996	.975	.995	.972	.993
.60	.258	.620	.216	.561	.193	.546	.204	.578	.248	.640	.314	.730	.568	.889	.780	.955	.904	.981	.911	.983	.897	.980	.886	.974	.873	.963
.50	.189	.535	.155	.479	.138	.472	.148	.506	.173	.562	.221	.641	.385	.782	.526	.853	.669	.915	.827	.964	.890	.979	.883	.974	.862	.959
.40	.137	.458	.123	.392	.099	.407	.114	.453	.147	.525	.206	.623	.381	.778	.523	.852	.668	.915	.827	.964	.890	.979	.883	.974	.862	.959
.30	.108	.402	.083	.348	.084	.375	.097	.417	.123	.482	.171	.570	.296	.700	.351	.744	.335	.770	.344	.792	.333	.778	.257	.713	.176	.577
.20	.040	.220	.025	.173	.024	.197	.027	.219	.032	.251	.041	.296	.070	.407	.125	.544	.231	.706	.310	.775	.302	.762	.235	.694	.141	.550
.10	.004	.056	.005	.073	.008	.113	.009	.137	.013	.171	.021	.226	.059	.383	.122	.540	.231	.706	.302	.775	.302	.762	.234	.694	.141	.549

TABLE C-7

Gamma - 50% Halogens, 1% Solids

Time After LOCA / Energy (MeV)	Fraction Below Given Energy																									
	1 Second*		1 Minute		20 Minutes		1 Hour		2 Hours		4 Hours		12 Hours		1 Day		2 Days		4 Days		8 Days		16 Days		30 Days	
	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle
5.20	1.000	1.000	1.000	1.000																						
5.00	.988	.997	.992	.998																						
4.50	.955	.991	.973	.995																						
4.00	.938	.986	.961	.992	1.000	1.000	1.000	1.000	1.000	1.000																
3.90	.929	.985	.953	.990	.992	.998	.996	.999	.998	.999																
3.80	.929	.985	.953	.990	.992	.998	.996	.999	.998	.999																
3.70	.922	.983	.949	.989	.992	.998	.996	.999	.998	.999																
3.60	.922	.983	.949	.989	.992	.998	.996	.999	.998	.999																
3.50	.921	.983	.948	.989	.992	.998	.995	.999	.998	.999																
3.40	.921	.983	.948	.989	.992	.998	.995	.999	.998	.999																
3.30	.920	.982	.947	.989	.991	.998	.995	.999	.998	.999																
3.20	.918	.980	.942	.987	.991	.998	.995	.999	.998	.999																
3.10	.903	.977	.936	.985	.991	.998	.995	.999	.998	.999																
3.00	.903	.977	.936	.985	.991	.998	.995	.999	.998	.999																
2.90	.889	.972	.927	.983	.991	.998	.995	.998	.997	.999																
2.80	.889	.972	.927	.983	.991	.998	.995	.998	.997	.999																
2.70	.877	.968	.919	.980	.991	.998	.995	.998	.997	.999																
2.60	.857	.961	.904	.975	.990	.997	.994	.998	.997	.999	1.000		1.000		1.000		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2.50	.855	.960	.902	.974	.988	.997	.993	.998	.996	.999	.998	1.000	.998		.998		.996	.999	.995	.999	.994	.999	.993	.998	.993	.998
2.40	.842	.955	.892	.970	.984	.995	.990	.997	.995	.998	.997	.999	.998		.998		.996	.999	.995	.999	.994	.999	.993	.998	.993	.998
2.30	.842	.955	.892	.970	.984	.995	.990	.997	.995	.998	.997	.999	.998		.998		.996	.999	.995	.999	.994	.999	.993	.998	.993	.998
2.20	.819	.945	.875	.963	.983	.995	.989	.997	.994	.998	.997	.999	.998		.998		.996	.999	.995	.999	.994	.999	.993	.998	.993	.998
2.10	.819	.945	.875	.963	.982	.995	.989	.997	.994	.998	.997	.999	.998		.997		.996	.999	.994	.999	.992	.998	.991	.998	.989	.997
2.00	.818	.945	.874	.963	.982	.995	.989	.997	.994	.998	.997	.999	.998	1.000	.997	1.000	.996	.999	.994	.999	.992	.998	.991	.998	.989	.997
1.90	.814	.942	.868	.960	.976	.992	.983	.994	.989	.996	.993	.997	.997	.999	.996	.999	.994	.999	.993	.998	.992	.998	.991	.998	.989	.997
1.80	.802	.936	.858	.955	.970	.989	.980	.993	.987	.995	.992	.997	.997	.999	.996	.999	.994	.999	.993	.998	.992	.998	.991	.998	.989	.997
1.70	.743	.903	.788	.918	.878	.946	.878	.946	.873	.944	.866	.944	.888	.961	.941	.983	.986	.997	.992	.998	.992	.998	.991	.998	.989	.997
1.60	.739	.898	.777	.912	.866	.940	.869	.941	.868	.942	.854	.943	.888	.961	.941	.983	.986	.996	.992	.998	.992	.998	.991	.998	.989	.997
1.50	.728	.885	.771	.908	.860	.937	.862	.938	.860	.938	.853	.938	.866	.953	.902	.971	.918	.978	.894	.972	.873	.967	.859	.960	.862	.955
1.40	.673	.857	.722	.878	.820	.914	.821	.915	.817	.915	.808	.915	.827	.937	.880	.963	.911	.975	.888	.971	.868	.965	.855	.958	.859	.954
1.30	.598	.808	.660	.835	.797	.900	.798	.901	.794	.901	.789	.905	.821	.934	.877	.962	.906	.974	.884	.970	.865	.964	.854	.958	.850	.954
1.20	.548	.764	.601	.792	.722	.850	.712	.846	.685	.840	.679	.840	.729	.890	.830	.943	.897	.971	.881	.968	.862	.963	.851	.957	.853	.951
1.10	.489	.715	.532	.737	.634	.787	.618	.780	.594	.771	.570	.771	.640	.844	.784	.924	.888	.967	.879	.968	.850	.963	.849	.956	.850	.950
1.00	.474	.701	.514	.721	.612	.770	.596	.763	.571	.754	.545	.753	.617	.831	.770	.917	.882	.965	.873	.965	.852	.960	.837	.951	.831	.941
.90	.456	.682	.492	.700	.587	.748	.571	.742	.547	.734	.525	.738	.608	.825	.761	.912	.869	.959	.855	.958	.834	.952	.818	.942	.809	.929
.80	.277	.478	.283	.474	.357	.525	.393	.574	.431	.628	.473	.693	.585	.809	.747	.904	.859	.954	.844	.953	.821	.945	.802	.934	.791	.918
.70	.185	.359	.217	.393	.276	.437	.310	.486	.348	.542	.400	.621	.539	.772	.692	.868	.785	.911	.755	.904	.720	.890	.673	.857	.593	.782
.60	.104	.237	.120	.256	.155	.283	.188	.333	.231	.401	.301	.510	.481	.718	.622	.815	.685	.845	.634	.828	.591	.808	.532	.760	.408	.635
.50	.041	.125	.046	.131	.048	.122	.055	.139	.069	.173	.100	.240	.201	.414	.308	.531	.429	.644	.529	.751	.550	.777	.487	.723	.346	.577
.40	.030	.103	.033	.105	.035	.098	.043	.117	.058	.153	.088	.221	.188	.397	.293	.515	.408	.624	.499	.724	.512	.742	.436	.672	.278	.498
.30	.008	.040	.008	.039	.006	.030	.008	.036	.013	.053	.025	.089	.066	.188	.088	.225	.071	.209	.057	.210	.055	.203	.047	.175	.042	.152
.20	.002	.017	.002	.018	.002	.017	.002	.116	.002	.017	.002	.022	.005	.041	.010	.069	.018	.117	.025	.157	.024	.154	.021	.128	.021	.108
.10	.000	.005	.000	.005	.000	.005	.000	.007	.001	.009	.001	.013	.002	.029	.005	.053	.011	.096	.016	.132	.015	.128	.010	.095	.005	.051

APPENDIX D

BETA PARTICLE/ENERGY SPECTRA

TABLE D-I

Beta Release Rates Per Watt of Reactor Power

Time After LOCA	50% Halogens 1% Solids		100% Noble Gases 25% Iodines		25% Iodines		100% Noble Gases		100% Solids		100% Release	
	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle
1 sec	1.37+10*	9.87+9†	2.57+10	2.16+10	2.97+9	3.22+9	2.27+10	1.84+10	1.53+11	1.30+11	2.00+11	1.65+11
1 min	5.07+9	6.77	1.36	1.57	1.47	2.51	1.21	1.31	1.11	1.11	1.31	1.35
20 min	2.73	5.23	6.14+9	1.06	1.02	2.15	5.12+9	8.47+9	5.43+10	7.50+10	6.38+10	9.24+10
1 hr	2.12	4.55	5.24	9.14+9	8.40+8	1.92	4.40	7.22	3.65	6.08	4.44	7.59
2 hr	1.68	3.94	4.03	7.78	6.79	1.67	3.35	6.11	2.89	5.42	3.50	6.71
4 hr	1.31	3.33	2.66	6.29	5.29	1.40	2.14	4.89	2.39	4.89	2.81	5.94
12 hr	8.80+8	2.42	1.07	4.08	3.51	1.00	7.16+8	3.08	1.77	4.09	1.98	4.79
1 day	6. 8	1.77	5.96+8	2.99	2.32	7.07+8	3.65	2.29	1.44	3.57	1.57	4.08
2 day	3.66	1.19	3.53	2.20	1.22	4.43	2.30	1.76	1.21	3.09	1.28	3.45
4 day	2.28	8.42+8	2.29	1.61	6.24+7	2.88	1.67	1.33	1.03	2.66	1.08	2.91
8 day	1.61	5.95	1.40	9.88+8	3.65	1.85	1.04	8.04+8	8.82+9	2.25	9.07+9	2.40
16 day	1.08	3.61	6.21+7	4.01	1.75	8.70+7	4.46+7	3.14	7.35	1.87	7.46	1.93
30 day	7.04+7	2.01	2.27	1.16	5.06+6	2.44	1.77	9.12+7	6.03	1.52	6.07	1.54

* Read as 1.37×10^{10} MeV/sec

† Read as 9.87×10^{9} particles/sec

TABLE D-2

Beta - 100% Release

Time After LOCA / Energy (MeV)	Fraction Below Given Energy																									
	1 Second		1 Minute		20 Minutes		1 Hour		2 Hours		4 Hours		12 Hours		1 Day		2 Days		4 Days		8 Days		16 Days		30 Days	
	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle
9.10	1.000																									
9.00	.999																									
8.50	.998	1.000	1.000																							
8.00	.995	.999	.999																							
7.50	.991	.998	.998																							
7.00	.983	.997	.995	1.000																						
6.50	.971	.995	.992	.998	1.000		1.000		1.000																	
6.00	.954	.991	.984	.997	.996	1.000	.997	1.000	.998		1.000															
5.50	.929	.986	.971	.995	.991	.998	.993	.999	.997	1.000	.999															
5.00	.887	.979	.952	.992	.982	.997	.987	.998	.994	.999	.998															
4.50	.858	.969	.927	.986	.968	.995	.977	.997	.988	.998	.997	1.000	1.000													
4.00	.808	.954	.894	.979	.949	.992	.963	.995	.980	.997	.993	.999	.999													
3.50	.745	.934	.849	.967	.924	.987	.946	.992	.969	.996	.987	.998	.998	1.000	1.000				1.000		1.000		1.000		1.000	
3.00	.669	.906	.789	.949	.889	.980	.921	.988	.951	.993	.976	.996	.994	.999	.999		1.000		.999		.999		.999		.999	
2.90	.652	.899	.775	.945	.881	.978	.915	.987	.947	.992	.972	.996	.993	.999	.998		.999		.999		.998		.998		.998	
2.80	.635	.891	.760	.939	.871	.976	.908	.985	.941	.991	.968	.995	.991	.998	.997	1.000	.998		.998	1.000	.997	1.000	.997	1.000	.996	1.000
2.70	.617	.883	.744	.934	.861	.973	.901	.984	.935	.990	.963	.994	.989	.998	.996	.999	.996	1.000	.995	.999	.995	.999	.994	.999	.993	.999
2.60	.597	.874	.726	.927	.850	.970	.892	.982	.927	.988	.957	.993	.985	.997	.993	.999	.993	.999	.992	.998	.991	.998	.989	.998	.987	.998
2.50	.578	.865	.707	.920	.837	.967	.882	.979	.919	.987	.949	.992	.980	.997	.989	.998	.989	.998	.987	.998	.985	.997	.982	.997	.979	.996
2.40	.557	.855	.687	.912	.823	.963	.871	.977	.909	.985	.940	.990	.973	.996	.983	.997	.983	.997	.981	.997	.977	.996	.973	.996	.968	.995
2.30	.536	.844	.666	.903	.807	.958	.858	.974	.897	.982	.930	.988	.965	.994	.976	.996	.976	.996	.972	.996	.968	.995	.962	.994	.954	.992
2.20	.514	.832	.643	.894	.790	.953	.844	.970	.884	.979	.917	.985	.955	.992	.968	.995	.967	.995	.963	.994	.958	.993	.948	.991	.939	.990
2.10	.491	.819	.619	.883	.770	.947	.827	.965	.868	.975	.903	.982	.944	.990	.958	.993	.957	.993	.951	.992	.943	.990	.933	.989	.920	.986
2.00	.467	.805	.593	.870	.748	.939	.808	.960	.852	.971	.887	.978	.931	.987	.947	.991	.945	.991	.938	.989	.928	.988	.915	.985	.899	.982
1.90	.442	.789	.565	.857	.723	.930	.786	.953	.832	.965	.869	.974	.916	.984	.933	.988	.931	.988	.922	.987	.910	.984	.894	.981	.876	.977
1.80	.416	.773	.536	.841	.696	.920	.762	.946	.810	.959	.848	.969	.899	.981	.918	.985	.916	.985	.904	.983	.890	.980	.872	.976	.850	.972
1.70	.390	.754	.505	.824	.657	.909	.736	.937	.785	.952	.826	.963	.880	.976	.900	.981	.893	.981	.885	.979	.868	.976	.848	.971	.822	.966
1.60	.363	.734	.473	.806	.635	.898	.706	.926	.758	.943	.801	.956	.860	.971	.881	.976	.878	.977	.864	.974	.845	.970	.822	.965	.793	.959
1.50	.335	.713	.440	.785	.601	.881	.675	.915	.729	.933	.775	.948	.837	.965	.860	.971	.857	.972	.842	.969	.821	.964	.795	.958	.763	.951
1.40	.307	.689	.407	.762	.566	.864	.642	.901	.697	.922	.746	.938	.812	.958	.837	.965	.834	.966	.817	.963	.795	.957	.767	.951	.732	.943
1.30	.279	.664	.372	.738	.529	.845	.606	.886	.663	.909	.714	.927	.784	.949	.810	.957	.807	.958	.788	.955	.764	.949	.733	.941	.698	.932
1.20	.251	.637	.337	.711	.490	.823	.568	.868	.627	.894	.679	.914	.751	.938	.778	.948	.774	.948	.754	.944	.727	.938	.694	.929	.655	.919
1.10	.223	.607	.302	.681	.448	.799	.526	.847	.586	.875	.639	.897	.712	.924	.740	.935	.735	.936	.712	.931	.683	.923	.648	.914	.607	.903
1.00	.195	.575	.266	.648	.405	.769	.481	.821	.540	.852	.593	.877	.666	.906	.693	.917	.687	.918	.664	.914	.633	.905	.597	.895	.555	.883
.90	.167	.539	.230	.611	.358	.735	.432	.791	.489	.824	.540	.850	.611	.882	.637	.895	.632	.897	.609	.893	.578	.884	.541	.872	.500	.861
.80	.140	.500	.194	.570	.310	.697	.379	.754	.432	.789	.481	.817	.548	.851	.572	.865	.568	.869	.548	.866	.519	.857	.483	.846	.444	.835
.70	.113	.458	.159	.524	.260	.651	.322	.710	.370	.746	.415	.775	.475	.812	.499	.827	.497	.834	.480	.833	.455	.825	.423	.815	.388	.805
.60	.088	.411	.125	.474	.210	.598	.264	.657	.305	.694	.344	.724	.398	.762	.420	.781	.451	.791	.410	.792	.390	.787	.364	.780	.335	.773
.50	.066	.361	.094	.419	.162	.537	.206	.596	.241	.633	.273	.663	.318	.702	.339	.724	.344	.738	.339	.745	.325	.743	.308	.739	.285	.737
.40	.045	.306	.066	.358	.117	.467	.151	.524	.178	.559	.203	.589	.239	.630	.258	.655	.268	.675	.268	.686	.260	.688	.248	.689	.234	.693
.30	.028	.245	.041	.289	.074	.384	.098	.436	.117	.469	.135	.497	.163	.540	.180	.569	.191	.594	.195	.609	.192	.615	.185	.620	.179	.631
.20	.013	.176	.020	.209	.038	.284	.051	.327	.062	.354	.073	.380	.091	.421	.104	.450	.113	.477	.117	.494	.116	.501	.114	.511	.114	.528
.10	.003	.096	.005	.115	.011	.160	.015	.186	.019	.204	.023	.222	.030	.252	.035	.276	.039	.294	.041	.306	.041	.311	.041	.322	.043	.341

TABLE D-3

Beta - 100% Noble Gases

Time After LOCA / Energy (MeV)	Fraction Below Given Energy																									
	1 Second		1 Minute		20 Minutes		1 Hour		2 Hours		4 Hours		12 Hours		1 Day		2 Days		4 Days		8 Days		13 Days		30 Days	
	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle
8.10	1.000																									
8.00	.999																									
7.50	.998																									
7.00	.996																									
6.50	.993																									
6.00	.988	1.000																								
5.50	.982	.996	1.000		1.000		1.000		1.000		1.000															
5.00	.971	.993	.999	1.000	.999	1.000	.999	1.000	.998	1.000	.998	1.000	1.000		1.000											
4.50	.953	.989	.996	.999	.991	.998	.995	.998	.982	.997	.983	.998	.993	1.000	.999											
4.00	.920	.979	.985	.996	.970	.995	.948	.992	.941	.992	.942	.994	.976	.998	.997											
3.50	.862	.960	.954	.989	.936	.990	.892	.983	.876	.983	.880	.986	.950	.997	.995											
3.00	.762	.923	.875	.966	.882	.980	.815	.969	.791	.968	.801	.976	.920	.994	.991											
2.90	.737	.911	.852	.959	.868	.977	.797	.965	.773	.965	.784	.973	.913	.994	.991											
2.80	.710	.899	.828	.951	.853	.974	.778	.961	.753	.961	.767	.971	.907	.993	.990											
2.70	.681	.885	.801	.942	.837	.970	.759	.957	.734	.957	.750	.968	.901	.993	.990											
2.60	.651	.873	.773	.932	.820	.966	.739	.952	.714	.953	.733	.965	.895	.992	.989	1.000										
2.50	.621	.858	.743	.922	.802	.962	.719	.947	.693	.949	.716	.962	.889	.992	.988	.999										
2.40	.589	.842	.713	.910	.783	.957	.697	.942	.672	.944	.698	.959	.882	.991	.988	.999										
2.30	.557	.825	.681	.897	.763	.952	.675	.936	.651	.939	.680	.956	.876	.991	.987	.999										
2.20	.524	.807	.647	.884	.741	.946	.652	.930	.629	.934	.662	.952	.870	.990	.987	.999										
2.10	.491	.788	.613	.869	.717	.940	.628	.923	.606	.928	.644	.949	.863	.989	.986	.999										
2.00	.456	.767	.576	.853	.690	.932	.602	.915	.584	.922	.626	.945	.857	.989	.985	.999										
1.90	.422	.745	.539	.835	.661	.923	.576	.907	.561	.915	.608	.941	.851	.988	.985	.999										
1.80	.387	.722	.501	.816	.630	.912	.549	.898	.538	.916	.590	.936	.844	.987	.984	.999										
1.70	.352	.697	.462	.795	.597	.901	.521	.889	.515	.901	.572	.932	.838	.986	.983	.998										
1.60	.318	.672	.423	.774	.564	.889	.494	.879	.492	.894	.555	.927	.832	.985	.983	.999										
1.50	.285	.646	.385	.751	.530	.876	.467	.868	.471	.886	.539	.923	.827	.984	.982	.998										
1.40	.253	.619	.348	.727	.496	.862	.441	.857	.451	.878	.524	.918	.821	.954	.982	.998										
1.30	.223	.591	.313	.703	.463	.847	.417	.846	.431	.871	.509	.914	.816	.983	.981	.998										
1.20	.196	.564	.280	.679	.432	.832	.394	.835	.414	.863	.496	.909	.812	.982	.981	.998										
1.10	.170	.537	.250	.655	.402	.816	.372	.823	.398	.855	.484	.905	.808	.981	.980	.998										
1.00	.148	.510	.222	.630	.374	.800	.352	.813	.383	.848	.474	.900	.804	.980	.980	.998									1.000	
.90	.127	.484	.197	.607	.348	.783	.334	.800	.370	.840	.464	.896	.801	.979	.980	.998	1.000								.999	
.80	.110	.458	.175	.582	.323	.765	.316	.787	.355	.830	.452	.890	.792	.977	.974	.997	.998	1.000							.999	
.70	.093	.430	.152	.554	.292	.740	.290	.766	.330	.812	.426	.874	.759	.967	.951	.992	.992	.998	1.000		1.000		1.000	1.000	.999	1.000
.60	.076	.398	.128	.520	.253	.705	.255	.733	.293	.781	.382	.845	.699	.945	.905	.981	.980	.996	.997	1.000	.997	1.000	.994	.998	.985	.995
.50	.060	.362	.103	.479	.210	.657	.213	.687	.247	.735	.326	.800	.618	.911	.842	.963	.959	.991	.988	.997	.983	.996	.961	.990	.903	.996
.40	.045	.321	.079	.429	.164	.595	.168	.625	.197	.674	.263	.739	.528	.865	.771	.937	.931	.983	.971	.992	.956	.988	.899	.970	.748	.900
.30	.030	.270	.055	.365	.117	.514	.122	.546	.146	.594	.201	.661	.439	.805	.695	.903	.888	.967	.935	.979	.910	.971	.814	.936	.559	.795
.20	.016	.197	.029	.269	.063	.384	.067	.413	.082	.454	.116	.513	.273	.651	.456	.750	.602	.817	.637	.829	.614	.818	.531	.775	.312	.603
.10	.003	.098	.007	.132	.015	.191	.017	.207	.020	.229	.029	.261	.072	.339	.124	.397	.167	.437	.176	.443	.188	.435	.143	.407	.077	.300

TABLE D-4

Beta - 100% Solids

Time After LOCA / Energy (MeV)	Fraction Below Given Energy																									
	1 Second		1 Minute		20 Minutes		1 Hour		2 Hours		4 Hours		12 Hours		1 Day		2 Days		4 Days		8 Days		16 Days		30 Days	
	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle
8.60	1.000																									
8.50	.999																									
8.00	.997	1.000	1.000																							
7.50	.994	.999	.998																							
7.00	.988	.998	.996	1.000	1.000																					
6.50	.979	.996	.992	.998	.999		1.000		1.000																	
6.00	.964	.993	.984	.997	.996	1.000	.997	1.000	.998		1.000															
5.50	.942	.989	.969	.995	.989	.998	.992	.999	.996	1.000	.999															
5.00	.911	.982	.948	.991	.979	.997	.984	.998	.992	.999	.998															
4.50	.872	.972	.920	.985	.964	.994	.974	.997	.988	.999	.998															
4.00	.823	.958	.883	.976	.943	.991	.962	.995	.983	.998	.997															
3.90	.812	.955	.875	.974	.938	.990	.959	.994	.982	.998	.997															
3.80	.800	.951	.865	.971	.933	.989	.956	.994	.980	.997	.996															
3.70	.787	.947	.856	.969	.928	.988	.953	.993	.979	.997	.996															
3.60	.775	.943	.846	.966	.922	.987	.950	.993	.978	.997	.996															
3.50	.761	.939	.835	.963	.917	.986	.947	.992	.977	.997	.996	1.000	1.000		1.000				1.000		1.000		1.000		1.000	
3.00	.687	.912	.775	.944	.882	.978	.927	.988	.966	.995	.989	.998	.997	1.000	.999		1.000		.999		.999		.999		.999	
2.90	.671	.905	.762	.940	.873	.976	.922	.988	.962	.994	.987	.998	.996	.999	.998		.999		.999		.998		.998		.998	
2.80	.654	.898	.747	.935	.864	.974	.916	.986	.958	.993	.983	.997	.994	.999	.997	1.000	.998	1.000	.997	1.000	.997	1.000	.997	1.000	.996	1.000
2.70	.636	.891	.731	.929	.854	.971	.903	.985	.952	.992	.979	.996	.991	.998	.996	.999	.996	.000	.995	.999	.995	.999	.994	.999	.993	.999
2.60	.618	.882	.714	.922	.842	.968	.901	.983	.946	.991	.973	.995	.987	.998	.992	.998	.993	.999	.992	.998	.990	.998	.989	.998	.987	.998
2.50	.598	.873	.696	.915	829	.964	.891	.981	.938	.989	.966	.994	.982	.997	.988	.998	.988	.998	.987	.998	.984	.997	.982	.997	.979	.996
2.40	.578	.863	.676	.907	.814	.960	.880	.978	.928	.987	.957	.992	.975	.995	.982	.997	.982	.997	.980	.997	.977	.996	.972	.995	.963	.995
2.30	.556	.853	.655	.898	.798	.955	.868	.975	.917	.985	.946	.990	.966	.994	.975	.996	.975	.996	.971	.995	.967	.994	.961	.993	.954	.992
2.20	.532	.841	.632	.888	.779	.949	.853	.971	.903	.982	.933	.987	.955	.992	.966	.994	.965	.994	.961	.993	.955	.992	.947	.991	.938	.990
2.10	.510	.828	.608	.877	.759	.942	.836	.966	.888	.978	.918	.984	.943	.989	.955	.992	.955	.992	.949	.991	.941	.990	.932	.988	.920	.986
2.00	.486	.814	.582	.864	.736	.934	.818	.960	.869	.973	.900	.979	.928	.986	.942	.989	.942	.990	.935	.989	.926	.987	.913	.985	.899	.982
1.90	.461	.799	.555	.850	.711	.924	.794	.953	.848	.957	.880	.974	.912	.983	.928	.986	.927	.987	.919	.985	.907	.983	.893	.981	.875	.977
1.80	.435	.782	.526	.834	.683	.913	.769	.945	.825	.960	.858	.969	.893	.978	.911	.983	.911	.983	.901	.981	.887	.979	.870	.976	.849	.972
1.70	.407	.764	.495	.817	.652	.901	.740	.936	.798	.952	.834	.962	.873	.973	.892	.978	.892	.979	.880	.977	.865	.974	.845	.970	.821	.965
1.60	.379	.744	.463	.797	.620	.886	.709	.924	.769	.943	.806	.954	.850	.967	.871	.973	.871	.974	.853	.972	.841	.968	.819	.964	.792	.958
1.50	.351	.722	.431	.776	.585	.870	.676	.911	.737	.932	.777	.944	.825	.960	.848	.967	.849	.968	.835	.966	.816	.962	.792	.957	.762	.591
1.40	.322	.698	.397	.753	.548	.852	.640	.896	.702	.919	.745	.933	.797	.952	.823	.960	.824	.962	.810	.959	.789	.955	.763	.949	.730	.942
1.30	.292	.672	.362	.727	.509	.831	.601	.879	.664	.904	.700	.921	.766	.942	.794	.951	.796	.954	.780	.950	.757	.945	.729	.939	.694	.931
1.20	.263	.644	.327	.699	.469	.807	.560	.859	.623	.887	.670	.905	.730	.928	.759	.940	.761	.943	.744	.939	.719	.933	.689	.927	.652	.918
1.10	.233	.614	.291	.668	.426	.781	.515	.836	.578	.866	.626	.886	.687	.913	.718	.926	.719	.929	.701	.925	.674	.918	.643	.911	.605	.902
1.00	.203	.580	.255	.633	.381	.750	.467	.808	.528	.840	.575	.863	.638	.893	.668	.907	.670	.910	.651	.906	.622	.899	.590	.891	.552	.882
.90	.173	.543	.219	.595	.335	.714	.415	.776	.474	.809	.519	.834	.581	.867	.611	.882	.613	.887	.594	.883	.566	.876	.534	.868	.497	.859
.80	.144	.503	.183	.553	.286	.673	.360	.737	.414	.772	.457	.799	.515	.833	.544	.850	.548	.857	.531	.854	.505	.847	.475	.841	.441	.833
.70	.116	.459	.149	.507	.238	.626	.303	.691	.351	.727	.390	.755	.443	.792	.470	.810	.475	.819	.461	.818	.440	.813	.414	.809	.385	.803
.60	.090	.412	.116	.457	.190	.573	.246	.638	.287	.675	.321	.703	.367	.741	.392	.761	.398	.772	.388	.774	.373	.773	.354	.772	.331	.770
.50	.067	.361	.086	.403	.146	.514	.191	.578	.224	.614	.252	.642	.291	.681	.313	.703	.320	.717	.316	.723	.307	.726	.29	.730	.281	.734
.40	.046	.306	.060	.343	.104	.447	.139	.508	.164	.543	.186	.570	.217	.610	.236	.634	.245	.652	.246	.662	.243	.670	.238	.680	.231	.590
.30	.028	.246	.037	.277	.066	.369	.090	.425	.108	.457	.123	.483	.147	.523	.162	.549	.172	.570	.176	.585	.177	.597	.178	.612	.177	.629
.20	.014	.179	.018	.203	.035	.277	.048	.324	.059	.351	.068	.374	.083	.412	.094	.438	.101	.459	.105	.475	.107	.487	.110	.505	.113	.528
.10	.004	.101	.005	.116	.011	.163	.016	.193	.019	.212	.023	.228	.029	.256	.034	.275	.037	.291	.038	.301	.039	.308	.040	.322	.043	.342

TABLE D-5

Beta - 100% Iodines

Time After LOCA / Energy (MeV)	Fraction Below Given Energy																									
	1 Second		1 Minute		20 Minutes		1 Hour		2 Hours		4 Hours		12 Hours		1 Day		2 Days		4 Days		8 Days		16 Days		30 Days	
	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle
7.70	1.000																									
7.50	.998	1.000																								
7.00	.992	.999																								
6.50	.973	.997	1.000																							
6.00	.954	.993	.999																							
5.50	.924	.988	.997	1.000																						
5.00	.888	.982	.994	.999																						
4.50	.846	.974	.988	.998																						
4.00	.797	.963	.979	.997																						
3.50	.741	.949	.964	.995																						
3.00	.682	.933	.943	.991																						
2.90	.670	.929	.938	.990																						
2.80	.659	.925	.933	.989																						
2.70	.647	.922	.928	.988																						
2.60	.637	.918	.923	.986	1.000																					
2.50	.626	.914	.917	.985	.999																					
2.40	.616	.910	.911	.984	.999																					
2.30	.606	.906	.909	.982	.999		1.000		1.000																	
2.20	.596	.903	.899	.981	.997	1.000	.999	1.000	.999																	
2.10	.586	.898	.892	.979	.995	.999	.997	.999	.998	1.000	1.000															
2.00	.576	.893	.882	.976	.990	.998	.994	.998	.996	.999	.999															
1.90	.564	.888	.871	.973	.983	.996	.989	.997	.993	.998	.997	1.000														
1.80	.551	.881	.857	.968	.974	.993	.981	.995	.988	.997	.996	.999														
1.70	.536	.873	.839	.962	.961	.990	.972	.993	.982	.996	.993	.998	1.000													
1.60	.518	.863	.819	.955	.946	.986	.960	.990	.975	.994	.990	.997	.999													
1.50	.497	.851	.794	.846	.928	.980	.946	.986	.966	.992	.986	.997	.999													
1.40	.473	.836	.767	.934	.907	.973	.930	.981	.955	.988	.981	.995	.998	1.000												
1.30	.447	.818	.736	.921	.882	.965	.911	.975	.942	.984	.975	.994	.997	.999	1.000		1.000									
1.20	.418	.797	.701	.904	.853	.954	.887	.967	.925	.979	.966	.991	.994	.998	.998	1.000	.999	1.000	1.000	1.000						
1.10	.386	.771	.658	.883	.814	.938	.853	.954	.897	.969	.945	.984	.981	.994	.986	.996	.990	.997	.996	.999	1.000					
1.00	.349	.739	.606	.854	.762	.914	.805	.934	.853	.952	.907	.970	.949	.984	.958	.987	.967	.991	.987	.997	.999					
.90	.308	.699	.545	.816	.695	.881	.741	.904	.793	.926	.850	.948	.899	.965	.911	.971	.929	.980	.972	.993	.997	1.000				
.80	.264	.651	.473	.766	.614	.836	.661	.863	.714	.888	.773	.914	.828	.936	.846	.946	.878	.963	.952	.988	.996	.999				
.70	.217	.593	.395	.705	.521	.777	.568	.809	.619	.837	.678	.866	.736	.893	.761	.909	.814	.940	.928	.982	.994	.998	1.000		1.000	
.60	.170	.527	.315	.633	.423	.706	.468	.741	.516	.772	.571	.804	.628	.835	.663	.859	.743	.910	.903	.973	.992	.998	.999	1.000	.998	1.000
.50	.126	.453	.236	.549	.325	.622	.365	.660	.408	.693	.456	.725	.508	.758	.548	.791	.653	.864	.849	.952	.953	.984	.959	.985	.957	.984
.40	.084	.368	.161	.450	.227	.519	.259	.557	.293	.589	.330	.619	.370	.651	.406	.688	.512	.778	.795	.883	.803	.918	.803	.915	.795	.909
.30	.047	.271	.091	.334	.132	.391	.154	.425	.175	.452	.199	.478	.225	.506	.254	.545	.341	.643	.497	.753	.559	.786	.559	.775	.540	.758
.20	.019	.167	.058	.208	.056	.247	.066	.270	.076	.290	.087	.308	.100	.331	.147	.365	.188	.452	.256	.545	.294	.568	.282	.552	.264	.530
.10	.003	.070	.007	.088	.011	.105	.013	.116	.015	.125	.017	.134	.020	.145	.025	.165	.038	.212	.060	.261	.069	.272	.064	.261	.059	.246

TABLE D-6

Beta - 100% Noble Gases, 25% Iodines

Time After LOCA / Energy (MeV)	Fraction Below Given Energy																											
	1 Second		1 Minute		20 Minutes		1 Hour		2 Hours		4 Hours		12 Hours		1 Day		2 Days		4 Days		8 Days		16 Days		30 Days	
	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle
8.10	1.000	1.000																										
8.00	.999	.999																										
7.50	.998	.999																										
7.00	.995	.999																										
6.50	.998	.998																										
6.00	.985	.997																										
5.50	.975	.995	1.000		1.000		1.000		1.000		1.000																	
5.00	.961	.992	.998	1.000	.999	1.000	.999	1.000	.999	1.000	.999	1.000	1.000															
4.50	.941	.987	.995	.999	.992	.999	.987	.998	.985	.998	.985	.998	.995	1.000	1.000													
4.00	.906	.977	.984	.997	.975	.996	.957	.994	.950	.994	.954	.995	.984	.999	.998													
3.50	.848	.958	.955	.990	.947	.992	.909	.987	.897	.986	.903	.989	.966	.997	.996													
3.00	.753	.923	.832	.970	.901	.984	.845	.975	.827	.975	.841	.981	.946	.996	.995													
2.90	.729	.914	.862	.964	.890	.981	.830	.972	.811	.972	.827	.979	.942	.995	.994													
2.80	.704	.903	.839	.957	.877	.979	.814	.969	.795	.969	.814	.977	.938	.995	.994													
2.70	.677	.892	.815	.949	.864	.976	.793	.956	.778	.965	.800	.975	.944	.995	.993													
2.60	.650	.879	.789	.941	.851	.973	.781	.962	.762	.963	.788	.973	.929	.994	.993													
2.50	.621	.866	.762	.932	.835	.976	.764	.958	.745	.959	.772	.971	.925	.994	.993													
2.40	.592	.852	.734	.922	.819	.966	.746	.954	.727	.956	.758	.968	.921	.993	.992													
2.30	.563	.837	.705	.911	.802	.962	.727	.949	.710	.952	.744	.966	.917	.993	.992													
2.20	.533	.821	.675	.899	.784	.957	.708	.944	.691	.948	.729	.963	.912	.992	.992	1.000												
2.10	.502	.804	.643	.886	.763	.951	.687	.939	.672	.943	.715	.960	.908	.992	.991	.999												
2.00	.470	.785	.609	.872	.740	.945	.665	.933	.653	.938	.700	.957	.904	.991	.991	.999												
1.90	.458	.766	.575	.857	.714	.937	.642	.926	.633	.933	.684	.954	.900	.991	.990	.999												
1.80	.406	.746	.539	.840	.687	.929	.618	.919	.613	.927	.670	.950	.895	.990	.990	.999												
1.70	.373	.724	.503	.822	.657	.919	.594	.911	.593	.922	.656	.947	.891	.989	.990	.999									1.000			
1.60	.341	.706	.465	.803	.627	.908	.569	.962	.574	.915	.641	.943	.887	.989	.989	.999							1.000		.999			
1.50	.309	.676	.429	.782	.598	.897	.544	.893	.554	.909	.628	.939	.883	.988	.989	.999					1.000		.999		.999			
1.40	.279	.651	.393	.761	.564	.884	.520	.883	.535	.902	.614	.935	.879	.987	.989	.999	1.000		1.000		.999		.999		.999			
1.30	.249	.625	.359	.738	.533	.871	.496	.873	.517	.895	.602	.931	.876	.987	.988	.999	.999	1.000	.999	1.000	.999		.999	1.000	.999	1.000		
1.20	.221	.599	.325	.715	.502	.856	.473	.863	.500	.888	.589	.927	.872	.986	.987	.998	.999	.999	.999	.999	.999	1.000	.999	.999	.999	.999		
1.10	.195	.572	.294	.691	.470	.841	.449	.851	.482	.880	.576	.922	.863	.984	.983	.998	.996	.999	.998	.999	.999	.999	.999	.999	.998	.999		
1.00	.171	.544	.264	.666	.438	.823	.425	.837	.452	.870	.560	.916	.852	.981	.971	.996	.988	.998	.996	.999	.999	.999	.999	.999	.999	.999		
.90	.148	.516	.235	.640	.405	.803	.400	.822	.441	.858	.541	.987	.833	.976	.953	.992	.975	.992	.992	.998	.999	.999	.999	.999	.999	.999		
.80	.127	.487	.207	.612	.371	.780	.371	.803	.415	.843	.516	.895	.804	.967	.924	.985	.956	.992	.986	.998	.998	.999	.999	.999	.999	.999		
.70	.107	.454	.178	.578	.330	.748	.335	.775	.379	.818	.476	.872	.752	.949	.877	.972	.936	.987	.980	.996	.998	.999	.999	.999	.999	.999		
.60	.087	.417	.148	.530	.282	.705	.289	.735	.331	.779	.420	.836	.676	.918	.811	.952	.898	.979	.972	.994	.996	.999	.995	.998	.988	.996		
.50	.067	.376	.118	.490	.229	.650	.237	.681	.274	.726	.352	.783	.582	.873	.728	.922	.853	.965	.950	.989	.975	.993	.960	.989	.915	.970		
.40	.049	.328	.080	.432	.174	.580	.182	.611	.213	.655	.277	.713	.476	.812	.629	.878	.786	.942	.898	.973	.916	.975	.872	.958	.759	.962		
.30	.032	.270	.059	.360	.120	.489	.127	.520	.151	.563	.206	.620	.369	.732	.523	.818	.699	.862	.816	.939	.821	.936	.742	.921	.555	.787		
.20	.016	.193	.038	.259	.062	.356	.067	.383	.081	.419	.118	.467	.216	.572	.324	.659	.452	.744	.533	.778	.530	.771	.460	.726	.391	.588		
.10	.003	.092	.007	.125	.015	.173	.016	.188	.019	.216	.027	.232	.055	.291	.085	.342	.122	.392	.144	.411	.142	.405	.121	.376	.073	.288		

TABLE D-7

Beta - 50% Halogens, 1% Solids

Time After LOCA / Energy (MeV)	Fraction Below Given Energy																									
	1 Second		1 Minute		20 Minutes		1 Hour		2 Hours		4 Hours		12 Hours		1 Day		2 Days		4 Days		8 Days		16 Days		30 Days	
	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle	Energy	Particle
9.50	1.000		1.000																							
9.00	.997	1.000	.999																							
8.50	.991	.998	.998																							
8.00	.982	.997	.996	1.000																						
7.50	.963	.994	.993	.999																						
7.00	.946	.990	.988	.998																						
6.50	.912	.983	.981	.998	1.000																					
6.00	.869	.973	.971	.996	.999		1.000		1.000																	
5.50	.817	.961	.958	.995	.997		.998		.999																	
5.00	.759	.945	.942	.992	.995	1.000	.997		.998																	
4.50	.698	.927	.922	.989	.992	.999	.995	1.000	.997		1.000															
4.00	.633	.916	.890	.985	.987	.998	.992	.999	.996		.999															
3.50	.564	.886	.869	.979	.979	.997	.988	.998	.995	1.000	.999		1.000										1.000		1.000	
3.00	.494	.851	.833	.971	.967	.995	.982	.998	.992	.999	.997		.999								1.000		.999		.999	
2.90	.481	.844	.825	.969	.964	.995	.980	.997	.991	.999	.997		.999		1.000		1.000		1.000		.998		.999		.998	
2.80	.468	.838	.815	.966	.961	.994	.973	.997	.991	.998	.996	1.000	.998		.999		.999		.999		.998		.998		.997	1.000
2.70	.455	.831	.807	.964	.957	.993	.977	.997	.988	.998	.995	.999	.998		.999		.998		.998		.997		.996	1.000	.994	.999
2.60	.443	.825	.798	.962	.953	.993	.974	.996	.987	.998	.994	.999	.997		.998		.997		.996	1.000	.995	1.000	.992	.999	.989	.998
2.50	.430	.818	.789	.959	.949	.992	.972	.996	.985	.998	.993	.998	.997	1.000	.997	1.000	.996	1.000	.994	.999	.991	.999	.987	.998	.982	.997
2.40	.418	.811	.779	.956	.945	.991	.969	.995	.983	.997	.991	.998	.994	.999	.995	.999	.994	.998	.991	.999	.987	.998	.981	.997	.972	.996
2.30	.405	.804	.763	.952	.940	.990	.966	.994	.981	.997	.989	.998	.993	.999	.994	.999	.991	.998	.987	.998	.982	.998	.973	.996	.961	.994
2.20	.394	.797	.756	.948	.933	.988	.962	.994	.978	.996	.986	.998	.991	.998	.991	.998	.988	.998	.982	.998	.975	.997	.964	.995	.947	.992
2.10	.382	.789	.742	.943	.926	.986	.957	.993	.974	.996	.983	.997	.988	.998	.989	.998	.985	.998	.977	.997	.963	.996	.953	.994	.931	.989
2.00	.369	.780	.727	.938	.916	.984	.950	.991	.969	.994	.979	.996	.985	.997	.986	.997	.981	.997	.970	.995	.959	.995	.941	.992	.913	.986
1.90	.356	.771	.709	.931	.904	.981	.941	.989	.962	.993	.975	.995	.982	.997	.982	.997	.976	.996	.963	.995	.949	.993	.927	.990	.893	.983
1.80	.342	.760	.689	.923	.890	.977	.930	.986	.954	.991	.969	.994	.978	.996	.978	.995	.970	.995	.955	.994	.936	.992	.912	.987	.870	.978
1.70	.327	.748	.666	.913	.873	.972	.917	.983	.945	.989	.963	.993	.974	.995	.974	.995	.964	.994	.946	.992	.926	.990	.895	.984	.847	.974
1.60	.319	.734	.641	.902	.854	.965	.901	.978	.933	.986	.955	.991	.969	.994	.969	.994	.957	.993	.935	.991	.913	.988	.877	.981	.822	.968
1.50	.292	.718	.613	.888	.832	.958	.884	.973	.920	.982	.946	.989	.963	.993	.964	.993	.950	.991	.925	.989	.899	.985	.859	.978	.796	.963
1.40	.274	.710	.583	.873	.807	.949	.864	.967	.905	.978	.937	.988	.957	.964	.958	.992	.942	.988	.913	.987	.884	.982	.839	.973	.769	.956
1.30	.254	.680	.552	.855	.780	.939	.841	.959	.887	.972	.925	.983	.951	.989	.950	.990	.932	.988	.900	.984	.867	.979	.817	.968	.748	.958
1.20	.234	.658	.518	.835	.749	.926	.815	.949	.866	.965	.910	.978	.951	.987	.951	.987	.920	.985	.883	.980	.846	.974	.789	.962	.702	.938
1.10	.213	.632	.480	.810	.710	.908	.780	.935	.836	.954	.886	.970	.922	.980	.922	.982	.900	.979	.862	.975	.821	.969	.758	.954	.661	.925
1.00	.190	.601	.436	.779	.661	.884	.733	.914	.782	.936	.846	.955	.887	.968	.889	.971	.869	.970	.832	.968	.793	.961	.722	.943	.616	.910
.90	.166	.566	.388	.741	.601	.851	.672	.884	.733	.910	.790	.931	.835	.848	.840	.953	.824	.956	.891	.958	.761	.952	.684	.931	.569	.893
.80	.140	.524	.334	.694	.530	.807	.599	.844	.659	.872	.716	.897	.765	.919	.774	.927	.766	.936	.761	.946	.727	.942	.644	.917	.521	.873
.70	.114	.476	.278	.637	.449	.751	.514	.791	.571	.822	.626	.850	.677	.876	.692	.889	.702	.909	.717	.930	.691	.928	.603	.911	.473	.851
.60	.089	.422	.220	.571	.365	.683	.423	.726	.474	.759	.526	.789	.576	.819	.598	.839	.629	.874	.674	.910	.653	.913	.552	.882	.427	.826
.50	.065	.362	.164	.495	.280	.583	.330	.647	.374	.682	.419	.713	.464	.745	.492	.773	.543	.826	.647	.880	.599	.886	.510	.853	.378	.795
.40	.044	.295	.111	.407	.195	.505	.234	.548	.269	.582	.304	.613	.339	.644	.366	.677	.424	.745	.497	.813	.498	.824	.421	.794	.312	.743
.30	.024	.219	.064	.305	.115	.385	.140	.423	.168	.452	.185	.479	.209	.509	.232	.546	.285	.624	.351	.720	.355	.714	.301	.691	.229	.660
.20	.010	.138	.027	.194	.050	.249	.061	.277	.072	.298	.083	.319	.096	.345	.111	.380	.146	.454	.188	.523	.192	.538	.166	.528	.136	.528
.10	.002	.061	.005	.087	.010	.113	.013	.126	.016	.138	.019	.149	.022	.165	.027	.187	.038	.232	.050	.274	.052	.286	.048	.292	.045	.319

DISTRIBUTION:

U.S. Nuclear Regulatory Comm. NRC-1 (220)
Division of Document Control
Attn: Steve Scott, Actg. Branch Chief
Distribution Services Branch
Washington, DC 20555

US Nuclear Regulatory Commission (24)
Washington, DC 20555
Attn: T. E. Murley, Acting Director
Div. of Reactor Safety Research, RES
L. S. Tong, Assistant Director
Water Reactor Safety Research, RES
Chief,
Research Applications Branch, RES
R. A. Feit (10)
Research Application Branch, RES
M. A. Taylor
Probabilistic Analysis Branch, RES
R. E. Heineman, Director
Div. of Systems Safety, NRR
P. Mathews
Div. of Systems Safety, NRR
R. Schull
Div. of Systems Safety, NRR
V. Stello, Director
Div. of Operating Reactors, NRR
R. Ferguson
Div. of Operating Reactors, NRR
L. Rubenstein, NRR
G. A. Arlotto, Director
Div. of Engineering Standards, SD
E. Imbro, SD
V. Thomas
Office of Inspection & Enforcement
S. Hanauer, Technical Advisor
Office of the Exec. Dir. for Operations

Babcock & Wilcox (3)
P.O. Box 1260
Lynchburg, VA 24505
Attn: R. Schemmel
J. Cuvelier
T. Grochowsky

Westinghouse Electric Corp. (4)
P.O. Box 355
Pittsburgh, PA 15230
Attn: R. B. Miller
I. Garber
J. Sejvar
W. D. Loftus

Rosemount Incorporated
P.O. Box 35129
Minneapolis, MN 55435
Attn: I. Ismail

Combustion Engineering (5)
1000 Prospect Hill Road
Windsor, CT 06095
Attn: D. Sentell
R. P. Daigle
G. Caruthers
L. M. Johnson
J. Carter

Electric Power Research Institute (4)
P.O. Box 10412
Palo Alto, CA 94303
Attn: R. Swanson
D. G. Cain
R. Pack
B. Bernstein

Duke Power Company (4)
P. O. Box 2178
Charlotte, NC 28242
Attn: J. L. Crenshaw
W. J. Foley
R. A. Pace
B. M. Rice

Stone & Webster Engineering Corp.
P.O. Box 5200
Cherry Hill, NJ 08034
Attn: T. Bates

Foxboro Company
Foxboro, MA 02035
Attn: J. Childs

Battelle Columbus Laboratory
505 King Avenue
Columbus, OH 43201

Bechtel Power Corp. (7)
180 Shady Grove Road
Gaithersburg, MD 20760
Attn: C. E. Corley
D. C. Gasdo
B. Kanga
N. Willoughby
F. Roddy
T. S. Killen
R. L. Ashley

General Atomic Company
P. O. Box 426
Platteville, CO 80651
Attn: J. T. Bauer

Franklin Institute Research Laboratories (3)
20th and Parkway
Philadelphia, PA 19103
Attn: S. P. Carfagno
D. Paulson
Z. Zudans

Isomedix, Incorporated (2)
P.O. Box 177
Parsippany, NJ 07054
Attn: N. M. Burstein
G. R. Dietz

Sargent and Lundy (6)
55 East Monroe Street
Chicago, IL 60603
Attn: C. L. Tsai
C. M. Chiappetta
C. Halstat
E. Normand
A. M. Levy
R. E. Cotta

DISTRIBUTION: (cont.)

Brookhaven National Laboratory (2)
Department of Applied Science
Associated Universities, Inc.
Upton, L.I., NY 11973
Attn: G. W. Bennett
D. L. Metz

IRT Corporation (3)
P.O. Box 80817
San Diego, CA 92138
Attn: J. A. Naber
N. Lurie
J. Wilkenfeld

ITT General Controls
801 Allen Avenue
Glendale, CA 92101
Attn: G. R. Brown

Naval Reasearch Laboratory (2)
Code 6603F
Washington, DC 20375
Attn: F. J. Campbell
E. L. Brancato

D. L. Dye
Consulting Physicist
12825 SE 45th Place
Bellevue, WA 98006

The Kerite Company
Seymour, CT 06483
Attn: J. B. Gardner

Anaconda Wire and Cable Company
East 8th Street
Marion, IN 46953
Attn: T. H. Ling

Science Applications Inc. (3)
P. O. Box 2351
La Jolla, CA 92037
Attn: V. J. Orphan
G. L. Simmons
W. A. Woolson

Stone & Webster Eng. Corp. (8)
P.O. Box 2325
Boston, MA 02107
Attn: T. J. McGrath
A. P. Stakutes
E. A. Warman
R. Lo
G. B. Enticknap
E. T. Boulette
A. Fitzpatrick
R. B. Taylor

D. G. Woodward
Neutron Products, Inc.
Dickerson, MD 20753

Reliance Electric Company
24800 Tungsten Road
Cleveland, OH 44117
Attn: W. G. Stiffler

Gilbert Associates (2)
525 Lancaster Avenue
Reading, PA 19603
Attn: V. Willems
T. L. Kamphouse

Commonwealth Associates, Inc.
209 E. Washington
Jackson, MI 49201
Attn: G. K. Henry
N. C. Olson
M. J. Kolar
J. R. McCarty

General Electric Company (3)
175 Curtner Avenue
San Jose, CA 95114
Attn: L. D. Test
D. R. Rogers
W. R. Shelton

United Engineers & Constructors
30 South 17th Street
Philadelphia, PA 19101
Attn: S. G. Kasturi
M. Pai
R. E. Allen

US Nuclear Regulatory Commission (7)
Washington, DC 20555
Attn: L. Soffer
J. Slider
B. Grimes
C. F. Miller
A. S. Hintze
D. S. Sullivan
I. Villalva

Charles T. Main, Inc.
Southeast Tower, Prudential Center
Boston, MA 02199
Attn: J. F. Bates

Tennessee Valley Authority
300 Union Building
Knoxville, TN 37902
Attn: F. W. Chandler

W. J. Denkowski
Limitorque Corp.
King of Prussia, PA 19406

Yankee Atomic Electric
20 Turnpike Road
Westborough, MA 01581
Attn: G. T. Dowd, Jr.

Westinghouse Electric Corp.
Electro-Mechanical Division
Cheswick, PA 15024
Attn: R. F. Edwards

Boston Ins. Wire & Cable Co.
65 Bay Street
Boston, MA 02125
Attn: A. Garshick

DISTRIBUTION: (cont)

Florida Power Corp.
P. O. Box 14042
St. Petersburg, FL 33733
Attn: A. L. Gomez

Cutler Hammer
4201 N. 27th St.
Milwaukee, WI 53216
Attn: J. Kroll

The Okonite Company
Ramsey, NJ 07446
Attn: E. E. McIllween
R. A. Guba

General Electric Company
1 River Road
Schenectady, NY 12345
Attn: D. J. Meraner

Washington Public Power Supply System (3)
P. O. Box 968
Richland, WA 99352
Attn: N. S. Porter
W. L. Nees
W. D. Bainard

ITE Imperial Corp
Route 309 & 463
Montgomeryville, PA 18936
Attn: E. W. Rhoads

Wyle Laboratories
7800 Governors Drive West
Huntsville, AL 35807
Attn: R. M. Scates

Power Conversion Products
42 East Street
Crystal Lake, IL 60014
Attn: C. F. Seyer

Pyle National Company
1334 North Kostner Avenue
Chicago, IL 60651
Attn: J. F. Shearer

Westinghouse R&D Center
Beulah Road
Pittsburgh, PA 15235
Attn: F. Trunzo

Gulf States Utilities Co.
P. O. Box 2951
Beaumont, TX 77704
Attn: J. C. Wright

Allis Chalmers
4620 Forest Avenue
Norwood, OH 45212
Attn: R. F. Gilton

Cleveland Electric Illuminating (2)
P.O. Box 5000
Cleveland, OH 44101
Attn: A. Kaplan
D. Green

Nuclear Controls & Electronics Corp.
175 W. 2950 South
Salt Lake City, UT 84115
Attn: R. J. Hall

Consolidated Edison Co. of N.Y., Inc.
4 Irving Place
New York, NY 10003
Attn: L. J. Savio

Philadelphia Electric Co. (3)
2301 Market Street - N3 - 1
Philadelphia, PA 19101
Attn: A. J. Simmons
J. Cannon
L. Hamilton

Neely Nuclear Center
Georgia Institute of Technology
225 No. Ave. NW
Atlanta, Georgia 30332
Attn: M. V. Davis

Wyle Laboratories
128 Maryland St.
El Segundo, CA 90245
Attn: P. M. Turkheimer

Bailey Meter Company
29801 Euclid Avenue
Wickliffe, Ohio 44092
Attn: R. K. Jahn

Carboline Company (2)
350 Hanley Industrial Court
St. Louis, MO 63144
Attn: J. R. Lopata
J. F. Montle

Institute of Electrical and
Electronics Engineers, Inc. (2)
345 East 47 Street
New York, NY 10017
Attn: J. Fragola
L. Hecht

Nuclear Regulatory Commission
Public Document Room
Washington, DC 20555

R. F. Fraley
Advisory Committee on Reactor Safeguards
Nuclear Regulatory Commission
Washington, DC 20555

NELPIA (3)
The Exchange - Suite
Farmington Avenue
Farmington, CT 06032
Attn: P. S. Snyder
L. P. Mariani
J. Carney

DISTRIBUTION: (cont)

Puget Power
Puget Power Building
Bellvue, WA 98009
Attn: R. Isernhagen

Offshore Power Systems
P.O. Box 8000
Jacksonville, FL 32211
Attn: J. W. Wanless

General Electric Co.
4720 Montgomery Lane
Suite 1107
Bethesda, MD 20014
Attn: N. C. Shirley

Bechtel Corporation (4)
50 Beale Street
San Francisco, CA 94105
Attn: T. G. Cullen
C. M. Graft
R. Nossardi
J. Wickert

Union Carbide Corporation
Oak Ridge Laboratories
P.O. Box X
Oak Ridge, TN 37830
Attn: G. Goldbert

Dow Corning (2)
Midland, MI 48640
Attn: F. C. Dall
T. Orbeck

American Electric Power Service
2 Broadway
New York, NY 10004
Attn: G. D. Weatherford

Florida Power & Light
P.O. Box 013100
Miami, FL 33101
Attn: W. Thue

Essex International
P.O. Box 1000
Lafayette, IN 47902
Attn: J. L. Steiner

3 M Company
2501 Hudson Road
St. Paul, MN 55119
Attn: W. P. Smith

Fisher Controls Co.
P.O. Box 190
Marshalltown, IA 50158
Attn: H. Rich

R. Salomon
1621 Kenmare Drive
Dresher, PA 19025

Niagara Mohawk
300 Erie Boulevard West
Syracuse, NY 13202
Attn: D. E. Sandwick

IIT Research Inst.
10 West 35th Street
Chicago, IL 60616
Attn: I. Pincus

Public Service Electric & Gas Co. (2)
80 Park Place
Newark, NJ 07102
Attn: T. J. Martin
J. Pirrong

E. I. du Pont de Nemours
Plastic Products & Resins
Parkersburg, WV 26101
Attn: J. O. Punderson

General Cable
800 Rahway Ave.
Union, NJ 07083
Attn: J. G. Quin

Southern Services Co. (2)
P.O. Box 2625
Birmingham, AL 35202
Attn: W. M. Pate
H. T. Hubbard

Boston Edison Co.
1165 Mass. Ave.
Boston, MA 02125
Attn: A. V. Morisi

Systems Development Corp.
2500 Colorado Avenue
Santa Monica, CA 90406
Attn: J. Mecozzi

Cyprus/Rome Cable
P.O. Box 71
Rome, NY 13440
Attn: I. J. Marwick

Northeast Utilities Service Co.
P. O. Box 270
Hartford, CT 08101
Attn: R. Luther

Pacific Gas & Electric (2)
245 Market Street
San Francisco, CA 94106
Attn: J. H. Lawson
F. J. Dan

Reynolds Metals Co.
P.O. Box 27003
Richmond, VA 23261
Attn: R. R. Howard

Uniroyal
Emic Bldg., Spencer St.
Naugatuck, CT 06770
Attn: J. D. Hunt

Detroit Edison
2000 Second Ave.
Detroit, MI 48226
Attn: V. J. Herter

Distribution: (cont)

Naval Ship Research and Devel. Center
Electronics Division Code 2772
Annapolis, MD 21402
Attn: M. A. DeLucia

C. A. Doak, President
Alison Control Inc.
35 Daniel Road
Fairfield, NJ 07006

Virginia Electric & Power
P.O. Box 26666
Richmond, VA 23261
Attn: J. M. Davis

General Atomic Co.
P.O. Box 81608
San Diego, CA 92138
Attn: T. R. Colandrea

General Electric
Wire & Cable Products Dept.
1285 Boston Ave.
Bridgeport, CT 06602
Attn: J. E. Conley

University of Connecticut
Department of Chemistry
Stoors, CT 06268
Attn: J. A. Tanaka

Mission Research Corp.
735 State Street
P.O. Box 719
Santa Barbara, CA 93102
Attn: A. M. Chodorow

Toledo Edison
Edison Plaza
300 Madison Ave.
Toledo, OH 43652
Attn: M. D. Calcamuggio

Long Island Lighting Co.
175 East Old Country Rd.
Hicksville, NY 11801
Attn: A. T. Baker

NUS Corporation
4 Research Place
Rockville, MD 20850
Attn: D. E. Bassett

The Anaconda Co.
Wire and Cable Division
421 King Street
Alexandria, VA 22314
Attn: M. J. Bork, Jr.

The Pennsylvania State Univ.
Applied Research Lab.
P.O. Box 30
State College, PA 16801
Attn: R. E. Bland

Calspan Corp.
P.O. Box 235
Buffalo, NY 14221
Attn: F. A. Bierl

Johns Hopkins University (3)
Applied Physics Lab.
John Hopkins Road
Laurel, MD 20810
Attn: W. Berl
R. Fristrom
L. Hunter

Stanford Research Inst. (2)
Menlo Park, CA 94025
Attn: S. Brauman
R. Woolfolk

Raychem Corporation (2)
300 Constitution Dr.
Menlo Park, CA 94025
Attn: F. LaFetra
W. T. Starr

Okonite
220 Passaic Street
Passaic, NJ 07055
Attn: J. S. Lasky

Kerite Company (2)
2 Penn Plaza
New York, NY 10803
Attn: E. N. Sleight
W. F. Parsons

E. I. du Pont de Nemours
Plastic Products & Resins Dept.
Wilmington, DE 19898
Attn: E. W. Fasig, Jr.

E. I. du Pont de Nemours
Film Dept.
Wilmington, DE 19898
Attn: C. Palmer

E. I. du Pont de Nemours
Elastomer Chemicals
Trenton, NJ 08600
Attn: J. C. Hedberg

General Electric Company
Silicones
Waterford, NY 12188
Attn: T. Loman

Phelps Dodge Magnet Wire Co.
P.O. Box 600
Ft. Wayne, IN 46801
Attn: P. E. Alexander

Hitachi Cable, Ltd.
777 Third Ave.
New York, NY 10017
Attn: H. J. Amino

DISTRIBUTION: (cont)

Westinghouse Research Labs. (2)
Pittsburgh, PA 15235
Attn: J. Bartko
L. Edelman

Cerro-Rockbestos
P.O. Box 1102
New Haven, CT 06504
Attn: G. Buettner

Southern California Edison Co.
P.O. Box 800
Rosehead, CA 91770
Attn: J. L. Cohon

General Electric Co.
6901 Elmwood Ave.
Philadelphia, PA 19142
Attn: P. W. Juneau, Jr.

M. A. Lamont
P. O. Box 4305
East Providence, RI 02914

Samuel Moore and Co.
P.O. Box 7
Aurora, OH 44202
Attn: R. Kroboth

General Electric Co.
3001 East Lake Rd.
Bldg. 9-1
Erie, PA 16531
Attn: W. B. Penn

Allis Chalmers Corp.
4620 Forest Ave.
Norwood, OH 45212
Attn: V. R. Scardina

Westinghouse Electric Corp.
469 Sharpsville Ave.
Sharon, PA 16146
Attn: H. R. Sheppard

PORTEC, Inc.
Electric Products Div.
1725 Clarkstone Rd.
Cleveland, OH 44112
Attn: P. M. Silverberg

General Electric Company (2)
Research and Development Center
Schenectady, NY 12305
Attn: K. N. Mathes
D. R. Johnston

2316 H. M. Barnett
5000 A. Narath
5100 J. K. Galt
5200 E. H. Beckner
5231 J. H. Renken
5400 A. W. Snyder
5410 D. J. McCloskey
5411 D. A. Dahlgren
5420 J. V. Walker
5430 R. M. Jefferson
5431 R. E. Nickell
5431 W. H. Schmidt
5432 R. E. Luna
5432 G. L. Cano
5432 L. L. Bonzon (50)
5432 D. W. Dugan
5432 L. J. Klamerus
5433 R. B. Pope
5440 R. W. Lynch
5450 J. A. Reuscher
5700 J. H. Scott
5800 R. S. Claassen
5811 L. A. Harrah
5813 J. B. Curro
5813 E. A. Salazar
5813 K. T. Gillen
5814 R. C. Hughes
8266 E. A. Aas
3141 C. A. Pepmueller (Actg) (5)
3151 W. L. Garner (8)
for ERDA/TIC (Unlimited Release)

ERDA/TIC (25)
(R. P. Campbell, 3172-3)