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Best-Estimate Offsite Dose from Dry Storage Cask Leakage

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Introduction

As part of its effort to license the Private Fuel Storage (PFS) facility, the Office of Nuclear Material Safety and Safeguards (NMSS) had requested the Office of Nuclear Regulatory Research (RES) to evaluate the offsite radiological consequences from dry storage cask leakage. This also is part of the ongoing activity to develop a detailed risk assessment for dry storage of spent fuel and to risk inform 10 CFR Part 72. Accordingly, RES completed an in-house analysis of offsite radiological consequences. A primary objective of the evaluation was to provide best-estimate quantification, with uncertainty bounds, of offsite doses associated with dry storage cask leakage by taking into account aerosol deposition inside the confinement.

The purpose of this report is to document the detailed technical basis of the offsite consequence evaluation. This report documents the offsite consequence calculations we performed using the RADTRAD (Radionuclide Transport and Removal and Dose Estimation) reactor accident analysis code.[1] This report also includes the input files used.

Previous Consequence Assessments

In the past, consequence assessments for dry storage cask accidents typically assumed that radioactive material released from the fuel into the confinement remained airborne in the confinement, and therefore available for leakage, for the duration of the accident. For normal and off-normal conditions, releases from the fuel also are assumed to remain airborne. These regulatory positions are documented in Interim Staff Guidance document number 5 (ISG-5).

The HI-STORM Safety Analysis Report (SAR) provides the consequence assessment for the dry storage casks to be used at PFS. In accordance with ISG-5, the HI-STORM SAR includes an evaluation of the consequences of dry storage cask design-basis leakage under accident, normal, and off-normal conditions. The HI-STORM SAR analysis assumes no aerosol deposition in the confinement. The work described in this current report extends the analysis in the HI-STORM SAR by calculating offsite consequences taking into account aerosol deposition in the confinement.

Base Case

The current analysis uses version 3.02 of the RADTRAD code to estimate offsite consequences for accident, normal, and off-normal conditions. Major input parameters for RADTRAD include the amount of radioactive material released into the confinement, the first-order rate constant for deposition, and the leak rate of the confinement.

Base case calculations were performed with RADTRAD using the modeling in the HI-STORM SAR to benchmark RADTRAD against the current design basis licensing calculation. The modeling for the base case calculations is shown in Table 1. The base case calculations also used the radionuclide inventories and dose conversion factors from the HI-STORM SAR.

Two base case calculations were run for each of the following conditions: accident, normal, and off-normal. The first base case calculation (Case 1) included modeling of radioactive decay. The second base case calculation (Case1nd) did not. The RADTRAD input files for Case 1 for

accident conditions are given in Appendix A. The base case results are given in Tables 2, 3, and 4, for accident, normal, and off-normal conditions, respectively. The results of the RADTRAD calculations are nearly identical to those in the HI-STORM SAR.

Table 1 Dose Modeling for Individual Offsite Dose from Dry Storage Cask Leakage
(From HI-STORM Safety Analysis Report)

Parameter	Value of parameter for...			
	Accident		Off-normal	Normal
Fraction of crud released	1		.15	.15
Fraction of fuel assemblies releasing fission products	1		.1	.01
Fraction of fission product inventory released from each fuel assembly	fission product gas	.3	same	same
	volatile fission products	2×10^{-4}	same	same
	actinides, non-volatile fission products (fines)	3×10^{-5}	same	same
free volume of the confinement	6.0×10^{6} cm^3		same	same
leak rate of the confinement	1.3×10^{-5} cm^3/sec		9.5×10^{-6} cm^3/sec	9.5×10^{-6} cm^3/sec
dilution factor (i.e., X/Q)	8.0×10^{-3} sec/m^3		1.6×10^{-4} sec/m^3	1.6×10^{-4} sec/m^3
breathing rate	3.3×10^{-4} m^3/sec		same	same
dose conversion factors	Federal Report Guidance Reports 11 and 12 using most conservative clearance class		same	same
accident duration	30 days		1 year	1 year
dose limit	TEDE	5 rem	25 mrem	25 mrem
	thyroid	50 rem	75 mrem	75 mrem
	other critical organ	50 rem	25 mrem	25 mrem
	lense of the eye	15 rem	-	-
	skin dose	50 rem	-	-

Table 2 Accident Dose Results of Cases 1 and 1nd (mrem)

Organ	RADTRAD Case 1 (with radioactive decay)	RADTRAD Case 1nd (without radioactive decay)	Spreadsheet in HI-STORM Safety Analysis Report
gonads	8.1	8.3	8.3
breast	4.6	4.6	4.6
lungs	120	120	120
red marrow	42	42	42
bone surface	470	470	470
thyroid	4.1	4.1	4.1
remainder	26	26	Not reported
effective (TEDE)	**44**	**44**	**44**
skin	.17	.17	.11

Table 3 Normal Dose Results of Cases 1 and 1nd (mrem)

Organ	RADTRAD Case 1 (with radioactive decay)	RADTRAD Case 1nd (without radioactive decay)	Total Dose (HI-STORM SAR)
gonads	.044	.046	.046
breast	.12	.12	.12
lungs	2.2	2.3	2.3
red marrow	.18	.18	.18
bone surface	.93	.95	.95
thyroid	.10	.11	.11
remainder	.25	.27	Not reported
effective (TEDE)	**.42**	**.44**	**.44**
skin	.0027	.0030	.0029

Table 4 Off-Normal Dose Results of Cases 1 and 1nd (mrem)

Organ	RADTRAD Case 1 (with radioactive decay)	RADTRAD Case 1nd (without radioactive decay)	Total Dose (HI-STORM SAR)
gonads	.16	.16	.16
breast	.12	.13	.13
lungs	2.8	3.0	3.0
red marrow	.79	.81	.81
bone surface	8.5	8.6	8.7
thyroid	.10	.11	.11
remainder	.54	.55	Not reported
effective (TEDE)	**.91**	**.94**	**.94**
skin	.0039	.0041	.0029

Deposition Inside the Confinement

Deposition is modeled in RADTRAD as a first-order rate process. The basic equation in RADTRAD is shown below in simplified form.

$$N = N_0 \cdot e^{-\lambda t}$$

where N is the amount of aerosol airborne at time t,
N_0 is the initial amount of aerosol airborne, and
λ is the first-order rate constant for aerosol deposition.

In this analysis, four approaches were used to determine lambda (λ). The first and simplest approach was to take values of lambda directly from NUREG/CR-6189, *A Simplified Model of Aerosol Removal by Natural Processes in Reactor Containments*, July 1996. NUREG/CR-6189 provides correlations for lambda for a reactor containment. Table 5 gives the lambdas calculated using the correlations in NUREG/CR-6189 for a 3000 MWt BWR. This approach provides a rough estimate of lambda for a dry storage cask confinement. However, this approach is based on the dimensions of, the thermal hydraulic conditions in, and the concentration of aerosol suspended in a reactor containment under accident conditions.

Table 5 Lambda from NUREG/CR-6189

Time interval (hr)	Lambda (1/hr)		
	Case 2a (90^{th} percentile)	Case 2b (50^{th} percentile)	Case 2c (10^{th} percentile)
.00 - .50	2.0	1.2	.63
.50 - 2.0	1.4	.95	.54
2.0 - 5.0	1.6	1.3	.91
5.0 - 8.3	1.3	.84	.58
8.3 - 12	1.2	.82	.50
12 - 19	1.2	.80	.46
19 - 24	1.2	.79	.44

The second approach was to use NUREG/CR-6189 values for lambda adjusted for cask dimensions. Table 6 gives the lambdas calculated using the correlations in NUREG/CR-6189, adjusted for cask dimensions. The values in Table 6 are the values in Table 5 multiplied by the ratio of the height of the containment (21 meters) to the height of the confinement (4.5 meters). The values in Table 6 are therefore a factor of 4.7 higher than in Table 5. This approach provides insight into the effect of the small dimensions of the cask in comparison with a containment. However, this approach is not directly applicable to dry storage casks, because it is unclear how much deposition is due to each mechanism.

Table 6 Lambda from NUREG/CR-6189 Adjusted for Cask Dimensions

Time interval (hr)	Lambda (1/hr)		
	Case 2a (90^{th} percentile)	Case 2b (50^{th} percentile)	Case 2c (10^{th} percentile)
.00 - .50	9.3	5.3	2.9
.50 - 2.0	6.4	4.3	2.5
2.0 - 5.0	7.4	5.7	4.1
5.0 - 8.3	5.8	3.8	2.6
8.3 - 12	5.6	3.7	2.3
12 - 19	5.6	3.6	2.1
19 - 24	5.6	3.6	2.0

The third approach was to perform a stand-alone calculation of gravitational settling using distributions for the aerosol density, the aerosol diameter, and the aerosol shape factor from NUREG/CR-6189 and NUREG/CR-5966, *A Simplified Model of Aerosol Removal by Containment Sprays*, July 1993. This approach, which is described below, ignores additional deposition due to thermophoresis and other natural deposition mechanisms.

The following is the basic equation for the stand-alone calculation of gravitational settling:

$$u_s = \frac{\rho \cdot d_e^2 \cdot g \cdot C_s}{18 \cdot \mu \cdot k}$$

where u_s is the settling velocity,
ρ is the aerosol density,
d_e is the aerosol diameter
g is the gravitational acceleration constant,
C_s is the Cunningham slip factor,
μ is the viscosity, and
k is the aerosol shape factor.

The uncertain parameters in this equation are the aerosol density, diameter, and shape factor. In this approach, the settling velocity was estimated through Monte Carlo sampling of the distributions for the aerosol density, diameter, and shape factor from NUREG/CR-6189 and NUREG/CR-5966. Using these distributions (see Table 7), a FORTRAN 90 code was written to generate a history of 100,000 settling velocities. This code is given in Appendix B. The 100,000 settling velocities were then binned using the XMGR5 plotting package and the results are shown in Figure 1. The 10th, 50th, and 90th percentile settling velocities from Figure 1 are .00022, .0010, and .0031 meters/second, respectively. These settling velocities then were divided by the fall height of the cask (4.5 meters) to determine lower-bound, best-estimate, and upper-bound lambdas of .18, .81, and 2.5 per hour, respectively.

Table 7 Uncertain Parameter Distributions from Reactor Accident Studies

Parameter	Range of Values	Distribution Type
aerosol density	3.3 to 11 g/cm^3	log-uniform
aerosol diameter	1.5 to 5.5 μm	uniform
aerosol shape factor	1.0 to 4.0	log-normal*

*mean and standard deviation of 1.3 and 3.0, respectively

The fourth approach, which provides a better estimate of lambda, also was to perform a stand-alone calculation of gravitational settling using distributions for the aerosol density, diameter, and shape factor. However, in this approach, the stand-alone calculation used distributions developed for a spent fuel cask. These distributions are given in Table 8. The basis for these distributions is given in Reference 2 and is summarized here. These distributions were

developed using the results of and insights gained from the MELCOR analyses for the TN-125 cask documented in Appendix IV of SAND98-1171/1, *Data and Methods for the Assessment of the Risks Associated with Maritime Transport of Radioactive Materials, Results of the SeaRAM Program Studies*, May 1998. In a spent fuel cask, the aerosol density is close to that of the fuel pellets (11 g/cm^3), because the aerosol particles are mainly fuel fines. Also, the shape factor is close to 1.0, because few of the aerosol particles consist of agglomerates. In contrast, in a reactor accident, the aerosols in containment are mainly agglomerates of condensed vapor of a number of fission product compounds of different densities. Therefore, reactor accident aerosols tend to have lower densities and higher shape factors. Finally, for a spent fuel cask, the mean diameter of 2.0 μm is based on the data in Reference 5.

Table 8 Uncertain Parameter Distributions for a Spent Fuel Cask

Parameter	Range of Values	Distribution Type
aerosol density	10 to 11 g/cm^3	uniform
aerosol diameter	1.0 to 4.0 μm	log-normal*
aerosol shape factor	1.0 to 1.3	uniform

*mean and standard deviation of 2.0 and 2.5, respectively

The 10th, 50th, and 90th percentile settling velocities calculated using the distributions in Table 8 are .00032, .00082, and .0026 meters/second, respectively. These settling velocities then were divided by the fall height of the cask (4.5 meters) to determine lower-bound, best-estimate, and upper-bound lambdas of .25, .65, and 2.1 per hour, respectively.

Offsite Consequence Results for Accident Conditions

Using the four approaches described above, RADTRAD calculations for a HI-STORM dry storage cask were performed to assess the magnitude of the decrease in the offsite consequences resulting from aerosol deposition inside the confinement. The results of these calculations are summarized in Table 9 for accident conditions and are discussed below.

Table 9 Doses for Accident Conditions

Case	Deposition Modeling	TEDE for an Individual at the Site Boundary (mrem)		
		lower bound	best estimate	upper bound
1	none	N/A	N/A	44
2a,2b,2c	NUREG/CR-6189	.037	.059	.097
3a,3b,3c	NUREG/CR-6189 with cask dimensions	.0088	.014	.024
4a,4b,4c	settling only, based on reactor containment conditions	.027	.077	.35
5a,5b,5c	settling only, based on cask conditions	.031	.096	.24

Case 1, which was the base case, was run to estimate the offsite consequences of a dry storage cask accident without crediting deposition in the confinement. The results of this case are the same as in the HI-STORM Safety Analysis Report. Cases 2a, 2b, and 2c were run to estimate the reduction in consequences, with uncertainty bounds, as a result of crediting deposition in the dry storage cask confinement. The dose for Case 2b, which used the median lambda for deposition from NUREG/CR-6189, was a factor of 700 lower than for Case 1. As a result of modeling aerosol deposition, the concentration of radioactive material airborne decreases as shown in Figure 2. Given the constant leak rate used for the dose assessment, the offsite dose is proportional to the area under the curve in Figure 2. Figure 2 indicates that, as a result of deposition, the offsite dose is a result of leakage during the first couple of hours following the release. Figure 3 shows the corresponding integrated dose for Cases 1 and 2b.

The doses in Cases 3a, 3b, and 3c are reduced by an additional factor of 4, because the fall height in a containment is 4.7 times that of a dry storage cask. The doses in Cases 4a, 4b, and 4c are higher than those in Cases 3a, 3b, and 3c, because they only credit removal by gravitational settling. Finally, the doses in Cases 5a, 5b, and 5c are about the same as those in Cases 4a, 4b, and 4c, because the dose decrease from the higher density and lower shape factor is offset by the dose increase from the lower diameter.

Offsite Consequence Results for Normal and Off-Normal Conditions

The cases for accident conditions were repeated using the normal and off-normal modeling shown in Table 1. The results of these calculations are shown in Tables 10 and 11. The best-estimate doses (for a year) with deposition are about a factor of 4500 lower than without deposition.

Table 10 Doses for Normal Conditions

Case	Deposition Modeling	TEDE for an Individual at the Site Boundary (mrem)		
		lower bound	best estimate	upper bound
1	none	N/A	N/A	.42
2a,2b,2c	NUREG/CR-6189	3.2E-5	5.1E-5	8.2E-5
3a,3b,3c	NUREG/CR-6189 with cask dimensions	9.4E-6	1.4E-5	2.2E-5
4a,4b,4c	settling only, based on reactor containment conditions	2.4E-5	6.6E-5	2.9E-4
5a,5b,5c	settling only, based on cask conditions	2.8E-5	8.1E-5	2.0E-4

Table 11 Doses for Off-Normal Conditions

Case	Deposition Modeling	TEDE for an Individual at the Site Boundary (mrem)		
		lower bound	best estimate	upper bound
1	none	N/A	N/A	.91
2a,2b,2c	NUREG/CR-6189	1.0E-4	1.3E-4	2.1E-4
3a,3b,3c	NUREG/CR-6189 with cask dimensions	5.1E-5	6.0E-5	7.8E-5
4a,4b,4c	settling only, based on reactor containment conditions	8.3E-5	1.7E-4	6.5E-4
5a,5b,5c	settling only, based on cask conditions	9.0E-5	2.0E-4	4.6E-4

The doses shown in Table 10 above are for leakage of one cask under normal conditions. For a facility with more than one cask, the dose to an individual under normal conditions should consider that a number of casks may leak simultaneously. However, extrapolation of this dose from one cask to a case with multiple casks should not be done linearly. The individual at the site boundary will get a smaller dose from some of the casks, because of the arrangement of the casks. For example, some casks will be farther away from the individual than the cask in Table 10. Also, as a result of being a number of casks deep, a release from a cask further away from the individual would travel past other casks and be further dispersed (wake effect). In addition, if the cask array is wide enough, the wind may not blow releases from all of the casks to the individual's location. Therefore, a new dilution factor should be used. Finally, not

all casks will be leaking at the design-basis rate with the design-basis number of fuel rod failures.

Comparison with MELCOR Results

The offsite doses calculated with RADTRAD in Cases 5a, 5b, and 5c modeled gravitational settling based on the distributions for the aerosol density, diameter, and shape factor representative of a spent fuel cask.[2] As noted above, a number of MELCOR analyses were performed earlier for the TN-125 cask. In this section, offsite doses are calculated with RADTRAD using lambdas equivalent to the decline in aerosol concentration predicted in these MELCOR analyses.

The TN-125 cask study includes MELCOR calculations for three accident scenarios, namely, collision without fire, collision with fire, and fire without collision. The time-dependent aerosol concentrations predicted by MELCOR in these scenarios assuming a 4 mm^2 hole are shown as the dotted lines in Figures 4, 5, and 6. The first-order rate constants for deposition (i.e., lambdas) that would produce the decline in aerosol concentration in Figures 4, 5, and 6, are given in the second column of Table 12 and are shown as solid lines in Figures 4, 5, and 6. The lambdas for the scenarios involving a collision are identical, because they are based on the release of the same amount of aerosols into the confinement (1.2 kg). The lambda for the fire-without-collision scenario is lower, because it is based on the release of a smaller amount of aerosols into the confinement (.18 kg). This effect is discussed in the following section. Also, a small amount of the MELCOR-predicted decline in aerosol concentration is due to leakage to the environment because the hole size used for the analysis was 4 mm^2. For example, for the collision-without-fire scenario, there is little aerosol remaining airborne in the cask after 400 seconds. Based on a leakage flow of 1.3×10^{-3} m^3/sec, .52 m^3 will be released from the cask during the first 400 seconds. This is equivalent to 20% of the TN-125 cask free volume of 2.7 m^3.

Table 12 Accident Doses using Lambdas Equivalent to MELCOR-Predicted Deposition

Scenario	Lambda equivalent to MELCOR-predicted decline in aerosol concentration (1/hr)	Lambda corrected for fall height (1/hr)	Accident dose predicted by RADTRAD (mrem)
collision without fire	27	.90	.070
collision with fire	27	.90	.070
fire without collision	17	.57	.11

The TN-125 cask modeled in the MELCOR analyses contains a basket with 12 cells (called lodgements). A fuel assembly is placed in each lodgement. In the MELCOR analyses, the TN-125 cask was on its side, and the fall height was modeled to be the free volume of the lodgement divided by the area of one side of the lodgement.[2] This resulted in a fall height of .15 meters. To account for the difference in fall heights between a TN-125 cask on its side and a HI-STORM cask on its end, the three lambdas from Figures 4, 5, and 6 then were divided by 30 which is the ratio of the fall height for the two casks (4.5 meters divided by .15 meters). The

corrected lambdas are given in the third column of Table 12. The results of RADTRAD calculations using these corrected lambdas are given in the fourth column of Table 12.

The accident dose predicted by RADTRAD in Case 5b (Table 9), which used a lambda for settling based on the distributions for the aerosol density, diameter, and shape factor representative of a spent fuel cask, was .10 mrem. The accident doses predicted by RADTRAD in Table 12, which use lambdas equivalent to the decline in aerosol concentration predicted in the MELCOR analyses, were .070 to .11 mrem. This agreement is expected, because the Case 5b calculation credits settling only and the deposition predicted in the MELCOR analyses is dominated by settling. MELCOR includes the deposition mechanisms of settling, Brownian motion, thermophoresis, and diffuseophoresis. Although the amount of deposition by each mechanism is currently not a direct output of MELCOR, side calculations performed using the MELCOR deposition modeling (i.e., MAEROS) indicated that about 97% of the deposition in the MELCOR analyses of the TN-125 cask is from settling.[2]

As note above, the fall height used in the MELCOR analyses of the TN-125 cask is a factor of 30 smaller than the fall height in the above RADTRAD analysis of the HI-STORM cask, because the TN-125 cask is on its side. This smaller fall height results in settling being the dominant mechanism in the MELCOR analyses. For the HI-STORM cask, Case 5b modeled only deposition by settling. However, for the HI-STORM cask, modeling other mechanisms in addition to settling may result in additional reductions in dose. This type of modeling may be done using the MELCOR or VICTORIA codes for a spent fuel cask in an upright position.

Effect of Aerosol Concentration

Because the aerosol coagulation rate, and hence the deposition rate, may be sensitive to the aerosol concentration, this effect was examined with the MELCOR code in the TN-125 cask study. The MELCOR results indicated that when the release fraction of fuel fines was increased a factor of 100 (from $1x10^{-5}$ to $1x10^{-3}$), the release fraction from the cask increased by a factor of 33. This suggests that the aerosol concentration does have an effect on the deposition rate. However, the effect is not great. In this case, increasing the aerosol concentration by a factor of 100 increases the lambda by a factor of 3.

Offsite doses calculated in Cases 2a through 4c are based on aerosol concentrations in reactor containments under accident conditions. NRC report AEB-99-01, *Impact of Source Term Aerosols on Fan Cooler Performance for the Indian Point 2 Pilot Plant Application*, March 1999, estimates an aerosol release into the reactor containment of 420 kg during the in-vessel phase. For a 57,000 m^3 containment, this corresponds to an aerosol concentration of 7.3 g/m^3. For the HI-STORM cask, a release fraction for fuel fines of $3x10^{-5}$ gives an aerosol release of .45 kg. For a 6.0 m^3 cask, this corresponds to an aerosol concentration of 74 g/m^3. For off-normal and normal conditions, this corresponds to aerosol concentrations of 7.4 g/m^3 and .74 g/m^3, because number of rods failing are a factor of 10 and 100 lower, respectively, than for accident conditions. The aerosol concentration in a cask under accident conditions is a factor of 10 higher than in a containment. Therefore, the doses calculated for a cask under accident conditions in Cases 2a through 4c (Table 9) would be a little lower if the higher cask aerosol concentration were considered. The aerosol concentration in a cask under normal conditions is a factor of 10 lower than in a containment. Therefore, the doses calculated for a cask under normal conditions in Cases 2a through 4c (Table 10) would be a little higher if the lower cask aerosol concentration were considered.

Effect of Volatile Isotopes

In accordance with ISG-5, the HI-STORM SAR assumes a fuel release fraction of $2x10^{-4}$ (for each fuel rod that fails) for the class of fission products called "volatiles." In the cases that credit aerosol deposition (Cases 2a through 5c), the isotopes in this class are modeled to deposit in the confinement as aerosols. By modeling these isotopes as aerosols in Cases 2a through 5c, they represent a small portion of the total offsite dose. However, depending on the temperature of the cask, a fraction of these isotopes may be in vapor form and thus not subject to deposition by aerosol removal mechanisms such as gravitational settling. The amount of these isotopes in vapor form is estimated below for accident and normal conditions to determine whether this amount may be large enough to limit the dose reduction from aerosol deposition in Cases 2a through 5c.

Accident Conditions:

Table 7.3.1 of the HI-STORM SAR gives the inventory per fuel assembly for each of the four fission product isotopes in this class that may be important to dose, Cs-134, Cs-137, Ru-106, and Sr-90. The inventory for a BWR fuel assembly for each of these isotopes is shown in the third column of Table 13. The total inventory in the 68 assemblies in the cask shown in the fourth column is 68 times the inventory in each assembly. The release into the cask (Curies) shown in the fifth column is $2x10^{-4}$ times the total inventory. The release into the cask (moles) shown in the sixth column is the release into the cask (Curies) divided by the radioactive decay constant. The total release into the cask of .044 moles shown at the bottom of the sixth column is the sum of the releases of these isotopes.

Table 13 Release of the Class of Fission Products called "Volatiles"

Isotope	Half-life (yr)	Inventory per assembly (Ci)	Total inventory in 68 assemblies (Ci)	Release from 68 assemblies into cask (Ci)	Release from 68 assemblies into cask (moles)	Release from 68 assemblies into cask (mole fraction)
Cs-134	2.1	7,200	490,000	98	.00060	.014
Cs-137	30	23,000	1,600,000	310	.026	.60
Ru-106	1.0	4,200	280,000	57	.00020	.0046
Sr-90	29	15,000	1,000,000	210	.017	.38
Total					.044	1.0

Assuming the condensed phase in the cask is an ideal solution of cesium, ruthenium, and strontium, then the vapor pressure for each element can be estimated as follows:

$$P_{Cs} = x_{Cs} P^0_{Cs}$$
$$P_{Ru} = x_{Ru} P^0_{Ru}$$
$$P_{Sr} = x_{Sr} P^0_{Sr}$$

where P_i is the vapor pressure of the element i in the solution,
P_i^0 is the vapor pressure of the element i when it is pure, and
x_i is the mole fraction of element i in the solution.

Further assuming that the pure element vapor pressure, P_i^0, for ruthenium and strontium is the same as for cesium, the above equations can be rewritten as shown below. This is a conservative assumption, because ruthenium and strontium are less volatile than cesium and, of these three elements, most of the dose is from ruthenium and strontium.

$$P_{Cs} = x_{Cs} P^0_{Cs}$$
$$P_{Ru} = x_{Ru} P^0_{Cs}$$
$$P_{Sr} = x_{Sr} P^0_{Cs}$$

For accident conditions, the HI-STORM SAR states that the short-term limit on the maximum cladding temperature is 1100 F. At 1100 F, Figure 7 indicates that the pure element vapor pressure of cesium is .70 Pa. (Figure 7 was developed using the equilibrium chemistry model in the VICTORIA fission product chemistry code[3] as part of the effort on NUREG/CR-6672, *Reexamination of Spent Fuel Shipment Risk Estimates*, March 2000.) Using the mole fractions from Table 13, the vapor pressures of cesium, ruthenium, and strontium are .43, .0032, and .27 Pa, respectively. Using the ideal gas law with a cask temperature of 1100 F and a free volume of 6.0 m^3, these vapor pressures are equivalent to .00037, .0000028, and .00023 moles of vapor, respectively. For each element, the number of moles of vapor is 1.4% of that released into the cask (Table 13). The HI-STORM SAR evaluation, which assumed all of the release of these elements into the cask remained airborne, calculated a total dose from these elements of 4.4 mrem. However, the above evaluation indicates that only 1.4% of these elements would remain airborne. Therefore, the total dose from these elements is 1.4% of 4.4 mrem, that is, .061 mrem.

The dose for isotopes which are in vapor form (.061 mrem) is about the same as the dose for Case 5b (.10 mrem), which assumes all fission products deposit as aerosols. However, the number of moles of vapor airborne is expected to decrease over the thirty-day accident duration as a result of the cooling of the cask back to normal operating temperature. Therefore, the isotopes which are in vapor form are expected to have a small effect on the dose for accident conditions.

Normal Conditions:

For normal conditions, the HI-STORM SAR indicates that the long-term maximum cladding temperature will not exceed 740 F. At 740 F, extrapolating using Figure 7 gives a pure element vapor pressure of cesium of .060 Pa. Applying the method and assumptions used above for accident conditions results in an offsite dose of 1.2×10^{-3} mrem for a one-year period.

Figure 8 shows the helium temperature in each channel in the cask under normal conditions using the COBRA thermal-hydraulics code with an ambient temperature of 60 F. Figure 8 was developed as part of the effort to license the PFS facility.[4] Figure 8 indicates that the average temperature of the helium in the cask is 300 F under normal conditions. At 300 F, extrapolating using Figure 7 gives a pure element vapor pressure of cesium of .00030 Pa. Applying the method and assumptions used above for accident conditions results in an offsite dose of 9.4×10^{-6} mrem for a one-year period.

The dose for Case 5b, which assumes all fission products deposit as aerosols, is 8.1×10^{-5} mrem. The doses from the four fission products in vapor form are 1.2×10^{-3} mrem and 9.4×10^{-6} mrem at 740 F and 300 F, respectively. These doses are a factor-of-15 higher and a factor-of-9 lower than the dose for Case 5b. Therefore, under normal conditions, modeling aerosol deposition in the HI-STORM cask is expected to result in a best-estimate offsite dose between 1.2×10^{-3} mrem and 8.1×10^{-5} mrem, depending on the temperature of the cask.

Comparison with Direct Shine Dose

The total dose from operation of a fuel storage facility is the sum of the dose from direct shine and cask leakage. Table 14 compares the shine dose with the leakage dose for cases with and without deposition. The shine doses shown in Table 14 are taken from Figure 5.1.3 of the HI-STORM SAR and are for a two-by-five array of dry storage casks at a distance of 100 meters. The leakage dose for accident conditions is for one leaking cask. The leakage dose for normal conditions is for ten leaking casks and was estimated by multiplying the dose for one cask by ten. The leakage dose for normal conditions is shown in Table 14 with a "less than" symbol, because multiplying the leakage dose from one cask by the number of casks in the array overestimates the dose as discussed above.

Table 14 Comparison with Direct Shine Dose

Pathway	TEDE (mrem)	
	Accident Conditions (30 days)	Normal Conditions (365 days)
Direct Shine	60	700
Leakage, without deposition (Case 1)	44	<4.2
Leakage, with deposition (Case 5b)	.096	<.012

Conclusion

The primary objective of our evaluation was to provide best-estimate quantification, with uncertainty bounds, of offsite doses associated with dry storage cask leakage by taking into account aerosol deposition in the cask.

For accident conditions, our evaluation showed that modeling gravitational settling of fission product aerosols in the cask reduces the offsite dose from 40 mrem to .1 mrem, lower by a factor of 400. Lower and upper bound estimates (i.e., 10^{th} and 90^{th} percentiles) for accident conditions are .03 mrem and .2 mrem, respectively. The uncertainty analysis for accident conditions considered the uncertainties in the diameter, density, and shape factor of the aerosols in the cask. For normal conditions, our evaluation showed that modeling aerosol deposition reduces the offsite dose for one leaking cask from .4 mrem to .001 mrem, lower by a factor of 400. For normal conditions, the dose reduction is limited by the small fraction of volatile fission products which can be in vapor form under normal operating temperatures and therefore not subject to aerosol deposition mechanisms. A better understanding of the cask temperature under normal conditions may result in an additional factor-of-15 reduction in the dose. An integral evaluation of deposition using a mechanistic accident analysis code such as MELCOR or VICTORIA may result in even larger reductions, as a result of considering additional aerosol deposition mechanisms beyond gravitational settling and more detailed modeling of the partitioning of the volatile fission products between condensed and vapor phases.

Based on the analyses in this report, we conclude that more realistic treatment of aerosol deposition in a dry storage cask would result in a significant reduction in unnecessary regulatory burden.

References

1. NUREG/CR-6604, Supp. 1, RADTRAD: *A Simplified Model for RADionuclide Transport and Removal And Dose Estimation*, June 1999

2. ARES Corporation letter report, *Recommended Aerosol Transport Parameters for Spent Fuel Accident Analysis*, ARES-0007703-01, June 14, 2000

3. NUREG/CR-6131, *VICTORIA 2.0: A Mechanistic Model for Radionuclide Behavior in a Nuclear Reactor Coolant System Under Severe Accident Conditions*, December 1998

4. Pacific Northwest National Laboratory letter Report, *TEMPEST Analysis of the Utah Private Fuel Storage Facility and COBRA-SFS Analysis of the Holtec HI-STORM 100 Storage System*, May 31, 2000

5. T.L. Sanders, et al, *A Method for Determining the Spent Fuel Contribution to Transport Cask Containment Requirements*, SAND90-2406, November 1992

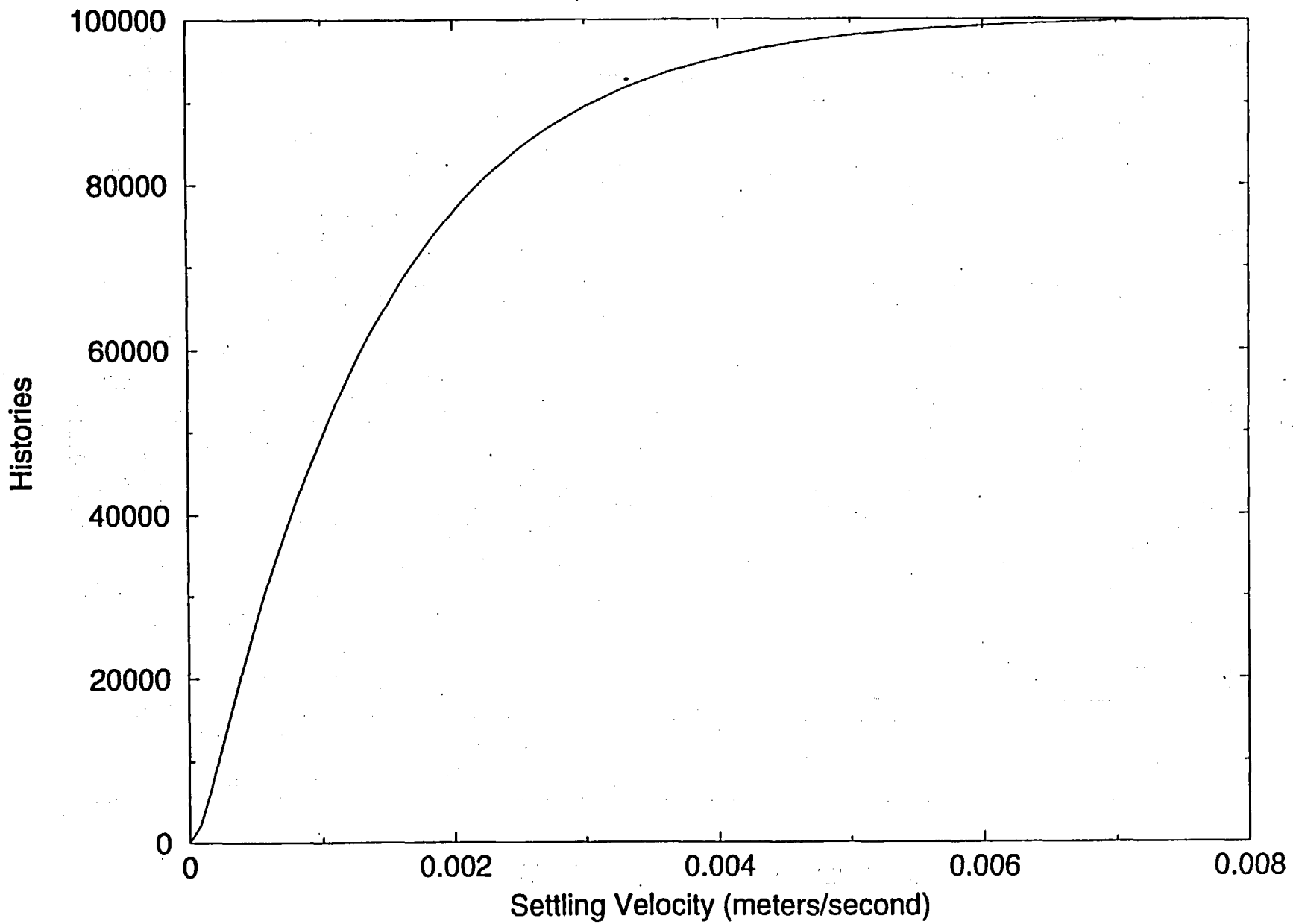
Distribution of Settling Velocities
(Cases 4a, 4b, and 4c)
100000
80000
60000
40000
20000
0
Histories
0
0.002
0.004
0.006
0.008
Settling Velocity (meters/second)

Figure 1

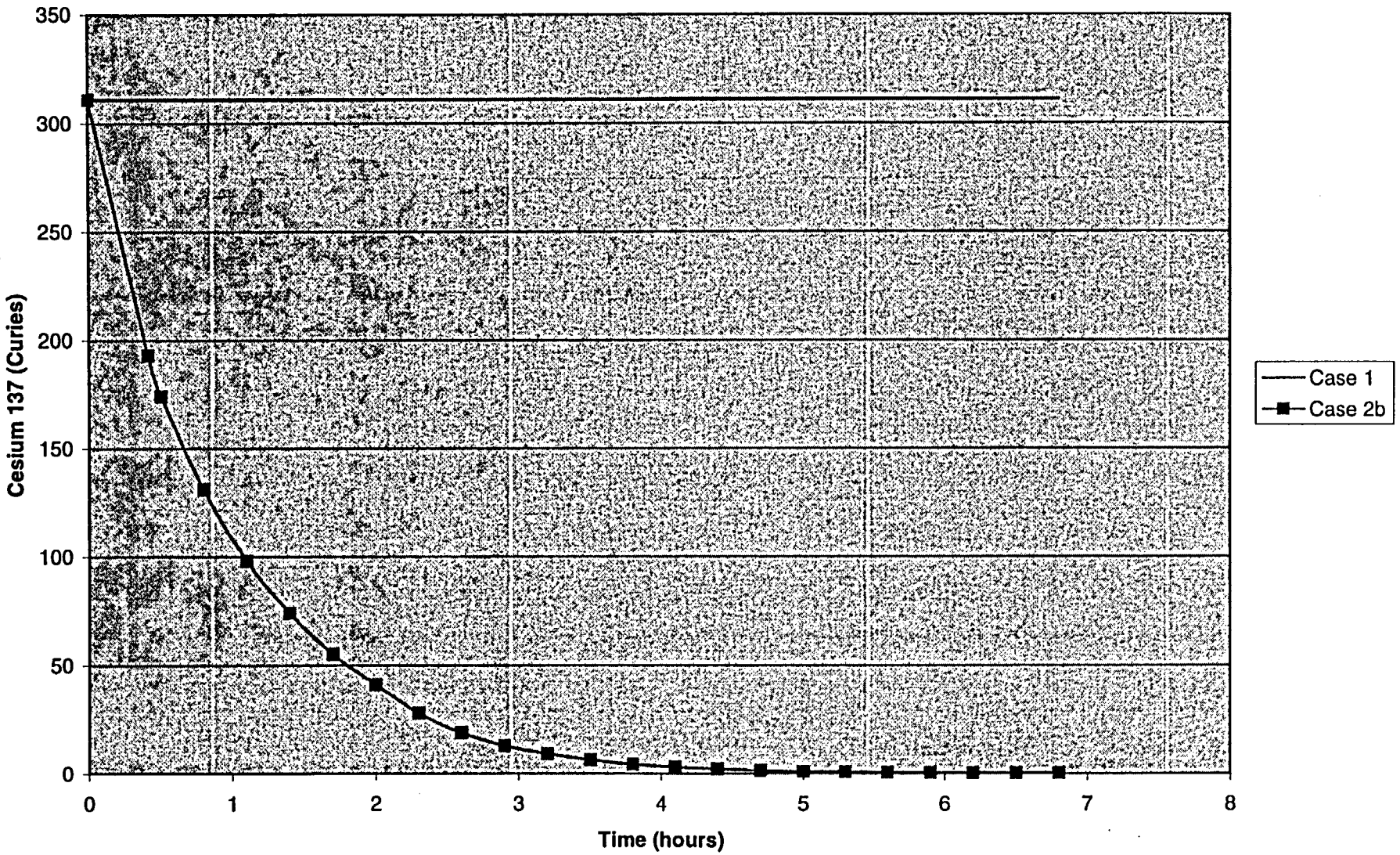
Airborne Particulate in Confinement
Cesium 137 (Curies)
350
300
250
200
150
100
50
0
0
1
2
3
4
5
6
7
8
Time (hours)
Case 1
Case 2b

Figure 2

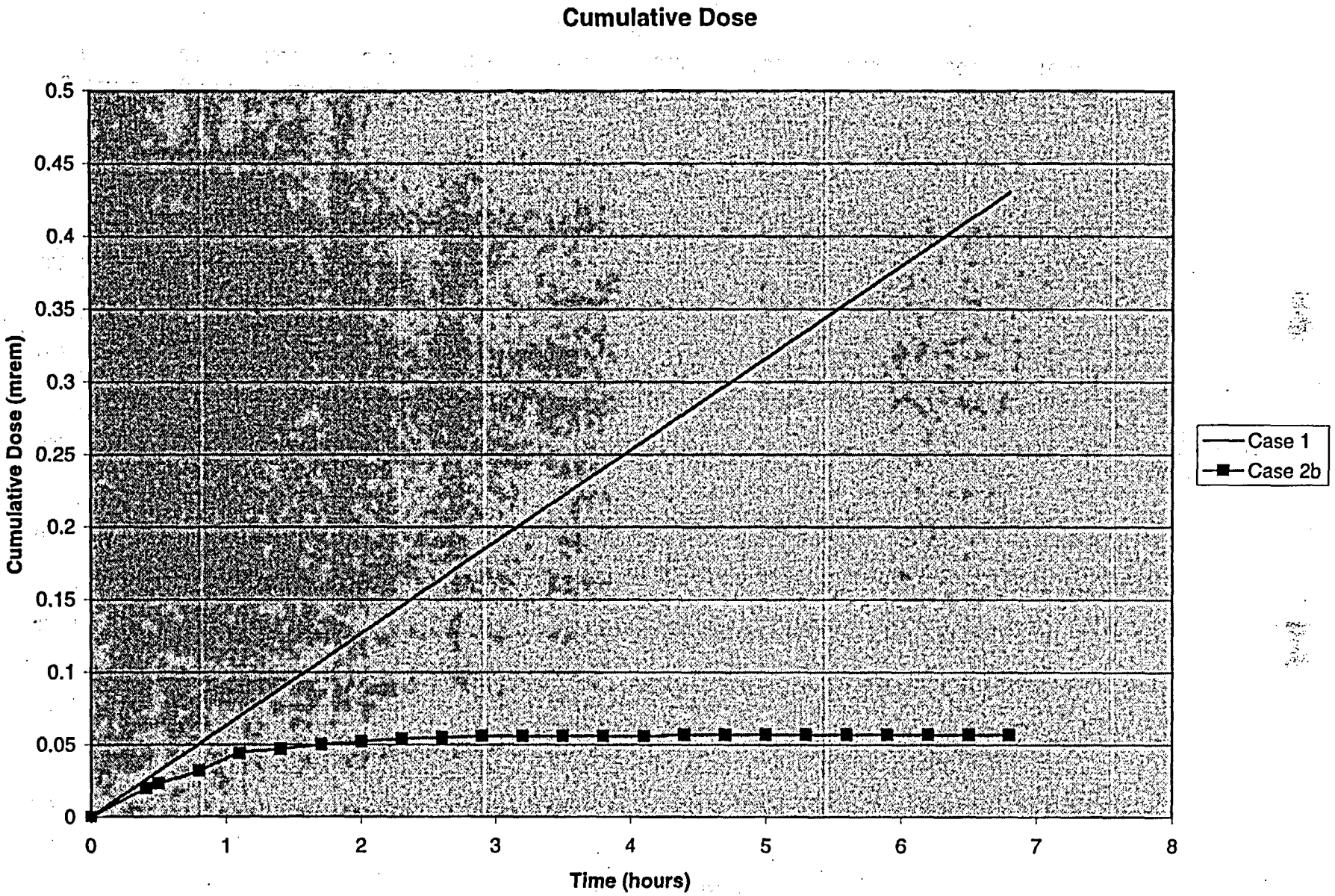
Cumulative Dose
Cumulative Dose (mrem)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
1
2
3
4
5
6
7
8
Time (hours)
Case 1
Case 2b

Figure 3

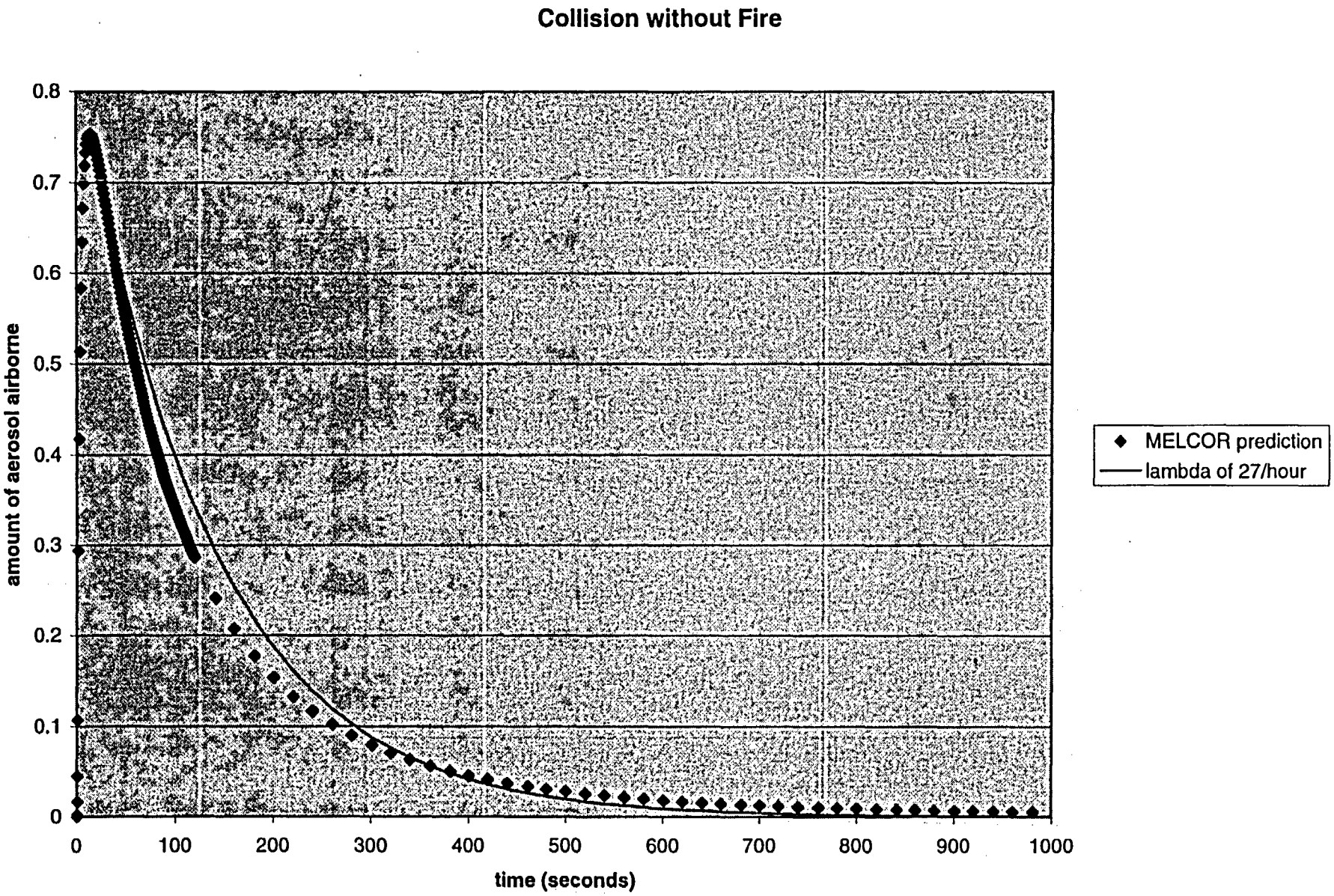
Collision without Fire
amount of aerosol airborne
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
100
200
300
400
500
600
700
800
900
1000
time (seconds)
MELCOR prediction
lambda of 27/hour

Figure 4

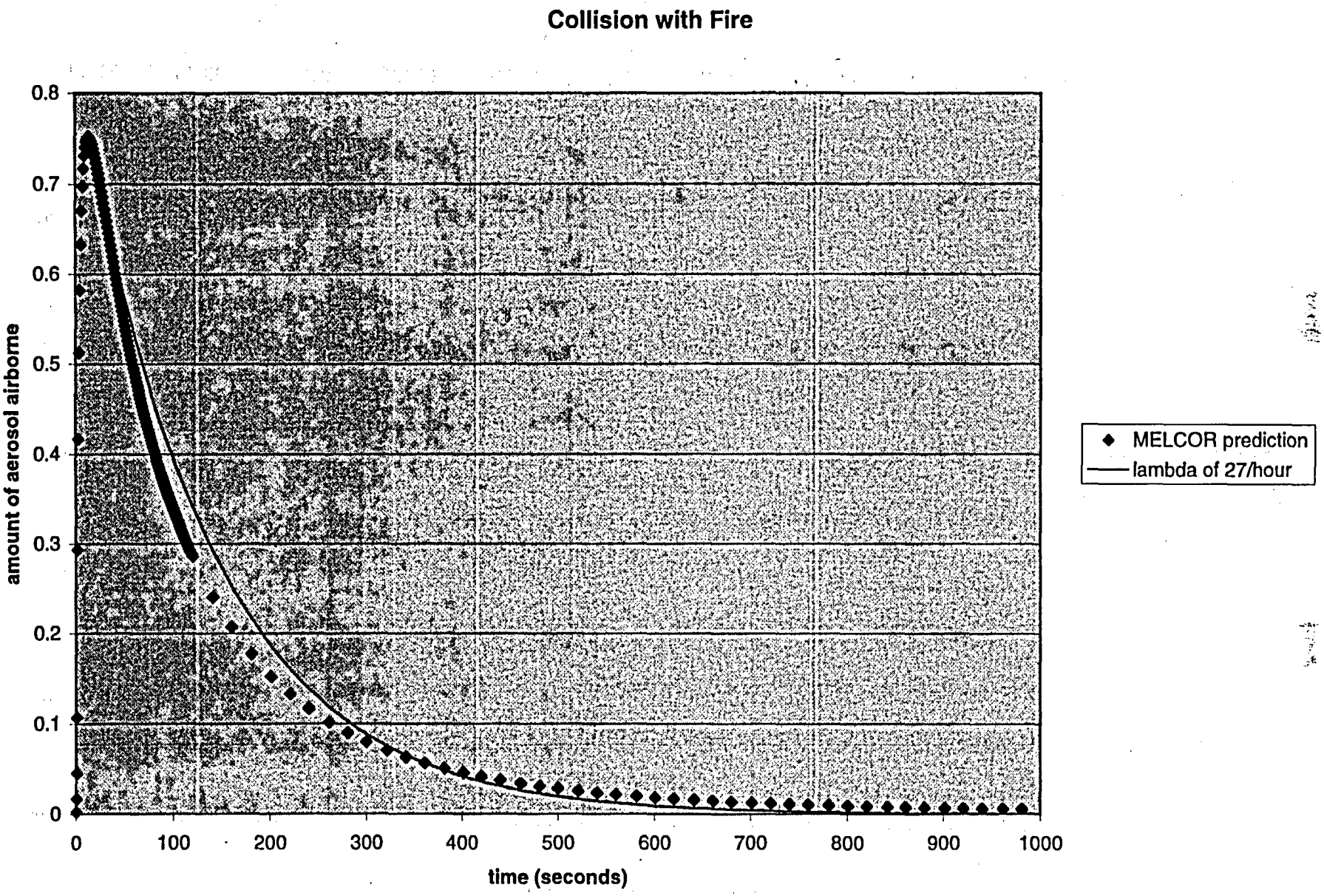
Collision with Fire
amount of aerosol airborne
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
100
200
300
400
500
600
700
800
900
1000
time (seconds)
MELCOR prediction
lambda of 27/hour

Figure 5

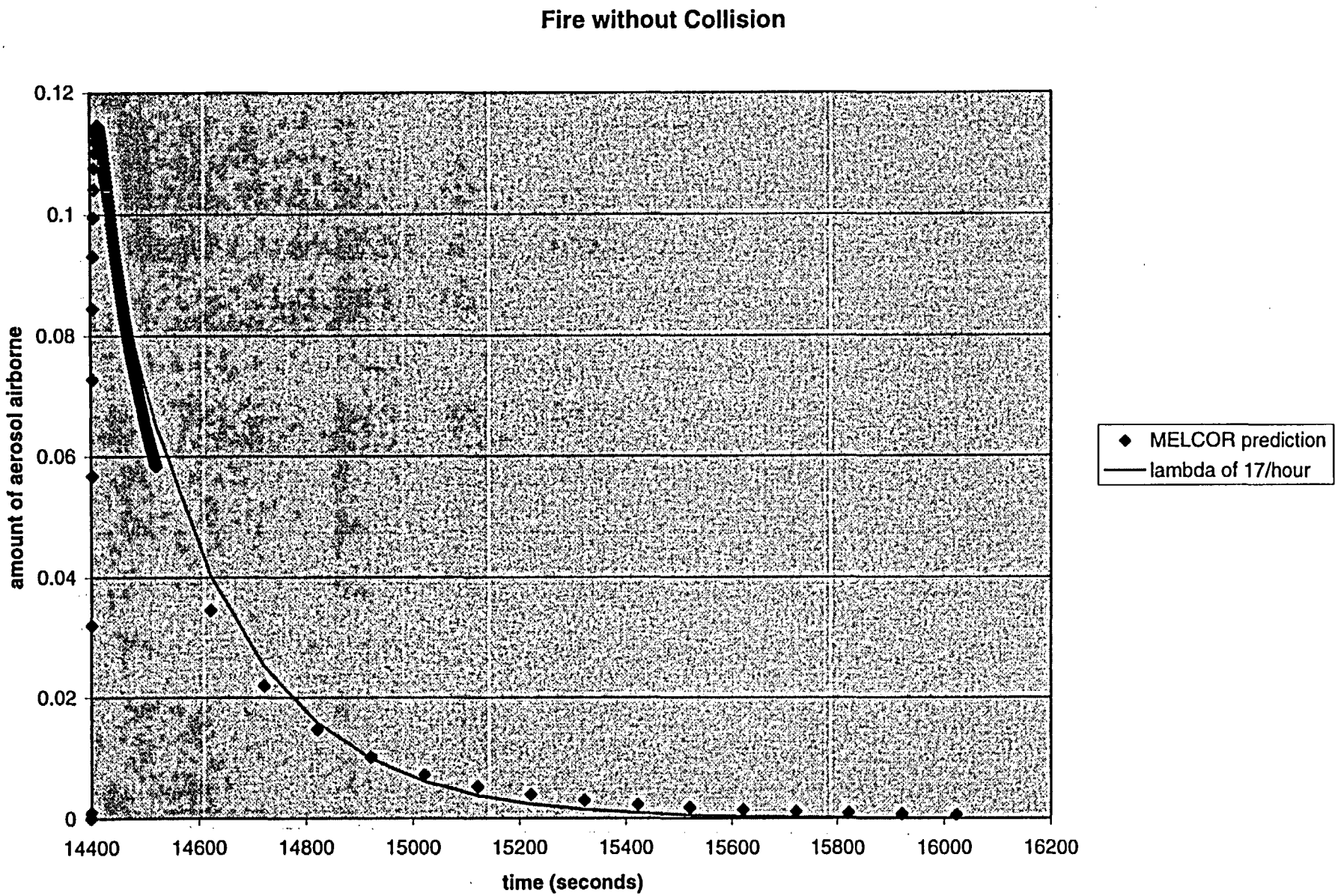
Fire without Collision
0.12
0.1
0.08
0.06
0.04
0.02
0
amount of aerosol airborne
14400
14600
14800
15000
15200
15400
15600
15800
16000
16200
time (seconds)
MELCOR prediction
lambda of 17/hour

Figure 6

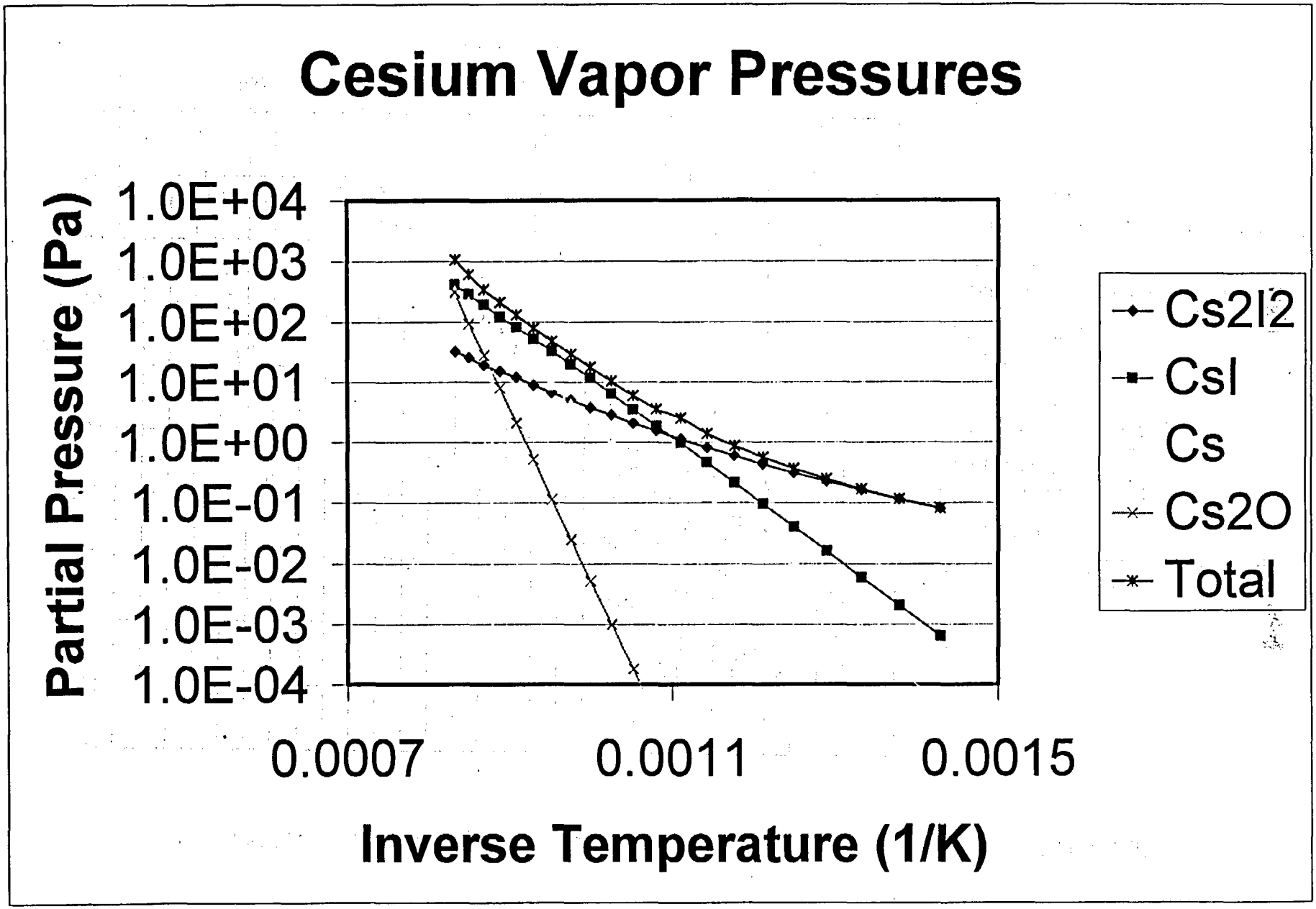
Cesium Vapor Pressures
Partial Pressure (Pa)
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
0.0007
0.0011
0.0015
Inverse Temperature (1/K)
Cs2I2
CsI
Cs
Cs2O
Total

Figure 7

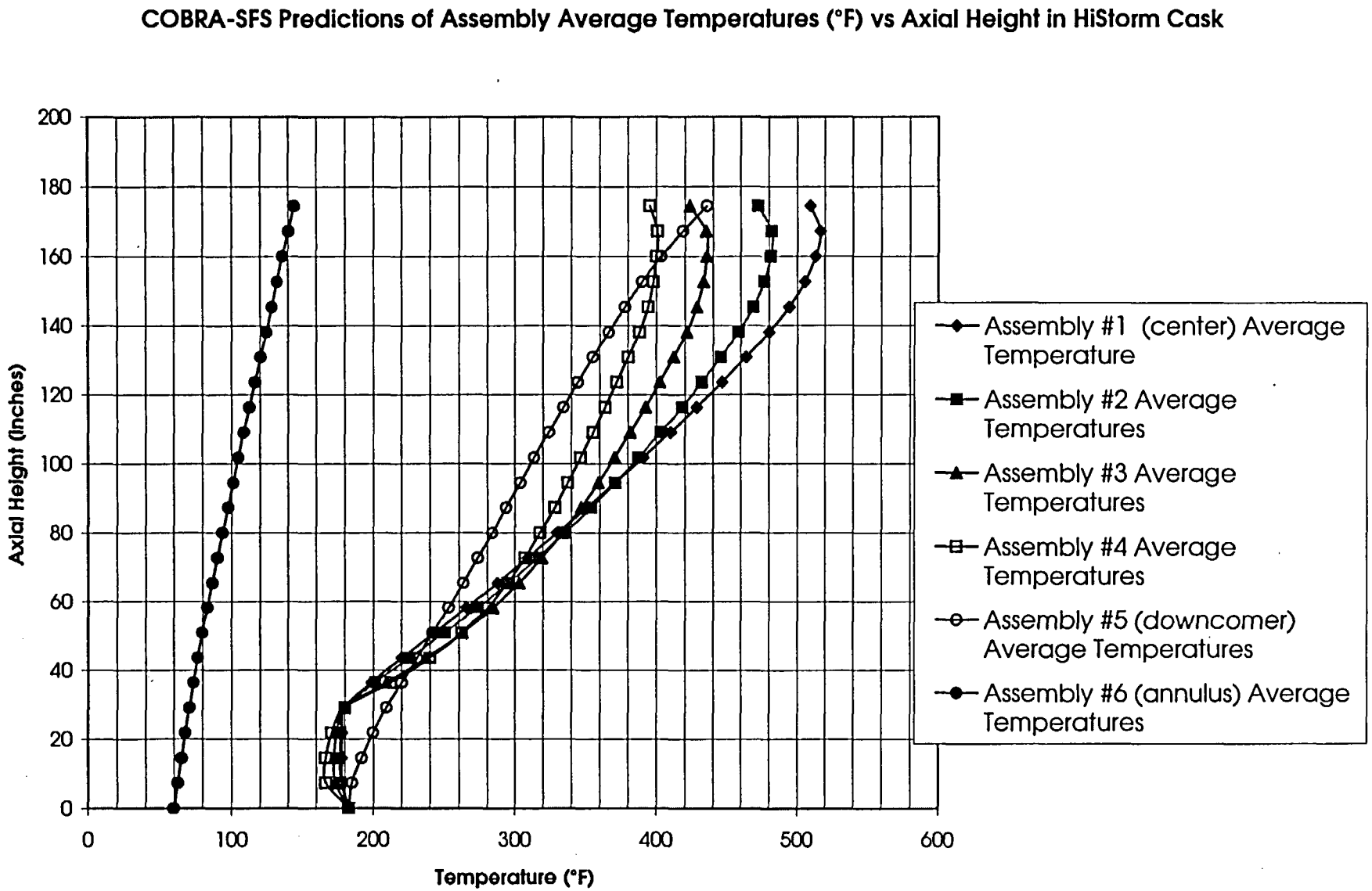
COBRA-SFS Predictions of Assembly Average Temperatures (°F) vs Axial Height in HiStorm Cask
Axial Height (inches)
Temperature (°F)
0
20
40
60
80
100
120
140
160
180
200
0
100
200
300
400
500
600
Assembly #1 (center) Average Temperature
Assembly #2 Average Temperatures
Assembly #3 Average Temperatures
Assembly #4 Average Temperatures
Assembly #5 (downcomer) Average Temperatures
Assembly #6 (annulus) Average Temperatures

Figure 8

Appendix A

RADTRAD Input Files for Case 1

This appendix contains the RADTRAD input files for Case 1. RADTRAD uses a total of four input files for each run. The first input file (DC1.PSF) contains all of the user input with the exception of the fraction and timing of the fission product release from the fuel and the physical data and the dose conversion factors for individual isotopes. The second input file (DC_DBA.RFT) contains the release fraction and timing. The third input file (DC_DEF.NIF) contains the physical data for individual isotopes. The fourth input file (DC_FGR.INP) contains the dose conversion factors for individual isotopes.

RADTRAD Input File for Case 1:

DC1.PSF

```
Radtrad 3.02 1/5/2000

Nuclide Inventory File:
C:\Program Files\U S Nuclear Regulatory Commission\Radtrad\radtrad-new\dc_def.nif
Plant Power Level:
 3.0000E+03
Compartments:
  2
Compartment 1:
Confinement
  3
 2.1200E+02
  0
  0
  0
  0
  0
Compartment 2:
Environment
  2
 0.0000E+00
  0
  0
  0
  0
  0
Pathways:
  1
Pathway 1:
Confinement to Environment
  1
  2
  4
End of Plant Model File
Scenario Description Name:

Plant Model Filename:

Source Term:
  1
  1   1.0000E+00
C:\Program Files\U S Nuclear Regulatory Commission\Radtrad\radtrad-new\dc_fgr.inp
C:\Program Files\U S Nuclear Regulatory Commission\Radtrad\radtrad-new\dc_dba.rft
  0.0000E+00
  0
  1.0000E+00   0.0000E+00   0.0000E+00   1.0000E+00
Overlying Pool:
  0
  0.0000E+00
  0
  0
  0
  0
Compartments:
  2
Compartment 1:
  1
  1
  0
  0
  0
  0
  0
  0
```

```
  0
Compartment 2:
  1
  1
  0
  0
  0
  0
  0
  0
  0
Pathways:
  1
Pathway 1:
  0
  0
  0
  0
  0
  0
  0
  0
  0
  0
  1
  1
  0.0000E+00    1.8000E-05
  0
Dose Locations:
  1
Location 1:
boundary (100 m)
  2
  1
  2
  0.0000E+00    8.0000E-03
  7.2000E+02    0.0000E+00
  1
  2
  0.0000E+00    3.3000E-04
  7.2000E+02    0.0000E+00
  0
Effective Volume Location:
  0
Simulation Parameters:
  1
  0.0000E+00    0.0000E+00
Output Filename:
C:\Program Files\U S Nuclear Regulatory Commission\Radtrad\radtrad-new\dc1.o0
  1
  1
  1
  1
  1
End of Scenario File
```

RADTRAD Input File for Case 1:

DC_DBA.RFT

```
Release Fraction and Timing Name:
Dry storage cask - Jason Schaperow 3/22/00
Duration (h):
 0.1000E-01  0.0000E+00  0.0000E+00  0.0000E+00
Noble Gases:
 0.3000E+00  0.0000E+00  0.0000E+00  0.0000E+00
Iodine:
 0.3000E+00  0.0000E+00  0.0000E+00  0.0000E+00
Cesium:
 2.0000E-04  0.0000E+00  0.0000E+00  0.0000E+00
Tellurium:
 3.0000E-05  0.0000E+00  0.0000E+00  0.0000E+00
Strontium:
 2.0000E-04  0.0000E+00  0.0000E+00  0.0000E+00
Barium:
 3.0000E-05  0.0000E+00  0.0000E+00  0.0000E+00
Ruthenium:
 1.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
Cerium:
 3.0000E-05  0.0000E+00  0.0000E+00  0.0000E+00
Lanthanum:
 3.0000E-05  0.0000E+00  0.0000E+00  0.0000E+00
Non-Radioactive Aerosols (kg):
 0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
End of Release File
```

RADTRAD Input File for Case 1:

DC_DEF.NIF

```
Nuclide Inventory Name:
Dry Storage Cask - Jason Schaperow 3/23/00
Power Level:
 4.4118E+01
Nuclides:
 60
Nuclide 001:
Co-58
  7
 0.6117120000E+07
 0.5800E+02
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 002:
Co-60
  7
 0.1663401096E+09
 0.6000E+02
 0.6500E+02
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 003:
Kr-85
  1
 0.3382974720E+09
 0.8500E+02
 0.1430E+04
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 004:
Kr-85m
  1
 0.1612800000E+05
 0.8500E+02
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 005:
Kr-87
  1
 0.4578000000E+04
 0.8700E+02
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 006:
Kr-88
  1
 0.1022400000E+05
 0.8800E+02
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 007:
Rb-86
  3
 0.1612224000E+07
```

```
 0.8600E+02
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 008:
Sr-89
   5
 0.4363200000E+07
 0.8900E+02
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 009:
Sr-90
   5
 0.9189573120E+09
 0.9000E+02
 0.1520E+05
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 010:
Sr-91
   5
 0.3420000000E+05
 0.9100E+02
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 011:
Sr-92
   5
 0.9756000000E+04
 0.9200E+02
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 012:
Y-90
   9
 0.2304000000E+06
 0.9000E+02
 0.1520E+05
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 013:
Y-91
   9
 0.5055264000E+07
 0.9100E+02
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 014:
Y-92
   9
 0.1274400000E+05
 0.9200E+02
```

```
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 015:
Y-93
  9
 0.3636000000E+05
 0.9300E+02
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 016:
Zr-95
  9
 0.5527872000E+07
 0.9500E+02
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 017:
Zr-97
  9
 0.6084000000E+05
 0.9700E+02
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 018:
Nb-95
  9
 0.3036960000E+07
 0.9500E+02
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 019:
Mo-99
  7
 0.2376000000E+06
 0.9900E+02
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 020:
Tc-99m
  7
 0.2167200000E+05
 0.9900E+02
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 021:
Ru-103
  7
 0.3393792000E+07
 0.1030E+03
 0.0000E+00
```

```
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 022:
Ru-105
   7
 0.1598400000E+05
 0.1050E+03
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 023:
Ru-106
   3
 0.3181248000E+08
 0.1060E+03
 0.4160E+04
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 024:
Rh-105
   7
 0.1272960000E+06
 0.1050E+03
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 025:
Sb-127
   4
 0.3326400000E+06
 0.1270E+03
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 026:
H-3
   1
 3.7800000000E+08
 0.3000E+01
 0.8720E+02
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 027:
I-129
   2
 5.3600000000E+14
 0.1290E+03
 0.7720E-02
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 028:
Sb-125
   4
 8.5100000000E+07
 0.1250E+03
 0.6400E+03
none      0.0000E+00
```

```
none      0.0000E+00
none      0.0000E+00
Nuclide 029:
Te-125m
  4
 5.0100000000E+06
 0.1250E+03
 0.1560E+03
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 030:
Rh-106
  4
 3.0000000000E+01
 0.1060E+03
 0.4160E+04
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 031:
Ba-137m
  6
 1.5000000000E+02
 0.1370E+03
 0.2160E+05
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 032:
Pr-144
  9
 1.0200000000E+03
 0.1440E+03
 0.2460E+04
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 033:
Pm-147
  9
 8.2000000000E+07
 0.1470E+03
 0.8880E+04
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 034:
Eu-154
  9
 5.0500000000E+08
 0.1540E+03
 0.1070E+04
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 035:
Eu-155
  9
 5.6800000000E+07
 0.1550E+03
 0.3510E+02
none      0.0000E+00
none      0.0000E+00
```

```
none      0.0000E+00
Nuclide 036:
Am-243
  9
 2.4900000000E+11
 0.2430E+03
 0.7390E+01
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 037:
Cm-243
  9
 1.0100000000E+09
 0.2430E+03
 0.4810E+01
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 038:
Xe-133
  1
 0.4531680000E+06
 0.1330E+03
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 039:
Xe-135
  1
 0.3272400000E+05
 0.1350E+03
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 040:
Cs-134
  3
 0.6507177120E+08
 0.1340E+03
 0.7200E+04
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 041:
Cs-136
  3
 0.1131840000E+07
 0.1360E+03
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 042:
Cs-137
  3
 0.9467280000E+09
 0.1370E+03
 0.2290E+05
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
```

```
Nuclide 043:
Ba-139
  6
 0.4962000000E+04
 0.1390E+03
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 044:
Ba-140
  6
 0.1100736000E+07
 0.1400E+03
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 045:
La-140
  9
 0.1449792000E+06
 0.1400E+03
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 046:
La-141
  9
 0.1414800000E+05
 0.1410E+03
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 047:
La-142
  9
 0.5550000000E+04
 0.1420E+03
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 048:
Ce-141
  8
 0.2808086400E+07
 0.1410E+03
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 049:
Ce-143
  8
 0.1188000000E+06
 0.1430E+03
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 050:
```

```
Ce-144
  8
 0.2456352000E+08
 0.1440E+03
 0.2460E+04
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 051:
Pr-143
  9
 0.1171584000E+07
 0.1430E+03
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 052:
Nd-147
  9
 0.9486720000E+06
 0.1470E+03
 0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 053:
Np-239
  8
 0.2034720000E+06
 0.2390E+03
 0.7390E+01
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 054:
Pu-238
  8
 0.2768863824E+10
 0.2380E+03
 0.7490E+03
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 055:
Pu-239
  8
 0.7594336440E+12
 0.2390E+03
 0.6160E+02
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 056:
Pu-240
  8
 0.2062920312E+12
 0.2400E+03
 0.1260E+03
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 057:
Pu-241
```

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  8
 0.4544294400E+09
 0.2410E+03
 0.2100E+05
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 058:
Am-241
  9
 0.1363919472E+11
 0.2410E+03
 0.2200E+03
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 059:
Cm-242
  9
 0.1406592000E+08
 0.2420E+03
 0.6100E+01
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 060:
Cm-244
  9
 0.5715081360E+09
 0.2440E+03
 0.9300E+03
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
End of Nuclear Inventory File
```

RADTRAD Input File for Case 1:

DC_FGR.INP

```
FGRDCF 10/24/95   03:24:50   beta-test version 1.10, minor FORTRAN fixes 5/4/95
Dry Storage Cask - Jason Schaperow 3/24/00
         9 ORGANS DEFINED IN THIS FILE:
GONADS
BREAST
LUNGS
RED MARR
BONE SUR
THYROID
REMAINDER
EFFECTIVE
SKIN(FGR)
        60 NUCLIDES DEFINED IN THIS FILE:
Co-58      Y
Co-60      Y
Kr-85
Kr-85m
Kr-87
Kr-88
Rb-86      D
Sr-89      Y
Sr-90      Y
Sr-91      Y      Including:Y-91m
Sr-92      Y
Y-90       Y
Y-91       Y
Y-92       Y
Y-93       Y
Zr-95      D
Zr-97      Y      Including:Nb-97m , Including:Nb-97
Nb-95      Y
Mo-99      Y
Tc-99m     D
Ru-103     Y      Including:Rh-103m
Ru-105     Y
Ru-106     Y      Including:Rh-106
Rh-105     Y
Sb-127     W
H-3        V      dry storage cask isotope
I-129      D      dry storage cask isotope
Sb-125     W      dry storage cask isotope

Te-125m    W      dry storage cask isotope

Rh-106            dry storage cask isotope

Ba-137m           dry storage cask isotope

Pr-144     Y      dry storage cask isotope

Pm-147     Y      dry storage cask isotope

Eu-154     W      dry storage cask isotope

Eu-155     W      dry storage cask isotope

Am-243     W      dry storage cask isotope

Cm-243     W      dry storage cask isotope

Xe-133
Xe-135
Cs-134     D
Cs-136     D
```

Cs-137	D	Including:Ba-137m
Ba-139	D	
Ba-140	D	
La-140	W	
La-141	D	
La-142	D	
Ce-141	Y	
Ce-143	Y	
Ce-144	Y	Including:Pr-144m, Including:Pr-144
Pr-143	Y	
Nd-147	Y	
Np-239	W	
Pu-238	Y	
Pu-239	Y	
Pu-240	Y	
Pu-241	Y	
Am-241	W	
Cm-242	W	
Cm-244	W	

	CLOUDSHINE	GROUND SHINE 8HR	GROUND SHINE 7DAY	GROUND SHINE RATE	INHALED ACUTE	INHALED CHRONIC	INGESTION
Co-58							
GONADS	4.660E-14	2.867E-11	5.828E-10	9.970E-16-1.000E+00	6.170E-10	1.040E-09	
BREAST	5.300E-14	2.737E-11	5.565E-10	9.520E-16-1.000E+00	9.370E-10	1.790E-10	
LUNGS	4.640E-14	2.617E-11	5.319E-10	9.100E-16-1.000E+00	1.600E-08	8.530E-11	
RED MARR	4.530E-14	2.671E-11	5.430E-10	9.290E-16-1.000E+00	9.230E-10	2.600E-10	
BONE SUR	7.410E-14	3.795E-11	7.716E-10	1.320E-15-1.000E+00	6.930E-10	1.250E-10	
THYROID	4.770E-14	2.720E-11	5.530E-10	9.460E-16-1.000E+00	8.720E-10	6.310E-11	
REMAINDER	4.440E-14	2.585E-11	5.255E-10	8.990E-16-1.000E+00	1.890E-09	1.580E-09	
EFFECTIVE	4.760E-14	2.732E-11	5.553E-10	9.500E-16-1.000E+00	2.940E-09	8.090E-10	
SKIN(FGR)	5.580E-14	3.278E-11	6.664E-10	1.140E-15-1.000E+00	0.000E+00	0.000E+00	
Co-60							
GONADS	1.230E-13	7.056E-11	1.480E-09	2.450E-15-1.000E+00	4.760E-09	3.190E-09	
BREAST	1.390E-13	6.739E-11	1.413E-09	2.340E-15-1.000E+00	1.840E-08	1.100E-09	
LUNGS	1.240E-13	6.537E-11	1.371E-09	2.270E-15-1.000E+00	3.450E-07	8.770E-10	
RED MARR	1.230E-13	6.710E-11	1.407E-09	2.330E-15-1.000E+00	1.720E-08	1.320E-09	
BONE SUR	1.780E-13	8.956E-11	1.879E-09	3.110E-15-1.000E+00	1.350E-08	9.390E-10	
THYROID	1.270E-13	6.480E-11	1.359E-09	2.250E-15-1.000E+00	1.620E-08	7.880E-10	
REMAINDER	1.200E-13	6.508E-11	1.365E-09	2.260E-15-1.000E+00	3.600E-08	4.970E-09	
EFFECTIVE	1.260E-13	6.768E-11	1.419E-09	2.350E-15-1.000E+00	5.910E-08	2.770E-09	
SKIN(FGR)	1.450E-13	7.948E-11	1.667E-09	2.760E-15-1.000E+00	0.000E+00	0.000E+00	
Kr-85							
GONADS	1.170E-16	8.121E-14	1.704E-12	2.820E-18-1.000E+00	0.000E+00	0.000E+00	
BREAST	1.340E-16	7.891E-14	1.656E-12	2.740E-18-1.000E+00	0.000E+00	0.000E+00	
LUNGS	1.140E-16	7.056E-14	1.481E-12	2.450E-18-1.000E+00	0.000E+00	0.000E+00	
RED MARR	1.090E-16	6.998E-14	1.469E-12	2.430E-18-1.000E+00	0.000E+00	0.000E+00	
BONE SUR	2.200E-16	1.287E-13	2.702E-12	4.470E-18-1.000E+00	0.000E+00	0.000E+00	
THYROID	1.180E-16	7.459E-14	1.565E-12	2.590E-18-1.000E+00	0.000E+00	0.000E+00	
REMAINDER	1.090E-16	6.941E-14	1.457E-12	2.410E-18-1.000E+00	0.000E+00	0.000E+00	
EFFECTIVE	1.190E-16	7.603E-14	1.596E-12	2.640E-18-1.000E+00	0.000E+00	0.000E+00	
SKIN(FGR)	1.320E-14	2.304E-11	4.835E-10	8.000E-16-1.000E+00	0.000E+00	0.000E+00	
Kr-85m							
GONADS	7.310E-15	2.594E-12	3.653E-12	1.570E-16-1.000E+00	0.000E+00	0.000E+00	
BREAST	8.410E-15	2.527E-12	3.560E-12	1.530E-16-1.000E+00	0.000E+00	0.000E+00	
LUNGS	7.040E-15	2.379E-12	3.351E-12	1.440E-16-1.000E+00	0.000E+00	0.000E+00	
RED MARR	6.430E-15	2.346E-12	3.304E-12	1.420E-16-1.000E+00	0.000E+00	0.000E+00	
BONE SUR	1.880E-14	5.286E-12	7.446E-12	3.200E-16-1.000E+00	0.000E+00	0.000E+00	
THYROID	7.330E-15	2.395E-12	3.374E-12	1.450E-16-1.000E+00	0.000E+00	0.000E+00	
REMAINDER	6.640E-15	2.313E-12	3.257E-12	1.400E-16-1.000E+00	0.000E+00	0.000E+00	
EFFECTIVE	7.480E-15	2.511E-12	3.537E-12	1.520E-16-1.000E+00	0.000E+00	0.000E+00	
SKIN(FGR)	2.240E-14	2.247E-11	3.164E-11	1.360E-15-1.000E+00	0.000E+00	0.000E+00	
Kr-87							
GONADS	4.000E-14	4.962E-12	5.026E-12	7.610E-16-1.000E+00	0.000E+00	0.000E+00	
BREAST	4.500E-14	4.740E-12	4.802E-12	7.270E-16-1.000E+00	0.000E+00	0.000E+00	

LUNGS	4.040E-14	4.603E-12	4.663E-12	7.060E-16-1.000E+00	0.000E+00	0.000E+00
RED MARR	4.000E-14	4.708E-12	4.769E-12	7.220E-16-1.000E+00	0.000E+00	0.000E+00
BONE SUR	6.020E-14	6.514E-12	6.598E-12	9.990E-16-1.000E+00	0.000E+00	0.000E+00
THYROID	4.130E-14	4.473E-12	4.531E-12	6.860E-16-1.000E+00	0.000E+00	0.000E+00
REMAINDER	3.910E-14	4.590E-12	4.650E-12	7.040E-16-1.000E+00	0.000E+00	0.000E+00
EFFECTIVE	4.120E-14	4.773E-12	4.835E-12	7.320E-16-1.000E+00	0.000E+00	0.000E+00
SKIN(FGR)	1.370E-13	8.802E-11	8.916E-11	1.350E-14-1.000E+00	0.000E+00	0.000E+00
Kr-88						
GONADS	9.900E-14	2.278E-11	2.655E-11	1.800E-15-1.000E+00	0.000E+00	0.000E+00
BREAST	1.110E-13	2.177E-11	2.537E-11	1.720E-15-1.000E+00	0.000E+00	0.000E+00
LUNGS	1.010E-13	2.139E-11	2.493E-11	1.690E-15-1.000E+00	0.000E+00	0.000E+00
RED MARR	1.000E-13	2.190E-11	2.552E-11	1.730E-15-1.000E+00	0.000E+00	0.000E+00
BONE SUR	1.390E-13	2.886E-11	3.363E-11	2.280E-15-1.000E+00	0.000E+00	0.000E+00
THYROID	1.030E-13	2.012E-11	2.345E-11	1.590E-15-1.000E+00	0.000E+00	0.000E+00
REMAINDER	9.790E-14	2.139E-11	2.493E-11	1.690E-15-1.000E+00	0.000E+00	0.000E+00
EFFECTIVE	1.020E-13	2.202E-11	2.567E-11	1.740E-15-1.000E+00	0.000E+00	0.000E+00
SKIN(FGR)	1.350E-13	5.607E-11	6.534E-11	4.430E-15-1.000E+00	0.000E+00	0.000E+00
Rb-86						
GONADS	4.710E-15	2.788E-12	5.187E-11	9.740E-17-1.000E+00	1.340E-09	2.150E-09
BREAST	5.340E-15	2.662E-12	4.953E-11	9.300E-17-1.000E+00	1.330E-09	2.140E-09
LUNGS	4.710E-15	2.553E-12	4.750E-11	8.920E-17-1.000E+00	3.300E-09	2.140E-09
RED MARR	4.640E-15	2.619E-12	4.873E-11	9.150E-17-1.000E+00	2.320E-09	3.720E-09
BONE SUR	7.050E-15	3.635E-12	6.764E-11	1.270E-16-1.000E+00	4.270E-09	6.860E-09
THYROID	4.840E-15	2.599E-12	4.836E-11	9.080E-17-1.000E+00	1.330E-09	2.140E-09
REMAINDER	4.520E-15	2.542E-12	4.729E-11	8.880E-17-1.000E+00	1.380E-09	2.330E-09
EFFECTIVE	4.810E-15	2.665E-12	4.958E-11	9.310E-17-1.000E+00	1.790E-09	2.530E-09
SKIN(FGR)	4.850E-14	2.210E-10	4.111E-09	7.720E-15-1.000E+00	0.000E+00	0.000E+00
Sr-89						
GONADS	7.730E-17	7.155E-14	1.436E-12	2.490E-18-1.000E+00	7.950E-12	8.050E-12
BREAST	9.080E-17	7.212E-14	1.447E-12	2.510E-18-1.000E+00	7.960E-12	7.980E-12
LUNGS	7.080E-17	5.689E-14	1.142E-12	1.980E-18-1.000E+00	8.350E-08	7.970E-12
RED MARR	6.390E-17	5.345E-14	1.073E-12	1.860E-18-1.000E+00	1.070E-10	1.080E-10
BONE SUR	1.940E-16	1.560E-13	3.131E-12	5.430E-18-1.000E+00	1.590E-10	1.610E-10
THYROID	7.600E-17	6.063E-14	1.217E-12	2.110E-18-1.000E+00	7.960E-12	7.970E-12
REMAINDER	6.710E-17	5.603E-14	1.124E-12	1.950E-18-1.000E+00	3.970E-09	8.250E-09
EFFECTIVE	7.730E-17	6.523E-14	1.309E-12	2.270E-18-1.000E+00	1.120E-08	2.500E-09
SKIN(FGR)	3.690E-14	1.914E-10	3.841E-09	6.660E-15-1.000E+00	0.000E+00	0.000E+00
Sr-90						
GONADS	7.780E-18	9.590E-15	2.014E-13	3.330E-19-1.000E+00	2.690E-10	5.040E-11
BREAST	9.490E-18	1.008E-14	2.116E-13	3.500E-19-1.000E+00	2.690E-10	5.040E-11
LUNGS	6.440E-18	6.307E-15	1.324E-13	2.190E-19-1.000E+00	2.860E-06	5.040E-11
RED MARR	5.440E-18	5.558E-15	1.167E-13	1.930E-19-1.000E+00	3.280E-08	6.450E-09
BONE SUR	2.280E-17	2.393E-14	5.025E-13	8.310E-19-1.000E+00	7.090E-08	1.390E-08
THYROID	7.330E-18	7.171E-15	1.506E-13	2.490E-19-1.000E+00	2.690E-10	5.040E-11
REMAINDER	6.110E-18	6.422E-15	1.348E-13	2.230E-19-1.000E+00	5.730E-09	6.700E-09
EFFECTIVE	7.530E-18	8.179E-15	1.717E-13	2.840E-19-1.000E+00	3.510E-07	3.230E-09
SKIN(FGR)	9.200E-15	4.032E-12	8.465E-11	1.400E-16-1.000E+00	0.000E+00	0.000E+00
Sr-91						
GONADS	4.819E-14	2.155E-11	5.062E-11	1.026E-15-1.000E+00	5.669E-11	2.520E-10
BREAST	5.477E-14	2.059E-11	4.838E-11	9.806E-16-1.000E+00	1.775E-11	3.676E-11
LUNGS	4.803E-14	1.970E-11	4.626E-11	9.376E-16-1.000E+00	2.170E-09	1.055E-11
RED MARR	4.691E-14	2.011E-11	4.722E-11	9.570E-16-1.000E+00	2.275E-11	5.659E-11
BONE SUR	7.674E-14	2.852E-11	6.709E-11	1.360E-15-1.000E+00	1.306E-11	2.070E-11
THYROID	4.938E-14	2.035E-11	4.782E-11	9.693E-16-1.000E+00	9.930E-12	1.968E-12
REMAINDER	4.610E-14	1.948E-11	4.573E-11	9.268E-16-1.000E+00	5.802E-10	2.557E-09
EFFECTIVE	4.924E-14	2.057E-11	4.832E-11	9.793E-16-1.000E+00	4.547E-10	8.455E-10
SKIN(FGR)	9.938E-14	1.748E-10	3.987E-10	8.080E-15-1.000E+00	0.000E+00	0.000E+00
Sr-92						
GONADS	6.610E-14	1.593E-11	1.830E-11	1.300E-15-1.000E+00	1.020E-11	8.180E-11
BREAST	7.480E-14	1.520E-11	1.745E-11	1.240E-15-1.000E+00	6.490E-12	1.700E-11
LUNGS	6.670E-14	1.483E-11	1.703E-11	1.210E-15-1.000E+00	1.050E-09	7.220E-12
RED MARR	6.620E-14	1.520E-11	1.745E-11	1.240E-15-1.000E+00	6.980E-12	2.290E-11
BONE SUR	9.490E-14	2.010E-11	2.308E-11	1.640E-15-1.000E+00	4.360E-12	8.490E-12
THYROID	6.820E-14	1.446E-11	1.661E-11	1.180E-15-1.000E+00	3.920E-12	1.300E-12

REMAINDER	6.450E-14	1.471E-11	1.689E-11	1.200E-15-1.000E+00	2.900E-10	1.720E-09
EFFECTIVE	6.790E-14	1.532E-11	1.759E-11	1.250E-15-1.000E+00	2.180E-10	5.430E-10
SKIN(FGR)	8.560E-14	2.280E-11	2.618E-11	1.860E-15-1.000E+00	0.000E+00	0.000E+00
Y-90						
GONADS	1.890E-16	1.586E-13	1.601E-12	5.750E-18-1.000E+00	5.170E-13	1.430E-14
BREAST	2.200E-16	1.578E-13	1.593E-12	5.720E-18-1.000E+00	5.170E-13	1.270E-14
LUNGS	1.770E-16	1.313E-13	1.326E-12	4.760E-18-1.000E+00	9.310E-09	1.260E-14
RED MARR	1.620E-16	1.261E-13	1.273E-12	4.570E-18-1.000E+00	1.520E-11	3.700E-13
BONE SUR	4.440E-16	3.228E-13	3.259E-12	1.170E-17-1.000E+00	1.510E-11	3.670E-13
THYROID	1.870E-16	1.385E-13	1.398E-12	5.020E-18-1.000E+00	5.170E-13	1.260E-14
REMAINDER	1.680E-16	1.291E-13	1.303E-12	4.680E-18-1.000E+00	3.870E-09	9.680E-09
EFFECTIVE	1.900E-16	1.468E-13	1.482E-12	5.320E-18-1.000E+00	2.280E-09	2.910E-09
SKIN(FGR)	6.240E-14	2.897E-10	2.924E-09	1.050E-14-1.000E+00	0.000E+00	0.000E+00
Y-91						
GONADS	2.560E-16	1.756E-13	3.546E-12	6.110E-18-1.000E+00	8.200E-12	3.540E-12
BREAST	2.930E-16	1.713E-13	3.459E-12	5.960E-18-1.000E+00	8.920E-12	5.540E-13
LUNGS	2.500E-16	1.526E-13	3.082E-12	5.310E-18-1.000E+00	9.870E-08	2.020E-13
RED MARR	2.410E-16	1.521E-13	3.070E-12	5.290E-18-1.000E+00	3.190E-10	6.590E-12
BONE SUR	4.560E-16	2.903E-13	5.862E-12	1.010E-17-1.000E+00	3.180E-10	6.130E-12
THYROID	2.600E-16	1.564E-13	3.157E-12	5.440E-18-1.000E+00	8.500E-12	1.290E-13
REMAINDER	2.390E-16	1.509E-13	3.047E-12	5.250E-18-1.000E+00	4.200E-09	8.570E-09
EFFECTIVE	2.600E-16	1.650E-13	3.332E-12	5.740E-18-1.000E+00	1.320E-08	2.570E-09
SKIN(FGR)	3.850E-14	1.989E-10	4.016E-09	6.920E-15-1.000E+00	0.000E+00	0.000E+00
Y-92						
GONADS	1.270E-14	3.855E-12	4.872E-12	2.650E-16-1.000E+00	2.610E-12	1.960E-11
BREAST	1.440E-14	3.680E-12	4.652E-12	2.530E-16-1.000E+00	1.500E-12	3.550E-12
LUNGS	1.270E-14	3.535E-12	4.468E-12	2.430E-16-1.000E+00	1.240E-09	1.390E-12
RED MARR	1.250E-14	3.608E-12	4.560E-12	2.480E-16-1.000E+00	2.070E-12	4.910E-12
BONE SUR	1.950E-14	5.091E-12	6.435E-12	3.500E-16-1.000E+00	1.510E-12	1.750E-12
THYROID	1.300E-14	3.579E-12	4.523E-12	2.460E-16-1.000E+00	1.050E-12	1.770E-13
REMAINDER	1.220E-14	3.506E-12	4.431E-12	2.410E-16-1.000E+00	2.030E-10	1.700E-09
EFFECTIVE	1.300E-14	3.680E-12	4.652E-12	2.530E-16-1.000E+00	2.110E-10	5.150E-10
SKIN(FGR)	1.140E-13	2.022E-10	2.556E-10	1.390E-14-1.000E+00	0.000E+00	0.000E+00
Y-93						
GONADS	4.670E-15	2.108E-12	4.989E-12	9.510E-17-1.000E+00	5.310E-12	2.200E-11
BREAST	5.300E-15	2.026E-12	4.794E-12	9.140E-17-1.000E+00	1.740E-12	3.130E-12
LUNGS	4.680E-15	1.937E-12	4.585E-12	8.740E-17-1.000E+00	2.520E-09	8.670E-13
RED MARR	4.580E-15	1.972E-12	4.669E-12	8.900E-17-1.000E+00	4.040E-12	4.930E-12
BONE SUR	7.580E-15	2.948E-12	6.977E-12	1.330E-16-1.000E+00	3.140E-12	1.730E-12
THYROID	4.790E-15	1.908E-12	4.516E-12	8.610E-17-1.000E+00	9.260E-13	1.260E-13
REMAINDER	4.510E-15	1.919E-12	4.543E-12	8.660E-17-1.000E+00	9.250E-10	4.090E-09
EFFECTIVE	4.800E-15	2.021E-12	4.784E-12	9.120E-17-1.000E+00	5.820E-10	1.230E-09
SKIN(FGR)	8.500E-14	2.726E-10	6.452E-10	1.230E-14-1.000E+00	0.000E+00	0.000E+00
Zr-95						
GONADS	3.530E-14	2.182E-11	4.421E-10	7.590E-16-1.000E+00	1.880E-09	8.160E-10
BREAST	4.010E-14	2.084E-11	4.223E-10	7.250E-16-1.000E+00	1.910E-09	1.050E-10
LUNGS	3.510E-14	1.989E-11	4.030E-10	6.920E-16-1.000E+00	2.170E-09	2.340E-11
RED MARR	3.430E-14	2.030E-11	4.112E-10	7.060E-16-1.000E+00	1.300E-08	2.140E-10
BONE SUR	5.620E-14	2.875E-11	5.824E-10	1.000E-15-1.000E+00	1.030E-07	4.860E-10
THYROID	3.610E-14	2.076E-11	4.205E-10	7.220E-16-1.000E+00	1.440E-09	8.270E-12
REMAINDER	3.360E-14	1.963E-11	3.978E-10	6.830E-16-1.000E+00	2.280E-09	2.530E-09
EFFECTIVE	3.600E-14	2.078E-11	4.211E-10	7.230E-16-1.000E+00	6.390E-09	1.020E-09
SKIN(FGR)	4.500E-14	2.561E-11	5.190E-10	8.910E-16-1.000E+00	0.000E+00	0.000E+00
Zr-97						
GONADS	4.331E-14	2.179E-11	7.799E-11	9.253E-16-1.000E+00	1.840E-10	6.228E-10
BREAST	4.928E-14	2.083E-11	7.455E-11	8.846E-16-1.000E+00	4.706E-11	8.137E-11
LUNGS	4.322E-14	1.992E-11	7.127E-11	8.456E-16-1.000E+00	4.108E-09	1.770E-11
RED MARR	4.224E-14	2.034E-11	7.279E-11	8.634E-16-1.000E+00	6.376E-11	1.302E-10
BONE SUR	6.897E-14	2.881E-11	1.031E-10	1.224E-15-1.000E+00	3.504E-11	4.558E-11
THYROID	4.443E-14	2.061E-11	7.377E-11	8.755E-16-1.000E+00	2.315E-11	2.671E-12
REMAINDER	4.139E-14	1.966E-11	7.035E-11	8.345E-16-1.000E+00	2.041E-09	6.990E-09
EFFECTIVE	4.432E-14	2.078E-11	7.438E-11	8.824E-16-1.000E+00	1.171E-09	2.283E-09
SKIN(FGR)	9.835E-14	2.281E-10	8.148E-10	9.587E-15-1.000E+00	0.000E+00	0.000E+00
Nb-95						

GONADS	3.660E-14	2.253E-11	4.435E-10	7.850E-16-1.000E+00	4.320E-10	8.050E-10
BREAST	4.160E-14	2.150E-11	4.231E-10	7.490E-16-1.000E+00	4.070E-10	1.070E-10
LUNGS	3.650E-14	2.055E-11	4.045E-10	7.160E-16-1.000E+00	8.320E-09	2.740E-11
RED MARR	3.560E-14	2.101E-11	4.135E-10	7.320E-16-1.000E+00	4.420E-10	1.990E-10
BONE SUR	5.790E-14	2.957E-11	5.819E-10	1.030E-15-1.000E+00	5.130E-10	2.940E-10
THYROID	3.750E-14	2.144E-11	4.220E-10	7.470E-16-1.000E+00	3.580E-10	1.180E-11
REMAINDER	3.490E-14	2.032E-11	4.000E-10	7.080E-16-1.000E+00	1.070E-09	1.470E-09
EFFECTIVE	3.740E-14	2.147E-11	4.226E-10	7.480E-16-1.000E+00	1.570E-09	6.950E-10
SKIN(FGR)	4.300E-14	2.598E-11	5.112E-10	9.050E-16-1.000E+00	0.000E+00	0.000E+00
Mo-99						
GONADS	7.130E-15	4.282E-12	4.403E-11	1.550E-16-1.000E+00	9.510E-11	2.180E-10
BREAST	8.130E-15	4.116E-12	4.233E-11	1.490E-16-1.000E+00	2.750E-11	3.430E-11
LUNGS	7.060E-15	3.867E-12	3.977E-11	1.400E-16-1.000E+00	4.290E-09	1.510E-11
RED MARR	6.820E-15	3.923E-12	4.034E-11	1.420E-16-1.000E+00	5.240E-11	8.320E-11
BONE SUR	1.240E-14	6.105E-12	6.278E-11	2.210E-16-1.000E+00	4.130E-11	6.320E-11
THYROID	7.270E-15	4.033E-12	4.147E-11	1.460E-16-1.000E+00	1.520E-11	1.030E-11
REMAINDER	6.740E-15	3.812E-12	3.920E-11	1.380E-16-1.000E+00	1.740E-09	4.280E-09
EFFECTIVE	7.280E-15	4.061E-12	4.176E-11	1.470E-16-1.000E+00	1.070E-09	1.360E-09
SKIN(FGR)	3.140E-14	1.039E-10	1.068E-09	3.760E-15-1.000E+00	0.000E+00	0.000E+00
Tc-99m						
GONADS	5.750E-15	2.334E-12	3.877E-12	1.240E-16-1.000E+00	2.770E-12	9.750E-12
BREAST	6.650E-15	2.258E-12	3.752E-12	1.200E-16-1.000E+00	2.150E-12	3.570E-12
LUNGS	5.490E-15	2.127E-12	3.533E-12	1.130E-16-1.000E+00	2.280E-11	3.140E-12
RED MARR	4.910E-15	2.070E-12	3.439E-12	1.100E-16-1.000E+00	3.360E-12	6.290E-12
BONE SUR	1.630E-14	5.383E-12	8.942E-12	2.860E-16-1.000E+00	2.620E-12	4.060E-12
THYROID	5.750E-15	2.145E-12	3.564E-12	1.140E-16-1.000E+00	5.010E-11	8.460E-11
REMAINDER	5.150E-15	2.070E-12	3.439E-12	1.100E-16-1.000E+00	1.020E-11	3.340E-11
EFFECTIVE	5.890E-15	2.277E-12	3.783E-12	1.210E-16-1.000E+00	8.800E-12	1.680E-11
SKIN(FGR)	7.140E-15	2.710E-12	4.502E-12	1.440E-16-1.000E+00	0.000E+00	0.000E+00
Ru-103						
GONADS	2.191E-14	1.404E-11	2.783E-10	4.892E-16-1.000E+00	3.070E-10	5.720E-10
BREAST	2.512E-14	1.350E-11	2.677E-10	4.705E-16-1.000E+00	3.110E-10	1.200E-10
LUNGS	2.180E-14	1.273E-11	2.522E-10	4.432E-16-1.000E+00	1.561E-08	7.310E-11
RED MARR	2.100E-14	1.287E-11	2.551E-10	4.483E-16-1.000E+00	3.190E-10	1.660E-10
BONE SUR	3.892E-14	1.958E-11	3.882E-10	6.823E-16-1.000E+00	2.370E-10	9.631E-11
THYROID	2.241E-14	1.331E-11	2.639E-10	4.638E-16-1.000E+00	2.570E-10	6.250E-11
REMAINDER	2.080E-14	1.248E-11	2.472E-10	4.346E-16-1.000E+00	1.250E-09	2.110E-09
EFFECTIVE	2.251E-14	1.332E-11	2.641E-10	4.642E-16-1.000E+00	2.421E-09	8.271E-10
SKIN(FGR)	2.774E-14	1.785E-11	3.543E-10	6.229E-16-1.000E+00	0.000E+00	0.000E+00
Ru-105						
GONADS	3.720E-14	1.327E-11	1.861E-11	8.070E-16-1.000E+00	1.590E-11	9.670E-11
BREAST	4.240E-14	1.271E-11	1.783E-11	7.730E-16-1.000E+00	6.610E-12	1.590E-11
LUNGS	3.700E-14	1.210E-11	1.697E-11	7.360E-16-1.000E+00	5.730E-10	6.210E-12
RED MARR	3.590E-14	1.230E-11	1.725E-11	7.480E-16-1.000E+00	7.700E-12	2.350E-11
BONE SUR	6.280E-14	1.809E-11	2.537E-11	1.100E-15-1.000E+00	4.620E-12	8.890E-12
THYROID	3.800E-14	1.260E-11	1.766E-11	7.660E-16-1.000E+00	4.150E-12	1.820E-12
REMAINDER	3.540E-14	1.189E-11	1.667E-11	7.230E-16-1.000E+00	1.610E-10	8.540E-10
EFFECTIVE	3.810E-14	1.265E-11	1.773E-11	7.690E-16-1.000E+00	1.230E-10	2.870E-10
SKIN(FGR)	6.730E-14	7.368E-11	1.033E-10	4.480E-15-1.000E+00	0.000E+00	0.000E+00
Ru-106						
GONADS	1.010E-14	6.411E-12	1.340E-10	2.230E-16-1.000E+00	1.300E-09	1.640E-09
BREAST	1.160E-14	6.152E-12	1.286E-10	2.140E-16-1.000E+00	1.780E-09	1.440E-09
LUNGS	1.010E-14	5.836E-12	1.220E-10	2.030E-16-1.000E+00	1.040E-06	1.420E-09
RED MARR	9.750E-15	5.893E-12	1.232E-10	2.050E-16-1.000E+00	1.760E-09	1.460E-09
BONE SUR	1.720E-14	8.883E-12	1.856E-10	3.090E-16-1.000E+00	1.610E-09	1.430E-09
THYROID	1.030E-14	6.066E-12	1.268E-10	2.110E-16-1.000E+00	1.720E-09	1.410E-09
REMAINDER	9.630E-15	5.721E-12	1.196E-10	1.990E-16-1.000E+00	1.200E-08	2.110E-08
EFFECTIVE	1.040E-14	6.095E-12	1.274E-10	2.120E-16-1.000E+00	1.290E-07	7.400E-09
SKIN(FGR)	1.090E-13	4.082E-10	8.531E-09	1.420E-14-1.000E+00	0.000E+00	0.000E+00
Rh-105						
GONADS	3.640E-15	2.127E-12	1.411E-11	7.980E-17-1.000E+00	2.110E-11	5.800E-11
BREAST	4.160E-15	2.063E-12	1.369E-11	7.740E-17-1.000E+00	5.610E-12	8.970E-12
LUNGS	3.570E-15	1.935E-12	1.284E-11	7.260E-17-1.000E+00	9.580E-10	3.860E-12
RED MARR	3.380E-15	1.946E-12	1.291E-11	7.300E-17-1.000E+00	7.770E-12	1.470E-11

BONE SUR	7.530E-15	3.332E-12	2.210E-11	1.250E-16-1.000E+00	4.460E-12	6.750E-12
THYROID	3.680E-15	1.983E-12	1.316E-11	7.440E-17-1.000E+00	2.880E-12	2.910E-12
REMAINDER	3.390E-15	1.885E-12	1.250E-11	7.070E-17-1.000E+00	4.530E-10	1.270E-09
EFFECTIVE	3.720E-15	2.031E-12	1.347E-11	7.620E-17-1.000E+00	2.580E-10	3.990E-10
SKIN(FGR)	1.070E-14	4.691E-12	3.112E-11	1.760E-16-1.000E+00	0.000E+00	0.000E+00
Sb-127						
GONADS	3.260E-14	1.985E-11	2.441E-10	7.100E-16-1.000E+00	2.520E-10	6.140E-10
BREAST	3.720E-14	1.904E-11	2.341E-10	6.810E-16-1.000E+00	9.120E-11	7.600E-11
LUNGS	3.240E-14	1.809E-11	2.224E-10	6.470E-16-1.000E+00	6.940E-09	1.570E-11
RED MARR	3.140E-14	1.834E-11	2.255E-10	6.560E-16-1.000E+00	1.610E-10	1.330E-10
BONE SUR	5.520E-14	2.720E-11	3.345E-10	9.730E-16-1.000E+00	1.340E-10	5.240E-11
THYROID	3.330E-14	1.884E-11	2.317E-10	6.740E-16-1.000E+00	6.150E-11	4.640E-12
REMAINDER	3.090E-14	1.775E-11	2.183E-10	6.350E-16-1.000E+00	2.330E-09	5.870E-09
EFFECTIVE	3.330E-14	1.890E-11	2.324E-10	6.760E-16-1.000E+00	1.630E-09	1.950E-09
SKIN(FGR)	5.580E-14	7.967E-11	9.799E-10	2.850E-15-1.000E+00	0.000E+00	0.000E+00
H-3						
GONADS	0.000E-00	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.730E-11	0.000E+00
BREAST	0.000E-00	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.730E-11	0.000E+00
LUNGS	2.750E-18	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.730E-11	0.000E+00
RED MARR	0.000E-00	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.730E-11	0.000E+00
BONE SUR	0.000E-00	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.730E-11	0.000E+00
THYROID	0.000E-00	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.730E-11	0.000E+00
REMAINDER	0.000E-00	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.730E-11	0.000E+00
EFFECTIVE	3.310E-19	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.730E-11	0.000E+00
SKIN(FGR)	0.000E-00	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
I-129						
GONADS	4.830E-16	0.000E+00	0.000E+00	0.000E+00-1.000E+00	8.690E-11	0.000E+00
BREAST	6.660E-16	0.000E+00	0.000E+00	0.000E+00-1.000E+00	2.090E-10	0.000E+00
LUNGS	2.140E-16	0.000E+00	0.000E+00	0.000E+00-1.000E+00	3.140E-10	0.000E+00
RED MARR	1.640E-16	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.400E-10	0.000E+00
BONE SUR	1.100E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.380E-10	0.000E+00
THYROID	3.860E-16	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.560E-06	0.000E+00
REMAINDER	2.300E-16	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.180E-10	0.000E+00
EFFECTIVE	3.800E-16	0.000E+00	0.000E+00	0.000E+00-1.000E+00	4.690E-08	0.000E+00
SKIN(FGR)	1.100E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
Sb-125						
GONADS	1.980E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	3.600E-10	0.000E+00
BREAST	2.270E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	4.160E-10	0.000E+00
LUNGS	1.950E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	2.170E-08	0.000E+00
RED MARR	1.870E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	5.350E-10	0.000E+00
BONE SUR	3.530E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	9.780E-10	0.000E+00
THYROID	2.010E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	3.240E-10	0.000E+00
REMAINDER	1.860E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.450E-09	0.000E+00
EFFECTIVE	2.020E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	3.300E-09	0.000E+00
SKIN(FGR)	2.650E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
Te-125m						
GONADS	5.960E-16	0.000E+00	0.000E+00	0.000E+00-1.000E+00	7.930E-11	0.000E+00
BREAST	8.480E-16	0.000E+00	0.000E+00	0.000E+00-1.000E+00	7.080E-11	0.000E+00
LUNGS	2.230E-16	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.040E-08	0.000E+00
RED MARR	1.860E-16	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.150E-09	0.000E+00
BONE SUR	1.220E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.180E-08	0.000E+00
THYROID	4.640E-16	0.000E+00	0.000E+00	0.000E+00-1.000E+00	3.870E-11	0.000E+00
REMAINDER	2.590E-16	0.000E+00	0.000E+00	0.000E+00-1.000E+00	6.750E-10	0.000E+00
EFFECTIVE	4.530E-16	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.970E-09	0.000E+00
SKIN(FGR)	1.940E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
Rh-106						
GONADS	1.010E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
BREAST	1.160E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
LUNGS	1.010E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
RED MARR	9.750E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
BONE SUR	1.720E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
THYROID	1.030E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
REMAINDER	9.630E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
EFFECTIVE	1.040E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00

SKIN(FGR)	1.090E-13	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
Ba-137m						
GONADS	2.820E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
BREAST	3.220E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
LUNGS	2.080E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
RED MARR	2.730E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
BONE SUR	4.630E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
THYROID	2.880E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
REMAINDER	2.680E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
EFFECTIVE	2.880E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
SKIN(FGR)	3.730E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
Pr-144						
GONADS	1.900E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	2.410E-15	0.000E+00
BREAST	2.150E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.050E-14	0.000E+00
LUNGS	1.900E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	9.400E-11	0.000E+00
RED MARR	1.870E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.380E-14	0.000E+00
BONE SUR	2.990E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.470E-14	0.000E+00
THYROID	1.950E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	8.470E-15	0.000E+00
REMAINDER	1.840E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.400E-12	0.000E+00
EFFECTIVE	1.950E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.170E-11	0.000E+00
SKIN(FGR)	8.430E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
Pm-147						
GONADS	7.480E-19	0.000E+00	0.000E+00	0.000E+00-1.000E+00	8.250E-15	0.000E+00
BREAST	9.560E-19	0.000E+00	0.000E+00	0.000E+00-1.000E+00	3.600E-14	0.000E+00
LUNGS	5.450E-19	0.000E+00	0.000E+00	0.000E+00-1.000E+00	7.740E-08	0.000E+00
RED MARR	4.460E-19	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.610E-09	0.000E+00
BONE SUR	2.180E-18	0.000E+00	0.000E+00	0.000E+00-1.000E+00	2.010E-08	0.000E+00
THYROID	6.750E-19	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.980E-14	0.000E+00
REMAINDER	5.260E-19	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.560E-09	0.000E+00
EFFECTIVE	6.930E-19	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.060E-08	0.000E+00
SKIN(FGR)	8.110E-16	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
Eu-154						
GONADS	6.000E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.170E-08	0.000E+00
BREAST	6.810E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.550E-08	0.000E+00
LUNGS	5.990E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	7.920E-08	0.000E+00
RED MARR	5.870E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.060E-07	0.000E+00
BONE SUR	9.430E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	5.230E-07	0.000E+00
THYROID	6.150E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	7.140E-09	0.000E+00
REMAINDER	5.750E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.130E-07	0.000E+00
EFFECTIVE	6.140E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	7.730E-08	0.000E+00
SKIN(FGR)	8.290E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
Eu-155						
GONADS	2.490E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	3.560E-10	0.000E+00
BREAST	2.950E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	6.140E-10	0.000E+00
LUNGS	2.220E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.190E-08	0.000E+00
RED MARR	1.850E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.430E-08	0.000E+00
BONE SUR	8.090E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.520E-07	0.000E+00
THYROID	2.410E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	2.400E-10	0.000E+00
REMAINDER	2.070E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.110E-08	0.000E+00
EFFECTIVE	2.490E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.120E-08	0.000E+00
SKIN(FGR)	3.390E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
Am-243						
GONADS	2.190E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	3.260E-05	0.000E+00
BREAST	2.610E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.520E-08	0.000E+00
LUNGS	1.920E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.780E-05	0.000E+00
RED MARR	1.550E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.730E-04	0.000E+00
BONE SUR	7.470E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	2.170E-03	0.000E+00
THYROID	2.090E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	8.290E-09	0.000E+00
REMAINDER	1.790E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	7.740E-05	0.000E+00
EFFECTIVE	2.180E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.190E-04	0.000E+00
SKIN(FGR)	2.750E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
Cm-243						
GONADS	5.770E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	2.070E-05	0.000E+00
BREAST	6.680E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	6.290E-09	0.000E+00

LUNGS	5.500E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.940E-05	0.000E+00
RED MARR	5.000E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.180E-04	0.000E+00
BONE SUR	1.500E-14	0.000E+00	0.000E+00	0.000E+00-1.000E+00	1.470E-03	0.000E+00
THYROID	5.760E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	3.830E-09	0.000E+00
REMAINDER	5.190E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	5.760E-05	0.000E+00
EFFECTIVE	5.880E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	8.300E-05	0.000E+00
SKIN(FGR)	9.790E-15	0.000E+00	0.000E+00	0.000E+00-1.000E+00	0.000E-00	0.000E+00
Xe-133						
GONADS	1.610E-15	1.465E-12	2.052E-11	5.200E-17-1.000E+00	0.000E+00	0.000E+00
BREAST	1.960E-15	1.505E-12	2.107E-11	5.340E-17-1.000E+00	0.000E+00	0.000E+00
LUNGS	1.320E-15	1.045E-12	1.464E-11	3.710E-17-1.000E+00	0.000E+00	0.000E+00
RED MARR	1.070E-15	8.791E-13	1.231E-11	3.120E-17-1.000E+00	0.000E+00	0.000E+00
BONE SUR	5.130E-15	4.254E-12	5.958E-11	1.510E-16-1.000E+00	0.000E+00	0.000E+00
THYROID	1.510E-15	1.181E-12	1.653E-11	4.190E-17-1.000E+00	0.000E+00	0.000E+00
REMAINDER	1.240E-15	1.042E-12	1.460E-11	3.700E-17-1.000E+00	0.000E+00	0.000E+00
EFFECTIVE	1.560E-15	1.299E-12	1.819E-11	4.610E-17-1.000E+00	0.000E+00	0.000E+00
SKIN(FGR)	4.970E-15	1.953E-12	2.734E-11	6.930E-17-1.000E+00	0.000E+00	0.000E+00
Xe-135						
GONADS	1.170E-14	5.455E-12	1.194E-11	2.530E-16-1.000E+00	0.000E+00	0.000E+00
BREAST	1.330E-14	5.325E-12	1.166E-11	2.470E-16-1.000E+00	0.000E+00	0.000E+00
LUNGS	1.130E-14	4.959E-12	1.086E-11	2.300E-16-1.000E+00	0.000E+00	0.000E+00
RED MARR	1.070E-14	4.959E-12	1.086E-11	2.300E-16-1.000E+00	0.000E+00	0.000E+00
BONE SUR	2.570E-14	9.120E-12	1.997E-11	4.230E-16-1.000E+00	0.000E+00	0.000E+00
THYROID	1.180E-14	5.023E-12	1.100E-11	2.330E-16-1.000E+00	0.000E+00	0.000E+00
REMAINDER	1.080E-14	4.829E-12	1.058E-11	2.240E-16-1.000E+00	0.000E+00	0.000E+00
EFFECTIVE	1.190E-14	5.217E-12	1.142E-11	2.420E-16-1.000E+00	0.000E+00	0.000E+00
SKIN(FGR)	3.120E-14	4.506E-11	9.867E-11	2.090E-15-1.000E+00	0.000E+00	0.000E+00
Cs-134						
GONADS	7.400E-14	4.607E-11	9.646E-10	1.600E-15-1.000E+00	1.300E-08	2.060E-08
BREAST	8.430E-14	4.406E-11	9.224E-10	1.530E-15-1.000E+00	1.080E-08	1.720E-08
LUNGS	7.370E-14	4.204E-11	8.802E-10	1.460E-15-1.000E+00	1.180E-08	1.760E-08
RED MARR	7.190E-14	4.262E-11	8.922E-10	1.480E-15-1.000E+00	1.180E-08	1.870E-08
BONE SUR	1.200E-13	6.105E-11	1.278E-09	2.120E-15-1.000E+00	1.100E-08	1.740E-08
THYROID	7.570E-14	4.377E-11	9.163E-10	1.520E-15-1.000E+00	1.110E-08	1.760E-08
REMAINDER	7.060E-14	4.147E-11	8.681E-10	1.440E-15-1.000E+00	1.390E-08	2.210E-08
EFFECTIVE	7.570E-14	4.377E-11	9.163E-10	1.520E-15-1.000E+00	1.250E-08	1.980E-08
SKIN(FGR)	9.450E-14	6.249E-11	1.308E-09	2.170E-15-1.000E+00	0.000E+00	0.000E+00
Cs-136						
GONADS	1.040E-13	6.223E-11	1.102E-09	2.180E-15-1.000E+00	1.880E-09	3.040E-09
BREAST	1.180E-13	5.966E-11	1.056E-09	2.090E-15-1.000E+00	1.670E-09	2.650E-09
LUNGS	1.040E-13	5.710E-11	1.011E-09	2.000E-15-1.000E+00	2.320E-09	2.620E-09
RED MARR	1.010E-13	5.824E-11	1.031E-09	2.040E-15-1.000E+00	1.860E-09	2.950E-09
BONE SUR	1.660E-13	8.422E-11	1.491E-09	2.950E-15-1.000E+00	1.700E-09	2.710E-09
THYROID	1.070E-13	5.852E-11	1.036E-09	2.050E-15-1.000E+00	1.730E-09	2.740E-09
REMAINDER	9.950E-14	5.652E-11	1.001E-09	1.980E-15-1.000E+00	2.190E-09	3.520E-09
EFFECTIVE	1.060E-13	5.966E-11	1.056E-09	2.090E-15-1.000E+00	1.980E-09	3.040E-09
SKIN(FGR)	1.250E-13	7.251E-11	1.284E-09	2.540E-15-1.000E+00	0.000E+00	0.000E+00
Cs-137						
GONADS	2.669E-14	1.669E-11	3.530E-10	5.840E-16-1.000E+00	8.760E-09	1.390E-08
BREAST	3.047E-14	1.596E-11	3.376E-10	5.585E-16-1.000E+00	7.840E-09	1.240E-08
LUNGS	2.649E-14	1.517E-11	3.209E-10	5.309E-16-1.000E+00	8.820E-09	1.270E-08
RED MARR	2.583E-14	1.542E-11	3.260E-10	5.394E-16-1.000E+00	8.300E-09	1.320E-08
BONE SUR	4.382E-14	2.238E-11	4.734E-10	7.832E-16-1.000E+00	7.940E-09	1.260E-08
THYROID	2.725E-14	1.588E-11	3.358E-10	5.556E-16-1.000E+00	7.930E-09	1.260E-08
REMAINDER	2.536E-14	1.490E-11	3.152E-10	5.215E-16-1.000E+00	9.120E-09	1.450E-08
EFFECTIVE	2.725E-14	1.585E-11	3.353E-10	5.546E-16-1.000E+00	8.630E-09	1.350E-08
SKIN(FGR)	4.392E-14	5.253E-11	1.110E-09	1.836E-15-1.000E+00	0.000E+00	0.000E+00
Ba-139						
GONADS	2.130E-15	3.368E-13	3.429E-13	4.790E-17-1.000E+00	2.560E-12	1.560E-12
BREAST	2.450E-15	3.297E-13	3.357E-13	4.690E-17-1.000E+00	2.460E-12	5.170E-13
LUNGS	2.030E-15	3.002E-13	3.057E-13	4.270E-17-1.000E+00	2.530E-10	3.890E-13
RED MARR	1.870E-15	2.932E-13	2.985E-13	4.170E-17-1.000E+00	3.410E-12	8.590E-13
BONE SUR	5.290E-15	6.841E-13	6.965E-13	9.730E-17-1.000E+00	2.490E-12	4.380E-13
THYROID	2.130E-15	3.044E-13	3.100E-13	4.330E-17-1.000E+00	2.400E-12	2.660E-13

REMAINDER	1.920E-15	2.932E-13	2.985E-13	4.170E-17-1.000E+00	4.820E-11	3.570E-10
EFFECTIVE	2.170E-15	3.227E-13	3.286E-13	4.590E-17-1.000E+00	4.640E-11	1.080E-10
SKIN(FGR)	6.160E-14	7.241E-11	7.373E-11	1.030E-14-1.000E+00	0.000E+00	0.000E+00
Ba-140						
GONADS	8.410E-15	5.451E-12	9.607E-11	1.910E-16-1.000E+00	4.300E-10	9.960E-10
BREAST	9.640E-15	5.280E-12	9.305E-11	1.850E-16-1.000E+00	2.870E-10	1.590E-10
LUNGS	8.270E-15	4.852E-12	8.550E-11	1.700E-16-1.000E+00	1.660E-09	6.630E-11
RED MARR	7.930E-15	4.880E-12	8.601E-11	1.710E-16-1.000E+00	1.290E-09	4.390E-10
BONE SUR	1.550E-14	8.020E-12	1.413E-10	2.810E-16-1.000E+00	2.410E-09	5.530E-10
THYROID	8.530E-15	5.109E-12	9.003E-11	1.790E-16-1.000E+00	2.560E-10	5.250E-11
REMAINDER	7.890E-15	4.766E-12	8.399E-11	1.670E-16-1.000E+00	1.410E-09	7.370E-09
EFFECTIVE	8.580E-15	5.137E-12	9.053E-11	1.800E-16-1.000E+00	1.010E-09	2.560E-09
SKIN(FGR)	2.520E-14	5.565E-11	9.808E-10	1.950E-15-1.000E+00	0.000E+00	0.000E+00
La-140						
GONADS	1.140E-13	6.027E-11	4.425E-10	2.240E-15-1.000E+00	4.540E-10	1.340E-09
BREAST	1.290E-13	5.758E-11	4.228E-10	2.140E-15-1.000E+00	1.450E-10	1.800E-10
LUNGS	1.150E-13	5.596E-11	4.109E-10	2.080E-15-1.000E+00	4.210E-09	4.010E-11
RED MARR	1.140E-13	5.731E-11	4.208E-10	2.130E-15-1.000E+00	2.140E-10	2.810E-10
BONE SUR	1.690E-13	7.776E-11	5.709E-10	2.890E-15-1.000E+00	1.410E-10	9.770E-11
THYROID	1.180E-13	5.462E-11	4.010E-10	2.030E-15-1.000E+00	6.870E-11	6.400E-12
REMAINDER	1.110E-13	5.569E-11	4.089E-10	2.070E-15-1.000E+00	2.120E-09	6.260E-09
EFFECTIVE	1.170E-13	5.812E-11	4.267E-10	2.160E-15-1.000E+00	1.310E-09	2.280E-09
SKIN(FGR)	1.660E-13	2.217E-10	1.628E-09	8.240E-15-1.000E+00	0.000E+00	0.000E+00
La-141						
GONADS	2.330E-15	7.315E-13	9.675E-13	4.740E-17-1.000E+00	1.010E-11	3.770E-12
BREAST	2.640E-15	7.007E-13	9.267E-13	4.540E-17-1.000E+00	9.840E-12	7.070E-13
LUNGS	2.340E-15	6.713E-13	8.879E-13	4.350E-17-1.000E+00	6.460E-10	2.720E-13
RED MARR	2.310E-15	6.852E-13	9.063E-13	4.440E-17-1.000E+00	2.930E-11	1.070E-12
BONE SUR	3.490E-15	9.923E-13	1.312E-12	6.430E-17-1.000E+00	1.200E-10	6.060E-13
THYROID	2.390E-15	6.590E-13	8.716E-13	4.270E-17-1.000E+00	9.400E-12	5.290E-14
REMAINDER	2.260E-15	6.682E-13	8.838E-13	4.330E-17-1.000E+00	2.280E-10	1.240E-09
EFFECTIVE	2.390E-15	7.007E-13	9.267E-13	4.540E-17-1.000E+00	1.570E-10	3.740E-10
SKIN(FGR)	6.580E-14	1.667E-10	2.204E-10	1.080E-14-1.000E+00	0.000E+00	0.000E+00
La-142						
GONADS	1.400E-13	1.978E-11	2.034E-11	2.540E-15-1.000E+00	1.660E-11	6.990E-11
BREAST	1.570E-13	1.885E-11	1.938E-11	2.420E-15-1.000E+00	1.130E-11	1.540E-11
LUNGS	1.420E-13	1.846E-11	1.898E-11	2.370E-15-1.000E+00	3.010E-10	8.400E-12
RED MARR	1.420E-13	1.900E-11	1.954E-11	2.440E-15-1.000E+00	1.360E-11	1.930E-11
BONE SUR	1.950E-13	2.484E-11	2.554E-11	3.190E-15-1.000E+00	1.110E-11	7.400E-12
THYROID	1.450E-13	1.768E-11	1.818E-11	2.270E-15-1.000E+00	8.740E-12	1.160E-12
REMAINDER	1.380E-13	1.853E-11	1.906E-11	2.380E-15-1.000E+00	8.070E-11	5.200E-10
EFFECTIVE	1.440E-13	1.916E-11	1.970E-11	2.460E-15-1.000E+00	6.840E-11	1.790E-10
SKIN(FGR)	2.160E-13	9.111E-11	9.368E-11	1.170E-14-1.000E+00	0.000E+00	0.000E+00
Ce-141						
GONADS	3.380E-15	2.213E-12	4.332E-11	7.710E-17-1.000E+00	5.540E-11	1.080E-10
BREAST	3.930E-15	2.170E-12	4.247E-11	7.560E-17-1.000E+00	4.460E-11	1.110E-11
LUNGS	3.170E-15	1.951E-12	3.820E-11	6.800E-17-1.000E+00	1.670E-08	1.430E-12
RED MARR	2.830E-15	1.860E-12	3.641E-11	6.480E-17-1.000E+00	8.960E-11	3.390E-11
BONE SUR	9.410E-15	5.166E-12	1.011E-10	1.800E-16-1.000E+00	2.540E-10	2.300E-11
THYROID	3.350E-15	2.003E-12	3.922E-11	6.980E-17-1.000E+00	2.550E-11	1.800E-13
REMAINDER	2.980E-15	1.894E-12	3.708E-11	6.600E-17-1.000E+00	1.260E-09	2.500E-09
EFFECTIVE	3.430E-15	2.118E-12	4.146E-11	7.380E-17-1.000E+00	2.420E-09	7.830E-10
SKIN(FGR)	1.020E-14	3.788E-12	7.416E-11	1.320E-16-1.000E+00	0.000E+00	0.000E+00
Ce-143						
GONADS	1.280E-14	7.900E-12	4.958E-11	2.980E-16-1.000E+00	7.530E-11	2.120E-10
BREAST	1.470E-14	7.688E-12	4.825E-11	2.900E-16-1.000E+00	1.660E-11	2.320E-11
LUNGS	1.230E-14	6.893E-12	4.325E-11	2.600E-16-1.000E+00	3.880E-09	3.820E-12
RED MARR	1.170E-14	6.787E-12	4.259E-11	2.560E-16-1.000E+00	2.960E-11	5.070E-11
BONE SUR	2.520E-14	1.323E-11	8.302E-11	4.990E-16-1.000E+00	1.640E-11	1.610E-11
THYROID	1.280E-14	7.211E-12	4.525E-11	2.720E-16-1.000E+00	6.230E-12	4.350E-13
REMAINDER	1.170E-14	6.734E-12	4.226E-11	2.540E-16-1.000E+00	1.420E-09	3.890E-09
EFFECTIVE	1.290E-14	7.396E-12	4.642E-11	2.790E-16-1.000E+00	9.160E-10	1.230E-09
SKIN(FGR)	3.960E-14	1.058E-10	6.638E-10	3.990E-15-1.000E+00	0.000E+00	0.000E+00
Ce-144						

GONADS	2.725E-15	6.328E-13	1.319E-11	6.088E-17-1.000E+00	2.390E-10	6.987E-11
BREAST	3.129E-15	6.274E-13	1.307E-11	5.922E-17-1.000E+00	3.480E-10	1.223E-11
LUNGS	2.639E-15	5.228E-13	1.089E-11	5.362E-17-1.000E+00	7.911E-07	6.551E-12
RED MARR	2.507E-15	4.755E-13	9.907E-12	5.247E-17-1.000E+00	2.880E-09	8.923E-11
BONE SUR	5.441E-15	1.646E-12	3.429E-11	1.127E-16-1.000E+00	4.720E-09	1.280E-10
THYROID	2.753E-15	5.529E-13	1.152E-11	5.418E-17-1.000E+00	2.920E-10	5.154E-12
REMAINDER	2.534E-15	5.086E-13	1.060E-11	5.283E-17-1.000E+00	1.910E-08	1.890E-08
EFFECTIVE	2.773E-15	5.909E-13	1.231E-11	5.766E-17-1.000E+00	1.010E-07	5.711E-09
SKIN(FGR)	8.574E-14	7.648E-13	1.594E-11	1.250E-14-1.000E+00	0.000E+00	0.000E+00
Pr-143						
GONADS	2.130E-17	2.264E-14	4.032E-13	7.930E-19-1.000E+00	4.370E-18	8.990E-18
BREAST	2.550E-17	2.330E-14	4.149E-13	8.160E-19-1.000E+00	2.220E-18	1.090E-18
LUNGS	1.860E-17	1.642E-14	2.923E-13	5.750E-19-1.000E+00	1.330E-08	1.910E-19
RED MARR	1.620E-17	1.493E-14	2.659E-13	5.230E-19-1.000E+00	1.480E-11	1.030E-12
BONE SUR	5.930E-17	5.454E-14	9.711E-13	1.910E-18-1.000E+00	1.490E-11	1.030E-12
THYROID	2.050E-17	1.802E-14	3.208E-13	6.310E-19-1.000E+00	1.680E-18	2.660E-20
REMAINDER	1.760E-17	1.642E-14	2.923E-13	5.750E-19-1.000E+00	1.970E-09	4.220E-09
EFFECTIVE	2.100E-17	2.002E-14	3.564E-13	7.010E-19-1.000E+00	2.190E-09	1.270E-09
SKIN(FGR)	1.760E-14	5.711E-11	1.017E-09	2.000E-15-1.000E+00	0.000E+00	0.000E+00
Nd-147						
GONADS	6.130E-15	4.218E-12	7.235E-11	1.480E-16-1.000E+00	8.410E-11	1.790E-10
BREAST	7.120E-15	4.132E-12	7.088E-11	1.450E-16-1.000E+00	3.450E-11	1.870E-11
LUNGS	5.820E-15	3.648E-12	6.257E-11	1.280E-16-1.000E+00	1.060E-08	2.440E-12
RED MARR	5.400E-15	3.505E-12	6.013E-11	1.230E-16-1.000E+00	9.190E-11	5.050E-11
BONE SUR	1.320E-14	8.265E-12	1.418E-10	2.900E-16-1.000E+00	3.260E-10	2.220E-11
THYROID	6.120E-15	3.876E-12	6.648E-11	1.360E-16-1.000E+00	1.820E-11	2.640E-13
REMAINDER	5.530E-15	3.562E-12	6.111E-11	1.250E-16-1.000E+00	1.760E-09	3.760E-09
EFFECTIVE	6.190E-15	3.961E-12	6.795E-11	1.390E-16-1.000E+00	1.850E-09	1.180E-09
SKIN(FGR)	1.950E-14	3.135E-11	5.377E-10	1.100E-15-1.000E+00	0.000E+00	0.000E+00
Np-239						
GONADS	7.530E-15	4.691E-12	4.380E-11	1.710E-16-1.000E+00	7.450E-11	1.620E-10
BREAST	8.730E-15	4.636E-12	4.329E-11	1.690E-16-1.000E+00	1.630E-11	1.720E-11
LUNGS	7.180E-15	4.115E-12	3.842E-11	1.500E-16-1.000E+00	2.360E-09	2.400E-12
RED MARR	6.500E-15	4.005E-12	3.740E-11	1.460E-16-1.000E+00	2.080E-10	4.660E-11
BONE SUR	2.000E-14	1.001E-11	9.349E-11	3.650E-16-1.000E+00	2.030E-09	3.590E-11
THYROID	7.520E-15	4.197E-12	3.919E-11	1.530E-16-1.000E+00	7.620E-12	2.070E-13
REMAINDER	6.760E-15	4.005E-12	3.740E-11	1.460E-16-1.000E+00	9.590E-10	2.770E-09
EFFECTIVE	7.690E-15	4.471E-12	4.175E-11	1.630E-16-1.000E+00	6.780E-10	8.820E-10
SKIN(FGR)	1.600E-14	7.215E-12	6.737E-11	2.630E-16-1.000E+00	0.000E+00	0.000E+00
Pu-238						
GONADS	6.560E-18	4.291E-14	9.011E-13	1.490E-18-1.000E+00	2.800E-05	2.330E-09
BREAST	1.270E-17	5.558E-14	1.167E-12	1.930E-18-1.000E+00	1.000E-09	1.800E-13
LUNGS	1.060E-18	2.267E-15	4.759E-14	7.870E-20-1.000E+00	1.840E-05	8.640E-14
RED MARR	1.680E-18	5.587E-15	1.173E-13	1.940E-19-1.000E+00	1.520E-04	1.270E-08
BONE SUR	9.300E-18	3.514E-14	7.378E-13	1.220E-18-1.000E+00	1.900E-03	1.580E-07
THYROID	4.010E-18	9.792E-15	2.056E-13	3.400E-19-1.000E+00	9.620E-10	7.990E-14
REMAINDER	1.990E-18	9.216E-15	1.935E-13	3.200E-19-1.000E+00	7.020E-05	2.180E-08
EFFECTIVE	4.880E-18	2.413E-14	5.068E-13	8.380E-19-1.000E+00	1.060E-04	1.340E-08
SKIN(FGR)	4.090E-17	2.776E-13	5.830E-12	9.640E-18-1.000E+00	0.000E+00	0.000E+00
Pu-239						
GONADS	4.840E-18	1.768E-14	3.713E-13	6.140E-19-1.000E+00	3.180E-05	2.640E-09
BREAST	7.550E-18	2.238E-14	4.699E-13	7.770E-19-1.000E+00	9.220E-10	1.210E-13
LUNGS	2.650E-18	2.267E-15	4.760E-14	7.870E-20-1.000E+00	1.730E-05	7.890E-14
RED MARR	2.670E-18	3.456E-15	7.258E-14	1.200E-19-1.000E+00	1.690E-04	1.410E-08
BONE SUR	9.470E-18	1.673E-14	3.514E-13	5.810E-19-1.000E+00	2.110E-03	1.760E-07
THYROID	3.880E-18	5.126E-15	1.077E-13	1.780E-19-1.000E+00	9.030E-10	7.500E-14
REMAINDER	2.860E-18	4.838E-15	1.016E-13	1.680E-19-1.000E+00	7.560E-05	2.120E-08
EFFECTIVE	4.240E-18	1.057E-14	2.220E-13	3.670E-19-1.000E+00	1.160E-04	1.400E-08
SKIN(FGR)	1.860E-17	1.057E-13	2.220E-12	3.670E-18-1.000E+00	0.000E+00	0.000E+00
Pu-240						
GONADS	6.360E-18	4.118E-14	8.649E-13	1.430E-18-1.000E+00	3.180E-05	2.640E-09
BREAST	1.230E-17	5.328E-14	1.119E-12	1.850E-18-1.000E+00	9.510E-10	1.730E-13
LUNGS	1.090E-18	2.249E-15	4.723E-14	7.810E-20-1.000E+00	1.730E-05	8.220E-14
RED MARR	1.650E-18	5.386E-15	1.131E-13	1.870E-19-1.000E+00	1.690E-04	1.410E-08

BONE SUR	9.260E-18	3.398E-14	7.137E-13	1.180E-18-1.000E+00	2.110E-03	1.760E-07
THYROID	3.920E-18	9.446E-15	1.984E-13	3.280E-19-1.000E+00	9.050E-10	7.510E-14
REMAINDER	1.960E-18	8.870E-15	1.863E-13	3.080E-19-1.000E+00	7.560E-05	2.130E-08
EFFECTIVE	4.750E-18	2.313E-14	4.857E-13	8.030E-19-1.000E+00	1.160E-04	1.400E-08
SKIN(FGR)	3.920E-17	2.644E-13	5.552E-12	9.180E-18-1.000E+00	0.000E+00	0.000E+00
Pu-241						
GONADS	7.190E-20	6.653E-17	1.396E-15	2.310E-21-1.000E+00	6.820E-07	5.660E-11
BREAST	8.670E-20	7.229E-17	1.517E-15	2.510E-21-1.000E+00	3.060E-11	2.790E-15
LUNGS	6.480E-20	4.090E-17	8.584E-16	1.420E-21-1.000E+00	7.420E-09	4.480E-15
RED MARR	5.630E-20	4.003E-17	8.403E-16	1.390E-21-1.000E+00	3.360E-06	2.780E-10
BONE SUR	2.190E-19	1.385E-16	2.908E-15	4.810E-21-1.000E+00	4.200E-05	3.480E-09
THYROID	6.980E-20	4.522E-17	9.491E-16	1.570E-21-1.000E+00	1.240E-11	1.010E-15
REMAINDER	6.090E-20	4.291E-17	9.007E-16	1.490E-21-1.000E+00	1.310E-06	1.850E-10
EFFECTIVE	7.250E-20	5.558E-17	1.167E-15	1.930E-21-1.000E+00	2.230E-06	2.070E-10
SKIN(FGR)	1.170E-19	2.033E-16	4.268E-15	7.060E-21-1.000E+00	0.000E+00	0.000E+00
Am-241						
GONADS	8.580E-16	9.360E-13	1.966E-11	3.250E-17-1.000E+00	3.250E-05	2.700E-07
BREAST	1.070E-15	1.014E-12	2.129E-11	3.520E-17-1.000E+00	2.670E-09	2.620E-11
LUNGS	6.740E-16	5.789E-13	1.216E-11	2.010E-17-1.000E+00	1.840E-05	3.360E-11
RED MARR	5.210E-16	4.838E-13	1.016E-11	1.680E-17-1.000E+00	1.740E-04	1.450E-06
BONE SUR	2.870E-15	2.678E-12	5.625E-11	9.300E-17-1.000E+00	2.170E-03	1.810E-05
THYROID	7.830E-16	6.365E-13	1.337E-11	2.210E-17-1.000E+00	1.600E-09	1.320E-11
REMAINDER	6.340E-16	5.933E-13	1.246E-11	2.060E-17-1.000E+00	7.820E-05	6.660E-07
EFFECTIVE	8.180E-16	7.920E-13	1.663E-11	2.750E-17-1.000E+00	1.200E-04	9.840E-07
SKIN(FGR)	1.280E-15	2.396E-12	5.032E-11	8.320E-17-1.000E+00	0.000E+00	0.000E+00
Cm-242						
GONADS	7.830E-18	4.893E-14	1.013E-12	1.700E-18-1.000E+00	5.700E-07	5.200E-09
BREAST	1.480E-17	6.159E-14	1.275E-12	2.140E-18-1.000E+00	9.440E-10	8.950E-12
LUNGS	1.130E-18	3.022E-15	6.257E-14	1.050E-19-1.000E+00	1.550E-05	8.840E-12
RED MARR	1.890E-18	6.562E-15	1.359E-13	2.280E-19-1.000E+00	3.900E-06	3.570E-08
BONE SUR	1.060E-17	4.231E-14	8.759E-13	1.470E-18-1.000E+00	4.870E-05	4.460E-07
THYROID	4.910E-18	1.261E-14	2.610E-13	4.380E-19-1.000E+00	9.410E-10	8.820E-12
REMAINDER	2.270E-18	1.079E-14	2.235E-13	3.750E-19-1.000E+00	2.450E-06	4.020E-08
EFFECTIVE	5.690E-18	2.751E-14	5.697E-13	9.560E-19-1.000E+00	4.670E-06	3.100E-08
SKIN(FGR)	4.290E-17	2.700E-13	5.589E-12	9.380E-18-1.000E+00	0.000E+00	0.000E+00
Cm-244						
GONADS	6.900E-18	4.522E-14	9.492E-13	1.570E-18-1.000E+00	1.590E-05	1.330E-07
BREAST	1.330E-17	5.702E-14	1.197E-12	1.980E-18-1.000E+00	1.040E-09	8.820E-12
LUNGS	7.080E-19	2.592E-15	5.441E-14	9.000E-20-1.000E+00	1.930E-05	8.810E-12
RED MARR	1.460E-18	5.875E-15	1.233E-13	2.040E-19-1.000E+00	9.380E-05	7.820E-07
BONE SUR	8.820E-18	3.859E-14	8.101E-13	1.340E-18-1.000E+00	1.170E-03	9.770E-06
THYROID	4.190E-18	1.146E-14	2.406E-13	3.980E-19-1.000E+00	1.010E-09	8.440E-12
REMAINDER	1.810E-18	9.821E-15	2.062E-13	3.410E-19-1.000E+00	4.780E-05	4.150E-07
EFFECTIVE	4.910E-18	2.529E-14	5.308E-13	8.780E-19-1.000E+00	6.700E-05	5.450E-07
SKIN(FGR)	3.910E-17	2.506E-13	5.260E-12	8.700E-18-1.000E+00	0.000E+00	0.000E+00

Appendix B

FORTRAN 90 Code used for Case 4

This appendix contains the FORTRAN 90 code (MC.F90-CHESTER) for Case 4.

```
program mc
  use RANDOM

  integer, parameter :: nval=20
  integer, parameter :: nhist=100000
  double precision xvel(nval), r,rho,dia,k,vel
  integer nvel(nval)
  REAL genbet,genchi,genf,gennch,gennf,genunf

  call seed_random_number(1)

  WRITE (*,*) ' Enter phrase to initialize rn generator'
  READ (*,'(a)') phrase
  CALL phrtsd(phrase,is1,is2)
  CALL setall(is1,is2)

  a=1.3
  b=3.04*3.04 ! 3.04 is the std dev!
  aa=a*a
  sig2=log(1.0+b/aa)
  sig=sqrt(sig2)
  xmu=-sig2/2.0+log(a)
  xxmed=exp(xmu)
  write(9,*) 'Given a LOGNORMAL with the parameters:'
  write(9,*) '     MEAN=',a
  write(9,*) '     Median=',xxmed
  write(9,*) '     Variance (std dev^2)=',b
  write(9,*) '     '
  write(9,*) 'Hence, the corresponding NORMAL has the parameters:'
  write(9,*) '     '
  write(9,*) '     MEAN=',xmu
  write(9,*) '     Variance (std dev^2)=',sig2

  DO i = 1,nhist

     ! get particle diameter - uniform dist with min=1.50 and max=5.50 microns

     dia=genunf(1.50,5.50)
     ! convert to meters
     dia=dia*1e-6

     ! get density of aersol - log-uniform distribution
     !  simply used the uniform distribution with
     !  min=log(3.25) and max=log(10.96)

     rho=genunf(log(3.25),log(10.96))
     ! convert back to value from log
     rho=exp(rho)

     ! the shape factor is the last of the random variables and
     ! it needs a log-normal distribution - simply used a
     ! normal distribution with mean=log(1.3) and std dev=log(3.04)

100  continue

     r=random_normal()
     ! scale r (normal with mean of 0 and std dev of 1) back to
     ! mean of log(1.3) and std dev of log(3.04), then
     ! take exponent to get out of log space
!     a=1.3
!     b=3.04
!     aa=a*a
!     sig2=log(1.0+b/aa)
!     sig=sqrt(sig2)
```

```
!      xmu=-sig2/2.0+log(a)
!      xxmed=exp(xmu)
      x=r*sig+xmu
      k=exp(x)

! limit values of the shape factor to between 1 and 4 as directed on
! page 66 & 87 of NUREG/CR 5966

      if (k < 1.0 .or. k > 4.0 ) then
         goto 100
      endif

      write(1,*) dia
      write(2,*) rho
      write(3,*) k

!      rho=3.678
!      dia=1.902e-6
!      k=.21
      vel=rho*dia*dia*9.81*1000.0/(18.0*1.93e-5*k)
      write(10,*) vel

  end do

end program mc
```