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A SIMPLIFIED MODEL FOR CALCULATING EARLY OFFSITE CONSEQUENCES FROM NUCLEAR REACTOR ACCIDENTS

I.K. Madni, E.G. Cazzoli, and M. Khatib-Rahbar

July 1988

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**DEPARTMENT OF NUCLEAR ENERGY, BROOKHAVEN NATIONAL LABORATORY
UPTON, LONG ISLAND, NEW YORK 11973**

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ABSTRACT

A personal computer-based model, SMART, has been developed that uses an integral approach for calculating early offsite consequences from nuclear reactor accidents. The solution procedure uses simplified meteorology and involves direct analytic integration of air concentration equations over time and position. This is different from the discretization approach currently used in the CRAC2 and MACCS codes. The SMART code is fast-running, thereby providing a valuable tool for sensitivity and uncertainty studies. The code was benchmarked against both MACCS version 1.4 and CRAC2. Results of benchmarking and detailed sensitivity/uncertainty analyses using SMART are presented.

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NOMENCLATURE

<u>Symbol</u>	<u>Description</u>	<u>Unit</u>
A	building cross-sectional area	m ²
Br	breathing rate of receptor	m ³ /s
c	shape factor	---
D _c	cloudshine dose	rem
D _g	groundshine dose	rem
D _i	total inhalation dose	rem
f _d	correction factor to air concentration due to dry deposition	---
f _w	correction factor to air concentration due to wet deposition	---
F _{c∞}	cloud-dose conversion factor	rem-m ³ /Ci-s
F _g	integral ground-dose conversion factor	rem-m ² /Ci
F _{in}	inhalation dose conversion factor	rem/Ci
h	height of release	m
K _x , K _y , K _z	diffusivities in the x, y, and z direction, respectively	m ² /s
Q	time-integrated source strength	Ci
Q ^o	radionuclide inventory in core	Ci
Q'	release rate of radionuclides from source	Ci/s
R	rainfall rate	mm/hr
t	time	s
$\bar{u}$	mean wind speed in the x-direction	m/s
v _d	dry deposition velocity	m/s
v _w	equivalent wet deposition velocity	m/s
x	horizontal coordinate along the wind	m
y	horizontal cross-wind coordinate	m
z	vertical coordinate	m
$\bar{z}$	effective height of the plume	m
Δt	duration of rain	s
λ	radioactive decay rate	s ⁻¹
Λ	fractional rate of material removed due to rain	s ⁻¹
σ _y	horizontal dispersion coefficient	m
σ _z	vertical dispersion coefficient	m
x, x _T	time integrated air concentration of a radionuclide	Ci-s/m ³
x _D	total ground concentration of a radionuclide	Ci/m ²
<u>Subscript</u>	<u>Description</u>	
D	related to daughter product	
I, i	related to radionuclide I	
p	related to parent	

EXECUTIVE SUMMARY

The Reactor Safety Study (RSS) presented the first comprehensive assessment of the risk from core meltdown accidents at two nuclear power plants. The CRAC model was developed as part of the RSS to calculate the health and economic consequences of accidental releases of radionuclides into the environment. Following the publication of the RSS, several other consequence models were developed. CRAC2, an improvement over CRAC, became available in 1982. In addition, the CRACIT computer code was developed by Pickard, Lowe, and Garrick (PLG) and first used in the Zion and Indian Point PRAs. This was followed by the development of the MELCOR Accident Consequence Code System (MACCS).

CRAC2 and MACCS are currently used to calculate severe accident risk by the U.S. Nuclear Regulatory Commission and their contractors. However, uncertainties in estimated consequences are large and were not quantified as part of the recently published Draft Reactor Risk Reference Document (NUREG-1150). Due to major differences in the predictions of these detailed and complex computer models, a need exists for an independent capability to address modeling and health consequence assumptions embodied in the various models. This verification tool should be efficient and sufficiently accurate to carry out sensitivity and uncertainty analyses.

This report presents a Personal Computer-based model that uses an integral approach for calculating early off-site consequences resulting from nuclear power plant accidents. The computing time requirements for a typical calculation on a mainframe computer using this model are two orders of magnitude lower than those of CRAC2 and MACCS codes, thus providing a valuable tool for sensitivity and uncertainty studies. The model predicts time-integrated air concentration of each radionuclide at any location from release as a function of time-integrated source strength using the Gaussian plume model. The concentration can be calculated at the centerline of a Gaussian profile or, optionally, as an average over the cross-section based on a top-hat distribution. The solution procedure involves direct analytic integration of air concentration equations over time and position. This is different from the discretization approach currently used in CRAC2 and MACCS codes.

The present model uses simplified meteorology. Dispersion parameters are calculated from exponential fits to the Pasquill-Gifford curves for six atmospheric stability classes designated A to F, and from an approximation as indicated in Regulatory Guide 1.145 for the seventh stability class G (extremely stable).

Following the approach in CRAC2 and MACCS, special features are modeled which effectively modify the basic Gaussian plume formulation. They include dry and wet deposition, radioactive decay and daughter buildup, reactor building wake effects on plume mixing, the inversion lid effect, the effect of plume rise due to buoyancy or momentum of the released activity, release duration, and grass height. The building wake correction to the dispersion parameters is derived from Slade. Also included are options for CRAC2 and MACCS building wake effects in order to facilitate sensitivity and uncertainty studies.

Once the air and ground concentrations of the radionuclide are estimated, the early dose to an individual is calculated via three pathways: cloudshine, short-term groundshine, and inhalation. The dose calculations are performed in the same manner as CRAC2 and MACCS depending on which health effects model is chosen as the input option. The health effects models in both CRAC2 and MACCS are included in the code for calculating early fatalities. The health effects model in MACCS for early injuries is also included. This Simplified Model for calculating Atmospheric Radionuclide Transport and Health Effects is called the SMART code.

The present code was benchmarked against both MACCS version 1.4 and CRAC2. A sensitivity study to plume dispersion parameters was performed, showing that the models included in the codes can produce a fairly large uncertainty in calculated doses up to two miles from the release point. A sensitivity study to source terms which covered almost the entire spectrum of accident release for a BWR showed that uncertainties in dose calculations span about one order of magnitude, and increase to two or three orders of magnitude in the calculation of health effects. A multi-parameter sensitivity analysis revealed that the uncertainty in all results is dominated by the choice of weather conditions, dry deposition velocity, and to a lesser degree by radionuclide releases. The uncertainty introduced by the calculation of dispersion parameters, however, can still be significant in the calculation of health effects at large distances from the release point.

1. INTRODUCTION

A severe accident in a nuclear power plant could release radionuclides in the form of noble gases, halogens, and aerosols to the containment. A breach of containment would then allow a fraction of these radionuclides to escape into the environment. The Reactor Safety Study (RSS) presented the first comprehensive assessment of the risk to society from nuclear power plant accidents. The CRAC model was developed as part of the RSS to calculate the health and economic consequences of accidental releases of radionuclides into the atmosphere [1]. Following publication of the RSS, several other consequence models were developed [2]. CRAC2, an improvement over CRAC, became available in 1982 [3]. In addition, CRACIT was developed by Pickard, Lowe, and Garrick (PLG) and first used in the Zion and Indian Point PRAs. This was followed by the development of the MELCOR Accident Consequence Code System (MACCS) [4].

CRAC2 and MACCS are used as the basis for severe accident risk assessments by the U.S. Nuclear Regulatory Commission. However, uncertainties in estimated consequences are large and were not quantified as part of the recently published Draft Reactor Risk Reference Document [5]. Due to major differences in the predictions of these detailed and complex computer models, a need exists for an independent capability to address modeling and health consequence assumptions embodied in the various models. This verification tool should be efficient and sufficiently accurate in order to carry out sensitivity and uncertainty analyses.

This report presents a Personal Computer-based model that uses an integral approach for calculation of early off-site consequences resulting from nuclear power plant accidents. The computing time requirements for a typical calculation on a mainframe computer using this model are two orders of magnitude lower than those of CRAC2 and MACCS codes, thus providing a valuable tool for sensitivity and uncertainty studies. The model predicts time-integrated air concentration of each radionuclide at any location from release as a function of time-integrated source strength using the Gaussian plume model [6]. The concentration can be calculated at the centerline of a Gaussian profile or, optionally, as an average over the cross-section based on a top-hat distribution. The solution procedure involves direct analytic integration of air concentration equations over time and position. This is different from the discretization approach currently used in CRAC2 and MACCS codes.

The present model uses simplified meteorology. Dispersion parameters are calculated from exponential fits to the Pasquill-Gifford curves for six atmospheric stability classes designated A to F, and from an approximation as indicated in Regulatory Guide 1.145 for the seventh stability class G (extremely stable).

Following the approach in CRAC2 and MACCS, special features are modeled which effectively modify the basic Gaussian plume formulation. They include dry and wet deposition, radioactive decay and daughter buildup, reactor building wake effects on plume mixing, the inversion lid effect, the effect of plume rise due to buoyancy or momentum of the released activity, release duration, and grass height. The building wake correction to the dispersion parameters is derived from Reference [6]. Also included are options for CRAC2 and MACCS building wake effects in order to facilitate sensitivity and uncertainty studies.

Once the air and ground concentrations of the radionuclide are estimated, the early dose to an individual is calculated via three pathways: cloudshine, short-term groundshine, and inhalation. The dose calculations are performed in the same manner as CRAC2 and MACCS depending on which health effects model is chosen as the input option. The health effects models in both CRAC2 and MACCS are included in the code for calculation of early fatalities. The health effects model in MACCS for early injuries is also included. This Simplified Model for calculating Atmospheric Radionuclide Transport and health effects is called the SMART code.

Detailed descriptions of models used in this study are provided in Chapter 2. Results of various calculations and comparisons with results from CRAC2 and MACCS calculations are presented in Chapter 3. Chapter 4 lists a summary of the conclusions from this study. In addition, several appendices are included in this report that provide a user's guide along with sample input and output data, subroutine flowcharts, data dictionary, a listing of the source code, and the nuclide data base, dose conversion factors, and other related information.

2. DESCRIPTION OF MODELS

This chapter provides a detailed description of the models used in this study, including a derivation of the basic Gaussian plume model and its various modifications, dose calculations, and health effects.

2.1 Atmospheric Dispersion

A severe accident in a nuclear power plant could release radionuclides in the form of noble gases, halogens, and aerosols to the containment atmosphere. A breach of containment would then allow a fraction of these radionuclides to escape into the environment where it would undergo atmospheric dispersion.

An assessment of the impact of such releases to the general public requires the calculation of atmospheric and ground concentrations of each radionuclide at various distances from the reactor, where public exposure may occur. The air concentrations depend on wind speed and atmospheric turbulence. The latter is difficult to measure directly and is conveniently related to measurable meteorological quantities, such as temperature gradients, or Richardson number.

2.1.1 Diffusion Equation and Air Concentration

When released into the atmosphere, radioactive gases and aerosols will follow prevailing winds and be diffused due to cumulative effects of atmospheric turbulence. Predictions of dispersion in the lower atmosphere are most commonly made from the semi-empirical 'Gaussian plume' model [6]. This model is used widely for analyzing the dispersion of atmospheric pollutants, due to its economy of computing time, simplified input requirements, and reasonable agreement with experimental data over flat terrain. For repetitive calculations, and for sensitivity studies, the use of this model is therefore justified.

In this model, the governing equations are derived by starting with the classical Fick's law diffusion equations. These equations are solved assuming that the coefficients of diffusivity are constants. In the resulting expressions, the diffusivity coefficients are then allowed to become dependent on both space and atmospheric stability conditions in order to fit the plume model to experimental data. For an ideal, non-isotropic, infinite atmosphere, the diffusion equation in cartesian coordinates is:

$$\frac{Dx}{Dt} = K_x \frac{\partial^2 x}{\partial x^2} + K_y \frac{\partial^2 x}{\partial y^2} + K_z \frac{\partial^2 x}{\partial z^2} \quad (2.1)$$

where $\frac{D}{Dt}$ is the particle derivative operator, and x is the concentration (Ci/m^3) of a particular radionuclide.

With an average wind speed $\bar{u}$ in the x-direction, eq. (2.1) is modified to

$$\frac{\partial x}{\partial t} + \bar{u} \frac{\partial x}{\partial x} = K_x \frac{\partial^2 x}{\partial x^2} + K_y \frac{\partial^2 x}{\partial y^2} + K_z \frac{\partial^2 x}{\partial z^2} \quad (2.2)$$

where y is horizontally cross-wind, and z is the vertical direction.

If we consider the concentration as being due to a point source emitting contaminant at a constant rate of Q' Ci/s, then, $\partial x / \partial t = 0$. Furthermore, diffusion in the direction of the wind is neglected, or $K_x = 0$. The above equation then reduces to

$$\bar{u} \frac{\partial x}{\partial x} = K_y \frac{\partial^2 x}{\partial y^2} + K_z \frac{\partial^2 x}{\partial z^2} \quad (2.3)$$

with boundary conditions corresponding to the source term at the release point, and $\frac{\partial x}{\partial y} = \frac{\partial x}{\partial z} = 0$ (from symmetry) at the plume centerline.

The solution of this equation is [9]

$$x = \frac{Q'}{2\pi\bar{u}\sigma_y\sigma_z} \exp \left[-\left(\frac{y^2}{2\sigma_y^2} + \frac{z^2}{2\sigma_z^2} \right) \right] \quad (2.4)$$

where σ_y , σ_z are, respectively, the horizontal and vertical dispersion coefficients, given by

$$\sigma_y = \sqrt{\frac{2xK_y}{\bar{u}}} ; \quad \sigma_z = \sqrt{\frac{2xK_z}{\bar{u}}} . \quad (2.5)$$

Postulated releases from reactor accidents would be at some altitude h above ground level, hence the earth's surface would be a barrier to downward diffusion and expansion of the plume. A conservative estimate of this effect can be made by assuming the ground to be a perfect reflector of the contaminants. An image source is placed at an altitude of $-h$, and the solution is obtained as

$$x = \frac{Q'}{2\pi\bar{u}\sigma_y\sigma_z} \exp \left[-y^2/2\sigma_y^2 \right] \left\{ \exp \left[-\frac{(z+h)^2}{2\sigma_z^2} \right] + \exp \left[-\frac{(z-h)^2}{2\sigma_z^2} \right] \right\} . \quad (2.6)$$

The concentration at $z = 0$, i.e., the receptor or observer is at ground level, is

$$x = \frac{Q'}{\pi\bar{u}\sigma_y\sigma_z} \exp \left[-\left(\frac{y^2}{2\sigma_y^2} + \frac{h^2}{2\sigma_z^2} \right) \right] . \quad (2.7)$$

For a release of finite duration, τ , the time-integrated source strength, Q (Ci), is given by:

$$Q = \int_0^\tau Q' dt \quad (2.8)$$

and the time integrated (total, cumulative) concentration, x_T (Ci-s/m³), is similarly defined as:

$$x_T = \int_0^\tau x dt \quad (2.9)$$

Eq. (2.7) then becomes

$$x_T = \frac{Q}{\pi \bar{u} \sigma_y \sigma_z} \exp \left[-\left(\frac{y^2}{2\sigma_y^2} + \frac{h^2}{2\sigma_z^2} \right) \right] . \quad (2.10)$$

In Eqs. (2.7) and (2.10), note that a ground-level release ($h = 0$) gives a conservative estimate of concentration, and hence should be used if the height of release is not known. In all subsequent sections of this report, x instead of x_T will be used to denote time integrated air concentration.

2.1.2 Dispersion Parameters and Weather Data

The dispersion parameters, σ_y and σ_z , given by Eq. (2.5) are functions of constant diffusivities K_y and K_z , respectively, and would, therefore, vary as x from the point of release for a given wind speed. However, these dispersion parameters are found to depend also on the atmospheric stability conditions. A more realistic model of dispersion would, therefore, use experimental values of σ_y and σ_z to calculate radionuclide concentrations.

Pasquill [8] proposed a simple scheme in which he presented information on lateral and vertical spreading of a plume as functions of six atmospheric stability classes designated A to F (see Table 2.1). Table 2.1 also includes stability classifications as defined by NRC Reg. Guide 1.23. Gifford [6] converted the plume spreading data into families of curves of the standard deviations, σ_y and σ_z , of the plume concentration distribution. These curves are frequently called the Pasquill-Gifford (P-G) curves (see Figures 2.1 and 2.2).

It can be seen from the figures that the dispersion parameters are increasing functions of x . The influence of atmospheric stability on σ_y is shown to be minimal. However, σ_z increases very rapidly with distance for unstable atmospheres and much less rapidly for stable atmospheres. For the present study, these curves were fitted by the following exponential expressions:

$$\sigma_y(x) = \exp [sy_0 + sy_1 \ln(x) + sy_2 \ln(x)^2] \quad (2.11)$$

$$\sigma_z(x) = \exp [sz_0 + sz_1 \ln(x) + sz_2 \ln(x)^2] . \quad (2.12)$$

The coefficients in these curve-fit equations are listed in Table 2.2. The seventh stability condition, type G, (extremely stable) has been approximated by the following relations [9], and are in accordance with Reg. Guide 1.145.

$$\sigma_z(G) = 3/5 \sigma_z(F) \quad (2.13a)$$

$$\sigma_y(G) = 2/3 \sigma_y(F) . \quad (2.13b)$$

Figure 2.1. Horizontal dispersion coefficient, σ_y , vs. downwind distance from source for different atmospheric stability classes [6].

Figure 2.2. Vertical dispersion coefficient, σ_z , vs. downwind distance from source for different atmospheric stability classes [6].

Table 2.1 Relation of Stability Classes To Weather Conditions

Stability Class	A	B	C	D	E	F	G
$\frac{\Delta T}{\Delta z} (^{\circ}\text{C}/100\text{m})$	≤ 1.9	-1.9 -1.7	-1.7 -1.5	-1.5 -1.3	0.5 1.0	1.5 2.0	> 4.0

Surface wind speed, m/sec	Daytime Insolation			Nighttime Conditions	
				Thin overcast or $> 4/8$ cloudiness**	$< 3/8$ cloudiness
	Strong	Moderate	Slight		
< 2	A	A-B	B		
2	A-B	B	C	E	F
4	B	B-C	C	D	E
6	C	C-D	D	D	D
> 6	C	D	D	D	D

*Applicable to heavy overcast, day or night.

**The degree of cloudiness is defined as that fraction of the sky above the local apparent horizon which is covered by clouds.

A-Extremely unstable
B-Moderately unstable
C-Slightly unstable

D-Neutral*
E-Slightly stable
F-Moderately stable

G-Extremely stable

Table 2.2 Curve Fitting Coefficients for Atmospheric Stability Classes A through F

Stability Class	sy_0	sy_1	sy_2
F (moderately stable)	-3.559	1.160	-1.719×10^{-2}
E (slightly stable)	-2.817	1.066	-1.147×10^{-2}
D (neutral)	-2.546	1.077	-1.252×10^{-2}
C (slightly unstable)	-1.969	1.022	-8.377×10^{-3}
B (moderately unstable)	-1.961	1.111	-1.405×10^{-2}
A (extremely unstable)	-1.790	1.151	-1.733×10^{-2}
Stability Class	sz_0	sz_1	sz_2
F (moderately stable)	-4.539	1.412	-5.45×10^{-2}
E (slightly stable)	-4.213	1.443	-5.471×10^{-2}
D (neutral)	-3.162	1.197	-3.459×10^{-2}
C (slightly unstable)	-2.981	1.212	-2.538×10^{-2}
B (moderately unstable)	2.693	-0.781	0.158
A (extremely unstable)	9.430	-3.393	0.425

The P-G curves of Figures 2.1 and 2.2 were also fitted by Martin and Tikvart. These curve-fits have been used by the consequence code CRAC2 [3]. Several other investigators have also proposed parametrizations of σ_y and σ_z to match the measured data of plume dispersion. Most of these have been reviewed by Gifford [10]. The work of Rogers and Gamertsfelder has also been referred to by Wilson et al. [11].

2.2 Corrections to Air Concentration

The basic Gaussian plume model is modified to take into account dry and wet deposition, radioactive decay and daughter buildup, reactor building wake effects on plume mixing, the inversion lid effect, plume rise due to buoyancy, release duration, and grass height. These modifications are based on approaches available in the literature, and are similar in approach to CRAC2 and MACCS models.

2.2.1 Dry Deposition

The processes of deposition are very complex, and thus approximations are the most desirable approach for consequence models.

The standard way of dealing with dry deposition is to assume that, if $x(x,y,0)$ is the ground-level time-integrated concentration in Ci-s/m³, the total activity deposited by the passing cloud (Ci/m²) is given by

$$x_D(x, y) = v_d x(x, y, 0) \quad (2.14)$$

where v_d is a proportionality constant, called the 'deposition velocity' (m/s). Deposition can occur by gravitational settling, turbulent and molecular diffusion, and inertial impaction [12], and depends on several factors, including the size and shape of particles, their chemical properties, ground roughness, nature of vegetation, and atmospheric stability. Values of v_d can range from 10⁻⁶ to 0.2 m/s [13]. For release from reactor accidents, v_d can be expected to be in the range 0.001 to 0.1 m/s [14]. The value of 0.01 m/s was chosen for use in the Reactor Safety Study. In the SMART code, it is left as a user input value for each radionuclide, including gases, defaulting to 0.01 m/s. Deposition velocities for the noble gases are taken to be zero.

At significant distances downwind, the equation for air concentration must be modified to account for the loss of the deposited contaminants. This effect can be incorporated by multiplying the source terms for x by [9]:

$$f_d = \exp \left(\frac{-v_d x}{\bar{u} \bar{z}} \right) \quad (2.15)$$

where $\bar{z}$ is the effective height of the plume given by

$$\bar{z} = \sqrt{\frac{\pi}{2}} \sigma_z \exp \left(\frac{h^2}{2\sigma_z^2} \right) \quad (2.16)$$

Thus, Eq. (2.10) for χ (Ci-s/m³) becomes:

$$\chi = \frac{Q}{\pi \bar{u} \sigma_y \sigma_z} \exp \left[-\left(\frac{v_d x}{\bar{u} z} + \frac{y^2}{2\sigma_y^2} + \frac{h^2}{2\sigma_z^2} \right) \right] \quad (2.17)$$

2.2.2 Wet Deposition

The potential for rain during atmospheric transport of the plume must also be considered. The radioactive particles (and gases) will be deposited due to rain onto the ground, by a process called washout or wet deposition. A number of techniques have been suggested in the literature. The approach used here is the one discussed in RSS Appendix 6 [14] and in Reference [15]. The fractional rate of material removed from the plume, Λ (s⁻¹), is expressed empirically [16] in the form:

$$\Lambda = CR \quad (2.18)$$

where R is the rainfall rate (mm/hr), and C is the proportionality constant. For stable and neutral atmospheric conditions C is set to 10⁻⁴ hr/mm-s while for unstable conditions C is set to 10⁻³ hr/mm -s [17]. Λ can vary from 10⁻⁵ to 10⁻² s⁻¹. This effect is incorporated into the SMART model via a correction factor for the air concentration

$$f_w = \exp [-\Lambda \Delta t] \quad (2.19)$$

where $\Delta t = t - t_0$ is the duration of rain from its onset time, t_0 .

Combining both dry and wet deposition, Eq. (2.10) becomes

$$\chi = \frac{Q}{\pi \bar{u} \sigma_y \sigma_z} \exp \left[-\left(\frac{v_d x}{\bar{u} z} + \Lambda \Delta t + \frac{y^2}{2\sigma_y^2} + \frac{h^2}{2\sigma_z^2} \right) \right] . \quad (2.20)$$

The total activity deposited on the ground due to both dry and wet deposition (Ci/m²) can be calculated from:

$$\chi_D = (v_d + v_w) \chi \quad (2.21)$$

where v_w is an equivalent 'wet' deposition velocity given by

$$v_w = \frac{\Lambda \Delta t \bar{u} \bar{z}}{\chi} . \quad (2.22)$$

2.2.3 Radioactive Decay and Daughter Buildup

Let Q_I^0 represent the inventory of radionuclide I in the core at the time of reactor accident. Following an accident in which release of radionuclides to containment takes place, the source of radionuclide I in containment available for release to the environment is

$$F_I^0 = f_I Q_I^0 \quad (2.23)$$

This source undergoes radioactive decay according to:

$$-\frac{dF_I}{dt} = \lambda_I F_I . \quad (2.24)$$

This equation has a solution of the form

$$F_I(t) = F_I^0 e^{-\lambda_I t} . \quad (2.25)$$

Thus, the source leaking into the environment following containment failure at $t = t_c$ will be

$$Q_I = f_I Q_I^0 e^{-\lambda_I t_c} . \quad (2.26a)$$

At any distance x downwind of the plume release, the strength of nuclide I will be

$$Q_I = f_I Q_I^0 e^{-\lambda_I (t_c + x/\bar{u})} \quad (2.26b)$$

If the decay of a radionuclide (parent) leads to the buildup of a daughter product D, the source of the daughter in containment available for release to the environment, is

$$F_D = f_D Q_D^0 \quad (2.27)$$

where Q_D^0 is the inventory of D in the core. This source undergoes radioactive decay, and buildup from the decay of its parent P according to

$$\frac{dF_D}{dt} = \lambda_P F_P - \lambda_D F_D \quad (2.28)$$

whose solution is

$$F_D(t) = F_D^0 e^{-\lambda_D t} + \frac{\lambda_P F_P^0}{\lambda_P - \lambda_D} [e^{-\lambda_D t} - e^{-\lambda_P t}] . \quad (2.29)$$

At the time of containment failure, the source of daughter nuclide into the environment will be

$$Q_D = f_D Q_D^0 e^{-\lambda_D t_c} + \frac{\lambda_P f_P Q_P^0}{\lambda_P - \lambda_D} [e^{-\lambda_D t_c} - e^{-\lambda_P t_c}] . \quad (2.30)$$

At any distance x downwind of the plume release, the strength of the daughter nuclide D will be determined by

$$Q_D = f_D Q_D^0 e^{-\lambda_D(t_c + x/u)} + \frac{\lambda_p f_p Q_p^0}{\lambda_p - \lambda_D} [e^{-\lambda_D(t_c + x/u)} - e^{-\lambda_p(t_c + x/u)}] \quad (2.31)$$

$$+ \frac{f_p Q_p^0 e^{-\lambda_p t_c}}{\lambda_p - \lambda_D} [e^{-\lambda_D x/u} - e^{-\lambda_p x/u}] .$$

The first two terms in Eq. (2.31) are the source at x from decay of initial daughter release into the environment, and the last term is the additional source at x due to parent decay during plume travel.

Eq. (2.20) is modified to account for this effect and becomes

$$\chi = \frac{Q(x)}{\pi \bar{u} \sigma_y \sigma_z} \exp \left[-\left(\frac{V_d x}{\bar{u} z} + \Delta t + \frac{y^2}{2\sigma_y^2} + \frac{h^2}{2\sigma_z^2} \right) \right] \quad (2.32)$$

where $Q(x)$ is given by Eq. (2.26) for any nuclide, including parent, and by Eq. (2.31) for a daughter product. Equation (2.32) is solved directly for χ at any distance x from the source, assuming constant meteorological conditions. This is in contrast to the approach in CRAC2 and MACCS which is based on discretization of the distance coordinate into mesh intervals over which meteorological changes are allowed.

2.2.4 Building Wake Effects

The diffusion formulas presented thus far have assumed the emitter to be a point source. In fact, when the effluent plume emerges from the reactor building, its dispersion into the atmosphere is increased by the turbulence in the wake region. This effect needs to be incorporated in calculating potential exposures. The default correction used in the present study is the one presented in section 3 of Meteorology and Atomic Energy [6]. According to this, an adjustment is made to the dispersion coefficients in Eq. (2.32) for air concentration as follows:

$$\sigma_y' = (\sigma_y^2 + \frac{cA}{\pi})^{1/2} \quad (2.33)$$

$$\sigma_z' = (\sigma_z^2 + \frac{cA}{\pi})^{1/2} \quad (2.34)$$

Where σ_y' and σ_z' are the corrected horizontal and vertical standard deviations of plume material, A is the cross-sectional area of the building perpendicular to the wind, and c is the shape factor, which can have values in the range 0.5 to 2. Reg. Guide 1.4 indicates that the building wake correction should be used in the first eight hours following release, with a shape factor c of 1/2 and the minimum cross-sectional area of the reactor building only.

Alternately, as was proposed by Holland [18] and is employed in CRAC and MACCS, a virtual point source can be assumed, that would produce a Gaussian plume, having dimensions comparable to those of the reactor building.

Any modification proposed to date is only an approximation and cannot be expected to be valid within the wake region of the reactor building. However, the adjustments presented here have the advantage of being a simple and economical approximation to account for this very complicated effect in calculating air concentrations further downwind. For complex building shapes, no reliable simple guidelines are presently available.

2.2.5 Plume Rise

The release height h in Eq. (2.32) is adjusted to account for plume rise on release, due to buoyancy [19, 3]. The equation for the corrected height h' is

$$h' = 2.6 \left(\frac{F}{\bar{u} s} \right)^{1/3} + h \quad (2.35)$$

where F is a buoyancy flux parameter given by [4, 20] as:

$$F = 8.79 \times 10^{-6} Q_H \quad (2.36)$$

Q_H is the thermal release in watts, $\bar{u}$ is the average wind speed (m/s) encountered during the rise, and s is a stability parameter which depends on the ambient temperature and the lapse rate of the atmosphere. Values of $s = 8.7 \times 10^{-4}$ and 1.75×10^{-3} for E and F stability classes, respectively, as in CRAC2, are used. These numbers are obtained from temperature lapse rates in Reg. Guide 1.23. The numbers in MACCS are obtained assuming the lapse rate for E and F stability are in the middle of the range specified in the Reg. Guide, and are lower.

For neutral or unstable conditions (A to D), the following relation is used [4, 21].

$$h' = 1.6 F^{1/3} x^{2/3} u^{-1} + h \quad (2.37)$$

where x is the distance travelled by the plume.

Buoyant plume rise may not occur if the high energy release gets trapped due to increased turbulence in the building wake. For this, a critical wind speed u' (m/s) is applied, above which plume rise is suppressed:

$$u' = \left(\frac{9.09 F}{L} \right)^{1/3} \quad (2.38)$$

where L is the height of the reactor building (m).

2.2.6 Grass Height

The vertical dispersion parameter from Pasquill-Gifford curves, $\sigma_z(x)$, is adjusted for surface roughness as recommended in [22] and implemented in CRAC2 and MACCS, to be more appropriate for a roughness of 10 cm, as follows:

$$\sigma_z = \sigma_{zP-G} \left(\frac{10\text{cm}}{3\text{cm}} \right)^{0.2} = 1.27 \sigma_{zP-G} \quad (2.39)$$

Alternatively, $\sigma_z(x)$ can be obtained from fits to Smith's curves presented in Reference [13] with correction factors for various roughnesses ranging from 1 cm to 400 cm.

2.2.7 Release Duration

For a release of longer duration T with the wind direction nominally constant, the time-averaged plume will probably be wider due to increased horizontal dispersion than it would be for a release of shorter duration T_E . This effect has been included simply by

$$\sigma_y = \sigma_{yP-G} \left(\frac{T}{T_E} \right)^n. \quad (2.40)$$

The horizontal dispersions from P-G curves are based on experiments where the release duration is a few minutes.

In CRAC2, T_E is taken to be 3 minutes; $n = 0.2$ for $3 < T \leq 60$ minutes and $n = 0.25$ for $60 < T \leq 600$ minute. The same scheme is used in the present study.

2.2.8 Inversion Lid

The atmospheric boundary layer is capped by a very stable layer, whose base forms an effective barrier to the upward growth of a plume. This is called the inversion lid. Estimates of the height of this lid H can be obtained from Holzworth [23]. In the present model, σ_z is allowed to grow to a maximum of $0.8H$, where H is a user-input value.

2.3 Dose Calculations

Once the atmospheric and ground level concentrations, x and x_0 , for each radionuclide are determined, the radiation dose accumulated by individuals can be considered in two phases: the initial or acute phase during and shortly after passage of the radioactive cloud, and the latent phase sometime after the cloud passage.

2.3.1 Dose Pathways

Radiation doses in the early phase can be received via the following pathways:

1. Direct external exposure to radiation emitted by radionuclides in the passing cloud (cloudshine),
2. early external exposure to radiation from radionuclide deposited on the ground (short-term groundshine), and
3. internal exposure due to inhalation of radionuclides from the cloud (inhalation).

Doses in the latent phase can be received via ingestion of contaminated food and drink by deposited radionuclides, inhalation of resuspended radionuclides, as well as long term exposure to groundshine. Early effects are more significant for determining the necessary emergency response actions, and are currently the only effects included within the scope of this study.

Of all the radionuclides released, the number considered significant for consequence calculations is 54 species as in CRAC2 (see also Appendix 6 of Reference [14]). A list of these radionuclides, along with their half-lives, can be found in Appendix C.

The dose calculations are performed in the same manner as CRAC2 or MACCS depending on which health effect model is chosen as the input option.

2.3.2 Cloudshine

The cloud exposure, E_C , is numerically equal to the integrated air concentration, χ (Ci-s/m³). The biological dose (rem) to organ j due to cloudshine is calculated from:

$$D_C^j = \sum_{i=1}^N x_i (F_{C\infty})_i^j \left(\frac{F_C}{F_{C\infty}}\right)_i^j SF_C \quad (2.41)$$

where x_i is the integrated air concentration (Ci-s/m³) of nuclide i at the reference location, and $(F_{C\infty})_i^j$ is the cloud-dose conversion factor for nuclide i (rem-m³/Ci-s).

Values of $F_{C\infty}$ taken from RSS Table VI C-1 [14] are tabulated in Appendix D. They are based on the assumption that the cloud is semi-infinite, having uniform concentration of radioactive material equal to that at its centerline. A correction factor $(F_C/F_{C\infty})$ is applied to account for the fact that the cloud is finite and that the receptor need not be at its centerline. The correction factors which effectively reduce the dose, are tabulated as functions of σ_z and $\bar{z}/\sigma_z$, where $\bar{z}$ is the effective height of the plume. They have been taken from RSS Table VI 8-1 [14], and were originally presented in Meteorology and Atomic Energy [6]. MACCS uses a somewhat different correction factor based on $\sqrt{\sigma_y \sigma_z}$ as the effective plume size [20]. The dose is further reduced by multiplying by an appropriate shielding factor (SF_C) for cloud exposure, which depends on the emergency response action.

2.3.3 Groundshine

Radioactive material from the passing cloud would be deposited on the ground and penetrate into structures, vehicles, etc., and would continue to emit gamma radiation long after the cloud has passed. The interest here is in the early exposure, which would be significant even if emergency plans included relocation.

The biological dose (rem) to organ j from external exposure to gamma radiation emitted by deposited radionuclides is:

$$D_g^j = \sum_{i=1}^N x_{Di} (F_g)_i^j SF_g \quad (2.42)$$

where D_g^j is the total groundshine dose (rem) to organ j , x_{Di} is the ground concentration of radionuclide i (Ci/m^3), $(F_g)_i^j$ is the integral ground-dose conversion factor for nuclide i and organ j ($\text{rem}\cdot\text{m}^2/\text{Ci}$), SF_g is a shielding factor to account for ground roughness, structures vehicles, etc. and depends on the emergency action.

The ground-dose conversion factor, F_g , is derived for a point one meter above a smooth surface, and includes radioactive decay and daughter buildup. Values of F_g for whole body, total marrow, and lung are tabulated for 1 day and 7 days in Appendix D. They were taken from Table A-3 of Reference [24]. An interpolation procedure is used for exposure durations between one and seven days, and an extrapolation procedure for durations less than one day.

2.3.4 Inhalation

Radionuclides retained in the body by inhalation will continuously deliver a dose to the body or its specific organs until they are removed by biological elimination or radioactive decay. Inhalation is included in the early phase because the amount entering the body depends on conditions in the passing cloud and the receptor's activity level at that time.

The dose due to inhaled radionuclides is calculated from:

$$D_i^j = \sum_{i=1}^N x_i (F_{in})_i^j Br \quad (2.43)$$

where D_i^j is the total inhalation dose (rem) to organ j , Br is the breathing rate of the receptor (m^3/s), and $(F_{in})_i^j$ is the dose conversion factor (rem/Ci inhaled).

Values of F_{in} were taken from Table A-4 in Reference [24], and are tabulated in Appendix D over various time periods ranging up to 30 years. The breathing rate is a user-input quantity and depends on the person's age and activity level. A default value equal to $2.66 \times 10^{-4} \text{ m}^3/\text{s}$ has been used in the code.

2.4 Health Effects

The health effects models of both MACCS and CRAC2 are included in SMART for early health effects only. These effects are early deaths and injuries modelled

for organ specific doses from the three pathways. The dose conversion factors for each pathway and organ are given in Appendix D.

MACCS uses the hazard function approach to calculate early fatalities as discussed in Reference [25]. First, the cumulative hazard is calculated as:

$$H = \ln(2) (D/D_{50})^v \quad (2.44)$$

where D is the dose and D_{50} is the dose required for producing an effect in 50% of the exposed individuals, and v determines the steepness of the dose effect curve. That fatality risk is then given as:

$$\text{Risk} = 1 - e^{-(H_1 + H_2 + H_3 + H_4)} \quad (2.45)$$

where H_1 is for red marrow, H_2 is for lungs, and H_3 and H_4 are for the lower large intestine and small intestine. The risk is assigned a threshold of .005.

In CRAC2, the dose response is piece-wise linear due to irradiation of the bone marrow, lung, and GI tract. The total risk is then:

$$R = R_1 + (1-R_1) R_2 + (1-R_1)(1-R_2)R_3 \quad (2.46)$$

where R_1 , R_2 , and R_3 are the risks to the three organs, respectively. MACCS gives somewhat higher risk, principally because the lung dose is now considered more effective in producing fatalities, and also because the hazard function gives some risk at lower doses.

The effect of the model differences is that MACCS predicts a higher probability for small numbers of deaths while CRAC2 predicts a higher probability for large numbers of deaths.

Early injuries in MACCS are also calculated using the hazard function except that the cumulative hazard is not summed as in Eq. (2.45). Rather, the risk of lung impairment, prodromal vomiting, hypothyroidism, and thyroid ablation are calculated separately. Several other injuries can be defined, although only persons who did not suffer early death are considered.

Early injuries in the CRAC2 model are calculated as in Eq. (2.46) using doses to the whole body, lungs, and lower large intestinal wall. The dose response is discussed in Appendix VI of Reference [14]. The risk of death is subtracted from the risk of injury.

The lifetime risk of latent cancer is not calculated.

3. RESULTS

An interactive computer code, SMART, (Appendix B) was developed, incorporating the integral models introduced in the previous section. Simplified dispersion models from CRAC2 [3] and MACCS [4] were also included as calculational options.

This chapter provides a discussion of results obtained using this code, along with comparisons to CRAC2 and MACCS calculations, and results of detailed sensitivity and uncertainty analyses of the various input and model parameters.

3.1 Computing Time Requirements

A typical single-weather MACCS or CRAC2 calculation of doses and health effects on a mainframe computer (VAX 11/785) uses approximately 10 minutes of running time. The present model can perform more than 500 such calculations in the same time. On an IBM AT personal computer, a full calculation using this model takes about 30 seconds.

3.2 Benchmark Comparisons with CRAC2 and MACCS

The present code was benchmarked by comparing results for Cs-137 air concentration, total dose to organs and health effects, with single-weather calculations performed by CRAC2 and MACCS version 1.4. The input data for all calculations was taken from Reference [26]. The radiological releases correspond to the largest release cluster as defined in Reference [26] for an early containment failure due to direct heating (Cluster 1). The core inventory selected was for a PWR operating at 3412 MWth power. For the remainder of the input, CRAC2 and MACCS default values were chosen [3,4]. Table 3.1 lists all the input variables used in these comparisons. Six separate calculations were performed with each computer code, for atmospheric stability classes A, D and F, and wind speeds of 1 and 5 m/s. Each case was labeled with the corresponding weather condition (A1, A5, D1, D5, F1, F5). Test D1 was also performed with dry deposition velocity equal to zero. In all cases, the present code was exercised using plume dispersion models consistent with those present in the code being compared with.

The last test (D1 with $v_d = 0$) showed agreement of results to better than four percent between the present code and both CRAC2 and MACCS for distances beyond one and one half mile from the source. However, large deviations, in some instances as large as one hundred percent, were observed in all the other cases. These discrepancies were traced to the calculation of plume dispersion parameters which, in the present code, are computed at a given location, while in CRAC2 and MACCS are averages over a spacial mesh. The good agreement obtained for case D1 without dry deposition is due to the elimination of the dominant term in Eq. (2.17) for air concentration, in which the vertical dispersion coefficient appears as an exponent.

Table 3.2 lists the values of plume dispersion parameters versus distance as calculated by CRAC2 and MACCS version 1.4 for weather stability classes A, D and F. In the table are also shown the values calculated by the independent polynomial - fit to the P-G curves developed for the present code. The three models calculate dispersion parameters which can vary by as much as fifty

Table 3.1 Input Variables Used for Benchmarking of Present Code with CRAC2 and MACCS

Parameter	Value	Units
Power Level	3412	MWth
Release Fractions		
Xe	.9	
I	.706	
Cs	.4	
Te	.4	
Sr	.05	
Ru	.4	
La	.003	
Ce	.003	
Ba	.05	
Time of Release	0.	hours
Duration of Release	0.5	hours
Height of Release	0.	m
Energy of Release	0.	watts
Width of Building	100.	m
Height of Building	25.	m
Dry Deposition Velocity	.01	m/s
Breathing Rate	2.66×10^{-4}	m ³ /s
Rain Time	0.	s
Cloud Shine Shielding Factor	.75	
Ground Shine Shielding Factor	.33	
Atmospheric Stability Class	A,D,F	
Average Wind Speed	1., 5.	m/s

Table 3.2 Dispersion Parameters vs. Distance as Calculated by Different Consequence Models.

Weather Stability Class A

	$\sigma_y(m)$		
	CRAC	MACCS	Present Model
Distance (m)			
800	159.5	142	206.8
1600	368.2	366	390.3
2400	556.3	572	615
3200	749	770	929
4000	831	962	1128
4800	1109	1150	1319
5600	1284	1340	1506
6400	1456	1520	1685
7200	1626	1700	1861
8000	1795	1880	2034
9600	2043	2140	2369
11300	2371	2490	2699

	$\sigma_z(m)$		
	CRAC	MACCS	Present Model
	199.6	349	214.3
	651.8	640	800
	800	640	800
	↓	↓	↓

Weather Stability Class D

800	92.1	69.6	76.2
1600	173.5	158	140
2400	250.4	240	219
3200	324.8	320	331
4000	397.3	397	401
4800	469	472	470
5600	539	547	537
6400	608	692	602
7200	676	764	666
8000	743	870	728
9600	843	1010	851
11300	975	1180	971

29.14	23.1	34.2
52.33	40.7	50.2
69.77	57.8	68.3
84.4	71	91.1
97.3	83	104
108.9	94	116
119.6	105	127
129.5	124	138
138.9	133	147
147.7	146	156
160.2	163	173
175.7	182	189

Weather Stability Class F

800	69.7	45.2	42.4
1600	108	87.6	74.2
2400	145	128	115
3200	181	166	174
4000	216	241	211
4800	251	277	247
5600	285	313	282
6400	318	348	316
7200	352	383	349
8000	385	435	382
9600	433	504	446
11300	498	588	508

18.4	15.7	23.4
27.1	22.9	28
33	28.7	33.4
37.7	33.8	40.1
41.5	42.8	43.9
44.7	46.8	47.2
47.6	50.6	50.2
50.1	54.3	52.9
52.5	57.7	55.4
54.6	62.7	57.7
57.5	69.	61.8
60.9	76.3	65.4

percent, especially near the release point, where building wake effects are more important. Furthermore, this difference gets magnified in the calculation of air concentration due to non-linearities in Eq. (2.17).

Therefore, for the benchmarking study, all the above cases were repeated using dispersion parameters obtained from either CRAC2 or MACCS. In addition, the distance was adjusted in the present code to reflect the "average" position at which CRAC2 and MACCS compute air concentration in a spacial mesh. The latter change was retained for all subsequent calculations. Figures 3.1 through 3.3 illustrate results of a benchmark comparison of total bone marrow dose versus distance for tests A5, D5 and F1 integral model and CRAC2 and MACCS differential models. Similar results were obtained for all other weather conditions, and doses to different organs. Calculations from the integral model are seen to agree to within three percent or better with both CRAC2 and MACCS for all distances. The small difference can be explained through two mechanisms. Firstly, CRAC2 and MACCS integrate differential equations in a series of spacial meshes, while the present code solves a single integrated equation at a given point. Secondly, the input values obtained from the codes for the dispersion parameters are not exact but are truncated, in some instances, to within one half of one per cent. As previously stated, even such a small deviation can produce a comparatively large uncertainty in results as shown in the next section.

In conclusion, the present code and models were shown to reproduce with good agreement the results obtained with both CRAC2 and MACCS version 1.4.

3.3 Single Parameter Sensitivity Studies

Two sensitivity studies were performed, using the present code. First, the impact of plume dispersion parameters and building-wake effects models on calculated doses was examined (Section 3.3.1). This single-parameter sensitivity analysis was done because in a full study, as described in section 3.4, parameters which dominate the uncertainties tend to overshadow less important parameters, and it was felt that the uncertainty introduced by these models had to be fully analyzed first in order to assess their impact on the dose calculations. Second, sensitivity to source term magnitude alone was examined (see section 3.3.2).

3.3.1 Sensitivity to Plume Dispersion and Building Wake Effects

The input data for this study was the same as used in benchmark analysis (Table 3.1), and the same weather stability classes (A1 through F5) were analyzed. Doses delivered to various organs were compared for distances up to five miles. Doses to different organs were qualitatively similar for all stability classes, with uncertainty, ranging between fifty and one hundred percent of the largest calculated value at a half mile from the release point; between twenty and forty percent at one mile, and between five and twenty percent at two miles. For larger distances, this uncertainty approaches zero. Figures 3.4 and 3.5 show the calculated total dose to bone marrow for weather stability class D and average wind speed of 5 m/s.

Figure 3.1 Total dose to bone marrow versus distance for weather stability class A, average wind speed 5 m/s.

Figure 3.2 Total dose to bone marrow versus distance for weather stability class D, average wind speed 5 m/s.

Figure 3.3 Total dose to bone marrow versus distance for weather stability class F, average wind speed 1 m/s.

Figure 3.4 Total dose to bone marrow versus distance for various dispersion parameter formulations using CRAC2 dose conversion factors: weather D5.

Figure 3.5 Total dose to bone marrow versus distance for various dispersion parameter formulations using MACCS dose conversion factors: weather D5.

As can be readily seen, the dispersion models used in MACCS predict larger doses at shorter distances for these weather conditions; for other weather conditions, the CRAC2 models predict higher doses, but the band in uncertainties remains approximately the same. The effect on the calculation of health effects could be dramatic if, for a given release, the models used in one code yielded sub-threshold doses and hence no effects, while the models used in the other code computed finite mortality and injury probabilities. For the large source term cluster used in the present analysis, such a dramatic effect was not seen due to calculated doses being well beyond the threshold. However, differences of a few percent in the probability of early fatalities were observed in those cases where mortality rate was less than 100% (see, for example, Table 3.3).

In conclusion, the dispersion parameters and building wake effects models used in the existing codes can introduce a significant uncertainty in calculated doses within a few miles of the release point.

3.3.2 Sensitivity to Source Terms

The Quasar project provided a full uncertainty analysis on the Source Term Code Package (STCP) results of a postulated short term station blackout accident at a BWR with MARK I containment [31]. The results covered a wide spectrum of containment failure modes (leak to massive rupture, early to late failures) and hence radionuclide releases. Discrete distributions for nine release groups modeled in the STCP, were obtained. Following these results, paired correlations were imposed between iodine and cesium, strontium and barium, and lanthanum and cerium releases. The parameter space used to generate release fractions is shown in Table 3.5.

A set of 100 independent releases was generated using a stratified Monte Carlo (Latin Hypercube Sampling) technique [30]. Two sets of calculations, for weather stability class D and windspeed of 1 m/s and 5 m/s, respectively, were performed with the SMART integral code using MACCS dose conversion factors and health effect models. The core inventory was that of a BWR, scaled according to the Peach Bottom operating power levels. Time, energy and height of release were zero, with duration of release 1 hour. All other inputs were the default values suggested for the MACCS model.

Tables 3.6 and 3.7 show the results for total dose to bone marrow and probability of early death for the D1 set of calculations. Tables 3.8 and 3.9 show the same results for the D5 set. Results for the other outputs calculated by the code can be found in Appendix F.

A regression analysis of the results showed only weak correlations to the Xe, Te, and Sr/Ba groups. All other groups had partial rank correlation coefficients of less than 0.4 in absolute value for all distances.

This result was not surprising because the nine release groups are not in general correlated. Hence, for instance, a high I/Cs source term can be predicted by the LHS program together with very low refractory releases. Doses and health effects, however, are dependent on the global source term. In both calculational sets, the relative uncertainty for doses is approximately the same. One order of magnitude separates the results for extremely low and extremely high releases. The probability of early death is narrowly distributed for

Table 3.3 Comparison of Early Fatality Probabilities Calculated by CRAC2 and MACCS Models for a Large Release Cluster, Weather Stability Class A, Wind Speed 1 m/s

Probability of Early Fatalities

Distance (m)	CRAC2 Health-effect Models		MACCS Health-effect Models	
	CRAC2 Dispersion Model	MACCS Dispersion Model	CRAC2 Dispersion Model	MACCS Dispersion Model
800	1	1	1	1
1600	1	1	1	1
2400	.09	.15	.97	.96
3200	.1	.05	.64	.61
4000	0.	.003	.48	.33
4800	0.	0.	.21	.19
5600	0.	0.	.13	.11
6400	0.	0.	.08	.07
7200	0.	0.	.06	.05
8000	0.	0.	.04	.03
9600	0.	0.	.02	.02
11300	0.	0.	.01	.01

Table 3.4 Weights Used to Collapse Individual Releases to Iodine and Cesium-Equivalent Releases. [31]

	Early Weight	Late Weight
Xe	0.1	0.001
I ₂	1.0	0.1
Cs	0.1	1.0
Te	0.8	0.14
Se	0.99	0.7
Ru	2.15	1.3
La	8.4	2.6
Ce	7.6	5.4
Ba	0.66	0.2

Table 3.5 Parameter Space for Sensitivity Analysis to Source Terms

Grp	Min Release Fraction	Max Release Fraction	Remarks
Xe	.1	1.	All piecewise uniform distributions
I ₂	1.E-04	.75	
Cs	5.E-04	.7	
Te	1.3E-05	.48	
Sr	6.4E-06	.7	
Ru	2.5E-10	1.E-04	Correlations I ₂ , Cs .9 Sr, Ba .9 La, Ce .9
La	1.E-04	.018	
Ce	1.E-06	.026	
Ba	5.E-06	.67	

Table 3.6 Total Dose to Bone Marrow as a Function of Distance; Case D1

DIST.(MI)	MIN	MAX	5-TH	50-TH	95-TH	AVER	SIGMA
0.5	1.740E+03	2.842E+04	2.178E+03	5.332E+03	1.815E+04	6.930E+03	5.335E+03
1.0	3.614E+02	5.746E+03	4.531E+02	1.092E+03	3.678E+03	1.416E+03	1.077E+03
2.0	1.235E+02	1.939E+03	1.551E+02	3.725E+02	1.244E+03	4.815E+02	3.645E+02
3.0	6.886E+01	1.089E+03	8.684E+01	2.088E+02	7.016E+02	2.712E+02	2.063E+02
4.0	4.303E+01	6.933E+02	5.451E+01	1.312E+02	4.456E+02	1.713E+02	1.311E+02
5.0	2.386E+01	3.976E+02	3.037E+01	7.307E+01	2.513E+02	9.611E+01	7.403E+01
10.0	7.617E+00	1.423E+02	9.729E+00	2.419E+01	8.559E+01	3.218E+01	2.551E+01
20.0	2.267E+00	5.667E+01	3.064E+00	8.268E+00	3.084E+01	1.086E+01	9.334E+00

Table 3.7 Probability of Early Death as a Function of Distance; Case D1

DIST.(MI)	MIN	MAX	5-TH	50-TH	95-TH	AVER	SIGMA
0.5	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00	0.0
1.0	4.473E-01	1.000E+00	8.442E-01	1.000E+00	1.000E+00	9.765E-01	8.608E-02
2.0	8.066E-03	1.000E+00	1.829E-02	5.057E-01	1.000E+00	5.183E-01	4.090E-01
3.0	1.274E-03	1.000E+00	2.708E-03	5.001E-02	1.000E+00	2.359E-01	3.514E-01
4.0	3.030E-04	1.000E+00	6.435E-04	9.630E-03	7.915E-01	1.064E-01	2.414E-01
5.0	4.989E-05	5.478E-01	1.072E-04	1.517E-03	8.703E-02	2.090E-02	7.760E-02
10.0	1.431E-06	6.767E-03	3.248E-06	4.518E-05	1.698E-03	3.549E-04	1.011E-02
20.0	0.000E+00	2.885E-04	5.960E-08	1.103E-06	4.992E-05	1.035E-05	3.428E-05

Table 3.8 Total Dose to Bone Marrow versus Distance; Case D5

DIST.(MI)	MIN	MAX	5-TH	50-TH	95-TH	AVER	SIGMA
0.5	1.841E+02	2.763E+03	2.283E+02	5.155E+02	1.603E+03	6.476E+02	4.692E+02
1.0	5.074E+01	7.186E+02	6.279E+01	1.397E+02	4.167E+02	1.729E+02	1.204E+02
2.0	2.070E+01	2.876E+02	2.465E+01	5.714E+01	1.668E+02	6.940E+01	4.756E+01
3.0	5.868E+00	1.749E+02	1.508E+01	3.499E+01	1.016E+02	4.204E+01	2.906E+01
4.0	3.067E+00	1.178E+02	9.887E+00	2.373E+01	6.846E+01	2.835E+01	1.961E+01
5.0	5.076E+01	7.126E+01	6.161E+00	1.435E+01	4.149E+01	1.724E+01	1.180E+01
10.0	1.916E+00	2.635E+01	2.354E+00	5.306E+01	1.543E+01	6.438E+00	4.351E+00
20.0	4.387E-01	6.181E+00	5.344E-01	1.206E+00	3.716E+00	1.505E+00	1.046E+00

Table 3.9 Probability of Early Death Versus Distance; Case D5

DIST.(MI)	MIN	MAX	5-TH	50-TH	95-TH	AVER	SIGMA
0.5	4.969E-02	1.000E+00	1.035E-01	9.912E-01	1.000E+00	7.312E-01	3.482E-01
1.0	8.454E-04	1.000E+00	1.435E-03	1.991E-02	7.140E-01	1.147E-01	2.315E-01
2.0	5.716E-05	2.073E-01	8.148E-05	1.185E-03	2.843E-02	8.357E-03	2.382E-02
3.0	1.550E-06	3.443E-02	1.800E-05	2.596E-04	6.114E-03	1.416E-03	4.150E-03
4.0	1.788E-07	9.490E-03	5.245E-06	7.823E-05	1.830E-03	4.120E-04	1.166E-03
5.0	8.941E-07	2.013E-03	1.222E-06	1.711E-05	3.998E-04	8.931E-05	2.489E-04
10.0	5.960E-08	9.882E-05	5.960E-08	8.345E-07	1.958E-05	4.436E-06	1.215E-05
20.0	0.000E+00	1.252E-06	0.000E+00	0.000E+00	2.384E-07	4.947E-08	1.534E-07

short distances from the source, where doses are in general saturated close to or above the one hundred percent mortality rate for all releases considered. The uncertainty in early death becomes wider for larger distances. Dose thresholds for health effects are extremely low in the MACCS model, and even low doses produce a finite probability of early death.

The two tests could be combined, which is roughly equivalent to a single test of LHS sample of 200, with additional uncertain variable being the wind speed, uniformly distributed with discrete values of 1 and 5 m/s. Almost all distribution would be wider by about two orders of magnitude, which is more than the uncertainty introduced by the source terms alone. The impact of weather conditions on uncertainties of consequences is investigated in more detail in the next section.

3.4 Multi-Parameter Sensitivity and Uncertainty Analysis

Alpert et al. [27] and Kocher et al. [28] performed multiparameter sensitivity and uncertainty studies on health and economic consequences using the CRAC2 code. Alpert's analysis was done primarily as a demonstration of uncertainty techniques, and included source term magnitude and release characteristics, and a few but not all parameters related to the dispersion and deposition models. The choice of parameter spaces appears to be arbitrary. Also included were parameters such as evacuation speed, which are not modeled in the present code. The analysis of Kocher et al was extended to the selection of weather bin sampling and dose conversion factors, but only used two classes of radionuclide release fractions and characteristics. Kaiser also performed sensitivity analysis of CRAC2 [29]. Kaiser's study considered evacuation parameters, health physics models, population distribution, and characteristics of the source term. In general, all of these analyses showed that the results are sensitive to the magnitude of the source terms. The analysis of Kocher et al also showed some sensitivity to the selection of weather sequences in bin-sampling. No published sensitivity/uncertainty study on the MACCS computer code has been published to date.

This section presents a full multi-parameter, sensitivity/uncertainty analysis of consequences using the present integral code, which has been benchmarked against the more sophisticated CRAC2 and MACCS differential codes.

A set of input parameters described in Section 3.4.1 was chosen, with parameter spaces and distributions taken from appropriate sources. The LHS technique [30] was applied to this set, and one hundred separate calculations were performed for both the CRAC2 and MACCS models. Doses delivered to different organs and health effects (output) were then correlated to the independent (input) variables through a rank regression analysis as described in Section 3.4.2. Statistical information is provided in Section 3.4.3, and conclusions are presented in Section 3.4.4.

3.4.1 Selection of Independent Variables.

A set of twenty-three independent input variables was selected; and were grouped as follows:

- i) Radionuclide releases and release characteristics: The results obtained from the QUASAR analysis were used, as in Section 3.3.1. Since no global correlation among release groups was observed, as previously mentioned, two independent variables were added in the regression analysis, collapsing all releases to early iodine--and late cesium-weighted effects [32]. The weights used are listed in Table 3.4. The QUASAR analysis [31] also provided discrete distributions for release time, duration, height and energy of release. These parameters were properly correlated to each other following the QUASAR results.
- ii) Plume Dispersion Models: A discrete distribution was provided for the choice of plume dispersion formulations, with equal weight for each model.
- iii) Weather Conditions: The Peach Bottom atmospheric data file for MACCS [33] was analyzed. Rather than sampling weather bins, as is done in MACCS, weather stability classes were provided with their relative frequency of occurrence. Average wind speed and rainfall rate were provided as distributions. It was found that a weak correlation existed between stability class and wind speed, and this correlation was therefore added to the LHS program input. It should be noted that the rainfall rate distribution provides for a 92 percent no-rain probability at the site. Hence, the effect of rain on concentration depletion from the plume can be expected to be minimal in the correlation analysis. This means that the importance of wet deposition in the distribution of uncertainties cannot be assessed in the present study. Such an assessment would require a single-parameter sensitivity study to wet deposition, or a specialized multi-parameter analysis using data restricted to rain conditions.
- iv) Input parameters with associated uncertainties: Parameter spaces and distributions were taken from the literature, namely; Dry deposition velocity [14], breathing rate [15], the rain depletion coefficient [17]. In addition, the height of the inversion lid was chosen as either 1000m or 800m. This primarily affects weather stability classes A and B. For cloudshine and groundshine shielding factors, wide ranges were chosen to cover a variety of emergency response actions. Dose conversion factors and health effects models were not considered as independent parameters in this analysis. However, the sensitivity analysis has included both CRAC2 and MACCS dose conversion factors and health effects models as choices in input. Tables 3.5 and 3.10 list all the independent parameters that are input to the Latin Hypercube Sampling program, which generates appropriate random vectors for the present code.

3.4.2 Correlation of Output to Input Uncertainties:

Two sets of one hundred independent calculations were performed with the SMART integral code, using the dose conversion factors and health effects models in CRAC2 and MACCS, respectively. As in Section 3.3.1, the core inventory was that of a BWR, scaled according to the Peach Bottom operating power levels. Results were stored for analysis at ten distances from the release point,

Table 3.10 Input Other Than Source Terms for the Full Uncertainty Analysis

Parameter	Parameter Space	Comments
Release Time (hours)	0 - 4.3	Piecewise Uniform
Duration of Release (hours)	6 - 12.7	Normal Distribution
Height of Release (m)	0 - 30	Uniform Distribution
Energy of Release (watts)	0 - 1.E+10	Log Uniform Distribution
Dispersion Models	1 = Polynomial 2 = CRAC2 3 = MACCS	User Distribution with Equal Weights
Weather Stability Classes	A - F	User Distribution with Weights (probability of occurrence) obtained from weather file [33]
Average Wind Speed (m/s)	.1 - 10.7	Piecewise Log Uniform Distributions obtained from [33]
Rainfall Duration (s)	0 - 3600	
Dry Deposition Velocity (m/s)	0.001 - .1	Log Uniform Distribution
Breathing Rate (m ³ /s)	9.E-05 - 5.E-04	Triangular Distribution with apex at 3.33×10^{-4}
Cloudshine Shielding factor	.1 - .9	Uniform Distributions
Groundshine Shielding factor	.1 - .9	
Rain Depletion Coefficient	1.E-05 - .01	Log Uniform Distribution
Inversion Lid (m)	800 - 1000	Discrete Distribution with Equal Weights

Correlations: Release time, duration -.9
 Release time, energy -.8
 Weather class, wind speed -.6
 Shielding factors .9

ranging from one half to 350 miles. For the CRAC2 run the following output was saved; total dose to whole body, bone marrow, lung, thyroid and lower large intestinal wall, together with probability of early fatality. For the MACCS calculations, total dose to stomach, bone marrow, lung, thyroid, small intestinal tract, lower large intestinal wall, and probability of early injury and early fatality, were saved.

A statistical program, PCCSRC [34], was used to correlate outputs to inputs. Partial rank correlation coefficients (PRCC), standardized rank regression coefficients (SRRC), partial correlation coefficients (PCC), and standardized regression coefficients (SRC) were produced. Some PRCC results are shown in Tables 3.11 through 3.15. PRCC's below .3 in absolute value are not shown. PRCC's for all other output exhibited similar behavior. Two parameters exhibit very strong correlations in most cases: (1) weather stability class, and (2) dry deposition velocity. Output correlations to iodine and cesium equivalent releases and individual releases were weak. Other parameters which provide weak correlations are: (1) breathing rate, (2) groundshine shielding factor, (3) wind speed, and (4) choice of dispersion model. The R^2 for dose parameters, which is an indication of the goodness of a linear fit of the data, was seen to be acceptable for all cases. For the probability of early fatality, there is no fit beyond 3 miles for CRAC2, and beyond 50 miles for MACCS. Beyond these distances the dependent parameters are zero, that is no consequences are predicted. This analysis was repeated with a sample set of 300 independent observations. No change was observed in the PRCC's. Another sample set of 100 observations was analyzed, discarding height of release, energy, cloudshine shielding factor and inversion layer lid, which never ranked better than the tenth place for any of the outputs. In this sample set, weather stability class was fixed at D (the most probable), and wind speed and rain rate distributions were provided for class D weather only. PRCC results did not change overall, except that the weak correlations observed in the analysis with the original 100 LHS sample, became stronger.

Scatter plots of all outputs were produced for the original LHS100 sample. These confirmed the PRCC analysis and no non-linear or oscillatory effect was found. Figures 3.6 through 3.11 show total dose to bone marrow at 1 mile from source as a function of a few independent inputs used for the CRAC2 analysis, and are typical of all results. Figures 3.6 through 3.9 demonstrate the weak correlations to releases. For Iodine and Cesium-equivalent releases, (Figs 3.6 and 3.7), the poor correlation is probably due to overwhelming effect of weather and dry deposition parameters. As noted in the previous section, the results were not surprising as far as individual group releases are concerned (Figs 3.8 and 3.9), since the total dose is a function of the total release from all groups. Individual release groups contribute only a small fraction to the total dose. Figures 3.11 and 3.12 illustrate the stronger correlations between total dose and weather stability class and dry deposition velocity. Figures 3.13 through 3.15 support the conclusions reached in section 3.3 regarding threshold effects as influenced by choice of dispersion models. Even though the uncertainty in probability of early fatality is dominated by weather stability class close to the source (see Fig. 3.14), a noticeable dependence of probability-quantiles to the choice of dispersion model is evidenced in Figure 3.13. Correlation to weather stability class is seen to diminish with increasing distance while dependence on dispersion model increases (compare Figs 3.13 and 3.15). The effect of dispersion model near the threshold of fatalities was most evident

Table 3.11 PRCC's for Whole Body Dose - CRAC2

Independent Parameter	Distance (Miles)								
	.5	1	2	3	4	5	10	20	50
Early Weight	.34	.42	.49	.50	.49	.51	.53	.44	
Late Weight									
Xe	-.39	-.43	-.42	-.39	-.37	-.32			
I ₂									
Cs									
Te									
Sr									
Ru									
La									
Ce									
Ba									
Dispers. Model									.32
Release Time									
Duration									
Height of Rel.									
Energy									
Weather	.82	.85	.85	.84	.82	.73	.71	.52	.53
Windspeed	-.55	-.42	-.30						
Dry Dep. Veloc.	.74	.72	.72	.70	.68	.55	.45		
Breath Rate									
Rain Rate									
CS Shielding									
GS Shielding	.42	.46	.49	.48	.46	.44	.40	.34	
Rain Depl.									
Inversion Lid									
R ²	.83	.84	.85	.83	.79	.80	.79	.77	.80

Table 3.12 PRCC's for Probability of Early Fatality - CRAC2

Independent Parameter	Distance (Miles)								
	.5	1	2	3	4	5	10	20	50
Early Weight	.39								
Late Weight									
Xe	-.34								
I ₂									
Cs									
Te									
Sr									
Ru									
La									
Ce									
Ba									
Dispers. Model				-.30					
Release Time									
Duration									
Height of Rel.									
Energy									
Weather	.63	.69	.50						
Windspeed	-.35								
Dry Dep. Veloc.	.48	.51	.30						
Breath Rate									
Rain Rate									
CS Shielding									
GS Shielding	-.30								
Rain Depl.									
Inversion Lid									
R ²	.68	.68	.39	.33	0	0	0	0	0

Table 3.13 PRCC's for Total Dose to Thyroid - MACCS

Independent Parameter	Distance (Miles)								
	.5	1	2	3	4	5	10	20	350
Early Weight	.41	.41	.39	.39	.39	.37	.36	.32	
Late Weight									
Xe	-.48	-.49	-.45	-.43	-.42	-.36	-.31		
I ₂									
Cs									
Te	.43	.39	.41	.42	.42	.41	.42	.44	
Sr									
Ru									
La									
Ce									
Ba									
Dispers. Model								.30	
Release Time									
Duration									
Height of Rel.									
Energy									
Weather	.86	.84	.81	.78	.76	.67	.56	.38	
Windspeed	-.54	-.35							.48
Dry Dep. Veloc.					-.31	-.40	-.58	-.72	-.80
Breath Rate	.53	.50	.51	.51	.51	.48	.48	.37	
Rain Rate									
CS Shielding									
GS Shielding									
Rain Depl.									
Inversion Lid									
R ²	.9	.88	.87	.86	.85	.83	.83	.84	.82

Table 3.14 PRCC's for Probability of Early Injury - MACCS

Independent Parameter	Distance (Miles)								
	.5	1	2	3	4	5	10	20	50
Early Weight	.32	.46	.48	.50	.49	.49	.50	.48	.48
Late Weight									
Xe		-.43	-.40	-.39	-.37	-.34			-.40
I ₂									
Cs									
Te									
Sr									
Ru									
La									
Ce									
Ba									
Dispers. Model									.32
Release Time									
Duration									
Height of Rel.									
Energy									
Weather	.68	.88	.85	.83	.80	.75	.68	.56	.37
Windspeed	-.42	-.38							
Dry Dep. Veloc.		.62	.54	.51	.46	.35		-.32	
Breath Rate									
Rain Rate									
CS Shielding									
GS Shielding	.35	.37	.36	.36	.34	.34	.33	.31	
Rain Depl.									
Inversion Lid									
R ²	.71	.87	.85	.84	.82	.79	.79	.78	.70

Table 3.15 PRCC's for Probability of Early Death - MACCS

Independent Parameter	Distance (Miles)								
	.5	1	2	3	4	5	10	20	50
Early Weight	.35	.40	.45	.46	.45	.44	.46	.43	
Late Weight									
Xe		-.43	-.40	-.40	-.37	-.34	-.30	-.35	
I ₂									
Cs									
Te									
Sr									
Ru									
La									
Ce									
Ba									
Dispers. Model									
Release Time								.32	
Duration									
Height of Rel.									
Energy									
Weather	.72	.88	.84	.83	.79	.74	.69	.41	
Windspeed	-.50	-.38							
Dry Dep. Veloc.	.39	.57	.41	.33			-.33		
Breath Rate		.33	.34	.35	.35	.34			
Rain Rate									
CS Shielding									
GS Shielding	.45	.32	.32	.31		.30	.30		
Rain Depl.									
Inversion Lid									
R ²	.75	.86	.85	.84	.82	.80	.80	.71	.31

Figure 3.6 Total dose to bone marrow versus Iodine-equivalent release, CRAC2 results at 1 mile.

Figure 3.7 Total dose to bone marrow versus Cs-equivalent release, CRAC2 results at 1 mile.

Figure 3.8 Total dose to bone marrow versus I_2 release, CRAC2 results at 1 mile.

Figure 3.9 Total dose to bone marrow versus Cs release, CRAC2 results at 1 mile.

Figure 3.10 Total dose to bone marrow versus dispersion models, CRAC2 results at 1 mile.

Figure 3.11 Total dose to bone marrow versus weather stability class - CRAC2 results at 1 mile.

Figure 3.12 Total lung dose vs dry deposition velocity - CRAC2 results at 1 mile.

Figure 3.13 Probability of early fatality vs. dispersion model - MACCS results at 0.5 mile.

Figure 3.14 Probability of early fatality vs. weather stability class - MACCS results at 0.5 mile.

Figure 3.15 Probability of early fatality vs. dispersion model; MACCS results at 5.0 miles.

in the calculation of probability of early fatality at 50 miles for weather stability class D only. The only contribution to non-zero probability of early deaths is from the MACCS dispersion model, which in 2 cases (seven percent of the time), leads to doses slightly above threshold.

3.4.3 Statistical Data Reduction

Tables 3.16 and 3.17 show the quantiles, mean values and standard deviations for total marrow dose calculated respectively with CRAC2 and MACCS dose conversion factors. Results for other organs can be found in Appendix G. Doses to individual organs, as calculated by CRAC2 and MACCS are seen to be very similar with the exception of lung dose, for which MACCS predictions are much higher. However, when comparing probabilities of early fatality (Tables 3.18 and 3.19), the predictions of finite probabilities of early death from MACCS persist much further away from source than from CRAC2. This happens because the CRAC2 model has a step-like threshold for early fatalities, while the MACCS model exhibits exponential decay with decrease in dose. Figure 3.16 shows comparisons of percentile envelopes for early fatality probability as computed by the two health effects models. The fifth quantile for CRAC2 is zero for all distances, and hence is not visible.

The same results for the 300 LHS sample test for MACCS are shown in Tables 3.20 and 3.21. As noted in the previous section, PRCCs were not affected by the increase in sample size. However, uncertainties increased by at least one order of magnitude because extreme weather samples were polled more often. Figure 3.17 illustrates the difference in quantiles and average values for the probability of early fatalities between the two tests with different sample sizes.

3.4.4 Conclusions

The results of the uncertainty and sensitivity analyses presented in this and the previous sections do not contradict the earlier studies of the CRAC2 code. Uncertainty due to weather conditions had been investigated in Reference [28] by comparing results of the 29 weather bins used in the code to results generated from 50 weather bins constructed by the authors. A low to moderate sensitivity of consequences to bin sampling was observed. In the present analysis, by using weather and rain distributions in an LHS technique, a possibly wider range of weather data was sampled, hence increasing the sensitivity of the results to weather stability class and average wind speed. Neither of the earlier uncertainty analyses had included the dry deposition velocity as an independent parameter. Low sensitivity to radionuclide releases is due in part to non-correlated release group distributions, and in part to a more narrow parameter space than the one used, for instance, in Reference [27]. In our analysis, the iodine-weighted releases varied between 0.12 and 1.04, while in Reference [27] this parameter varied between 0.07 and 1.43.

Moreover, uncertainties related to releases were shown in Section 3.3.2 to span approximately one order of magnitude for doses. In the full multiparameter analysis these uncertainties increased to more than three orders of magnitude, hence uncertainty due to source terms is overwhelmed by uncertainties in other parameters, which the PRCC analysis showed to be more strongly correlated to the outputs. Low probability of rain for the Peach Bottom site makes rain rate and wet depletion models unimportant in a general, multi-parameter analysis. The

Table 3.16 Multiparameter Uncertainty Analysis: Total Bone Marrow Dose Using CRAC2 Dose Conversion Factors

DIST.(MI)	MIN	MAX	5-TH	50-TH	95-TH	AVER	SIGMA
0.5	2.114E+01	1.266E+04	1.042E+02	9.397E+02	5.061E+03	1.774E+03	2.401E+03
1.0	7.355E+00	4.265E+03	2.416E+01	3.114E+02	1.841E+03	1.67035E+02	7.768E+02
2.0	6.503E-05	8.191E+02	5.094E+00	7.683E+01	3.662E+02	1.266E+02	1.410E+02
3.0	3.102E-09	4.306E+02	2.896E+00	4.532E+01	2.094E+02	6.988E+01	7.656E+01
4.0	1.614E-13	2.705E+02	1.980E+00	2.888E+01	1.397E+02	4.529E+01	4.932E+01
5.0	8.995E-18	1.580E+02	1.255E+00	1.729E+01	9.206E+01	2.738E+01	3.007E+01
10.0	1.785E-24	4.844E+01	5.351E-01	5.929E+00	3.375E+01	9.169E+00	9.932E+00
20.0	7.907E-25	1.602E+01	8.835E-02	1.600E+00	9.944E+00	2.842E+00	3.235E+00
50.0	2.050E-25	2.996E+00	5.305E-03	4.433E-01	2.530E+00	7.074E-01	7.825E-01
350.0	2.886E-28	6.544E-02	7.368E-05	1.815E-03	3.001E-02	6.598E-03	1.115E-02

Table 3.17 Multiparameter uncertainty Analysis: Total Bone Marrow Using MACCS Dose Conversion Factors

DIST.(MI)	MIN	MAX	5-TH	50-TH	95-TH	AVER	SIGMA
0.5	1.439E+01	8.697E+03	6.538E+01	7.572E+02	4.833E+03	1.357E+03	1.709E+03
1.0	9.767E-02	1.304E+03	6.066E+00	1.372E+02	7.136E+02	2.268E+02	2.531E+02
2.0	4.132E-06	4.673E+02	3.203E+00	5.287E+01	2.749E+02	8.600E+01	9.094E+01
3.0	2.030E-10	2.599E+02	1.887E+00	3.083E+01	1.532E+02	5.004E+01	5.267E+01
4.0	1.076E-14	1.658E+02	1.330E+00	2.057E+01	1.010E+02	3.293E+01	3.465E+01
5.0	5.338E-20	9.816E+01	8.481E-01	1.269E+01	6.394E+01	2.010E+01	2.127E+01
10.0	1.748E-24	3.472E+01	4.303E-01	4.816E+00	2.578E+01	7.481E+00	7.937E+00
20.0	5.138E-25	1.012E+01	4.981E-02	1.009E+00	6.187E+00	1.794E+00	1.998E+00
50.0	2.089E-25	2.515E+00	3.675E-03	3.557E-01	2.028E+00	5.725E-01	6.282E-01
350.0	3.006E-28	5.413E-02	2.080E-05	6.906E-04	2.944E-02	5.433E-03	9.953E-03

Table 3.18 Multiparameter Uncertainty Analysis: Probability of Early Death Calculated by the CRAC2 Health Effect Model

DIST.(MI)	MIN	MAX	5-TH	50-TH	95-TH	AVER	SIGMA
0.5	0.000E+00	1.000E+00	0.000E+00	1.000E+00	1.000E+00	6.286E-01	4.752E-01
1.0	0.000E+00	1.000E+00	0.000E+00	0.000E+00	1.000E+00	3.129E-01	4.512E-01
2.0	0.000E+00	1.000E+00	0.000E+00	0.000E+00	1.731E-02	1.274E-02	9.979E-02
3.0	0.000E+00	4.148E-02	0.000E+00	0.000E+00	0.000E+00	4.148E-04	4.127E-03
4.0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
5.0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
10.0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
20.0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
50.0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Table 3.19 Multi-parameter Uncertainty Analysis: Probability of Early Death Calculated by the MACCS Health Effect Model

DIST.(MI)	MIN	MAX	5-TH	50-TH	95-TH	AVER	SIGMA
0.5	1.287E-05	1.000E+00	1.541E-03	1.000E+00	1.000E+00	7.321E-01	4.066E-01
1.0	0.000E+00	1.000E+00	2.414E-06	2.582E-02	1.000E+00	2.755E-01	3.922E-01
2.0	0.000E+00	8.869E-01	4.768E-07	8.122E-04	2.864E-01	4.423E-02	1.278E-01
3.0	0.000E+00	2.179E-01	1.192E-07	2.078E-04	5.437E-02	8.593E-03	2.762E-02
4.0	0.000E+00	7.948E-02	2.980E-08	4.873E-05	1.489E-02	2.495E-03	8.976E-03
5.0	0.000E+00	2.091E-02	0.000E+00	1.040E-05	3.765E-03	6.043E-04	2.307E-03
10.0	0.000E+00	1.339E-03	0.000E+00	4.470E-07	1.733E-04	3.438E-05	1.450E-04
20.0	0.000E+00	2.128E-05	0.000E+00	0.000E+00	1.669E-06	4.870E-07	2.369E-06
50.0	0.000E+00	7.749E-07	0.000E+00	0.000E+00	2.980E-08	1.490E-08	9.363E-08

Table 3.20 Multiparameter Uncertainty Analysis With Larger Sample Size: Total Dose to Bone Marrow Calculated with MACCS Dose Conversion Factors

DIST.(MI)	MIN	MAX	5-TH	50-TH	95-TH	AVER	SIGMA
0.5	1.266E+01	4.026E+04	5.658E+01	6.325E+02	6.306E+03	1.672E+03	3.481E+03
1.0	2.804E-03	5.096E+03	5.390E+00	1.132E+02	1.123E+03	2.842E+02	5.538E+02
2.0	6.469E-07	2.054E+03	2.019E+00	4.592E+01	4.165E+02	1.049E+02	1.937E+02
3.0	3.113E-07	1.224E+03	1.436E+00	2.606E+01	2.439E+02	6.057E+01	1.110E+02
4.0	6.606E-09	8.241E+02	1.038E+00	1.711E+01	1.518E+02	3.967E+01	7.265E+01
5.0	3.219E-12	5.384E+02	8.238E-01	1.062E+01	8.651E+01	2.424E+01	4.494E+01
10.0	6.208E-19	2.204E+02	4.780E-01	4.169E+00	3.340E+01	9.122E+00	1.724E+01
20.0	7.898E-37	5.575E+01	5.711E-02	9.133E-01	8.249E+00	2.290E+00	4.721E+00
50.0	1.870E-37	2.125E+01	9.031E-03	3.151E-01	3.371E+00	8.609E-01	2.184E+00
350.0	0.000E+00	2.480E-01	2.330E-05	5.305E-04	3.471E-02	6.614E-03	1.841E-02

Table 3.21 Multiparameter Uncertainty Analysis With Larger Sample Size: Probability of Early Death Calculated by the MACCS Health Effects Model

DIST.(MI)	MIN	MAX	5-TH	50-TH	95-TH	AVER	SIGMA
0.5	2.199E-05	1.000E+00	1.383E-03	1.000E+00	1.000E+00	7.081E-01	4.094E-01
1.0	0.000E+00	1.000E+00	1.431E-06	1.300E-02	1.000E+00	2.401E-01	3.741E-01
2.0	0.000E+00	1.000E+00	8.941E-08	6.157E-04	8.696E-01	7.744E-02	2.286E-01
3.0	0.000E+00	1.000E+00	2.980E-08	1.122E-04	1.427E-01	3.566E-02	1.517E-01
4.0	0.000E+00	1.000E+00	0.000E+00	2.879E-05	3.354E-02	1.391E-02	7.869E-02
5.0	0.000E+00	1.000E+00	0.000E+00	5.364E-06	8.255E-03	5.270E-03	5.826E-02
10.0	0.000E+00	2.825E-01	0.000E+00	2.980E-07	3.620E-04	1.041E-03	1.628E-02
20.0	0.000E+00	3.829E-03	0.000E+00	0.000E+00	6.407E-06	1.443E-05	2.207E-04
50.0	0.000E+00	1.402E-04	0.000E+00	0.000E+00	2.980E-07	5.827E-07	8.123E-06

Figure 3.16 Comparison between CRAC2 and MACCS calculations - probability of early fatality vs. distance.

Figure 3.17 Comparison of LHS sample size - MACCS probability of early fatality vs. distance.

dependence of uncertainties on weather conditions (stability class, windspeed) is so strong that perhaps bin sampling in the codes should be re-evaluated, to ensure that more samples be taken from extreme weather conditions.

An illustration of this dependence is shown in Figures 3.18 and 3.19. Uncertainties of fifth and ninety fifth percentiles for dose to marrow calculated by the SMART code using MACCS dose conversion factors at two miles increase by one order of magnitude for the larger sample size, and are three orders of magnitude wider than the uncertainties related to source terms alone. The increase in dose uncertainty is magnified in the calculation of probability of early death. Minima for the LHS100 and LHS 300 results are several orders of magnitude below the fifth percentile while for the sensitivity study to source terms alone they are still within the scale shown in the figures.

Again, weather-driven uncertainty is so large that quoting mean values for consequences does not properly represent the results, and the usage of quantiles provides a more meaningful estimate. For instance, Table 3.22 shows results for total cancer deaths from MACCS calculations for two Zion releases [26], namely, cluster 1, and cluster 26, which are respectively the largest and smallest releases considered. The mean consequences for the two releases are vastly different. However, the consequence distributions are seen to overlap.

A more careful review of the data on dry and wet deposition velocities should be performed, and uncertainties in these parameters narrowed if possible, since they are major contributors to uncertainty in consequences. As evidenced in the literature, the currently used dispersion models are not valid beyond 50 miles of the release point, while they still appear to contribute substantially to the uncertainties. For distances up to 2 miles, building wake effect is very important. Finally, as concluded in Reference [29], the CRAC2 health effect model for probability of early death predicts zero mortality rates beyond a very short distance from the release point (three miles in the present calculations, two miles in the sensitivity analysis of [29]). MACCS models predict in general higher mortality rates up to that point, and a finite probability of early death that persists up to 50 miles.

Figure 3.18 Uncertainty in total dose to bone marrow at 2 miles calculated by SMART code.

Figure 3.19 Uncertainties in probability of early death at 2 miles calculated by SMART code.

Table 3.22 Total Cancer Deaths Calculated by MACCS for ZION Clusters 1 and 26.

Cluster	Iodine-Equivalent Weight	Total Mean Cancer Deaths	5th	50th	95th	99th	Peak
1	301	18100	2500	14000	49900	75600	105000
26	.12	448	35	265	1660	4350	8270
Ratio 1/26	25.1	40.4	71.4	52.8	30.1	17.4	12.7

4. CONCLUSIONS

A personal computer-based model has been developed that uses an integral approach for calculating early offsite consequences from nuclear reactor accidents. The computing time requirements for a typical calculation on a mainframe computer using this model are over two orders of magnitude lower than those of CRAC2 and MACCS codes, thus providing a valuable tool for sensitivity and uncertainty studies. The model uses simplified meteorology and predicts the time-integrated air concentration of each radionuclide at any distance from the point of release as a function of the time-integrated source strength using the Gaussian plume model. The solution procedure involves direct analytic integration of air concentration equations over time and position. This is different from the discretization approach currently used in the CRAC2 and MACCS codes. Following the approach in CRAC2 and MACCS, the model includes dry and wet deposition, radioactive decay and daughter buildup, and the effects of reactor building wake, inversion lid, plume rise, release duration, and grass height. Early dose to an individual is calculated via cloudshine, short-term groundshine, and inhalation. The dose calculations are performed in the same manner as CRAC2 and MACCS. The health effect models in both CRAC2 and MACCS are included for the calculation of early fatalities. The health effects model in MACCS for early injuries is also included.

The present code was benchmarked against both MACCS version 1.4 and CRAC2. A sensitivity study to plume dispersion parameters showed that the models included in the codes can produce a fairly large uncertainty in calculated doses up to two miles from release point. An uncertainty analysis related to the magnitude of the source terms, which covered almost the entire spectrum of accident releases for a BWR, showed that uncertainties in dose calculations span about one order of magnitude, and increase to two or three orders of magnitude in the calculation of health effects. A multi-parameter uncertainty analysis revealed that the uncertainty in all results is dominated by the choice of weather conditions, dry deposition velocity, and to a lesser degree by radionuclide releases. The uncertainty introduced by the calculation of dispersion parameters, however, can still be significant in the calculation of health effects at large distances from the release point.

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A-1

APPENDIX A
User's Guide

Compilation and use of the program

The commands used to compile and run SMART on a VAX mainframe computer are:

```
FORTRAN SMART
LINK SMART
RUN SMART
```

On a PC, the program can be divided into sections for editing and compiling ease. In the example given below, the following sections were defined: SMMAIN (main program), subroutines COMP, EFFEC and a section named SMSUBS which includes all other subroutines.

These were compiled with the PROFORT IBM compiler and afterwards linked with the default IBM FORTRAN linker:

```
PROFORT SMMAIN
PROFORT COMP
PROFORT EFFEC
PROFORT SMSUBS
LINK SMMAIN+COMP+EFFEC+SMSUBS;
```

The executable file thus generated occupies approximately 124K memory. To run the program, enter the command:

```
SMMAIN.
```

Output from the run is saved on TAPE2 (FOR002.DAT on a VAX, FORT2 on a PC).

Caution should be exercised in using the printout option on a PC, since a large output with individual nuclide contribution to doses can be generated. It is suggested that this option be used only on a mainframe computer. Abbreviated output is saved on the same tape. All doses are expressed in Rems, even if internally the code uses Bq units for MACCS calculations.

SMART executes interactively. Most parameters can be changed at run time. Appendix E shows most of the menu of questions which must be answered. In a batch version, as the one used for the sensitivity/uncertainty analysis with input generated by an external code, the interactive reader subroutine must be replaced.

Data bases are provided as inputs. PWR and BWR core inventories (in Ci) for 54 nuclides are contained in files PWR.DAT and BWR.DAT. In the present data bases, reference power is respectively 3412 and 3578 MWth.

At run time, inventories are converted to Sv if MACCS dose conversion factors are used. These files also provide nuclide half lives, parent-daughter relationships and a map of radionuclides to the nine groups Noble Gases, Iodines, Cs, Te, Sr, Ru, La, Ce and Ba.

In each of these files, the following data is also defined:

- Distances from release points at which concentrations are calculated.

- Default dose conversion factor tables to be used.

- P.G. curves fitting parameters.

- Deposition velocity and breathing rate.

Deposition velocity is assumed to be zero by SMART for all noble gases.

Default conversion tables, which can be changed at run time, for

CRAC2 are:

Ground-shine: 0 to 1 day
 Inhalation red marrow 0 to 7 days
 Inhalation LLIW 0 to 30 years
 Inhalation thyroid 0 to 30 years
 Inhalation lung 0 to 30 years.

Two data bases are provided for CRAC2 and MACCS dose conversion tables, DOSECR.DAT and DOSEMACCS.DAT.

The first file contains the following tabular data for each of the 54 nuclides :

Cloudshine dose conversion factors for whole body, total marrow, lung, thyroid and LLIW.

Groundshine conversion factors for the same organs for one day exposure.

Groundshine conversion factors for 7 days exposure.

Whole body inhalation conversion factors, 0-2 days.

Marrow inhalation factors, 0-2 days, 0-7 days, 0-30 days, 0-30 years.

LLIW inhalation conversion factors, same exposures as marrow.

Thyroid conversion factors, same exposures as marrow.

Lung conversion factors, 0-2 days, 0-7 days, 0-30 days, 0-1 year, 0-30 years.

Skeleton conversion factors, same exposures as lung.

All the data was taken from Reference [24] . A comparison with CRAC2 dose conversion tables was performed and a few inconsistencies corrected to reflect data used in CRAC2. Some tables, as the whole body inhalation, are missing in [24], and taken directly from the CRAC2 data base.

DOSEMACCS.DAT contains the following dose conversion factors for each of the 54 nuclides:

cloudshine,
 groundshine 8 hours,
 groundshine 7 days,
 lifetime inhalation,

for stomach, small intestine, lungs, red marrow, thyroid and LLIW.

The data was extracted from the dose conversion factor file provided for MACCS 1.4.

Subroutine description

SMART: main program.

RDRCR: this subroutine reads CRAC2 dose conversion factors file (TAPE1).
 Core inventory (in Ci), default values, P.G. curves coefficients and distances at which doses and consequences are calculated are also input here (TAPE31).

COMP: this subroutine calculates air concentrations and doses .

EFFEC: this subroutine calculates health effects with both CRAC2 and MACCS models.

CROUT: this subroutine outputs CRAC2 data. All doses are in Rem units.

SIG: this subroutine calculates dispersion parameters using a polynomial fit to P.G. curves.

RDR2: this subroutine controls all interactive input.

SHINCF: this subroutine calculates finite cloud effect on cloud-shine.

POL2: this subroutine interpolates for finite cloud effect.

RDRMA: this subroutine reads MACCS dose conversion factors file (TAPE1). Core inventory (in Ci), default values, P.G. curves coefficients and distances at which doses and consequences are calculated are also input here (TAPE31). Core inventory is converted to Sv units for consistency with MACCS calculations.

MAOUT: this subroutine outputs MACCS data. All doses are in Rem units.

REST: this subroutine resets to zero arrays used in the calculations for all distances; this subroutine is called if calculations are to be repeated from the beginning.

SIGCR: this subroutine calculates dispersion parameters using the CRAC2 and MACCS models.

ZZBAR: this subroutine calculates the effective height of the plume.

B-1

APPENDIX B
Source Code Listing


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1      PROGRAM SMART
2 C
3 C      INTEGRAL MODEL TO CALCULATE AIR CONCENTRATIONS,DOSES
4 C      AND HEALTH EFFECTS----- INTERACTIVE PC VERSION
5 C
6 C      DEVELOPED AT :
7 C      BROOKHAVEN NATIONAL LABORATORY, DEPARTMENT OF NUCLEAR ENERGY
8 C      REVISED VERSION MAY 1988
9 C
10 C
11      COMMON/MORE/ IWHICH,FCTHY(54),FCLLIW(54),FGTHY(54,2),
12 +      FGLLIW(54,2),NXDAT,XDAT(35),DCTHY(54,5),DGTHY(54,5),
13 +      DCLLIW(54,5),DGLLIW(54,5),FCSTO(54),FGSTO(54,2),
14 +      FISTO(54),FCSMI(54),FGSMI(54,2),FISMI(54),
15 +      DCSTO(54,5),DGSTO(54,5),DISTO(54,5),
16 +      DCSMI(54,5),DGSMI(54,5),DISMI(54,5),
17 +      TOTSTO(35),TOTSMI(35),ISIG,ZBAR,IG
18 C
19      COMMON /VAR/ IPAR(54),MAP(54),QINV(54),HALF(54),FCBOD(54),
20 +      FCMAR(54),FCLUN(54),FGBOD(54,2),FGMAR(54,2),
21 +      FGLUN(54,2),FIBOD(54),FIMAR(54,4),FILLIW(54,4),
22 +      FITHY(54,4),FILUN(54,5),FISKE(54,5),DIBOD(54,5),
23 +      FRAC(9,5),Q(54,5),CHI(54,5),DCBOD(54,5),
24 +      DCMAR(54,5),DCLUN(54,5),DGBOD(54,5),DGMAR(54,5),
25 +      DGLUN(54,5),DIMAR(54,5),DILLIW(54,5),DITHY(54,5),
26 +      DILUN(54,5),DISKE(54,5),TOTMAR(35),TOTBOD(35),
27 +      TOTLUN(35),TOTLLIW(35),TOTSKE(35),TOTTHY(35)
28      COMMON/RCTR/IPBWR
29      COMMON/DP/ ASIGY(6,3),ASIGZ(6,3)
30      COMMON/ENRGY/ ENEREL(2)
31 C
32      COMMON /STATIC/ NUCLID,NG,UDEP,BR,DISTO,NCALC,AREA,NOUT,
33 +      RELTIM(2),IWEATH,UBAR,HEIGHT(2),DELTAT(2),UD,IFG,IFIMAR,
34 +      IFILLIW,IFITHY,IFILUN,IFISKE,DIST,SIGY(2),SIGZ(2)
35 +      ,CDUR(2),HGRAS(2),NPUF,IPROF,SHCS,SHGS,SHIN,WIDT
36 C
37 C
38 10000  CONTINUE
39      WRITE(6,3785)
40 3785  FORMAT('  ENTER REACTOR TYPE : 1-PWR, 2-BWR',/)
41      READ(5,*) IPBWR
42      WRITE(6,100)
43 100   FORMAT('  ENTER DOSE CONVERSION FACTORS TABLES TO USE :',/,
44 +           '          1= CRAC2;',/,
45 +           '          2= MACCS',/)
46      READ(5,*) IWHICH
47      WRITE(6,789)
48 789  FORMAT('  ENTER CHOICE OF SIGMA CALCULATION:',/,
49 +           '          1 = POLYNOMIAL;',/,
50 +           '          2 = CRAC2 OR MACCS MODEL',/)
51      READ(5,*) ISIG
52      IF(IWHICH.EQ.2) GOTO 200
53      CALL RDRCR
54      GOTO 300
55 200   CONTINUE
56      CALL RDRMA
57 300   CONTINUE

```

```

58      CALL RDR2
59      CALL COMP
60      CALL REST
61      WRITE(6,600)
62 600  FORMAT('  IF YOU WISH TO REPEAT , ENTER 1',/)
63      READ(5,*) IREDO
64      IF(IREDO.EQ.1) GOTO 10000
65 C
66 C
67      STOP
68      END

69      SUBROUTINE RDRCR
70 C
71 C      READ CRAC2 DATA BASE FOR CONVERSION FACTORS
72 C
73 C
74      COMMON/MORE/ IWHICH,FCPTHY(54),FCLLIW(54),FGTHY(54,2),
75      + FGLLIW(54,2), NXDAT,XDAT(35), DCTHY(54,5),DGTHY(54,5),
76      + DCLLIW(54,5),DGLLIW(54,5), FCSTO(54),FGSTO(54,2),
77      + FISTO(54),FCSMI(54),FGSMI(54,2),FISMI(54),
78      + DCSTO(54,5),DGSTO(54,5),DISTO(54,5),
79      + DCSMI(54,5),DGSMI(54,5),DISMI(54,5),
80      + TOTSTO(35),TOTSMI(35),ISIG,ZBAR,IG
81 C
82      COMMON /VAR/ IPAR(54),MAP(54),QINV(54),HALF(54),FCBOD(54),
83      + FCMAR(54),FCLUN(54),FCBOD(54,2),FGMAR(54,2),
84      + FGLUN(54,2),FIBOD(54),FIMAR(54,4),FILLIW(54,4),
85      + FITHY(54,4),FILUN(54,5),FISKE(54,5),DIBOD(54,5),
86      + FRAC(9,5),Q(54,5),CHI(54,5),DCBOD(54,5),
87      + DCMAR(54,5),DCLUN(54,5),DGBOD(54,5),DGMAR(54,5),
88      + DGLUN(54,5),DIMAR(54,5),DILLIW(54,5),DITHY(54,5),
89      + DILUN(54,5),DISKE(54,5),TOTMAR(35),TOTBOD(35),
90      + TOTLUN(35),TOTLLIW(35),TOTSKE(35),TOTTHY(35)
91      COMMON/DP/ ASIGY(6,3),ASIGZ(6,3)
92      COMMON/RCTR/IPBWR
93 C
94      COMMON /STATIC/ NUCLID,NG,UDEP,BR,DISTO,NCALC,AREA,NOUT,
95      + RELTIM(2),IWEATH,UBAR,HEIGHT(2),DELTAT(2),UD,IFG,IFIMAR,
96      + IFILLIW,IFITHY,IFILUN,IFISKE,DIST,SIGY(2),SIGZ(2)
97      + ,CDUR(2),HGRAS(2),NPUF,IPROF,SHCS,SHGS,SHIN,WIDT
98 C
99 C
100 C  NG = NUMBER OF NUCLIDE GROUPS (9 as in STCP)
101 C  nuclid = number of radioisotopes (54 as in CRAC2)
102 C      groups: 1-noble gases; 2-12; 3-Cs; 4-Te;
103 C              5-Sr; 6-Ru; 7-La; 8-Ce; 9-Ba
104 C
105      OPEN(UNIT=1,FILE='DOSECR.DAT',STATUS='OLD')
106      IF(IPBWR.EQ.1)
107      + OPEN(UNIT=31,FILE='PWR.DAT',STATUS='OLD')
108      IF(IPBWR.EQ.2)
109      + OPEN(UNIT=31,FILE='BWR.DAT',STATUS='OLD')
110      NUCLID = 54
111      NG = 9
112 C
113 C      READ NUCLIDE MAP TO 9 GROUPS
114 C

```

```

115      READ(31,1) DUM
116 1      FORMAT(A1)
117      READ(31,*) (MAP(I),I=1,NUCLID)
118 C
119 C      READ MAP OF PARENT ISOTOPES
120 C
121      READ(31,1) DUM
122      READ(31,*) (IPAR(I),I=1,NUCLID)
123 C
124 C      READ INIT. INV. (CURIES) AND HALF LIVES (DAYS)
125 C
126      READ(31,1) DUM
127      READ(31,1) DUM
128      DO 10 I=1,NUCLID
129      READ(31,*) IDUM,QINV(I),HALF(I)
130 10      CONTINUE
131      DO 5000 I=1,NUCLID
132      HALF(I) = .693/(3600.*24.*HALF(I))
133 5000      CONTINUE
134 C
135 C      CONVERSION FACTORS FOR IMMERSION
136 C      IN CONTAMINATED AIR (REM PER CI-SEC/M**3)
137 C      WHOLE BODY, MARROW,LUNG,THYROID,LLIW
138 C
139      READ(1,1) DUM
140      READ(1,1) DUM
141      DO 20 I=1,NUCLID
142      READ(1,*) IDUM,FCBOD(I),FCMAR(I),FCLUN(I),FCTHY(I),FCLLIW(I)
143 20      CONTINUE
144 C
145 C      CONVERSION FACTORS FOR EXPOSURE TO
146 C      CONTAMINATED GROUND ( REM PER CI/M**2)
147 C      WHOLE BODY, MARROW,LUNG,THYROID,LLIW EACH FOR 1 AND 7 DAYS
148 C
149      READ(1,1) DUM
150      DO 30 IJK=1,2
151      READ(1,1) DUM
152      DO 31 I=1,NUCLID
153      READ(1,*) IDUM,FGBOD(I,IJK),FGMAR(I,IJK),FGLUN(I,IJK)
154      +      ,FGTHY(I,IJK),FGLLIW(I,IJK)
155 31      CONTINUE
156 30      CONTINUE
157 C
158 C      CONVERT TO 1 DAY EXPOSURE (APPROXIMATE)
159 C
160      DO 4045 N=1,NUCLID
161      FGLLIW(N,1) = FGLLIW(N,1) +
162      +      (FGLLIW(N,2)-FGLLIW(N,1))*0.22
163      FGTHY(N,1) = FGTHY(N,1) + (FGTHY(N,2)-FGTHY(N,1))*0.22
164      FGBOD(N,1) = FGBOD(N,1)*1.139
165      FGMAR(N,1) = FGMAR(N,1)*1.139
166      FGLUN(N,1) = FGLUN(N,1)*1.139
167 4045      CONTINUE
168 C
169 C      CRAC2 TABLE: WH. BODY INHAL. 0-2 DAYS ONLY
170 C
171      READ(1,1) DUME
172      DO 9988 I=1,NUCLID
173      READ(1,*) IDUM,FIBOD(I)
174 9988      CONTINUE

```

```

175 C
176 C
177 C      CONVERSION FACTORS FOR INHALED
178 C      RADIONUCLIDES (REM/CI)
179 C      MARROW, 0-2 DAYS, 0-30 DAYS, 0-30 YEARS
180 C
181      READ(1,1) DUM
182      DO 40 I=1,NUCLID
183      READ(1,*) IDUM,(FIMAR(I,J),J=1,4)
184 40 CONTINUE
185 C
186 C      SAME, LOWER LARGE INTESTINE WALL,
187 C      0-2 DAYS, 0-7 DAYS, 0-30 DAYS
188 C
189      READ(1,1) DUM
190      DO 50 I=1,NUCLID
191      READ(1,*) IDUM,(FILLIW(I,J),J=1,4)
192 50 CONTINUE
193 C
194 C      SAME, THYROID,
195 C      0-2 DAYS, 0-7 DAYS, 0-30 DAYS
196 C
197      READ(1,1) DUM
198      DO 60 I=1,NUCLID
199      READ(1,*) IDUM,(FITHY(I,J),J=1,4)
200 60 CONTINUE
201 C
202 C      SAME, LUNG
203 C      0-2 DAYS, 0-30 DAYS, 0-30 YEARS
204 C
205      READ(1,1) DUM
206      DO 70 I=1,NUCLID
207      READ(1,*) IDUM,(FILUN(I,J),J=1,5)
208 70 CONTINUE
209 C
210 C      SAME, SKELETON
211 C      0-2 DAYS, 0-7 DAYS, 0-30 DAYS, 0-1 YEAR, 0-30 YEARS
212 C
213      READ(1,1) DUM
214      DO 80 I=1,NUCLID
215      READ(1,*) IDUM,(FISKE(I,J),J=1,5)
216 80 CONTINUE
217 C
218 C      GRID DATA
219 C
220      READ(31,1) DUM
221      READ(31,*) NXDAT
222      READ(31,*) (XDAT(I),I=1,NXDAT)
223 C
224 C      READ DEFAULT VALUES FOR IF'S
225 C
226      READ(31,1) DUM
227      READ(31,*) IFG,IFIMAR,IFILLIW,IFITHY,IFILUN
228 C
229 C      DISPERSION COEFFICIENTS CURVE FITTING PARAMETERS
230 C
231      READ(31,1) DUM
232      DO 90 I=1,6
233      READ(31,*) IDUM,JDUM,(ASIGY(I,J),J=1,3)
234 90 CONTINUE

```

```
235      DO 91 I=1,6
236      READ(31,*) IDUM,JDUM,(ASIGZ(I,J),J=1,3)
237 91    CONTINUE
238 C
239 C      DEP. VELOCITY (M/S) AND BREATHING RATE (M**3/S)
240 C
241      READ(31,1) DUM
242      READ(31,*) UDEP,BR
243 C
244      CLOSE(1)
245      CLOSE(31)
246 C
247      RETURN
248      END
```

```

1      SUBROUTINE  COMP
2  C
6      COMMON/MORE/  IWHICH,FCTHY(54),FCLLIW(54),FGTHY(54,2),
7      +  FGLLIW(54,2), NXDAT,XDAT(35), DCTHY(54,5),DGTHY(54,5),
8      +  DCLLIW(54,5),DGLLIW(54,5), FCSTO(54),FGSTO(54,2),
9      +  FISTO(54),FCSMI(54),FGSMI(54,2),FISMI(54),
10     +  DCSTO(54,5),DGSTO(54,5),DISTO(54,5),
11     +  DCSMI(54,5),DGSMI(54,5),DISMI(54,5),
12     +  TOTSTO(35),TOTSMI(35),ISIG,ZBAR,IG
13  C
14     COMMON /VAR/  IPAR(54),MAP(54),QINV(54),HALF(54),FCBOD(54),
15     +  FCMAR(54),FCLUN(54),FCBOD(54,2),FGMAR(54,2),
16     +  FGLUN(54,2),FIBOD(54),FIMAR(54,4),FILLIW(54,4),
17     +  FITHY(54,4),FILUN(54,5),FISKE(54,5),DIBOD(54,5),
18     +  FRAC(9,5),Q(54,5),CHI(54,5),DCBOD(54,5),
19     +  DCMAR(54,5),DCLUN(54,5),DGBOD(54,5),DGMAR(54,5),
20     +  DGLUN(54,5),DIMAR(54,5),DILLIW(54,5),DITHY(54,5),
21     +  DILUN(54,5),DISKE(54,5),TOTMAR(35),TOTBOD(35),
22     +  TOTLUN(35),TOTLLIW(35),TOTSKE(35),TOTTHY(35)
23  C
24     COMMON/DP/  ASIGY(6,3),ASIGZ(6,3)
25     COMMON /STATIC/  NUCLID,NG,UDEP,BR,DISTO,NCALC,AREA,NOUT,
26     +  RELTIM(2),IWEATH,UBAR,HEIGHT(2),DELTAT(2),UD,IFG,IFIMAR,
27     +  IFILLIW,IFITHY,IFILUN,IFISKE,DIST,SIGY(2),SIGZ(2)
28     +  ,CDUR(2),HGRAS(2),NPUF,IPROF,SHCS,SHGS,SHIN,WIDT
29  C
30  C
31  C
32  C      CALCULATE RELEASES AS SPECIFIED IN INPUT
33  C
34     DO 10 I=1,NUCLID
35     IJ = MAP(I)
36     DO 11 J=1,NPUF
37     Q(I,J) = FRAC(IJ,J)*QINV(I)*EXP(-HALF(I)*RELTIM(J))
38  C
39  C      PARENT-DAUGHTER DECAY UP TO TIME OF RELEASE
40  C
41     IP = IPAR(I)
42     IF(IP.EQ.0) GOTO 11
43     QQQ = FRAC(IJ,J)*QINV(IP)
44     Q(I,J) = Q(I,J) + QQQ*
45     +  HALF(I)/(HALF(I)-HALF(IP)) *
46     +  (EXP(-HALF(IP)*RELTIM(J)) -
47     +  EXP(-HALF(I)*RELTIM(J)))
48 11  CONTINUE
49 10  CONTINUE
50  C
51  C      FOR COMPARISON WITH EXACT DATA
52  C
53     PI = 3.141592654
54     DO 100 NC=1,NXDAT
55     TM = 0.
56     TB = 0.
57     TL = 0.
58     TLL = 0.
59     TT = 0.
60     TSTO = 0.
61     TSMI = 0.
62     DIST = XDAT(NC)
63     IF(DIST.LT.1000.) DIST = 1.5*DIST

```

```

64 C      FIRST SPATIAL CORRECTED FOR COMP. WITH CRAC
65      DX = 0.
66      IF(NC.LT.(NXDAT-1)) DX = (XDAT(NC+1)-DIST)/2.
67      IF(NC.LT.3) DX = 0.
68      DO 999 NP = 1,NPUF
69      IF(NC.NE.1) GOTO 47
70      HITE = 0.0
71      IF(HEIGHT(NP).GT.AREA) HITE = HEIGHT(NP)
72 47      CONTINUE
73 C
74 C      CALCULATE SIGMAY AND SIGMAZ
75 C
76      DXPOL = 0.
77      IF(ISIG.EQ.1) CALL SIG(NP,SY,SZ,DXPOL)
78      IF(ISIG.EQ.2) CALL SIGCR(NP,NC,SY,SZ,DX)
79 C
80 C
81      SIGY(NP) = SY
82      SIGZ(NP) = SZ
83      ZMAX = 1000.
84      CAP = .8
85 C
86 C      USE THIS IF IN MACCS ZMAX = 800.
87 C      IF(IWHICH.EQ.2) CAP = .64
88      IF(SIGZ(NP).GT.(CAP*ZMAX)) SIGZ(NP) = CAP*ZMAX
89 C
90 C      CALCULATE CENTERLINE DOSE
91 C
92      TIME1 = (DIST+DX)/UBAR
93      CALL ZZBAR(NP,DX,TIME1,HITE)
94      ZBAR = SQRT(2./PI)*SIGZ(NP)*EXP(HITE**2/2./SIGZ(NP)**2)
95      DENOM = PI*UBAR*SIGY(NP)*SIGZ(NP)
96      DENOM1 = 3./2.*SQRT(2.*PI)*UBAR*SIGY(NP)*SIGZ(NP)
97      ZZ4 = HITE**2 / (2.*SIGZ(NP)**2)
98      TIME = DIST/UBAR
99      DO 101 N=1,NUCLID
100      KKK = MAP(N)
101      UDD = UDEP
102      IF(KKK.NE.1) GOTO 3789
103      UDD = 0.
104 3789      CONTINUE
105      ZZ1 = UDD*(DIST+DX)/(UBAR*ZBAR)
106      ALAMW = 1.E-05
107      IF(IWEATH.GT.3) ALAMW = 1.E-02
108      ZZ2 = ALAMW * DELTAT(NP)
109      ZZ3 = HALF(N) * TIME
110      SUM = ZZ1 + ZZ2 + ZZ4
111      QQ = 0.0
112      IF(ZZ3.GT.90.) GOTO 10000
113      QQ = Q(N,NP) * EXP( -ZZ3 )
114 10000      CONTINUE
115      IP = IPAR(N)
116      IF(IP.EQ.0) GOTO 475
117 C
118 C      CORRECTION FOR PARENT-DAUGHTER
119 C
120      IJK = MAP(N)
121      QQQ = Q(IP,NP)
122      EX1 = 0.
123      IF((HALF(IP)*TIME).GT.90.) GOTO 11000

```

```

124      EX1 = EXP(-HALF(IP)*TIME)
125 11000  CONTINUE
126      EX2 = 0.0
127      IF((HALF(N)*TIME).GT.90.) GOTO 11001
128      EX2 = EXP(-HALF(N)*TIME)
129 11001  CONTINUE
130      QQ = QQ+QQQ*HALF(N)/(HALF(N)-HALF(IP)) * (EX1-EX2)
131 475    CONTINUE
132      CHI(N,NP) = 0.0
133      IF(SUM.GT.90.) GOTO 101
134      IF(IPROF.EQ.2)
135          + CHI(N,NP) = QQ / DENOM * EXP( - SUM )
136      IF(IPROF.EQ.1)
137          + CHI(N,NP) = QQ /DENOM1 * EXP( - SUM )
138 101    CONTINUE
139 C
140 C      CLOUDSHINE
141 C
142      HH = HEIGHT(NP)
143      SS = SIGZ(NP)
144      IF(IWHICH.EQ.2) SS = SQRT(SIGY(NP)*SIGZ(NP))
145      CALL SHINCF(SS,HH,SHN)
146      DO 102 N=1,NUCLID
147          DCBOD(N,NP) = SHN*SHCS*CHI(N,NP)*FCBOD(N)
148          DCMAR(N,NP) = SHN*SHCS*CHI(N,NP)*FCMAR(N)
149          DCLUN(N,NP) = SHN*SHCS*CHI(N,NP)*FCLUN(N)
150          DCTHY(N,NP) = SHN*SHCS*CHI(N,NP)*FCTHY(N)
151          DCLLIW(N,NP) = SHN*SHCS*CHI(N,NP)*FCLLIW(N)
152          DCSTO(N,NP) = SHN*SHCS*CHI(N,NP)*FCSTO(N)
153          DCSMI(N,NP) = SHN*SHCS*CHI(N,NP)*FCSMI(N)
154 102    CONTINUE
155 C
156 C      GROUNDSHINE
157 C
158      DELTT = (DIST+DX)/UBAR/3600.
159      IF(DELTT.GT.24.) DELTT = 0.
160      CONF = 24./(24.-DELTT)
161      DO 103 N=1,NUCLID
162          UUU = (UDEP+ALAMW*TTRR*UBAR*ZBAR/DIST)*CONF
163          IF(MAP(N).EQ.1) UUU = 0.
164          DGBOD(N,NP) = UUU*SHGS*CHI(N,NP)*FGBOD(N,IFG)
165          DGMAR(N,NP) = UUU*SHGS*CHI(N,NP)*FGMAR(N,IFG)
166          DGLUN(N,NP) = UUU*SHGS*CHI(N,NP)*FGLUN(N,IFG)
167          DGTHY(N,NP) = UUU*SHGS*CHI(N,NP)*FGTHY(N,IFG)
168          DGLLIW(N,NP) = UUU*SHGS*CHI(N,NP)*FGLLIW(N,IFG)
169          DGSTO(N,NP) = UUU*SHGS*CHI(N,NP)*FGSTO(N,IFG)
170          DGSMI(N,NP) = UUU*SHGS*CHI(N,NP)*FGSMI(N,IFG)
171 103    CONTINUE
172 C
173 C      INHALATION
174 C
175      DO 104 N=1,NUCLID
176          DIBOD(N,NP) = BR*SHIN*CHI(N,NP)*FIBOD(N)
177          DIMAR(N,NP) = BR*SHIN*CHI(N,NP)*FIMAR(N,IFIMAR)
178          DILLIW(N,NP) = BR*SHIN*CHI(N,NP)*FILLIW(N,IFILLIW)
179          DITHY(N,NP) = BR*SHIN*CHI(N,NP)*FITHY(N,IFITHY)
180          DILUN(N,NP) = BR*SHIN*CHI(N,NP)*FILUN(N,IFILUN)
181          DISTO(N,NP) = BR*SHIN*CHI(N,NP)*FISTO(N)
182          DISMI(N,NP) = BR *SHIN*CHI(N,NP)*FISMI(N)
183 104    CONTINUE

```



```

184 C
185 C
186 DO 105 N=1,NUCLID
187 TB = TB + DIBOD(N,NP) + DCBOD(N,NP) + DGBOD(N,NP)
188 TM = TM + DCMAR(N,NP) + DGMAR(N,NP) + DIMAR(N,NP)
189 TL = TL + DGLUN(N,NP) + DCLUN(N,NP) + DILUN(N,NP)
190 TLL = TLL + DCLLIW(N,NP)+DGLLIW(N,NP)+DILLIW(N,NP)
191 TT = TT + DCTHY(N,NP) + DGTHY(N,NP) + DITHY(N,NP)
192 TSTO = TSTO + DCSTO(N,NP) + DGSTO(N,NP) + DISTO(N,NP)
193 TSMI = TSMI + DCSMI(N,NP) + DGSMI(N,NP) + DISMI(N,NP)
194 105 CONTINUE
195 999 CONTINUE
196 TOTSTO(NC) = TSTO
197 TOTSMI(NC) = TSMI
198 TOTMAR(NC) = TM
199 TOTBOD(NC) = TB
200 TOTLUN(NC) = TL
201 TOTLLIW(NC) = TLL
202 TOTTHY(NC) = TT
203 IF(IWHICH.EQ.1) CALL CROUT(NC)
204 IF(IWHICH.EQ.2) CALL MAOUT(NC)
205 CALL EFFEC(NC)
206 3786 CONTINUE
207 100 CONTINUE
208 C
209 C
210 RETURN
211 END

1 SUBROUTINE EFFEC(NC)
2 C
3 C
4 COMMON/MORE/ IWHICH,FCTHY(54),FCLLIW(54),FGTHY(54,2),
5 + FGLLIW(54,2), NXDAT,XDAT(35), DCTHY(54,5),DGTHY(54,5),
6 + DCLLIW(54,5),DGLLIW(54,5), FCSTO(54),FGSTO(54,2),
7 + FISTO(54),FCSMI(54),FGSMI(54,2),FISMI(54),
8 + DCSTO(54,5),DGSTO(54,5),DISTO(54,5),
9 + DCSMI(54,5),DGSMI(54,5),DISMI(54,5),
10 + TOTSTO(35),TOTSMI(35),ISIG,ZBAR,IG
11 C
12 COMMON /VAR/ IPAR(54),MAP(54),QINV(54),HALF(54),FCBOD(54),
13 + FCMAR(54),FCLUN(54),FGBOD(54,2),FGMAR(54,2),
14 + FGLUN(54,2),FIBOD(54),FIMAR(54,4),FILLIW(54,4),
15 + FITHY(54,4),FILUN(54,5),FISKE(54,5),DIBOD(54,5),
16 + FRAC(9,5),Q(54,5),CHI(54,5),DCBOD(54,5),
17 + DCMAR(54,5),DCLUN(54,5),DGBOD(54,5),DGMAR(54,5),
18 + DGLUN(54,5),DIMAR(54,5),DILLIW(54,5),DITHY(54,5),
19 + DILUN(54,5),DISKE(54,5),TOTMAR(35),TOTBOD(35),
20 + TOTLUN(35),TOTLLIW(35),TOTSKE(35),TOTTHY(35)
21 COMMON/DP/ ASIGY(6,3),ASIGZ(6,3)
22 C
23 COMMON /STATIC/ NUCLID,NG,UDEP,BR,DISTO,NCALC,AREA,NOUT,
24 + RELTIM(2),IWEATH,UBAR,HEIGHT(2),DELTAT(2),UD,IFG,IFIMAR,
25 + IFILLIW,IFITHY,IFILUN,IFISKE,DIST,SIGY(2),SIGZ(2)
26 + ,CDUR(2),HGRAS(2),NPUF,IPOF,SHCS,SHGS,SHIN,WIDT
27 C
28 REAL*8 H1,H2,H3,H4,H5,H6,R,R1,ALPHA,BETA,XXX,HTOT
29 C
30 C EARLY FATALITIES : LUNG

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31 C          MARROW
32 C          LLIW
33 C
34          DIMENSION DBPM(4),DBPLLI(4),DBPL(4),PM(4),PLLI(4),PL(4)
35          DATA DBPM/ 320., 400., 510., 615./
36          DATA PM/ 0., .03, .5, 1./
37          DATA DBPLLI/ 2000., 5000., 5000., 5000./
38          DATA PLLI/ 0., 1., 1., 1./
39          DATA DBPL/ 5000., 14800., 22400., 24000./
40          DATA PL/ 0., .24, .73, 1./
41 C
42 C
43          IF(IWHICH.EQ.2) GOTO 10000
44          XLUN = TOTLUN(NC)
45          P1 = 0.
46          IF(XLUN.LE.DBPL(1)) GOTO 10
47          IF(XLUN.GT.DBPL(4)) GOTO 30
48          DO 20 I=1,3
49              IM = 1
50              IF(XLUN.GT.DBPL(I).AND.XLUN.LE.DBPL(I+1)) GOTO 21
51 20          CONTINUE
52 21          CONTINUE
53              P1 = PL(IM) + (PL(IM+1)-PL(IM))*
54          +      (XLUN-DBPL(IM))/(DBPL(IM+1)-DBPL(IM))
55              GOTO 10
56 30          P1 = PL(4)
57 10          CONTINUE
58 C
59          XMAR = TOTMAR(NC)
60          P2 = 0.
61          IF(XMAR.LE.DBPM(1)) GOTO 100
62          IF(XMAR.GT.DBPM(4)) GOTO 300
63          DO 200 I=1,3
64              IM = 1
65              IF(XMAR.GT.DBPM(I).AND.XMAR.LE.DBPM(I+1)) GOTO 210
66 200          CONTINUE
67 210          CONTINUE
68              P2 = PM(IM) + (PM(IM+1)-PM(IM))*
69          +      (XMAR-DBPM(IM))/(DBPM(IM+1)-DBPM(IM))
70              GOTO 100
71 300          P2 = PM(4)
72 100          CONTINUE
73 C
74          XLLIW = TOTLLIW(NC)
75          P3 = 0.
76          IF(XLLIW.LE.DBPLLI(1)) GOTO 230
77          IF(XLLIW.GT.DBPLLI(4)) GOTO 400
78          DO 211 I=1,3
79              IM = 1
80              IF(XLLIW.GT.DBPLLI(I).AND.XLLIW.LE.DBPLLI(I+1)) GOTO 220
81 211          CONTINUE
82 220          CONTINUE
83              P3 = PLLI(IM) + (PLLI(IM+1)-PLLI(IM))*
84          +      (XLLIW-DBPLLI(IM))/(DBPLLI(IM+1)-DBPLLI(IM))
85              GOTO 230
86 400          P3 = PLLI(4)
87 230          CONTINUE
88          PROB = P1 + (1.-P1)*P2 + (1.-P1)*(1.-P2)*P3
89 C
90          WRITE(2,1000)    PROB

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91 1000      FORMAT(/, ' CRAC2 PROBABILITY OF EARLY FATALITIES = ',
92          +   F10.3,/)
93          RETURN
94 C
95 C          EARLY HEALTH EFFECTS
96 C
97 C          MACCS MODEL
98 10000      CONTINUE
99          ALPHA = 4.D+00
100          BETA = 6.D+00
101          XXX = TOTMAR(NC)
102          H1 = .693D+00*(XXX/(ALPHA*100.D+00))**BETA
103          ALPHA = 8.D+00
104          BETA = 3.D+00
105          XXX = TOTLUN(NC)
106          H2 = .693D+00*(XXX/(ALPHA*100.D+00))**BETA
107          ALPHA = 15.D+00
108          BETA = 10.D+00
109          XXX = TOTSMI(NC)
110          H3 = .693D+00*(XXX/(ALPHA*100.D+00))**BETA
111          XXX = TOTLLIW(NC)
112          H4 = .693D+00*(XXX/(ALPHA*100.D+00))**BETA
113          HTOT = H1+H2+H3+H4
114          R = 1.D+00
115          IF(HTOT.GT.230.D+00) GOTO 10001
116          R = 1.D+00-DEXP(-(HTOT))
117 10001      CONTINUE
118          WRITE(2,1010) R
119 1010      FORMAT('          PROBABILITY OF EARLY FATALITIES, MACCS = ',
120          +   D10.3)
121 C
122 C          EARLY INJURIES
123 C
124          ALPHA = 1.8D+00
125          BETA = 3.D+00
126          XXX = TOTSTO(NC)
127          H5 = .693D+00*(XXX/(ALPHA*100.D+00))**BETA
128          ALPHA = 4.D+00
129          XXX = TOTLUN(NC)
130          H6 = .693D+00*(XXX/(ALPHA*100.D+00))**BETA
131          R1 = 1.D+00
132          HTOT = H5 + H6
133          IF(HTOT.GT.230.D+00) GOTO 10002
134          R1 = 1.D+00 - DEXP(-(H5+H6))
135 10002      CONTINUE
136          WRITE(2,1020) R1
137 1020      FORMAT('          PROBABILITY OF EARLY INJURIES = ',
138          +   D10.3)
139 C
140          RETURN
141          END

1          SUBROUTINE CROUT(NC)
2 C
3 C
4 C
5          COMMON/MORE/ IWHICH, FCTHY(54), FCLLIW(54), FGTHY(54,2),
6          +   FGLLIW(54,2), NXDAT, XDAT(35), DCTHY(54,5), DGTHY(54,5),
7          +   DCLLIW(54,5), DGLLIW(54,5), FCSTO(54), FGSTO(54,2),

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1      SUBROUTINE CROUT(NC)
2  C
3  C
4  C
5      COMMON/MORE/ IWHICH, FCTHY(54), FCLLIW(54), FGTHY(54,2),
6  +    FGLLIW(54,2), NXDAT, XDAT(35), DCTHY(54,5), DGTHY(54,5),
7  +    DCLLIW(54,5), DGLLIW(54,5), FCSTO(54), FGSTO(54,2),
8  +    FISTO(54), FCSMI(54), FGSMI(54,2), FISMI(54),
9  +    DCSTO(54,5), DGSTO(54,5), DISTO(54,5),
10 +    DCSMI(54,5), DGSMI(54,5), DISMI(54,5),
11 +    TOTSTO(35), TOTSMI(35), ISIG, ZBAR, IG
12 C
13     COMMON /VAR/ IPAR(54), MAP(54), QINV(54), HALF(54), FCBOD(54),
14 +    FCMAR(54), FCLUN(54), FGBOD(54,2), FGMAR(54,2),
15 +    FGLUN(54,2), FIBOD(54), FIMAR(54,4), FILLIW(54,4),
16 +    FITHY(54,4), FILUN(54,5), FISKE(54,5), DIBOD(54,5),
17 +    FRAC(9,5), Q(54,5), CHI(54,5), DCBOD(54,5),
18 +    DCMAR(54,5), DCLUN(54,5), DGBOD(54,5), DGMAR(54,5),
19 +    DGLUN(54,5), DIMAR(54,5), DILLIW(54,5), DITHY(54,5),
20 +    DILUN(54,5), DISKE(54,5), TOTMAR(35), TOTBOD(35),
21 +    TOTLUN(35), TOTLLIW(35), TOTSKE(35), TOTTHY(35)
22 C
23     COMMON/DP/ ASIGY(6,3), ASIGZ(6,3)
24     COMMON /STATIC/ NUCLID, NG, UDEP, BR, DISTO, NCALC, AREA, NOUT,
25 +    RELTIM(2), IWEATH, UBAR, HEIGHT(2), DELTAT(2), UD, IFG, IFIMAR,
26 +    IFILLIW, IFITHY, IFILUN, IFISKE, DIST, SIGY(2), SIGZ(2)
27 +    , CDUR(2), HGRAS(2), NPUF, IPROF, SHCS, SHGS, SHIN, WIDT
28 C
29     CHARACTER*8 NAME(54)
30     CHARACTER*1 CLASS
31     DIMENSION GRBOD(9), GRMAR(9), GRLUN(9), GRLLIW(9),
32 +    GRTHY(9), GRSKE(9)
33 C
34 C
35     IF(IWEATH.EQ.1) CLASS = 'F'
36     IF(IWEATH.EQ.2) CLASS = 'E'
37     IF(IWEATH.EQ.3) CLASS = 'D'
38     IF(IWEATH.EQ.4) CLASS = 'C'
39     IF(IWEATH.EQ.5) CLASS = 'B'
40     IF(IWEATH.EQ.6) CLASS = 'A'
41     WRITE(2,30030)
42 30030  FORMAT(/,5X,20(1H*), ' CRAC CONVERSION FACTORS',
43 +    3X,20(1H*), '/')
44     NAME(1) = 'CO-58'
45     NAME(2) = 'CO-60'
46     NAME(3) = 'KR-85'
47     NAME(4) = 'KR-85M'
48     NAME(5) = 'KR-87'
49     NAME(6) = 'KR-88'
50     NAME(7) = 'RB-86'
51     NAME(8) = 'SR-89'
52     NAME(9) = 'SR-90'
53     NAME(10) = 'SR-91'
54     NAME(11) = 'Y-90'
55     NAME(12) = 'Y-91'
56     NAME(13) = 'ZR-95'
57     NAME(14) = 'ZR-97'
58     NAME(15) = 'NB-95'

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59      NAME(16) = 'MO-99'
60      NAME(17) = 'TC-99M'
61      NAME(18) = 'RU-103'
62      NAME(19) = 'RU-105'
63      NAME(20) = 'RU-106'
64      NAME(21) = 'RH-105'
65      NAME(22) = 'TE-127'
66      NAME(23) = 'TE-127M'
67      NAME(24) = 'TE-129'
68      NAME(25) = 'TE-129M'
69      NAME(26) = 'TE-131M'
70      NAME(27) = 'TE-132'
71      NAME(28) = 'SB-127'
72      NAME(29) = 'SB-129'
73      NAME(30) = 'I-131'
74      NAME(31) = 'I-132'
75      NAME(32) = 'I-133'
76      NAME(33) = 'I-134'
77      NAME(34) = 'I-135'
78      NAME(35) = 'XE-133'
79      NAME(36) = 'XE-135'
80      NAME(37) = 'CS-134'
81      NAME(38) = 'CS-136'
82      NAME(39) = 'CS-137'
83      NAME(40) = 'BA-140'
84      NAME(41) = 'LA-140'
85      NAME(42) = 'CE-141'
86      NAME(43) = 'CE-143'
87      NAME(44) = 'CE-144'
88      NAME(45) = 'PR-143'
89      NAME(46) = 'ND-147'
90      NAME(47) = 'NP-239'
91      NAME(48) = 'PU-238'
92      NAME(49) = 'PU-239'
93      NAME(50) = 'PU-240'
94      NAME(51) = 'PU-241'
95      NAME(52) = 'AM-241'
96      NAME(53) = 'CM-242'
97      NAME(54) = 'CM-244'
98 C
99      WRITE(2,1000) XDAT(NC),UBAR
100 1000      FORMAT(///,
101            +      '      DISTANCE = ',1PE12.3,' M',/,
102            +      '      WIND VELOCITY = ',1PE12.3,' M/S',/
103            +      )
104      IF(IG.EQ.1) WRITE(2,1009)
105 1009      FORMAT('      ATMOSPHERIC STABILITY CLASS G',/)
106      IF(IG.EQ.0) WRITE(2,1019) CLASS
107 1019      FORMAT('      ATMOSPHERIC STABILITY CLASS ',A1,/)
108 C
109      DO 999 NP=1,NPUF
110      WRITE(2,40999) NP
111 40999      FORMAT(//,'      PUFF NUMBER ',I4,/)
112      DCBT = 0.
113      DGBT = 0.
114      DCMT = 0.
115      DGMT = 0.
116      DCLT = 0.
117      DGLT = 0.
118      DCTT = 0.

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119      DGTT = 0.
120      DCLLT = 0.
121      DGLLT = 0.
122      DIBT = 0.
123      DIMT = 0.
124      DILT = 0.
125      DITT = 0.
126      DILLT = 0.
127      DO 3033 N=1,NUCLID
128          DCBT = DCBT + DCBOD(N,NP)
129          DGBT = DGBT + DGBOD(N,NP)
130          DCMT = DCMT + DCMAR(N,NP)
131          DGMT = DGMT + DGMAR(N,NP)
132          DCLT = DCLT + DCLUN(N,NP)
133          DGLT = DGLT + DGLUN(N,NP)
134          DCTT = DCTT + DCTHY(N,NP)
135          DGTT = DGTT + DGTHY(N,NP)
136          DCLLT = DCLLT + DCLLIW(N,NP)
137          DGLLT = DGLLT + DGLLIW(N,NP)
138          DIBT = DIBT + DIBOD(N,NP)
139          DIMT = DIMT + DIMAR(N,NP)
140          DILT = DILT + DILUN(N,NP)
141          DITT = DITT + DITHY(N,NP)
142          DILLT = DILLT + DILLIW(N,NP)
143 3033      CONTINUE
144          WRITE(2,20001) SIGY(NP),SIGZ(NP)
145 20001      FORMAT(' HORIZONTAL DISPERSION COEFFICIENT = ',
146          +      1PE12.3,' M',/,
147          +      ' VERTICAL DISPERSION COEFFICIENT = ',
148          +      1PE12.3,' M',/)
149          WRITE(2,2333)
150 2333      FORMAT(/,40X,'CLOUD SHINE',/)
151          WRITE(2,2334)
152 2334      FORMAT(2X,10X,'WHOLE BODY ',1X,' MARROW ',1X,
153          +      ' LUNG ',1X,' THYROID ',
154          +      ' LLIW ',/)
155          IF(NOUT.NE.1) GOTO 3456
156          DO 2500 N=1,NUCLID
157              WRITE(2,2501) NAME(N),DCBOD(N,NP),DCMAR(N,NP),DCLUN(N,NP),
158              +      DCTHY(N,NP),DCLLIW(N,NP)
159 2501      FORMAT(2X,1X,A8,1X,5(1PE9.3,1X))
160 3034      FORMAT(2X,60(1H_),/,2X,' TOTAL ',2X,5(1PE9.3,1X))
161 2500      CONTINUE
162 3456      CONTINUE
163          WRITE(2,3034) DCBT,DCMT,DCLT,DCTT,DCLLT
164          WRITE(2,2502)
165 2502      FORMAT(/,40X,'GROUND SHINE',/)
166          WRITE(2,2334)
167          IF(NOUT.NE.1) GOTO 3457
168          DO 2600 N=1,NUCLID
169              WRITE(2,2501) NAME(N),DGBOD(N,NP),DGMAR(N,NP),DGLUN(N,NP),
170              +      DGTHY(N,NP),DGLLIW(N,NP)
171 2600      CONTINUE
172 3457      CONTINUE
173          WRITE(2,3034) DGBT,DGMT,DGLT,DGTT,DGLLT
174          WRITE(2,2503)
175 2503      FORMAT(/,40X,' INHALATION',/)
176          WRITE(2,2334)
177          IF(NOUT.NE.1) GOTO 3458
178          DO 2700 N=1,NUCLID

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179      WRITE(2,2501) NAME(N),DIBOD(N,NP),DIMAR(N,NP),
180      +      DILUN(N,NP),DITHY(N,NP),DILLIW(N,NP)
181 2700    CONTINUE
182 3458    CONTINUE
183      WRITE(2,3034) DIET,DIMT,DILT,DITT,DILLT
184 999     CONTINUE
185 C
186      WRITE(2,20002) TOTBOD(NC),TOTMAR(NC),TOTLUN(NC),
187      +      TOTLLIW(NC),TOTTHY(NC)
188 20002    FORMAT(////, '      TOTAL BODY DOSE      = ',1PE12.3,/,
189      +      '      TOTAL MARROW DOSE      = ',1PE12.3,/,
190      +      '      TOTAL LUNG DOSE      = ',1PE12.3,/,
191      +      '      TOTAL LLIW DOSE      = ',1PE12.3,/,
192      +      '      TOTAL THYROID DOSE     = ',1PE12.3,/,
193      +      //)
194 C
195 C
196      IF(NOUT.NE.1) RETURN
197      DO 4040 I=1,NG
198      GRBOD(I) = 0.
199      GRMAR(I) = 0.
200      GRLUN(I) = 0.
201      GRLLIW(I) = 0.
202      GRTHY(I) = 0.
203 4040    CONTINUE
204      DO 4041 NP=1,NPUF
205      DO 4041 IJ=1,NUCLID
206      I = MAP(IJ)
207      GRBOD(I) = GRBOD(I) + DCBOD(IJ,NP) + DGBOD(IJ,NP)
208      +      + DIBOD(IJ,NP)
209      GRMAR(I) = GRMAR(I) + DCMAR(IJ,NP) + DGMAR(IJ,NP) +
210      +      DIMAR(IJ,NP)
211      GRLUN(I) = GRLUN(I) + DCLUN(IJ,NP) + DGLUN(IJ,NP) +
212      +      DILUN(IJ,NP)
213      GRLLIW(I) = GRLLIW(I) + DILLIW(IJ,NP)
214      +      DGLLIW(IJ,NP) + DCLLIW(IJ,NP)
215      GRTHY(I) = GRTHY(I) + DITHY(IJ,NP)
216      +      DGTHY(IJ,NP) + DCTHY(IJ,NP)
217 4041    CONTINUE
218      WRITE(2,30333)
219 30333    FORMAT(////, '      GROUP: ',1X,10H  XE-KR      ,1X,
220      +      10H      I      ,1X,10H      CS      ,1X,
221      +      10H      TE      ,1X,10H      SR      ,1X,
222      +      10H      RU      ,1X,10H      LA      ,1X,
223      +      10H      CE      ,1X,10H      BA      ,/)
224      WRITE(2,30334) ( GRBOD(IJ),IJ=1,NG)
225 30334    FORMAT('  WHOLE BODY',9(1X,1PE10.3))
226      WRITE(2,30335) (GRMAR(IJ),IJ=1,NG)
227 30335    FORMAT('  MARROW      ',9(1X,1PE10.3))
228      WRITE(2,30336) ( GRLUN(IJ),IJ=1,NG)
229 30336    FORMAT('  LUNG      ',9(1X,1PE10.3))
230      WRITE(2,30337) ( GRLLIW(IJ),IJ=1,NG)
231 30337    FORMAT('  LLIW      ',9(1X,1PE10.3))
232      WRITE(2,30338) (GRTHY(IJ),IJ=1,NG)
233 30338    FORMAT('  THYROID     ',9(1X,1PE10.3))
234 C
235 C
236      RETURN
237      END

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238      SUBROUTINE SIG(K,SY,SZ,DX)
239 C
240 C
241 C
242      COMMON/MORE/ IWHICH,FC THY(54),FCLLIW(54),FGTHY(54,2),
243 +      FGLLIW(54,2), NXDAT,XDAT(35), DCTHY(54,5),DGTHY(54,5),
244 +      DCLLIW(54,5),DGLLIW(54,5), FCSTO(54),FGSTO(54,2),
245 +      FISTO(54),FCSMI(54),FGSMI(54,2),FISMI(54),
246 +      DCSTO(54,5),DGSTO(54,5),DISTO(54,5),
247 +      DCSMI(54,5),DGSMI(54,5),DISMI(54,5),
248 +      TOTSTO(35),TOTSMI(35),ISIG,ZBAR,IG
249 C
250      COMMON /VAR/ IPAR(54),MAP(54),QINV(54),HALF(54),FCBOD(54),
251 +      FCMAR(54),FCLUN(54),FGBOD(54,2),FGMAR(54,2),
252 +      FGLUN(54,2),FIBOD(54),FIMAR(54,4),FILLIW(54,4),
253 +      FITHY(54,4),FILUN(54,5),FISKE(54,5),DIBOD(54,5),
254 +      FRAC(9,5),Q(54,5),CHI(54,5),DCBOD(54,5),
255 +      DCMAR(54,5),DCLUN(54,5),DGBOD(54,5),DGMAR(54,5),
256 +      DGLUN(54,5),DIMAR(54,5),DILLIW(54,5),DITHY(54,5),
257 +      DILUN(54,5),DISKE(54,5),TOTMAR(35),TOTBOD(35),
258 +      TOTLUN(35),TOTLLIW(35),TOTSKE(35),TOTTHY(35)
259 C
260      COMMON/DP/ ASIGY(6,3),ASIGZ(6,3)
261      COMMON /STATIC/ NUCLID,NG,UDEP,BR,DISTO,NCALC,AREA,NOUT,
262 +      RELTIM(2),IWEATH,UBAR,HEIGHT(2),DELTAT(2),UD,IFG,IFIMAR,
263 +      IFILLIW,IFITHY,IFILUN,IFISKE,DIST,SIGY(2),SIGZ(2)
264 +      ,CDUR(2),HGRAS(2),NPUF,I PROF,SHCS,SHGS,SHIN,WIDT
265 C
266 C
267 C
268      XX = DIST
269      XX = LOG(XX)
270      XZ = DIST + DX
271      XZ = LOG(XZ)
272      SY = 0.
273      SZ = 0.
274      DO 10 J=1,3
275      SY = SY + ASIGY(IWEATH,J)*XX**(J-1)
276      SZ = SZ + ASIGZ(IWEATH,J)*XZ**(J-1)
277 10 CONTINUE
278      SY = EXP(SY)
279      SZ = EXP(SZ)
280      IF(IG.EQ.0) GOTO 20
281      SY = 0.666666 * SY
282      SZ = 0.6 * SZ
283 20 CONTINUE
284 C
285 C      CORRECTIONS FOR DURATION AND HEIGHT OF GRASS
286 C
287      SY = SY * CDUR(K)
288      SZ = SZ * HGRAS(K)
289 C
290 C      BUILDING WAKE CORRECTION (GEOMETRIC)
291 C
292      SY = SQRT (SY**2 + (WIDT*AREA)/6.28)
293      SZ = SQRT (SZ**2 + (WIDT*AREA)/6.28)
294 C
295 C
296      RETURN

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297      END

298      SUBROUTINE RDR2
299 C
300 C
301 C
302      COMMON/MORE/ IWHICH, FCTHY(54), FCLLIW(54), FGTHY(54,2),
303 +      FGLLIW(54,2), NXDAT, XDAT(35), DCTHY(54,5), DGTHY(54,5),
304 +      DCLLIW(54,5), DGLLIW(54,5), FCSTO(54), FGSTO(54,2),
305 +      FISTO(54), FCSMI(54), FGSMI(54,2), FISMI(54),
306 +      DCSTO(54,5), DGSTO(54,5), DISTO(54,5),
307 +      DCSMI(54,5), DGSMI(54,5), DISMI(54,5),
308 +      TOTSTO(35), TOTSMI(35), ISIG, ZBAR, IG
309 C
310      COMMON /VAR/ IPAR(54), MAP(54), QINV(54), HALF(54), FCBOD(54),
311 +      FCMAR(54), FCLUN(54), FGBOD(54,2), FGMAR(54,2),
312 +      FGLUN(54,2), FIBOD(54), FIMAR(54,4), FILLIW(54,4),
313 +      FITHY(54,4), FILUN(54,5), FISKE(54,5), DIBOD(54,5),
314 +      FRAC(9,5), Q(54,5), CHI(54,5), DCBOD(54,5),
315 +      DCMAR(54,5), DCLUN(54,5), DGBOD(54,5), DGMAR(54,5),
316 +      DGLUN(54,5), DIMAR(54,5), DILLIW(54,5), DITHY(54,5),
317 +      DILUN(54,5), DISKE(54,5), TOTMAR(35), TOTBOD(35),
318 +      TOTLUN(35), TOTLLIW(35), TOTSKE(35), TOTTHY(35)
319      COMMON/RCTR/ IPBWR
320      COMMON/DP/ ASIGY(6,3), ASIGZ(6,3)
321      COMMON/ENRGY/ ENEREL(2)
322 C
323      COMMON /STATIC/ NUCLID, NG, UDEP, BR, DISTO, NCALC, AREA, NOUT,
324 +      RELTIM(2), IWETH, UBAR, HEIGHT(2), DELTAT(2), UD, IFG, IFIMAR,
325 +      IFILLIW, IFITHY, IFILUN, IFISKE, DIST, SIGY(2), SIGZ(2)
326 +      , CDUR(2), HGRAS(2), NPUF, IPROF, SHCS, SHGS, SHIN, WIDT
327 C
328      DIMENSION PI(6)
329      DATA PI/ .55, .35, .15, .1, .07, .07/
330 C
331 C      ON-LINE SELECTION OF INPUTS AND PARAMETERS
332 C
333      WRITE(6,80)
334 80      FORMAT('      SELECT OUTPUT CONTROL :',/,
335 +      '          1 = DETAILED NUCLIDE INVENTORY',/,
336 +      '          2 = ABBREVIATED OUTPUT',/)
337      READ(5,*) NOUT
338      WRITE(6,81)
339 81      FORMAT(' IF YOU WISH TO REPEAT THE RUN WITHOUT',
340 +      ' CHANGING REMAINING INPUT PARAMETERS, ENTER 1',/)
341      READ(5,*) JSKIP
342      IF(JSKIP.EQ.1) RETURN
343      WRITE(6,82)
344 82      FORMAT(' IF YOU WANT TO CHANGE WEATHER CLASS ONLY ENTER 1',/)
345      READ(5,*) ICHW
346      IF(ICHW.EQ.1) GOTO 83
347      PPO = 3412.
348      IF(IPBWR.EQ.2) PPO = 3578.
349      WRITE(6,90) PPO
350 90      FORMAT('      ENTER SCALING FACTOR FOR CORE INV.',/,
351 +      '      REFERENCE POWER = ', F12.1, ' MWTH ',/)
352      READ(5,*) POWER
353      DO 91 I=1, NUCLID
354 91      QINV(I) = QINV(I) * POWER

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```

355      WRITE(6,100)
356 100    FORMAT('    ENTER NUMBER OF PUFFS, UP TO 2 ALLOWED',/)
357      READ(5,*) NPUF
358      DO 999 NP=1,NPUF
359      WRITE(6,1000) NP
360 1000   FORMAT('    ENTER RELEASE FRACTIONS FOR 9 GROUPS FOR PUFF '
361         +   ',I3,/)
362      WRITE(6,1001)
363 1001   FORMAT('        NG      I      CS      TE      SR      RU      LA      CE      BA'
364         +   ',/)
365      READ(5,*) (FRAC(I,NP),I=1,NG)
366      WRITE(2,10000) NP,(FRAC(I,NP),I=1,NG)
367 10000  FORMAT('    RELEASE FRACTIONS FOR THE 9 GROUPS FOR PUFF '
368         +   ',I3,/,
369         +   '    9(3X,1PE10.3))
370 999    CONTINUE
371      WRITE(6,1999)
372 1999   FORMAT('    SELECT OPTION FOR DOSE CALCULATION:',/,
373         +   '        1 = TOP HAT PROFILE (AS USED IN CRAC2);',/,
374         +   '        2 = GAUSSIAN PROFILE (AS USED IN MACCS).',/)
375      READ(5,*) IPROF
376      WRITE(6,2099)
377 2099   FORMAT('    ENTER WIDTH AND HEIGHT OF BUILDING (M)',/)
378      READ(5,*) WIDT,AREA
379      WRITE(2,10001) WIDT,AREA
380 10001  FORMAT(/,'    WIDTH AND HEIGHT OF BUILDING =',
381         +   '    2X,2(1PE12.3), ' M',/)
382      NCALC = NXDAT
383      DO 998 NP=1,NPUF
384      WRITE(2,40109)
385 40109  FORMAT(1H1)
386      WRITE(6,40100) NP
387 40100  FORMAT('    ENTER RELEASE TIME (HRS) FOR PUFF ',I3,/)
388      READ(5,*) RT
389      RELTIM(NP) = RT * 3600.
390      WRITE(6,40000) NP
391 40000  FORMAT('    ENTER DURATION (HRS) FOR PUFF ',I3,/)
392      READ(5,*) DURAT
393      WRITE(2,40001) NP,RT,DURAT
394 40001  FORMAT('    PUFF ',I3,'    RELEASE TIME = ',F10.2,
395         +   '    HOURS ',/,
396         +   '    F10.2, ' HOURS',/)
397      DURAT = DURAT * 60.
398      CCC = .2
399      IF(DURAT.GT.60.) CCC = .25
400      CDUR(NP) = (DURAT / 3.) ** CCC
401 998    CONTINUE
402 C
403 C      CORRECTION FOR GRASS HEIGHT
404 C
405      DO 997 NP=1,NPUF
406 997    HGRAS(NP) = (10./3.)**.2
407      WRITE(6,2001) UDEP,BR
408 2001   FORMAT('    DEFAULT DEPOSITION VELOCITY = ',1PE12.4,' M/S',/,
409         +   '    BREATHING RATE = ',1PE12.3,' M**3/S',/,
410         +   '    ENTER NEW VALUES; USE REAL NUMBERS AND NOT INTEGERS;',/,
411         +   '    IF NEGATIVE, DEFAULT WILL BE USED'
412         +   ',/)
413      READ(5,*) UDEPP,BRP
414      IF(UDEPP.LT.0.0) GOTO 2010

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415      UDEP = UDEPP
416 2010  CONTINUE
417      IF(BRP.LT.0.0) GOTO 2011
418      BR = BRP
419 2011  CONTINUE
420      WRITE(2,10002) UDEP,BR
421 10002  FORMAT(/,' DEPOSITION VELOCITY = ',1PE12.3,' M/S',/,
422      +    ' BREATHING RATE      = ',1PE12.3,' M**3/S',/)
423 83    CONTINUE
424      WRITE(6,1002)
425      WRITE(2,1002)
426 1002  FORMAT(' ENTER WEATHER CONDITIONS :',/)
427      WRITE(6,1003)
428      WRITE(2,1003)
429 1003  FORMAT(' 1-MOD. STABLE, 2-SLIGTHLY STABLE',/)
430      WRITE(2,1004)
431      WRITE(6,1004)
432 1004  FORMAT(' 3-NEUTRAL,      4-SLIGHTLY UNSTABLE',/)
433      WRITE(6,1005)
434      WRITE(2,1005)
435 1005  FORMAT(' 5-MOD. UNSTABLE,6-EXTREM. UNSTABLE',/
436      +    ' 7 = CLASS G (EXTRAPOLATED )',/)
437      READ(5,*) IWEATH
438      WRITE(2,10006) IWEATH
439 10006  FORMAT(' SELECTION OF WEATHER = ',I5,/)
440      IG = 0
441      IF(IWEATH.EQ.7) IG = 1
442      IF(IWEATH.EQ.7) IWEATH = 1
443      WRITE(6,3000)
444 3000  FORMAT(' ENTER AVERAGE WIND SPEED, M/S',/)
445      READ(5,*) UBAR
446      WRITE(2,10007) UBAR
447 10007  FORMAT(' AVERAGE WIND SPEED = ',1PE12.3,' M/S',/)
448      IF(UBAR.EQ.0.0) UBAR = 1.E-10
449      IF(ICHW.EQ.1) RETURN
450      DO 996 NP=1,NPUF
451      WRITE(6,3001) NP
452 3001  FORMAT(' ENTER RELEASE HEIGHT , M FOR PUFF ',I3,/)
453      READ(5,*) HEIGHT(NP)
454      WRITE(2,10008) NP,HEIGHT(NP)
455 10008  FORMAT(' PUFF ',I3,' RELEASE HEIGHT = ',1PE12.3,' M',/)
456 C
457 C      ENERGY OF RELEASE IN WATTS
458 C
459      WRITE(6,7432) NP
460 7432  FORMAT(' ENTER ENERGY OF RELEASE (WATTS) FOR PUFF',5X,
461      +    I3,/)
462      READ(5,*) ENEREL(NP)
463      WRITE(6,3002)
464 3002  FORMAT(' ENTER DURATION OF RAIN, S',/)
465      READ(5,*) DELTAT(NP)
466      WRITE(2,10009) DELTAT(NP)
467 10009  FORMAT(' DURATION OF RAIN = ',1PE12.3,' S',/)
468 996   CONTINUE
469      WRITE(6,8765)
470 8765  FORMAT(' ENTER THREE SHIELDING FACTORS ,RESPECTIVELY :',/,
471      +    ' CLOUD-SHINE',/,
472      +    ' GROUND-SHINE',/,
473      +    ' INHALATION',/)
474      READ(5,*) SHCS,SHGS,SHIN

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475      WRITE(6,10097)
476 10097  FORMAT(' DOSE CONVERSION TABLES USED FROM EITHER',
477      +    ' MACCS OR CRAC2 DATA ARE DEFAULT;',/,
478      +    ' IF YOU WISH TO SELECT DIFFERENT TABLES IN',
479      +    ' CRAC2 DATA BASE, ENTER 1',/,
480      +    ' DATA BASE PROVIDED FOR MACCS HAS ONLY DEFAULT OPTION',/)
481      READ(5,*) ITAB
482      IF(ITAB.NE.1) GOTO 10077
483      WRITE(6,1006)
484 1006    FORMAT(' ENTER CONTAMINATED GROUND EXPOSURE N DAYS',/)
485      WRITE(6,1007)
486 1007    FORMAT(' 1= 1DAY, 2=7DAYS',/)
487      READ(5,*) IFG
488      WRITE(6,1219)
489 1219    FORMAT(' ENTER EXPOSURE TO CONTAMINATED GROUND, ',
490      +    ' IN HOURS OR DAYS ACCORDING TO TABLE SELECTED',/)
491      READ(5,*) EXPOS
492      TEX = 24.
493      IF(IFG.EQ.2) GOTO 5678
494      DO 1223 IJ=1,NUCLID
495      FGBOD(IJ,IFG) = FGBOD(IJ,IFG) * EXPOS/TEX
496      FGMAR(IJ,IFG) = FGMAR(IJ,IFG) * EXPOS/TEX
497      FGLUN(IJ,IFG) = FGLUN(IJ,IFG) * EXPOS/TEX
498 1223    CONTINUE
499      GOTO 5679
500 5678    CONTINUE
501      TEX = 7.
502      DO 5680 IJ=1,NUCLID
503      FGBOD(IJ,IFG) = FGBOD(IJ,IFG-1) +
504      +    (FGBOD(IJ,IFG)-FGBOD(IJ,IFG-1))*(EXPOS-1.)/(TEX-1.)
505      FGMAR(IJ,IFG) = FGMAR(IJ,IFG-1) +
506      +    (FGMAR(IJ,IFG)-FGMAR(IJ,IFG-1))*(EXPOS-1.)/(TEX-1.)
507      FGLUN(IJ,IFG) = FGLUN(IJ,IFG-1) +
508      +    (FGLUN(IJ,IFG)-FGLUN(IJ,IFG-1))*(EXPOS-1.)/(1.-TEX)
509 5680    CONTINUE
510 5679    CONTINUE
511      WRITE(6,1008)
512 1008    FORMAT(' ENTER TIME EXPOSURE FOR INHAL. TO MARROW',/)
513      WRITE(6,1009)
514 1009    FORMAT(' 1=0-2 DAYS, 2=0-7 DAYS, 3=0-30 DAYS, 4=0-30 YEARS',/)
515      READ(5,*) IFIMAR
516      WRITE(6,1010)
517 1010    FORMAT(' SAME FOR LLIW',/)
518      WRITE(6,1011)
519 1011    FORMAT(' 1=0-2 DAYS,2=0-7 DAYS,3=0-30 DAYS,4=0-30 YEARS',/)
520      READ(5,*) IFILLIW
521      WRITE(6,1012)
522 1012    FORMAT(' SAME FOR THYROID',/
523      +    )
524      WRITE(6,1013)
525 1013    FORMAT(' 1= 0-2 DAYS,2=0-7 DAYS,3=0-30 DAYS,4=0-30 YEARS',/)
526      READ(5,*) IFITHY
527      WRITE(6,1014)
528 1014    FORMAT(' SAME FOR LUNG',/)
529      WRITE(6,1015)
530 1015    FORMAT(' 1=0-2 DAYS, 2=0-7 DAYS, 3=0-30 DAYS ,4=0-1 YEAR',
531      +    ' 5=0-30 YEARS', /)
532      READ(5,*) IFILUN
533 10077    CONTINUE
534      WRITE(2,20000) IFG,IFIMAR,IFILLIW,IFITHY,IFILUN

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535 20000    FORMAT('  SELECTION OF TABLES FOR CONVERSION FACTORS :',
536          +    /,5X,6I5,/)
537 C
538 C
539          RETURN
540          END

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541          SUBROUTINE SHINCF(S,H,SHIN)
542 C
543          DIMENSION SY(6),SZ(9),D(6,9)
544 C
545          DATA SY/ 0., 1., 2., 3., 4., 5. /
546          DATA SZ/ .477, 1., 1.301, 1.477, 1.699, 2.,
547          +    2.301, 2.602, 3. /
548          DATA D/ -1.699, -1.745, -1.979, -1.18, -2.301, -2.398,
549          +    -1.131, -1.222, -1.444, -1.699, -1.824, -1.959,
550          +    -.824, -.921, -1.187, -1.456, -1.62, -1.796,
551          +    -.658, -.77, -1.055, -1.337, -1.538, -1.769,
552          +    -.456, -.602, -.886, -1.268, -1.553, -1.886,
553          +    -.252, -.42, -.824, -1.347, -1.796, -2.409,
554          +    -.119, -.292, -.824, -1.62, -2.456, -3.,
555          +    -.046, -.222, -.854, -1.854, -2.959, -3.,
556          +    -.022, -.222, -.886, -1.959, -3., -3. /
557 C
558          I = 1
559          J = 1
560          SS = ALOG10(S)
561          HH = H/S
562          CALL POL2(SY,SZ,D,6,9,HH,SS,CF,I,J,0)
563          SHIN = 10.**CF
564          RETURN
565          END

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566          SUBROUTINE POL2(X,Y,Z,IXT,JYT,XP,YP,ZP,I,J,MES)
567 C
568 C
569          DIMENSION X(IXT),Y(JYT),Z(IXT,JYT)
570 C
571 10      IF(XP.LE.X(I+1)) GOTO 20
572          I = I + 1
573          IF(I.GE.IXT) GOTO 30
574          GOTO 10
575 20      IF(XP.GE.X(I)) GOTO 30
576          I = I - 1
577          IF(I.LT.1) GOTO 30
578          GOTO 20
579 C
580 30      IF(YP.LE.Y(J+1)) GOTO 40
581          J = J + 1
582          IF(J.GE.JYT) GOTO 60
583          GOTO 30
584 40      IF(YP.GE.Y(J)) GOTO 50
585          J = J - 1
586          IF(J.LT.1) GOTO 60
587          GOTO 40
588 C
589 50      IF(I.LT.1.OR.I.GE.IXT) GOTO 60
590          A = (XP-X(I))/(X(I+1)-X(I))

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591      B = (YP-Y(J))/(Y(J+1)-Y(J))
592      OMA = 1.-A
593      OMB = 1. - B
594      ZP = OMA*OMB*Z(I,J) + B*OMA*Z(I,J+1) +
595      +      A*OMB*Z(I+1,J) + A*B*Z(I+1,J+1)
596      RETURN
597 C
598 60      IF(MES.EQ.0) GOTO 65
599      RETURN
600 65      CONTINUE
601      IF(I.LT.1.AND.J.LT.1) GOTO 70
602      IF(I.GE.IXT.AND.J.GE.JYT) GOTO 75
603      IF(I.LT.1.AND.J.GE.JYT) GOTO 80
604      IF(I.GE.IXT.AND.J.LT.1) GOTO 85
605      IF(I.LT.1.AND.J.LT.JYT) GOTO 90
606      IF(I.GE.IXT.AND.J.LT.JYT) GOTO 95
607      IF(I.LT.IXT.AND.J.GE.JYT) GOTO 100
608      ZP = (Z(I,1)-Z(I+1,1))*(XP-X(I)) /
609      +      (X(I)-X(I+1)) + Z(I,1)
610      I = 1
611      J = 1
612      RETURN
613 70      ZP = Z(1,1)
614      I = 1
615      J = 1
616      RETURN
617 75      ZP = Z(IXT,JYT)
618      I = IXT-1
619      J = JYT - 1
620      RETURN
621 80      ZP = Z(1,JYT)
622      I = 1
623      J = JYT - 1
624      RETURN
625 85      ZP = Z(IXT,1)
626      I = IXT - 1
627      J = 1
628      RETURN
629 90      ZP = (Z(1,J)-Z(1,J+1))*(YP-Y(J)) /
630      +      (Y(J)-Y(J+1)) + Z(1,J)
631      I = 1
632      RETURN
633 95      ZP = (Z(IXT,J)-Z(IXT,J+1))*(YP-Y(J)) /
634      +      (Y(J)-Y(J+1)) + Z(IXT,J)
635      I = IXT - 1
636      RETURN
637 100     ZP = (Z(I,JYT) - Z(I+1,JYT))*(XP-X(I)) /
638      +      (X(I)-X(I+1)) + Z(I,JYT)
639      J = JYT - 1
640      RETURN
641      END

642      SUBROUTINE RDRMA
643 C
644 C
645 C
646      COMMON/MORE/ IWHICH,FCTHY(54),FCLLIW(54),FGTHY(54,2),
647      +      FGLLIW(54,2),NXDAT,XDAT(35),DCTHY(54,5),DGTHY(54,5),
648      +      DCLLIW(54,5),DGLLIW(54,5),FCSTO(54),FGSTO(54,2),

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649      + FISTO(54),FCSMI(54),FGSMI(54,2),FISMI(54),
650      + DCSTO(54,5),DGSTO(54,5),DISTO(54,5),
651      + DCSMI(54,5),DGSMI(54,5),DISMI(54,5),
652      + TOTSTO(35),TOTSMI(35),ISIG,ZBAR,IG
653      COMMON/RCTR/ IPBWR
654 C
655      COMMON /VAR/ IPAR(54),MAP(54),QINV(54),HALF(54),FCBOD(54),
656      + FCMAR(54),FCLUN(54),FGBOD(54,2),FGMAR(54,2),
657      + FGLUN(54,2),FIBOD(54),FIMAR(54,4),FILLIW(54,4),
658      + FITHY(54,4),FILUN(54,5),FISKE(54,5),DIBOD(54,5),
659      + FRAC(9,5),Q(54,5),CHI(54,5),DCBOD(54,5),
660      + DCMAR(54,5),DCLUN(54,5),DGBOD(54,5),DGMAR(54,5),
661      + DGLUN(54,5),DIMAR(54,5),DILLIW(54,5),DITHY(54,5),
662      + DILUN(54,5),DISKE(54,5),TOTMAR(35),TOTBOD(35),
663      + TOTLUN(35),TOTLLIW(35),TOTSKE(35),TOTTHY(35)
664      COMMON/DP/ ASIGY(6,3),ASIGZ(6,3)
665 C
666      COMMON /STATIC/ NUCLID,NG,UDEP,BR,DISTO,NCALC,AREA,NOUT,
667      + RELTIM(2),IWEATH,UBAR,HEIGHT(2),DELTAT(2),UD,IFG,IFIMAR,
668      + IFILLIW,IFITHY,IFILUN,IFISKE,DIST,SIGY(2),SIGZ(2)
669      + ,CDUR(2),HGRAS(2),NPUF,IPOF,SHCS,SHGS,SHIN,WIDT
670 C
671 C
672 C
673      OPEN(UNIT=1,FILE='DOSEMACCS.DAT',STATUS='OLD')
674      IF(IPBWR.EQ.1)
675      + OPEN(UNIT=31,FILE='PWR.DAT',STATUS='OLD')
676      IF(IPBWR.EQ.2)
677      + OPEN(UNIT=31,FILE='BWR.DAT',STATUS='OLD')
678      NUCLID = 54
679      NG = 9
680 C
681 C      READ NUCLIDE MAP TO 9 GROUPS
682 C
683      READ(31,1) DUM
684 1      FORMAT(A1)
685      READ(31,*) (MAP(I),I=1,NUCLID)
686 C
687 C      READ MAP OF PARENT ISOTOPES
688 C
689      READ(31,1) DUM
690      READ(31,*) (IPAR(I),I=1,NUCLID)
691 C
692 C      READ INIT. INV. (CURIES) AND HALF LIVES (DAYS)
693 C
694      READ(31,1) DUM
695      READ(31,1) DUM
696      DO 10 I=1,NUCLID
697      READ(31,*) IDUM,QINV(I),HALF(I)
698 10      CONTINUE
699      DO 5000 I=1,NUCLID
700      HALF(I) = .693/(3600.*24.*HALF(I))
701 C      CI TO BEQ
702      QINV(I) = QINV(I) /2.7E-11
703 5000      CONTINUE
704 C
705 C      READ CONVERSION TABLES
706 C
707      READ(1,1) DUM
708      READ(1,1) DUM

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```

709      DO 60 I=1,NUCLID
710      READ(1,*) FCSTO(I),FGSTO(I,1),FGSTO(I,2),FISTO(I)
711      READ(1,*) FCSMI(I),FGSMI(I,1),FGSMI(I,2),FISMI(I)
712      READ(1,*) FCLUN(I),FGLUN(I,1),FGLUN(I,2),FILUN(I,1)
713      READ(1,*) FCMAR(I),FGMAR(I,1),FGMAR(I,2),FIMAR(I,1)
714      READ(1,*) FCTHY(I),FGTHY(I,1),FGTHY(I,2),FITHY(I,1)
715      READ(1,*) FCLLIW(I),FGLLIW(I,1),FGLLIW(I,2),
716      +    FILLIW(I,1)
717 60    CONTINUE
718      DO 70 I=1,NUCLID
719      FGSTO(I,1) = FGSTO(I,1) + (FGSTO(I,2)-FGSTO(I,1))*0.22
720      FGSMI(I,1) = FGSMI(I,1) + (FGSMI(I,2)-FGSMI(I,1))*0.22
721      FGLUN(I,1) = FGLUN(I,1) + (FGLUN(I,2)-FGLUN(I,1))*0.22
722      FGMAR(I,1) = FGMAR(I,1) + (FGMAR(I,2)-FGMAR(I,1))*0.22
723      FGTHY(I,1) = FGTHY(I,1) + (FGTHY(I,2)-FGTHY(I,1))*0.22
724      FGLLIW(I,1) = FGLLIW(I,1) + (FGLLIW(I,2)-FGLLIW(I,1))*0.22
725 70    CONTINUE
726 C
727 C    TRANSFORM TO REMS
728 C
729      ZC = 100.
730      DO 80 I=1,NUCLID
731      FGSTO(I,1) = FGSTO(I,1)*ZC
732      FGSMI(I,1) = FGSMI(I,1)*ZC
733      FGLUN(I,1) = FGLUN(I,1)*ZC
734      FGMAR(I,1) = FGMAR(I,1)*ZC
735      FGTHY(I,1) = FGTHY(I,1)*ZC
736      FGLLIW(I,1) = FGLLIW(I,1)*ZC
737      FCSTO(I) = FCSTO(I)*ZC
738      FCSMI(I) = FCSMI(I)*ZC
739      FCLUN(I) = FCLUN(I)*ZC
740      FCMAR(I) = FCMAR(I)*ZC
741      FCTHY(I) = FCTHY(I)*ZC
742      FCLLIW(I) = FCLLIW(I)*ZC
743      FISTO(I) = FISTO(I)*ZC
744      FISMI(I) = FISMI(I) * ZC
745      FILUN(I,1) = FILUN(I,1)*ZC
746      FIMAR(I,1) = FIMAR(I,1)*ZC
747      FITHY(I,1) = FITHY(I,1)*ZC
748      FILLIW(I,1) = FILLIW(I,1)*ZC
749 80    CONTINUE
750 C
751 C    READ SPATIAL GRID DATA
752 C
753      READ(31,1) DUM
754      READ(31,*) NXDAT
755      READ(31,*) (XDAT(I),I=1,NXDAT)
756 C
757 C    READ DEF.: FOR MACCS ALL = 1
758 C
759      READ(31,1) DUM
760      READ(31,*) IFG,IFIMAR,IFILLIW,IFITHY,IFILUN
761      IFG = 1
762      IFIMAR = 1
763      IFILLIW = 1
764      IFITHY = 1
765      IFILUN = 1
766 C
767 C    DISPERSION COEFFICIENTS CURVE FITTING PARAMETERS
768 C

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769      READ(31,1) DUM
770      DO 90 I=1,6
771      READ(31,*) IDUM,JDUM,(ASIGY(I,J),J=1,3)
772 90    CONTINUE
773      DO 91 I=1,6
774      READ(31,*) IDUM,JDUM,(ASIGZ(I,J),J=1,3)
775 91    CONTINUE
776 C
777 C      DEP. VELOCITY (M/S) AND BREATHING RATE (M**3/S)
778 C
779      READ(31,1) DUM
780      READ(31,*) UDEP,BR
781 C
782 C
783      CLOSE(1)
784      CLOSE(31)
785      RETURN
786      END

787      SUBROUTINE MAOUT(NC)
788 C
789 C
790 C
791      COMMON/MORE/ IWHICH,FCTHY(54),FCLLIW(54),FGTHY(54,2),
792 +      FGLLIW(54,2), NXDAT,XDAT(35), DCthy(54,5),DGTHY(54,5),
793 +      DCLLIW(54,5),DGLLIW(54,5), FCSTO(54),FGSTO(54,2),
794 +      FISTO(54),FCSMI(54),FGSMI(54,2),FISMI(54),
795 +      DCSTO(54,5),DGSTO(54,5),DISTO(54,5),
796 +      DCSMI(54,5),DGSMI(54,5),DISMI(54,5),
797 +      TOTSTO(35),TOTSMI(35),ISIG,ZBAR,IG
798 C
799      COMMON /VAR/ IPAR(54),MAP(54),QINV(54),HALF(54),FCBOD(54),
800 +      FCMAR(54),FCLUN(54),FGBOD(54,2),FGMAR(54,2),
801 +      FGLUN(54,2),FIBOD(54),FIMAR(54,4),FILLIW(54,4),
802 +      FITHY(54,4),FILUN(54,5),FISKE(54,5),DIBOD(54,5),
803 +      FRAC(9,5),Q(54,5),CHI(54,5),DCBOD(54,5),
804 +      DCMAR(54,5),DCLUN(54,5),DGBOD(54,5),DGMAR(54,5),
805 +      DGLUN(54,5),DIMAR(54,5),DILLIW(54,5),DITHY(54,5),
806 +      DILUN(54,5),DISKE(54,5),TOTMAR(35),TOTBOD(35),
807 +      TOTLUN(35),TOTLLIW(35),TOTSKE(35),TOTTHY(35)
808 C
809      COMMON/DP/ ASIGY(6,3),ASIGZ(6,3)
810      COMMON /STATIC/ NUCLID,NG,UDEP,BR,DISTO,NCALC,AREA,NOUT,
811 +      RELTIM(2),IWEATH,UBAR,HEIGHT(2),DELTAT(2),UD,IFG,IFIMAR,
812 +      IFILLIW,IFITHY,IFILUN,IFISKE,DIST,SIGY(2),SIGZ(2)
813 +      ,CDUR(2),HGRAS(2),NPUF,IPOF,SHCS,SHGS,SHIN,WIDT
814 C
815      CHARACTER*8 NAME(54)
816      CHARACTER*1 CLASS
817      DIMENSION GRSTO(9),GRMAR(9),GRLUN(9),GRLLIW(9),
818 +      GRSMI(9),GRTHY(9),GRSKE(9)
819 C
820 C
821      IF(IWEATH.EQ.1) CLASS = 'F'
822      IF(IWEATH.EQ.2) CLASS = 'E'
823      IF(IWEATH.EQ.3) CLASS = 'D'
824      IF(IWEATH.EQ.4) CLASS = 'C'
825      IF(IWEATH.EQ.5) CLASS = 'B'
826      IF(IWEATH.EQ.6) CLASS = 'A'

```

```

827      WRITE(2,30030)
828 30030  FORMAT(//,5X,20(1H*), '  MACCS CONVERSION FACTORS',
829      +    3X,20(1H*),///)
830      NAME(1) = 'CO-58'
831      NAME(2) = 'CO-60'
832      NAME(3) = 'KR-85'
833      NAME(4) = 'KR-85M'
834      NAME(5) = 'KR-87'
835      NAME(6) = 'KR-88'
836      NAME(7) = 'RB-86'
837      NAME(8) = 'SR-89'
838      NAME(9) = 'SR-90'
839      NAME(10) = 'SR-91'
840      NAME(11) = 'Y-90'
841      NAME(12) = 'Y-91'
842      NAME(13) = 'ZR-95'
843      NAME(14) = 'ZR-97'
844      NAME(15) = 'NB-95'
845      NAME(16) = 'MO-99'
846      NAME(17) = 'TC-99M'
847      NAME(18) = 'RU-103'
848      NAME(19) = 'RU-105'
849      NAME(20) = 'RU-106'
850      NAME(21) = 'RH-105'
851      NAME(22) = 'TE-127'
852      NAME(23) = 'TE-127M'
853      NAME(24) = 'TE-129'
854      NAME(25) = 'TE-129M'
855      NAME(26) = 'TE-131M'
856      NAME(27) = 'TE-132'
857      NAME(28) = 'SB-127'
858      NAME(29) = 'SB-129'
859      NAME(30) = 'I-131'
860      NAME(31) = 'I-132'
861      NAME(32) = 'I-133'
862      NAME(33) = 'I-134'
863      NAME(34) = 'I-135'
864      NAME(35) = 'XE-133'
865      NAME(36) = 'XE-135'
866      NAME(37) = 'CS-134'
867      NAME(38) = 'CS-136'
868      NAME(39) = 'CS-137'
869      NAME(40) = 'BA-140'
870      NAME(41) = 'LA-140'
871      NAME(42) = 'CE-141'
872      NAME(43) = 'CE-143'
873      NAME(44) = 'CE-144'
874      NAME(45) = 'PR-143'
875      NAME(46) = 'ND-147'
876      NAME(47) = 'NP-239'
877      NAME(48) = 'PU-238'
878      NAME(49) = 'PU-239'
879      NAME(50) = 'PU-240'
880      NAME(51) = 'PU-241'
881      NAME(52) = 'AM-241'
882      NAME(53) = 'CM-242'
883      NAME(54) = 'CM-244'
884 C
885      WRITE(2,1000) DIST,UBAR
886 1000  FORMAT(///,

```

```

887      +      '    DISTANCE = ',1PE12.3,' M',/,
888      +      '    WIND VELOCITY = ',1PE12.3,' M/S',/
889      +      )
890      IF(IG.EQ.1) WRITE(2,1009)
891 1009      FORMAT('    ATMOSPHERIC STABILITY CLASS G',/)
892      IF(IG.EQ.0) WRITE(2,1019) CLASS
893 1019      FORMAT('    ATMOSPHERIC STABILITY CLASS ',A1,/)
894 C
895      DO 999 NP=1,NPUF
896      WRITE(2,40999) NP
897 40999      FORMAT(/, '    PUFF NUMBER ',I4,/)
898      DCMT = 0.
899      DGMT = 0.
900      DCLT = 0.
901      DGLT = 0.
902      DCTT = 0.
903      DGTT = 0.
904      DCLLT = 0.
905      DGLLT = 0.
906      DIMT = 0.
967 2600      CONTINUE
968 3457      CONTINUE
969      WRITE(2,3034) DGSTOT,DGMT,DGLT,
970      +      DGTT,DGSMIT,DGLLT
971      WRITE(2,2503)
972 2503      FORMAT(/,40X,'    INHALATION',/)
973      WRITE(2,2334)
974      IF(NOUT.NE.1) GOTO 3458
975      DO 2700 N=1,NUCLID
976      WRITE(2,2501) NAME(N),DISTO(N,NP),DIMAR(N,NP),
977      +      DILUN(N,NP),DITHY(N,NP),DISMI(N,NP),DILLIW(N,NP)
978 2700      CONTINUE
979 3458      CONTINUE
980      WRITE(2,3034) DISTOT,DIMT,DILT,
981      +      DITT,DISMIT,DILLT
982 999      CONTINUE
983 C
984      WRITE(2,20002) TOTSTO(NC),TOTMAR(NC),TOTLUN(NC),
985      +      TOTSMI(NC),TOTLLIW(NC),TOTTHY(NC)
986 20002      FORMAT(/,/, '    TOTAL STOMACH DOSE    = ',1PE12.3,/,
987      +      '    TOTAL MARROW DOSE    = ',1PE12.3,/,
988      +      '    TOTAL LUNG DOSE    = ',1PE12.3,/,
989      +      '    TOTAL SM. INT. DOSE = ',1PE12.3,/,
990      +      '    TOTAL LLIW DOSE    = ',1PE12.3,/,
991      +      '    TOTAL THYROID DOSE = ',1PE12.3,/,
992      +      //)
993 C
994 C
995      IF(NOUT.NE.1) RETURN
996      DO 4040 I=1,NG
997      GRSTO(I) = 0.
998      GRMAR(I) = 0.
999      GRLUN(I) = 0.
1000      GRLLIW(I) = 0.
1001      GRTHY(I) = 0.
1002      GRSMI(I) = 0.
1003 4040      CONTINUE
1004      DO 4041 NP=1,NPUF
1005      DO 4041 IJ=1,NUCLID
1006      I = MAP(IJ)

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1007      GRSTO(I) = GRSTO(I) + DCSTO(IJ,NP) + DGSTO(IJ,NP)
1008      +      + DISTO(IJ,NP)
1009      GRMAR(I) = GRMAR(I) + DCMAR(IJ,NP) + DGMAR(IJ,NP) +
1010      +      + DIMAR(IJ,NP)
1011      GRLUN(I) = GRLUN(I) + DCLUN(IJ,NP) + DGLUN(IJ,NP) +
1012      +      + DILUN(IJ,NP)
1013      GRSMI(I) = GRSMI(I) + DCSMI(IJ,NP) + DGSMI(IJ,NP) +
1014      +      + DISMI(IJ,NP)
1015      GRLLIW(I) = GRLLIW(I) + DILLIW(IJ,NP)
1016      +      + DGLLIW(IJ,NP) + DCLLIW(IJ,NP)
1017      GRTHY(I) = GRTHY(I) + DITHY(IJ,NP)
1018      +      + DGTHY(IJ,NP) + DCTHY(IJ,NP)
1019 4041      CONTINUE
1020      WRITE(2,30333)
1021 30333      FORMAT(///,'      GROUP:',1X,10H      XE-KR      ,1X,
1022      +      10H      I      ,1X,10H      CS      ,1X,
1023      +      10H      TE      ,1X,10H      SR      ,1X,
1024      +      10H      RU      ,1X,10H      LA      ,1X,
1025      +      10H      CE      ,1X,10H      BA      ,/)
1026      WRITE(2,30334) ( GRSTO(IJ),IJ=1,NG)
1027 30334      FORMAT('      STOMACH      ',9(1X,1PE10.3))
1028      WRITE(2,30335) (GRMAR(IJ),IJ=1,NG)
1029      WRITE(2,30349) (GRSMI(IJ),IJ=1,NG)
1030 30349      FORMAT('      SM. INT.      ',9(1X,1PE10.3))
1031 30335      FORMAT('      MARROW      ',9(1X,1PE10.3))
1032      WRITE(2,30336) ( GRLUN(IJ),IJ=1,NG)
1033 30336      FORMAT('      LUNG      ',9(1X,1PE10.3))
1034      WRITE(2,30337) ( GRLLIW(IJ),IJ=1,NG)
1035 30337      FORMAT('      LLIW      ',9(1X,1PE10.3))
1036      WRITE(2,30338) (GRTHY(IJ),IJ=1,NG)
1037 30338      FORMAT('      THYROID      ',9(1X,1PE10.3))
1038 C
1039 C
1040      RETURN
1041      END

1042      SUBROUTINE REST
1043 C
1044 C
1045      COMMON/MORE/ IWHICH,FCTHY(54),FCLLIW(54),FGTHY(54,2),
1046      +      FGLLIW(54,2), NXDAT,XDAT(35), DCTHY(54,5),DGTHY(54,5),
1047      +      DCLLIW(54,5),DGLLIW(54,5), FCSTO(54),FGSTO(54,2),
1048      +      FISTO(54),FCSMI(54),FGSMI(54,2),FISMI(54),
1049      +      DCSTO(54,5),DGSTO(54,5),DISTO(54,5),
1050      +      DCSMI(54,5),DGSMI(54,5),DISMI(54,5),
1051      +      TOTSTO(35),TOTSMI(35),ISIG,ZBAR,IG
1052 C
1053      COMMON /VAR/ IPAR(54),MAP(54),QINV(54),HALF(54),FCBOD(54),
1054      +      FCMAR(54),FCLUN(54),FCBOD(54,2),FGMAR(54,2),
1055      +      FGLUN(54,2),FIBOD(54),FIMAR(54,4),FILLIW(54,4),
1056      +      FITHY(54,4),FILUN(54,5),FISKE(54,5),DIBOD(54,5),
1057      +      FRAC(9,5),Q(54,5),CHI(54,5),DCBOD(54,5),
1058      +      DCMAR(54,5),DCLUN(54,5),DGBOD(54,5),DGMAR(54,5),
1059      +      DGLUN(54,5),DIMAR(54,5),DILLIW(54,5),DITHY(54,5),
1060      +      DILUN(54,5),DISKE(54,5),TOTMAR(35),TOTBOD(35),
1061      +      TOTLUN(35),TOTLLIW(35),TOTSKE(35),TOTTHY(35)
1062      COMMON/DP/ ASIGY(6,3),ASIGZ(6,3)
1063 C
1064      COMMON /STATIC/ NUCLID,NG,UDEP,BR,DISTO,NCALC,AREA,NOUT,

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1065      +      RELTIM(2),IWEATH,UBAR,HEIGHT(2),DELTAT(2),UD,IFG,IFIMAR,
1066      +      IFILLIW,IFITHY,IFILUN,IFISKE,DIST,SIGY(2),SIGZ(2)
1067      +      ,CDUR(2),HGRAS(2),NPUF,IPOF,SHCS,SHGS,SHIN,WIDT
1068 C
1069      DO 10 I=1,35
1070      TOTBOD(I) = 0.
1071      TOTSMI(I) = 0.
1072      TOTSTO(I) = 0.
1073      TOTMAR(I) = 0.
1074      TOTLUN(I) = 0.
1075      TOTLLIW(I) = 0.
1076      TOTTHY(I) = 0.
1077 10    CONTINUE
1078 C
1079 C
1080      RETURN
1081      END

1082      SUBROUTINE SIGCR(K,NC,SY,SZ,DX)
1083 C
1084 C
1085 C
1086      COMMON/MORE/ IWHICH,FCPTHY(54),FCLLIW(54),FGTHY(54,2),
1087      +      FGLLIW(54,2), NXDAT,XDAT(35), DCTHY(54,5),DGTHY(54,5),
1088      +      DCLLIW(54,5),DGLLIW(54,5), FCSTO(54),FGSTO(54,2),
1089      +      FISTO(54),FCSMI(54),FGSMI(54,2),FISMI(54),
1090      +      DCSTO(54,5),DGSTO(54,5),DISTO(54,5),
1091      +      DCSMI(54,5),DGSMI(54,5),DISMI(54,5),
1092      +      TOTSTO(35),TOTSMI(35),ISIG,ZBAR,IG
1093 C
1094      COMMON /VAR/ IPAR(54),MAP(54),QINV(54),HALF(54),FCBOD(54),
1095      +      FCMAR(54),FCLUN(54),FGBOD(54,2),FGMAR(54,2),
1096      +      FGLUN(54,2),FIBOD(54),FIMAR(54,4),FILLIW(54,4),
1097      +      FITHY(54,4),FILUN(54,5),FISKE(54,5),DIBOD(54,5),
1098      +      FRAC(9,5),Q(54,5),CHI(54,5),DCBOD(54,5),
1099      +      DCMAR(54,5),DCLUN(54,5),DGBOD(54,5),DGMAR(54,5),
1100      +      DGLUN(54,5),DIMAR(54,5),DILLIW(54,5),DITHY(54,5),
1101      +      DILUN(54,5),DISKE(54,5),TOTMAR(35),TOTBOD(35),
1102      +      TOTLUN(35),TOTLLIW(35),TOTSKE(35),TOTTHY(35)
1103 C
1104      COMMON/DP/ ASIGY(6,3),ASIGZ(6,3)
1105      COMMON /STATIC/ NUCLID,NG,UDEP,BR,DISTO,NCALC,AREA,NOUT,
1106      +      RELTIM(2),IWEATH,UBAR,HEIGHT(2),DELTAT(2),UD,IFG,IFIMAR,
1107      +      IFILLIW,IFITHY,IFILUN,IFISKE,DIST,SIGY(2),SIGZ(2)
1108      +      ,CDUR(2),HGRAS(2),NPUF,IPOF,SHCS,SHGS,SHIN,WIDT
1109      DIMENSION AY(6),BY(6),AZ(6),BZ(6)
1110      DIMENSION SY1(12)
1111      DIMENSION SZ1(12)
1112 C      MACCS 1.4 WEATHER A
1113 C
1114 C      DATA SZ1/ 340., 640., 640., 640., 640.,
1115 C      +      640., 640., 640., 640., 640., 640.,640./
1116 C      DATA SY1/ 142., 366., 572., 770., 962.,
1117 C      +      1150., 1340., 1520., 1700., 1880.,2140.,2490./
1118 C      CRAC2 A WEATHER
1119 C      DATA SZ1/ 199.6,651.8,800., 800., 800., 800., 800.,
1120 C      +      800., 800., 800., 800., 800./
1121 C      DATA SY1/ 159.5, 368.2, 556.3, 749., 831., 1109.,
1122 C      +      1284., 1456., 1626., 1795., 2043., 2371./

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1123 C      CRAC2 D WEATHER
1124 C      DATA SZ1/29.14,52.33,69.77,84.39,97.25,108.9,119.6,
1125 C      + 129.5,138.9,147.7,160.2,175.7/
1126 C      DATA SY1/92.1,173.5,250.4,324.8,397.3,468.5,539.,
1127 C      + 608.,676.,743.,843.,975./
1128 C      MACCS 1.4 D WEATHER
1129 C      DATA SZ1/23.1,42.7,57.8,71.,83.,94.2,105.,124.,133.,
1130 C      + 146.,163.,182./
1131 C      DATA SY1/69.6,158.,240.,320.,397.,472.,547.,692.,764.,870.,1010.
1132 C      + ,1180./
1133 C      CRAC2 F WEATHER
1134 C      DATA SZ1/18.36,27.05,33.02,37.65,41.46,44.72,47.59,
1135 C      + 50.14,52.46,54.58,57.46,60.87/
1136 C      DATA SY1/69.7,108.2,145.1,181.,216.2,250.8,284.8,
1137 C      + 318.4,351.7,384.6,433.3,497.5/
1138 C      MACCS 1.4 F WEATHER
1139 C      DATA SZ1/15.7,22.9,28.7,33.8,42.8,46.8,50.6,54.3,
1140 C      + 57.7,62.7,69.,76.3/
1141 C      DATA SY1/45.2,87.6,128.,166.,241.,277.,313.,348.,
1142 C      + 383.,435.,504.,588./
1143 C
1144      DATA AY/ .0722, .1046, .1471, .2089,
1145      + .2751, .3658/
1146      DATA BY/ .9031, .9031, .9031, .9031,
1147      + .9031, .9031/
1148      DATA AZ/ .2,.4,.3,.2, 1.9E-03, 2.5E-04/
1149      DATA BZ/ .602, .6021, .6532, .8534,
1150      + 1.6021, 2.125/
1151 C
1152 C
1153 C
1154      XX = DIST
1155      DDX = 0.
1156      IF(IWHICH.EQ.1) DDX = 1.*DX
1157      CON1 = 3.
1158      IF(IWHICH.EQ.2) CON1 = 6.75
1159      CON2 = 2.15
1160      IF(IWHICH.EQ.2) CON2 = 2.80
1161      X1 = (WIDT/CON1/AY(IWEATH))*(1./BY(IWEATH))
1162      X2 = (AREA/CON2/AZ(IWEATH))*(1./BZ(IWEATH))
1163      SY = AY(IWEATH)*(XX + X1)**BY(IWEATH)
1164      SZ = AZ(IWEATH)*(XX+DDX + X2)**BZ(IWEATH)
1165      IF(IG.EQ.0) GOTO 20
1166      SY = 0.666666 * SY
1167      SZ = 0.6 * SZ
1168 20      CONTINUE
1169 C
1170 C      CORRECTIONS FOR DURATION AND HEIGHT OF GRASS
1171 C
1172      SY = SY * CDUR(K)
1173      IF(IWHICH.EQ.1) SZ = SZ * HGRAS(K)
1174      IF(IWHICH.EQ.2) SZ = SZ * 1.27
1175 C
1176 C
1177      RETURN
1178      END

1179      SUBROUTINE ZZBAR(NP,DIST1,TIME,HITE)
1180 C

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1181      COMMON/MORE/ IWHICH,FCTHY(54),FCLLIW(54),FGTHY(54,2),
1182      + FGLLIW(54,2), NXDAT,XDAT(35), DCTHY(54,5),DGTHY(54,5),
1183      + DCLLIW(54,5),DGLLIW(54,5), FCSTO(54),FGSTO(54,2),
1184      + FISTO(54),FCSMI(54),FGSMI(54,2),FISMI(54),
1185      + DCSTO(54,5),DGSTO(54,5),DISTO(54,5),
1186      + DCSMI(54,5),DGSMI(54,5),DISMI(54,5),
1187      + TOTSTO(35),TOTSMI(35),ISIG,ZBAR,IG
1188 C
1189      COMMON /VAR/ IPAR(54),MAP(54),QINV(54),HALF(54),FCBOD(54),
1190      + FCMAR(54),FCLUN(54),FGBOD(54,2),FGMAR(54,2),
1191      + FGLUN(54,2),FIBOD(54),FIMAR(54,4),FILLIW(54,4),
1192      + FITHY(54,4),FILUN(54,5),FISKE(54,5),DIBOD(54,5),
1193      + FRAC(9,5),Q(54,5),CHI(54,5),DCBOD(54,5),
1194      + DCMAR(54,5),DCLUN(54,5),DGBOD(54,5),DGMAR(54,5),
1195      + DGLUN(54,5),DIMAR(54,5),DILLIW(54,5),DITHY(54,5),
1196      + DILUN(54,5),DISKE(54,5),TOTMAR(35),TOTBOD(35),
1197      + TOTLUN(35),TOTLLIW(35),TOTSKE(35),TOTTHY(35)
1198      COMMON/DP/ ASIGY(6,3),ASIGZ(6,3)
1199      COMMON/ENRGY/ ENEREL(2)
1200 C
1201      COMMON /STATIC/ NUCLID,NG,UDEP,BR,DISTO,NCALC,AREA,NOUT,
1202      + RELTIM(2),IWEATH,UBAR,HEIGHT(2),DELTAT(2),UD,IFG,IFIMAR,
1203      + IFILLIW,IFITHY,IFILUN,IFISKE,DIST,SIGY(2),SIGZ(2)
1204      + ,CDUR(2),HGRAS(2),NPUF,IPOF,SHCS,SHGS,SHIN,WIDT
1205 C
1206      DIMENSION PI(6)
1207      DATA PI/ .55, .35, .15, .1, .07, .07/
1208 C
1209      F = 8.79E-06 * ENEREL(NP)
1210      WIND = UBAR * ( AREA/10.) ** (PI(IWEATH))
1211      WIND = .5*(UBAR + WIND)
1212 C
1213 C      IF WIND VELOCITY IS LESS THAN CRITICAL SPEED, SUPPRESS
1214 C
1215      UCRIT = SQRT(9.09*F/AREA)
1216      IF(WIND.LT.UCRIT) RETURN
1217 C
1218      IF(IWEATH.GT.2) GOTO 100
1219      S = 8.7E-04
1220      IF(IWEATH.EQ.1) S = 1.75E-03
1221      DH = 2.6 * ( F / WIND / S )** .33333333
1222      HITE = HITE + DH
1223      RETURN
1224 C
1225 C      NEUTRAL OR UNSTABLE PLUME RISE
1226 C
1227 100      CONTINUE
1228      DH = 1.6 * F **.333333 * DIST1 **.666666 / WIND
1229      IF(DH.GT.(300.*F/WIND**3)) RETURN
1230      IF((2.15*SIGZ(NP)).GT.1000.) RETURN
1231      IF(TIME.GT.3600.) RETURN
1232      HITE = HITE + DH
1233 C
1234 C
1235      RETURN
1236      END

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C-1

APPENDIX C
PWR and BWR Core Inventories

Map of nuclides into 9 groups

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6 6 1 1 1 1 3 5 5 5 7 7 7 7 6 6 6 6 6 6 4 4 4 4
4 4 4 4 2 2 2 2 2 1 1 3 3 3 9 7 8 8 8 7 7 8 8 8 8
8 8 8 8

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Map of parent isotopes

```

0 0 0 0 0 0 0 0 0 0
9 10 0 0 13 0 16
0 0 0 19 28 0 29 0
0 0 0 0 26 27 0
0 0 32 34 0 0 0 0
40 0 0 0 43 0 0 53
47 54 0 51 0 0

```

Table 1 : Nuclide NUMBER, Inventory (Ci) for BWR 3578 MWTH ref. power,

	Half-life (days)		
1	5.465E+05	71.3	CO-58
2	6.542E+05	1921.	CO-60
3	8.956E+05	3919.	KR-85
4	3.256E+07	.1867	KR-85M
5	5.921E+07	.05278	KR-87
6	7.992E+07	.1167	KR-88
7	5.011E+04	18.65	RB-86
8	9.917E+07	52.0	SR-89
9	7.017E+06	10260.	SR-90
10	1.288E+08	.395	SR-91
11	7.514E+06	2.67	Y-90
12	1.210E+08	58.8	Y-91
13	1.593E+08	65.5	ZR-95
14	1.640E+08	.70	ZR-97
15	1.507E+08	35.1	NB-95
16	1.738E+08	2.751	MO-99
17	1.500E+08	.2508	TC-99M
18	1.317E+08	39.59	RU-103
19	.8786E+08	.185	RU-105
20	.3583E+08	369.	RU-106
21	6.558E+07	1.479	RH-105
22	8.043E+06	.3896	TE-127
23	1.083E+06	109.	TE-127M
24	2.705E+07	.04861	TE-129
25	7.112E+06	33.4	TE-129M
26	1.366E+07	1.25	TE-131M
27	1.335E+08	3.25	TE-132
28	8.308E+06	3.80	SB-127
29	2.884E+07	.1808	SB-129
30	9.226E+07	8.04	I-131
31	1.355E+08	.09521	I-132
32	1.936E+08	.8667	I-133
33	2.120E+08	.03653	I-134
34	1.823E+08	.2744	I-135
35	1.939E+08	5.29	XE-133
36	4.779E+07	.3821	XE-135
37	1.511E+07	752.4	CS-134
38	4.05E+06	13.	CS-136
39	9.045E+06	10990.	CS-137
40	1.761E+08	12.79	BA-140
41	1.797E+08	1.676	LA-140
42	1.599E+08	32.53	CE-141
43	1.557E+08	1.375	CE-143
44	1.037E+08	284.4	CE-144
45	1.524E+08	13.58	PR-143
46	.6809E+08	10.99	ND-147

47	2.029E+09	2.35	NP-239
48	1.411E+05	32510.	PU-238
49	3.578E+04	8.912E+06	PU-239
50	4.479E+04	2.469E+06	PU-240
51	7.711E+06	5333.	PU-241
52	7.838E+03	1.581E+05	AM-241
53	2.073E+06	163.	CM-242
54	1.117E+05	6611.	CM-244

Grid distances (10 DISTANCES) avg. radius in m.

10	402.	1210.	3219.	4828.	6437.
	8047.	16100.	30200.	84500.	684000.

Default conversion factors (CRAC2) IFG, IFIMAR, IFILLIW, IFITHY, IFILUN

1	2	4	4	5
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Curve fitting parameters

1	1	-3.559349462600479	1.160048586537639	-1.7190794757384000E-02
2	1	-2.816749412492209	1.065570910709667	-1.1470301922137058E-02
3	1	-2.546075845819127	1.077350459808095	-1.2523526943953700E-02
4	1	-1.969425829970786	1.021951293791542	-8.3770326083625144E-03
5	1	-1.960802209317214	1.110646206756064	-1.4053660078375977E-02
6	1	-1.790242998442716	1.150797093701679	-1.7333186632828135E-02
1	2	-4.539003975280546	1.411814492169336	-5.4496510043164801E-02
2	2	-4.213246071985861	1.443245116001938	-5.4706872600918071E-02
3	2	-3.162197496882786	1.196700871322801	-3.4587696416624102E-02
4	2	-2.981190111191164	1.212371210070850	-2.5384904034518616E-02
5	2	2.693340867043741	-0.7812153059161314	0.1579966646452930
6	2	9.430199759984714	-3.392720906582776	0.4248442241950466

Deposition velocity and breathing rate

0.01	2.660E-04
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Map of nuclides into 9 groups

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6 6 1 1 1 1 3 5 5 5 7 7 7 7 6 6 6 6 6 6 4 4 4 4
4 4 4 4 2 2 2 2 2 1 1 3 3 3 9 7 8 8 8 7 7 8 8 8 8
8 8 8 8

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Map of parent isotopes

```

0 0 0 0 0 0 0 0 0 0
9 10 0 0 13 0 16
0 0 0 19 28 0 29 0
0 0 0 0 26 27 0
0 0 32 34 0 0 0 0
40 0 0 0 43 0 0 53
47 54 0 51 0 0

```

Table 1 : Nuclide number, inventory for PWR (Ci) ref. power 3412 MWTh.

	Half-life (days)		
1	7.46E+05	71.3	CO-58
2	4.495E+03	1921.	CO-60
3	6.639E+05	3919.	KR-85
4	3.126E+07	.1867	KR-85M
5	5.696E+07	.05278	KR-87
6	7.691E+07	.1167	KR-88
7	4.815E+04	18.65	RB-86
8	9.588E+07	52.0	SR-89
9	5.171E+06	10260.	SR-90
10	1.238E+08	.395	SR-91
11	5.546E+06	2.67	Y-90
12	1.169E+08	58.8	Y-91
13	1.489E+08	65.5	ZR-95
14	1.561E+08	.70	ZR-97
15	1.407E+08	35.1	NB-95
16	1.655E+08	2.751	MO-99
17	1.428E+08	.2508	TC-99M
18	1.244E+08	39.59	RU-103
19	.8211E+08	.185	RU-105
20	.2892E+08	369.	RU-106
21	5.574E+07	1.479	RH-105
22	7.452E+06	.3896	TE-127
23	9.839E+05	109.	TE-127M
24	2.547E+07	.04861	TE-129
25	6.698E+06	33.4	TE-129M
26	1.281E+07	1.25	TE-131M
27	1.268E+08	3.25	TE-132
28	7.72E+06	3.80	SB-127
29	2.714E+07	.1808	SB-129
30	8.737E+07	8.04	I-131
31	1.286E+08	.09521	I-132
32	1.84E+08	.8667	I-133
33	2.017E+08	.03653	I-134
34	1.734E+08	.2744	I-135
35	1.841E+08	5.29	XE-133
36	.38E+08	.3821	XE-135
37	1.261E+07	752.4	CS-134
38	3.91E+06	13.	CS-136
39	6.537E+06	10990.	CS-137
40	1.681E+08	12.79	BA-140
41	1.717E+08	1.676	LA-140
42	1.527E+08	32.53	CE-141
43	1.485E+08	1.375	CE-143
44	9.156E+07	284.4	CE-144
45	1.455E+08	13.58	PR-143
46	.6529E+08	10.99	ND-147

47	1.85E+09	2.35	NP-239
48	1.168E+05	32510.	PU-238
49	2.581E+04	8.912E+06	PU-239
50	2.839E+04	2.469E+06	PU-240
51	5.421E+06	5333.	PU-241
52	3.624E+03	1.581E+05	AM-241
53	1.369E+06	163.	CM-242
54	8.406E+04	6611.	CM-244

Grid distances avg. radius in m.

34

402.	1210.	2010.	3219.	4023.	4828.	5633.	6437.
7242.	8047.	9660.	11300.	13700.	16100.		
20100.	22100.	26200.	30200.	36200.	44300.	52300.	
60400.	68400.	76400.	84500.	92500.	101000.	109000.	
125000.	149000.	201000.	282000.	443000.	684000.		

Default conversion factors (CRAC2) IFG, IFIMAR, IFILLIW, IFITHY, IFILUN

1	2	4	4	5
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Curve fitting parameters

1	1		
-3.559349462600479	1.160048586537639	-1.7190794757384000E-02	
2	1		
-2.816749412492209	1.065570910709667	-1.1470301922137058E-02	
3	1		
-2.546075845819127	1.077350459808095	-1.2523526943953700E-02	
4	1		
-1.969425829970786	1.021951293791542	-8.3770326083625144E-03	
5	1		
-1.960802209317214	1.110646206756064	-1.4053660078375977E-02	
6	1		
-1.790242998442716	1.150797093701679	-1.7333186632828135E-02	
1	2		
-4.539003975280546	1.411814492169336	-5.4496510043164801E-02	
2	2		
-4.213246071985861	1.443245116001938	-5.4706872600918071E-02	
3	2		
-3.162197496882786	1.196700871322801	-3.4587696416624102E-02	
4	2		
-2.981190111191164	1.212371210070850	-2.5384904034518616E-02	
5	2		
2.693340867043741	-0.7812153059161314	0.1579966646452930	
6	2		
9.430199759984714	-3.392720906582776	0.4248442241950466	

Deposition velocity and breathing rate

0.01	2.660E-04
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APPENDIX D
CRAC2 and MACCS Dose Conversion Factors

Table 2 :Radionuclide, Whole Body, Total Marrow, Lung, THYROID, LLIW immersion in contaminated air (Rem per Ci-sec/m**3)

1	2.16E-01	2.4E-01	2.01E-01	.171	.142
2	6.E-01	6.31E-01	5.67E-01	.533	.461
3	4.75E-04	5.78E-04	4.47E-04	5.E-04	3.42E-04
4	3.64E-02	5.5E-02	3.22E-02	.035	.0202
5	1.81E-01	1.02E-01	1.72E-01	.174	.143
6	4.67E-01	4.83E-01	4.47E-01	.431	.383
7	2.07E-02	2.27E-02	1.94E-02	.0154	.0133
8	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.
10	1.69E-01	1.93E-01	1.6E-01	.154	.121
11	0.	0.	0.	0.	0.
12	6.25E-04	6.39E-04	5.94E-04	6.22E-04	5.39E-04
13	1.62E-01	1.87E-01	1.52E-01	.143	.11
14	4.22E-02	4.72E-02	4.E-02	.0394	.0317
15	1.66E-01	1.83E-01	1.56E-01	.122	.107
16	3.64E-02	4.44E-02	3.42E-02	.0356	.0252
17	3.06E-02	5.42E-02	2.54E-02	.0372	.0158
18	1.11E-01	1.36E-01	1.05E-01	.117	.0803
19	1.79E-01	2.21E-01	1.67E-01	.182	.125
20	4.31E-02	5.22E-02	4.06E-02	.0447	.0308
21	1.82E-02	2.74E-02	1.61E-02	.0173	.0101
22	9.36E-04	1.16E-03	8.78E-04	9.81E-04	6.64E-04
23	1.1E-03	1.79E-03	5.61E-04	1.15E-03	1.38E-04
24	1.47E-02	1.81E-02	1.35E-02	.0147	9.92E-03
25	7.83E-03	9.92E-03	6.97E-03	8.17E-03	5.06E-03
26	3.14E-01	3.56E-01	2.84E-01	.261	.214
27	4.75E-02	7.31E-02	4.19E-02	.0458	.0261
28	1.51E-01	1.84E-01	1.43E-01	.15	.106
29	2.68E-01	2.97E-01	2.53E-01	.225	.185
30	8.72E-02	1.08E-01	8.22E-02	.0917	.0622
31	5.11E-01	5.89E-01	4.83E-01	.472	.364
32	1.54E-01	1.83E-01	1.46E-01	.156	.113
33	5.33E-01	5.8E-01	5.E-01	.428	.361
34	4.19E-01	4.42E-01	4.E-01	.389	.333
35	9.06E-03	1.59E-02	6.97E-03	.0107	3.97E-03
36	5.67E-02	8.47E-02	5.06E-02	.0547	.0319
37	3.5E-01	4.03E-01	3.28E-01	.314	.241
38	4.78E-01	5.42E-01	4.44E-01	.381	.314
39	1.22E-01	1.49E-01	1.15E-01	.128	.0878
40	4.44E-02	5.61E-02	4.14E-02	.0461	.0308
41	5.67E-01	6.06E-01	5.39E-01	.547	.458
42	1.83E-02	3.22E-02	1.5E-02	.0222	9.17E-03
43	6.81E-02	9.36E-02	6.08E-02	.0636	.0406
44	4.31E-03	7.61E-03	3.44E-03	5.14E-03	2.06E-03
45	0.	0.	0.	0.	0.
46	3.14E-02	4.39E-02	2.78E-02	.0336	.0197
47	3.08E-02	4.07E-02	2.65E-02	.0322	.0166
48	5.25E-05	4.25E-05	9.58E-06	7.78E-06	1.41E-05
49	2.3E-05	2.17E-05	5.42E-06	6.E-06	6.03E-06
50	4.64E-05	3.8E-05	9.17E-06	7.78E-06	1.27E-05
51	4.17E-10	8.53E-10	2.94E-10	4.E-10	1.64E-10
52	4.56E-03	9.33E-03	3.22E-03	4.39E-03	1.8E-03
53	5.E-05	3.89E-05	8.31E-06	6.11E-06	1.31E-05
54	1.42E-03	2.81E-03	1.07E-03	1.5E-03	6.28E-04

Table 3 : per 1 Day< Nucl., Whole Body, Marrow, Lung, THYR., LLIW> exposure to contaminated ground (Rem per Ci/m**2)

1	3.29E+02	3.67E+02	3.08E+02	87.	72.7
2	8.48E+02	8.89E+02	7.99E+02	251.	217.

3	0.	0.	0.	.255	.176
4	0.	0.	0.	10.	5.76
5	0.	0.	0.	17.7	14.4
6	0.	0.	0.	108.	95.
7	2.93E+01	3.22E+01	2.75E+01	7.3	6.39
8	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.
10	1.68E+02	1.96E+02	1.59E+02	83.	62.4
11	0.	0.	0.	0.	0.
12	8.82E-01	8.98E-01	8.39E-01	.293	.254
13	2.47E+02	2.85E+02	2.32E+02	72.4	55.8
14	3.33E+02	4.02E+02	3.14E+02	144.	101.
15	249.	273.	233.	62.3	53.9
16	77.3	107.	69.5	24.2	15.6
17	15.2	27.	12.6	11.8	5.06
18	175.	214.	165.	61.4	42.2
19	72.3	90.4	67.7	52.6	36.2
20	65.1	79.6	61.7	22.7	15.7
21	22.	33.2	19.5	8.2	4.71
22	.677	.843	.638	.383	.259
23	7.9	12.7	4.4	2.66	.386
24	1.98	2.44	1.83	1.96	1.33
25	36.3	45.4	32.8	11.6	7.46
26	381.	436.	356.	124.	101.
27	677.	804.	636.	168.	125.
28	212.	257.	200.	74.3	52.6
29	100.	112.	94.7	61.5	51.2
30	128.	159.	121.	46.5	31.4
31	107.	123.	101.	90.	69.3
32	163.	193.	154.	69.7	50.3
33	41.4	45.6	38.8	33.3	28.
34	252.	277.	238.	138.	116.
35	0.	0.	0.	8.9	3.28
36	0.	0.	0.	20.5	12.
37	530.	610.	407.	159.	122.
38	684.	779.	637.	186.	153.
39	186.	228.	176.	65.4	44.6
40	213.	242.	202.	42.7	31.3
41	649.	688.	612.	237.	198.
42	27.7	49.3	22.8	11.3	4.68
43	90.	124.	30.6	32.9	20.9
44	17.2	23.9	15.2	6.06	3.69
45	0.	0.	0.	0.	0.
46	52.	72.8	46.3	19.1	11.1
47	58.9	95.3	50.9	22.7	11.7
48	.895	.717	.182	.044	.0796
49	.376	.356	.0882	.032	.0329
50	.784	.653	.155	.045	.0711
51	4.52E-05	9.23E-05	3.18E-05	4.8E-06	1.98E-06
52	20.6	42.1	14.5	6.6	2.71
53	.792	.614	.131	.032	.0692
54	4.96	9.73	3.73	1.74	.727
Table 3 :same per 7 Day< Nucl., Whole Body, Marrow, Lung, THYROID, LLIW>					
1	2.24E+03	2.50E+03	2.10E+03	1780.	1480.
2	5.88E+03	6.22E+03	5.58E+03	5280.	4540.
3	0.	0.	0.	5.38	3.68
4	0.	0.	0.	14.	8.11
5	0.	0.	0.	17.9	14.6
6	0.	0.	0.	126.	111.
7	1.85E+02	2.02E+02	1.73E+02	137.	119.

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8	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.
10	2.05E+02	2.39E+02	1.83E+02	195.	147.
11	0.	0.	0.	0.	0.
12	5.91	6.06	5.66	5.94	5.12
13	1770.	2040.	1670.	1540.	1200.
14	5.38E+02	6.52E+02	5.10E+02	558.	392.
15	1640.	1800.	1540.	1220.	1060.
16	325.	465.	291.	346.	202.
17	16.2	28.8	13.5	19.7	8.4
18	1160.	1420.	1090.	1220.	836.
19	79.4	99.9	73.7	80.1	54.3
20	456.	554.	430.	476.	328.
21	56.7	85.5	50.1	54.5	31.3
22	.813	1.01	.767	.86	.58
23	58.4	92.	33.7	62.	12.6
24	1.98	2.44	1.83	1.98	1.34
25	246.	307.	222.	250.	162.
26	960.	1100.	890.	810.	649.
27	3080.	3630.	2880.	2850.	2140.
28	920.	1110.	865.	920.	646.
29	104.	116.	97.8	87.	71.7
30	708.	873.	663.	737.	503.
31	107.	123.	101.	99.	76.
32	311.	375.	291.	315.	222.
33	41.4	45.6	38.8	33.4	28.
34	285.	318.	269.	266.	217.
35	0.	0.	0.	125.	46.1
36	0.	0.	0.	45.2	26.4
37	3600.	4260.	3470.	3310.	2550.
38	4100.	4680.	3320.	3280.	2710.
39	1310.	1600.	1240.	1380.	944.
40	3650.	3980.	3460.	3550.	2900.
41	1800.	1920.	1710.	1740.	1460.
42	182.	324.	150.	220.	91.7
43	224.	398.	200.	210.	133.
44	120.	167.	107.	130.	79.6
45	0.	0.	0.	0.	0.
46	305.	426.	270.	328.	191.
47	202.	326.	174.	211.	109.
48	6.2	5.92	1.14	.92	1.67
49	2.63	2.49	.622	.69	.691
50	5.47	4.57	1.08	.95	1.49
51	2.21E-03	4.52E-03	1.56E-03	2.12E-03	8.72E-04
52	143.	295.	102.	138.	56.9
53	5.46	4.25	.905	.66	1.43
54	34.6	68.1	26.1	35.9	15.3

CRAC2 table : whole body inhalation 0-2 days

1	280.
2	680.
3	.31
4	.26
5	1.
6	2.3
7	600.
8	420.
9	310.
10	220.
11	410.
12	340.

13 270.
 14 460.
 15 230.
 16 240.
 17 9.8
 18 190.
 19 63.
 20 830.
 21 69.
 22 33.
 23 140.
 24 9.8
 25 340.
 26 350.
 27 700.
 28 360.
 29 100.
 30 150.
 31 70.
 32 180.
 33 30.
 34 150.
 35 .66
 36 1.2
 37 610.
 38 710.
 39 400.
 40 440.
 41 620.
 42 120.
 43 210.
 44 720.
 45 160.
 46 180.
 47 140.
 48 20000.
 49 18000.
 50 18000.
 51 2.9
 52 20000.
 53 22000.
 54 21000.

Table A-4 : Inhalation Marrow; Nuclide, 0-2 Days, 0-7 days, 0-30 Days, 0-30 Years

1	230.	795.	1100.	3100.
2	550.	2000.	2800.	58000.
3	.6	.61	.61	.61
4	.39	.39	.39	.39
5	1.3	1.3	1.3	1.3
6	3.1	3.1	3.1	3.1
7	500.	3250.	4800.	6500.
8	520.	3350.	5000.	13000.
9	360.	6100.	10000.	600000.
10	190.	215.	230.	320.
11	200.	470.	510.	510.
12	160.	1430.	2300.	9300.
13	180.	670.	940.	3600.
14	170.	190.	190.	190.
15	180.	575.	770.	1400.
16	75.	125.	130.	130.
17	11.	11.	11.	11.

18	130.	405.	550.	1100.
19	23.	24.	24.	24.
20	76.	440.	660.	6200.
21	16.	23.	23.	23.
22	3.7	3.9	3.9	3.9
23	26.	182.	270.	800.
24	1.1	1.1	1.1	1.1
25	67.	375.	530.	840.
26	210.	300.	310.	310.
27	480.	940.	1000.	1000.
28	170.	310.	330.	330.
29	45.	46.	46.	46.
30	77.	150.	180.	190.
31	50.	50.	50.	50.
32	88.	93.5	94.	94.
33	20.	20.	20.	20.
34	91.	91.	91.	91.
35	1.5	1.6	1.6	1.6
36	2.1	2.1	2.1	2.1
37	580.	4950.	7000.	48000.
38	690.	3550.	5000.	6000.
39	360.	3250.	5200.	37000.
40	480.	2100.	2800.	3400.
41	440.	670.	680.	680.
42	37.	113.	150.	270.
43	66.	95.5	100.	110.
44	62.	235.	350.	9200.
45	3.	17.8	26.	34.
46	55.	140.	170.	200.
47	40.	62.	64.	64.
48	18.	171.	280.	870000.
49	16.	159.	260.	920000.
50	16.	164.	260.	920000.
51	.0033	.042	.072	15000.
52	40.	265.	420.	990000.
53	21.	203.	330.	8500.
54	20.	201.	330.	580000.

Table A-4 : Same, LLIW

1	3200.	6900.	7100.	4280.
2	8000.	18000.	18000.	10100.
3	.18	.18	.18	.0612
4	.22	.22	.22	.0946
5	1.	1.	1.	.81
6	2.3	2.3	2.3	2.07
7	1200.	2700.	5800.	1400.
8	9200.	14000.	14000.	6860.
9	7300.	14000.	16000.	9100.
10	2400.	2600.	2600.	1430.
11	22000.	40000.	40000.	26000.
12	20000.	46000.	49000.	23000.
13	6100.	14000.	14000.	3920.
14	15000.	18000.	19000.	11000.
15	3200.	6900.	7000.	3110.
16	12000.	20000.	21000.	7400.
17	11.	11.	11.	6.93
18	4800.	10000.	11000.	2000.
19	910.	1200.	1200.	492.
20	55000.	120000.	130000.	88800.
21	3300.	5100.	5100.	408.
22	730.	780.	780.	179.

23	6900.	17000.	20000.	3570.
24	5.7	5.7	5.7	2.56
25	15000.	34000.	36000.	15000.
26	5800.	8500.	8500.	5350.
27	3300.	6000.	6100.	3300.
28	13000.	26000.	26000.	9100.
29	790.	810.	810.	486.
30	280.	330.	330.	72.6
31	60.	60.	60.	44.4
32	300.	330.	330.	152.
33	20.	20.	20.	17.2
34	220.	220.	220.	108.
35	.42	.42	.42	.13
36	.99	.99	.99	.485
37	900.	2800.	10000.	2100.
38	990.	2800.	6400.	2320.
39	680.	1900.	6300.	912.
40	9400.	16000.	16000.	7840.
41	13000.	21000.	21000.	10700.
42	6700.	15000.	15000.	1200.
43	9800.	16000.	16000.	5760.
44	52000.	120000.	120000.	85200.
45	12000.	25000.	25000.	6750.
46	10000.	21000.	22000.	3990.
47	7400.	13000.	13000.	1040.
48	22000.	50000.	51000.	5000.
49	20000.	46000.	47000.	4600.
50	21000.	47000.	48000.	4700.
51	210.	470.	480.	0.
52	23000.	52000.	54000.	5200.
53	24000.	55000.	56000.	5500.
54	23000.	52000.	54000.	5200.

Table A-4 : Same ,Thyroid

1	110.	200.	950.	110.
2	240.	650.	2300.	240.
3	.18	.18	.18	.18
4	.2	.2	.2	.2
5	.97	.97	.97	.97
6	2.	2.	2.	2.
7	500.	1700.	4800.	500.
8	200.	500.	920.	260.
9	180.	700.	1000.	180.
10	130.	140.	160.	130.
11	8.2	17.	21.	8.2
12	7.1	25.	98.	7.1
13	79.	220.	800.	79.
14	77.	86.	86.	77.
15	81.	210.	640.	81.
16	94.	140.	150.	94.
17	46.	46.	46.	46.
18	52.	140.	430.	52.
19	14.	15.	15.	14.
20	48.	170.	620.	48.
21	6.4	9.6	9.9	6.4
22	2.9	3.	3.	2.9
23	16.	63.	160.	16.
24	.81	.81	.81	.81
25	43.	140.	320.	43.
26	4500.	34000.	87000.	4500.
27	48000.	88000.	97000.	48000.

28	100.	180.	220.	100.
29	37.	37.	38.	37.
30	130000.	480000.	1.E+06	130000.
31	6600.	6600.	6600.	6600.
32	120000.	180000.	180000.	120000.
33	1100.	1100.	1100.	1100.
34	43000.	44000.	44000.	43000.
35	.39	.4	.4	.39
36	.91	.91	.91	.91
37	580.	2000.	7900.	580.
38	690.	2100.	5000.	690.
39	360.	1300.	5100.	360.
40	220.	590.	1000.	220.
41	150.	220.	230.	150.
42	6.	16.	46.	6.
43	18.	24.	25.	18.
44	5.1	13.	45.	5.1
45	.093	.29	.79	.093
46	12.	28.	60.	12.
47	8.2	14.	15.	8.2
48	18.	62.	280.	18.
49	16.	58.	260.	16.
50	16.	58.	260.	16.
51	.0017	.0069	.045	1.7E-03
52	20.	73.	330.	20.
53	21.	75.	330.	21.
54	20.	73.	330.	20.

Table A-4 : same ,Lung

1	1900.	17000.	59000.	61000.	59000.
2	4800.	49000.	4.6E+05	1.3E+06	4.6E+05
3	.18	.18	.18	.18	.18
4	.21	.21	.21	.21	.21
5	.96	.96	.96	.96	.96
6	2.	2.	2.	2.	2.
7	7200.	12000.	14000.	14000.	14000.
8	6000.	7200.	7800.	7800.	7800.
9	4600.	12000.	16000.	18000.	16000.
10	3400.	3800.	4300.	4300.	4300.
11	17000.	33000.	33000.	33000.	33000.
12	13000.	100000.	200000.	200000.	200000.
13	3500.	34000.	130000.	130000.	130000.
14	14000.	15000.	15000.	15000.	15000.
15	1800.	15000.	31000.	31000.	31000.
16	7700.	16000.	16000.	16000.	16000.
17	89.	89.	89.	89.	89.
18	2900.	24000.	54000.	54000.	54000.
19	2100.	2200.	2200.	2200.	2200.
20	33000.	330000.	2.5E+06	3.9E+06	2.5E+06
21	2500.	3600.	3600.	3600.	3600.
22	1500.	1600.	1600.	1600.	1600.
23	5200.	52000.	120000.	120000.	120000.
24	560.	560.	560.	560.	560.
25	13000.	95000.	150000.	150000.	150000.
26	6600.	11000.	11000.	11000.	11000.
27	13000.	30000.	30000.	30000.	30000.
28	9100.	24000.	25000.	25000.	25000.
29	3100.	3100.	3200.	3200.	3200.
30	2100.	2400.	2400.	2400.	2400.
31	1000.	1000.	1000.	1000.	1000.
32	3100.	3100.	3100.	3100.	3100.

33	560.	560.	560.	560.	560.
34	2500.	2500.	2500.	2500.	2500.
35	.41	.41	.41	.41	.41
36	.94	.94	.94	.94	.94
37	3000.	11000.	45000.	51000.	45000.
38	2900.	7300.	8200.	8200.	8200.
39	3200.	8300.	34000.	40000.	34000.
40	4600.	6100.	6300.	6300.	6300.
41	10000.	16000.	16000.	16000.	16000.
42	4000.	31000.	62000.	62000.	62000.
43	7000.	12000.	13000.	13000.	13000.
44	29000.	300000.	2.1E+06	2.9E+06	2.1E+06
45	6900.	40000.	49000.	49000.	49000.
46	6100.	31000.	37000.	38000.	37000.
47	5000.	9200.	9200.	9300.	9200.
48	1.3E+06	1.3E+07	1.2E+08	3.1E+08	1.2E+08
49	1.2E+06	1.2E+07	1.2E+08	2.E+08	1.2E+08
50	1.2E+06	1.2E+07	1.2E+08	2.9E+08	1.2E+08
51	130.	1800.	64000.	570000.	64000.
52	1.3E+06	1.3E+07	1.3E+08	3.1E+08	1.3E+08
53	1.4E+06	1.4E+07	7.6E+07	8.7E+07	7.6E+07
54	1.4E+06	1.4E+07	1.3E+08	3.1E+08	1.3E+08

Table A-4 : same ,Skeleton, 0-2 days, 0-7 days, 0-30 days, 0-30 years

1	150.	330.	840.	2500.	2600.
2	350.	800.	2200.	18000.	50000.
3	.15	.15	.15	.15	.15
4	.19	.19	.19	.19	.19
5	.83	.83	.83	.83	.83
6	1.8	1.8	1.8	1.8	1.8
7	500.	1700.	4800.	6500.	6500.
8	720.	3800.	19000.	30000.	30000.
9	530.	3800.	21000.	240000.	280000.
10	190.	200.	230.	340.	340.
11	410.	860.	1000.	1000.	1000.
12	340.	1200.	4700.	10000.	19000.
13	120.	200.	790.	3300.	3400.
14	120.	130.	130.	130.	130.
15	120.	260.	620.	1200.	1200.
16	62.	100.	110.	110.	110.
17	10.	10.	10.	10.	10.
18	77.	180.	430.	880.	880.
19	16.	17.	17.	17.	17.
20	58.	190.	600.	3400.	5900.
21	11.	16.	16.	16.	16.
22	5.	5.2	5.2	5.2	5.2
23	31.	130.	440.	1800.	2000.
24	1.2	1.2	1.2	1.2	1.2
25	75.	260.	750.	1400.	1400.
26	160.	230.	250.	250.	250.
27	440.	800.	910.	910.	910.
28	120.	210.	250.	260.	260.
29	38.	38.	38.	39.	39.
30	76.	120.	200.	210.	210.
31	47.	47.	47.	47.	47.
32	87.	92.	92.	92.	92.
33	19.	19.	19.	19.	19.
34	87.	87.	87.	87.	87.
35	.35	.36	.36	.36	.36
36	.72	.72	.72	.72	.72
37	570.	2000.	7800.	42000.	47000.

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38	660.	2000.	4900.	5900.	5900.	
39	360.	1300.	5100.	31000.	36000.	
40	610.	2000.	4200.	5200.	5200.	
41	420.	670.	700.	700.	700.	
42	25.	61.	160.	320.	320.	
43	47.	71.	94.	110.	110.	
44	100.	200.	630.	7200.	10000.	
45	7.6	24.	65.	86.	86.	
46	38.	85.	160.	190.	240.	
47	30.	49.	54.	54.	160.	
48	9900.	35000.	160000.	3.4E+06	4.9E+08	
49	9200.	33000.	150000.	3.1E+06	5.2E+08	
50	9200.	33000.	150000.	3.1E+06	5.2E+08	
51	.24	1.2	13.	2700.	8.3E+06	
52	11000.	39000.	180000.	3.6E+06	5.5E+08	
53	12000.	43000.	180000.	1.8E+06	4.8E+06	
54	11000.	41000.	190000.	3.7E+06	3.3E+08	

Maccs conversion factors, by nuclide, 6 organs , cs,gs 8hrs, gs 7days, inh
for each isotope, dose conv fact. in Bq, six records per isotope

3.520E-14	1.979E-11	4.023E-10	1.558E-10	STOMACH	CO-58
3.203E-14	1.796E-11	3.652E-10	3.307E-10	SMALL INT.	
3.805E-14	2.143E-11	4.356E-10	1.039E-09	LUNGS	
3.869E-14	2.179E-11	4.430E-10	1.577E-10	RM	
4.788E-14	2.690E-11	5.469E-10	6.142E-11	THY	
3.456E-14	1.942E-11	3.948E-10	9.144E-10	LLIW	
9.132E-14	4.602E-11	9.655E-10	3.840E-10		
8.530E-14	4.301E-11	9.022E-10	8.077E-10		
9.862E-14	4.986E-11	1.046E-09	5.186E-09		
9.957E-14	5.032E-11	1.055E-09	3.986E-10		
1.230E-13	6.219E-11	1.305E-09	1.465E-10		
9.069E-14	4.575E-11	9.597E-10	2.386E-09		
7.674E-17	.000E+00	.000E+00	6.757E-14		
6.881E-17	.000E+00	.000E+00	6.781E-14		
8.340E-17	.000E+00	.000E+00	4.754E-13		
8.562E-17	.000E+00	.000E+00	6.808E-14		
1.037E-16	.000E+00	.000E+00	6.689E-14		
7.484E-17	.000E+00	.000E+00	6.781E-14		
5.232E-15	.000E+00	.000E+00	6.102E-14		
4.566E-15	.000E+00	.000E+00	6.102E-14		
5.771E-15	.000E+00	.000E+00	4.890E-13		
5.549E-15	.000E+00	.000E+00	6.372E-14		
7.737E-15	.000E+00	.000E+00	5.531E-14		
5.105E-15	.000E+00	.000E+00	5.912E-14		
3.161E-14	.000E+00	.000E+00	2.220E-13		
2.946E-14	.000E+00	.000E+00	2.210E-13		
3.393E-14	.000E+00	.000E+00	2.430E-12		
3.456E-14	.000E+00	.000E+00	2.180E-13		
4.091E-14	.000E+00	.000E+00	2.150E-13		
3.133E-14	.000E+00	.000E+00	2.250E-13		
1.064E-13	.000E+00	.000E+00	3.749E-13		
1.001E-13	.000E+00	.000E+00	3.780E-13		
1.140E-13	.000E+00	.000E+00	4.263E-12		
1.156E-13	.000E+00	.000E+00	3.669E-13		
1.367E-13	.000E+00	.000E+00	3.540E-13		
1.059E-13	.000E+00	.000E+00	3.972E-13		
3.488E-15	1.806E-12	3.361E-11	3.020E-10		
3.203E-15	1.670E-12	3.108E-11	2.042E-10		
3.742E-15	1.951E-12	3.631E-11	1.595E-09		
3.805E-15	1.979E-12	3.682E-11	8.078E-10		
4.725E-15	2.460E-12	4.577E-11	2.497E-10		
3.425E-15	1.788E-12	3.327E-11	2.041E-10		
5.042E-18	2.743E-15	5.505E-14	1.832E-10		
4.598E-18	2.497E-15	5.011E-14	2.672E-10		
5.422E-18	2.952E-15	5.925E-14	1.328E-09		
5.518E-18	2.998E-15	6.017E-14	9.471E-10		
6.849E-18	3.727E-15	7.480E-14	8.280E-11		
4.947E-18	2.697E-15	5.413E-14	1.975E-09		
.000E+00	.000E+00	.000E+00	1.137E-10		
.000E+00	.000E+00	.000E+00	1.596E-10		
.000E+00	.000E+00	.000E+00	7.430E-10		
.000E+00	.000E+00	.000E+00	1.726E-09		
.000E+00	.000E+00	.000E+00	1.074E-10		
.000E+00	.000E+00	.000E+00	1.606E-09		
3.567E-14	1.451E-11	3.408E-11	1.634E-10		
3.241E-14	1.319E-11	3.098E-11	2.312E-10		
3.857E-14	1.568E-11	3.685E-11	8.682E-10		
3.920E-14	1.593E-11	3.743E-11	8.976E-11		

4.849E-14	1.963E-11	4.612E-11	3.424E-11
3.502E-14	1.419E-11	3.335E-11	5.211E-10
.000E+00	.000E+00	.000E+00	3.745E-10
.000E+00	.000E+00	.000E+00	8.713E-10
.000E+00	.000E+00	.000E+00	3.546E-09
.000E+00	.000E+00	.000E+00	8.668E-12
.000E+00	.000E+00	.000E+00	3.153E-13
.000E+00	.000E+00	.000E+00	6.544E-09
1.316E-16	6.690E-14	1.351E-12	2.740E-10
1.224E-16	6.234E-14	1.259E-12	6.656E-10
1.424E-16	7.246E-14	1.463E-12	6.923E-09
1.436E-16	7.310E-14	1.476E-12	2.798E-11
1.782E-16	9.060E-14	1.830E-12	6.243E-13
1.306E-16	6.644E-14	1.342E-12	6.908E-09
2.660E-14	1.504E-11	3.048E-10	1.541E-10
2.407E-14	1.358E-11	2.752E-10	3.296E-10
2.876E-14	1.623E-11	3.288E-10	1.505E-09
2.924E-14	1.650E-11	3.343E-10	2.846E-10
3.615E-14	2.042E-11	4.138E-10	6.141E-11
2.607E-14	1.468E-11	2.974E-10	1.573E-09
5.595E-14	2.467E-11	9.615E-11	3.772E-10
5.066E-14	2.235E-11	8.706E-11	7.834E-10
6.049E-14	2.665E-11	1.039E-10	2.836E-09
6.159E-14	2.712E-11	1.057E-10	1.079E-10
7.574E-14	3.350E-11	1.306E-10	2.788E-11
5.486E-14	2.422E-11	9.440E-11	2.609E-09
2.778E-14	1.557E-11	3.063E-10	1.287E-10
2.515E-14	1.411E-11	2.776E-10	2.838E-10
3.000E-14	1.684E-11	3.314E-10	7.399E-10
3.051E-14	1.711E-11	3.367E-10	1.212E-10
3.773E-14	2.121E-11	4.173E-10	4.278E-11
2.724E-14	1.529E-11	3.009E-10	9.234E-10
5.518E-15	3.814E-12	5.353E-11	1.895E-10
4.978E-15	3.404E-12	4.738E-11	4.221E-10
5.993E-15	4.157E-12	5.867E-11	1.592E-09
6.057E-15	4.105E-12	5.672E-11	3.096E-11
7.579E-15	5.367E-12	7.714E-11	5.914E-12
5.422E-15	3.734E-12	5.236E-11	2.860E-09
4.154E-15	1.731E-12	2.875E-12	1.437E-11
3.583E-15	1.498E-12	2.489E-12	3.397E-12
4.598E-15	1.928E-12	3.203E-12	2.924E-11
4.217E-15	1.755E-12	2.915E-12	2.296E-12
6.342E-15	2.656E-12	4.412E-12	1.968E-11
4.027E-15	1.689E-12	2.806E-12	3.371E-12
1.662E-14	9.838E-12	1.950E-10	1.212E-10
1.487E-14	8.816E-12	1.747E-10	2.683E-10
1.808E-14	1.075E-11	2.131E-10	1.307E-09
1.849E-14	1.093E-11	2.166E-10	8.176E-11
2.246E-14	1.331E-11	2.638E-10	2.856E-11
1.624E-14	9.656E-12	1.914E-10	1.489E-09
2.809E-14	9.331E-12	1.389E-11	7.924E-11
2.532E-14	8.371E-12	1.246E-11	1.205E-10
3.046E-14	1.008E-11	1.502E-11	5.005E-10
3.100E-14	1.027E-11	1.532E-11	7.221E-12
3.844E-14	1.270E-11	1.892E-11	3.876E-12
2.751E-14	9.118E-12	1.358E-11	2.058E-10
7.293E-15	4.175E-12	8.726E-11	6.984E-10
6.564E-15	3.765E-12	7.869E-11	1.589E-09
7.896E-15	4.531E-12	9.469E-11	3.044E-08
8.054E-15	4.622E-12	9.660E-11	8.744E-11

9.862E-15	5.652E-12	1.181E-10	4.022E-11
7.135E-15	4.093E-12	8.555E-11	1.604E-08
2.600E-15	1.488E-12	9.870E-12	6.353E-11
2.315E-15	1.327E-12	8.804E-12	1.353E-10
2.841E-15	1.631E-12	1.082E-11	4.985E-10
2.936E-15	1.682E-12	1.116E-11	5.385E-12
3.615E-15	2.071E-12	1.374E-11	1.432E-12
2.556E-15	1.462E-12	9.701E-12	7.389E-10
1.639E-16	7.509E-14	1.679E-13	4.321E-11
1.462E-16	6.717E-14	1.502E-13	6.822E-11
1.788E-16	8.198E-14	1.833E-13	3.748E-10
1.836E-16	8.405E-14	1.879E-13	3.342E-12
2.245E-16	1.033E-13	2.310E-13	1.590E-12
1.605E-16	7.371E-14	1.648E-13	1.640E-10
4.566E-17	7.804E-14	2.953E-12	8.892E-11
3.165E-17	5.837E-14	2.406E-12	1.832E-10
6.247E-17	1.013E-13	3.555E-12	2.476E-09
2.632E-17	5.643E-14	2.669E-12	2.769E-10
1.237E-16	1.852E-13	5.663E-12	1.337E-11
4.059E-17	7.121E-14	2.788E-12	2.309E-09
1.842E-15	2.273E-13	2.293E-13	1.553E-11
1.652E-15	2.027E-13	2.044E-13	1.083E-11
2.007E-15	2.482E-13	2.503E-13	1.526E-10
2.042E-15	2.501E-13	2.522E-13	6.131E-13
2.527E-15	3.145E-13	3.172E-13	5.088E-13
1.804E-15	2.217E-13	2.235E-13	1.838E-12
1.157E-15	1.223E-12	2.666E-11	2.603E-10
1.040E-15	1.089E-12	2.375E-11	5.055E-10
1.262E-15	1.339E-12	2.919E-11	4.429E-09
1.259E-15	1.325E-12	2.893E-11	4.854E-10
1.617E-15	1.729E-12	3.761E-11	3.040E-11
1.132E-15	1.191E-12	2.597E-11	4.897E-09
5.522E-14	2.765E-11	1.750E-10	2.201E-10
5.014E-14	2.513E-11	1.588E-10	3.919E-10
5.963E-14	2.990E-11	1.894E-10	1.244E-09
6.025E-14	3.022E-11	1.917E-10	9.406E-11
7.488E-14	3.772E-11	2.388E-10	6.406E-09
5.421E-14	2.720E-11	1.721E-10	1.333E-09
6.976E-15	3.219E-11	5.471E-10	1.874E-10
6.152E-15	2.912E-11	4.957E-10	2.624E-10
7.706E-15	3.493E-11	5.930E-10	5.591E-10
7.642E-15	3.531E-11	6.006E-10	2.788E-10
1.021E-14	4.414E-11	7.469E-10	7.757E-08
6.849E-15	3.154E-11	5.362E-10	7.713E-10
2.337E-14	1.314E-11	1.623E-10	2.278E-10
2.106E-14	1.181E-11	1.459E-10	5.199E-10
2.534E-14	1.420E-11	1.755E-10	1.907E-09
2.584E-14	1.456E-11	1.799E-10	9.334E-11
3.171E-14	1.784E-11	2.204E-10	2.443E-11
2.289E-14	1.287E-11	1.590E-10	3.663E-09
5.264E-14	1.654E-11	2.319E-11	1.226E-10
4.820E-14	1.514E-11	2.123E-11	1.888E-10
5.676E-14	1.788E-11	2.507E-11	8.374E-10
5.771E-14	1.814E-11	2.544E-11	1.608E-11
7.103E-14	2.237E-11	3.137E-11	9.521E-12
5.169E-14	1.627E-11	2.281E-11	2.014E-10
1.291E-14	7.742E-12	1.238E-10	5.997E-11
1.154E-14	6.914E-12	1.106E-10	1.572E-11
1.408E-14	8.444E-12	1.351E-10	4.616E-10
1.449E-14	8.678E-12	1.388E-10	3.518E-11

1.776E-14	1.062E-11	1.699E-10	6.395E-08
1.265E-14	7.589E-12	1.214E-10	1.465E-11
8.308E-14	1.738E-11	1.909E-11	9.896E-11
7.547E-14	1.579E-11	1.735E-11	1.245E-11
8.974E-14	1.879E-11	2.065E-11	2.702E-10
9.132E-14	1.910E-11	2.099E-11	1.401E-11
1.126E-13	2.352E-11	2.584E-11	1.721E-09
8.149E-14	1.703E-11	1.871E-11	1.126E-11
2.121E-14	1.074E-11	4.574E-11	1.023E-10
1.915E-14	9.700E-12	4.130E-11	2.006E-11
2.305E-14	1.170E-11	4.983E-11	7.128E-10
2.350E-14	1.194E-11	5.086E-11	2.454E-11
2.873E-14	1.459E-11	6.212E-11	2.389E-08
2.077E-14	1.050E-11	4.471E-11	1.910E-11
9.672E-14	8.230E-12	8.245E-12	7.081E-11
8.847E-14	7.524E-12	7.537E-12	5.521E-12
1.043E-13	8.893E-12	8.909E-12	1.429E-10
1.059E-13	9.008E-12	9.025E-12	6.067E-12
1.306E-13	1.114E-11	1.116E-11	2.848E-10
9.513E-14	8.100E-12	8.115E-12	4.800E-12
5.866E-14	1.984E-11	3.495E-11	9.819E-11
5.486E-14	1.854E-11	3.266E-11	1.878E-11
6.342E-14	2.151E-11	3.789E-11	4.295E-10
6.405E-14	2.170E-11	3.821E-11	2.194E-11
7.864E-14	2.658E-11	4.681E-11	7.172E-09
5.835E-14	1.972E-11	3.473E-11	1.765E-11
9.450E-16	.000E+00	.000E+00	1.312E-13
7.991E-16	.000E+00	.000E+00	1.368E-13
1.113E-15	.000E+00	.000E+00	3.562E-13
7.293E-16	.000E+00	.000E+00	1.558E-13
1.719E-15	.000E+00	.000E+00	1.212E-13
8.689E-16	.000E+00	.000E+00	1.357E-13
8.213E-15	.000E+00	.000E+00	2.547E-13
7.293E-15	.000E+00	.000E+00	2.560E-13
9.006E-15	.000E+00	.000E+00	7.754E-13
9.228E-15	.000E+00	.000E+00	2.532E-13
1.167E-14	.000E+00	.000E+00	2.308E-13
8.118E-15	.000E+00	.000E+00	2.479E-13
5.581E-14	3.159E-11	6.615E-10	3.462E-10
5.042E-14	2.858E-11	5.984E-10	3.382E-10
6.025E-14	3.424E-11	7.169E-10	1.036E-09
6.152E-14	3.488E-11	7.303E-10	9.057E-10
7.579E-14	4.292E-11	8.986E-10	4.736E-10
5.454E-14	3.095E-11	6.481E-10	3.349E-10
7.892E-14	4.255E-11	7.539E-10	3.756E-10
7.191E-14	3.884E-11	6.882E-10	3.663E-10
8.528E-14	4.608E-11	8.165E-10	7.041E-10
8.624E-14	4.653E-11	8.245E-10	7.018E-10
1.076E-13	5.830E-11	1.033E-09	3.585E-10
7.764E-14	4.191E-11	7.427E-10	3.617E-10
2.010E-14	1.149E-11	2.430E-10	2.251E-10
1.812E-14	1.037E-11	2.194E-10	1.956E-10
2.178E-14	1.243E-11	2.630E-10	9.533E-10
2.217E-14	1.260E-11	2.666E-10	5.625E-10
2.730E-14	1.560E-11	3.301E-10	2.960E-10
1.968E-14	1.123E-11	2.376E-10	1.953E-10
6.405E-15	6.623E-12	5.941E-10	1.376E-10
5.708E-15	6.025E-12	5.512E-10	2.827E-10
6.976E-15	7.209E-12	6.438E-10	9.563E-10
7.071E-15	7.296E-12	6.525E-10	4.728E-10

8.752E-15	9.019E-12	7.951E-10	6.494E-11
6.247E-15	6.515E-12	5.891E-10	2.331E-09
8.657E-14	4.027E-11	2.954E-10	3.570E-10
8.086E-14	3.754E-11	2.754E-10	7.481E-10
9.354E-14	4.359E-11	3.198E-10	2.048E-09
9.481E-14	4.419E-11	3.242E-10	1.440E-10
1.148E-13	5.366E-11	3.936E-10	3.768E-11
8.593E-14	4.001E-11	2.935E-10	2.946E-09
2.388E-15	1.547E-12	3.029E-11	9.040E-11
2.074E-15	1.338E-12	2.619E-11	2.167E-10
2.664E-15	1.729E-12	3.385E-11	1.538E-09
2.419E-15	1.556E-12	3.047E-11	2.434E-11
3.678E-15	2.412E-12	4.721E-11	3.186E-12
2.328E-15	1.502E-12	2.940E-11	1.972E-09
8.720E-15	4.926E-12	3.092E-11	1.854E-10
7.769E-15	4.380E-12	2.749E-11	4.174E-10
9.545E-15	5.422E-12	3.403E-11	1.512E-09
9.545E-15	5.330E-12	3.345E-11	2.039E-11
1.234E-14	7.087E-12	4.448E-11	3.686E-12
8.498E-15	4.792E-12	3.007E-11	2.311E-09
1.796E-15	9.327E-13	2.005E-11	6.003E-10
1.639E-15	8.429E-13	1.813E-11	1.461E-09
1.963E-15	1.026E-12	2.204E-11	2.631E-08
1.886E-15	9.629E-13	2.073E-11	4.025E-11
2.509E-15	1.345E-12	2.883E-11	3.906E-12
1.764E-15	9.127E-13	1.963E-11	1.526E-08
3.234E-22	1.802E-19	3.209E-18	1.398E-10
2.917E-22	1.630E-19	2.902E-18	3.371E-10
3.488E-22	1.947E-19	3.467E-18	1.960E-09
3.552E-22	1.983E-19	3.531E-18	4.864E-12
4.376E-22	2.454E-19	4.370E-18	8.229E-14
3.158E-22	1.766E-19	3.144E-18	3.304E-09
4.313E-15	2.675E-12	4.589E-11	1.419E-10
3.805E-15	2.359E-12	4.046E-11	3.388E-10
4.756E-15	2.982E-12	5.116E-11	1.634E-09
4.471E-15	2.729E-12	4.682E-11	3.426E-11
6.279E-15	4.003E-12	6.868E-11	4.598E-12
4.154E-15	2.567E-12	4.403E-11	2.868E-09
5.296E-15	3.236E-12	3.022E-11	1.061E-10
4.630E-15	2.818E-12	2.632E-11	2.392E-10
5.898E-15	3.610E-12	3.371E-11	9.589E-10
5.454E-15	3.314E-12	3.095E-11	5.671E-11
7.991E-15	4.915E-12	4.590E-11	4.052E-12
5.137E-15	3.149E-12	2.941E-11	1.496E-09
6.723E-19	1.397E-15	2.934E-14	5.398E-10
4.566E-19	4.256E-16	8.937E-15	1.263E-09
1.008E-18	3.023E-15	6.348E-14	2.872E-06
4.535E-19	1.114E-15	2.340E-14	5.105E-09
1.465E-18	3.726E-15	7.825E-14	2.959E-11
6.659E-19	1.781E-15	3.740E-14	1.308E-08
1.776E-18	1.489E-15	3.126E-14	5.034E-10
1.481E-18	9.863E-16	2.071E-14	1.182E-09
2.074E-18	2.210E-15	4.642E-14	2.704E-06
1.671E-18	1.379E-15	2.896E-14	4.799E-09
2.901E-18	2.877E-15	6.042E-14	2.761E-11
1.735E-18	1.616E-15	3.395E-14	1.227E-08
6.976E-19	1.388E-15	2.915E-14	5.053E-10
4.820E-19	4.521E-16	9.494E-15	1.188E-09
1.034E-18	2.950E-15	6.195E-14	2.704E-06
4.661E-19	1.096E-15	2.302E-14	4.800E-09

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1.522E-18	3.662E-15	7.691E-14	2.761E-11
6.849E-19	1.744E-15	3.663E-14	1.232E-08
.000E+00	.000E+00	.000E+00	2.421E-12
.000E+00	.000E+00	.000E+00	5.854E-12
.000E+00	.000E+00	.000E+00	1.575E-09
.000E+00	.000E+00	.000E+00	6.371E-13
.000E+00	.000E+00	.000E+00	2.238E-15
.000E+00	.000E+00	.000E+00	6.220E-11
4.883E-16	4.037E-13	8.477E-12	9.959E-10
4.122E-16	3.379E-13	7.096E-12	1.641E-09
5.930E-16	4.959E-13	1.041E-11	1.276E-06
3.203E-16	2.658E-13	5.581E-12	9.669E-08
9.418E-16	7.836E-13	1.646E-11	5.507E-10
4.313E-16	3.589E-13	7.538E-12	1.213E-08
7.008E-19	1.652E-15	3.420E-14	1.086E-09
4.439E-19	4.317E-16	8.939E-15	1.776E-09
1.081E-18	3.541E-15	7.332E-14	1.229E-06
4.915E-19	1.296E-15	2.683E-14	1.022E-07
1.560E-18	4.581E-15	9.487E-14	6.093E-10
7.135E-19	2.090E-15	4.328E-14	1.302E-08
5.105E-19	1.388E-15	2.914E-14	1.034E-09
3.000E-19	3.087E-16	6.480E-15	1.690E-09
8.308E-19	3.050E-15	6.404E-14	1.343E-06
3.583E-19	1.096E-15	2.301E-14	1.019E-07
1.186E-18	3.927E-15	8.244E-14	5.815E-10
5.359E-19	1.790E-15	3.758E-14	1.249E-08

E-1

APPENDIX E

Sample Interactive Input and Output

SMMAIN

ENTER REACTOR TYPE : 1-PWR, 2-BWR

1

ENTER DOSE CONVERSION FACTORS TABLES TO USE :

1- CRAC2;

2- MACCS

1

ENTER CHOICE OF SIGMA CALCULATION:

1 - POLYNOMIAL;

2 - CRAC2 OR MACCS MODEL

2

SELECT OUTPUT CONTROL :

1 - DETAILED NUCLIDE INVENTORY

2 - ABBREVIATED OUTPUT

2

IF YOU WISH TO REPEAT THE RUN WITHOUT CHANGING REMAINING INPUT PARAMETERS, ENTER 1

0

IF YOU WANT TO CHANGE WEATHER CLASS ONLY ENTER 1

0

ENTER SCALING FACTOR FOR CORE INV.

REFERENCE POWER - 3412. MWTH

1.

ENTER NUMBER OF PUFFS, UP TO 2 ALLOWED

1

ENTER RELEASE FRACTIONS FOR 9 GROUPS FOR PUFF 1

NG	I	CS	TE	SR	RU	LA	CE	BA
.9	.706	.4	.4	.05	.3	.001	.001	.05

SELECT OPTION FOR DOSE CALCULATION:

1 - TOP HAT PROFILE (AS USED IN CRAC2)

2 - GAUSSIAN PROFILE (AS USED IN MACCS)

1

ENTER WIDTH AND HEIGHT OF BUILDING (M)

100. 25.

ENTER RELEASE TIME (HRS) FOR PUFF 1

0.

ENTER DURATION (HRS) FOR PUFF 1

1.

DEFAULT DEPOSITION VELOCITY - 1.0000E-02 M/S

BREATHING RATE - 2.660E-04 M**3/S

ENTER NEW VALUES; USE REAL NUMBERS AND NOT INTEGERS; IF NEGATIVE, DEFAULT WILL BE USED

-1. -1.

ENTER WEATHER CONDITIONS :

1 - MOD. STABLE, 2 - SLIGHTLY STABLE,

3 - NEUTRAL, 4 - SLIGHTLY UNSTABLE,

5 - MOD. UNSTABLE, 6 - EXTREM. UNSTABLE

7 - CLASS G (EXTRAPOLATED)

3

ENTER AVERAGE WIND SPEED, M/S

5.

ENTER RELEASE HEIGHT, M FOR PUFF 1

0.

ENTER ENERGY OF RELEASE (WATTS) FOR PUFF 1

1.E+08

ENTER DURATION OF RAIN, S

0.

ENTER THREE SHIELDING FACTORS, RESPECTIVELY :

CLOUD-SHINE

GROUND-SHINE

INHALATION

.75 .33 1.

DOSE CONVERSION TABLES USED FROM EITHER MACCS OR CRAC2 DATA ARE DEFAULT;
IF YOU WISH TO SELECT DIFFERENT TABLES IN CRAC2 DATA BASE, ENTER 1
DATA BASE PROVIDED FOR MACCS HAS ONLY DEFAULT OPTION

0

IF YOU WISH TO REPEAT, ENTER 1

0

Execution terminated : 0

E-4

RELEASE FRACTIONS FOR THE 9 GROUPS FOR PUFF 1
9.000E-01 7.060E-01 4.000E-01 4.000E-01 5.000E-02 3.000E-01

WIDTH AND HEIGHT OF BUILDING = 1.000E+02 2.500E+01 M

1 PUFF 1 RELEASE TIME = 0.00 HOURS
DURATION = 1.00 HOURS

DEPOSITION VELOCITY = 1.000E-02 M/S
BREATHING RATE = 2.660E-04 M**3/S

ENTER WEATHER CONDITIONS :

1=MOD. STABLE, 2=SLIGHTLY STABLE,
3=NEUTRAL, 4=SLIGHTLY UNSTABLE,
5=MOD. UNSTABLE, 6=EXTREM. UNSTABLE
7 = CLASS G (EXTRAPOLATED FROM F)

SELECTION OF WEATHER = 3

AVERAGE WIND SPEED = 5.000E+00 M/S

PUFF 1 RELEASE HEIGHT = 0.000E-01 M

DURATION OF RAIN = 0.000E-01 S

SELECTION OF TABLES FOR CONVERSION FACTORS :
1 2 4 4 5

***** CRAC CONVERSION FACTORS *****

DISTANCE = 4.020E+02 M
WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 1.382E+02 M
VERTICAL DISPERSION COEFFICIENT = 3.183E+01 M

CLOUD SHINE

WHOLE BODY MARROW LUNG THYROID LLIW

TOTAL	5.395E+02	5.946E+02	5.090E+02	4.900E+02	3.935E+02
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GROUND SHINE

WHOLE BODY	MARROW	LUNG	THYROID	LLIW
------------	--------	------	---------	------

TOTAL	5.841E+03	6.852E+03	5.473E+03	5.242E+03	3.914E+03
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INHALATION

WHOLE BODY	MARROW	LUNG	THYROID	LLIW
------------	--------	------	---------	------

TOTAL	4.447E+02	5.992E+02	8.796E+04	9.836E+04	5.193E+03
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TOTAL BODY DOSE	=	6.826E+03
TOTAL MARROW DOSE	=	8.046E+03
TOTAL LUNG DOSE	=	9.395E+04
TOTAL LLIW DOSE	=	9.500E+03
TOTAL THYROID DOSE	=	1.041E+05

CRAC2 PROBABILITY OF EARLY FATALITIES = 1.000

***** CRAC CONVERSION FACTORS *****

DISTANCE = 1.210E+03 M
WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT =	2.115E+02	M
VERTICAL DISPERSION COEFFICIENT =	4.493E+01	M

CLOUD SHINE

WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	3.326E+02	3.667E+02	3.138E+02	3.023E+02	2.427E+02
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GROUND SHINE

WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	2.647E+03	3.106E+03	2.480E+03	2.377E+03	1.774E+03
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INHALATION

WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	2.014E+02	2.716E+02	3.990E+04	4.456E+04	2.356E+03
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TOTAL BODY DOSE	=	3.181E+03
TOTAL MARROW DOSE	=	3.744E+03
TOTAL LUNG DOSE	=	4.270E+04
TOTAL LLIW DOSE	=	4.373E+03
TOTAL THYROID DOSE	=	4.724E+04

CRAC2 PROBABILITY OF EARLY FATALITIES = 1.000

***** CRAC CONVERSION FACTORS *****

DISTANCE = 2.010E+03 M
WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT	=	3.041E+02	M
VERTICAL DISPERSION COEFFICIENT	=	6.948E+01	M

CLOUD SHINE

E-7

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	1.988E+02	2.192E+02	1.876E+02	1.809E+02	1.452E+02
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GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	1.159E+03	1.360E+03	1.086E+03	1.041E+03	7.772E+02
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INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	8.797E+01	1.188E+02	1.747E+04	1.948E+04	1.031E+03
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TOTAL BODY DOSE	=	1.446E+03
TOTAL MARROW DOSE	=	1.698E+03
TOTAL LUNG DOSE	=	1.874E+04
TOTAL LLIW DOSE	=	1.953E+03
TOTAL THYROID DOSE	=	2.070E+04

CRAC2 PROBABILITY OF EARLY FATALITIES = 1.000

***** CRAC CONVERSION FACTORS *****

DISTANCE = 3.219E+03 M
WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 4.387E+02 M
VERTICAL DISPERSION COEFFICIENT = 8.448E+01 M

CLOUD SHINE

E-8

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	1.254E+02	1.384E+02	1.183E+02	1.143E+02	9.166E+01
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GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	6.502E+02	7.631E+02	6.091E+02	5.851E+02	4.365E+02
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INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	4.933E+01	6.673E+01	9.824E+03	1.093E+04	5.798E+02
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TOTAL BODY DOSE	=	8.249E+02
TOTAL MARROW DOSE	=	9.682E+02
TOTAL LUNG DOSE	=	1.055E+04
TOTAL LLIW DOSE	=	1.108E+03
TOTAL THYROID DOSE	=	1.163E+04

CRAC2 PROBABILITY OF EARLY FATALITIES = 1.000

***** CRAC CONVERSION FACTORS *****

DISTANCE = 4.023E+03 M
WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 5.257E+02 M
VERTICAL DISPERSION COEFFICIENT = 9.551E+01 M

E-9

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	9.857E+01	1.088E+02	9.300E+01	8.993E+01	7.206E+01
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GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	4.750E+02	5.576E+02	4.450E+02	4.278E+02	3.191E+02
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INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	3.601E+01	4.877E+01	7.186E+03	7.982E+03	4.241E+02
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TOTAL BODY DOSE	=	6.096E+02
TOTAL MARROW DOSE	=	7.152E+02
TOTAL LUNG DOSE	=	7.724E+03
TOTAL LLIW DOSE	=	8.153E+02
TOTAL THYROID DOSE	=	8.499E+03

CRAC2 PROBABILITY OF EARLY FATALITIES = 1.000

***** CRAC CONVERSION FACTORS *****

DISTANCE = 4.828E+03 M
WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 6.113E+02 M
VERTICAL DISPERSION COEFFICIENT = 1.059E+02 M

E-10

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	7.934E+01	8.761E+01	7.485E+01	7.245E+01	5.803E+01
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GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	3.651E+02	4.286E+02	3.420E+02	3.291E+02	2.454E+02
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INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	2.765E+01	3.750E+01	5.530E+03	6.132E+03	3.263E+02
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TOTAL BODY DOSE	=	4.721E+02
TOTAL MARROW DOSE	=	5.537E+02
TOTAL LUNG DOSE	=	5.946E+03
TOTAL LLIW DOSE	=	6.297E+02
TOTAL THYROID DOSE	=	6.533E+03

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.109

***** CRAC CONVERSION FACTORS *****

DISTANCE = 5.633E+03 M
WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT	=	6.956E+02	M
VERTICAL DISPERSION COEFFICIENT	=	1.158E+02	M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	6.511E+01	7.194E+01	6.143E+01	5.952E+01	4.764E+01
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GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	2.911E+02	3.418E+02	2.727E+02	2.626E+02	1.958E+02
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INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	2.203E+01	2.990E+01	4.413E+03	4.886E+03	2.604E+02
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TOTAL BODY DOSE	=	3.782E+02
TOTAL MARROW DOSE	=	4.436E+02
TOTAL LUNG DOSE	=	4.748E+03
TOTAL LLIW DOSE	=	5.038E+02
TOTAL THYROID DOSE	=	5.209E+03

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.046

***** CRAC CONVERSION FACTORS *****

DISTANCE = 6.437E+03 M
 WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 7.788E+02 M
 VERTICAL DISPERSION COEFFICIENT = 1.252E+02 M

E-12

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	5.468E+01	6.045E+01	5.159E+01	5.003E+01	4.003E+01

GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	2.386E+02	2.802E+02	2.235E+02	2.154E+02	1.605E+02

INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	1.804E+01	2.452E+01	3.621E+03	4.003E+03	2.137E+02

TOTAL BODY DOSE	=	3.113E+02
TOTAL MARROW DOSE	=	3.651E+02
TOTAL LUNG DOSE	=	3.896E+03
TOTAL LLIW DOSE	=	4.142E+02
TOTAL THYROID DOSE	=	4.269E+03

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.017

***** CRAC CONVERSION FACTORS *****

DISTANCE = 7.242E+03 M
WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 8.610E+02 M
VERTICAL DISPERSION COEFFICIENT = 1.343E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	4.674E+01	5.170E+01	4.410E+01	4.281E+01	3.423E+01

GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	1.998E+02	2.346E+02	1.871E+02	1.805E+02	1.345E+02

INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	1.509E+01	2.053E+01	3.035E+03	3.350E+03	1.791E+02

TOTAL BODY DOSE = 2.616E+02
 TOTAL MARROW DOSE = 3.069E+02
 TOTAL LUNG DOSE = 3.267E+03
 TOTAL LLIW DOSE = 3.478E+02
 TOTAL THYROID DOSE = 3.574E+03

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

***** CRAC CONVERSION FACTORS *****

DISTANCE = 8.047E+03 M
 WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 9.425E+02 M

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VERTICAL DISPERSION COEFFICIENT = 1.474E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	3.979E+01	4.403E+01	3.754E+01	3.647E+01	2.915E+01
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GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	1.650E+02	1.938E+02	1.545E+02	1.492E+02	1.111E+02
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INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	1.244E+01	1.694E+01	2.507E+03	2.763E+03	1.479E+02
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TOTAL BODY DOSE	=	2.172E+02
TOTAL MARROW DOSE	=	2.547E+02
TOTAL LUNG DOSE	=	2.699E+03
TOTAL LLIW DOSE	=	2.882E+02
TOTAL THYROID DOSE	=	2.948E+03

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

***** CRAC CONVERSION FACTORS *****

DISTANCE = 9.660E+03 M
WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

E-15

HORIZONTAL DISPERSION COEFFICIENT = 1.104E+03 M
VERTICAL DISPERSION COEFFICIENT = 1.641E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	3.100E+01	3.434E+01	2.924E+01	2.846E+01	2.272E+01
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GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	1.251E+02	1.470E+02	1.172E+02	1.133E+02	8.438E+01
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INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	9.415E+00	1.285E+01	1.904E+03	2.092E+03	1.123E+02
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TOTAL BODY DOSE	=	1.655E+02
TOTAL MARROW DOSE	=	1.942E+02
TOTAL LUNG DOSE	=	2.051E+03
TOTAL LLIW DOSE	=	2.194E+02
TOTAL THYROID DOSE	=	2.234E+03

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

***** CRAC CONVERSION FACTORS *****

DISTANCE = 1.130E+04 M
WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 1.265E+03 M
 VERTICAL DISPERSION COEFFICIENT = 1.836E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	2.458E+01	2.727E+01	2.319E+01	2.261E+01	1.803E+01

GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	9.639E+01	1.133E+02	9.029E+01	8.743E+01	6.510E+01

INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	7.234E+00	9.896E+00	1.469E+03	1.608E+03	8.660E+01

TOTAL BODY DOSE = 1.282E+02
 TOTAL MARROW DOSE = 1.504E+02
 TOTAL LUNG DOSE = 1.582E+03
 TOTAL LLIW DOSE = 1.697E+02
 TOTAL THYROID DOSE = 1.719E+03

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

***** CRAC CONVERSION FACTORS *****

DISTANCE = 1.370E+04 M
 WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

E-17

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 1.497E+03 M
VERTICAL DISPERSION COEFFICIENT = 2.055E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	1.859E+01	2.065E+01	1.754E+01	1.714E+01	1.364E+01
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GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	7.177E+01	8.439E+01	6.723E+01	6.525E+01	4.855E+01
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INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	5.371E+00	7.369E+00	1.096E+03	1.195E+03	6.461E+01
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TOTAL BODY DOSE	=	9.573E+01
TOTAL MARROW DOSE	=	1.124E+02
TOTAL LUNG DOSE	=	1.181E+03
TOTAL LLIW DOSE	=	1.268E+02
TOTAL THYROID DOSE	=	1.277E+03

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

***** CRAC CONVERSION FACTORS *****

DISTANCE = 1.610E+04 M
WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 1.725E+03 M
 VERTICAL DISPERSION COEFFICIENT = 2.328E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	1.405E+01	1.564E+01	1.326E+01	1.299E+01	1.032E+01

GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	5.421E+01	6.376E+01	5.078E+01	4.939E+01	3.674E+01

INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	4.036E+00	5.554E+00	8.279E+02	8.985E+02	4.878E+01

TOTAL BODY DOSE = 7.230E+01
 TOTAL MARROW DOSE = 8.495E+01
 TOTAL LUNG DOSE = 8.919E+02
 TOTAL LLIW DOSE = 9.584E+01
 TOTAL THYROID DOSE = 9.609E+02

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

***** CRAC CONVERSION FACTORS *****

DISTANCE = 2.010E+04 M
 WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

E-19

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 2.098E+03 M
VERTICAL DISPERSION COEFFICIENT = 2.570E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	1.009E+01	1.126E+01	9.518E+00	9.360E+00	7.419E+00

GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	3.970E+01	4.672E+01	3.718E+01	3.629E+01	2.697E+01

INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	2.947E+00	4.073E+00	6.093E+02	6.563E+02	3.588E+01

TOTAL BODY DOSE = 5.273E+01
TOTAL MARROW DOSE = 6.205E+01
TOTAL LUNG DOSE = 6.560E+02
TOTAL LLIW DOSE = 7.028E+01
TOTAL THYROID DOSE = 7.020E+02

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

***** CRAC CONVERSION FACTORS *****

DISTANCE = 2.210E+04 M
WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 2.282E+03 M
 VERTICAL DISPERSION COEFFICIENT = 2.804E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	8.406E+00	9.397E+00	7.930E+00	7.811E+00	6.184E+00

GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	3.315E+01	3.903E+01	3.105E+01	3.036E+01	2.256E+01

INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	2.448E+00	3.391E+00	5.080E+02	5.452E+02	2.991E+01

TOTAL BODY DOSE = 4.401E+01
 TOTAL MARROW DOSE = 5.181E+01
 TOTAL LUNG DOSE = 5.470E+02
 TOTAL LLIW DOSE = 5.865E+01
 TOTAL THYROID DOSE = 5.834E+02

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

DISTANCE = 2.620E+04 M
 WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 2.655E+03 M
 VERTICAL DISPERSION COEFFICIENT = 3.100E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	6.326E+00	7.093E+00	5.967E+00	5.897E+00	4.656E+00
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GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	2.541E+01	2.993E+01	2.380E+01	2.335E+01	1.734E+01
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INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	1.865E+00	2.595E+00	3.900E+02	4.154E+02	2.295E+01
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TOTAL BODY DOSE	=	3.360E+01
TOTAL MARROW DOSE	=	3.961E+01
TOTAL LUNG DOSE	=	4.198E+02
TOTAL LLIW DOSE	=	4.494E+01
TOTAL THYROID DOSE	=	4.447E+02

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

***** CRAC CONVERSION FACTORS *****

DISTANCE = 3.020E+04 M
 WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 3.013E+03 M
 VERTICAL DISPERSION COEFFICIENT = 3.445E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	4.875E+00	5.481E+00	4.598E+00	4.558E+00	3.590E+00

GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	1.989E+01	2.344E+01	1.863E+01	1.834E+01	1.361E+01

INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	1.447E+00	2.022E+00	3.048E+02	3.223E+02	1.793E+01

TOTAL BODY DOSE = 2.621E+01
 TOTAL MARROW DOSE = 3.094E+01
 TOTAL LUNG DOSE = 3.280E+02
 TOTAL LLIW DOSE = 3.512E+01
 TOTAL THYROID DOSE = 3.452E+02

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

***** CRAC CONVERSION FACTORS *****

DISTANCE = 3.620E+04 M

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WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 3.541E+03 M
VERTICAL DISPERSION COEFFICIENT = 3.903E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	3.507E+00	3.959E+00	3.307E+00	3.291E+00	2.583E+00
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GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	1.471E+01	1.734E+01	1.377E+01	1.362E+01	1.010E+01
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INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
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TOTAL	1.057E+00	1.485E+00	2.248E+02	2.351E+02	1.321E+01
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TOTAL BODY DOSE	=	1.927E+01
TOTAL MARROW DOSE	=	2.279E+01
TOTAL LUNG DOSE	=	2.418E+02
TOTAL LLIW DOSE	=	2.589E+01
TOTAL THYROID DOSE	=	2.520E+02

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

***** CRAC CONVERSION FACTORS *****

E-24

DISTANCE = 4.430E+04 M
WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 4.242E+03 M
VERTICAL DISPERSION COEFFICIENT = 4.394E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	2.415E+00	2.742E+00	2.277E+00	2.277E+00	1.778E+00

GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	1.072E+01	1.266E+01	1.004E+01	9.988E+00	7.398E+00

INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	7.597E-01	1.076E+00	1.636E+02	1.688E+02	9.604E+00

TOTAL BODY DOSE = 1.390E+01
TOTAL MARROW DOSE = 1.647E+01
TOTAL LUNG DOSE = 1.759E+02
TOTAL LLIW DOSE = 1.878E+01
TOTAL THYROID DOSE = 1.810E+02

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

***** CRAC CONVERSION FACTORS *****

DISTANCE = 5.230E+04 M
 WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 4.922E+03 M
 VERTICAL DISPERSION COEFFICIENT = 4.857E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	1.758E+00	2.005E+00	1.656E+00	1.663E+00	1.293E+00

GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	8.253E+00	9.747E+00	7.725E+00	7.729E+00	5.719E+00

INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	5.759E-01	8.209E-01	1.255E+02	1.276E+02	7.356E+00

TOTAL BODY DOSE = 1.059E+01
 TOTAL MARROW DOSE = 1.257E+01
 TOTAL LUNG DOSE = 1.349E+02
 TOTAL LLIW DOSE = 1.437E+01
 TOTAL THYROID DOSE = 1.370E+02

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

***** CRAC CONVERSION FACTORS *****

E-26

DISTANCE = 6.040E+04 M
WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 5.600E+03 M
VERTICAL DISPERSION COEFFICIENT = 5.297E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	1.330E+00	1.525E+00	1.253E+00	1.262E+00	9.769E-01

GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	6.582E+00	7.779E+00	6.160E+00	6.196E+00	4.582E+00

INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	4.520E-01	6.486E-01	9.958E+01	9.991E+01	5.831E+00

TOTAL BODY DOSE = 8.364E+00
TOTAL MARROW DOSE = 9.952E+00
TOTAL LUNG DOSE = 1.070E+02
TOTAL LLIW DOSE = 1.139E+01
TOTAL THYROID DOSE = 1.074E+02

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

***** CRAC CONVERSION FACTORS *****

E-27

DISTANCE = 6.840E+04 M
WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 6.261E+03 M
VERTICAL DISPERSION COEFFICIENT = 5.717E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	1.042E+00	1.200E+00	9.809E-01	9.911E-01	7.641E-01

GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	5.413E+00	6.403E+00	5.066E+00	5.122E+00	3.784E+00

INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	3.657E-01	5.279E-01	8.139E+01	8.057E+01	4.760E+00

TOTAL BODY DOSE = 6.821E+00
TOTAL MARROW DOSE = 8.130E+00
TOTAL LUNG DOSE = 8.744E+01
TOTAL LLIW DOSE = 9.309E+00
TOTAL THYROID DOSE = 8.668E+01

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

***** CRAC CONVERSION FACTORS *****

DISTANCE = 7.640E+04 M
 WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 6.915E+03 M
 VERTICAL DISPERSION COEFFICIENT = 6.123E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	8.366E-01	9.670E-01	7.872E-01	7.974E-01	6.123E-01

GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	4.552E+00	5.387E+00	4.259E+00	4.328E+00	3.195E+00

INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	3.021E-01	4.387E-01	6.791E+01	6.635E+01	3.968E+00

TOTAL BODY DOSE = 5.691E+00
 TOTAL MARROW DOSE = 6.793E+00
 TOTAL LUNG DOSE = 7.296E+01
 TOTAL LLIW DOSE = 7.775E+00
 TOTAL THYROID DOSE = 7.148E+01

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

DISTANCE = 8.450E+04 M
 WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 7.571E+03 M
 VERTICAL DISPERSION COEFFICIENT = 6.515E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	6.844E-01	7.941E-01	6.438E-01	6.536E-01	5.000E-01

GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	3.894E+00	4.611E+00	3.643E+00	3.719E+00	2.744E+00

INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	2.538E-01	3.706E-01	5.759E+01	5.553E+01	3.361E+00

TOTAL BODY DOSE = 4.832E+00
 TOTAL MARROW DOSE = 5.775E+00
 TOTAL LUNG DOSE = 6.187E+01
 TOTAL LLIW DOSE = 6.605E+00
 TOTAL THYROID DOSE = 5.990E+01

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

DISTANCE = 9.250E+04 M
 WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 8.212E+03 M
 VERTICAL DISPERSION COEFFICIENT = 6.904E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	5.696E-01	6.632E-01	5.355E-01	5.447E-01	4.152E-01

GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	3.383E+00	4.008E+00	3.164E+00	3.246E+00	2.394E+00

INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	2.162E-01	3.174E-01	4.951E+01	4.713E+01	2.886E+00

TOTAL BODY DOSE = 4.168E+00
 TOTAL MARROW DOSE = 4.989E+00
 TOTAL LUNG DOSE = 5.321E+01
 TOTAL LLIW DOSE = 5.695E+00
 TOTAL THYROID DOSE = 5.092E+01

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

***** CRAC CONVERSION FACTORS *****

DISTANCE = 1.010E+05 M
 WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 8.888E+03 M
 VERTICAL DISPERSION COEFFICIENT = 7.282E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	4.776E-01	5.580E-01	4.488E-01	4.574E-01	3.474E-01

GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	2.962E+00	3.512E+00	2.771E+00	2.856E+00	2.105E+00

INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	1.855E-01	2.739E-01	4.288E+01	4.028E+01	2.497E+00

TOTAL BODY DOSE = 3.625E+00
 TOTAL MARROW DOSE = 4.344E+00
 TOTAL LUNG DOSE = 4.610E+01
 TOTAL LLIW DOSE = 4.949E+00
 TOTAL THYROID DOSE = 4.360E+01

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

***** CRAC CONVERSION FACTORS *****

DISTANCE = 1.090E+05 M
 WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 9.519E+03 M
 VERTICAL DISPERSION COEFFICIENT = 7.814E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	3.988E-01	4.674E-01	3.746E-01	3.824E-01	2.895E-01

GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	2.603E+00	3.087E+00	2.434E+00	2.520E+00	1.856E+00

INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	1.577E-01	2.341E-01	3.676E+01	3.411E+01	2.138E+00

TOTAL BODY DOSE = 3.159E+00
 TOTAL MARROW DOSE = 3.789E+00
 TOTAL LUNG DOSE = 3.957E+01
 TOTAL LLIW DOSE = 4.284E+00
 TOTAL THYROID DOSE = 3.701E+01

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

***** CRAC CONVERSION FACTORS *****

DISTANCE = 1.250E+05 M
 WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 1.077E+04 M
 VERTICAL DISPERSION COEFFICIENT = 8.000E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	3.097E-01	3.652E-01	2.906E-01	2.976E-01	2.238E-01

GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	2.215E+00	2.630E+00	2.071E+00	2.162E+00	1.591E+00

INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	1.267E-01	1.899E-01	3.002E+01	2.719E+01	1.742E+00

TOTAL BODY DOSE = 2.651E+00
 TOTAL MARROW DOSE = 3.185E+00
 TOTAL LUNG DOSE = 3.238E+01
 TOTAL LLIW DOSE = 3.557E+00
 TOTAL THYROID DOSE = 2.965E+01

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

***** CRAC CONVERSION FACTORS *****

DISTANCE = 1.490E+05 M
 WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 1.261E+04 M
 VERTICAL DISPERSION COEFFICIENT = 8.000E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	2.202E-01	2.620E-01	2.063E-01	2.122E-01	1.580E-01

GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	1.858E+00	2.209E+00	1.736E+00	1.834E+00	1.348E+00

INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	9.367E-02	1.423E-01	2.269E+01	1.984E+01	1.313E+00

TOTAL BODY DOSE = 2.171E+00
 TOTAL MARROW DOSE = 2.613E+00
 TOTAL LUNG DOSE = 2.463E+01
 TOTAL LLIW DOSE = 2.819E+00
 TOTAL THYROID DOSE = 2.188E+01

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

***** CRAC CONVERSION FACTORS *****

DISTANCE = 2.010E+05 M
WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 1.652E+04 M
VERTICAL DISPERSION COEFFICIENT = 8.000E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	1.217E-01	1.473E-01	1.135E-01	1.179E-01	8.596E-02

GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	1.448E+00	1.727E+00	1.353E+00	1.463E+00	1.072E+00

INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	5.531E-02	8.630E-02	1.399E+01	1.139E+01	8.041E-01

TOTAL BODY DOSE	=	1.625E+00
TOTAL MARROW DOSE	=	1.960E+00
TOTAL LUNG DOSE	=	1.546E+01
TOTAL LLIW DOSE	=	1.962E+00
TOTAL THYROID DOSE	=	1.297E+01

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

***** CRAC CO

DISTANCE = 2.820E+05 M
WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 2.241E+04 M
VERTICAL DISPERSION COEFFICIENT = 8.000E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	5.496E-02	6.831E-02	5.095E-02	5.368E-02	3.790E-02

GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	1.830E+00	2.188E+00	1.708E+00	1.901E+00	1.390E+00

INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	2.617E-02	4.231E-02	7.008E+00	5.151E+00	3.988E-01

TOTAL BODY DOSE = 1.911E+00
TOTAL MARROW DOSE = 2.298E+00
TOTAL LUNG DOSE = 8.767E+00
TOTAL LLIW DOSE = 1.827E+00
TOTAL THYROID DOSE = 7.106E+00

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

***** CRAC CONVERSION FACTORS *****

DISTANCE = 4.430E+05 M
WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 3.369E+04 M
VERTICAL DISPERSION COEFFICIENT = 8.000E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	2.354E-02	2.993E-02	2.167E-02	2.321E-02	1.586E-02

GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	1.330E-01	1.595E-01	1.240E-01	1.438E-01	1.050E-01

INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	1.222E-02	2.085E-02	3.582E+00	2.216E+00	2.001E-01

TOTAL BODY DOSE = 1.688E-01
TOTAL MARROW DOSE = 2.103E-01
TOTAL LUNG DOSE = 3.727E+00
TOTAL LLIW DOSE = 3.210E-01
TOTAL THYROID DOSE = 2.383E+00

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

***** CRAC CONVERSION FACTORS *****

DISTANCE = 6.840E+05 M
WIND VELOCITY = 5.000E+00 M/S

ATMOSPHERIC STABILITY CLASS D

PUFF NUMBER 1

HORIZONTAL DISPERSION COEFFICIENT = 4.985E+04 M
VERTICAL DISPERSION COEFFICIENT = 8.000E+02 M

CLOUD SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	7.020E-03	9.346E-03	6.343E-03	7.075E-03	4.522E-03

GROUND SHINE

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	3.662E-02	4.394E-02	3.410E-02	4.109E-02	2.999E-02

INHALATION

	WHOLE BODY	MARROW	LUNG	THYROID	LLIW
TOTAL	3.469E-03	6.291E-03	1.122E+00	5.639E-01	6.111E-02

TOTAL BODY DOSE	=	4.711E-02
TOTAL MARROW DOSE	=	5.957E-02
TOTAL LUNG DOSE	=	1.162E+00
TOTAL LLIW DOSE	=	9.562E-02
TOTAL THYROID DOSE	=	6.121E-01

E-39

CRAC2 PROBABILITY OF EARLY FATALITIES = 0.000

F-1

APPENDIX F

Results for the Sensitivity Study to Source
Terms: Doses and Probabilities of Early Injuries for
Sampled Weather Conditions D1 and D5.

MACCS RESULTS : LHS 100 WITH CLASS D ONLY, U-1M/S

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*** TOT STOMACH DOSE ***
DIST.(MI)  MIN      MAX      5-TH      50-TH      95-TH      AVER      SIGMA
0.5      1.691E+03  2.456E+04  2.045E+03  4.974E+03  1.614E+04  6.402E+03  4.824E+03
1.0      3.484E+02  4.941E+03  4.326E+02  1.005E+03  3.300E+03  1.301E+03  9.684E+02
2.0      1.183E+02  1.660E+03  1.473E+02  3.383E+02  1.132E+03  4.403E+02  3.262E+02
3.0      6.564E+01  9.286E+02  8.206E+01  1.901E+02  6.353E+02  2.471E+02  1.839E+02
4.0      4.087E+01  5.953E+02  5.127E+01  1.199E+02  4.022E+02  1.557E+02  1.165E+02
5.0      2.256E+01  3.422E+02  2.842E+01  6.723E+01  2.265E+02  8.709E+01  6.565E+01
10.0     7.123E+00  1.236E+02  9.127E+00  2.194E+01  7.828E+01  2.901E+01  2.259E+01
20.0     2.074E+00  5.056E+01  2.803E+00  7.425E+00  2.807E+01  9.771E+00  8.352E+00
50.0     6.604E+00  2.232E+02  9.248E+00  2.582E+01  1.018E+02  3.516E+01  3.308E+01
350.0    6.271E-05  5.997E-04  8.236E-05  2.296E-04  5.351E-04  2.914E-04  1.708E-04

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*** TOT MARROW DOSE ***
DIST.(MI)  MIN      MAX      5-TH      50-TH      95-TH      AVER      SIGMA
0.5      1.740E+03  2.842E+04  2.178E+03  5.332E+03  1.815E+04  6.935E+03  5.335E+03
1.0      3.614E+02  5.746E+03  4.531E+02  1.092E+03  3.678E+03  1.416E+03  1.077E+03
2.0      1.235E+02  1.939E+03  1.551E+02  3.725E+02  1.244E+03  4.815E+02  3.645E+02
3.0      6.886E+01  1.089E+03  8.684E+01  2.088E+02  7.016E+02  2.712E+02  2.063E+02
4.0      4.303E+01  6.933E+02  5.451E+01  1.312E+02  4.456E+02  1.713E+02  1.311E+02
5.0      2.386E+01  3.976E+02  3.037E+01  7.307E+01  2.513E+02  9.611E+01  7.403E+01
10.0     7.617E+00  1.423E+02  9.729E+00  2.419E+01  8.559E+01  3.218E+01  2.551E+01
20.0     2.267E+00  5.667E+01  3.064E+00  8.268E+00  3.084E+01  1.086E+01  9.334E+00
50.0     7.306E+00  2.456E+02  1.021E+01  2.857E+01  1.120E+02  3.882E+01  3.644E+01
350.0    5.248E-05  5.071E-04  7.091E-05  1.914E-04  4.401E-04  2.408E-04  1.396E-04

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*** TOT LUNG DOSE ***
DIST.(MI)  MIN      MAX      5-TH      50-TH      95-TH      AVER      SIGMA
0.5      2.526E+03  3.977E+04  3.226E+03  7.690E+03  2.340E+04  9.883E+03  7.168E+03
1.0      5.182E+02  7.952E+03  6.555E+02  1.555E+03  4.755E+03  1.991E+03  1.431E+03
2.0      1.753E+02  2.652E+03  2.213E+02  5.229E+02  1.619E+03  6.684E+02  4.783E+02
3.0      9.739E+01  1.480E+03  1.241E+02  2.954E+02  9.215E+02  3.740E+02  2.682E+02
4.0      6.062E+01  9.267E+02  7.776E+01  1.861E+02  5.875E+02  2.347E+02  1.689E+02
5.0      3.327E+01  5.104E+02  4.291E+01  1.034E+02  3.314E+02  1.298E+02  9.387E+01
10.0     1.024E+01  1.615E+02  1.338E+01  3.218E+01  1.064E+02  4.149E+01  3.079E+01
20.0     2.658E+00  5.935E+01  3.554E+00  9.308E+00  3.325E+01  1.216E+01  9.990E+00
50.0     7.272E+00  2.435E+02  1.029E+01  2.842E+01  1.112E+02  3.857E+01  3.611E+01
350.0    8.438E-05  8.176E-04  1.135E-04  3.095E-04  7.207E-04  3.933E-04  2.299E-04

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*** TOT THYROID DOSE ***
DIST.(MI)  MIN      MAX      5-TH      50-TH      95-TH      AVER      SIGMA
0.5      2.007E+04  4.493E+05  2.928E+04  6.544E+04  2.681E+05  9.502E+04  8.018E+04
1.0      4.053E+03  8.939E+04  5.851E+03  1.306E+04  5.343E+04  1.898E+04  1.599E+04
2.0      1.358E+03  2.959E+04  1.944E+03  4.332E+03  1.772E+04  6.308E+03  5.310E+03
3.0      7.612E+02  1.651E+04  1.086E+03  2.419E+03  9.903E+03  3.530E+03  2.972E+03
4.0      4.766E+02  1.030E+04  6.781E+02  1.510E+03  6.195E+03  2.208E+03  1.858E+03
5.0      2.591E+02  5.559E+03  3.668E+02  8.162E+02  3.367E+03  1.197E+03  1.007E+03
10.0     7.585E+01  1.599E+03  1.061E+02  2.356E+02  9.870E+02  3.486E+02  2.926E+02

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20.0	1.401E+01	2.666E+02	1.828E+01	4.278E+01	1.774E+02	6.198E+01	5.107E+01
50.0	1.281E+01	3.079E+02	1.648E+01	4.623E+01	1.784E+02	6.025E+01	5.203E+01
350.0	1.455E-04	1.238E-03	1.854E-04	4.584E-04	1.048E-03	5.640E-04	3.063E-04

*** TOT SMALL INT.DOSE ***

DIST. (MI)	MIN	MAX	5-TH	50-TH	95-TH	AVER	SIGMA
0.5	1.462E+03	2.207E+04	1.809E+03	4.340E+03	1.468E+04	5.662E+03	4.295E+03
1.0	3.039E+02	4.462E+03	3.802E+02	8.896E+02	2.974E+03	1.157E+03	8.672E+02
2.0	1.039E+02	1.525E+03	1.303E+02	3.041E+02	1.012E+03	3.934E+02	2.937E+02
3.0	5.790E+01	8.781E+02	7.285E+01	1.708E+02	5.732E+02	2.215E+02	1.663E+02
4.0	3.617E+01	5.665E+02	4.566E+01	1.076E+02	3.638E+02	1.399E+02	1.057E+02
5.0	2.004E+01	3.256E+02	2.539E+01	6.008E+01	2.051E+02	7.847E+01	5.979E+01
10.0	6.375E+00	1.174E+02	8.215E+00	1.981E+01	7.191E+01	2.628E+01	2.071E+01
20.0	1.873E+00	4.746E+01	2.539E+00	6.756E+00	2.549E+01	8.898E+00	7.693E+00
50.0	5.973E+00	2.070E+02	8.358E+00	2.332E+01	9.223E+01	3.199E+01	3.040E+01
350.0	5.453E-05	5.243E-04	7.220E-05	1.994E-04	4.644E-04	2.532E-04	1.481E-04

*** TOT LLIW DOSE ***

DIST. (MI)	MIN	MAX	5-TH	50-TH	95-TH	AVER	SIGMA
0.5	1.671E+03	3.342E+04	2.303E+03	5.771E+03	1.906E+04	7.385E+03	5.894E+03
1.0	3.509E+02	6.825E+03	4.796E+02	1.183E+03	3.885E+03	1.505E+03	1.193E+03
2.0	1.209E+02	2.338E+03	1.629E+02	4.047E+02	1.322E+03	5.107E+02	4.043E+02
3.0	6.765E+01	1.342E+03	9.147E+01	2.279E+02	7.368E+02	2.878E+02	2.296E+02
4.0	4.240E+01	8.618E+02	5.759E+01	1.437E+02	4.596E+02	1.818E+02	1.461E+02
5.0	2.356E+01	4.894E+02	3.216E+01	7.998E+01	2.538E+02	1.016E+02	8.223E+01
10.0	7.506E+00	1.684E+02	1.026E+01	2.589E+01	8.572E+01	3.339E+01	2.771E+01
20.0	2.190E+00	5.887E+01	2.961E+00	7.874E+00	2.935E+01	1.050E+01	9.266E+00
50.0	6.527E+00	2.243E+02	9.184E+00	2.542E+01	1.003E+02	3.485E+01	3.301E+01
350.0	5.943E-05	5.931E-04	8.305E-05	2.153E-04	5.027E-04	2.756E-04	1.597E-04

*** PROB EARLY INJUR. ***

[illegible]

*** PROB. EARLY DEATH ***

[illegible]

MACCS RESULTS : LHS 100 , RELEASES, WEATHER D5

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*** TOT STOMACH DOSE ***
DIST.(MI)  MIN      MAX      5-TH      50-TH      95-TH      AVER      SIGMA
0.5  1.841E+02  2.317E+03  2.197E+02  4.871E+02  1.450E+03  6.079E+02  4.264E+02
1.0  4.966E+01  6.049E+02  5.937E+01  1.350E+02  3.854E+02  1.617E+02  1.097E+02
2.0  2.016E+01  2.423E+02  2.351E+01  5.500E+01  1.557E+02  6.471E+01  4.311E+01
3.0  5.677E+00  1.472E+02  1.435E+01  3.318E+01  9.476E+01  3.911E+01  2.629E+01
4.0  3.084E+00  9.904E+01  9.600E+00  2.243E+01  6.379E+01  2.632E+01  1.773E+01
5.0  4.887E+00  5.980E+01  5.855E+00  1.358E+01  3.846E+01  1.598E+01  1.063E+01
10.0 1.845E+00  2.198E+01  2.232E+00  5.006E+00  1.405E+01  5.945E+00  3.892E+00
20.0 4.178E-01  5.061E+00  5.058E-01  1.126E+00  3.198E+00  1.373E+00  9.186E-01
50.0 1.229E-01  1.633E+00  1.544E-01  3.388E-01  1.133E+00  4.381E-01  3.131E-01
350.0 1.193E-03  3.200E-02  1.538E-03  4.097E-03  1.445E-02  5.485E-03  4.776E-03

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*** TOT MARROW DOSE ***
DIST.(MI)  MIN      MAX      5-TH      50-TH      95-TH      AVER      SIGMA
0.5  1.814E+02  2.763E+03  2.283E+02  5.155E+02  1.603E+03  6.476E+02  4.692E+02
1.0  5.074E+01  7.186E+02  6.279E+01  1.397E+02  4.167E+02  1.729E+02  1.204E+02
2.0  2.070E+01  2.876E+02  2.465E+01  5.714E+01  1.668E+02  6.940E+01  4.756E+01
3.0  5.868E+00  1.749E+02  1.508E+01  3.499E+01  1.016E+02  4.204E+01  2.906E+01
4.0  3.067E+00  1.178E+02  9.887E+00  2.373E+01  6.846E+01  2.835E+01  1.961E+01
5.0  5.076E+00  7.126E+01  6.161E+00  1.435E+01  4.149E+01  1.724E+01  1.180E+01
10.0 1.916E+00  2.635E+01  2.354E+00  5.306E+00  1.543E+01  6.438E+00  4.351E+00
20.0 4.387E-01  6.181E+00  5.344E-01  1.206E+00  3.716E+00  1.505E+00  1.046E+00
50.0 1.275E-01  2.056E+00  1.607E-01  3.874E-01  1.275E+00  4.887E-01  3.649E-01
350.0 1.266E-03  3.861E-02  1.670E-03  4.817E-03  1.635E-02  6.509E-03  5.917E-03

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*** TOT LUNG DOSE ***
DIST.(MI)  MIN      MAX      5-TH      50-TH      95-TH      AVER      SIGMA
0.5  3.156E+02  4.674E+03  3.823E+02  9.124E+02  2.697E+03  1.143E+03  7.966E+02
1.0  8.533E+01  1.181E+03  1.016E+02  2.381E+02  6.878E+02  2.928E+02  2.001E+02
2.0  3.481E+01  4.656E+02  3.919E+01  9.544E+01  2.722E+02  1.150E+02  7.781E+01
3.0  1.048E+01  2.815E+02  2.369E+01  5.765E+01  1.647E+02  6.910E+01  4.728E+01
4.0  5.292E+00  1.886E+02  1.572E+01  3.866E+01  1.104E+02  4.630E+01  3.176E+01
5.0  8.700E+00  1.138E+02  9.603E+00  2.329E+01  6.656E+01  2.807E+01  1.904E+01
10.0 3.187E+00  4.178E+01  3.668E+00  8.566E+00  2.435E+01  1.042E+01  6.955E+00
20.0 7.043E-01  9.690E+00  8.335E-01  1.955E+00  5.621E+00  2.425E+00  1.635E+00
50.0 2.079E-01  3.191E+00  2.644E-01  6.317E-01  1.958E+00  7.930E-01  5.549E-01
350.0 2.185E-03  5.528E-02  3.227E-03  8.252E-03  2.631E-02  1.071E-02  8.826E-03

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*** TOT THYROID DOSE ***
DIST.(MI)  MIN      MAX      5-TH      50-TH      95-TH      AVER      SIGMA
0.5  3.163E+03  7.171E+04  4.622E+03  9.992E+03  4.265E+04  1.498E+04  1.274E+04
1.0  7.886E+02  1.752E+04  1.141E+03  2.446E+03  1.043E+04  3.670E+03  3.112E+03
2.0  3.091E+02  6.787E+03  4.445E+02  9.483E+02  3.858E+03  1.403E+03  1.180E+03
3.0  1.365E+02  4.084E+03  2.593E+02  5.475E+02  2.325E+03  8.341E+02  7.102E+02
4.0  9.169E+01  2.729E+03  1.700E+02  3.662E+02  1.555E+03  5.556E+02  4.761E+02
5.0  7.577E+01  1.646E+03  1.081E+02  2.212E+02  9.398E+02  3.372E+02  2.861E+02
10.0 2.800E+01  6.066E+02  3.988E+01  8.491E+01  3.480E+02  1.260E+02  1.057E+02

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20.0	6.593E+00	1.435E+02	9.424E+00	2.011E+01	8.360E+01	3.022E+01	2.547E+01
50.0	2.219E+00	4.906E+01	3.208E+00	6.947E+00	2.933E+01	1.042E+01	8.836E+00
350.0	3.059E-02	6.625E-01	4.357E-02	9.980E-02	4.479E-01	1.472E-01	1.282E-01

*** TOT SM. INT.DOSE			***				
DIST.(MI)	MIN	MAX	5-TH	50-TH	95-TH	AVER	SIGMA
0.5	1.547E+02	2.047E+03	1.883E+02	4.221E+02	1.261E+03	5.247E+02	3.663E+02
1.0	4.356E+01	5.368E+02	5.138E+01	1.149E+02	3.284E+02	1.406E+02	9.437E+01
2.0	1.776E+01	2.157E+02	2.009E+01	4.660E+01	1.318E+02	5.656E+01	3.733E+01
3.0	4.837E+00	1.313E+02	1.230E+01	2.846E+01	8.031E+01	3.428E+01	2.284E+01
4.0	2.475E+00	8.848E+01	8.250E+00	1.924E+01	5.416E+01	2.312E+01	1.542E+01
5.0	4.185E+00	5.352E+01	5.040E+00	1.164E+01	3.283E+01	1.406E+01	9.277E+00
10.0	1.642E+00	1.977E+01	1.951E+00	4.326E+00	1.222E+01	5.249E+00	3.419E+00
20.0	3.758E-01	4.605E+00	4.420E-01	9.825E-01	3.052E+00	1.223E+00	8.213E-01
50.0	1.084E-01	1.539E+00	1.366E-01	3.083E-01	1.028E+00	3.944E-01	2.865E-01
350.0	1.083E-03	3.350E-02	1.467E-03	3.789E-03	1.336E-02	5.162E-03	4.779E-03

*** TOT LLIW			DOSE		***			
DIST. (MI)	MIN	MAX	5-TH	50-TH	95-TH	AVER	SIGMA	
0.5	1.840E+02	3.628E+03	2.464E+02	6.009E+02	1.860E+03	7.740E+02	6.157E+02	
1.0	5.273E+01	9.254E+02	6.510E+01	1.626E+02	4.822E+02	2.023E+02	1.543E+02	
2.0	2.213E+01	3.669E+02	2.572E+01	6.680E+01	1.927E+02	8.057E+01	6.064E+01	
3.0	6.764E+00	2.226E+02	1.547E+01	3.950E+01	1.172E+02	4.874E+01	3.696E+01	
4.0	2.805E+00	1.496E+02	1.030E+01	2.677E+01	7.888E+01	3.282E+01	2.489E+01	
5.0	5.658E+00	9.053E+01	6.238E+00	1.624E+01	4.773E+01	1.994E+01	1.502E+01	
10.0	2.086E+00	3.353E+01	2.422E+00	6.206E+00	1.768E+01	7.442E+00	5.569E+00	
20.0	4.599E-01	7.963E+00	5.611E-01	1.430E+00	4.175E+00	1.756E+00	1.363E+00	
50.0	1.325E-01	3.001E+00	1.817E-01	4.486E-01	1.415E+00	5.847E-01	4.928E-01	
350.0	1.425E-03	7.182E-02	2.266E-03	5.927E-03	2.075E-02	8.928E-03	1.011E-02	

[illegible][illegible]

APPENDIX G

Results for the Multiparameter Uncertainty Study:
Doses Calculated Using CRAC2 and MACCS Dose Conversion Factors.

CRAC2 RESULTS : LHS 100

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*** TOT. BODY DOSE ***
DIST.(MI)  MIN      MAX      5-TH      50-TH      95-TH      AVER      SIGMA
0.5      1.832E+01  1.092E+04  7.238E+01  7.451E+02  4.313E+03  1.459E+03  2.055E+03
1.0      6.375E+00  3.594E+03  1.855E+01  2.527E+02  1.541E+03  4.907E+02  6.562E+02
2.0      5.643E-05  6.897E+02  3.239E+00  6.088E+01  3.158E+02  1.020E+02  1.161E+02
3.0      2.692E-09  3.621E+02  1.910E+00  3.387E+01  1.744E+02  5.623E+01  6.263E+01
4.0      1.400E-13  2.271E+02  1.448E+00  2.243E+01  1.163E+02  3.637E+01  4.018E+01
5.0      7.804E-18  1.325E+02  9.136E-01  1.418E+01  7.338E+01  2.194E+01  2.436E+01
10.0     1.547E-24  4.038E+01  4.443E-01  4.781E+00  2.561E+01  7.299E+00  7.987E+00
20.0     6.845E-25  1.338E+01  7.381E-02  1.230E+00  7.866E+00  2.250E+00  2.606E+00
50.0     1.780E-25  2.189E+00  3.966E-03  3.237E-01  2.022E+00  5.458E-01  6.148E-01
350.0    2.548E-28  3.564E-02  4.017E-05  9.264E-04  1.664E-02  3.755E-03  6.535E-03

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*** TOT. MARROW DOSE ***
DIST.(MI)  MIN      MAX      5-TH      50-TH      95-TH      AVER      SIGMA
0.5      2.114E+01  1.266E+04  1.042E+02  9.397E+02  5.061E+03  1.774E+03  2.401E+03
1.0      7.355E+00  4.265E+03  2.416E+01  3.114E+02  1.841E+03  6.035E+02  7.768E+02
2.0      6.503E-05  8.191E+02  5.094E+00  7.683E+01  3.662E+02  1.266E+02  1.410E+02
3.0      3.102E-09  4.306E+02  2.896E+00  4.532E+01  2.094E+02  6.988E+01  7.656E+01
4.0      1.614E-13  2.705E+02  1.980E+00  2.888E+01  1.397E+02  4.529E+01  4.932E+01
5.0      8.995E-18  1.580E+02  1.255E+00  1.729E+01  9.206E+01  2.738E+01  3.007E+01
10.0     1.785E-24  4.844E+01  5.351E-01  5.929E+00  3.375E+01  9.169E+00  9.932E+00
20.0     7.907E-25  1.602E+01  8.835E-02  1.600E+00  9.944E+00  2.842E+00  3.235E+00
50.0     2.050E-25  2.996E+00  5.305E-03  4.433E-01  2.530E+00  7.074E-01  7.825E-01
350.0    2.886E-28  6.544E-02  7.368E-05  1.815E-03  3.001E-02  6.598E-03  1.115E-02

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*** TOT. LUNG DOSE ***
DIST.(MI)  MIN      MAX      5-TH      50-TH      95-TH      AVER      SIGMA
0.5      3.572E+01  7.222E+04  1.823E+02  2.579E+03  1.843E+04  5.669E+03  8.712E+03
1.0      1.239E+01  2.598E+04  4.245E+01  7.402E+02  7.431E+03  2.202E+03  3.375E+03
2.0      5.397E-05  5.021E+03  1.431E+01  1.563E+02  1.906E+03  4.901E+02  7.368E+02
3.0      2.565E-09  2.661E+03  9.159E+00  9.304E+01  1.088E+03  2.722E+02  4.093E+02
4.0      1.331E-13  1.676E+03  6.456E+00  6.321E+01  7.104E+02  1.772E+02  2.675E+02
5.0      7.387E-18  9.733E+02  3.521E+00  3.802E+01  3.909E+02  1.076E+02  1.623E+02
10.0     1.463E-24  3.887E+02  1.088E+00  1.276E+01  1.258E+02  3.606E+01  5.540E+01
20.0     6.445E-25  1.463E+02  9.767E-02  3.642E+00  3.425E+01  1.075E+01  1.792E+01
50.0     1.671E-25  4.558E+01  8.561E-03  1.036E+00  9.237E+00  2.895E+00  5.333E+00
350.0    2.900E-28  5.638E-01  3.253E-05  1.589E-03  2.412E-01  5.020E-02  9.871E-02

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*** TOT. THYROID DOSE ***
DIST.(MI)  MIN      MAX      5-TH      50-TH      95-TH      AVER      SIGMA
0.5      2.196E+02  1.482E+05  4.930E+02  1.044E+04  8.140E+04  2.004E+04  2.843E+04
1.0      2.897E+01  8.295E+04  1.036E+02  3.906E+03  3.664E+04  8.290E+03  1.314E+04
2.0      7.518E-05  2.626E+04  3.346E+01  7.528E+02  8.837E+03  1.989E+03  3.614E+03
3.0      3.499E-09  1.623E+04  2.157E+01  4.110E+02  4.754E+03  1.121E+03  2.130E+03
4.0      1.796E-13  1.124E+04  1.650E+01  2.551E+02  3.006E+03  7.361E+02  1.439E+03
5.0      9.701E-18  6.959E+03  1.049E+01  1.385E+02  1.780E+03  4.563E+02  9.029E+02
10.0     1.993E-24  2.580E+03  2.775E+00  4.299E+01  6.104E+02  1.536E+02  3.166E+02

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20.0	9.049E-25	8.172E+02	1.978E-01	1.136E+01	1.853E+02	4.488E+01	9.625E+01
50.0	2.648E-25	2.324E+02	2.005E-02	2.764E+00	3.850E+01	1.072E+01	2.547E+01
350.0	4.967E-28	4.909E+00	4.557E-05	2.396E-03	5.448E-01	1.417E-01	5.226E-01

*** TOT. LLIW DOSE ***								
DIST. (MI)	MIN	MAX	5-TH	50-TH	95-TH	AVER	SIGMA	
0.5	1.323E+01	8.585E+03	6.417E+01	8.601E+02	4.972E+03	1.404E+03	1.678E+03	
1.0	4.606E+00	2.701E+03	1.661E+01	2.367E+02	1.738E+03	4.884E+02	5.623E+02	
2.0	4.784E-05	4.885E+02	3.561E+00	6.336E+01	3.203E+02	1.049E+02	1.089E+02	
3.0	2.303E-09	2.664E+02	2.066E+00	3.976E+01	1.733E+02	5.820E+01	5.989E+01	
4.0	1.210E-13	1.746E+02	1.467E+00	2.566E+01	1.122E+02	3.786E+01	3.892E+01	
5.0	6.797E-18	1.124E+02	8.228E-01	1.489E+01	6.969E+01	2.294E+01	2.389E+01	
10.0	1.408E-24	4.117E+01	3.872E-01	4.479E+00	2.321E+01	7.707E+00	8.095E+00	
20.0	6.629E-25	1.582E+01	6.211E-02	1.308E+00	7.719E+00	2.370E+00	2.721E+00	
50.0	1.977E-25	4.957E+00	3.360E-03	3.598E-01	1.910E+00	6.268E-01	7.585E-01	
350.0	3.065E-28	8.710E-02	1.815E-05	7.393E-04	4.369E-02	7.447E-03	1.439E-02	

[illegible]

MACCS RESULTS : LHS 100

*** TOT STOMACH DOSE ***

DIST.(MI)	MIN	MAX	5-TH	50-TH	95-TH	AVER	SIGMA
0.5	1.385E+01	7.969E+03	6.109E+01	7.307E+02	4.400E+03	1.256E+03	1.564E+03
1.0	8.855E-02	1.236E+03	6.001E+00	1.263E+02	6.565E+02	2.110E+02	2.353E+02
2.0	3.746E-06	4.411E+02	3.345E+00	4.917E+01	2.631E+02	8.001E+01	8.552E+01
3.0	1.840E-10	2.445E+02	1.996E+00	2.831E+01	1.605E+02	4.649E+01	4.967E+01
4.0	9.758E-15	1.555E+02	1.417E+00	1.890E+01	1.086E+02	3.055E+01	3.272E+01
5.0	4.839E-20	9.169E+01	8.027E-01	1.179E+01	6.938E+01	1.861E+01	2.011E+01
10.0	1.584E-24	3.363E+01	3.817E-01	4.278E+00	2.688E+01	6.892E+00	7.478E+00
20.0	4.655E-25	9.193E+00	4.507E-02	9.247E-01	5.773E+00	1.627E+00	1.844E+00
50.0	1.893E-25	2.435E+00	3.369E-03	3.131E-01	1.769E+00	5.084E-01	5.687E-01
350.0	2.697E-28	4.588E-02	2.278E-05	7.893E-04	1.983E-02	4.171E-03	7.695E-03

*** TOT MARROW DOSE ***

DIST.(MI)	MIN	MAX	5-TH	50-TH	95-TH	AVER	SIGMA
0.5	1.439E+01	8.697E+03	6.538E+01	7.572E+02	4.833E+03	1.357E+03	1.709E+03
1.0	9.767E-02	1.304E+03	6.066E+00	1.372E+02	7.136E+02	2.268E+02	2.531E+02
2.0	4.132E-06	4.673E+02	3.203E+00	5.287E+01	2.749E+02	8.600E+01	9.094E+01
3.0	2.030E-10	2.599E+02	1.887E+00	3.083E+01	1.532E+02	5.004E+01	5.267E+01
4.0	1.076E-14	1.658E+02	1.330E+00	2.057E+01	1.010E+02	3.293E+01	3.465E+01
5.0	5.338E-20	9.816E+01	8.481E-01	1.269E+01	6.394E+01	2.010E+01	2.127E+01
10.0	1.748E-24	3.472E+01	4.303E-01	4.816E+00	2.578E+01	7.481E+00	7.937E+00
20.0	5.138E-25	1.012E+01	4.981E-02	1.009E+00	6.187E+00	1.794E+00	1.998E+00
50.0	2.089E-25	2.515E+00	3.675E-03	3.557E-01	2.028E+00	5.725E-01	6.282E-01
350.0	3.006E-28	5.413E-02	2.080E-05	6.906E-04	2.944E-02	5.433E-03	9.953E-03

*** TOT LUNG DOSE ***

DIST.(MI)	MIN	MAX	5-TH	50-TH	95-TH	AVER	SIGMA
0.5	2.119E+01	1.252E+04	1.027E+02	1.314E+03	7.292E+03	2.226E+03	2.382E+03
1.0	9.773E-02	1.932E+03	1.197E+01	2.348E+02	1.308E+03	4.064E+02	4.469E+02
2.0	4.109E-06	8.831E+02	6.908E+00	8.343E+01	5.665E+02	1.568E+02	1.775E+02
3.0	2.015E-10	5.656E+02	4.176E+00	5.308E+01	3.369E+02	9.148E+01	1.056E+02
4.0	1.067E-14	3.939E+02	2.973E+00	3.284E+01	2.213E+02	6.031E+01	7.071E+01
5.0	5.282E-20	2.499E+02	1.454E+00	1.968E+01	1.397E+02	3.697E+01	4.417E+01
10.0	1.727E-24	9.965E+01	6.665E-01	6.907E+00	4.983E+01	1.377E+01	1.687E+01
20.0	5.071E-25	2.504E+01	5.619E-02	1.568E+00	1.064E+01	3.177E+00	4.041E+00
50.0	2.060E-25	8.377E+00	4.598E-03	5.516E-01	2.794E+00	9.920E-01	1.315E+00
350.0	3.128E-28	1.661E-01	3.375E-05	1.112E-03	5.688E-02	1.176E-02	2.377E-02

*** TOT THYROID DOSE ***

DIST.(MI)	MIN	MAX	5-TH	50-TH	95-TH	AVER	SIGMA
0.5	2.863E+02	1.981E+05	7.220E+02	1.384E+04	1.121E+05	2.786E+04	3.933E+04
1.0	1.701E-01	6.396E+04	7.769E+01	2.276E+03	2.855E+04	5.870E+03	9.730E+03
2.0	6.426E-06	2.916E+04	3.642E+01	8.462E+02	1.046E+04	2.369E+03	4.233E+03
3.0	3.043E-10	1.867E+04	2.596E+01	4.713E+02	6.125E+03	1.405E+03	2.606E+03
4.0	1.569E-14	1.302E+04	2.019E+01	2.882E+02	4.041E+03	9.391E+02	1.787E+03
5.0	7.476E-20	8.271E+03	1.271E+01	1.607E+02	2.482E+03	5.891E+02	1.148E+03
10.0	2.378E-24	3.319E+03	2.746E+00	5.343E+01	9.911E+02	2.293E+02	4.653E+02

20.0	6.846E-25	8.613E+02	1.734E-01	1.210E+01	1.895E+02	5.421E+01	1.182E+02
50.0	2.728E-25	3.075E+02	2.521E-02	4.063E+00	5.969E+01	1.749E+01	4.127E+01
350.0	6.780E-28	8.114E+00	3.687E-05	3.185E-03	1.240E+00	2.813E-01	8.983E-01

*** TOT SM. INT.DOSE ***								
DIST.(MI)	MIN	MAX	5-TH	50-TH	95-TH	AVER	SIGMA	
0.5	1.188E+01	7.150E+03	5.460E+01	6.294E+02	4.008E+03	1.107E+03	1.399E+03	
1.0	8.106E-02	1.054E+03	5.035E+00	1.101E+02	5.691E+02	1.841E+02	2.043E+02	
2.0	3.431E-06	3.778E+02	2.427E+00	4.410E+01	2.209E+02	6.966E+01	7.265E+01	
3.0	1.685E-10	2.100E+02	1.460E+00	2.573E+01	1.228E+02	4.050E+01	4.195E+01	
4.0	8.940E-15	1.339E+02	1.021E+00	1.705E+01	8.093E+01	2.663E+01	2.755E+01	
5.0	4.434E-20	7.927E+01	6.646E-01	1.061E+01	4.998E+01	1.623E+01	1.686E+01	
10.0	1.452E-24	2.806E+01	3.172E-01	3.814E+00	2.033E+01	6.028E+00	6.284E+00	
20.0	4.267E-25	8.209E+00	4.089E-02	8.367E-01	4.809E+00	1.441E+00	1.596E+00	
50.0	1.737E-25	2.274E+00	3.083E-03	2.872E-01	1.581E+00	4.565E-01	5.024E-01	
350.0	2.516E-28	3.397E-02	2.048E-05	7.231E-04	2.236E-02	3.994E-03	7.064E-03	

*** TOT LLIW		DOSE		***				
DIST. (MI)	MIN	MAX	5-TH	50-TH	95-TH	AVER	SIGMA	
0.5	1.362E+01	8.987E+03	6.710E+01	9.208E+02	5.869E+03	1.559E+03	1.787E+03	
1.0	8.825E-02	1.191E+03	6.735E+00	1.455E+02	8.827E+02	2.699E+02	2.876E+02	
2.0	3.720E-06	4.603E+02	3.280E+00	6.379E+01	3.253E+02	1.028E+02	1.064E+02	
3.0	1.825E-10	2.720E+02	2.004E+00	3.580E+01	1.802E+02	5.991E+01	6.191E+01	
4.0	9.673E-15	1.816E+02	1.446E+00	2.329E+01	1.154E+02	3.947E+01	4.093E+01	
5.0	4.791E-20	1.166E+02	9.542E-01	1.452E+01	7.518E+01	2.414E+01	2.538E+01	
10.0	1.567E-24	5.525E+01	4.253E-02	4.974E+00	2.792E+01	9.013E+00	9.826E+00	
20.0	4.607E-25	1.628E+01	4.740E-02	1.184E+00	6.545E+00	2.160E+00	2.552E+00	
50.0	1.875E-25	6.189E+00	3.730E-03	4.010E-01	2.166E+00	7.045E-01	8.824E-01	
350.0	2.980E-28	1.082E-01	2.221E-05	8.340E-04	4.934E-02	8.762E-03	1.706E-02	

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