Defense Threat Reduction Agency
8725 John J. Kingman Road, Stop
6201 Fort Belvoir, VA 22060-6201

DTRA-TR- 07-11

TECHNICAL REPORT

FIIDOS, A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs

Computer User's Guide (Revision 4)

Approved for public release; distribution is unlimited.

May 2007

HDTRA1-07-C-0015

Dudley A. Raine III, et al.

Prepared by:
SAIC
1710 SAIC Drive
McLean, VA 22101

REPORT DOCUMENTATION PAGE	***Form Approved*** **OMB No. 0704-0188**

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
00-05-2007	Technical report	

4. TITLE AND SUBTITLE FIIDOS – A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs Computer User's Guide (Revision 4)	**5a. CONTRACT NUMBER** HDTRA1-07-C-0015 **5b. GRANT NUMBER** **5c. PROGRAM ELEMENT NUMBER** 139D
6. AUTHOR(S) Dudley A. Raine III, Stephen D. Egbert, John H. Stiver, and David R. Case	**5d. PROJECT NUMBER** CS **5e. TASK NUMBER** AH **5f. WORK UNIT NUMBER** DH21501
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) SAIC 1710 SAIC Drive McLean, VA 22101-1303	**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Defense Threat Reduction Agency 8725 John J. Kingman Road, STOP 6201 Fort Belvoir, VA 22060-6201 RD-NTSN/ P. Blake	**10. SPONSOR/MONITOR'S ACRONYM(S)** DTRA RD-NTSN **11. SPONSORING/MONITORING AGENCY REPORT NUMBER** DTRA-TR-07-11

12. DISTRIBUTION AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
This work was sponsored by the Defense Threat Reduction Agency under RDT&E RMSS Code B 139D D R400 CS AH 21501.

14. ABSTRACT
This report discusses the technical aspects of the computer code FIIDOS (Fallout Inhalation and Ingestion Dose to Organs, Version 4), describes user inputs and operations, and includes sample problems. This report updates the original FIIDOS Computer User's Guide published in 1985.

15. SUBJECT TERMS
Nuclear Test Personnel Review, Veterans, Atmospheric Nuclear Weapons Test, Fallout, Inhalation Dose, Ingestion Dose, Internal Dose

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**	UU	169	Dr. Paul K. Blake
U	U	U			**19b. TELEPONE NUMBER (*Include area code)*** 703 767-3384

TABLE OF CONTENTS

SECTION **PAGE**

Figures

Tables

SECTION 1

OVERVIEW

1.1 INTRODUCTION

This report discusses the technical aspects of the computer code FIIDOS (Fallout Inhalation and Ingestion Dose to Organs, Version 4), describes user inputs and operations, and includes sample problems. This report updates the original FIIDOS Computer User's Guide published in 1985 (DNA, 1985). The Nuclear Test Personnel Review (NTPR) Program uses FIIDOS to determine the dose to internal organs from the inhalation or ingestion of contaminants created by a nuclear detonation under various conditions common to participants in atmospheric nuclear testing and the occupation of Hiroshima and Nagasaki, Japan (NTPR, 2006). To do this, it calculates an internal dose in an organ from the intake of contaminants produced by a nuclear detonation, which is typically determined by relating the external gamma-ray intensity rate above a fallout field to the fallout contamination level on the ground surface. The intake of contaminants may also be determined from other measurements, including air-sampling data or radiation intensities within a debris cloud (while on the ground or in the air). It determines the dose from the mixture of activation products, actinides, and fission products in fallout. Doses from low-linear energy transfer (LET) radiation (beta particles and gamma rays) are reported separately from doses from high-LET (alpha particle) radiation.

The NTPR Program has prepared internal dose determinations since the early 1980s using methods incorporated into the FIIDOS code. Approaches to internal dose determination included estimates of airborne radioactivity concentrations based on ambient radiation dose (Lee, 1983 and Barrett, 1986). Other approaches included estimates based on analyses of fission products and plutonium in urine (SAIC, 1983). A review of those methods (NRC, 1985) concluded that personnel exposed to heavy fallout received internal doses that were much smaller than their external doses, with the possible exception of doses to the thyroid. The review also concluded that the methods for estimating internal doses were not as well developed or as scientifically defensible as the methods used to estimate external doses. These conclusions were based on a lack of data about the material inhaled or ingested by nuclear weapon test participants or occupation forces at Hiroshima or Nagasaki and on the reliability of certain assumptions used in the estimates. The review expressed concerns about fractionation of airborne radionuclides and deposited fallout, particle size distributions, and particle solubilities.

The concerns about internal dosimetry methods discussed in NRC's review (NRC, 1985) pertain to assumptions of various parameters required to estimate the dose to tissues and organs in the absence of measurements of radioactivity concentrations. Suggestions for the use of urine bioassay to estimate concentrations of radionuclides in the body combined with appropriate models to derive estimates of material inhaled or ingested were apparently rejected as not feasible. The NTPR Program worked to re-evaluate assumptions about the critical parameters used in calculating internal doses – resuspension factor, breathing rate, fractionation, and scenario elements – to conclude that reasonable margins of high-siding were applied.

In the late 1990s, the NTPR Program studied whether bioassay testing using the measurement of plutonium in urine could be used to assess the reliability of the methods for estimating inhalation doses. The effort resolved numerous technical, analytical, and methodological issues, and collected and analyzed urine samples from about 100 veterans. Results of the assessments provided the source data for several papers on the analytical issues involved (e.g., Klemm, 2003). However, the results did not prove useful in providing an assessment of the reliability of the methods for estimating internal doses.

A more recent National Research Council review (NRC, 2003) evaluated methods for estimating internal dose and concluded that the methods had important shortcomings centered around three issues. First, the committee concluded that the reliability of methods for estimating concentrations of radionuclides based on measurements of external photon exposure had not been demonstrated. Second, the committee concluded that the lack of consideration of resuspension of previously deposited fallout by the blast wave and the neglect of fractionation in fallout could result in underestimates of inhalation dose. Third, the substantial uncertainty in dose coefficients for inhalation of radionuclides had not been taken into account. The committee summarized its evaluation of the methods for estimating inhalation dose by concluding that they do not consistently provide credible upper bounds. The committee also considered estimates of doses from ingestion of radionuclides, offered several examples of plausible scenarios, and concluded that ingestion was rarely considered in estimating internal dose.

1.2 HISTORY OF THE CODE

1.2.1 FIIDOS1

The original version of FIIDOS, completed in 1985, was written in FORTRAN-IV for operation on a DEC PDP-11 mini-computer with problem input read from a keyboard and output directed to an off-line printer. The code required 32 kilobytes (Kb) of core memory and 100 Kb of external disk memory storage. A typical FIIDOS problem used 10 minutes of running time. Since 1985, with the substantial increases in the available computing power, FIIDOS has undergone a gradual evolution to a code that, though it still functions in much the same way, has substantially greater capabilities.

1.2.2 FIIDOS2

a. Overview

The first revision to FIIDOS in 1995, called FIIDOS2 included the following three significant changes:

1) ORIGEN2 - Oak Ridge Isotope Generation and Depletion Code, Version 2.1 (Croff, 1980), was integrated into the FIIDOS code and

its input data modified. It was run using initial fission product inventories directly for both fast (1-MeV) and 14-MeV fission from U-235, U-238 and Pu-239 datasets recommended to the Defense Nuclear Agency (DNA) by Tal England of Los Alamos National Laboratory (LANL) (England, 1993a and England, 1993b). England was the reviewer for these inventories in the previously released ENDF/B-VI fission product dataset (Rose, 1991). He made the recommendation to use the updated inventories because he obtained better agreement with fission product gamma- and beta-emission measurements from very early to late times. This dataset was used extensively for other projects such as the Japanese A-Bomb dosimetry study. However, because it was a work in progress at LANL, it was not forwarded to the Brookhaven National Laboratory (BNL) National Nuclear Data Center for public access.

2) An option to include dose conversion factors from Federal Guidance Report 11 (FGR-11) (Eckerman, 1988) was added to supplement the tables of dose conversion factors used in the original version of FIIDOS, which are based on ORNL TM-190 (Killough, 1981) and ICRP-30 (ICRP, 1979).

3) A plutonium bioassay prediction capability was included.

4) An integrated exposure option was added to the original version's three discrete exposure options to assess internal doses in situations where the period of intake is long enough that significant changes occur in the radionuclide inventory; e.g., for an extended period on a residence island after an operation.

The code was rewritten in Fortran 77 and compiled for various computing platforms, including UNIX, Macintosh, and MS-DOS compatible systems. Runtimes on the various platforms ranged from 20 seconds up to 9 minutes, depending on the speed of the system and the compiler options specified.

b. Data Changes

The original FIIDOS used data tables containing time-dependent radionuclide and gamma-ray spectral information for various fission radionuclides produced in a fast reactor that were generated in the original version of ORIGEN. FIIDOS interpolated between the standard times of the data tables to calculate the inventory and spectra at the times of interest. FIIDOS2 incorporated ORIGEN2, the latest available version of that code, as a callable subroutine, with modifications to support the NTPR Program needs. Thus, many of the original data tables were no longer necessary because the required information was passed directly from ORIGEN2 into FIIDOS via common block variables, which eliminated the interpolation steps. Additional modifications to ORIGEN2 included: 1) expanding the gamma-ray spectral data for many more isotopes to provide accurate spectra at early times after detonation; 2) using the initial fission product inventories available in the fission product dataset obtained from LANL (England, 1993a and England, 1993b) for fission from U-235, U-238, and Pu-239; and 3) correcting for a few inconsistencies in the decay constants and gamma-ray spectra, which were found by comparing late-time decay inventory and spectra output from ORIGEN2-SAIC with that calculated by a LANL in-house code called CINDER10 (England, 1993a and England, 1993b). This modified version of ORIGEN2 was called ORIGEN2-SAIC (Roberts, 1996). For most scenarios using ORIGEN2-SAIC, the resulting organ doses produced by FIIDOS2 showed only minor differences from those generated by the original version of FIIDOS (generally less than one to two percent at exposures more than one hour after detonation).

c. Dose Conversion Factors Added

The new dose conversion factors added into FIIDOS2 were taken from FGR-11, which utilized the ICRP-30 methods and models and expanded the inventory of dose conversion factors to 412 radionuclides. Additional large particle internal dose conversion factors for a particle size distribution of 10-micrometers (μm) activity median aerodynamic diameter (AMAD) were created using the computer code, DFINT (Eckerman, 1993). Inhalation dose conversion factors were selected for each nuclide according to the respiratory clearance class associated with the oxide form of each element. The addition of this data set had little, if any, impact on the internal organ doses reported by the NTPR Program because the organ doses resulting from ORNL TM-190 dose conversion factors tended to be greater than those from FGR-11. As directed by the Government for the NTPR program, the data set most favorable to the veterans continued to be the default choice.

d. Plutonium Bioassay Added

A plutonium bioassay capability was added using the available radionuclide inventory data in FIIDOS to determine the total intake of Pu-239 based on the inhaled or ingested total number of curies (Ci) as calculated during the internal dose calculations. The Pu-239 excretion rate is represented by a five-term exponential function (Jones, 1985), which is used to predict the Pu-239 activity excreted in urine during any 24-hr period at specific times after uptake. While this modification had no effect on the resulting organ doses calculated by FIIDOS, it provided a tool to assess radiological uptake if a participant had a bioassay result greater than the population average during the period of the NTPR-sponsored Pu-239 bioassay program (1998-1999).

1.2.3 FIIDOS3

Revisions to FIIDOS in 1999, called FIIDOS3 changed the program flow so that multiple discrete or integrated exposures with multiple measurements (all from the same detonation) could be handled in a single run. Previously, each measurement could have multiple exposure times associated with it, but only one measurement time could be used in a given run. This change enabled the user to include 50 measurement/exposure pairs for discrete exposures (or any combination of measurements and exposures totaling 100), or 33 measurement/exposure pairs for integrated exposures. In addition, the plutonium bioassay capability was expanded to be more flexible by allowing the user to specify the number of excretion times to be evaluated and modifying the time of excretion to be specified relative to the detonation (instead of intake), which facilitates combining contributions from multiple or integrated exposures. Because of the substantial increase in computer power available at the time, even longer runs with a full input deck of 100 (measurement plus exposure) times usually took less than one minute on a personal computer. No other technical changes were made and the code output was verified to be consistent with the output from FIIDOS2.

1.2.4 FIIDOS4

Three modifications have been made to FIIDOS since 1999. In 2001, options to include dose conversion factors for inhalation and ingestion from FGR-13 (EPA, 1999) were added to the code. The dose conversion factors presented in FGR-13 use the latest methods and models from the ICRP, including the ICRP-66 human respiratory tract model (HRTM) (ICRP, 1994a). Notably, these dose conversion factors provide the equivalent dose, which is the absorbed dose averaged over a tissue or organ and weighted by a radiation weighting factor (w_R). Only one set of inhalation dose conversion factors for a particle size distribution of one-micrometer AMAD was incorporated into FIIDOS along with a new set of ingestion dose conversion factors. Because these dose conversion factors did not result in appreciable increases or decreases in the total reported organ doses for most participants relative to those calculated using the existing ICRP-30 or FGR-11 tables, the FGR-13 tables were only used in situations requiring a dose to an internal organ that was not contained in the other dose conversion factor tables.

In 2006, a second change allow the reporting of alpha-particle doses separately from beta particle and gamma-ray doses to accommodate the Department of Veterans Affairs' use of the Interactive RadioEpidemiological Program for calculating the probability of causation for cancers. This modification assumes that the alpha-particle dose to an organ equals the total organ dose for the alpha-particle emitting radionuclides in the FIIDOS inventory.

Also in 2006, a third change involved revision of the code in response to DTRA guidance to implement only the most current dose coefficients for determining internal dose. Namely, these were the dose coefficients based on ICRP-72 (ICRP, 1996). As part of this revision, options to use dose conversion factors previously included (ORNL TM-190, ICRP-30, FGR-11, and FGR-13) were removed from the code. However, records of their use in generating dose factor tables were retained for legacy purposes, and the revised code included the flexibility to accommodate dose coefficient data sets (including, if necessary, the old data sets) with up to 40 organs as input. The ICRP-72 dose conversion factors are based on the conceptual framework of ICRP-60 (ICRP, 1991) as implemented in the latest dosimetric and biokinetic models (ICRP, 1991; 1994a; 1994b; 1996). The ICRP-72 inhalation dose coefficients, as input to FIIDOS, were selected to address concerns about particle size distribution. This set uses the dose coefficient for the particle size distribution that produces the highest dose to the organ of interest from among 1-, 3-, 5-, and 10-micrometer AMAD particle size distributions for the absorption type applicable to the oxide form of each constituent radionuclide. This set of "maximum dose" inhalation dose conversion factors supplants all previous sets for internal dose assessments.

The changes noted above outline the major differences between the original version of FIIDOS and the current version. Since FIIDOS2, no changes have been made that affect the methods used to calculate the doses; ensuing changes involve the dose conversion factors, program flow, options, and output presentation.

1.3 SUMMARY

The purpose of FIIDOS is to calculate the 50-year committed equivalent dose to various body organs and tissues resulting from the inhalation or the ingestion of fallout from nuclear weapons.

Figure 1 portrays the key features of FIIDOS. Four characteristics of FIIDOS enhance its applicability to radiation dose calculations associated with nuclear detonations:

a) the production and radioactive decay of the radionuclides present in nuclear weapon fallout (including fission products, activation products, and actinide elements) is considered, permitting modifications to this radionuclide inventory to reflect detonation-specific analyses of activity fractions in the various isotopes of the nuclear debris;
b) the dose calculation is based on a specific radiological measurement of the nuclear debris or fallout (such as a measurement of gross activity concentration or gamma-ray radiation intensity);
c) calculated doses from both high linear energy transfer (LET) (alpha-particle) and low LET (beta-particle and gamma-ray) radiations support the calculation of probability of causation; and,
d) the plutonium concentration in urine for times since detonation (corrected for time of uptake) is calculated.

Figure 2 illustrates, in a simplified manner, the logic used in FIIDOS to calculate committed organ doses. The computation can begin with any one of the nine types of radiological measurements listed in Figure 1 and indicated in Figure 2. The most common calculation scheme, based on a measurement of the radiation intensity above a contaminated surface, is described in the following sections.

The computation begins with the user-supplied radiation intensity, such as survey data in Roentgen per hour (R hr^{-1}). FIIDOS calls the ORIGEN2-SAIC code to calculate a debris inventory and radiation intensity spectrum. After modifying the inventory and the gamma spectrum to reflect any post-detonation changes (e.g., the removal of the gases krypton and xenon or fractionation effects), FIIDOS calculates the relationship between the radiation intensity and the surface activity concentration in Curies per square meter (Ci m^{-2}). A user-supplied resuspension factor, which relates airborne contamination to surface contamination, converts the surface activity concentration to an airborne activity concentration (Ci m^{-3}). Using this airborne activity concentration and user-supplied information on the exposure duration (hr) and the breathing rate (m^3 hr^{-1}); FIIDOS determines the discreet activity for each radionuclide (Ci) present in the inhaled radioactive material. Based on the inventory of this radionuclide activity intake and a set of radionuclide-specific, inhalation dose conversion factors (in dose equivalent per material activity, i.e., rem μCi^{-1}) contained in FIIDOS, internal committed equivalent doses are calculated. Given the FIIDOS-calculated activity intake of Pu-239, a five-term exponential excretion function (Jones, 1985) is applied to calculate the Pu-239 activity concentration that is expected in 24-hour urine samples at specified times post-detonation.

As mentioned above and indicated in Figure 2, FIIDOS calculates factors that are used to convert the radiation intensity into an airborne or surface activity concentration and factors that are used to determine the activity of specific radionuclides in the ingested or inhaled radioactive material. Figure 3 illustrates the approach used in FIIDOS to calculate these factors.

As seen in Figure 3, the calculation of the factor used to convert radiation intensity to an airborne or surface activity concentration begins with the gamma-ray spectral data and the radionuclide inventory data for a reference amount (10^{14} fissions) of radioactive material as calculated by ORIGEN2-SAIC. In response to user-supplied information on the weapon, the fallout, and the radiological measurement, the spectral and inventory data are modified to reflect the gamma-ray emission rate (γ hr^{-1}) and the activity (Ci) of the reference amount of fallout material or nuclear debris at the time of the radiological measurement. Gamma-ray exposure factors are used to determine the radiation intensity (R hr^{-1}) of the material present as airborne or surface contamination. The ratio of the radiation intensity to activity gives the factor used by FIIDOS to convert the measured radiation intensity to a calculated airborne activity concentration (R hr^{-1} per Ci m^{-3}) or surface activity concentration (R hr^{-1} per Ci m^{-2}). The activity derived from these factors is adjusted within FIIDOS for the actual time of exposure (depicted in Figure 2). The material given above provides an overview of the calculation scheme used in FIIDOS. A complete description of the technical approach used in FIIDOS is provided in Section 2.

FIIDOS can handle two types of basic dose calculation problems: single (acute) exposures and long duration (chronic) exposures. A single exposure problem involves a single radiological measurement and a single radiation exposure. This is a basic dose calculation handled by FIIDOS. Multiple exposures tied to single or multiple measurements may be entered with an equal or greater number of exposure times. A maximum of 100 entries, comprised of any combination of measurement and exposure times, may be entered for a single program execution. A long duration exposure problem involves an exposure long enough that the debris inventory significantly changes, and thus the dose calculation requires time integration. As with single exposures, a long duration problem may include multiple measurements and an equal or greater number of exposures. A maximum of 33 measurement or exposure times is permitted for this type of problem.

Generally, the types of user-supplied input data required by FIIDOS are summarized in Table 1. The user input data are discussed in detail in subsequent sections of this report; Section 2 provides a technical discussion of the input data and Section 3 addresses the input data format requirements for the computer program.

RADIONUCLIDES

- ORIGEN2-SAIC - calculates decay inventory and spectra from 1600 isotopes of which the following subsets in FIIDOS.
  - Fission Products - 148 radionuclides from fast and 14-MeV neutron fission of U-235, U-238, and Pu-239.
  - Activation Products - 17 radionuclides.
  - Actinide Elements - 18 radionuclides.

RADIOLOGICAL MEASUREMENTS

- Gross Ingestion Activity Intake (Ci).
- Gross Inhalation Activity Intake (Ci).
- Specific Ingestion Activity of Single Isotope as Part of Decayed Inventory (Ci).
- Specific Inhalation Activity of Single Isotope as Part of Decayed Inventory (Ci).
- Gross Airborne Activity Concentration (Ci m^{-3}).
- Gross Surface Activity Concentration (Ci m^{-2}).
- Radiation Intensity Aloft Inside Debris Cloud (R hr^{-1}).
- Radiation Intensity at Surface Inside Debris Cloud (R hr^{-1}).
- Radiation Intensity Above Contaminated Surface (intensity: R hr^{-1}, tissue dose rate: rad hr^{-1}, and film badge dose rate: rem hr^{-1}).

ORGAN DOSES

- 50-Year Committed Equivalent Dose.
  - Ingestion or Inhalation (ICRP-72 data set).
  - Up to 40 organs or tissues; currently 23 organs (adrenals, bone surface, brain, breast, stomach wall, small intestine wall, upper large intestine wall, lower large intestine wall, kidneys, liver, extra-thoracic region, lung, muscle, ovaries, pancreas, red marrow, skin, spleen, testes, thymus, thyroid, uterus, urinary bladder wall) <u>plus</u> effective dose.
- Plutonium Excretion Functions for Urine (Jones, 1985)

Figure 1. Key features of computer code FIIDOS.

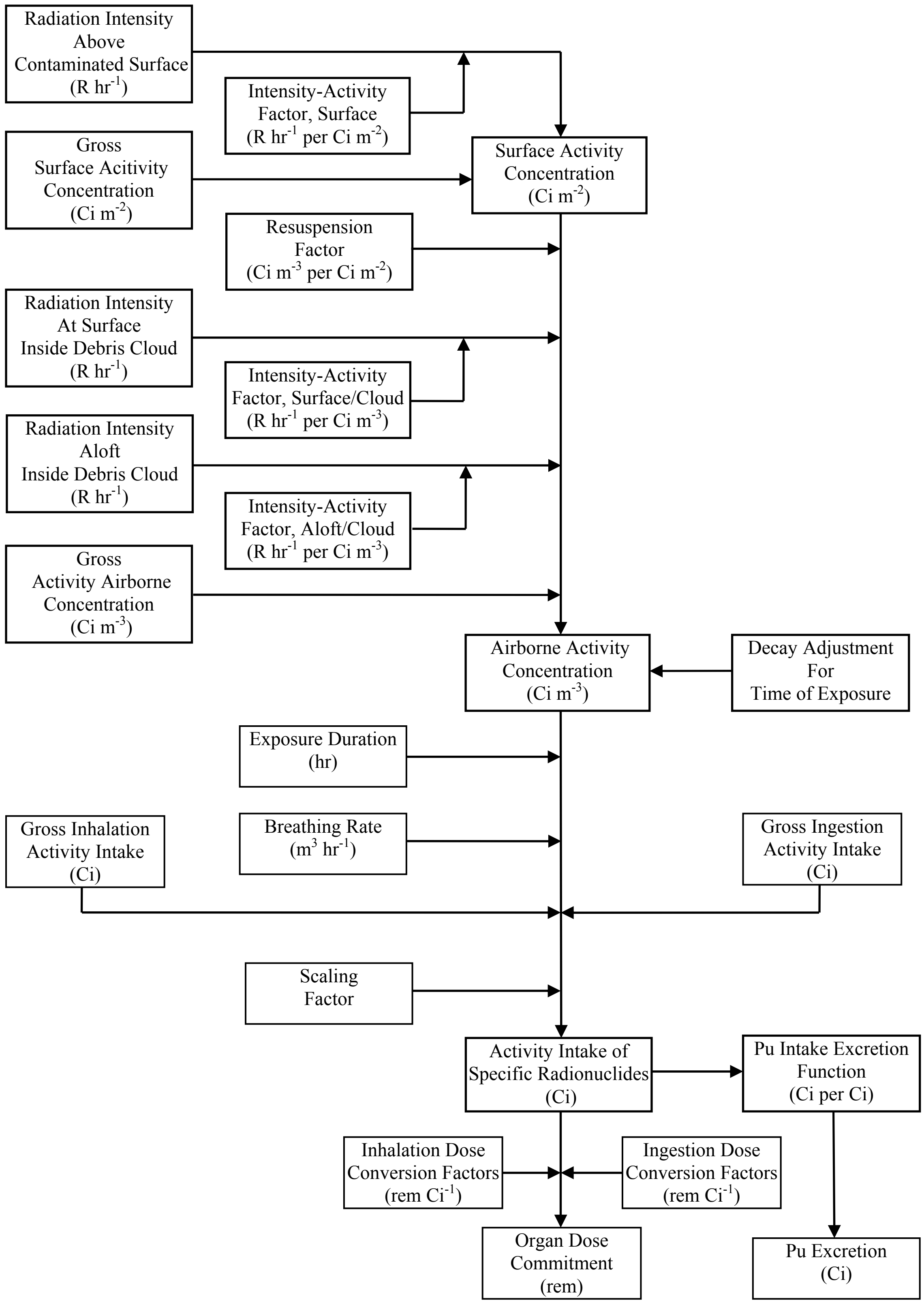


Figure 2. Schematic for calculation of organ dose.

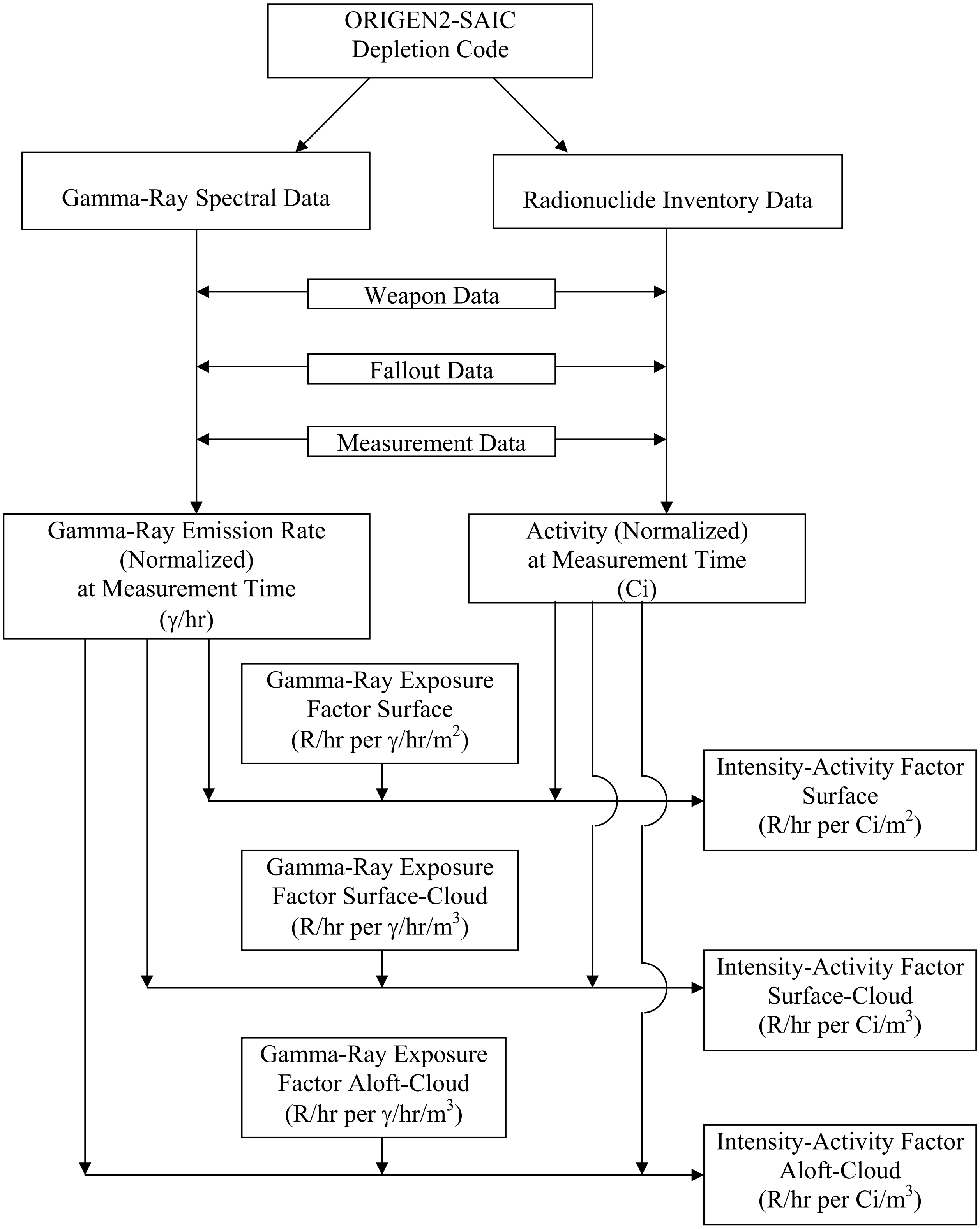


Figure 3. Schematic for calculation of intensity activity factors.

Table 1. User-supplied input for FIIDOS.

Problem Identification and Control Data

- Title of Problem
- Type of Problem
- Optional Output

Weapon Data

- Yield for Fissionable Material-Neutron Energy Sets
- Activation Product Production
- Actinide Element Production

Radiological Measurement Data

- Type of Measurement
- Time of Measurement
- Measured Value
- Type of Measurement Device
- Supplemental Measurement Data

Fallout Data

- Krypton-Xenon Removal
- Fractionated Fission Product Identification
- Fractionated Fission Product Factor
- Fractionated Fission Product Spectrum

Dose Calculation Data

- Number of Exposure Incidents
- Time of Exposure
- Duration of Exposure
- Breathing Rate
- Airborne Activity - Surface Activity Ratio
- Type of Dose Conversion Factor

FIIDOS provides standard output and user-selected optional output. The standard output occurs automatically and provides a listing of the user-supplied problem input data and the basic dose results of a FIIDOS calculation. Three optional output modes can provide supplemental information on the details of a FIIDOS calculation. Section 3 provides a detailed description of the FIIDOS output.

The computer program FIIDOS consists of a main program and 18 subroutines in addition to the ORIGEN2-SAIC code and its subroutines. A data library consists of 19 files (17 read by FIIDOS and 2 read by the ORIGEN2-SAIC code) to provide capability to calculate a wide variety of problems. FORTRAN listings of the main program and subroutines are provided in Appendix B.

FIIDOS calls the ORIGEN2-SAIC code, which is a slightly modified version of the ORIGEN2 code with inventory and spectra databases prepared by Science Applications International Corporation (SAIC). The fast fission inventories were supplied by England (1993a and 1993b) of LANL. SAIC corrected several inconsistencies and transcription errors in the gamma-ray production data (Roberts, 1996). The results have been benchmarked against measurements of gamma-ray spectra from fission products produced from fast neutrons for measurement times of seconds to days. Previously this kind of agreement had been difficult. The agreement is currently good to within a few percent. The fission product inventories from 14 MeV neutrons were also supplied by England.

Sample problems that illustrate the use of FIIDOS are given in Appendix C. They show FIIDOS's capability to use different types of radiological measurements for calculating doses to internal organs.

SECTION 2

TECHNICAL APPROACH

2.1 INTRODUCTION

The computer code FIIDOS calculates committed equivalent doses to various body organs that would result from the ingestion or inhalation of radioactive material produced by a nuclear detonation. These organ dose calculations are based on the amount of radioactive material ingested or inhaled, the radionuclide composition of the material, and organ dose conversion factors for each radionuclide.

A variety of options is available within FIIDOS either to specify or to calculate the amount of radioactive material taken into the body. When the mode of intake is ingestion, the amount of material must be specified as input to FIIDOS. When the mode of intake is inhalation, the amount of material may be specified as input to FIIDOS or may be determined by FIIDOS for selected exposure situations. These situations include exposure inside a nuclear debris cloud and exposure above a contaminated surface. For either situation, the level of contamination may be specified in terms of activity concentration or radiation intensity. The time at which the level of contamination is specified may precede, follow, or be coincident with the time at which the inhalation exposure occurs.

The radionuclide composition of the radioactive material is determined within FIIDOS by calling the ORIGEN2-SAIC code. It handles the production and decay of fission products, activation products, and actinides; it is time-dependent because of differential decay of the isotopic mix. FIIDOS uses data files with the fission product inventories for the fissioning of U-235, U-238, and Pu-239 by fast and 14-MeV neutrons; these files are read by ORIGEN2-SAIC. Provisions to modify the radionuclide composition to remove gaseous fission products and to reflect fission product fractionation effects are included in FIIDOS to be consistent with the original version. However, the ORIGEN2-SAIC code in FIIDOS could be used to allow additional fractionation by modifying the inventory at each time step of the calculations. This modification, if adopted, would allow for continuous fractionation adjustments. This is currently not done in FIIDOS because of the large uncertainties in the required input parameters and a systematic analysis of the impacts has not been performed. A fractionation report (Trabalka and Kocher, 2007) provides some bounding of the issue, but that is currently under peer review and an assessment of impact is needed before any implementation or adjustments to current procedures.

The current version represents a reconfiguration of the code to include only one set of dose coefficients (e.g., from ICRP-72) for inhalation and one set for ingestion and has the capacity to work with up to 40 organs to provide for future expansion. For current use in the NTPR Program FIIDOS uses two sets of dose conversion factors (also called dose coefficients) to produce 50-year tissue or organ dose commitments from the ingestion and inhalation pathways. Conversion factors are tabulated for individual organs and effective dose for up to 148 fission products, 17 activation products, and 18 actinides. Organ dose conversion factors are available from ICRP-72 (currently 23 organs plus effective dose).

Previous releases of FIIDOS included up to 11 sets of internal dose conversion factors as user-selectable options. ORNL TM-190 contained factors for 148 fission product isotopes and ICRP-30 contained factors for 104 and 42 isotopes for small and large particles, respectively. A third optional set of internal dose conversion factors provided an expanded inventory of 412 nuclides that was also based upon methods and models of ICRP Publication 30.

A urinary excretion function calculation for Pu-239 is included as an option in FIIDOS. With this option, the activity of Pu-239 that is inhaled or ingested serves as input to an exponential excretion function (Jones, 1985) to predict the activity that is expected in 24-hour urine samples at specified times post-detonation. Where $F(t)$ is the unitless fraction of initial uptake (e.g., to the bloodstream) found in 24-hour urine at time t (days) after uptake, the function is expressed as:

$$F(t) = 4.75 \times 10^{-3} (e^{-(0.558\,t)}) + 2.39 \times 10^{-4} (e^{-(.0442\,t)}) + 8.55 \times 10^{-5} (e^{-(0.0038\,t)}) + 1.42 \times 10^{-5} (e^{-(0.0000284\,t)}). \quad (2.1)$$

For intake I (Ci), the fraction of I that is absorbed into the bloodstream from the small intestine is given by an uptake fraction, $f1$, which is specific to the mode of intake. The following $f1$ values from ICRP-30 are used:

for ingestion of Pu,

$$f1 = 1 \times 10^{-5},$$

and for inhalation of Pu,

$$f1 = 5 \times 10^{-2}.$$

Then, the 24-hr urine activity $U(t)$ (Ci) is given by:

$$U(t) = F(t) \times I \times f1. \quad (2.2)$$

Additional details concerning the technical approach adopted for FIIDOS are described in the following material. Section 2.2 presents the basic equations and parameters used for organ dose calculations and the specific procedures used in FIIDOS to determine the values of the parameters in the dose equations. A discussion of the limitations of the methodology and data used in FIIDOS is given in Section 2.3.

2.2 EQUATIONS AND PARAMETERS

The equation for determining the committed equivalent dose to organ *j* resulting from the intake of radionuclide *i* is:

$$D_{i,j} = A \times P_i \times DCF_{i,} \text{ x}10^6 \qquad (2.3)$$

Where:

$D_{i,j}$ = committed equivalent dose (rem) to organ *j* due to intake of radionuclide *i*,

A = gross activity (Ci) of the radioactive material taken into the body by ingestion or inhalation,

P_i = activity fraction of radionuclide *i* in the material (Ci per Ci), and

$DCF_{i,j}$ = 50-year organ dose conversion factor (rem μCi^{-1}) for the dose to organ *j* resulting from the intake of radionuclide *i* by ingestion or inhalation.

As mentioned in Section 2.1, a variety of options can be used to specify or determine the amount of radioactive material taken into the body. These options include:

- gross ingestion activity intake - A_{ing} (Ci),
- gross inhalation activity intake - A_{inh} (Ci),
- gross airborne activity concentration - AC (Ci m^{-3}),
- gross surface activity concentration - SC (Ci m^{-2}),
- radiation intensity aloft inside debris cloud - I_{ca} (R hr^{-1}),
- radiation intensity at surface inside debris cloud - I_{cs} (R hr^{-1}), and
- radiation intensity above contaminated surface - I_s (R hr^{-1}).

It should be noted that for the first option, A_{ing}, the mode of intake is ingestion; for the other options, the mode of intake is inhalation.

For those options in which the level of contamination is specified in terms of activity (Ci) or activity concentration (Ci m^{-3} or Ci m^{-2}), the amount of radioactive material taken into the body, A (Ci), is given by one of the following equations:

$$A = A_{ing} \tag{2.4}$$

$$A = A_{inh} \tag{2.5}$$

$$A = AC \times BR \times T \text{ or} \tag{2.6}$$

$$A = SC \times K \times BR \times T \tag{2.7}$$

Where:

BR = breathing rate ($m^3\ hr^{-1}$),

T = duration of exposure (hr), and

K = resuspension factor (Ci m^{-3} per Ci m^{-2}, or m^{-1}).

For those options in which the level of contamination is specified in terms of radiation intensity (R hr^{-1}), the amount of radioactive material taken into the body, A (Ci), is given by one of the following equations:

$$A = [I_{ca} \times (\textstyle\sum_E S \times \psi_{ca})^{-1}] \times BR \times T \tag{2.8}$$

$$A = [I_{cs} \times (\textstyle\sum_E S \times \psi_{cs})^{-1}] \times BR \times T, \text{ or} \tag{2.9}$$

$$A = [I_s \times (\textstyle\sum_E S \times \psi_s)^{-1}] \times BR \times T \tag{2.10}$$

Where:

S = emission rate of gamma rays of energy E from the radioactive material ($\gamma\ hr^{-1}$ per Ci),

ψ_{ca} = energy dependent factor relating radiation intensity aloft inside debris cloud to gamma ray emission rate density (R hr^{-1} per $\gamma\ hr^{-1}m^{-3}$),

ψ_{cs} = energy dependent factor relating radiation intensity at surface inside debris cloud to gamma ray emission rate density (R hr^{-1} per $\gamma\ hr^{-1}m^{-3}$), and

ψ_s = energy dependent factor relating radiation intensity above contaminated surface to gamma ray emission rate surface density (R hr^{-1} per $\gamma\ hr^{-1}m^{-2}$).

The bracketed expression in Equations 2.8 and 2.9 provide the basis for translating radiation intensity (R hr^{-1}) into an equivalent gross airborne activity concentration

(Ci m^{-3}); similarly, the bracketed expression in Equation 2.10 yields an equivalent gross surface activity concentration (Ci m^{-2}).

These equations can be used to calculate the committed organ dose resulting from the ingestion or inhalation of a specific radionuclide. However, a set of equations that is more closely related to the type of input data available to FIIDOS will be developed by replacing the activity fraction parameter (i.e., P_i in Equation 2.3) and the gamma-ray emission rate parameter (i.e., S in Equations 2.8, 2.9, and 2.10) with more basic parameters.

As previously discussed, FIIDOS uses radionuclide inventory data and gamma-ray spectral data calculated by the computer code ORIGEN2-SAIC. The basis for these ORIGEN2-SAIC calculations is the number of fissions specified to have occurred in a fuel material (e.g., U-235). The radionuclide inventory data and the gamma-ray spectral data calculated for FIIDOS are based on 10^{14} fissions in a fuel material with the corresponding normalized activities of actinides and activation products. This fission input value for the ORIGEN2-SAIC calculations is somewhat arbitrary, but was selected to avoid computer arithmetic limits that could occur if very low values or very high values had been used. Accordingly, the parameters taken directly from the ORIGEN2-SAIC run are:

A_i = activity of radionuclide *i* resulting from 10^{14} fissions (Ci per 10^{14} fissions),

A_T = total activity resulting from 10^{14} fissions (Ci per 10^{14} fissions), and

S_T = rate of emission of gamma rays of energy E from the radioactive material produced by 10^{14} fissions (γ hr^{-1} per 10^{14} fissions).

The relationships between the above parameters and the parameters P_i and S are:

$$P_i = A_i \times (A_T)^{-1} \text{ and} \tag{2.11}$$

$$S = S_T \times (A_T)^{-1} \tag{2.12}$$

A set of dose calculation equations, with each equation applicable to a specific material intake option, is constructed by successively substituting Equations 2.4 through 2.10 into Equation 2.3 and using Equations 2.11 and 2.12 to eliminate the parameters P_i and S. The resulting equations are:

$$D_{i,j} = DCF_{i,j} \times A_i \times A_{ing} \times (A_T)^{-1} \times 10^6 \tag{2.13}$$

$$D_{i,j} = T \times BR \times DCF_{i,j} \times A_i \times AC \times (A_T)^{-1} \times 10^6 \tag{2.15}$$

$$D_{i,j} = T \times BR \times K \times DCF_{i,j} \times A_i \times SC \times (A_T)^{-1} \times 10^6 \tag{2.16}$$

$$D_{i,j} = T \times BR \times DCF_{i,j} \times A_i \times I_{ca} \times (\sum_E S_T \times \psi_{ca})^{-1} \times 10^6 \tag{2.17}$$

$$D_{i,j} = T \times BR \times DCF_{i,j} \times A_i \times I_{cs} \times (\sum_E S_T \times \psi_{cs})^{-1} \times 10^6 \tag{2.18}$$

$$D_{i,j} = T \times BR \times K \times DCF_{i,j} \times A_i \times I_s \times (\sum_E S_T \times \psi_s)^{-1} \times 10^6 \tag{2.19}$$

The structure of the above set of equations suggests that a general dose calculation equation be defined as:

$$D_{i,j} = T \times BR \times K \times DCF_{i,j} \times A_i \times SF \times 10^6 \tag{2.20}$$

Where:

T, BR, and *K* are set equal to dimensionless unity if the gross ingestion intake (*AC* in Equation 2.13), or the gross inhalation intake (A_{inh} in Equation 2.14) is specified, *K* is set equal to dimensionless unity if the gross airborne activity concentration (*AC* in Equation 2.15), the radiation intensity aloft inside a debris cloud (I_{ca} in Equation 2.17), or the radiation intensity at the surface inside a debris cloud (I_{cs} in Equation 2.18) is specified, and *SF* is given by one of the following equations:

$$SF = A_{ing} \times (A_T)^{-1} \tag{2.21}$$

$$SF = A_{inh} \times (A_T)^{-1} \tag{2.22}$$

$$SF = AC \times (A_T)^{-1} \tag{2.23}$$

$$SF = SC \times (A_T)^{-1} \tag{2.24}$$

$$SF = I_{ca} \times (\sum_E S_T \times \psi_{ca})^{-1} \tag{2.25}$$

$$SF = I_{cs} \times (\sum_E S_T \times \psi_{cs})^{-1} \tag{2.26}$$

$$SF = I_s \times (\sum_E S_T \times \psi_s)^{-1} \tag{2.27}$$

Note that in Equation 2.20 the committed equivalent dose is calculated with the restriction that all parameters remain constant during the period of exposure. If the conditions of exposure change or there is significant decay, the period of exposure should be subdivided into smaller intervals. Apply Equation 2.20 successively to each interval with the results summed to give the committed equivalent dose for the total period. The long duration option available in FIIDOS should be utilized for this type of "time-dependent" dose calculation.

The following sections provide descriptions of the six parameters in Equation 2.20. Three of the parameters (i.e., *T, BR,* and *K*) are user-supplied input to FIIDOS; guidance is provided regarding the selection of values for the parameters. The parameter $DCF_{i,j}$ is contained within FIIDOS as sets of ingestion and inhalation dose conversion factors; the basis for these factors is discussed. The parameters A_i and *SF* are calculated within FIIDOS; the procedures used to calculate these parameters and the required user-input for the calculations are discussed.

2.2.1 Duration of Exposure

The duration of exposure *T* (hr), is the amount of time the individual is exposed to the inhalation source. If the gross ingestion or inhalation activity intake is specified, the parameter *T* should be set to one (1.0). The duration of exposure is a user-supplied input to FIIDOS.

2.2.2 Breathing Rate

The breathing rate, *BR* (m^3 hr^{-1}), is a user-supplied input. If the gross ingestion or inhalation activity intake is specified, the parameter *BR* should be set to one (1.0). Since the breathing rate is dependent upon the physical activity of the individual during his exposure, the following material assists the FIIDOS user in selecting the appropriate breathing rate.

The breathing rate for a typical adult male is specified in ICRP (1975) Publication 23 and NCRP (1997) Report No. 125 as 1.2 m^3 hr^{-1} for light activity. According to Bates (1966), this value is the approximate breathing rate during walking on a flat surface at a speed of about three miles per hour.

Higher breathing rates would result from more physically demanding activities. Based on the material according to Bates (1966) and ICRP (1975) Publication 23, and NCRP (1997) Report No. 125, breathing rates of 1.5 m^3 hr^{-1} for moderate activity and 2.0 m^3 hr^{-1} for heavy activity appear reasonable. Correspondingly, lower breathing rates would result from less physically demanding activities. The breathing rate cited in ICRP (1975) Publication 23 for resting is 0.45 m^3 hr^{-1}. That cited in NCRP (1997) Report No. 125 for low activity is 0.6 m^3 hr^{-1}, where low activity is defined as approximately 30 percent above basal with respect to minute volume.

2.2.3 Airborne Activity-Surface Activity Ratio

The parameter K (m^{-1}) is the ratio of the airborne activity (Ci m^{-3}) to the surface activity (Ci m^{-2}). This parameter is needed for a dose calculation if information on the airborne contamination is not directly available but rather must be inferred from information on the surface contamination. For example, a post-shot radiation survey of an area contaminated with fallout that measures the radiation intensity (R hr^{-1}) of the deposited fallout provides information on the surface contamination, not airborne contamination.

The airborne activity-surface activity ratio used in the dose calculation equation should be the ratio that is appropriate for the time at which the inhalation exposure occurred. If the duration of the exposure is long, it may be necessary to subdivide the period of exposure into smaller intervals and use different values of the ratio for each interval. Such a situation could occur if the phenomena or mechanisms that relate airborne activity and surface activity change during the exposure period.

In the FIIDOS methodology, the parameter K is a user-supplied input and no default values are provided. The following material introduces approaches that can be used to develop estimates of the airborne activity-surface activity ratio. Section 2.2.3.1 addresses the relationship between airborne activity and surface activity that would occur during the passage of a fallout-depositing, aerosol cloud. Section 2.2.3.2 addresses the relationship between the airborne activity and surface activity that would occur due to the resuspension of previously deposited material by natural or other sources.

2.2.3.1 Deposition from Aerosol Cloud

An aerosol cloud with an airborne activity concentration AC (Ci m^{-3}) deposits fallout material during its passage. The surface activity concentration, SC (Ci m^{-2}), produced by the passing cloud is:

$$SC = \int_t AC \times V \times \mathrm{dt} \qquad (2.28)$$

Where

V (m sec^{-1}) = the rate at which material falls from the cloud.

Assuming that AC and V are independent of time, the surface activity concentration resulting from the cloud for a deposition period of T (sec) is:

$$SC = AC \times V \times T \qquad (2.29)$$

Thus, the ratio of the airborne activity to the surface activity, K (m^{-1}), is:

$$K = (V \times T)^{-1} \qquad (2.30)$$

In the above equation, the fall velocity V (m sec^{-1}) is a single-valued parameter. V could be either a nominal value or an average value. An average value could be calculated if information on the distribution of activity as a function of particle size were available. Where particle size data are unavailable, V can be obtained from the nuclear cloud stabilization height and time after burst.

As an illustration, consider an exposure scenario involving a high-yield nuclear detonation. The time-period during which fallout deposition occurred at the location of interest was 10 hours. The fallout particles had a measured diameter of 60 μm and a density of 2 g cm^{-3}, giving a fall velocity of 0.2 m sec^{-1}. For these values of V and T, the value of K is 1.4×10^{-4} m^{-1}.

2.2.3.2 Resuspension of Deposited Material

Resuspension refers to a process in which previously deposited radioactive particles are removed from the surface to form an airborne aerosol. In literature on resuspension, the ratio of the airborne activity (Ci m^{-3}) to the surface activity (Ci m^{-2}) is characterized by a resuspension factor (m^{-1}). The resuspension factor is a form of the parameter K used in the FIIDOS methodology when the exposure scenario involves resuspension.

The concept of a resuspension factor is best suited to situations having spatial independence in both airborne activity and surface activity. Nevertheless, resuspension factors have been reported for many situations involving disturbances to the surface of limited area extent. A good introduction to resuspension factors is provided in the Reactor Safety Study (USNRC, 1975). Table 2 shows the results of the literature survey cited in the study and lists the references.

Resuspension is a rather complicated process, and the principles governing the process are not well understood. However, resuspension factors have been determined experimentally for several conditions. These results show that the resuspension factor depends on the activity causing resuspension, the characteristics of the surface, and the characteristics of the deposited particles. In addition, the resuspension factor is time-dependent, is affected by the wind velocity, and is dependent upon the height above the surface. Unfortunately, the data on resuspension processes are not adequate to permit the development of a general model of resuspension that incorporates all observed effects.

Natural resuspension refers to the wind-driven resuspension that occurs in the absence of any extraordinary activity that could cause resuspension. Models of natural resuspension are based on the resuspension of nuclear detonation fallout or dispersed plutonium in desert environments, because most of the available resuspension data have been taken from such situations. Since the resuspension factor decreases with time, the natural resuspension value includes a time dependent resuspension factor.

For natural resuspension, the Reactor Safety Study proposed a time dependent resuspension factor of the following form:

$$K(t) = K_0 \times e^{-(\lambda t)} + K_e \qquad (2.31)$$

The initial resuspension factor (K_0) is given a value of 10^{-5} m^{-1}; this value is termed a "reasonable estimate" and generally corresponds to the values cited for natural, wind-driven resuspension factors. The equilibrium resuspension factor (K_e) is given a value of 10^{-9} m^{-1}; this value is based on measurements of the resuspension factor in aged (~17 years) fallout fields and contaminated areas. The decay constant (λ) is given a value of 0.677 y^{-1}; which reflects a half-life ($T_{1/2}$= (ln 2) × λ^{-1}) of 0.977 yr; this half-life is based on assuming that the resuspension factor decreases exponentially from 10^{-5} m^{-1} to 10^{-9} m^{-1} in 17 years.

The Reactor Safety Study resuspension factor model is "calibrated" to the long-term behavior of the resuspension factor and might not correctly portray the short-term behavior. A model which is "calibrated" to both the short-and long-term behavior of the resuspension factor was suggested by Anspaugh (1975). This model has the following form:

$$K(t) = K_0 \times e^{-(\lambda \times [SQRT\{t\}])} + K_e \qquad (2.32)$$

In this model, the initial resuspension factor (K_0) is given a value of 10^{-4} m^{-1}; this value has been termed “conservative”, and appears to encompass both natural resuspension and artificial or man-made resuspension. As with the Reactor Safety Study model, the equilibrium resuspension factor (K_e) is given a value of 10^{-9} m^{-1}. The decay constant (λ) is given a value of 0.15 in units of $days^{-1/2}$. This value, along with the exp ($-\lambda \times t^{1/2}$) expression, is intended to cause the resuspension factor to exhibit: a half-life of 5 weeks during the first 10 weeks after the initial deposition, a half-life of about 10 weeks during the next 30 weeks, and an equilibrium value after 17 years.

A comparison of the Anspaugh and the Reactor Safety Study resuspension models is given in Figure 4. The initial order-of-magnitude difference between the two resuspension factor expressions disappears rapidly and the difference between the two factors is at most a factor of two after one year.

Wind speed also affects the resuspension factor. The effect of the wind speed is strongly dependent upon the characteristics of the deposited particles and the surface material. In addition, as time passes and the deposited particles become more intimately mixed with the surface material, the effect of the wind speed is likely to be lessened. Because of these complications, various wind speed relationships are reported in the resuspension factor literature; for example, Stewart (1964) reports cases where no relationship between airborne concentration and wind speed was observed and cases where the value of the resuspension factor varied approximately as the wind speed cubed.

Table 2. Resuspension factors reported in reactor safety study.

Arid/Desert

4×10^{-7}	near road graded in fallout field [a]	
3×10^{-5}	in Land Rover during travel to work site and outside during work; fission products (5-18 hr)[a]	
3 to 10×10^{-4}	downwind of crater [a]	for UO_2
1×10^{-3}	mechanical disturbances [a]	for UO_2
5×10^{-4}	dust from vehicles	for PuO_2
10^{-4} to 10^{-6}	dust from pedestrians [a]	for PuO_2
3×10^{-7}	particles of 7 μm MMD on 6-m circles (sandy) furrowed and rocky with sand base (dry) [b]	
1×10^{-7} to 3×10^{-7}	(wet) [b]	
1.2×10^{-7}	in 1000 μg/m^2 isopleth	PuO_2 Safety Test [c]
1.4×10^{-7}	in 100 μg/m^2 isopleth	PuO_2 Safety Test [c]
1.6×10^{-6}	in 10 μg/m^2 isopleth	PuO_2 Safety Test [c]
~35 day half-time	air concentration decay 1 to 3 μm median aerosol size	
38 day half-time	for resuspension of fission products of Schooner [d]	
76 day half-time	for resuspension of fission products from Baneberry [d]	
3×10^{-10}	for 8- to 10- year Pu aged deposit [e]	
2×10^{-9}	for direction of strongest wind [e]	

Semiarid/Grassland

5×10^{-6}	(ZnS) walking and loading boxes [f]	
1×10^{-5}	($\pm .5 \times 10^{-5}$)limestone, rock, sand, grass, bushes; fission products [a]	
.8 to 2×10^{-7}	crater of tower shot; fission products; road graded from soil disturbance [a]	
2×10^{-5} to 4×10^{-6}	in vehicle on road graded through fallout [a]	
8×10^{-6}	0 to 4 μm U_3O_8	undisturbed sandy soil with desert grasses [a]
5×10^{-7}	0 to 12 μm U_3O_8	undisturbed sandy soil with desert grasses [a]
8×10^{-9} to 10^{-11}	Y-91 aqueous solution on sandy soil-rain weathering small plot [a]	
1×10^{-7}	for particles of 7 μm MMD on 6-m circles, grass plot (dry) [b]	
4×10^{-8}	for particles of 7 μm MMD on 6-m circles, grass plot protected by snow fence (dry) [b]	
2×10^{-7}	both cases, above, wet [b]	

Urban/Suburban

2.5×10^{-6}	sandblasting for I-131 removal [g]
2×10^{-6}	0 to 4 μm U_3O_8 particles on concrete slabs [a]
1.5×10^{-7}	0 to 12 μm U_3O_8 particles on concrete [a]
10^{-4} to 10^{-2}	fraction resuspended per pass through particles[h]
2×10^{-2} to 2×10^{-4}	initially very rapid half-time of a few days
~2×10^{-5} to 2×10^{-3}	at 4 days

Interiors

1×10^{-5}	heavy work [i] ZnS (3.1 μm)
7×10^{-4}	light work [i] CuO (2 μm)
2×10^{-3}	operations [j]
.4 to 7×10^{-3}	clothes change and other activity [k]
1.2×10^{-4}	people walking in change room [k]
5×10^{-5}	PuO_2, many steps [l]
3×10^{-6}	$PuNO_3$, many steps [l]
2×10^{-4} to 4×10^{-5}	in enclosed space I-131 in brick dust [a,g]

Table 2. Resuspension factors reported in reactor safety study (Concluded)

(a) Stewart, K. 1964. "The Resuspension of Particulate Material from Surfaces." in Proc. Symp. Surface Contamination, Gatlinburg, Tenn. 1964. Oxford, U.K.: Pergamon Press.

(b) Healy, J. W., Fuguoy, J. J. 1959. "Wind Pickup of Radioactivity Particles from the Ground." Progress in Nuclear Energy, Series 12, Vol. 1, pp. 427-436.

(c) Wilson, R. H., Thomas, R. G., Stannard, J. N. 1960. Biomedical and Aerosol Studies Associated with a Field Release of Plutonium. Sandia Corporation. Report WT-1511.

(d) Anspaugh, L. R., Phelps, P. L., Kennedy, N. C., Booth, H. G. 1973. "Wind Driven Redistribution of Surface-Deposited Radioactivity" in Proc. IAEA Symp. Environmental Behavior of Radionuclides Released In the Nuclear Industry, Aix-en-Provence, May 14-18, 1973.

(e) Anspaugh, L. R. 1973. "Relationship Between Resuspended Plutonium in Air and Soil." U.S. Department of Energy, Nevada Operations Office. NVO-140.

(f) Schwendiman, L. C. 1958. "Probability of Human Contact and Inhalation of Particles." Health Physics, 1, 352-355.

(g) Chamberlain, A. C., Chadwick, R. C. 1965. "Transport of Iodine from Atmosphere to Ground." Harwell, Berkshire: United Kingdom Atomic Energy Authority Report AERE-R 4870.

(h) Anspaugh, L. R., Shinn, J. H., Wilson, D. W. 1974. "Evaluation of the Resuspension Pathway Towards Protective Guidelines for Soil Contamination with Radioactivity," in Proc. IAEA/WHO Symp. on Radiological Safety Evaluation of Population Doses and Application of Radiological Safety Standards to Man and the Environment, Portoroz, Yugoslavia, May 20-24, 1974.

(i) Fish, B. R., et al. 1965. "Redispersion of Settled Particulates." Oak Ridge, TN: Oak Ridge National Laboratory. Report ORNL-TM-1049.

(j) Bailey, J. C., Rohr, R. C. 1953. "Air-Borne Contamination Resulting from Transferable Contamination on Surfaces." Oak Ridge, TN: Union Carbide Nuclear Company, Oak Gaseous Diffusion Plant. Report K-1088.

(k) Brunskill. 1964. "The Relationship Between Surface and Airborne Contamination." in Proc. Symp. Surface Gatlinburg, Tenn. Oxford, U.K.: Pergamon Press.

(l) Jones, I. S., Pond, S. F. 1964. "Some Experiments to Determine the Resuspension Factor of Plutonium Various Surfaces." in Proc. Symp. Surface Contamination, Gatlinburg, Tenn. Oxford, U.K.: Pergamon Press.

Resuspension factor modeling by Anspaugh (1975) is most applicable to the resuspension of material in a desert environment. Based on soil erosion studies conducted at the Nevada Test Site, Anspaugh modeling suggests that the resuspension factor is proportional to the wind speed squared. The comparison between the model and experimental measurements showed good agreement.

The resuspension factor is also dependent on the height above the surface at which the air concentration is measured. However, this effect is likely to be dependent on the characteristics of the deposited particles and the surface material. Not surprisingly, various height effects are reported in the resuspension factor literature. Stewart (1964) observed that the resuspension factor decreased by a factor of three as the height was increased from 1 to 2 feet above the surface. However, Anspaugh's (1975) modeling indicates that the resuspension factor varies by only 20 percent over a height range of 0.5 to 2 meters. The existing models of natural resuspension are very simplistic. Estimated resuspension factors should be considered order-of-magnitude estimates. Rather than estimating specific resuspension factors, it might be more appropriate to provide an upper-bound estimate of a resuspension factor.

Man-made resuspension refers to the resuspension caused by human activity such as pedestrian and vehicular traffic. Some of the resuspension factor values cited in Table 2 reflect man-made resuspension. The values range from 10^{-4} m^{-1} to 10^{-6} m^{-1} for pedestrian-promoted resuspension, and from 2×10^{-5} m^{-1} to 4×10^{-6} m^{-1} for resuspension caused by vehicular traffic; however, because derivation of these data are taken from different experiments, direct comparisons should not be made.

No models of man-made resuspension are proposed. Estimates of resuspension factors should be based on the experimental data that most adequately characterize the situation of interest.

2.2.4 Dose Coefficients

The dose coefficients, $DCF_{i,j}$ (rem μCi^{-1}), used in the most recent version of FIIDOS provide 50-year equivalent dose commitments to organ *j* per unit intake of radionuclide *i* and are based on the concepts in ICRP-60 and the models described in ICRP Publications 66, 68, and 72. As discussed in Section 1.2.4, the ICRP-72 inhalation dose coefficients provide a maximum dose commitment for intakes of aerosols of 1-, 3-, 5-, or 10-micrometer AMAD. Figure 1 lists the 23 organs and tissues for which ICRP-72 dose coefficients are provided in FIIDOS. The ICRP-72 dose coefficients represent a significant departure from those based on ICRP-30 and earlier publications in several respects, as outlined below (Leggett, 2003).

Dosimetric Quantities

ICRP-60 introduces a new dosimetric quantity, the equivalent dose (H_T), which is the absorbed dose (energy absorbed per unit mass) averaged over a tissue or organ and weighted by the radiation quality that is of interest. The weighting factor is the radiation weighting factor (w_R) and is selected for the type and energy of the radiation incident on the body, or, in the case of sources within the body, emitted by the source. In ICRP-30, the weighting factor was applied to the absorbed dose at a point and called the quality factor (Q). The weighted absorbed dose was called the dose equivalent (H).

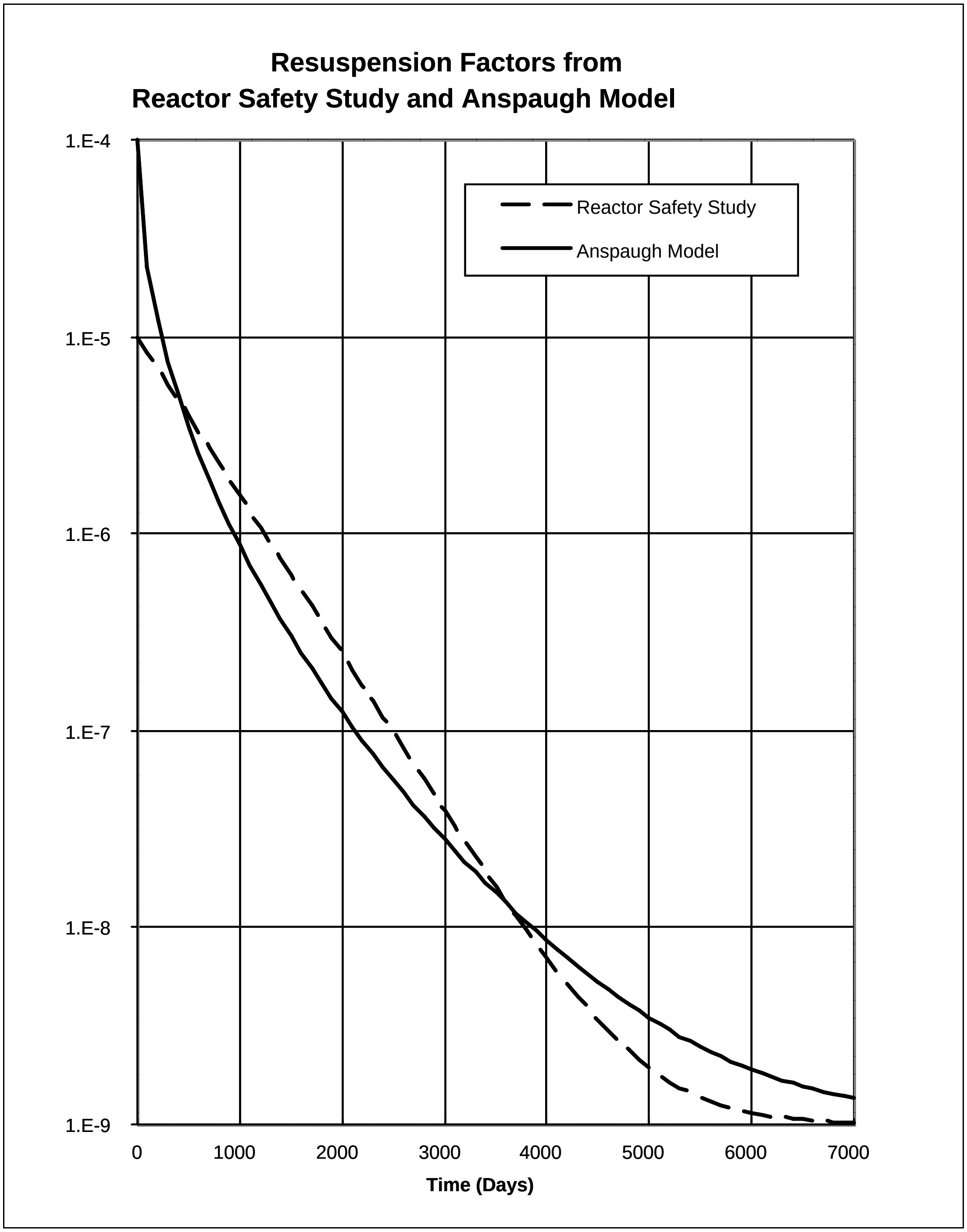


Figure 4. Comparison of time-dependent resuspension models.

Subsidiary dosimetric quantity: The committed equivalent dose, $H_T(\tau)$, is the time integral of the equivalent dose rate, where τ is the integration time in years following the intake. When *τ* is not specified, the implied value for adults is 50 years.

Under ICRP-60, the effective dose (*E*) is the equivalent dose weighted by the tissue weighting factor, which represents the relative contribution of that organ or tissue to the total detriment due to stochastic effects resulting from uniform irradiation of the whole body. The effective dose replaces effective dose equivalent in ICRP-26 and -30. ICRP-60 provides a modified and expanded set of tissue weighting factors as compared to ICRP-30. In most cases, effective dose conversion factors are relatively insensitive to changes in the tissue weighting factors.

Subsidiary dosimetric quantity: The committed effective dose, $E(\tau)$, is the time integral of the effective dose rate, where *τ* is the integration time in years following the intake. When *τ* is not specified, the implied value for adults is 50 years.

Respiratory Tract Model

The updated human respiratory tract model (ICRP-66) addresses age, gender, breathing rate, and other factors (particle sizes) in total and regional deposition of inhaled material in the respiratory tract. For a reference adult male, the ICRP-66 model predicts lower total deposition in the respiratory tract and lower deposition in the lower lungs than does the Task Group Lung Model (TGLM) used in ICRP-30 for most particle sizes.

The ICRP-66 model predicts much different rates of absorption from the respiratory tract to blood. The updated model addresses the heterogeneous distribution of radiosensitive cells within the respiratory tract. In contrast, the TGLM assumes that the total activity in the lungs is uniformly distributed in the total blood-filled lungs with a mass of 1000 g. The differences in the biokinetic and dosimetric properties of the updated ICRP-66 model and the TGLM lead to substantially different estimates of lung dose in many cases.

Gastrointestinal Absorption Fractions (f1)

For the reference, adult male, substantial changes in *f1* values have been made for some forms of cobalt, tellurium, lanthanides, and actinide elements, including uranium. Doses to systemic tissues change nearly in proportion to *f1* in most cases (except when doses to tissues result mainly from penetrating radiations originating in the intestinal contents). Some systemic models used in ICRP-68 feature feedback from systemic tissues back to gastrointestinal contents.

Systemic Biokinetic Models

The updated models provide age-specific biokinetics for 31 elements. The models for some elements are more detailed and physiologically realistic than the corresponding models in ICRP-30.

In ICRP-30, decay chain members produced in the body generally were assigned the biokinetic model of the parent radionuclide; this is referred to as "shared kinetics" of decay chains. The updated models retain "shared kinetics" for many decay chains. If the parent is an isotope of lead, radium, thorium, or uranium, then a radionuclide (other than a noble gas) formed either in soft tissue or on bone surfaces is assumed to have "independent kinetics," and a radionuclide formed in the bone volume is assigned the biokinetics of the parent.

Comparisons were made between maximum dose ICRP-72 inhalation DCFs with ICRP-30 based factors (1- and 20-micrometer AMAD aerosols) and ICRP-72 with ICRP-30 for ingestion (all in rem per curie intake) for a five organs of interest. A representative high-yield oceanic shot was selected (CASTLE BRAVO). Times after detonation range from H+1 to H+8760 hours. Comparisons are depicted in Figures 5 through 7.

The two sets of ingestion and inhalation dose conversion factors used in FIIDOS for current dose calculations are given in Appendix A, Tables A-1 and A-2.

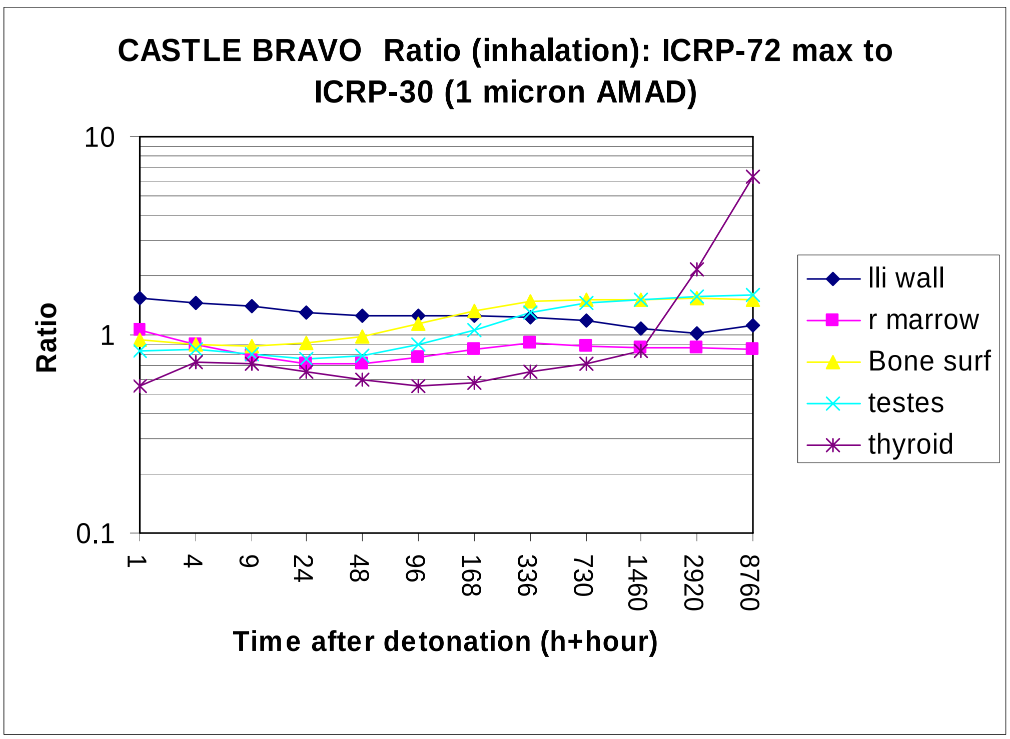


Figure 5. The ratio of the ICRP-72 maximum organ dose to the ICRP-30 organ dose from inhalation of 1-micrometer AMAD particles for selected organs.

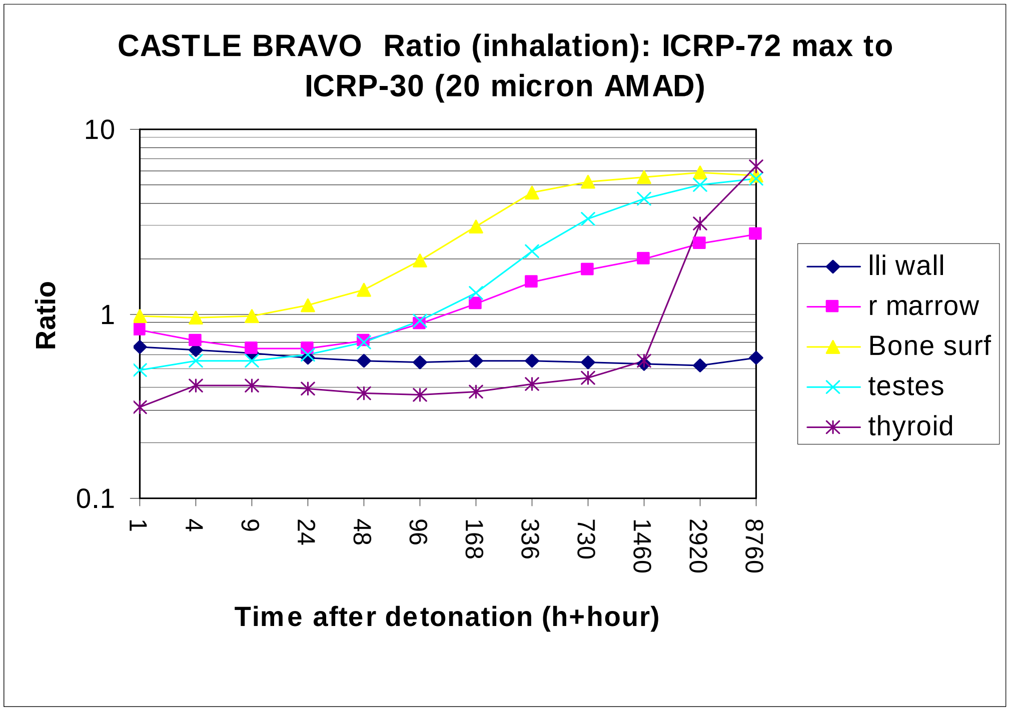


Figure 6. The ratio of the ICRP-72 maximum organ dose to the ICRP-30 organ dose from inhalation of 20-micrometer AMAD particles for selected organs.

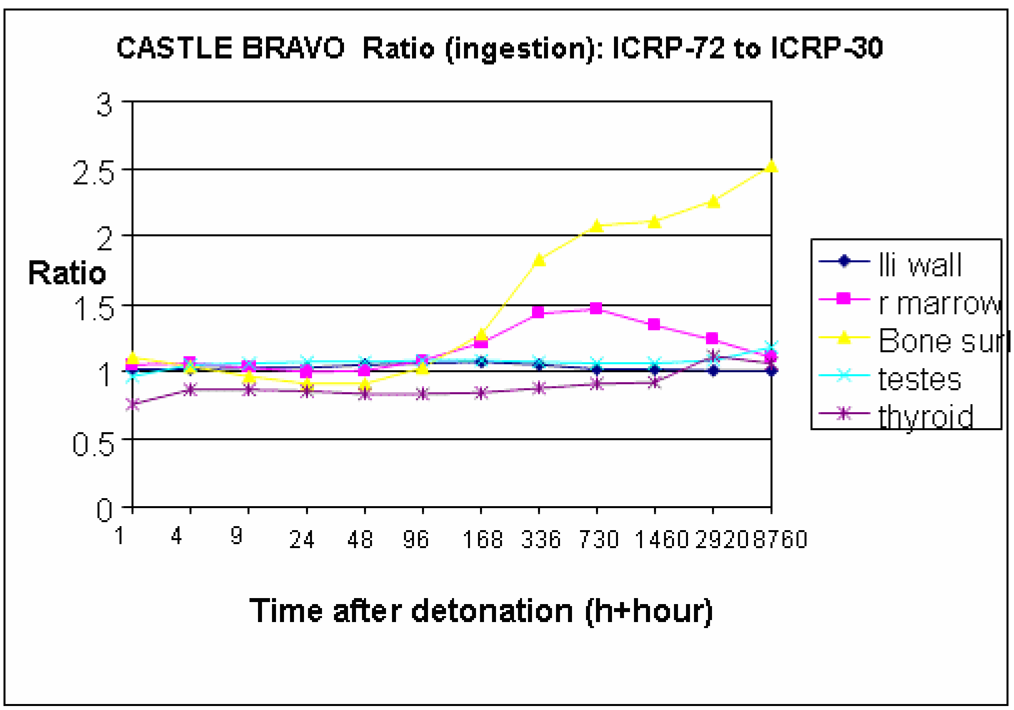


Figure 7. The ratio of the ICRP-72 maximum organ dose to the ICRP-30 organ dose from ingestion for selected organs.

Tables A-1 and A-2 provide the ingestion and inhalation dose conversion factors from ICRP-72 (ICRP, 1996) which are based on ICRP-60 and the lung and systemic biokinetic models based thereon (ICRP, 1991; 1994a; 1994b).

2.2.5 Relative Radionuclide Inventory

The relative radionuclide inventory is the amount of each radionuclide (Ci) present in a model sample of nuclear debris or fallout (based on 10^{14} fissions) at a specified time. This inventory includes fission products, activation products, and actinide elements. The inventory appears in the dose calculation equation, Equation 2.20, as the parameter A_i.

The relative radionuclide inventory is calculated in the ORIGEN2-SAIC code. The initial inventory is constructed based on user-supplied data on fission yield, activation product production, and actinide element production. After decay, the inventory can be modified by removing gaseous fission products and by adjusting specific radionuclide concentrations to reflect fission product fractionation effects. The techniques used to construct and to modify the relative radionuclide inventory are described below.

Fission Products

FIIDOS obtains a decayed fission product inventory by a mixing of initial fission products from U-235, U-238, and Pu-239 by fast or 14-MeV neutrons. The mixture of the initial six inventories is decayed by the isotope generation and depletion code ORIGEN2-SAIC. The inventories are based on 10^{14} fissions with an instantaneous (i.e., 1 msec) irradiation time to avoid computer underflow problems. This code is a slightly modified version of the ORIGEN2 code with modifications made by SAIC to use fission product data provided by England (1993a and 1993b), and ENDF/B-VI decay and gamma-ray spectral information. Information for actinides and activation products is provided as user input to the ORIGEN2-SAIC code. Nearly 1600 isotopes are calculated, i.e. 688, 129, and 781 activation products, actinides, and fission products, respectively. The decay of this mixed inventory is calculated through 40 standard decay times. These standard decay times range from 0.001 seconds to 317 years in three time steps per decade. The decay inventory and spectra at any specific time of interest are calculated by one additional decay from the nearest standard decay time. When the inventory output is requested the activity of 148 fission product radionuclides are listed (see Table 3). These radionuclides were determined to be the important fission product radionuclides in terms of dose to internal organs.

The user must provide the nuclear detonation yield. ORIGEN2-SAIC starts with an inventory produced by mixing the six fissionable material/neutron energy inventories. FIIDOS requires six yields in kilotons (kT) in order to combine the six fission product inventories as described above. The original version of FIIDOS had only one option; i.e. it required the user to give the yield for all six. This information may not be available, especially for the fission yields that were produced directly from 14-MeV neutrons.

Information about the fusion yield of the weapon is more likely to be available. Thus in FIIDOS2, FIIDOS3, and FIIDOS4, an additional option for specifying the total yields by fissile fuel isotope is provided. For this option, the total yield, each fissile isotope yield and the fusion yield are required. The six yield fractions are determined by solving a balance equation involving the amounts of energy released from fast fission, 14-MeV fission, and fusion. Information from calculations on a homogeneous sphere of fissile material is used to estimate some of the parameters in the balance equation to provide a reasonable approximation for dividing the fission yields between fast and 14-MeV types. The equations are encoded in the FISFRC.FOR subroutine and are too lengthy for inclusion here, but the results are illustrated in Figure 8. The main observation is that a small amount of fusion can produce a large increase in 14-MeV fission and this can result in an inventory change. An additional observation is that as the fusion fraction of the yield gets larger than 50%, a constant ratio between the fast and 14-MeV proportions develops, which is independent of the fusion fraction. These results are based on simplified balance equations and should be viewed as a non-rigorous method for determining the six fission yields. This option is recommended when detailed weapon yield information is not available.

FIIDOS determines the complete relative radionuclide inventory, which includes all fission product radionuclides present in nuclear debris or fallout at the exposure time and the measurement time.

Activation Products

ORIGEN2-SAIC calculates the decayed inventory for 17 activation products and their daughters (see Table 4). These radionuclides were selected because of their possible importance to internal organ doses. Data on the amount of each activation product radionuclide (Ci kT^{-1}) initially produced by the nuclear weapon are input by the user (from LLNL, ca. 1970). FIIDOS calculates the amount of each activation product radionuclide present at either the exposure time or the measurement time. The inventory is normalized to 10^{14} fissions to produce a relative radionuclide inventory of activation products.

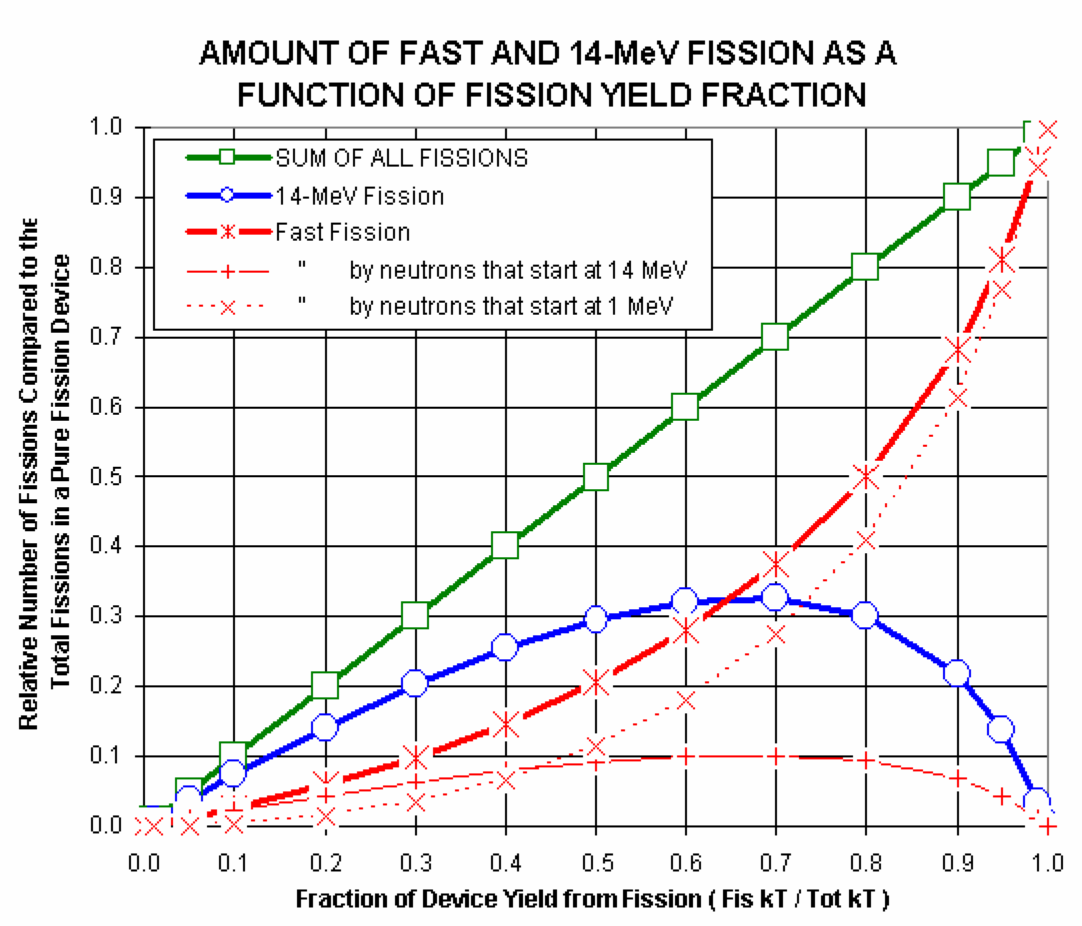


Figure 8. Fission fraction results from subroutine FISFRC.

Table 3. Fission product radionuclides and standard decay times* used in FIIDOS.

Se-79	Y-92	Mo-105	Sb-129	Cs-134m	Pr-144
Br-82	Sr-93	Tc-105	Te-l29	I-135	Pr-144m
Br-83	Y-93	Ru-105	Te-129m	Xe-135	Ce-145
Kr-83m	Zr-93	Rh-105	I-129	Xe-135m	Pr-145
Br-84	Nb-93m	Rh-105m	Sn-130	Cs-135	Ce-146
Br-85	Y-94	Ru-105	Sb-130m	Cs-136	Pr-146
Kr-85	Y-95	Rh-105	I-130	Xe-l37	Ce-147
Kr-85m	Zr-95	Pd-107	Sb-131	Cs-137	Pr-147
Rb-86	Nb-95	Rh-109	Te-l31	Ba-137m	Nd-147
Kr-87	Y-96	Pd-109	Te-131m	Xe-138	Pm-147
Rb-87	Zr-97	Ag-109m	I-131	Cs-138	Pr-148
Kr-88	Nb-97	Ag-110m	Xe-131m	Cs-139	Pm-148
Rb-88	Nb-97m	Ag-111	Sb-132	Ba-139	Pm-148m
Kr-89	Nb-98m	Cd-113m	Sb-132m	Cs-140	Pm-149
Rb-89	Mo-99	Cd-115m	Te-132	Ba-140	Pm-151
Sr-89	Tc-99	Sn-123	I-132	La-140	Sm-151
Rb-90	Tc-99m	Sb-124	Sb-133	Ba-141	Eu-152
Rb-90m	Mo-10l	Sn-125	Te-133	La-141	Sm-153
Sr-90	Tc-101	Sb-125	Te-133m	Ce-141	Eu-154
Y-90	Mo-102	Te-125m	I-133	Ba-142	Eu-155
Rb-91	Tc-102	Sn-126	Xe-133	La-142	Eu-156
Sr-91	Tc-103	Sb-126	Xe-133m	La-143	Tb-160
Y-91	Ru-103	Sb-127	Te-134	Ce-143	Ho-166m
Y-91m	Rh-103m	Te-127	I-134	Pr-143	
Sr-92	Tc-104	Te-127m	Cs-134	Ce-144	

Standard Decay Times (seconds)

0.001	0.00215	0.00464	0.01	0.0215	0.0464
0.1	0.215	0.464	1.	2.15	4.64
10	21.5	46.4	100.	215	464
1.00×10^3	2.15×10^3	4.64×10^3	1.00×10^4	2.15×10^4	4.64×10^4
1.00×10^5	2.15×10^5	4.64×10^5	1.00×10^6	2.15×10^6	4.64×10^6
1.00×10^7	2.15×10^7	4.64×10^7	1.00×10^8	2.15×10^8	4.64×10^8
1.00×10^9	2.15×10^9	4.64×10^9	1.00×10^{10}		

1 hour = 3600 sec   1 day = 86400 sec   1month = 2.59×10^6 sec   1 year = 3.15×10^7 sec

* The FIIDOS database uses these 40 specific decay times for calculation of radionuclide inventories and spectra. Values for other decay times are obtained by one additional decay calculation from the nearest time.

Actinides

ORIGEN2-SAIC calculates the decayed inventory for 18 actinide radionuclides (see Table 5). These radionuclides are produced in a nuclear detonation or are remnant from the nuclear device. Data on the amount of each actinide radionuclide (Ci per kT) immediately after detonation are input by the user from radio-chemistry data (LLNL, ca. 1970). FIIDOS calculates the amount of each actinide radionuclide present at the exposure time and the measurement time. The inventory is normalized to 10^{14} fissions to produce a relative radionuclide inventory of actinides.

Table 4. Activation product radionuclides.

Be- 7	Co- 58	W-187
Na-24	Co- 60	W-188
Mn-54	Cu- 64	Au-198
Fe-55	Cu- 67	Au-199
Fe-59	W-181	Pb-203
Co-57	W-185	

Table 5. Actinide product radionuclides.

Th-229	U-237	Pu-238
Th-230	U-238	Pu-239
Th-234	U-240	Pu-240
U-233	Np-237	Pu-241
U-234	Np-239	Am-241
U-235	Np-240	Cm-242

Table 6. Gaseous fission product radionuclides.

Kr-83 m	Kr -89	Xe-135 m
Kr-85	Xe-131 m	Xe-137
Kr-85 m	Xe-133	Xe-138
Kr-87	Xe-133 m	
Kr-88	Xe-135	

Inventory Modifications

The fallout field produced by a nuclear weapon does not contain some of the fission products, such as noble gases, and the relative abundance of a specific radionuclide in the fallout field is not necessarily the same as that calculated by basic fission product buildup and depletion codes. FIIDOS provides a simple capability for the user to modify the fission product inventory to reflect these observations.

One form of fission product inventory modification involves the removal of the radionuclides of the gaseous fission products krypton and xenon (see Table 6). If this option is selected, FIIDOS automatically modifies the relative radionuclide inventory to give zero amounts for the gaseous fission products. FIIDOS also maintains a record of the amount of each gaseous fission product radionuclide deleted from the inventory, in order to adjust the gamma-ray emission spectrum (discussed in Section 2.2.6.3).

The second form of fission product inventory modification involves the adjustment of specific radionuclide inventories to reflect the effects of fission product fractionation. To implement this inventory modification option, the user must input a specific fractionation factor and gamma-ray emission data for each radionuclide affected. In FIIDOS, this factor is used as a multiplier to increase or decrease the amount of the radionuclide in the relative radionuclide inventory. FIIDOS maintains a record of the amount of each radionuclide removed from the inventory, so that the gamma-ray emission spectrum can be adjusted.

2.2.6 Radiological Contamination Scaling Factor

The parameter SF in Equation 2.20 is the radiological contamination scaling factor. The scaling factor is not a user-supplied input to FIIDOS. The factor is calculated within FIIDOS, and the units depend on the specified input options.

For those options in which the level of contamination is specified in terms of activity (Ci) or activity concentration (Ci m^{-3} or Ci m^{-2}), the scaling factor is calculated by:

$$SF = A_{ing} \times (A_T)^{-1} \quad (2.33)$$

$$SF = A_{inh} \times (A_T)^{-1} \quad (2.34)$$

$$SF = AC \times (A_T)^{-1} \text{ or} \quad (2.35)$$

$$SF = SC \times (A_T)^{-1} \quad (2.36)$$

where:

A_{ing} = gross ingestion activity intake (Ci),

A_{inh} = gross inhalation activity intake (Ci),

AC = gross airborne activity concentration (Ci m^{-3}),

SC = gross surface activity concentration (Ci m^{-2}), and

A_T = total activity of relative radionuclide inventory (Ci per 10^{14} fissions).

The factor *SF* thus has units of 10^{14} fissions, 10^{14} fissions m^{-3} or 10^{14} fissions m^{-2}, depending on the option selected.

For those options in which the level of contamination is specified in terms of radiation intensity (R hr^{-1}), the scaling factor is calculated by:

$$SF = I_{ca} \times (\sum_E S_T \times \psi_{ca})^{-1} \quad (2.37)$$

$$SF = I_{cs} \times (\sum_E S_T \times \psi_{cs})^{-1} \quad (2.38)$$

$$SF = I_{s} \times (\sum_E S_T \times \psi_{s})^{-1} \quad (2.39)$$

where:

I_{ca} = radiation intensity aloft inside debris cloud (R hr^{-1}),

I_{cs} = radiation intensity at surface inside debris cloud (R hr^{-1}),

I_s = radiation intensity above contaminated surface (R hr^{-1}),

S_T = rate of emission of gamma rays of energy E from relative radionuclide inventory (γ hr^{-1} per 10^{14} fissions), and

ψ_{ca}, ψ_{cs}, ψ_s = energy-dependent factors relating radiation intensity to a unit gamma ray volume, or surface, emission rate (R hr^{-1} per γ hr^{-1} m^{-3} or R hr^{-1} per γ hr^{-1} m^{-2}), for the selected exposure situation.

The factor *SF* has units of (10^{14} fissions m^{-3}) or (10^{14} fissions m^{-2}), depending on the option selected.

The following sections discuss the quantities used in the calculation of the scaling factor *SF*. The user-supplied radiological measurement quantities are addressed in Section 2.2.6.1. The approach used in FIIDOS to determine the total activity of the relative radionuclide inventory, A_T, is described in Section 2.2.6.2. Section 2.2.6.3 addresses the FIIDOS procedures used to calculate the gamma-ray emission spectrum, S_T. The methods used to calculate the gamma-ray exposure factors, ψ_{ca}, ψ_{cs}, ψ_s are contained in FIIDOS are explained in Section 2.2.6.4.

2.2.6.1 Radiological Measurement Quantities

There are two basic types of radiological measurement quantities that are input by the user: gross (or isotope specific) activity or radiation intensity.

A gross activity radiological measurement quantity may be an ingestion activity intake (Ci), an inhalation activity intake (Ci), an airborne activity concentration (Ci m^{-3}), or a surface activity concentration (Ci m^{-2}). When a gross activity quantity is used, the user-supplied input must include the measured value and the time after burst at which the measurement was made. An option in FIIDOS allows the user to input the activity of a one specific isotope of the complete inventory. The corresponding gross activity is then determined for input into FIIDOS.

The other basic type of radiological measurement accommodated by FIIDOS is radiation intensity. When this type of radiological measurement is used, the user-supplied input data must include the measured value, the time at which the measurement was made, and identification parameters denoting the characteristics of the measurement device and the geometry of the measurement situation.

In FIIDOS, two types of gamma-ray radiation measurement devices are considered: a non-specific RADIAC meter and a radiation film badge. For the RADIAC meter, it is assumed that the measured radiation intensity will be reported in terms of the intensity in air (R hr^{-1}) or a free-in-air, tissue dose rate (rad hr^{-1}). The film badge is assumed to use DuPont Type 502 film shielded by a lead-tin laminate. The reported film badge dose rate (rem hr^{-1}) can be for either free-in-air or in-situ irradiation conditions, and should be an average value based on the total film badge dose recorded for the period of exposure to airborne contaminants.

In FIIDOS, three geometric arrangements of the radiation intensity measurement situation are considered: the radiation measuring device may be above a contaminated surface, aloft inside a nuclear debris cloud, or at a near-surface position inside a nuclear debris cloud. More specific information on these geometries is provided in Section 2.2.6.4.

2.2.6.2 Total Activity of Relative Radionuclide Inventory

The relative radionuclide inventory, and the procedures used in FIIDOS to construct the inventory, are discussed in Section 2.2.5. It is important to recognize that for the scaling factor calculation, the relative radionuclide inventory must be referenced to the time at which the radiological measurement was performed. Note that it may be necessary for FIIDOS to determine the relative radionuclide inventory at the radiological measurement time for use in the determination of the gamma-ray emission spectrum. As is discussed in Section 2.2.6.3, radionuclide-specific information is utilized where the gamma-ray emission spectrum requires modification to reflect activation products, actinide elements, or fractionated fission products.

2.2.6.3 Gamma-ray Emission Spectrum

The gamma-ray emission spectrum is the gamma-ray emission rate from a model sample of nuclear debris or fallout based on 10^{14} fissions. Since the gamma-ray emission spectrum is used in the calculation of a scaling factor keyed to a radiation intensity measurement, the spectrum is determined for the time at which the radiological measurement was performed. The spectrum is given in terms of an 18-energy group structure that spans a gamma-ray energy range from 0.010 MeV to 11.0 MeV.

The gamma-ray emission spectrum is constructed when FIIDOS calls the ORIGEN2-SAIC code. It includes the gamma rays from fission products, activation products, and actinide elements. If the FIIDOS user desires, the gamma-ray emission spectrum is modified to reflect fission product inventory adjustments due to gaseous fission product removal or fission product fractionation effects. The techniques used to construct the gamma-ray emission spectrum are described below.

Fission Product Gamma Rays

FIIDOS calls the ORIGEN2-SAIC code which calculates the gamma-ray emission spectra for fission products produced by the fission of U-235, U-238, and Pu-239 by fast and 14-MeV neutrons. The spectra are based on 10^{14} fissions with an instantaneous (i.e., 1 msec) irradiation time.

The spectral contribution from each fissionable material-neutron energy set is determined using the fission fraction of each set as was done for the relative radionuclide inventory. This spectral contribution is determined for the specified measurement time. The individual spectral contributions from 781 isotopes are summed within the ORIGEN2-SAIC code to obtain the total gamma-ray emission spectrum from the fission products.

Activation Product Gamma Rays

ORIGEN2-SAIC calculates the gamma-ray emission data for any of 688 activation product radionuclides of which 17 are currently used in calculating organ dose in FIIDOS (see Table 4). The data are presented in the form of gamma rays per disintegration in the 18-energy group structure.

Actinide Element Gamma Rays

In the same manner as described for the activation products, FIIDOS obtains, for the radionuclides given in Table 5, the gamma-ray emission spectrum contributed by the actinide elements. ORIGEN2-SAIC calculates the gamma-ray emission data for any of 129 actinides, of which 18 are currently used in calculating organ dose in FIIDOS.

Spectrum Modifications

As is the case with the relative radionuclide inventory construction described in Section 2.2.5, FIIDOS provides the capability to modify the gamma-ray emission spectrum to reflect the effects of gaseous fission product removal or fission product radionuclide fractionation.

Based on prior calculations of the relative radionuclide inventory at the measurement time, information is available on the amount (Ci per 10^{14} fissions) of each gaseous fission product radionuclide and fractionated fission product radionuclide removed from the relative radionuclide inventory.

Gamma-ray emission data, in the form of gamma rays per disintegration in the 18-energy group structure, are available in FIIDOS for specific gaseous fission product radionuclides (see Table 6). However, similar data for fractionated fission product radionuclides is not currently accessed in FIIDOS, but must be provided as user-supplied input in conjunction with the user-supplied radionuclide fractionation factors discussed in Section 2.2.5.

By considering the amount of each radionuclide removed from the relative radionuclide inventory and the gamma-ray emission data for the radionuclide, FIIDOS determines the necessary gamma-ray emission spectrum modifications.

The isotope fractionation method in FIIDOS is the same as in the original version of FIIDOS. However, because the complete inventory and gamma spectrum are being generated at all 40 time steps and can be accessed at any measurement time, future modifications are possible so as to use ORIGEN2-SAIC to fractionate the inventory.

Gamma-ray Energy Group Structure

At this point, it should be noted that the 18-energy group structure used for the gamma-ray emission spectrum does not exactly match the energy group structure that is used for the gamma-ray exposure factor discussed in Section 2.2.6.4. Since the FIIDOS methodology uses the product of the gamma-ray emission spectrum and the gamma-ray exposure factor, the energy group structure of the emission spectrum is modified to make the two energy group structures compatible.

As seen in Table 7, the first 15 gamma-ray spectrum energy groups from ORIGEN match the last 15 exposure factor energy groups from radiation transport cross section of DLC-31 (Bartine, 1977); however, the 16th gamma-ray spectrum energy group (4.0 - 6.0 MeV) encompasses both the 5th (5.0 - 6.0 MeV) and the 6th (4.0 - 5.0 MeV) exposure factor energy groups. To accommodate this mismatch, the 16th gamma-ray spectrum energy group is subdivided into two groups with 55% of the gamma ray emission rate assigned to a 4.0 - 5.0 MeV energy group and 45% of the emission rate assigned to a 5.0 - 6.0 MeV energy group. This 55% - 45% gamma ray emission rate allocation results in a 50% - 50% energy emission rate allocation to each of the two groups. Table 7 also shows that the energy group structures mismatch for the last two gamma-ray spectrum energy groups and the first four exposure factor energy groups. However, these mismatches are not important, since the nuclear debris or fallout does not emit any high energy gamma rays associated with the 17th and 18th gamma-ray spectrum energy groups.

2.2.6.4 Gamma-ray Exposure Factor

The gamma-ray exposure factor (R hr^{-1}, rad hr^{-1}, rem hr^{-1} per γ sec^{-1} m^{-2} or γ sec^{-1} m^{-3}) is the exposure rate resulting from a unit gamma-ray surface, or volume, emission rate. The factor is in terms of a 21-energy group structure that spans a gamma-ray energy range from 0.01 MeV to 14.0 MeV. The gamma-ray exposure factor is dependent upon the characteristics of the radiation measurement device and the geometry of the radiation measurement situation.

The radiation measurement devices considered include a non-specific radical meter that measures either intensity in air (R hr^{-1}) or tissue dose rate (rad hr^{-1}), and a radiation film badge that provides a dose rate (rem hr^{-1}) value based on a measured dose and exposure duration. The gamma-ray response functions for these devices are shown in Table 8. For air, the conversion from gamma-ray fluence (γ sec^{-1}) to radiation intensity (R hr^{-1}) is based on the ICRU recommendations in NBS Handbook 85 (NBS, 1964), restructured to a 21-energy group structure. Tissue is as represented by elements of a man-phantom described by Snyder (1974). The film badge response is for DuPont Type 502 film shielded by a lead-tin laminate, with the approximation of normally incident radiation (DNA, 1979a).

The radiation measurement situations considered include radiation intensity above a contaminated surface, radiation intensity aloft inside a debris cloud, and radiation intensity at the surface inside a debris cloud. The methodology used to calculate the gamma-ray exposure factor for each of these measurement situations is described below.

Table 7. Gamma-ray energy group structures.

Group	ORIGEN2 Energy Range (MeV)	Group	DLC-31 Energy Range (MeV)
1	0.010-0.020	21	0.010-0.020
2	0.020-0.030	20	0.020-0.030
3	0.030-0.045	19	0.030-0.045
4	0.045-0.070	18	0.045-0.070
5	0.070-0.100	17	0.070-0.100
6	0.100-0.150	16	0.100-0.150
7	0.150-0.300	15	0.150-0.300
8	0.300-0.450	14	0.300-0.450
9	0.450-0.700	13	0.450-0.700
10	0.700-1.000	12	0.700-1.000
11	1.000-1.500	11	1.000-1.500
12	1.500-2.000	10	1.500-2.000
13	2.000-2.500	9	2.000-2.500
14	2.500-3.000	8	2.500-3.000
15	3.000-4.000	7	3.000-4.000
16	4.000-6.000	6	4.000-5.000
17	6.000-8.000	5	5.000-6.000
18	8.000-11.00	4	6.000-7.000
		3	7.000-8.000
		2	8.000-10.000
		1	10.000-14.000

Table 8. Gamma-ray response functions.

Energy	Range	(MeV)	Tissue(1) (rad per γcm^{-2})	Air(2) (R per γcm^{-2})	Film Badge(3) (rem per γcm^{-2})
0.010	-	0.020	4.378×10^{-10}	4.320×10^{-10}	0.000
0.020	-	0.030	1.359×10^{-10}	1.340×10^{-10}	0.000
0.030	-	0.045	6.166×10^{-11}	5.850×10^{-11}	7.908×10^{-14}
0.045	-	0.070	3.615×10^{-11}	3.580×10^{-11}	3.310×10^{-12}
0.070	-	0.100	3.766×10^{-11}	3.690×10^{-11}	2.284×10^{-11}
0.100	-	0.150	5.352×10^{-11}	5.560×10^{-11}	3.919×10^{-11}
0.150	-	0.300	1.085×10^{-10}	1.130×10^{-10}	9.827×10^{-11}
0.300	-	0.450	1.931×10^{-10}	2.010×10^{-10}	1.821×10^{-10}
0.450	-	0.700	2.979×10^{-10}	3.110×10^{-10}	2.850×10^{-10}
0.700	-	1.000	4.262×10^{-10}	4.410×10^{-10}	4.111×10^{-10}
1.000	-	1.500	5.839×10^{-10}	6.020×10^{-10}	5.887×10^{-10}
1.500	-	2.000	7.498×10^{-10}	7.750×10^{-10}	7.826×10^{-10}
2.000	-	2.500	8.933×10^{-10}	9.280×10^{-10}	9.317×10^{-10}
2.500	-	3.000	1.023×10^{-9}	1.050×10^{-9}	1.065×10^{-9}
3.000	-	4.000	1.202×10^{-9}	1.240×10^{-9}	1.253×10^{-9}
4.000	-	5.000	1.423×10^{-9}	1.470×10^{-9}	1.488×10^{-9}
5.000	-	6.000	1.630×10^{-9}	1.690×10^{-9}	1.709×10^{-9}
6.000	-	7.000	1.829×10^{-9}	1.920×10^{-9}	1.942×10^{-9}
7.000	-	8.000	2.028×10^{-9}	2.100×10^{-9}	2.114×10^{-9}
8.000	-	10.000	2.338×10^{-9}	2.440×10^{-9}	2.458×10^{-9}
10.000	-	14.000	2.949×10^{-9}	3.060×10^{-9}	3.088×10^{-9}

(1) MIRD (Snyder) Phantom (Snyder, 1974).
(2) ICRU recommended values restructured to 21-energy group structure (NBS, 1964).
(3) DuPont Type 502 film shielding by a tin-lead laminate (DNA, 1979a).

Radiation Intensity Above a Contaminated Surface

The source term for this gamma-ray exposure factor calculation is a soil slab of infinite lateral dimensions, having a thickness of 1 meter. The soil is represented by Area 7 Nevada Test Site soil, described in Table 9 (DNA, 1979b). The radioactive material within the soil slab is modeled as two planar sources of equal source strength, one at a depth of 0.25 cm and the other at a depth of 0.75 cm. This depth distribution is not meant to indicate the actual distribution of radioactivity in the soil, but is simply a mechanism used to account for the shielding effect of ground roughness. As shown in Figure 9 (Glasstone, 1977), this modeling gives a ground roughness factor that compares favorably with the value of 0.7, commonly mentioned in the fallout literature. The gamma-ray exposure factor for the RADIAC meter is given for a free-in-air, unshielded condition. The meter is assumed to be located at a height of one meter above the contaminated surface.

The gamma-ray exposure factor for the film badge is given for both free-in-air and in-situ conditions. In the free-in-air condition, no consideration is given to the partial shielding of the film badge by the human body. For the in-situ conditions, the human body is represented by a man phantom model, and the film badge is taken to be a point on the chest of the model, see Figure 10 (Kaul, 1977). The shielding effectiveness of the body depends upon the geometric characterization of the irradiation as affected by the orientation of the body and the characteristics of the radiation. The calculated distribution of a representative fallout field radiation environment is shown in Figure 11. A badged individual passing through the field, walking erect, would thus be exposed primarily in his polar midplane to azimuthally isotropic radiation. On the other hand, an individual assuming random orientations while in the field, perhaps by reason of some assigned task, would be exposed in a more generally isotropic fashion. Therefore, FIIDOS includes separate film badge exposure factors for these two situations, calculated on the basis of azimuthally isotropic, polar midplane exposure in the case of a standing individual and on the basis of isotropic exposure for a man assuming various random orientations while in the fallout field. The body provides more effective shielding of the film badge for conditions of isotropic exposure than that in the midplane. Therefore, the film badge gamma-ray exposure factors for in-situ (isotropic) irradiation are less than the factors for in-situ (midplane) irradiation. Leaving aside the differences between isotropic or midplane irradiation, the ratio of in-situ dose to free-in-air dose ranges from 0.5 for low energy gamma rays to 0.9 for high energy gamma rays; for a typical fallout radiation gamma-ray spectrum, the ratio is approximately 0.7. Thus, the overall efficiency in transmission of gamma-ray emissions from fallout to a in-situ film badge, considering both body shielding and ground roughness, is approximately 0.5.

Table 9. Elemental composition of Nevada Test Site* soil.

Element	Weight Percent	Element	Weight Percent
H(organic)	0.50	P	0.02
H(water)	0.66	S	0.03
C	0.90	Cl	0.08
N	0.01	K	1.92
O	50.85	Ca	6.72
Na	0.79	Ti	0.13
Mg	2.04	Mn	0.071
Al	7.61	Fe	1.5
Si	25.03	Other	1.14

* As represented by Area 7 (DNA, 1979b).

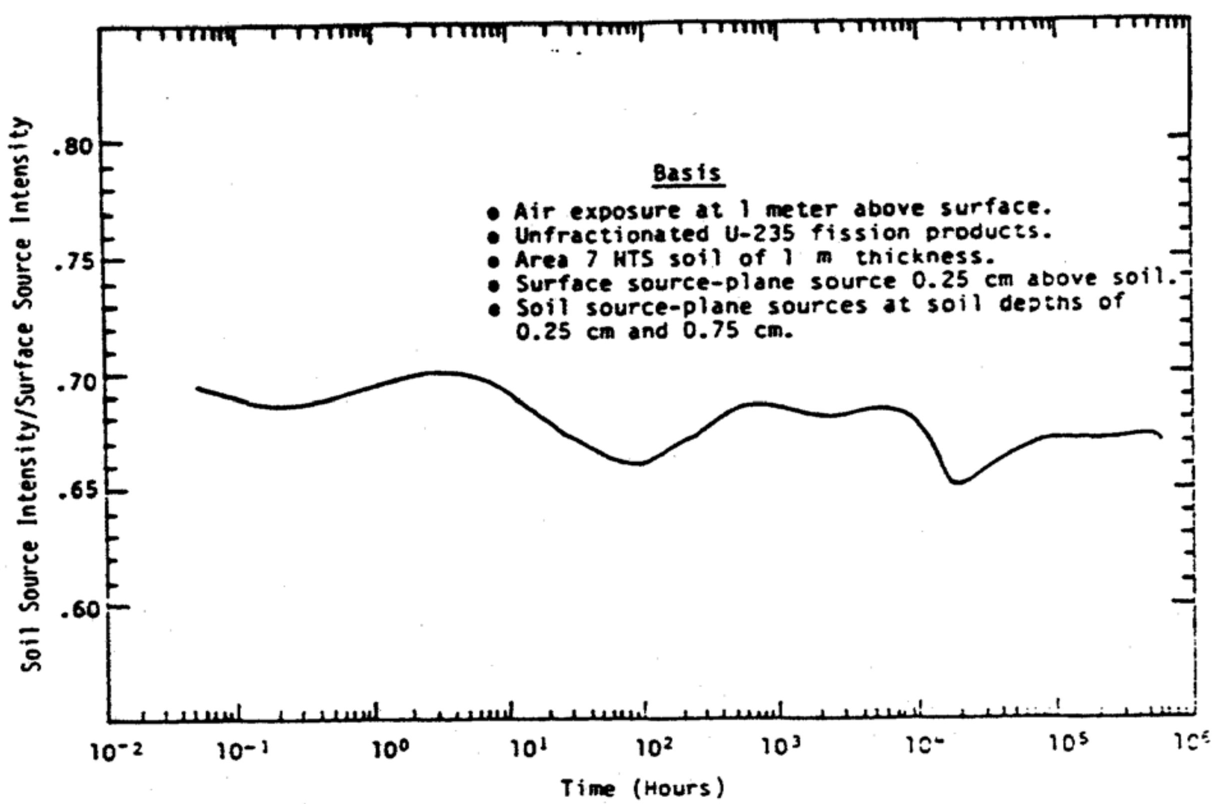


Figure 9. Equivalent ground roughness for soil source.

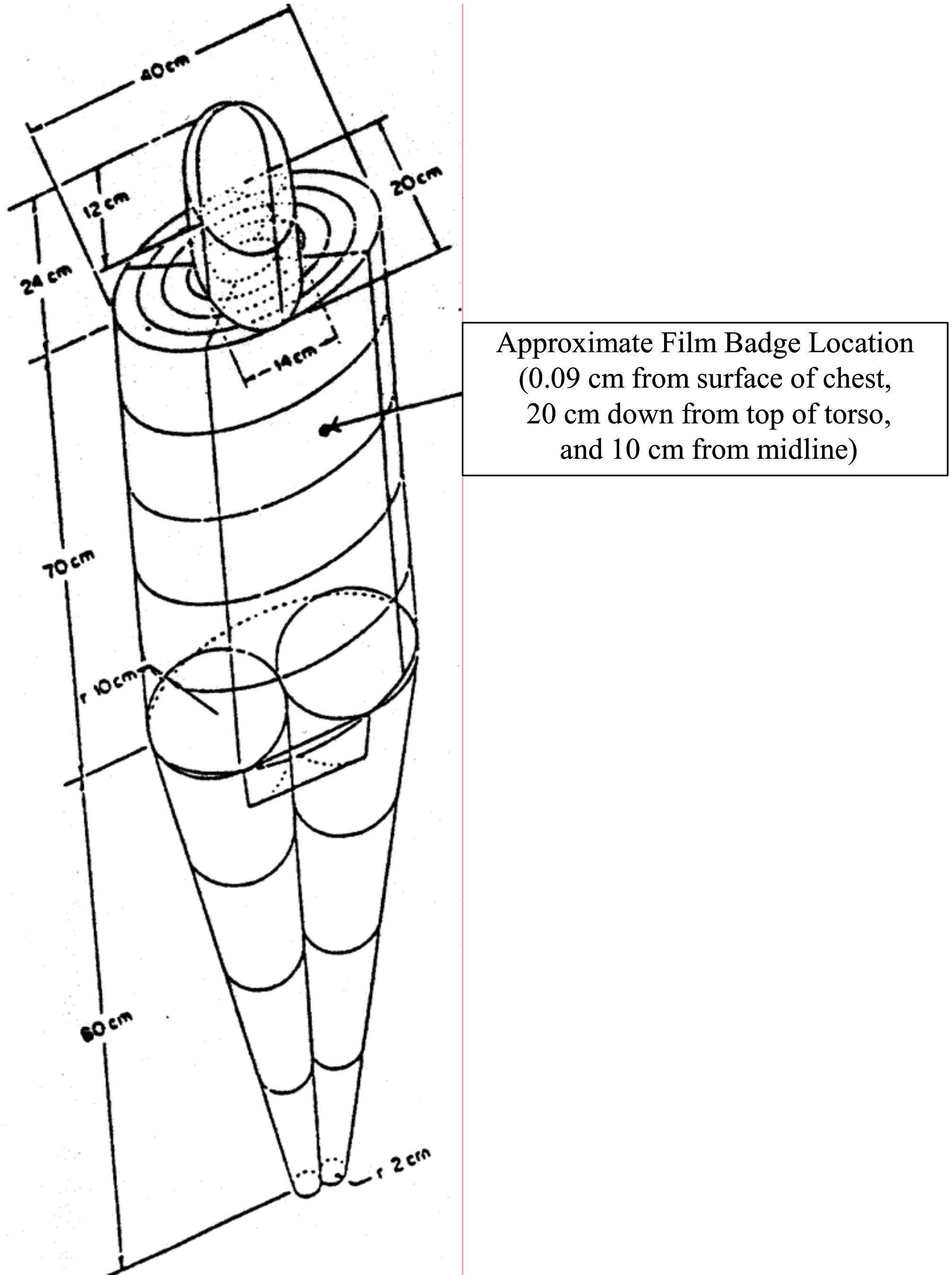


Figure 10. Man phantom model.

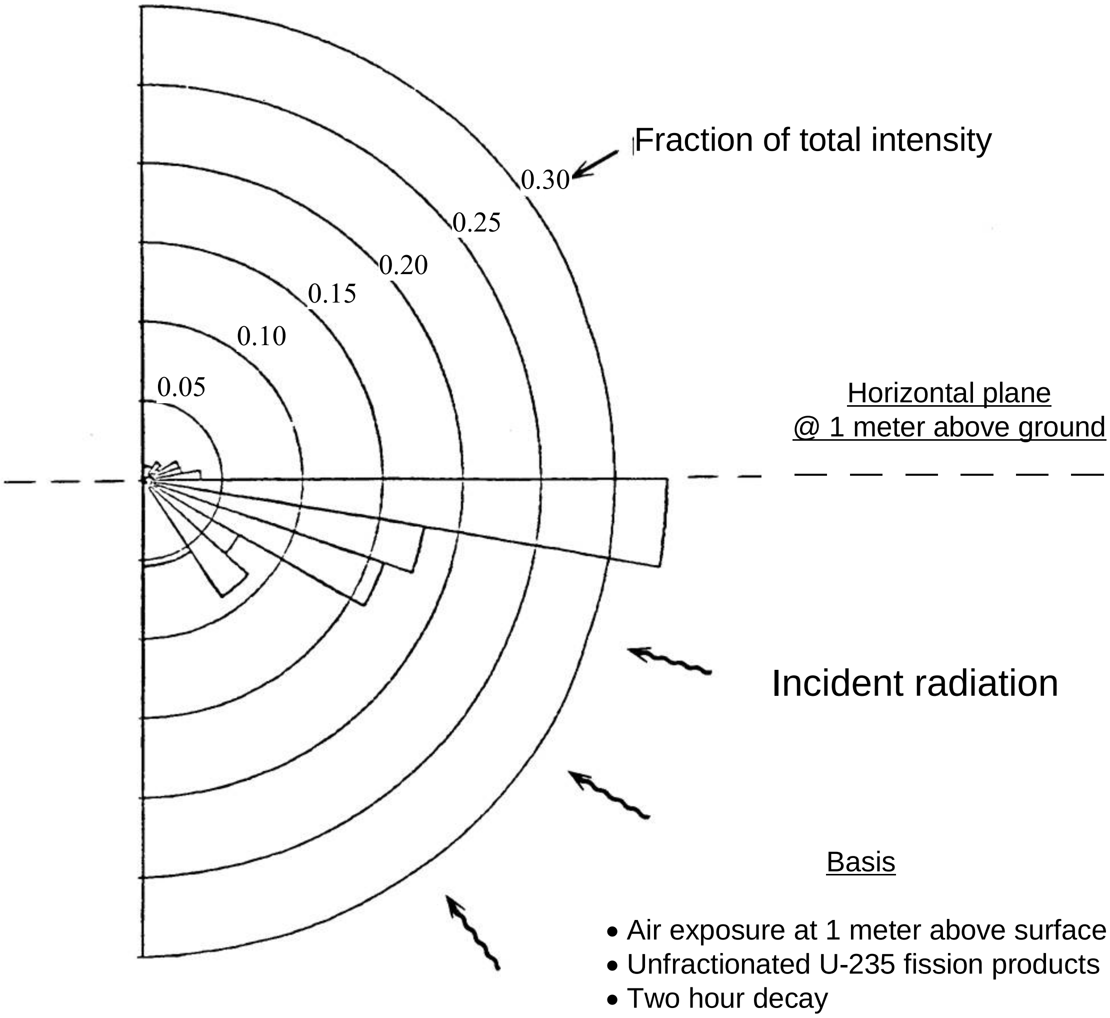


Figure 11. Angular contribution of fallout intensity.

The radiation transport calculations of the gamma-ray exposure factors were performed using the code ANISN (Engle, 1973). The calculations were performed for the 21-energy group structure shown earlier in Table 7. The atmosphere was modeled as low-humidity air at the NTS elevation based on meteorological data typical of Operation TEAPOT (NDL, 1965). That the film badge response uses the approximation of normally incident radiation principally affects the small exposure factors at low energies (which contribute minimally to dose from a fallout field). The comparison among film badge orientations of the exposure factors at such energies is not meaningful.

Table 10 provides the gamma-ray exposure factor for radiation intensity above a contaminated surface.

Radiation Intensity Aloft Inside Debris Cloud

This gamma-ray exposure factor is calculated using an adaptation of the method given in Meteorology and Atomic Energy (Slade, 1968). It is assumed that the debris cloud is effectively infinite in extent; i.e. of uniform contamination density throughout the range of gamma-ray radiation. The gamma-ray exposure factor given in Table 11 is for a radical meter that measures intensity in air (R hr^{-1}), unshielded, within a debris cloud.

Radiation Intensity at Surface Inside Debris Cloud

This gamma-ray exposure factor is determined using the same procedures cited above for radiation intensity inside a debris cloud, except that the bottom half of the cloud is assumed to be replaced by the ground. Accordingly, the gamma-ray exposure factor for the radiation intensity below the cloud is one-half of the exposure factor inside the cloud.

2.3 LIMITATIONS OF TECHNICAL APPROACH

FIIDOS is designed to provide a tool for calculating the radiation dose to various body organs that would result from the ingestion or inhalation of nuclear weapon fallout. While FIIDOS is intended for use in the assessment of radiation exposure of military personnel from atmospheric nuclear detonations, its calculation flexibility facilitates additional applications. The technical approach adopted for FIIDOS is adequate for the purposes of its intended application; however, there are limitations of the technical approach that should be identified to avoid a misuse of FIIDOS or a misunderstanding of FIIDOS results. The limitations encompass both the methodology and the data used in FIIDOS.

Three aspects of the methodology impose limitations on the application of FIIDOS. All three relate to the use of a radiological measurement to characterize a radiological environment. First, it must be recognized that the radiological measurement quantifies the radioactive contamination at a specific location. The radiological environment that FIIDOS calculates is referenced to this same location. FIIDOS does not provide a mechanism for translating a radiological measurement at one location to another location. Second, when a radiological measurement at one time is used to determine the radiological environment at a different time, the only effect that FIIDOS considers is radioactive decay. Decontamination and other effects that alter the distribution of the radioactive material, such as wind and rain, are not included in the FIIDOS methodology. Third, the association of the radiological hazard with the radiological measurement is valid only as long as the fallout debris emits sufficient gamma-ray radiation to give meaningful measurements. This condition exists in a fresh fallout field and continues for several years; however, after some time, the fallout radiation level will become indistinguishable from the prevailing background radiation level. At these late times, the fallout material could still contain some radionuclides that contribute significantly to an internal dose, even though the gamma-ray radiation emission rate from the fallout material is low.

Table 10. Gamma-ray exposure factor for surface contamination.

Gamma-ray Exposure Factor (units as measured per γ hr^{-1} cm^{-2})

				Film Badge (Sn-Pb Shielded Type 502)		
Group	Energy Range (MeV)	Tissue Free-In-Air (rad hr^{-1})	Air Free-In-Air (R hr^{-1})	Free-In-Air (rem hr^{-1})	In-Situ (Midplane) (rem hr^{-1})	In-Situ (Isotropic) (rem hr^{-1})
1	10.0-14.0	5.75×10^{-9}	5.96×10^{-9}	5.99×10^{-9}	5.41×10^{-9}	5.05×10^{-9}
2	8.0-10.0	4.57×10^{-9}	4.77×10^{-9}	4.78×10^{-9}	3.93×10^{-9}	3.88×10^{-9}
3	7.0-8.0	3.97×10^{-9}	4.11×10^{-9}	4.11×10^{-9}	4.08×10^{-9}	3.63×10^{-9}
4	6.0-7.0	3.57×10^{-9}	3.74×10^{-9}	3.76×10^{-9}	3.27×10^{-9}	3.23×10^{-9}
5	5.0-6.0	3.17×10^{-9}	3.29×10^{-9}	3.30×10^{-9}	2.77×10^{-9}	2.65×10^{-9}
6	4.0-5.0	2.75×10^{-9}	2.84×10^{-9}	2.85×10^{-9}	2.12×10^{-9}	2.27×10^{-9}
7	3.0-4.0	2.30×10^{-9}	2.37×10^{-9}	2.37×10^{-9}	2.07×10^{-9}	1.91×10^{-9}
8	2.5-3.0	1.93×10^{-9}	1.98×10^{-9}	1.98×10^{-9}	1.65×10^{-9}	1.62×10^{-9}
9	2.0-2.5	1.66×10^{-9}	1.73×10^{-9}	1.71×10^{-9}	1.58×10^{-9}	1.40×10^{-9}
10	1.5-2.0	1.38×10^{-9}	1.42×10^{-9}	1.41×10^{-9}	1.17×10^{-9}	1.10×10^{-9}
11	1.0-1.5	1.06×10^{-9}	1.09×10^{-9}	1.04×10^{-9}	8.91×10^{-10}	8.31×10^{-10}
12	0.7-1.0	7.66×10^{-10}	7.93×10^{-10}	7.20×10^{-10}	5.64×10^{-10}	5.36×10^{-10}
13	.45-.70	5.46×10^{-10}	5.68×10^{-10}	5.01×10^{-10}	4.21×10^{-10}	4.04×10^{-10}
14	.30-.45	3.69×10^{-10}	3.83×10^{-10}	3.21×10^{-10}	2.63×10^{-10}	2.61×10^{-10}
15	.15-.30	2.22×10^{-10}	2.29×10^{-10}	1.80×10^{-10}	1.54×10^{-10}	1.48×10^{-10}
16	.10-.15	1.12×10^{-10}	1.14×10^{-10}	6.65×10^{-11}	6.32×10^{-11}	5.88×10^{-11}
17	.07-.10	7.52×10^{-11}	7.37×10^{-11}	3.07×10^{-11}	2.91×10^{-11}	2.57×10^{-11}
18	.045-.070	5.43×10^{-11}	5.33×10^{-11}	3.94×10^{-12}	3.58×10^{-12}	3.14×10^{-12}
19	.030-.045	4.10×10^{-11}	3.90×10^{-11}	4.75×10^{-14}	2.96×10^{-14}	3.23×10^{-14}
20	.020-.030	2.64×10^{-11}	2.61×10^{-11}	0	0	0
21	.010-.020	9.94×10^{-12}	9.80×10^{-12}	0	0	0

Table 11. Gamma-ray exposure factor for airborne contamination.

Gamma-ray Group	Free Air Energy Range (MeV)	Gamma-ray Exposure Factor ($R\ hr^{-1}$ per $\gamma\ hr^{-1}\ m^{-3}$)
1	10.0-14.0	1.69×10^{-10}
2	8.0-10.0	1.27×10^{-10}
3	7.0-8.0	1.06×10^{-10}
4	6.0-7.0	9.14×10^{-11}
5	5.0-6.0	7.73×10^{-11}
6	4.0-5.0	6.33×10^{-11}
7	3.0-4.0	4.92×10^{-11}
8	2.5-3.0	3.87×10^{-11}
9	2.0-2.5	3.16×10^{-11}
10	1.5-2.0	2.46×10^{-11}
11	1.0-1.5	1.76×10^{-11}
12	0.7-1.0	1.20×10^{-11}
13	0.45-0.70	8.09×10^{-12}
14	0.30-0.45	7.38×10^{-12}
15	0.15-0.30	3.12×10^{-12}
16	0.10-0.15	1.76×10^{-12}
17	0.07-0.10	1.20×10^{-12}
18	0.045-0.070	8.16×10^{-13}
19	0.030-0.045	5.34×10^{-13}
20	0.020-0.030	3.52×10^{-13}
21	0.010-0.020	2.11×10^{-13}

Limitations on the accuracy of FIIDOS-calculated organ doses arise from data internal to FIIDOS and user-supplied input data. One major limitation of the original FIIDOS code was that the ORIGEN2 database lacked many early gamma rays, especially before 5 minutes. The ORIGEN2-SAIC calculated gamma-ray spectra are very accurate, even to early times, as was demonstrated by the excellent agreement with measurements and other calculations (Roberts, 1996).

The ORIGEN2-SAIC code calculates up to 1600 total isotopes in the inventory. FIIDOS currently uses only 148 of the 781 fission product radionuclides available from ORIGEN2-SAIC for determining internal dose. Most of the other isotopes make a negligible contribution to internal dose because they decay before the earliest fallout deposition times.

Dose conversion factors for short-lived radionuclides are low values, especially for organs outside the organ of uptake. Most radionuclides lacking dose conversion factors have half-lives of a few minutes or less. In this early period, distribution of radionuclides to other organs is limited. The shorter-lived radionuclides included in Appendix A, Tables A-1 and A-2 clearly demonstrate these effects.

The upper limit of the organ dose at early times has been crudely estimated by assuming the radionuclides lacking dose conversion factors in FIIDOS have a dose conversion factor similar to the rest of the inventory. The potential upper limit of the organ dose was then 41 percent more if inhaled at 3 minutes, 7 percent more at 9 minutes, and 4 percent more at 30 minutes than obtained by FIIDOS.

The original version of FIIDOS was based on ORIGEN2 calculations with a very incomplete gamma-ray spectra database from only 180 isotopes. With FIIDOS, the time-dependent gamma-ray emission spectrum of the weapon debris is determined from spectra calculated by ORIGEN2-SAIC. The ORIGEN2-SAIC database contains spectral information on 781 fission-product radionuclides.

The 148 fission products radionuclides in the FIIDOS inventory include most fission-product nuclides of biological significance beyond the first minutes of decay. The FIIDOS code can easily be expanded to include dose from the other isotopes calculated by ORIGEN2-SAIC to accommodate more dose coefficients.

The choice of 18 actinides appears to introduce some problems when in much degraded fallout fields. The daughters and granddaughters of these 18 isotopes can contribute doses comparable to the parent's dose. Because the daughters are not included in the FIIDOS inventory, their dose will be unaccounted.

SECTION 3

COMPUTER PROGRAM

3.1 INTRODUCTION

The computer program FIIDOS is written in FORTRAN primarily for operation on an IBM-compatible PC running Windows (95-XP), but could easily be recompiled for use on a UNIX workstation or an Apple Macintosh computer. A typical FIIDOS problem has a running time of about 1 second, with more complicated problems being completed in less than 5 seconds.

FIIDOS consists of a main program, eighteen subroutines and the code ORIGEN2-SAIC with its subroutines. FIIDOS uses a data library that has several files containing problem-independent data. User input provides problem-dependent data and program control instructions. Program output occurs in sequential fashion from the main program and selected subroutines.

The equations and operations of the computer code FIIDOS are discussed in Section 3.2. The main program and subroutines, data library, user input, and program output for FIIDOS are discussed in Sections 3.3, 3.4, 3.5, and 3.6, respectively. FORTRAN listing of the main program and subroutines is provided in Appendix B.

3.2 EQUATIONS AND OPERATIONS

The equations used in FIIDOS for calculating the committed organ dose resulting from the intake of a radionuclide are computerized versions of Equations 2.20 through 2.27 given in Section 2. The computer equations and their parameters are given in Figure 12.

Figure 13 illustrates, in a simplified manner, the concept of the computer code FIIDOS. The relationship of the FIIDOS data library and processing to the user-supplied inputs is shown.

The actual sequence of operations used by the computer code FIIDOS is shown in Figure 14. Each element of the flow diagram is numbered to facilitate subsequent discussion of the program.

As seen in Figure 14, the first five elements of the flow diagram are concerned with the input data handling and some preliminary calculations. The procedure to calculate the radiological contamination scaling factor is reflected by elements 6 through 11. The path followed from element 6 to 11 depends upon whether the radiological measurement is of gross activity or radiation intensity, with or without modifications to the gamma-ray emission spectrum to reflect activation products, actinide elements, or fractionated fission products. The procedure to calculate the relative radionuclide inventory at the time of exposure is reflected in element 12. The calculation of the organ dose occurs at element 13. At that point, the program flow branches. If integrated (chronic) doses are to be calculated, a loop is entered (elements 15 to 18) which calculates the relative radionuclide inventory at each standard time after the start of the exposure and up to the end of the exposure period. The resulting dose increments from exposure to those inventories are summed to produce a total dose. The integrated exposure branch is rejoined by the acute exposure branch at element 19 and, if requested, the intermediate results are written to the output file. If the calculation is complete (no additional exposures), then the program ends and the final output is written. Otherwise, the program flow returns to element 6 as many times as required.

3.3 MAIN PROGRAM AND SUBROUTINES

FIIDOS consists of a main program, eighteen subroutines and the code ORIGEN2-SAIC. Figure 15 shows the basic organization and hierarchy of FIIDOS. The main program controls the execution of FIIDOS. The actual problem calculations are performed by the subroutines. Each routine is briefly described below.

Program MAIN is the control module for FIIDOS. The basic flow of program MAIN is shown in Figure 14. As seen in the figure, program MAIN consists primarily of decisions for branching and calls for subroutines. Program variables appearing in the diagram are discussed in Section 3.5 as follows: ITRM--Item 6; and ITPM--Item 2.

Subroutine INPUT obtains the input data provided by the FIIDOS user. A discussion of the user input data is given in Section 3.5.

Subroutine FISFRC converts the weapon yield data provided by the user in units of kilotons into the relative number of fissions for each fissionable material-neutron energy set. The fissionable materials considered include U-235, U-238, and Pu-239; the neutron energies considered include fast neutrons and 14-MeV neutrons.

Subroutine ORGSRC prepares the input for the ORIGEN2-SAIC code.

Subroutine RRI calculates the relative radionuclide inventory of a mixture of radionuclides at a specified time of concern, which can be either the measurement time or the exposure time. Subroutine RRI itself is a control module; as shown in Figure 15, subroutine RRI has five subordinate modules that perform the inventory-related calculations.

Subroutine GFPI accepts the relative radionuclide inventory of fission products calculated by ORIGEN2-SAIC.

Subroutine KRXERI determines the amount of each krypton and xenon radionuclide removed from the relative radionuclide inventory of fission products, if required.

$$D(I,J) = DUR \times BR \times AKFAC \times DCF(I,J) \times AFP(I) \times SF \times 10^6 \quad (3.1)$$

with,

$$SF = ACTMES \times (ACTOT)^{-1} \quad (3.2)$$

or

$$SF = RIMES \times (\textstyle\sum_E SPEC \times GREF)^{-1} \quad (3.3)$$

where:

D(I,J) = dose commitment (rem) to organ *J* from radionuclide *I*,

DUR = duration of exposure (hr),

BR = breathing rate ($m^3\ hr^{-1}$),

AKFAC = airborne activity-surface activity ratio ($Ci\ m^{-3}$ per $Ci\ m^{-2}$), or resuspension factor (m^{-1}),

DCF(I,J) = dose conversion factor (rem μCi^{-1}) for the dose to organ *J* resulting from the ingestion or inhalation of radionuclide *I*, and

AFP(I) = amount of radionuclide I (Ci per 10^{14} fissions) in the relative radionuclide inventory of the nuclear debris (note that *AFP* pertains to fission products.

Similar parameters are defined for activation products and actinide elements),

SF = radiological contamination scaling factor (10^{14} fissions, 10^{14} fissions m^{-2}, or 10^{14} fissions m^{-3}),

ACTMES = measured gross activity intake (Ci), surface concentration ($Ci\ m^{-2}$) or airborne concentration ($Ci\ m^{-3}$),

ACTTOT = total activity of relative radionuclide inventory (Ci per 10^{14} fissions),

RIMES = measured radiation intensity ($R\ hr^{-1}$) above contaminated surface, at surface inside debris cloud, or aloft inside debris cloud,

SPEC = rate of emission of gamma-rays of energy *E* from relative radionuclide inventory ($\gamma\ hr^{-1}$ per 10^{14} fissions), and

GREF = energy-dependent factor of energy E, relating radiation intensity ($R\ hr^{-1}$) to gamma-ray emission rate from contaminated surface ($\gamma\ hr^{-1}\ m^{-2}$) or debris cloud ($\gamma\ hr^{-1}\ m^{-3}$).

Figure 12. Dose equations for computer calculations.

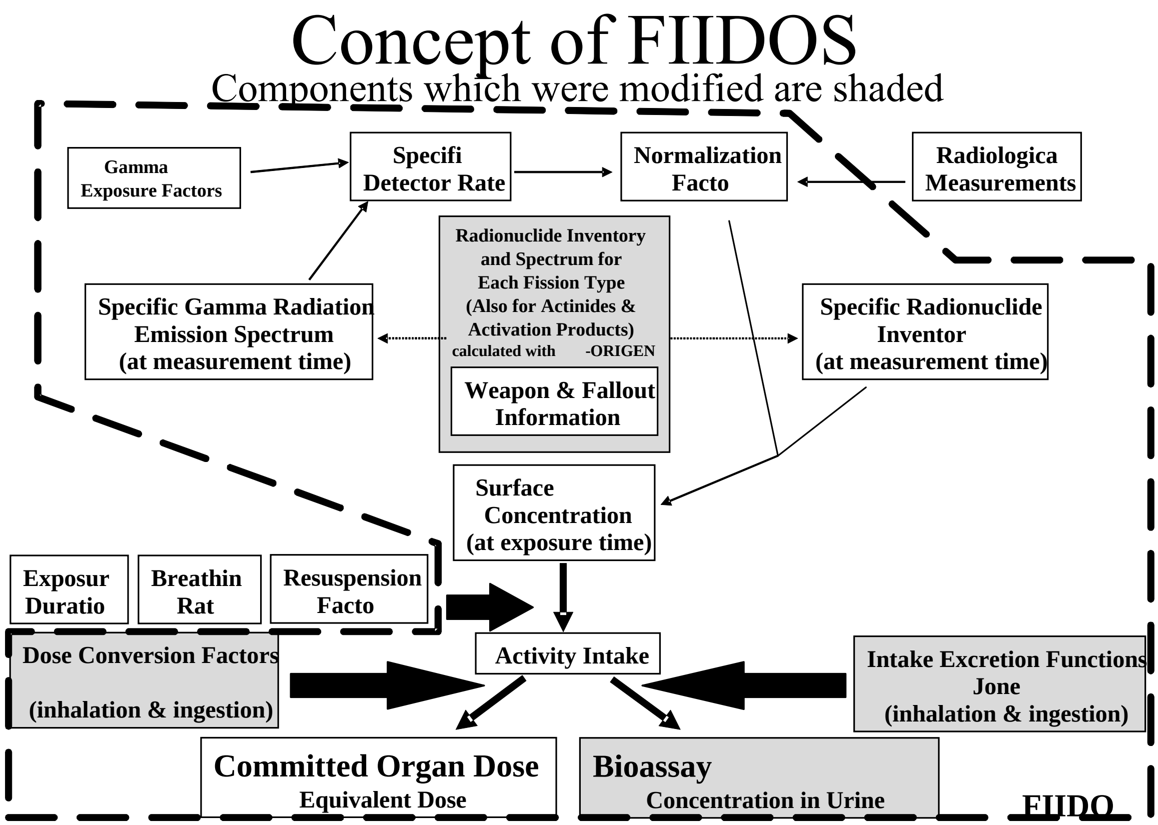
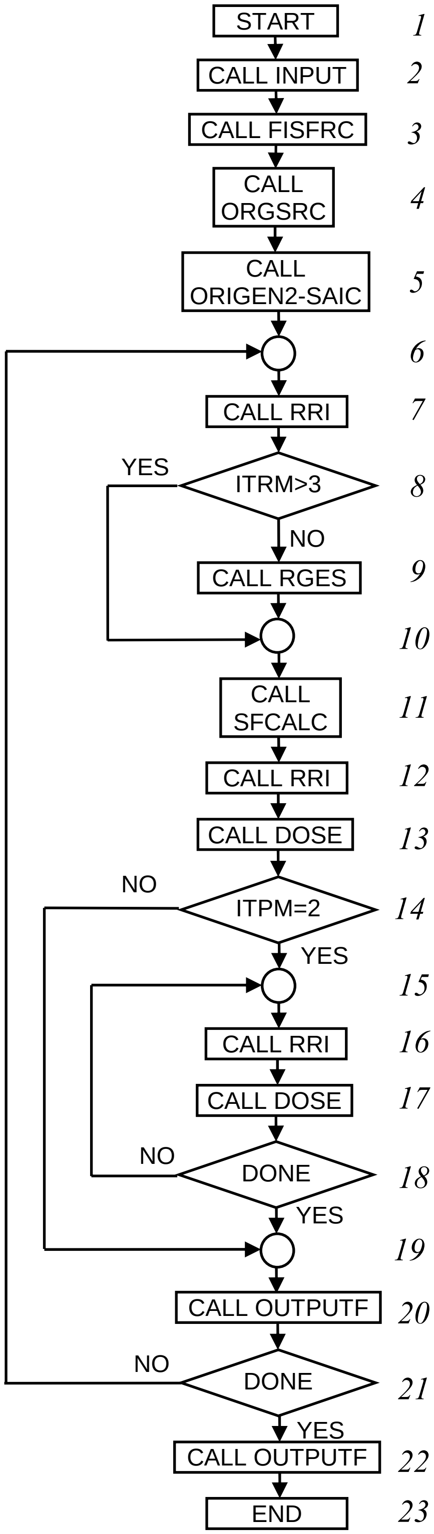


Figure 13. Concept of FIIDOS.



1. Start of program MAIN.
2. Subroutine INPUT reads the input data provided by the user.
3. Subroutine FISFRC converts the weapon yield in KT into relative number of fissions for each fissionable material-neutron energy set.
4. Subroutine ORGSRC converts user input into ORIGEN2-SAIC input.
5. Subroutine ORIGEN2-SAIC combines inventories and decays them to times of interest.
6. Connector shows point in MAIN where problem is reentered for multiple measurement/exposure pairs.
7. Subroutine RRI calculates the relative radionuclide inventory at the time of measurement for the purposes of 1) modifying the relative gamma emission spectrum and 2) providing the necessary inventory information to calculate the scaling factor.
8. Decision for branching based on whether radiological measurement is gross activity or radiation intensity.
9. Subroutine RGES calculates the relative gamma emission spectrum used to generate the scaling factor (only for intensity-based measurements).
10. Connector shows point where branches rejoin the program flow.
11. Subroutine SFCALC calculates the scaling factor based on the measured radiological quantity.
12. Subroutine RRI calculates the relative radionuclide inventory at the time of exposure.
13. Subroutine DOSE calculates the inhalation and ingestion dose to organs and the Pu-239 excretion.
14. Decision for branching based on integrated (chronic) versus acute exposures.
15. Connector shows reentry point in program flow for integrated exposures.
16. Subroutine RRI calculates the relative radionuclide inventory for each intermediate time of exposure and at the end of the exposure.
17. Subroutine DOSE calculates each increment of internal dose and Pu-239 excretion for integrated exposures.
18. Decision for branching based on completion of the integrated dose calculation.
19. Connector shows point where the acute and integrated exposure branches rejoin after the total dose is calculated for a single measurement/exposure pair.
20. Subroutine OUTPUTF prints the intermediate results of each measurement/exposure pair (if requested).
21. Decision for branching based on completion of calculations of dose for all measurement/exposure pairs.
22. Subroutine OUTPUTF prints the final total internal doses and the total Pu-239 excretions from all exposures.
23. End of program.

Figure 14. Relationship of principal subroutines.

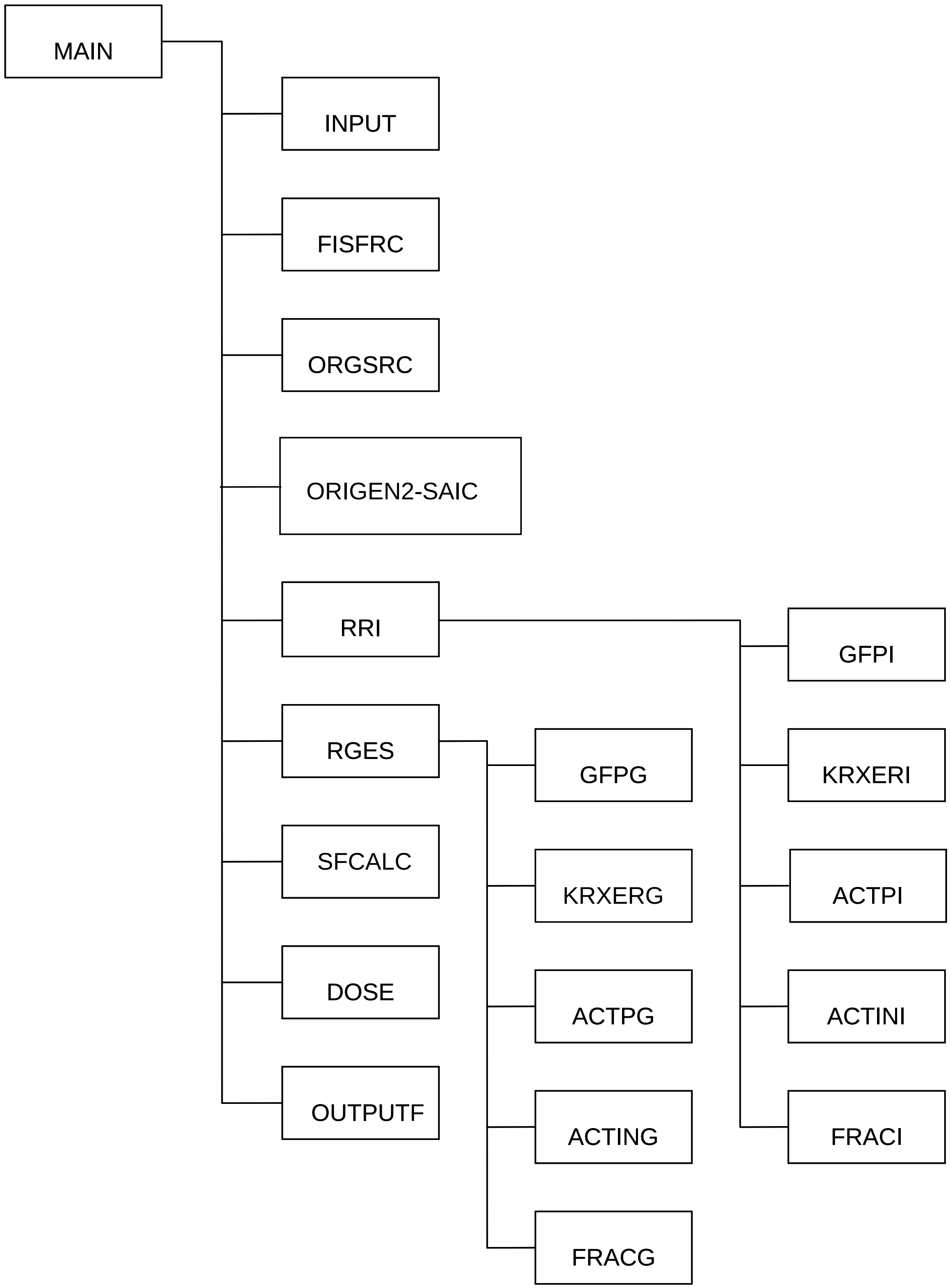


Figure 15. Organization and hierarchy of FIIDOS.

Subroutine ACTPI accepts the relative radionuclide inventory of activation products calculated by ORIGEN2-SAIC, if required.

Subroutine ACTINI accepts the relative radionuclide inventory of actinide elements products calculated by ORIGEN2-SAIC, if required.

Subroutine FRACI is used to calculate the change in the relative radionuclide inventory of fission products resulting from fractionation, if required. This calculation uses radionuclide-specific fractionation factors provided by the user and radionuclide inventory data produced by subroutine GFPI.

Subroutine RGES calculates the relative gamma-ray emission spectrum of a mixture of radionuclides at the measurement time, if required. Subroutine RGES itself is primarily a control module; as shown in Figure 15, subroutine RGES has five subordinate modules that perform the spectrum-related calculations.

Subroutine GFPG accepts the relative gamma-ray emission spectrum from the fission product radionuclides, calculated by ORIGEN2-SAIC, considering the contribution from each fissionable material-neutron energy set.

Subroutine KRXERG determines the relative gamma-ray emission spectrum contributed by the krypton and xenon radionuclides removed from the fission product inventory, if required. This calculation uses gamma-ray emission spectral data contained in a data file and radionuclide inventory data produced by subroutine KRXERI.

Subroutine ACTPG accepts the relative gamma-ray emission spectrum contributed by the activation products, calculated by ORIGEN2-SAIC, if required.

Subroutine ACTING accepts the relative gamma-ray emission spectrum contributed by the actinide elements calculated by ORIGEN2-SAIC, if required.

Subroutine FRACG is used to calculate the change in the relative gamma-ray emission spectrum of fission products resulting from fractionation, if required. This calculation uses gamma-ray emission spectral data provided by the user and radionuclide inventory data produced by subroutine FRACI.

Subroutine SFCALC calculates the radiological contamination scaling factor based on the radiological measurement data provided by the user. As appropriate, this scaling factor is the intake, airborne concentration, or surface concentration of the radioactive material.

Subroutine DOSE calculates the radiation dose to each organ contributed by each radionuclide and performs the plutonium excretion calculations, if requested.

Subroutine OUTPUTF provides the calculated doses and other elements of calculation data. A discussion of the program output is in Section 3.6.

Subroutine ORIGEN2-SAIC is called by the main routine to calculate inventory and spectra at times of interest. More information on this code is available (Croff, 1980; Roberts, 1996).

3.4 DATA LIBRARY

FIIDOS makes extensive use of files stored in a data library to provide problem-independent input data. Table 12 identifies the FIIDOS data library files. FIIDOS causes ORIGEN2-SAIC to calculate the decay inventory and spectra at 40 basic times after detonation. The 40 times are given in Table 13.

The gamma-ray emission spectra are calculated for 18 energy groups by ORIGEN2-SAIC. The gamma-ray release rate is expressed in terms of gamma-rays per second and is based on 10^{14} fissions. Table 14 provides the 18 gamma-ray energy groups. The files KRXE.GAM, contain gamma-ray emission spectra for krypton and xenon radionuclides. The spectra are expressed in gamma rays per disintegration and are provided in the 18-energy group structure given above.

The files GREF.SUR, GREF.INC, and GREF.BLC contain the gamma-ray exposure factor for radiation intensity above a contaminated surface, inside a debris cloud, and at the surface below a debris cloud, respectively. In the file GREF.SUR the factors are given in units of rad hr^{-1}, R hr^{-1}, or rem hr^{-1} per γ hr^{-1} cm^{-2} and factors are provided for several detector-orientation combinations. In the files GREF.INC and GREF.BLC the factors are given in units of R hr^{-1} per γ hr^{-1} cm^{-2} and factors are provided for a single detector-orientation combination. The factors are represented in the 21-energy group structure given in Table 15.

The files INH.DCF and ING.DCF contain the ingestion and inhalation dose conversion factors. The factors are given in units of rem μCi^{-1}.

3.5 INPUT DESCRIPTION

The user-supplied, problem-dependent input data required by the computer code FIIDOS is identified in Table 16. A discussion of this input data, keyed to the entries in Table 16, is provided below.

3.6 OUTPUT DESCRIPTION

The computer code FIIDOS has two basic types of output: standard and optional. Standard output, which provides the basic dose results of a FIIDOS calculation, occurs automatically and is not under any form of user control. Optional output, which provides supplemental information on the details of the FIIDOS calculations, is permitted or suppressed by user-specified control parameters.

Table 12. FIIDOS data library.

FIIDOS data files

Unit Number	File Name	File Contents
1	fiidos.out	FIIDOS output
2	inh.dcf	Inhalation Dose Conversion Factors (ICRP-72)
2	ing.dcf	Ingestion Dose Conversion Factors (ICRP-72)
2	input.dat	FIIDOS input file
2	krxe.gam	Gamma-ray Emission Spectrum for Krypton and Xenon Radionuclides
2	gref.sur	Gamma-ray Exposure Factor above Contaminated Surface
2	gref.inc	Gamma-ray Exposure Factor Aloft inside Debris Cloud
2	gref.blc	Gamma-ray Exposure Factor at Surface inside Debris Cloud
2	tape5.inp	ORIGEN2-SAIC input file created by subroutine orgsrc.ftn
3	orgsrc.dat	Initial 1 msec fission product inventory for U-235, U-238, Pu-239; fast & 14 MeV
2 & 3	frac.gam	Gamma-ray Emission Spectrum for Fractionated Fission Products (user supplied)

ORIGEN2-SAIC data files

Unit Number	File Name	File Contents
3	tape3.inp	(not used) substitute library cards
4	tape4.inp	(not used)
5	tape5.inp	ORIGEN2-SAIC input file
6	tape6.out	ORIGEN2-SAIC output file
7	tape7.out	(not used) punch output
9	tape9.inp	decay library
10	tape10.inp	gamma-ray library
11	tape11.out	alternative output file
12	tape12.out	table of contents for tape6.out
13	tape13.out	(not used)table of contents for tape11.out
15	tape15.out	debugging file
16	tape16.out	info on variable actinide cross sections
50	tape50.out	copy of tape5.inp

Table 13. The 40 basic time intervals that ORIGEN2-SAIC used when performing the decay calculations.

Interval	Seconds	Seconds	Hours	Days	Years
1	1.00×10^{-3}				
2	2.15×10^{-3}				
3	4.64×10^{-3}				
4	1.00×10^{-2}				
5	2.15×10^{-2}				
6	4.64×10^{-2}	0.05			
7	1.00×10^{-1}	0.10			
8	2.15×10^{-1}	0.22			
9	4.64×10^{-1}	0.46			
10	1.00×10^{0}	1.00			
11	2.15×10^{0}	2.15			
12	4.64×10^{0}	4.64			
13	1.00×10^{1}	10.00			
14	2.15×10^{1}	21.54			
15	4.64×10^{1}	46.42			
16	1.00×10^{9}	100.00			
17	2.15×10^{9}	215.40	0.06		
18	4.64×10^{9}	464.20	0.13		
19	1.00×10^{9}	1000.0	0.28		
20	2.15×10^{9}		0.60		
21	4.64×10^{9}		1.29	0.05	
22	1.00×10^{9}		2.78	0.12	
23	2.15×10^{9}		5.98	0.25	
24	4.64×10^{9}		12.89	0.54	
25	1.00×10^{9}		27.78	1.16	
26	2.15×10^{9}			2.49	
27	4.64×10^{9}			5.37	
28	1.00×10^{9}			11.57	
29	2.15×10^{9}			24.93	0.07
30	4.64×10^{9}			53.73	0.15
31	1.00×10^{9}			115.7	0.32
32	2.15×10^{9}			249.3	0.68
33	4.64×10^{9}			537.2	1.47
34	1.00×10^{9}				3.17
35	2.15×10^{9}				6.83
36	4.64×10^{9}				14.72
37	1.00×10^{9}				31.71
38	2.15×10^{9}				68.30
39	4.64×10^{9}				147.2
40	1.00×10^{10}				317.1

Table 14. Eighteen energy groups for gamma-ray spectra with their midpoint energies noted.

Group	E_{mid}(MeV)	Group	E_{mid}(MeV)	Group	E_{mid}(MeV)
1	0.010	7	0.225	13	2.25
2	0.025	8	0.375	14	2.75
3	0.0375	9	0.575	15	3.50
4	0.0575	10	0.850	16	5.00
5	0.0850	11	1.25	17	7.00
6	0.125	12	1.75	18	9.50

Table 15. Twenty one energy groups for gamma-ray exposure factors spectra with their midpoint energies noted.

Group	E_{mid}(MeV)	Group	E_{mid}(MeV)	Group	E_{mid}(MeV)
1	14.0	8	3.0	15	0.3
2	10.0	9	2.5	16	0.15
3	8.0	10	2.0	17	0.1
4	7.0	11	1.5	18	0.07
5	6.0	12	1.0	19	0.045
6	5.0	13	0.7	20	0.03
7	4.0	14	0.45	21	0.02

Table 16. Input data required by FIIDOS.

1. Title
2. Index for Type of Problem
3. First Index for Output Control
4. Second Index for Output Control
5. Third Index for Output Control
6. Fourth Index for Output Control
7. Fifth Index for Output Control
8. Number of Measurements
9. Types of Radiological Measurements
10. Times at which Radiological Measurements are Performed
11. Measured Radiation Intensities
12. Types of Radiation Intensity Measurement Devices
13. Measured Gross Activities
14. Number of Exposure Incidents
15. Times at which the Exposures Occurred
16. Measurement Correspondences of Exposures
17. Durations of the Exposures
18. Breathing Rates During the Exposures
19. Ratios of Airborne to Surface Activity during the Exposures
20. Types of Dose Conversion Factors for Exposures
21. Fissile Yields for Fission Products
22. Index for Activation Products
23. Activation Product Yields
24. Index for Actinides
25. Actinide Yields
26. Index for Krypton and Xenon
27. Index for Fractionation of Fission Products
28. Number of Fission Product Radionuclides to be Modified by Fractionation
29. Identification Numbers of Fractionated Fission Products
30. Remaining Fractions of Fission Product Inventory
31. Gamma-ray Emission Spectrum for Fractionated Fission Products
32. Index for Plutonium Excretion
33. Number of Times to Calculate Pu-239 Excretion
34. User Specified Times for Pu-239 Urine Excretion

Table 16. Input data required by FIIDOS (Continued).

(1) Item: Title
Name: TITLE(I)
Remarks: Title of problem selected by user.

(2) Item: Index for Type of Problem
Name: ITPM
Remarks: The index parameter ITPM may have the integer value of 1 or 2.

The following scheme is used:

Value	Type of Problem
1	Short (Acute) Exposures (up to 100 measurement plus exposure times)
2	Long Duration (Integrated) Exposures (up to 33 long duration integrations)

(3) Item: First Index for Output Control
Name: IOUT1
Remarks: The index parameter IOUT1 may have the integer value of 0 or 1. If IOUT1 = 0, this output option is not used. If IOUT1 = 1, either the relative gamma-ray emission spectrum at the time of measurement or the measured activity of radiological material, and the radiological contamination scaling factor are provided as code output.

(4) Item: Second Index for Output Control
Name: IOUT2
Remarks: The index parameter IOUT2 may have the integer value of 0 or 1. If IOUT2 = 0, this output option is not used. If IOUT2 = 1, the relative radionuclide inventories for fission products, activation products, and actinide elements, at the time of exposure, are provided as code output. Suppressed for ITPM=2.

(5) Item: Third Index for Output Control
Name: IOUT3
Remarks: The index parameter IOUT3 may have the integer value of 0 or 1. If IOUT3 = 0, this output option is not used. If IOUT3 = 1, the dose to each organ from each radionuclide is provided as code output. Suppressed for ITPM=2.

Table 16. Input data required by FIIDOS (Continued).

(6) Item: Fourth Index for Output Control
Name: IOUT4
Remarks: The index parameter IOUT4 may have the integer value of 0 or 1. If OUT4 = 0, only the total dose from all exposures is printed in the output file. If IOUT4 = 1, the intermediate doses corresponding to each exposure are printed. If IOUT4 = 0, output for IOUT1, IOUT2, and IOUT3 is suppressed.

(7) Item: Fifth Index for Output Control
Name: IOUT5
Remarks: The index parameter IOUT5 may have the integer value of 0 or 1. If IOUT5 = 0, this output option is not used. If IOUT5 = 1, a summary dose table is create in a separate file (FIIDOST.OUT) with dose contributions by exposure as well as by source (alpha emitters and beta plus gamma emitters). This option is ideal for creating dose lookup tables to be imported into spreadsheet programs.

(8) Item: Number of Radiological Measurements
Name: NMEAS
Remarks: For ITPM = 1, the parameter NMEAS may have an integer value between 1 and 99, with the additional requirement that NMEAS + NEXP ≤ 100. For ITPM = 2, NMEAS may have an integer value between 1 and 33. FIIDOS will ignore measurements that do not have corresponding exposures.

*** Data items 9, 10, 11, 12, and 13 are entered in sequence for each measurement ***

(9) Item: Types of Radiological Measurements
Name: XITRM (NMEAS entries required)
Remarks: The index parameter XITRM(I) may have the integer value of 1, 2, 3, 4, 5, or 6.
The following scheme is used:

Value	Type of Radiological Measurement
1	Radiation Intensity - Above Contam. Surface
2	Radiation Intensity - Inside Debris Cloud
3	Radiation Intensity - Below Debris Cloud
4	Gross Activity - Airborne Concentration
5	Gross Activity - Surface Concentration
6	Gross Activity - Ingestion or Inhalation Intake (if XRIMES(I) ≠ 0; indicates Specific Activity Intake)

Table 16. Input data required by FIIDOS (Continued).

(10) Item: Times at which Radiological Measurements are Performed
Name: XTMEAS (NMEAS entries required)
Remarks: This time is referenced to the time of the nuclear explosion and is given in units of hours.

(11) Item: Measured Radiation Intensities
Name: XRIMES (NMEAS entries required)
Remarks: If corresponding XITRM = 1, enter the radiation measurement in rad hr^{-1}, R hr^{-1}, or rem hr^{-1}. If XITRM = 2 or 3, enter the radiation intensity (R/hr). If XITRM = 4, or 5, enter a zero. If XITRM = 6, enter a zero for gross activity intake, or enter FIIDOS isotope # for specific activity intake for that isotope).

(12) Item: Types of Radiation Intensity Measurement Devices
Name: XITMI (NMEAS entries required)
Remarks: If corresponding XITRM = 1, enter the integer value of 1, 2, 3, 4, or 5.

The following scheme is used:

Value	Type of Measurement Device
1	Tissue, Free-In-Air
2	Air, Free-In-Air
3	Film Badge, Free-In-Air
4	Film Badge, In-Situ (Midplane)
5	Film Badge, In-Situ (Isotropic)

If XITRM = 2 or 3, enter 2.
If XITRM = 4, 5, or 6, enter zero.

(13) Item: Measured Gross Activities
Name: ACTMES (NMEAS entries required)
Remarks: If corresponding XITRM = 1, 2, or 3, enter a zero. If XITRM = 4, 5, or 6, enter the measured gross activity in units of Ci-m^{3}, Ci m^{-2}, or Ci, as appropriate.

(14) Item: Number of Exposure Incidents
Name: NEXP
Remarks: If ITPM = 1, up to 99 exposure incidents can be calculated, with the additional requirement that NMEAS + NEXP 100. If ITPM = 2, up to 33 exposure incidents can be entered.

Table 16. Input data required by FIIDOS (Continued).

*** Data items 15, 16, 17, 18, 19 and 20 are entered in sequence for each exposure ***

(15)	Item:	Times at which Exposures Occurred
	Name:	XTEXP (NEXP entries required)
	Remarks:	This time is referenced to the time of the nuclear explosion and is given in units of hours.

(16)	Item:	Measurement Correspondences of Exposures
	Name:	XCMEAS (NEXP entries required)
	Remarks:	This index determines the measurement time corresponding to the exposure.

The following scheme is used:

Value	Types of Measurement Correspondence
1	Nearest measurement time after exposure
0	Nearest measurement time prior to exposure
-#	Exposure corresponds to #th measurement

(17)	Item:	Durations of Exposures
	Name:	XDUR (NEXP entries required)
	Remarks:	This duration is given in units of hours. If corresponding XITRM = 6, enter 10.

(18)	Item:	Breathing Rates during Exposures
	Name:	XBR (NEXP entries required)
	Remarks:	The breathing rate is given in units of m^3 hr^{-1}. If corresponding XITRM = 6, enter the value 1.0.

(19)	Item:	Ratios of Airborne to Surface Activity during Exposures
	Name:	XKFAC (NEXP entries required)
	Remarks:	If corresponding XITRM = 1 or 5, enter the ratio in units of m^{-1}. If XITRM = 2, 3, 4, or 6, enter the value 1.0.

(20)	Item:	Types of Dose Conversion Factor during Exposures
	Name:	ITDCF (NEXP entries required)
	Remarks:	The index parameter ITDCF may have the integer value of 1 or 2.

The following scheme is used.

Value	Dose Conversion Factor
1	Inhalation (currently ICRP-72)
2	Ingestion (currently ICRP-72)

Table 16. Input data required by FIIDOS (Continued).

(21) Item: Fissile Yields from Fissionable Material-Neutron Energy Set
Name: YKT (6 entries required)
Remarks: Enter the weapon yield in kilotons from one of the two options.

I	FIIDOS option 1 Fission/Fusion Yields	FIIDOS option 2 Fission by Neutron Energy
1	-1	U-235, Fast Neutron
2	Total Yield	U-235, 14-MeV Neutron
3	Total U-235 Yield	U-238, Fast Neutron
4	Total U-238 Yield	U-238, 14-MeV Neutron
5	Total Pu-239 Yield	Pu-239, Fast Neutron
6	Total Fusion yield (for yield balance)	Pu-239, 14-MeV Neutron

(22) Item: Index for Activation Products
Name: IACTP
Remarks: The index parameter IACTP may have the integer value of 0 or 1. If IACTP = 0, activation products are not considered. If IACTP = 1, activation products are considered.

(23) Item: Activation Product Production
Name: ACTPP (20 entries required if IACTP=1)
Remarks: If IACTP = 0, this data is not required. If IACTP = 1, enter the production data, in units of Ci kT^{-1}, for 20 specific radionuclides in the following order.

(1) Be-7	(2) Na-24	(3) Mn-54	(4) Fe-55
(5) Fe-59	(6) Co-57	(7) Co-58	(8) Co-60
(9) Cu-64	(10) Cu-67	(11) W-181	(12) W-185
(13) W-187	(14) W-188	(15) Au-198	(16) Au-199
(17) Pb-203	(18) Not used	(19) Not used	(20) Not used

(24) Item: Index for Actinides
Name: IACTIN
Remarks: The index parameter IACTIN may have the integer value of 0 or 1. If IACTIN = 0, actinide elements are not considered. If IACTIN = 1, actinide elements are considered.

Table 16. Input data required by FIIDOS (Continued).

(25) Item: Actinide Production
Name: ACTINP (20 entries required if IACTP=1)
Remarks: If IACTIN = 0, this data is not required. If IACTIN = 1, enter the production data, in units of Ci kT^{-1}, for 20 specific radionuclides in the following order:

(1) Th-229	(2) Th-230	(3) Th-234	(4) U-233
(5) U-234	(6) U-235	(7) U-237	(8) U-238
(9) U-240	(10) Np-237	(11) Np-239	(12) Np-240
(13) Pu-238	(14) Pu-239	(15) Pu-240	(16) Pu-241
(17) Am-241	(18) Cm-242	(19) Not used	(20) Not used

(26) Item: Index for Krypton and Xenon
Name: IKRXER
Remarks: The index parameter IKRXER may have the integer value of 0 or 1. If IKRXER=0, the fission product inventory is not modified. If IKRXER = 1, krypton and xenon radionuclides are removed from the fission product inventory.

(27) Item: Index for Fractionation of Fission Products
Name: IFRAC
Remarks: The index parameter IFRAC may have the integer value of 0 or 1. If IFRAC = 0, the fission product inventory is not modified. If IFRAC = 1, the fission product inventory is modified to reflect fractionation effects.

(28) Item: Number of Fission Product Radionuclides to be Modified by Fractionation
Name: NFRAC
Remarks: If IFRAC = 0, this entry is not required. If IFRAC = 1, enter the number of radionuclides to be considered.

Data Items 29, 30, and 31 are entered in sequence for each radionuclide

(29) Item: Identification Numbers of Fractionated Fission Products
Name: IDFRAC (NFRAC entries required if IFRAC=1)
Remarks: If IFRAC = 0, this data is not required. If IFRAC = 1, enter the identification number for each fractionated fission product using the identification numbers given below.

Table 16. Input data required by FIIDOS (Continued).

(1)	SE-79	(2)	BR-82	(3)	BR-83	(4)	KR-83M	(5)	BR-84
(6)	BR-85	(7)	KR-85	(8)	KR-85M	(9)	RB-86	(10)	KR-87
(11)	RB-87	(12)	KR-88	(13)	RB-88	(14)	KR-89	(15)	RB-89
(16)	SR-89	(17)	RB-90	(18)	RB-90M	(19)	SR-90	(20)	Y-90
(21)	RB-91	(22)	SR-91	(23)	Y-91	(24)	Y-91M	(25)	SR-92
(26)	Y-92	(27)	SR-93	(28)	Y-93	(29)	ZR-93	(30)	NB-93M
(31)	Y-94	(32)	Y-95	(33)	ZR-95	(34)	NB-95	(35)	Y-96
(36)	ZR-97	(37)	NB-97	(38)	NB-97M	(39)	NB-98M	(40)	MO-99
(41)	TC-99	(42)	TC-99M	(43)	MD-101	(44)	TC-101	(45)	MO-102
(46)	TC-102	(47)	TC-103	(48)	RU-103	(49)	RH-103M	(50)	TC-104
(51)	MO-105	(52)	TC-106	(53)	RU-105	(54)	RH-105	(55)	RH-105M
(56)	RU-106	(57)	RH-106	(58)	PD-107	(59)	RH-109	(60)	PD-109
(61)	AG-109M	(62)	AG-110M	(63)	AG-111	(64)	CD-113M	(65)	CD-115M
(66)	SN-123	(67)	SB-124	(68)	SN-125	(69)	SB-125	(70)	TE-125M
(71)	SN-126	(72)	SB-126	(73)	SB-127	(74)	TE-127	(75)	TE-127M
(76)	SB-129	(77)	TE-129	(78)	TE-129M	(79)	I-129	(80)	SN-130
(81)	SB-130M	(82)	I-130	(83)	SB-131	(84)	TE-131	(85)	TE-131M
(86)	I-131	(87)	XE-131M	(88)	SB-132	(89)	SB-132M	(90)	TE-132
(91)	I-132	(92)	SB-133	(93)	TE-133	(94)	TE-133M	(95)	I-133
(96)	XE-133	(97)	XE-133M	(98)	TE-134	(99)	I-134	(100)	CS-134
(101)	CS-134M	(102)	I-135	(103)	XE-135	(104)	XE-135M	(105)	CS-135
(106)	CS-136	(107)	XE-137	(108)	CS-137	(109)	BA-137M	(110)	XE-138
(111)	CS-138	(112)	CS-139	(113)	BA-139	(114)	CS-140	(115)	BA-140
(116)	LA-140	(117)	BA-141	(118)	LA-141	(119)	CE-141	(120)	BA-142
(121)	LA-142	(122)	LA-143	(123)	CE-143	(124)	PR-143	(125)	CE-144
(126)	PR-144	(127)	PR-144M	(128)	CE-145	(129)	PR-145	(130)	CE-146
(131)	PR-146	(132)	CE-147	(133)	PR-147	(134)	ND-147	(135)	PM-147
(136)	PR-148	(137)	PM-148	(138)	PM-148M	(139)	PM-149	(140)	PM-151
(141)	SM-151	(142)	EU-152	(143)	SM-153	(144)	EU-154	(145)	EU-155
(146)	EU-156	(147)	TB-160	(148)	HO-166M	(149)	NOT USED	(150)	NOT USED

(30) Item: Remaining Fractions of Fission Product Inventory

Name: FFRAC (NFRAC entries required if IFRAC=1)

Remarks: If IFRAC = 0, this data is not required. If IFRAC = 1, enter the fraction of the basic fission product inventory that is present in the fractionated fallout material which corresponds to each identified fission product.

Table 16. Input data required by FIIDOS (Concluded).

(31)	Item:	Gamma-ray Emission Spectrum for Fractionated Fission Products
	Name:	GAMMA (18 entries for each NFRAC fission products, required if IFRAC = 1)
	Remarks:	If IFRAC = 0, this data is not required. If IFRAC = 1, enter the gamma-ray emission spectrum in units of γ sec^{-1} Ci^{-1} in the ORIGEN2 18-energy group structure which corresponds to each identified fission product.
(32)	Item:	Index for Plutonium Excretion
	Name:	IPLUT
	Remarks:	The index parameter IPLUT may have the integer value of 0 or 1. If IPLUT = 0, the plutonium excretion calculations are not included in the program output. If IPLUT = 1, plutonium excretion calculation is done for each exposure, with all times normalized to the shot time.
(33)	Item:	Number of Times to Calculate Pu-239 Excretion
	Name:	NPLUT
	Remarks:	The maximum value for NPLUT is 10. This data is not required if IPLUT = 0.
(34)	Item:	User Specified Times for Pu-239 Excretion
	Name:	TYRS (NPLUT entries required if IPLUT=1)
	Remarks:	FIIDOS normalizes all excretions to the shot time so that excretions from multiple exposures may be added for a total excretion value from all exposures. This data is not required if IPLUT = 0.

Standard FIIDOS output includes the user-supplied input data and the total calculated organ doses. The input data produced include the data given in Table 16. The calculated doses for each organ include the doses from fission products, activation products, and actinide elements and the total dose from all radionuclides. If specified in the input file, the Pu-239 urine excretion amounts are included in the output for the specified times.

Optional FIIDOS outputs include five separate options under user control:

- first option provides details on the radiological contamination scaling factor, including, as appropriate, either the relative gamma-ray emission spectrum at the time of measurement or the measured activity of radiological material;
- second option produces a listing of the relative radiological inventories for fission products, activation products, and actinide elements, at the time of exposure;
- third option produces a listing of the dose to each organ from each radionuclide;
- fourth option indicates whether the intermediate results from multiple exposure will be produced; and,
- fifth option produces a secondary output file in tabular format with all the intermediate and total doses, convenient for importing into a spreadsheet application for further processing.

If no intermediate results are requested, the output from the first three options is suppressed.

The collective output provided by FIIDOS when all four options pertaining to the main output file are exercised is shown in Figure 16. The example problem is illustrated in Figure 16 is a 15-minute inhalation exposure to depleted fallout 4 hours after the detonation. This fallout scenario is characterized by a radiation intensity of 10 R hr^{-1} at H+1 hour. The weapon yield is 10 kT, all from U-235 fast fission. No activation products or actinides are considered. The fallout is considered to be depleted of the fission gases krypton and xenon, but no other fractionation effects are considered. The secondary file output from this run is not reproduced herein.

```
                          fiidos   input
title:      FIIDOS VERSION 4.3 EXAMPLE PROBLEM ONE
--------------------------------------------------------------------------------
itpm    problem type            single/integrated    1/2         1
iout1   print spectrum              no/yes           0/1         1
iout2   print inventory             no/yes           0/1         1
iout3   print dose inventory        no/yes           0/1         1
iout4   print intermediate doses    no/yes           0/1         1
iout5   print dose tables           no/yes           0/1         1

nmeas   number of measurement calculations                       1
itrm    rad measurement indices                                  1
tmeas   time of rad measurements                               1.00
rimes   rad intensity (itrm=1-3); index nuclide (itrm=6)       10.0
itmi    meas index tis/air/fb/fb-man/fb-man 1/2/3/4/5            2
actmes  activity measurement (itrm=4-6)                        0.00

nexp    number of exposure calculations                          1
texp    exposed @ h+(hr)                                       4.00
icmeas  rad exposure to measurement indices (re-sorted)          1
dur     duration (hr)                                         0.250
br      breathing rate (m**3/hr)                               1.20
kfac    resuspension factors (m**-1)                          1.000E-05
itdcf   dose conversion factor set index 1/2                     1

iactp   activation products         no/yes           0/1         0
iactin  actinides                   no/yes           0/1         0
ikrxer  noble gases removed         no/yes           0/1         1
ifrac   fractionation               no/yes           0/1         0

iplut   plutonium bioassay          no/yes           0/1         1
nplut   number of entries for plutonium bioassay                 3
tyrs    times after shot for Pu conc in urine                  50.0      55.0      60.0


                          fiidos output


  time of measurement       1.00     hours
spec(j)-relative gamma emission spectrum at time of measurement
                  (gamma/hr per 10**14 fissions)
```

group #	fission product	activation product	actinides	total	noble gases	fractionated
1	4.140E+11	0.00	0.00	4.140E+11	1.260E+11	0.00
2	1.444E+12	0.00	0.00	1.444E+12	3.149E+10	0.00
3	1.096E+12	0.00	0.00	1.096E+12	3.453E+10	0.00
4	7.883E+10	0.00	0.00	7.883E+10	5.261E+08	0.00
5	7.442E+11	0.00	0.00	7.442E+11	2.103E+08	0.00
6	1.790E+12	0.00	0.00	1.790E+12	2.686E+09	0.00
7	4.983E+12	0.00	0.00	4.983E+12	7.058E+11	0.00
8	6.026E+12	0.00	0.00	6.026E+12	7.673E+11	0.00
9	8.902E+12	0.00	0.00	8.902E+12	1.444E+11	0.00

Figure 16. FIIDOS output - all options.

```
   10      1.320E+13          0.00             0.00            1.320E+13         2.120E+11        0.00
   11      9.872E+12          0.00             0.00            9.872E+12         1.021E+11        0.00
   12      2.386E+12          0.00             0.00            2.386E+12         2.961E+11        0.00
   13      1.840E+12          0.00             0.00            1.840E+12         6.322E+11        0.00
   14      9.412E+11          0.00             0.00            9.412E+11         1.060E+11        0.00
   15      3.465E+11          0.00             0.00            3.465E+11         3.973E+09        0.00
   16      4.501E+09          0.00             0.00            4.501E+09         7.963E+05        0.00
   17       5.65              0.00             0.00             5.65              0.00            0.00
   18       0.00              0.00             0.00             0.00              0.00            0.00

       sf       scaling factor(10**14 fissions [per m**2, m**3])  2.54

 inventory of 150 fission products, 20 activation products, 20 actinides (ci/10**14 fissions)
           1           2           3           4           5           6           7           8           9          10
   0   1.541E-12   2.429E-08   4.277E-04    0.00       6.631E-05   6.437E-27    0.00        0.00       1.082E-09    0.00
  10   2.724E-17    0.00       2.697E-03    0.00       2.019E-06   1.902E-05   8.465E-20   1.498E-18   1.151E-07   5.839E-09
  20    0.00       2.357E-03   4.521E-06   1.425E-03   4.043E-03   3.582E-03   4.910E-11   2.493E-03   5.629E-13   5.736E-17
  30   1.545E-05   2.599E-08   2.182E-05   6.677E-08    0.00       1.588E-03   1.503E-03   1.507E-03   2.669E-06   4.352E-04
  40   1.951E-13   1.435E-04   1.271E-06   1.273E-05   4.907E-08   4.946E-08    0.00       1.795E-05   1.696E-05   4.234E-06
  50    0.00       1.632E-11   7.627E-04   7.446E-05   2.172E-04   3.118E-07   3.118E-07   2.536E-14    0.00       2.590E-05
  60   2.590E-05   1.668E-13   1.208E-06   8.930E-12   5.693E-09   2.340E-09   1.151E-11   1.526E-07   1.035E-08   4.545E-12
  70   5.087E-13   2.456E-09   1.507E-05   2.847E-06   2.488E-09   4.143E-04   4.019E-04   1.248E-06   8.066E-15   1.752E-21
  80    0.00       3.657E-08   2.825E-05   2.553E-04   7.629E-05   7.388E-05    0.00       5.924E-19   3.320E-27   2.983E-04
  90   2.405E-04   3.688E-30   2.152E-04   9.516E-04   1.475E-03    0.00        0.00       8.914E-04   4.685E-03   1.356E-11
 100   2.012E-08   3.235E-03    0.00        0.00       1.029E-13   2.441E-07    0.00       1.250E-07   1.180E-07    0.00
 110   6.272E-04   3.606E-09   3.704E-03    0.00       1.011E-04   6.867E-06   1.140E-05   4.208E-03   1.835E-05   2.460E-08
 120   3.458E-03   1.003E-06   8.401E-04   6.766E-06   4.031E-06   4.025E-06   5.648E-08   4.559E-25   2.094E-03   3.084E-07
 130   8.768E-05    0.00       2.565E-07   4.171E-05   4.610E-09   5.690E-33   1.301E-11   4.658E-12   7.830E-05   6.924E-05
 140   2.353E-10   7.886E-17   1.711E-05   9.328E-14   5.155E-09   7.433E-08   2.476E-13   2.434E-19    0.00        0.00
   0    0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
  10    0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
   0    0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
  10    0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00

       acttot   total activity(curies/10**14 fissions)          5.214E-02

                 dose commitment in rem from each radionuclide

 iso #   adrenals    bone surf   brain       breast      st wall     si wall     uli wall    lli wall    kidneys     liver       et region   lung
   1     6.518E-15   6.518E-15   6.518E-15   6.518E-15   7.822E-15   9.125E-15   2.303E-14   5.649E-14   2.216E-13   9.560E-14   2.477E-13   8.691E-13
   2     1.781E-10   1.713E-10   1.439E-10   1.439E-10   2.466E-10   1.850E-10   2.329E-10   2.877E-10   1.507E-10   1.644E-10   1.028E-08   1.987E-09
   3     4.825E-08   4.825E-08   4.825E-08   4.825E-08   1.206E-06   6.514E-08   7.840E-08   5.910E-08   4.825E-08   4.825E-08   1.037E-05   3.739E-06
   4      0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
   5     8.977E-09   9.351E-09   9.351E-09   7.855E-09   3.553E-07   1.309E-08   1.010E-08   7.668E-09   8.416E-09   8.229E-09   1.795E-06   2.244E-07
   6      0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
   7      0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
   8      0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
   9     3.357E-11   1.221E-10   3.357E-11   3.052E-11   3.662E-11   3.357E-11   4.578E-11   7.019E-11   3.357E-11   3.357E-11   1.129E-10   3.357E-11
  10      0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
  11     4.303E-19   1.690E-18   4.303E-19   4.303E-19   4.533E-19   4.303E-19   6.147E-19   9.988E-19   4.303E-19   4.303E-19   1.844E-18   4.533E-19
  12      0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
  13     1.749E-07   1.977E-07   1.825E-07   1.673E-07   8.366E-06   3.575E-07   2.053E-07   1.673E-07   1.749E-07   1.673E-07   2.738E-05   2.510E-06
```

Figure 16. FIIDOS output - all options (Continued).

14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	1.367E-10	2.050E-10	1.480E-10	1.196E-10	3.075E-09	1.765E-10	1.423E-10	1.310E-10	1.253E-10	1.196E-10	3.075E-08	1.480E-09
16	1.234E-07	3.755E-06	1.234E-07	1.234E-07	1.931E-07	2.414E-07	1.180E-06	3.165E-06	1.234E-07	1.234E-07	1.234E-06	1.395E-07
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	2.532E-09	1.558E-06	2.532E-09	2.532E-09	2.662E-09	2.792E-09	8.766E-09	2.500E-08	2.532E-09	2.532E-09	1.007E-08	2.630E-09
20	8.399E-15	2.470E-13	8.399E-15	8.399E-15	7.081E-11	1.647E-10	9.058E-10	2.141E-09	8.399E-15	2.470E-13	3.623E-10	1.285E-09
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	2.459E-06	1.196E-05	2.459E-06	1.861E-06	1.263E-05	1.861E-05	5.516E-05	5.849E-05	2.526E-06	2.260E-06	2.526E-04	4.519E-06
23	6.120E-10	8.032E-09	2.040E-10	6.629E-10	3.825E-08	9.562E-08	5.737E-07	1.657E-06	3.442E-10	8.159E-09	8.159E-07	8.797E-06
24	5.628E-08	4.422E-08	3.939E-08	3.618E-08	6.432E-07	3.055E-07	3.939E-07	3.899E-07	5.628E-08	4.824E-08	1.085E-05	2.010E-06
25	2.394E-06	1.368E-05	2.394E-06	1.938E-06	1.368E-05	2.508E-05	7.525E-05	5.359E-05	2.508E-06	2.280E-06	2.622E-04	5.701E-06
26	2.223E-07	2.021E-07	1.515E-07	1.616E-07	5.455E-05	7.577E-05	1.313E-04	6.466E-05	2.627E-07	2.324E-07	1.313E-04	7.072E-05
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	1.195E-07	1.336E-07	7.735E-08	9.141E-08	3.516E-05	6.961E-05	2.180E-04	2.391E-04	1.477E-07	1.477E-07	1.055E-04	1.125E-04
29	2.381E-16	7.938E-12	3.334E-16	1.175E-16	1.905E-16	4.763E-16	2.381E-15	6.985E-15	9.366E-17	7.938E-17	1.524E-14	4.604E-14
30	1.618E-20	8.735E-20	7.602E-21	1.618E-20	3.559E-20	6.955E-20	3.882E-19	1.132E-18	1.181E-19	1.601E-19	6.632E-18	2.265E-17
31	4.357E-10	3.791E-10	3.878E-10	3.355E-10	6.971E-08	1.786E-08	4.357E-09	5.228E-10	3.834E-10	3.311E-10	2.876E-07	3.616E-08
32	3.885E-13	3.079E-13	3.005E-13	3.592E-13	5.498E-11	8.063E-12	1.393E-12	4.618E-13	2.492E-13	3.005E-13	3.225E-10	3.738E-11
33	9.231E-07	8.001E-06	2.339E-07	7.385E-07	4.739E-07	4.862E-07	9.847E-07	2.154E-06	4.246E-07	6.154E-07	6.770E-06	1.969E-05
34	1.036E-09	5.272E-10	1.036E-10	1.092E-09	6.402E-10	7.155E-10	1.525E-09	3.201E-09	4.142E-10	9.226E-10	1.450E-08	2.260E-08
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	2.195E-06	3.808E-06	1.389E-06	1.702E-06	2.240E-05	5.824E-05	2.105E-04	3.001E-04	2.509E-06	2.419E-06	3.718E-04	1.613E-04
37	1.017E-07	8.053E-08	6.782E-08	6.782E-08	5.510E-06	4.111E-06	3.137E-06	6.782E-07	1.060E-07	8.901E-08	4.662E-05	8.477E-06
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	2.823E-07	3.068E-07	8.837E-08	2.577E-07	2.577E-06	6.382E-06	3.068E-05	7.119E-05	3.437E-07	3.927E-07	4.909E-05	7.978E-05
41	5.336E-17	5.336E-17	5.336E-17	5.336E-17	3.081E-15	6.602E-16	4.181E-15	1.210E-14	5.336E-17	7.152E-17	4.346E-14	1.870E-13
42	7.687E-09	1.376E-08	4.855E-09	4.855E-09	6.473E-08	8.496E-08	1.699E-07	1.173E-07	9.709E-09	8.496E-09	1.780E-06	3.762E-07
43	4.302E-11	3.944E-11	3.944E-11	3.227E-11	3.191E-09	8.605E-10	2.366E-10	3.944E-11	3.585E-11	3.227E-11	3.191E-08	3.550E-09
44	9.694E-11	1.005E-10	8.976E-11	7.181E-11	1.185E-08	2.262E-09	4.668E-10	7.540E-11	8.258E-11	7.540E-11	1.652E-07	1.580E-08
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48	2.025E-07	8.607E-08	1.823E-08	2.025E-07	1.316E-07	1.772E-07	5.569E-07	1.468E-06	7.088E-08	1.671E-07	3.949E-06	1.114E-05
49	1.004E-12	2.344E-12	6.218E-13	9.566E-13	4.066E-09	2.487E-09	1.435E-09	2.248E-10	8.131E-13	1.483E-12	4.400E-09	8.609E-09
50	2.150E-10	1.911E-10	1.911E-10	1.672E-10	1.791E-08	4.180E-09	1.146E-09	2.030E-10	1.911E-10	1.672E-10	9.195E-08	8.956E-09
51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
53	1.914E-07	1.850E-07	1.248E-07	1.355E-07	4.087E-06	6.238E-06	1.355E-05	1.140E-05	2.366E-07	2.065E-07	5.377E-05	1.957E-05
54	1.092E-08	1.113E-08	6.090E-09	9.030E-09	1.659E-07	3.780E-07	1.638E-06	3.150E-06	1.050E-08	1.113E-08	4.410E-06	5.460E-06
55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
56	9.671E-09	4.748E-09	2.198E-09	9.671E-09	1.143E-08	1.846E-08	9.671E-08	2.901E-07	4.132E-09	8.089E-09	1.934E-07	4.660E-06
57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
58	2.074E-20	3.075E-19	2.074E-20	2.074E-20	3.647E-18	9.296E-18	5.506E-17	1.645E-16	1.359E-17	7.151E-18	9.296E-17	3.432E-15
59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
60	1.680E-10	6.208E-10	7.303E-11	1.461E-10	1.388E-07	2.921E-07	1.022E-06	1.388E-06	2.337E-09	1.315E-09	1.826E-06	1.826E-06
61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
62	4.185E-14	1.693E-14	3.433E-15	4.468E-14	2.304E-14	9.405E-15	1.505E-14	2.445E-14	1.552E-14	3.856E-14	1.505E-13	3.339E-13
63	2.181E-10	1.601E-10	8.178E-11	2.113E-10	5.793E-09	1.431E-08	8.178E-08	2.147E-07	1.431E-10	1.908E-09	1.056E-07	4.430E-07
64	5.289E-13	5.289E-13	5.289E-13	5.289E-13	5.540E-13	6.044E-13	9.066E-13	1.587E-12	8.562E-11	1.486E-11	1.058E-11	4.281E-11
65	1.429E-11	1.268E-11	1.188E-11	1.349E-11	6.101E-11	1.268E-10	6.903E-10	1.926E-09	1.766E-09	3.211E-10	9.151E-10	9.311E-09

Figure 16. FIIDOS output - all options (Continued).

66	7.920E-12	1.584E-10	7.260E-12	7.920E-12	2.244E-11	4.620E-11	2.574E-10	7.260E-10	7.260E-12	7.920E-12	4.290E-10	4.092E-09
67	4.546E-13	6.170E-13	7.469E-14	4.546E-13	3.182E-13	3.897E-13	1.266E-12	3.150E-12	2.013E-13	4.222E-13	5.845E-12	1.429E-11
68	3.961E-10	2.755E-09	1.507E-10	3.788E-10	1.894E-09	4.305E-09	2.368E-08	6.457E-08	2.497E-10	3.401E-10	2.152E-08	8.610E-08
69	3.504E-10	2.540E-09	8.468E-11	2.920E-10	2.015E-10	1.752E-10	3.796E-10	8.468E-10	1.606E-10	4.088E-10	3.212E-09	9.344E-09
70	6.153E-15	7.563E-13	2.564E-15	6.410E-15	1.038E-14	2.051E-14	1.013E-13	2.820E-13	3.077E-14	6.666E-15	7.948E-13	3.718E-12
71	1.148E-13	4.017E-13	5.452E-14	9.039E-14	6.887E-14	6.887E-14	1.420E-13	3.156E-13	6.600E-14	8.752E-14	5.452E-13	2.582E-12
72	5.471E-11	4.848E-11	1.108E-11	5.333E-11	5.125E-11	9.696E-11	2.424E-10	5.402E-10	2.701E-11	4.987E-11	1.662E-09	1.177E-09
73	3.399E-08	5.949E-08	1.275E-08	3.187E-08	1.062E-07	2.635E-07	1.232E-06	3.272E-06	2.507E-08	4.079E-08	3.442E-06	5.099E-06
74	8.831E-11	2.087E-10	8.831E-11	8.831E-11	7.225E-09	1.284E-08	3.934E-08	4.094E-08	2.729E-10	9.633E-11	1.044E-07	7.064E-08
75	4.280E-12	7.016E-10	3.157E-12	4.069E-12	7.016E-12	1.473E-11	1.123E-10	3.789E-10	5.262E-11	4.069E-12	6.876E-10	4.139E-09
76	1.869E-07	2.453E-07	1.285E-07	1.402E-07	3.271E-06	6.075E-06	1.285E-05	8.178E-06	2.220E-07	2.103E-07	4.323E-05	1.145E-05
77	4.987E-09	5.780E-09	4.307E-09	4.194E-09	1.473E-06	1.043E-06	7.140E-07	1.360E-07	5.894E-09	4.760E-09	8.160E-06	2.040E-06
78	3.485E-09	1.197E-07	2.218E-09	3.238E-09	9.856E-09	2.358E-08	1.408E-07	3.872E-07	3.379E-08	3.168E-09	2.499E-07	1.725E-06
79	1.365E-17	4.549E-17	1.592E-17	1.251E-17	1.638E-17	1.365E-17	2.502E-17	4.549E-17	1.319E-17	1.342E-17	3.185E-16	1.979E-17
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82	3.610E-11	5.879E-11	6.498E-11	3.300E-11	1.341E-10	3.919E-11	4.229E-11	5.054E-11	3.300E-11	3.404E-11	8.457E-09	8.354E-11
83	2.310E-09	2.231E-09	1.832E-09	1.673E-09	1.115E-07	5.019E-08	2.470E-08	1.195E-08	2.071E-09	1.832E-09	8.763E-07	1.354E-07
84	5.617E-09	5.401E-09	4.104E-09	4.248E-09	6.265E-07	2.016E-07	7.921E-08	5.905E-08	4.753E-09	4.537E-09	5.113E-06	7.921E-07
85	1.786E-07	3.442E-07	9.466E-08	1.506E-07	6.239E-07	1.377E-06	4.518E-06	8.175E-06	2.367E-07	1.807E-07	2.151E-05	1.076E-05
86	5.209E-08	1.438E-07	1.688E-07	6.667E-08	1.500E-07	4.792E-08	6.459E-08	1.063E-07	4.584E-08	5.000E-08	9.792E-06	1.771E-07
87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90	2.019E-06	3.197E-06	8.413E-07	1.935E-06	3.197E-06	9.254E-06	3.449E-05	7.908E-05	1.767E-06	1.935E-06	1.430E-04	8.413E-05
91	1.085E-07	1.289E-07	1.289E-07	8.819E-08	8.819E-07	1.221E-07	1.221E-07	1.153E-07	1.018E-07	9.497E-08	1.832E-05	3.324E-07
92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93	4.855E-09	4.734E-09	4.370E-09	3.823E-09	3.095E-07	7.890E-08	1.092E-07	1.578E-07	4.309E-09	4.066E-09	3.277E-06	3.823E-07
94	2.093E-07	1.825E-07	1.530E-07	1.476E-07	5.904E-06	3.757E-06	4.294E-06	3.757E-06	2.147E-07	1.825E-07	5.368E-05	7.515E-06
95	8.737E-07	1.290E-06	1.415E-06	8.321E-07	4.992E-06	9.569E-07	1.248E-06	1.581E-06	8.321E-07	8.321E-07	1.664E-04	2.455E-06
96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
98	1.810E-07	1.609E-07	1.257E-07	1.232E-07	4.022E-06	3.268E-06	2.765E-06	6.536E-07	2.011E-07	1.659E-07	4.777E-05	6.285E-06
99	1.083E-06	1.176E-06	1.176E-06	8.324E-07	1.321E-05	1.216E-06	1.150E-06	9.513E-07	9.778E-07	9.249E-07	1.982E-04	5.021E-06
100	3.824E-12	3.671E-12	2.868E-12	2.638E-12	3.441E-12	3.824E-12	3.709E-12	4.206E-12	3.594E-12	3.633E-12	8.412E-12	3.250E-12
101	2.043E-12	2.270E-12	1.816E-12	1.646E-12	1.362E-11	2.270E-12	2.440E-12	2.270E-12	1.930E-12	1.986E-12	3.802E-10	1.930E-11
102	1.916E-06	2.646E-06	2.829E-06	1.734E-06	1.004E-05	2.099E-06	2.372E-06	2.464E-06	1.825E-06	1.825E-06	3.650E-04	5.110E-06
103	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
104	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
105	2.698E-15	2.698E-15	2.698E-15	2.698E-15	2.756E-15	2.698E-15	2.901E-15	3.772E-15	2.698E-15	2.698E-15	5.803E-15	2.756E-15
106	1.101E-08	1.101E-08	8.259E-09	7.571E-09	1.032E-08	1.101E-08	1.101E-08	1.170E-08	1.032E-08	1.032E-08	1.308E-07	9.636E-09
107	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
108	2.397E-08	2.326E-08	2.009E-08	1.903E-08	2.256E-08	2.397E-08	2.432E-08	2.820E-08	2.291E-08	2.291E-08	4.582E-08	2.185E-08
109	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
110	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
111	1.026E-07	1.079E-07	1.079E-07	8.668E-08	2.123E-06	1.362E-07	1.114E-07	8.491E-08	9.552E-08	9.198E-08	1.610E-05	6.368E-07
112	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
113	2.298E-07	1.567E-06	2.298E-07	2.194E-07	1.358E-05	1.024E-05	2.507E-05	5.746E-06	2.298E-07	2.298E-07	5.223E-05	3.761E-06
114	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
115	8.269E-07	7.698E-06	5.417E-07	3.421E-07	7.698E-07	1.939E-06	1.140E-05	3.707E-05	7.128E-07	4.847E-07	2.452E-05	5.702E-07
116	2.711E-08	2.517E-08	1.143E-08	2.130E-08	8.908E-08	2.130E-07	6.778E-07	1.297E-06	2.517E-08	7.359E-08	2.711E-06	7.746E-07
117	5.142E-10	2.475E-09	5.142E-10	4.178E-10	2.057E-08	1.028E-08	3.214E-08	1.543E-08	5.142E-10	4.821E-10	1.607E-07	9.320E-09

Figure 16. FIIDOS output - all options (Continued).

118	2.136E-07	1.543E-06	1.543E-07	1.780E-07	4.035E-05	5.815E-05	1.056E-04	6.171E-05	1.899E-07	2.611E-06	1.187E-04	8.426E-05
119	3.157E-08	5.175E-08	2.018E-09	3.053E-08	5.692E-08	1.294E-07	6.727E-07	1.915E-06	9.832E-09	4.140E-08	3.001E-06	1.708E-05
120	1.318E-12	2.845E-12	1.318E-12	9.020E-13	2.290E-11	1.388E-11	3.122E-11	8.327E-12	1.457E-12	1.249E-12	3.886E-10	1.527E-11
121	1.073E-06	9.266E-07	7.803E-07	7.705E-07	2.828E-05	2.341E-05	2.243E-05	6.242E-06	1.170E-06	1.268E-06	2.243E-04	2.633E-05
122	7.636E-12	1.386E-11	5.657E-12	6.222E-12	2.461E-09	5.939E-10	5.374E-10	9.051E-10	7.071E-12	5.374E-11	1.216E-08	2.404E-09
123	3.317E-07	4.265E-07	1.398E-07	3.080E-07	5.449E-06	1.279E-05	5.449E-05	1.114E-04	3.317E-07	4.265E-07	9.240E-05	1.256E-04
124	2.862E-12	4.389E-10	2.862E-12	2.862E-12	2.862E-08	7.060E-08	4.198E-07	1.164E-06	7.441E-10	3.625E-09	6.487E-07	3.625E-06
125	3.069E-08	2.274E-07	9.094E-09	3.069E-08	7.844E-08	1.933E-07	1.137E-06	3.410E-06	1.478E-08	6.593E-07	3.410E-06	4.774E-05
126	2.951E-12	2.497E-12	2.724E-12	2.384E-12	1.135E-08	2.611E-09	4.881E-10	2.611E-11	2.497E-12	2.270E-12	4.995E-08	7.378E-09
127	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
128	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
129	1.063E-08	1.299E-08	7.086E-09	8.267E-09	1.594E-05	2.716E-05	6.495E-05	5.019E-05	2.008E-08	2.598E-08	7.086E-05	4.842E-05
130	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
131	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
132	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
133	4.413E-12	4.702E-12	3.907E-12	3.328E-12	4.051E-10	7.958E-11	2.894E-11	3.617E-11	3.473E-12	3.400E-12	4.196E-09	5.354E-10
134	4.940E-08	1.153E-07	5.763E-09	5.058E-08	1.882E-07	4.470E-07	2.352E-06	6.234E-06	2.000E-08	7.292E-08	5.881E-06	2.235E-05
135	8.971E-15	6.370E-10	3.510E-15	8.451E-15	4.290E-12	1.066E-11	6.500E-11	1.950E-10	5.070E-15	1.690E-10	2.340E-09	5.070E-09
136	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
137	2.861E-14	1.834E-14	6.969E-15	2.971E-14	1.540E-13	3.668E-13	1.834E-12	4.768E-12	1.761E-14	2.971E-14	2.347E-12	4.768E-12
138	2.233E-13	1.077E-13	1.839E-14	2.365E-13	1.314E-13	1.445E-13	3.416E-13	7.751E-13	8.276E-14	1.971E-13	2.759E-12	5.124E-12
139	1.745E-09	2.871E-09	6.183E-10	1.590E-09	3.754E-07	8.833E-07	4.637E-06	1.016E-05	1.435E-09	5.742E-09	5.079E-06	1.038E-05
140	2.734E-08	3.515E-08	1.289E-08	2.343E-08	3.320E-07	7.616E-07	3.124E-06	5.468E-06	2.929E-08	3.124E-08	7.030E-06	5.468E-06
141	3.251E-15	7.299E-10	1.393E-15	1.128E-15	6.370E-14	1.593E-13	9.953E-13	2.986E-12	1.725E-15	1.924E-10	7.299E-12	2.057E-11
142	1.067E-16	4.225E-16	2.024E-17	2.891E-17	3.781E-17	4.003E-17	5.115E-17	3.336E-17	7.116E-17	6.004E-16	4.670E-17	1.379E-16
143	2.653E-09	3.666E-08	9.166E-10	2.171E-09	6.271E-08	1.495E-07	7.236E-07	1.495E-06	2.123E-09	4.052E-08	1.351E-06	2.123E-06
144	1.105E-13	1.079E-12	2.105E-14	3.157E-14	3.946E-14	4.209E-14	5.525E-14	4.472E-14	7.629E-14	8.945E-13	7.366E-14	2.631E-13
145	2.762E-10	1.745E-08	4.071E-11	6.107E-11	9.305E-11	1.003E-10	1.745E-10	2.617E-10	2.036E-10	5.380E-09	8.433E-10	2.762E-09
146	1.027E-09	2.935E-09	1.824E-10	8.594E-10	1.069E-09	2.033E-09	7.546E-09	1.908E-08	1.488E-09	3.983E-09	2.515E-08	4.821E-08
147	1.187E-14	9.777E-14	2.095E-15	8.380E-15	6.076E-15	7.682E-15	1.955E-14	4.679E-14	9.777E-15	3.771E-14	1.117E-13	3.282E-13
148	1.030E-18	4.942E-18	1.647E-19	2.197E-19	5.079E-19	3.501E-19	4.324E-19	2.540E-19	6.452E-19	4.187E-18	2.814E-19	8.237E-19
149	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
150	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 16. FIIDOS output - all options (Continued).

20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

iso #	muscle	ovaries	pancreas	r marrow	skin	spleen	testes	thymus	thyroid	uterus	ubld wall	eff dose
1	6.518E-15	1.217E-14	3.389E-14	6.518E-15	6.518E-15	3.780E-14	1.955E-14	6.518E-15	6.518E-15	6.518E-15	7.387E-15	1.217E-13
2	1.576E-10	1.918E-10	1.850E-10	1.644E-10	1.028E-10	1.644E-10	1.302E-10	2.055E-10	1.713E-10	1.781E-10	1.781E-10	6.097E-10
3	4.825E-08	4.825E-08	4.945E-08	4.825E-08	4.825E-08	4.825E-08	4.825E-08	4.825E-08	4.825E-08	4.825E-08	5.549E-08	8.443E-07
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	9.538E-09	7.668E-09	1.365E-08	8.977E-09	7.294E-09	1.066E-08	6.546E-09	1.085E-08	9.912E-09	7.668E-09	7.107E-09	1.141E-07
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	3.357E-11	3.357E-11	3.357E-11	6.103E-11	3.052E-11	3.357E-11	3.357E-11	3.357E-11	3.357E-11	3.357E-11	4.272E-11	3.967E-11
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	4.303E-19	4.303E-19	4.303E-19	8.452E-19	4.303E-19	4.303E-19	4.303E-19	4.303E-19	4.303E-19	4.303E-19	5.762E-19	5.839E-19
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	1.825E-07	1.673E-07	2.130E-07	1.825E-07	1.673E-07	1.901E-07	1.597E-07	1.977E-07	1.901E-07	1.673E-07	1.597E-07	2.130E-06
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	1.480E-10	1.082E-10	2.221E-10	1.594E-10	1.082E-10	1.708E-10	9.110E-11	1.822E-10	1.594E-10	1.082E-10	1.025E-10	1.367E-09
16	1.234E-07	1.234E-07	1.234E-07	3.004E-06	1.234E-07	1.234E-07	1.234E-07	1.234E-07	1.234E-07	1.234E-07	4.238E-07	7.510E-07
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	2.532E-09	2.532E-09	2.532E-09	6.818E-07	2.532E-09	2.532E-09	2.532E-09	2.532E-09	2.532E-09	2.532E-09	5.520E-09	1.007E-07
20	8.399E-15	8.564E-15	8.399E-15	2.470E-13	8.399E-15	8.399E-15	8.399E-15	8.399E-15	8.399E-15	8.399E-15	3.952E-14	3.129E-10
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	2.658E-06	4.785E-06	2.658E-06	1.130E-05	1.927E-06	2.326E-06	1.927E-06	2.592E-06	2.526E-06	3.522E-06	1.329E-05	1.861E-05
23	3.697E-10	3.442E-10	4.972E-10	8.159E-09	2.677E-10	5.100E-10	1.785E-10	7.394E-10	3.570E-10	2.422E-10	2.550E-10	1.135E-06
24	5.628E-08	1.045E-07	1.407E-07	6.030E-08	2.492E-08	9.245E-08	5.226E-09	6.432E-08	4.422E-08	8.441E-08	2.573E-08	6.030E-07
25	2.622E-06	3.877E-06	2.850E-06	9.236E-06	2.052E-06	2.508E-06	1.938E-06	2.736E-06	2.508E-06	3.307E-06	1.710E-05	2.052E-05
26	2.627E-07	8.385E-07	4.041E-07	2.930E-07	1.212E-07	2.829E-07	5.556E-08	2.627E-07	1.717E-07	5.455E-07	2.223E-07	2.930E-05
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	1.547E-07	6.117E-07	1.758E-07	1.899E-07	6.891E-08	1.336E-07	4.992E-08	1.477E-07	9.141E-08	3.305E-07	1.828E-07	4.289E-05
29	2.064E-16	7.303E-17	5.398E-17	6.350E-13	1.746E-16	6.985E-17	3.651E-17	1.048E-16	5.874E-17	3.810E-17	1.746E-16	1.588E-13

Figure 16. FIIDOS output - all options (Continued).

30	3.235E-20	9.220E-21	9.058E-21	3.235E-20	8.249E-21	1.779E-20	7.441E-21	9.705E-21	7.602E-21	7.602E-21	9.705E-21	2.912E-18
31	4.793E-10	4.313E-10	1.176E-09	4.183E-10	2.266E-10	7.843E-10	3.137E-11	6.100E-10	4.270E-10	3.660E-10	1.176E-10	2.004E-08
32	3.592E-13	2.052E-13	7.330E-13	3.225E-13	1.759E-13	5.278E-13	2.199E-14	5.791E-13	3.592E-13	1.686E-13	6.890E-14	1.906E-11
33	4.246E-07	4.431E-07	6.154E-07	1.477E-06	2.400E-07	5.723E-07	1.046E-07	8.616E-07	3.939E-07	2.646E-07	1.969E-07	3.077E-06
34	4.896E-10	6.779E-10	7.720E-10	6.402E-10	2.448E-10	7.532E-10	7.532E-11	1.262E-09	4.331E-10	3.201E-10	2.260E-10	3.389E-09
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	2.733E-06	1.075E-05	2.777E-06	4.928E-06	1.299E-06	2.240E-06	1.210E-06	2.598E-06	1.658E-06	5.376E-06	3.584E-06	6.272E-05
37	1.060E-07	2.331E-07	2.331E-07	1.102E-07	4.663E-08	1.568E-07	1.272E-08	1.144E-07	7.630E-08	1.780E-07	5.510E-08	3.094E-06
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	2.455E-07	1.043E-06	2.700E-07	3.314E-07	1.056E-07	2.455E-07	1.068E-07	3.437E-07	1.473E-07	4.909E-07	3.559E-07	1.596E-05
41	5.336E-17	5.336E-17	5.336E-17	5.336E-17	5.336E-17	5.336E-17	5.336E-17	5.336E-17	1.375E-15	5.336E-17	2.201E-16	2.366E-14
42	9.709E-09	3.398E-08	1.416E-08	1.092E-08	3.641E-09	1.011E-08	2.508E-09	9.305E-09	3.236E-08	2.185E-08	1.133E-08	1.214E-07
43	4.661E-11	3.944E-11	1.183E-10	3.944E-11	2.187E-11	7.888E-11	2.653E-12	6.095E-11	4.302E-11	3.406E-11	1.111E-11	1.613E-09
44	1.077E-10	7.899E-11	2.513E-10	9.335E-11	5.027E-11	1.687E-10	1.508E-11	1.293E-10	5.386E-10	6.822E-11	3.195E-11	7.540E-09
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48	9.113E-08	1.215E-07	1.519E-07	1.164E-07	4.506E-08	1.418E-07	1.519E-08	2.430E-07	8.101E-08	5.569E-08	4.101E-08	1.570E-06
49	4.400E-12	7.175E-12	5.261E-12	1.052E-12	8.131E-13	1.913E-12	5.740E-13	8.131E-13	6.218E-13	2.726E-12	1.531E-12	1.483E-09
50	2.269E-10	2.030E-10	5.374E-10	2.030E-10	1.182E-10	3.702E-10	3.344E-11	2.985E-10	1.051E-09	1.791E-10	7.762E-11	5.613E-09
51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
53	2.366E-07	8.173E-07	3.441E-07	2.796E-07	9.894E-08	2.366E-07	5.592E-08	2.151E-07	1.463E-07	4.947E-07	2.151E-07	5.592E-06
54	1.197E-08	4.410E-08	1.239E-08	1.449E-08	6.090E-09	1.071E-08	6.300E-09	1.239E-08	7.560E-09	2.310E-08	1.827E-08	9.450E-07
55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
56	4.836E-09	2.901E-09	7.297E-09	5.803E-09	3.253E-09	7.034E-09	1.934E-09	1.143E-08	4.748E-09	2.374E-09	2.462E-09	5.803E-07
57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
58	2.074E-20	2.074E-20	2.074E-20	1.144E-19	2.074E-20	2.074E-20	2.074E-20	2.074E-20	2.074E-20	2.074E-20	2.503E-19	4.219E-16
59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
60	4.090E-10	2.191E-09	2.629E-10	3.067E-10	9.494E-11	1.972E-10	7.011E-11	1.753E-10	8.764E-11	5.258E-10	5.623E-10	3.871E-07
61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
62	1.834E-14	7.995E-15	3.057E-14	2.304E-14	9.876E-15	3.010E-14	1.129E-15	5.173E-14	1.740E-14	4.280E-15	2.822E-15	5.643E-14
63	1.636E-10	4.430E-10	1.976E-10	1.976E-10	9.881E-11	1.806E-10	8.859E-11	2.556E-10	1.261E-10	2.283E-10	1.772E-10	6.815E-08
64	5.289E-13	5.289E-13	5.289E-13	5.289E-13	5.289E-13	5.289E-13	5.289E-13	5.289E-13	5.289E-13	5.289E-13	5.289E-13	7.807E-12
65	1.268E-11	1.332E-11	1.365E-11	1.300E-11	1.220E-11	1.365E-11	1.188E-11	1.397E-11	1.252E-11	1.252E-11	1.220E-11	1.236E-09
66	7.260E-12	7.260E-12	7.920E-12	5.676E-11	7.260E-12	7.920E-12	7.260E-12	7.920E-12	7.260E-12	7.260E-12	1.188E-11	5.346E-10
67	2.241E-13	2.858E-13	3.572E-13	3.897E-13	1.266E-13	3.247E-13	5.196E-14	5.521E-13	2.111E-13	1.494E-13	1.396E-13	2.111E-12
68	2.712E-10	6.027E-10	3.229E-10	1.765E-09	1.722E-10	3.100E-10	1.335E-10	4.305E-10	2.239E-10	3.186E-10	4.735E-10	1.464E-08
69	1.752E-10	1.489E-10	2.599E-10	4.964E-10	1.022E-10	2.365E-10	6.132E-11	3.504E-10	1.606E-10	1.051E-10	9.344E-11	1.402E-09
70	4.999E-15	7.179E-15	3.718E-15	6.538E-14	2.436E-15	4.999E-15	1.923E-15	5.384E-15	3.974E-14	2.692E-15	6.025E-15	4.871E-13
71	6.743E-14	5.882E-14	8.752E-14	2.009E-13	4.591E-14	8.034E-14	3.587E-14	1.076E-13	6.600E-14	4.878E-14	4.448E-14	4.017E-13
72	3.117E-11	8.311E-11	4.294E-11	4.848E-11	1.524E-11	4.017E-11	1.039E-11	6.372E-11	2.493E-11	4.017E-11	3.117E-11	2.563E-10
73	2.889E-08	1.062E-07	3.272E-08	6.374E-08	1.445E-08	2.847E-08	1.360E-08	3.909E-08	1.955E-08	5.099E-08	4.674E-08	8.923E-07
74	9.633E-11	1.204E-10	9.633E-11	2.007E-10	8.831E-11	9.633E-11	8.831E-11	9.633E-11	3.372E-10	1.044E-10	6.583E-10	1.606E-08
75	3.718E-12	3.999E-12	3.578E-12	1.894E-10	3.017E-12	3.718E-12	2.806E-12	3.929E-12	7.016E-11	3.087E-12	8.419E-12	5.543E-10
76	2.220E-07	7.126E-07	3.154E-07	2.921E-07	1.086E-07	2.337E-07	6.542E-08	2.220E-07	1.519E-07	4.556E-07	2.921E-07	4.206E-06
77	5.440E-09	8.387E-09	8.500E-09	5.667E-09	3.854E-09	6.460E-09	3.060E-09	5.327E-09	5.667E-09	6.914E-09	1.473E-08	6.574E-07
78	2.781E-09	3.450E-09	3.027E-09	5.280E-08	2.253E-09	2.992E-09	2.077E-09	3.450E-09	4.576E-08	2.534E-09	6.688E-09	2.464E-07
79	3.412E-17	1.410E-17	1.365E-17	1.570E-17	1.570E-17	1.342E-17	1.274E-17	1.934E-17	2.275E-13	1.388E-17	4.777E-17	1.160E-14
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 16. FIIDOS output - all options (Continued).

82	6.188E-11	4.229E-11	4.641E-11	5.260E-11	3.610E-11	3.816E-11	3.300E-11	7.323E-11	1.857E-08	5.673E-11	4.848E-10	1.000E-09
83	2.390E-09	3.187E-09	5.497E-09	2.310E-09	1.195E-09	3.744E-09	3.983E-10	2.948E-09	4.939E-08	2.549E-09	1.514E-09	5.656E-08
84	5.617E-09	7.201E-09	1.224E-08	5.329E-09	2.808E-09	8.641E-09	1.224E-09	6.985E-09	4.897E-07	5.689E-09	4.681E-09	3.312E-07
85	1.893E-07	7.100E-07	2.001E-07	2.582E-07	9.036E-08	1.721E-07	8.606E-08	2.130E-07	7.745E-06	3.442E-07	3.227E-07	3.012E-06
86	1.458E-07	5.000E-08	5.625E-08	1.146E-07	7.709E-08	5.209E-08	3.959E-08	1.771E-07	4.375E-04	5.834E-08	7.709E-07	2.292E-05
87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90	1.851E-06	6.562E-06	1.935E-06	2.356E-06	9.254E-07	1.767E-06	1.010E-06	2.356E-06	5.384E-05	3.197E-06	6.898E-06	2.524E-05
91	1.357E-07	1.085E-07	1.560E-07	1.221E-07	8.819E-08	1.221E-07	8.819E-08	1.560E-07	1.289E-05	1.357E-07	1.153E-06	1.357E-06
92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93	5.644E-09	9.103E-09	1.032E-08	5.401E-09	2.731E-09	7.283E-09	1.153E-09	6.676E-09	3.277E-07	5.462E-09	7.283E-09	1.942E-07
94	2.281E-07	4.831E-07	4.562E-07	2.308E-07	1.074E-07	3.221E-07	4.831E-08	2.496E-07	6.709E-06	3.489E-07	2.523E-07	3.757E-06
95	1.331E-06	9.569E-07	9.985E-07	1.165E-06	9.153E-07	8.737E-07	7.905E-07	1.498E-06	1.706E-03	1.165E-06	2.288E-05	8.737E-05
96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
98	1.986E-07	4.525E-07	4.022E-07	2.061E-07	9.302E-08	2.765E-07	4.022E-08	2.087E-07	8.799E-07	3.520E-07	2.363E-07	2.765E-06
99	1.229E-06	9.513E-07	1.718E-06	1.110E-06	7.928E-07	1.321E-06	7.267E-07	1.453E-06	4.757E-05	1.070E-06	7.003E-06	1.031E-05
100	3.212E-12	3.824E-12	3.824E-12	3.441E-12	2.409E-12	3.594E-12	3.212E-12	3.441E-12	3.441E-12	4.206E-12	3.747E-12	3.671E-12
101	1.930E-12	2.043E-12	2.157E-12	1.873E-12	1.589E-12	1.986E-12	1.816E-12	1.986E-12	1.930E-12	2.043E-12	2.100E-12	1.476E-11
102	2.737E-06	2.099E-06	2.464E-06	2.372E-06	1.825E-06	2.099E-06	1.734E-06	3.285E-06	7.482E-04	2.646E-06	3.011E-05	4.197E-05
103	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
104	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
105	2.698E-15	2.698E-15	2.698E-15	2.698E-15	2.698E-15	2.698E-15	2.698E-15	2.698E-15	2.698E-15	2.698E-15	3.192E-15	2.872E-15
106	8.948E-09	1.101E-08	1.170E-08	9.636E-09	6.607E-09	1.032E-08	8.948E-09	1.032E-08	1.032E-08	1.170E-08	1.101E-08	1.308E-08
107	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
108	2.150E-08	2.432E-08	2.432E-08	2.220E-08	1.833E-08	2.291E-08	2.150E-08	2.220E-08	2.220E-08	2.467E-08	2.467E-08	2.361E-08
109	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
110	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
111	1.097E-07	8.491E-08	1.592E-07	1.026E-07	8.137E-08	1.274E-07	7.076E-08	1.291E-07	1.167E-07	8.491E-08	7.606E-08	7.960E-07
112	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
113	2.298E-07	2.612E-07	2.507E-07	1.567E-06	2.194E-07	2.403E-07	2.194E-07	2.298E-07	2.298E-07	2.507E-07	2.194E-06	5.746E-06
114	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
115	6.273E-07	1.910E-06	6.273E-07	5.417E-06	3.707E-07	4.847E-07	3.992E-07	4.562E-07	4.562E-07	9.694E-07	9.694E-07	4.562E-06
116	2.517E-08	1.046E-07	2.905E-08	3.486E-08	1.239E-08	2.324E-08	1.104E-08	2.905E-08	1.569E-08	5.035E-08	3.292E-08	2.905E-07
117	5.464E-10	6.106E-10	8.035E-10	2.314E-09	4.178E-10	6.428E-10	3.535E-10	6.106E-10	5.464E-10	5.464E-10	2.539E-09	1.125E-08
118	1.899E-07	3.086E-07	2.255E-07	4.391E-07	1.543E-07	2.018E-07	1.305E-07	2.018E-07	1.662E-07	2.374E-07	1.662E-07	2.730E-05
119	1.449E-08	2.225E-08	2.329E-08	1.915E-08	6.210E-09	2.277E-08	1.915E-09	3.829E-08	1.138E-08	1.035E-08	7.245E-09	2.173E-06
120	1.596E-12	2.706E-12	2.220E-12	3.053E-12	9.020E-13	1.596E-12	6.869E-13	1.665E-12	1.388E-12	2.012E-12	3.608E-12	1.804E-11
121	1.170E-06	2.536E-06	2.146E-06	1.170E-06	5.754E-07	1.561E-06	2.341E-07	1.268E-06	8.875E-07	1.951E-06	7.315E-07	1.463E-05
122	7.919E-12	1.980E-11	1.046E-11	1.301E-11	4.808E-12	8.202E-12	4.242E-12	8.485E-12	6.222E-12	1.103E-11	7.636E-12	9.333E-10
123	4.028E-07	1.895E-06	4.028E-07	4.976E-07	1.493E-07	3.317E-07	1.493E-07	4.028E-07	1.967E-07	8.530E-07	5.449E-07	2.606E-05
124	2.862E-12	2.862E-12	2.862E-12	4.389E-10	2.862E-12	2.862E-12	2.862E-12	2.862E-12	2.862E-12	2.862E-12	1.526E-11	5.343E-07
125	1.705E-08	1.069E-08	2.387E-08	1.364E-07	1.250E-08	2.387E-08	7.957E-09	3.524E-08	1.591E-08	9.322E-09	8.753E-09	6.025E-06
126	3.178E-12	2.611E-12	7.606E-12	2.724E-12	1.589E-12	5.108E-12	2.951E-13	4.200E-12	2.951E-12	2.270E-12	8.854E-13	3.405E-09
127	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
128	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
129	1.358E-08	4.960E-08	1.771E-08	1.712E-08	6.495E-09	1.299E-08	3.897E-09	1.299E-08	8.267E-09	2.893E-08	1.476E-08	1.535E-05
130	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
131	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
132	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
133	4.919E-12	3.617E-12	1.158E-11	4.051E-12	2.170E-12	7.958E-12	2.387E-13	6.222E-12	4.341E-12	2.894E-12	1.013E-12	2.170E-10

Figure 16. FIIDOS output - all options (Continued).

134	2.823E-08	8.586E-08	3.881E-08	4.117E-08	1.129E-08	3.764E-08	6.939E-09	6.116E-08	2.000E-08	3.646E-08	2.470E-08	3.176E-06
135	5.590E-15	3.770E-15	7.540E-15	5.070E-11	4.290E-15	7.020E-15	3.380E-15	9.751E-15	5.070E-15	3.640E-15	3.510E-14	6.370E-10
136	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
137	2.091E-14	7.336E-14	2.457E-14	2.751E-14	9.903E-15	2.311E-14	7.336E-15	3.594E-14	1.394E-14	3.374E-14	2.311E-14	9.536E-13
138	1.012E-13	1.274E-13	1.708E-13	1.314E-13	5.124E-14	1.576E-13	1.314E-14	2.759E-13	9.196E-14	5.912E-14	4.073E-14	7.751E-13
139	1.700E-09	7.508E-09	1.855E-09	3.312E-09	6.846E-10	1.590E-09	7.067E-10	2.076E-09	9.717E-10	3.533E-09	2.429E-09	2.054E-06
140	3.320E-08	1.543E-07	3.515E-08	4.101E-08	1.269E-08	2.929E-08	1.289E-08	3.320E-08	1.718E-08	7.421E-08	4.687E-08	1.347E-06
141	1.593E-15	1.128E-15	1.858E-15	5.773E-11	1.194E-15	1.062E-15	9.290E-16	1.128E-15	9.953E-16	9.290E-16	2.787E-14	2.654E-11
142	3.113E-17	3.113E-17	8.006E-17	1.557E-16	1.957E-17	2.891E-17	8.228E-18	2.891E-17	1.846E-17	2.224E-17	1.468E-17	9.340E-17
143	2.798E-09	1.351E-08	2.991E-09	1.399E-08	1.013E-09	2.316E-09	1.013E-09	2.846E-09	1.254E-09	5.789E-09	4.583E-09	3.859E-07
144	3.157E-14	3.157E-14	8.155E-14	2.394E-13	2.052E-14	3.157E-14	8.682E-15	3.157E-14	1.973E-14	2.394E-14	1.552E-14	1.394E-13
145	7.124E-11	7.124E-11	2.181E-10	1.454E-09	3.344E-11	6.688E-11	1.221E-11	7.270E-11	3.780E-11	4.798E-11	2.908E-11	1.003E-09
146	5.031E-10	1.132E-09	7.965E-10	1.425E-09	2.725E-10	6.708E-10	1.342E-10	9.852E-10	3.983E-10	5.240E-10	3.983E-10	7.965E-09
147	4.679E-15	5.517E-15	8.380E-15	2.025E-14	2.654E-15	6.355E-15	9.777E-16	9.079E-15	3.911E-15	3.073E-15	2.165E-15	5.098E-14
148	2.608E-19	2.608E-19	5.560E-18	1.030E-18	1.579E-19	4.324E-19	6.658E-20	2.334E-19	1.441E-19	1.922E-19	1.236E-19	8.237E-19
149	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
150	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 16. FIIDOS output - all options (Continued).

16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

total dose commitments in rem for intake at time = 4.00 hours
with duration time = 0.250 hours

	fission products	activation products	actinides(g+b)	actinides(a)	total
adrenals	1.940E-05	0.00	0.00	0.00	1.940E-05
bone surf	6.665E-05	0.00	0.00	0.00	6.665E-05
brain	1.655E-05	0.00	0.00	0.00	1.655E-05
breast	1.577E-05	0.00	0.00	0.00	1.577E-05
st wall	3.192E-04	0.00	0.00	0.00	3.192E-04
si wall	4.332E-04	0.00	0.00	0.00	4.332E-04
uli wall	1.109E-03	0.00	0.00	0.00	1.109E-03
lli wall	1.226E-03	0.00	0.00	0.00	1.226E-03
kidneys	1.897E-05	0.00	0.00	0.00	1.897E-05
liver	2.182E-05	0.00	0.00	0.00	2.182E-05
et region	3.062E-03	0.00	0.00	0.00	3.062E-03
lung	1.066E-03	0.00	0.00	0.00	1.066E-03
muscle	2.120E-05	0.00	0.00	0.00	2.120E-05
ovaries	4.477E-05	0.00	0.00	0.00	4.477E-05
pancreas	2.386E-05	0.00	0.00	0.00	2.386E-05
r marrow	5.019E-05	0.00	0.00	0.00	5.019E-05
skin	1.308E-05	0.00	0.00	0.00	1.308E-05
spleen	1.977E-05	0.00	0.00	0.00	1.977E-05
testes	1.176E-05	0.00	0.00	0.00	1.176E-05
thymus	2.342E-05	0.00	0.00	0.00	2.342E-05
thyroid	3.033E-03	0.00	0.00	0.00	3.033E-03
uterus	2.950E-05	0.00	0.00	0.00	2.950E-05
ubld wall	1.108E-04	0.00	0.00	0.00	1.108E-04
eff dose	5.270E-04	0.00	0.00	0.00	5.270E-04

radionuclides contributing > 1% to effective dose equivalent

nuclide	rem	percent
sr-91	1.861E-05	3.5
sr-92	2.052E-05	3.9
y-92	2.930E-05	5.6
y-93	4.289E-05	8.1
zr-97	6.272E-05	11.9
mo-99	1.596E-05	3.0
ru-105	5.592E-06	1.1
i-131	2.292E-05	4.3
te-132	2.524E-05	4.8
i-133	8.737E-05	16.6
i-134	1.031E-05	2.0
i-135	4.197E-05	8.0

Figure 16. FIIDOS output - all options (Continued).

ba-139	5.746E-06	1.1
la-141	2.730E-05	5.2
la-142	1.463E-05	2.8
ce-143	2.606E-05	4.9
ce-144	6.025E-06	1.1
pr-145	1.535E-05	2.9

pu239 fraction in urine from inhalation exposure   uptake fraction=5.000E-02

time after shot (yrs)	50.	55.	60.
conc (ci/day) or (ci/1.4l)	0.0	0.0	0.0

total of all measurements and exposures

total dose commitments in rem for all intakes by DCF set

Doses from Specified DCF File
DCF File Info: ICRP-72 Inhalation DCFs - Max dose from all particle sizes - 3-28-2006

	fission products	activation products	actinides(g+b)	actinides(a)	total
adrenals	1.940E-05	0.00	0.00	0.00	1.940E-05
bone surf	6.665E-05	0.00	0.00	0.00	6.665E-05
brain	1.655E-05	0.00	0.00	0.00	1.655E-05
breast	1.577E-05	0.00	0.00	0.00	1.577E-05
st wall	3.192E-04	0.00	0.00	0.00	3.192E-04
si wall	4.332E-04	0.00	0.00	0.00	4.332E-04
uli wall	1.109E-03	0.00	0.00	0.00	1.109E-03
lli wall	1.226E-03	0.00	0.00	0.00	1.226E-03
kidneys	1.897E-05	0.00	0.00	0.00	1.897E-05
liver	2.182E-05	0.00	0.00	0.00	2.182E-05
et region	3.062E-03	0.00	0.00	0.00	3.062E-03
lung	1.066E-03	0.00	0.00	0.00	1.066E-03
muscle	2.120E-05	0.00	0.00	0.00	2.120E-05
ovaries	4.477E-05	0.00	0.00	0.00	4.477E-05
pancreas	2.386E-05	0.00	0.00	0.00	2.386E-05
r marrow	5.019E-05	0.00	0.00	0.00	5.019E-05
skin	1.308E-05	0.00	0.00	0.00	1.308E-05
spleen	1.977E-05	0.00	0.00	0.00	1.977E-05
testes	1.176E-05	0.00	0.00	0.00	1.176E-05
thymus	2.342E-05	0.00	0.00	0.00	2.342E-05
thyroid	3.033E-03	0.00	0.00	0.00	3.033E-03
uterus	2.950E-05	0.00	0.00	0.00	2.950E-05
ubld wall	1.108E-04	0.00	0.00	0.00	1.108E-04
eff dose	5.270E-04	0.00	0.00	0.00	5.270E-04

pu239 fraction in urine from all exposures

time after shot (yrs)	50.	55.	60.
conc (ci/day) or (ci/1.4l)	0.0	0.0	0.0

end

Figure 16. FIIDOS output - all options (Concluded).

SECTION 4

REFERENCES

Anspaugh, L. R., Shinn, J.H., Phelps, P.L., and Kennedy, N.C. 1975. Resuspension and Redistribution of Plutonium in Soils. *Health Phys* 29:571-582.

Barrett, M., Goetz, J., Klemm, J., McRaney, W., and Phillips, J. 1986. "Low Level Internal Dose Screen - CONUS Tests." Report DNA-TR-85-317, Science Applications International Corporation, McLean VA.

Bartine, D. E., Knight, J. R., Pace, J. V. and Roussin R. W. 1977. "Production and Testing of the DNA Few-Group Coupled Neutron-Gamma Cross-Section Library." Report ORNL/TM-4840, Oak Ridge National Laboratory; Oak Ridge, TN.

Bates D. V., Fish B. R., Hatch T. F., Mercer T. T., Morrow P. E. 1966. "Task Group on Lung Dynamics: Deposition and Retention Models for Internal Dosimetry of the Human Respiratory Tract." *Health Phys* 12:173-207.

Croff, A. G. 1980. "ORIGEN2 - A Revised and Updated Version of the Oak Ridge Isotope Generation and Depletion Code." Report ORNL-5621, Oak Ridge National Laboratory, Oak Ridge, TN.

DNA (Defense Nuclear Agency). 1979a. "Analysis of Radiation Exposure for Task Force Warrior, Shot SMOKY, Exercise Desert Rock VII-VIII, Operation PLUMBBOB." Report DNA 4747F, Washington, DC.

DNA (Defense Nuclear Agency). 1979b. "Soil Activation by Neutrons, Project 2.1, Operation PLUMBBOB." Report WT-1410-EX, Washington, DC.

DNA (Defense Nuclear Agency). 1985. "FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide." Report DNA-TR-84-375, Washington, DC.

Eckerman, K. F. 1988. "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion." Federal Guidance Report 11, Environmental Protection Agency, Washington, DC.

Eckerman, K. F. 1993. "DFINT Version 4.0 - A Code to Preview the Dosimetric Data of ICRP Publication 30, Parts 1-4." Oak Ridge, TN.

England, T. R. 1993a. "The CINDER10 code for DNA use at LANL." Los Alamos, NM: private communication with Jim Roberts of SAIC in San Diego, CA.

England, T. R. and Wilson, W. B. 1993b. "The CINDER10 code for DNA use at LANL." Report LA-UR-93-2930, Los Alamos National Laboratory, Los Alamos, NM.

Engle, W. W., Jr. 1973. "A User's Manual for ANISN, a One-Dimensional Discrete Ordinates Transport Code with Anisotropic Scattering." Report K-1693, Oak Ridge National Laboratory, Oak Ridge, TN.

EPA (U.S. Environmental Protection Agency). 1999. "Cancer Risk Coefficients for Environmental Exposure to Radionuclides." Federal Guidance Report 13. Environmental Protection Agency, Washington, DC.

Glasstone, S., Dolan, P. J. 1977. The Effects of Nuclear Weapons. US Department of Defense and US Department of Energy, Washington, DC.

Hoenes, G. R., Soldat., J. K. 1977. Age-specific Radiation Dose Commitment Factors for a One Year Chronic Intake, Report NUREG-0172, Battelle Pacific Northwest Laboratories, Richland, WA.

ICRP (International Commission on Radiation Protection). 1959. "Report of ICRP Committee II on Permissible Dose for Internal Radiation." ICRP Publication 2, Pergamon Press, Oxford, U.K.

ICRP (International Commission on Radiation Protection). 1975. "Report of the Task Group on Reference Man." ICRP Publication 23, Pergamon Press, Oxford, U.K.

ICRP (International Commission on Radiation Protection). 1979. "Limits for Intakes by Workers, A Report of Committee 2 of the International Commission on Radiological Protection." ICRP Publication 30, Pergamon Press. Elmsford, NY.

ICRP (International Commission on Radiation Protection). 1991. "1990 Recommendations of the International Commission on Radiological Protection." ICRP Publication 60, Pergamon Press, Elmsford, NY.

ICRP (International Commission on Radiation Protection). 1994a. "Human Respiratory Tract Model for Radiological Protection." ICRP Publication 66, Pergamon Press, Elmsford, NY.

ICRP (International Commission on Radiation Protection). 1994b. "Dose Coefficients for Intakes of Radionuclides by Workers." ICRP Publication 68, Pergamon Press, Elmsford, NY.

ICRP (International Commission on Radiation Protection). 1996. "Age Dependent Doses to Members of the Public from Intake of Radionuclides: Part 5, Compilation of Ingestion and Inhalation Dose Coefficients." ICRP Publication 72, Pergamon Press, Elmsford, NY.

Jones, S. R. 1985. "Derivation and Validation of a Urinary Excretion Function for Plutonium Applicable Over Tens of Years Post Uptake." *Radiat Prot Dosimetry* 11:19-27.

Kaul, D. C., Jarka, R. 1977. "Radiation Dose Deposition in the Active Marrow of Reference Man." Report DNA 4442F, Defense Nuclear Agency, Washington, DC.

Killough, G. G., Dunning, D. E., Jr., Bernard, S. R., and Pleasant, J. C. 1981. "Estimates of Internal Dose Equivalent to 22 Target Organs for Radionuclides Occurring in Routine Releases from Nuclear Fuel-Cycle Facilities." Report ORNL/NUREG/TM-190, Oak Ridge National Laboratory, Oak Ridge, TN.

Klemm, W. J., Brodsky, A., Schaeffer, D. M. 2003. Radioanalytical Data Interpretation When the Ratio Reading/Median Is Lognormally Distributed. *Health Phys* 85:721-732.

Lee, H., Franco, E., Pettijohn R., Parsons, S., Donahue, R., and Cubit, L. 1983. Organ doses from Radionuclide Intake by Nuclear Test Personal, 1945-1962. Advanced Research and Applications Corporation for the U.S. Defense Nuclear Agency, Sunnyvale, CA.

Leggett, R. W., Eckerman, K. F. 2003. "Dosimetric Significance of the ICRP's Updated Guidance and Models, 1989-2003, and Implications for U.S. Federal Guidance." Report ORNL/TM-2003/207, Oak Ridge National Laboratory, Oak Ridge, TN.

LLNL (Lawrence Livermore National Laboratory). ca. 1970. "Atmospheric Shots at NTS, 1951-1968, Draft Rad-Chem Data Summary." Lawrence Livermore National Laboratory (unpublished), Livermore, CA.

NBS (National Bureau of Standards). 1964. "Physical Aspects of Irradiation, Recommendations of the International Commission on Radiological Units and Measurements." NBS Handbook 85; same as ICRU 10b, National Bureau of Standards, Washington, DC.

NCRP (National Council on Radiation Protection and Measurements). 1997. Deposition, Retention and Dosimetry of Inhaled Radioactive Substances, NCRP Report No. 125, Bethesda, MD.

NDL (U.S. Nuclear Defense Laboratory). 1965. "Initial Gamma Data from Nuclear Weapon Tests 1948-1962.": extract version prepared by Defense Nuclear Agency; Report NDL-TR-53 (EX). Edgewood Arsenal, MD.

NRC (National Research Council). 1985. Review of the Methods Used to Assign

Radiation Doses to service Personnel at Nuclear Weapon Tests. National Academy Press, Washington, DC.

NRC (National Research Council). 2003. A Review of the Dose Reconstruction Program of the Defense Threat Reduction Agency. National Academy Press, Washington, DC.

NTPR (Nuclear Test Personnel Review) description available at http://www.dtra.mil Accessed 19 June 2006.

Roberts, J. A., Dolatshahi, F., Egbert, S. D. 1996. “Implementation of ENDF/B-VI Fission Product Data in ORIGEN.”: Proceedings of 1996 Topical Meeting on Radiation Protection and Shielding, North Falmouth, MA.

Rose, P. F., Dunford, C. L., editors. 1991. “ENDF-102 Data Formats and Procedures for the Evaluated Nuclear Data File ENDF-6.” Report BNL-NCS 44945, National Nuclear Data Center, Brookhaven National Laboratory, Upton, NY.

SAIC. 1983. Compendium of 1982-1983 Dose Assessments: Oceanic Nuclear Tests. Compendium of Memoranda dated 1/21/82 to 5/4/83. Science Applications, Corp. McLean, VA.

Slade, D. H., ed. 1968. “Meteorology and Atomic Energy 1968.” Report TID-24190, U.S. Atomic Energy Commission, Washington, DC.

Snyder, W. S., Ford, M. R., Warner, G. G.,Watson, S. B. 1974. “A Tabulation of Dose Equivalent per Micro Curie-Day for Source and Target Organs of an Adult for Various Radionuclides.” Report ORNL-5000, Oak Ridge National Laboratory, Oak Ridge, TN.

Stewart, K. 1964. “The Resuspension of Particulate Material from Surfaces.” pp. 63-74 in: Fish, B. R. ed. Proceedings of a Symposium on Surface Contamination at Gatlinburg, Tennessee, Pergamon Press, Oxford, U.K.

Trabalka, J. R. and Kocher, D. C 2007. “Bounding Analysis of Effects of Fractionation of Radionuclides in Fallout on Estimation of Doses to Atomic Veterans.” DTRA-TR-07-5. Senes Oak Ridge, Inc., Oak Ridge, TN.

USNRC (US Nuclear Regulatory Commission). 1975. “Calculation of Reactor Accident Consequences.” Reactor Safety Study; Report WASH-1400, Appendix VI, Washington, DC.

APPENDIX A

DOSE FACTORS

Table A-1. Ingestion dose conversion factors based on ICRP-72.

Ingestion Dose Conversion Factors (rem/µCi)

Nuclide	Adrenals	B Surface	Brain	Breast	S Wall	SI Wall	ULI Wall	LLI Wall	Kidneys	Liver	ET Region	Lung
Se-79	3.58E-03	3.58E-03	3.58E-03	3.58E-03	3.81E-03	3.70E-03	5.27E-03	8.52E-03	1.20E-01	5.15E-02	3.58E-03	3.58E-03
Br-82	1.81E-03	1.67E-03	1.22E-03	1.13E-03	3.09E-03	2.09E-03	2.68E-03	3.40E-03	1.71E-03	1.69E-03	1.51E-03	1.45E-03
Br-83	2.71E-05	2.70E-05	2.68E-05	2.69E-05	1.12E-03	5.40E-05	6.53E-05	4.11E-05	2.71E-05	2.70E-05	2.69E-05	2.69E-05
Kr-83m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	3.51E-05	2.15E-05	1.64E-05	2.11E-05	2.53E-03	8.75E-05	5.52E-05	2.72E-05	3.39E-05	2.73E-05	1.81E-05	2.43E-05
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	8.20E-03	3.06E-02	8.04E-03	7.94E-03	1.09E-02	8.24E-03	1.16E-02	1.81E-02	8.13E-03	8.10E-03	8.09E-03	8.05E-03
Kr-87	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-87	4.28E-03	1.70E-02	4.28E-03	4.28E-03	4.75E-03	4.29E-03	6.14E-03	9.74E-03	4.28E-03	4.28E-03	4.28E-03	4.28E-03
Kr-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-88	1.24E-05	9.95E-06	8.01E-06	9.19E-06	2.71E-03	7.24E-05	2.43E-05	1.06E-05	1.21E-05	1.05E-05	8.30E-06	9.90E-06
Kr-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	2.05E-05	1.77E-05	6.85E-06	1.04E-05	1.34E-03	4.49E-05	2.68E-05	1.62E-05	1.93E-05	1.44E-05	7.62E-06	1.26E-05
Sr-89	7.25E-04	2.21E-02	7.25E-04	7.25E-04	3.21E-03	5.07E-03	2.88E-02	8.20E-02	7.25E-04	7.25E-04	7.25E-04	7.25E-04
Rb-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-90m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-90	2.46E-03	1.51E+00	2.46E-03	2.46E-03	3.33E-03	4.20E-03	2.16E-02	8.10E-02	2.46E-03	2.46E-03	2.46E-03	2.46E-03
Y-90	4.77E-08	1.38E-06	4.77E-08	4.77E-08	3.95E-03	9.46E-03	5.01E-02	1.17E-01	4.77E-08	1.35E-06	4.77E-08	4.77E-08
Rb-91	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-91	1.59E-04	5.24E-04	6.90E-05	7.91E-05	3.16E-03	4.78E-03	1.39E-02	1.47E-02	2.28E-04	1.81E-04	7.39E-05	9.52E-05
Y-91	1.28E-06	2.32E-05	4.49E-07	6.39E-07	2.57E-03	6.42E-03	3.86E-02	1.12E-01	2.26E-06	2.28E-05	4.81E-07	7.20E-07
Y-91m	1.07E-05	3.79E-06	5.25E-08	2.39E-06	1.83E-04	8.64E-05	1.05E-04	8.99E-05	1.38E-05	8.38E-06	2.48E-07	3.77E-06
Sr-92	9.60E-05	2.60E-04	3.68E-05	4.90E-05	1.95E-03	3.82E-03	1.14E-02	8.06E-03	1.32E-04	1.02E-04	3.96E-05	5.75E-05
Y-92	1.30E-05	7.74E-06	1.06E-07	3.02E-06	5.26E-03	7.34E-03	1.23E-02	6.33E-03	2.30E-05	1.59E-05	4.51E-07	4.48E-06
Sr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-93	8.61E-06	7.75E-06	9.74E-08	1.95E-06	4.74E-03	9.29E-03	2.93E-02	3.24E-02	1.75E-05	1.24E-05	3.59E-07	2.82E-06
Zr-93	5.22E-06	1.95E-01	7.87E-06	2.69E-06	8.51E-05	2.10E-04	1.26E-03	3.70E-03	2.13E-06	1.83E-06	1.35E-06	2.82E-06
Nb-93m	1.38E-05	1.39E-04	1.37E-05	1.34E-05	1.38E-04	3.24E-04	1.88E-03	5.48E-03	2.12E-04	2.45E-04	1.35E-05	1.37E-05
Y-94	1.01E-05	2.69E-06	8.43E-08	2.66E-06	2.37E-03	6.03E-04	1.46E-04	1.72E-05	1.08E-05	6.37E-06	3.29E-07	3.99E-06
Y-95	4.11E-06	1.10E-06	6.20E-08	1.31E-06	1.39E-03	2.09E-04	3.30E-05	7.48E-06	4.39E-06	2.60E-06	1.98E-07	1.79E-06
Zr-95	4.97E-04	8.33E-03	1.98E-04	1.38E-04	1.42E-03	3.98E-03	1.15E-02	2.90E-02	6.14E-04	4.01E-04	1.57E-04	2.24E-04
Nb-95	2.75E-04	3.51E-04	4.34E-05	7.15E-05	1.05E-03	3.07E-03	6.79E-03	1.49E-02	5.81E-04	5.32E-04	4.79E-05	1.09E-04
Y-96	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zr-97	1.94E-04	2.34E-04	8.71E-06	4.46E-05	4.51E-03	1.20E-02	4.52E-02	6.57E-02	4.10E-04	2.95E-04	1.40E-05	6.42E-05
Nb-97	1.71E-05	6.95E-06	1.54E-07	3.87E-06	1.44E-03	1.05E-03	7.99E-04	1.76E-04	2.39E-05	1.50E-05	4.93E-07	6.00E-06
Nb-97m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb-98m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mo-99	1.25E-03	3.78E-03	8.95E-04	8.98E-04	2.75E-03	1.10E-03	1.55E-03	2.14E-03	1.15E-02	1.03E-02	9.36E-04	1.02E-03
Tc-99	1.43E-04	1.43E-04	1.43E-04	1.43E-04	8.01E-03	6.84E-04	5.06E-03	1.46E-02	1.43E-04	1.91E-04	1.43E-04	1.43E-04
Tc-99m	1.45E-05	1.93E-05	4.53E-06	4.87E-06	2.06E-04	1.42E-04	2.87E-04	1.99E-04	2.04E-05	1.61E-05	5.40E-06	7.70E-06
Mo-101	1.65E-05	8.25E-06	5.10E-06	7.71E-06	1.20E-03	3.97E-05	2.29E-05	1.03E-05	1.75E-05	1.32E-05	5.74E-06	9.70E-06
Tc-101	2.73E-06	9.21E-07	1.19E-07	6.70E-07	5.55E-04	9.99E-05	2.05E-05	2.94E-06	2.86E-06	1.67E-06	1.60E-07	1.07E-06
Mo-102	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc-102	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Nuclide	Muscle	Ovaries	Pancreas	R Marrow	Skin	Spleen	Testes	Thymus	Thyroid	Uterus	Bld Wall	Eff Dose
Se-79	3.58E-03	6.75E-03	1.85E-02	3.58E-03	3.58E-03	2.06E-02	1.06E-02	3.58E-03	3.58E-03	3.58E-03	4.11E-03	1.07E-02
Br-82	1.47E-03	2.14E-03	2.09E-03	1.59E-03	1.03E-03	1.79E-03	1.45E-03	1.53E-03	1.51E-03	1.99E-03	1.99E-03	2.02E-03
Br-83	2.69E-05	2.70E-05	2.76E-05	2.69E-05	2.68E-05	2.73E-05	2.69E-05	2.69E-05	2.69E-05	2.70E-05	3.09E-05	1.62E-04
Kr-83m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	2.38E-05	2.53E-05	8.57E-05	2.32E-05	1.86E-05	5.93E-05	1.79E-05	2.15E-05	1.81E-05	2.47E-05	2.06E-05	3.26E-04
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	8.06E-03	8.19E-03	8.17E-03	1.56E-02	7.93E-03	8.11E-03	8.04E-03	8.06E-03	8.09E-03	8.17E-03	1.07E-02	1.05E-02
Kr-87	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-87	4.28E-03	4.28E-03	4.28E-03	8.47E-03	4.28E-03	4.28E-03	4.28E-03	4.28E-03	4.28E-03	4.28E-03	5.75E-03	5.45E-03
Kr-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-88	9.76E-06	9.92E-06	2.51E-05	9.83E-06	8.63E-06	1.86E-05	8.28E-06	9.14E-06	8.30E-06	9.76E-06	8.83E-06	3.35E-04
Kr-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	1.21E-05	1.24E-05	5.89E-05	1.40E-05	8.78E-06	3.91E-05	7.61E-06	1.01E-05	7.62E-06	1.20E-05	1.00E-05	1.73E-04
Sr-89	7.25E-04	7.25E-04	7.25E-04	1.77E-02	7.25E-04	7.25E-04	7.25E-04	7.25E-04	7.25E-04	7.25E-04	2.49E-03	9.49E-03
Rb-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-90m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-90	2.46E-03	2.46E-03	2.46E-03	6.63E-01	2.46E-03	2.46E-03	2.46E-03	2.46E-03	2.46E-03	2.46E-03	5.49E-03	1.02E-01
Y-90	4.79E-08	5.28E-08	4.78E-08	1.38E-06	4.77E-08	4.77E-08	4.77E-08	4.77E-08	4.77E-08	4.78E-08	2.24E-07	9.94E-03
Rb-91	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-91	1.68E-04	8.07E-04	2.55E-04	5.81E-04	9.79E-05	1.93E-04	1.25E-04	8.21E-05	7.39E-05	4.69E-04	6.92E-04	2.40E-03
Y-91	2.02E-06	1.38E-05	2.06E-06	2.44E-05	1.06E-06	1.71E-06	1.75E-06	5.88E-07	4.81E-07	6.25E-06	4.68E-06	8.75E-03
Y-91m	6.55E-06	2.99E-05	3.65E-05	8.35E-06	2.50E-06	2.32E-05	1.45E-06	1.72E-06	2.48E-07	2.35E-05	7.28E-06	4.27E-05
Sr-92	8.77E-05	3.46E-04	1.90E-04	2.39E-04	5.53E-05	1.37E-04	5.72E-05	4.76E-05	3.96E-05	2.42E-04	4.60E-04	1.58E-03
Y-92	1.26E-05	8.16E-05	3.36E-05	1.78E-05	4.97E-06	2.22E-05	5.16E-06	2.18E-06	4.51E-07	5.25E-05	2.04E-05	1.83E-03
Sr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-93	1.11E-05	8.15E-05	1.90E-05	1.64E-05	4.35E-06	1.34E-05	6.39E-06	1.43E-06	3.59E-07	4.42E-05	2.32E-05	4.27E-03
Zr-93	4.91E-06	1.65E-06	1.25E-06	1.57E-02	3.95E-06	1.61E-06	8.61E-07	2.38E-06	1.35E-06	9.10E-07	4.23E-06	4.12E-03
Nb-93m	1.39E-05	2.32E-05	1.37E-05	5.36E-05	1.33E-05	1.36E-05	1.35E-05	1.35E-05	1.35E-05	1.37E-05	1.78E-05	4.60E-04
Y-94	4.86E-06	1.42E-05	3.63E-05	5.22E-06	2.08E-06	2.27E-05	9.32E-07	2.00E-06	3.29E-07	1.20E-05	3.76E-06	3.01E-04
Y-95	1.97E-06	4.45E-06	1.59E-05	1.97E-06	9.11E-07	9.90E-06	3.96E-07	1.00E-06	1.98E-07	3.71E-06	1.38E-06	1.71E-04
Zr-95	5.06E-04	3.25E-03	5.47E-04	1.78E-03	2.34E-04	4.15E-04	3.87E-04	1.61E-04	1.57E-04	1.50E-03	1.06E-03	3.56E-03
Nb-95	3.91E-04	3.04E-03	4.35E-04	6.45E-04	1.59E-04	3.30E-04	3.31E-04	6.92E-05	4.79E-05	1.37E-03	9.66E-04	2.17E-03
Y-96	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zr-97	2.95E-04	2.31E-03	3.91E-04	4.90E-04	1.12E-04	2.83E-04	2.05E-04	3.50E-05	1.40E-05	1.14E-03	6.76E-04	7.64E-03
Nb-97	1.17E-05	6.00E-05	5.45E-05	1.55E-05	4.51E-06	3.48E-05	3.10E-06	2.81E-06	4.93E-07	4.55E-05	1.45E-05	2.54E-04
Nb-97m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb-98m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mo-99	9.59E-04	1.02E-03	1.21E-03	2.27E-03	8.71E-04	1.05E-03	9.08E-04	9.53E-04	9.36E-04	1.01E-03	1.60E-03	2.24E-03
Tc-99	1.43E-04	1.43E-04	1.43E-04	1.43E-04	1.43E-04	1.43E-04	1.43E-04	1.43E-04	3.74E-03	1.43E-04	5.93E-04	2.37E-03
Tc-99m	1.30E-05	6.19E-05	3.29E-05	1.62E-05	5.79E-06	2.30E-05	7.61E-06	5.93E-06	1.76E-04	4.14E-05	2.88E-05	8.25E-05
Mo-101	9.35E-06	9.69E-06	4.85E-05	9.14E-06	6.50E-06	3.21E-05	5.68E-06	7.60E-06	5.74E-06	9.28E-06	7.01E-06	1.53E-04
Tc-101	1.26E-06	2.98E-06	1.04E-05	1.29E-06	5.35E-07	6.61E-06	2.45E-07	5.18E-07	4.42E-06	2.57E-06	8.85E-07	6.96E-05
Mo-102	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc-102	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table A-1. Ingestion dose conversion factors based on ICRP-72.

Ingestion Dose Conversion Factors (rem/μCi)

Nuclide	Adrenals	B Surface	Brain	Breast	S Wall	SI Wall	ULI Wall	LLI Wall	Kidneys	Liver	ET Region	Lung
Tc-103	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	3.78E-04	4.10E-04	2.14E-04	2.18E-04	1.14E-03	2.94E-03	9.53E-03	2.45E-02	5.02E-04	4.17E-04	2.49E-04	2.68E-04
Rh-103m	1.41E-08	2.37E-08	1.23E-08	1.23E-08	9.51E-05	5.86E-05	3.33E-05	5.28E-06	1.70E-08	1.68E-08	1.23E-08	1.52E-08
Tc-104	1.70E-05	5.37E-06	9.07E-07	5.14E-06	2.30E-03	5.03E-04	1.35E-04	2.18E-05	1.84E-05	1.12E-05	1.37E-06	7.32E-06
Mo-105	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc-105	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-105	5.44E-05	3.94E-05	4.81E-06	1.44E-05	1.84E-03	2.75E-03	5.89E-03	4.92E-03	9.61E-05	6.79E-05	6.23E-06	2.03E-05
Rh-105	2.43E-05	3.02E-05	1.05E-05	1.23E-05	7.20E-04	1.62E-03	7.16E-03	1.41E-02	4.06E-05	3.04E-05	1.11E-05	1.41E-05
Rh-105m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	5.44E-03	5.44E-03	5.29E-03	5.27E-03	1.16E-02	2.05E-02	9.46E-02	2.66E-01	5.48E-03	5.44E-03	5.35E-03	5.35E-03
Rh-106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd-107	3.76E-08	5.46E-07	3.76E-08	3.76E-08	3.96E-05	9.84E-05	5.98E-04	1.75E-03	2.48E-05	1.28E-05	3.76E-08	3.76E-08
Rh-109	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd-109	8.92E-07	4.70E-06	3.51E-07	4.06E-07	1.79E-03	3.70E-03	1.33E-02	1.73E-02	2.49E-05	1.35E-05	3.54E-07	5.05E-07
Ag-109m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag-110m	6.85E-03	3.19E-03	1.27E-03	2.12E-03	6.37E-03	1.29E-02	2.31E-02	4.27E-02	6.05E-03	2.81E-02	1.71E-03	3.65E-03
Ag-111	7.54E-05	7.48E-05	6.35E-05	6.51E-05	1.60E-03	3.68E-03	2.07E-02	5.52E-02	8.10E-05	2.17E-03	6.41E-05	6.77E-05
Cd-113m	1.30E-02	1.30E-02	1.30E-02	1.30E-02	1.38E-02	1.49E-02	2.45E-02	4.68E-02	2.09E+00	3.60E-01	1.30E-02	1.30E-02
Cd-115m	6.68E-04	6.25E-04	6.11E-04	6.16E-04	3.24E-03	6.83E-03	3.76E-02	1.07E-01	9.57E-02	1.66E-02	6.13E-04	6.25E-04
Sn-123	1.22E-04	2.54E-03	1.20E-04	1.19E-04	2.35E-03	5.57E-03	3.32E-02	9.67E-02	1.23E-04	1.22E-04	1.20E-04	1.20E-04
Sb-124	1.44E-03	1.01E-02	6.75E-04	6.28E-04	4.03E-03	9.74E-03	3.16E-02	8.08E-02	1.70E-03	2.36E-03	6.92E-04	8.42E-04
Sn-125	1.11E-04	9.26E-04	3.72E-05	4.81E-05	3.79E-03	9.31E-03	5.05E-02	1.37E-01	1.86E-04	1.37E-04	3.86E-05	5.81E-05
Sb-125	1.58E-03	3.36E-02	9.72E-04	7.67E-04	1.83E-03	3.62E-03	9.39E-03	2.30E-02	1.42E-03	2.91E-03	9.58E-04	1.06E-03
Te-125m	2.83E-04	7.32E-02	2.61E-04	2.05E-04	7.37E-04	1.27E-03	5.93E-03	1.64E-02	3.02E-03	2.22E-04	2.15E-04	2.38E-04
Sn-126	3.45E-03	2.00E-02	2.63E-03	1.71E-03	6.00E-03	1.59E-02	5.99E-02	1.63E-01	3.27E-03	2.65E-03	2.30E-03	2.33E-03
Sb-126	1.32E-03	3.92E-03	4.34E-04	4.44E-04	4.46E-03	1.17E-02	2.97E-02	6.74E-02	1.91E-03	1.88E-03	4.55E-04	6.48E-04
Sb-127	2.70E-04	1.10E-03	1.04E-04	1.16E-04	2.14E-03	5.36E-03	2.55E-02	6.69E-02	4.15E-04	5.27E-04	1.08E-04	1.48E-04
Te-127	1.68E-05	3.81E-05	1.63E-05	1.64E-05	9.05E-04	1.30E-03	3.99E-03	4.21E-03	5.09E-05	1.69E-05	1.64E-05	1.65E-05
Te-127m	5.53E-04	1.19E-01	5.31E-04	4.92E-04	9.32E-04	1.58E-03	1.12E-02	3.87E-02	8.50E-03	5.02E-04	5.01E-04	5.15E-04
Sb-129	9.75E-05	1.06E-04	1.22E-05	2.98E-05	2.68E-03	4.83E-03	1.06E-02	6.67E-03	1.65E-04	1.27E-04	1.51E-05	4.04E-05
Te-129	3.38E-06	3.14E-06	1.98E-06	2.25E-06	1.47E-03	9.63E-04	6.60E-04	1.29E-04	4.45E-06	3.17E-06	2.02E-06	2.47E-06
Te-129m	9.34E-04	4.60E-02	8.53E-04	8.10E-04	2.57E-03	5.05E-03	2.98E-02	8.47E-02	1.28E-02	8.56E-04	8.36E-04	8.49E-04
I-129	4.56E-04	1.48E-03	5.28E-04	4.22E-04	7.38E-04	4.67E-04	8.33E-04	1.59E-03	4.47E-04	4.53E-04	5.28E-04	5.69E-04
Sn-130	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sn-130m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-130	2.78E-04	2.93E-04	2.62E-04	1.87E-04	2.17E-03	3.40E-04	4.34E-04	4.86E-04	2.60E-04	2.42E-04	2.93E-04	2.63E-04
Sb-131	2.37E-05	1.06E-05	1.76E-06	6.87E-06	1.73E-03	7.57E-04	3.44E-04	8.42E-05	2.78E-05	1.68E-05	2.37E-06	1.02E-05
Te-131	5.74E-06	3.19E-06	1.44E-06	1.90E-06	1.22E-03	3.71E-04	1.13E-04	1.80E-05	6.40E-06	4.02E-06	1.56E-06	2.99E-06
Te-131m	4.57E-04	1.86E-03	2.09E-04	2.11E-04	2.49E-03	5.02E-03	1.64E-02	2.93E-02	1.11E-03	4.98E-04	2.32E-04	2.74E-04
I-131	1.87E-04	4.88E-04	5.32E-04	2.18E-04	1.12E-03	2.00E-04	3.28E-04	6.01E-04	1.70E-04	1.81E-04	5.45E-04	3.82E-04
Xe-131m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb-132	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb-132m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	1.12E-03	4.25E-03	7.18E-04	6.74E-04	2.83E-03	5.70E-03	2.76E-02	7.16E-02	1.84E-03	1.20E-03	8.18E-04	8.37E-04
I-132	1.31E-04	9.51E-05	7.15E-05	7.46E-05	2.34E-03	1.73E-04	1.95E-04	1.40E-04	1.22E-04	1.05E-04	8.28E-05	9.45E-05
Sb-133	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Nuclide	Muscle	Ovaries	Pancreas	R Marrow	Skin	Spleen	Testes	Thymus	Thyroid	Uterus	Bld Wall	Eff Dose
Tc-103	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	4.43E-04	2.12E-03	4.96E-04	5.95E-04	2.59E-04	4.27E-04	4.21E-04	2.61E-04	2.49E-04	1.10E-03	8.93E-04	2.72E-03
Rh-103m	3.02E-08	1.66E-07	1.19E-07	1.82E-08	1.33E-08	3.45E-08	1.23E-08	1.23E-08	1.23E-08	6.06E-08	3.25E-08	1.41E-05
Tc-104	8.59E-06	2.20E-05	6.19E-05	8.98E-06	4.05E-06	3.91E-05	2.19E-06	4.16E-06	3.32E-05	1.88E-05	6.86E-06	2.96E-04
Mo-105	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc-105	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-105	5.70E-05	3.65E-04	1.32E-04	8.15E-05	2.32E-05	8.90E-05	2.80E-05	1.21E-05	6.23E-06	2.24E-04	1.09E-04	9.79E-04
Rh-105	3.28E-05	1.94E-04	3.96E-05	4.58E-05	1.73E-05	3.19E-05	2.67E-05	1.24E-05	1.11E-05	1.02E-04	8.07E-05	1.36E-03
Rh-105m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	5.42E-03	6.21E-03	5.51E-03	5.51E-03	5.28E-03	5.44E-03	5.41E-03	5.36E-03	5.35E-03	5.77E-03	6.45E-03	2.59E-02
Rh-106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd-107	3.76E-08	3.76E-08	3.76E-08	2.05E-07	3.76E-08	3.76E-08	3.76E-08	3.76E-08	3.76E-08	3.76E-08	4.50E-07	1.37E-04
Rh-109	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd-109	2.19E-06	2.76E-05	2.74E-06	2.87E-06	6.53E-07	1.59E-06	8.14E-07	3.84E-07	3.54E-07	6.38E-06	6.41E-06	2.03E-03
Ag-109m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag-110m	3.50E-03	1.29E-02	6.73E-03	4.50E-03	1.99E-03	3.46E-03	2.55E-03	2.32E-03	1.71E-03	6.93E-03	5.14E-03	1.03E-02
Ag-111	7.57E-05	1.60E-04	8.08E-05	8.28E-05	6.72E-05	7.42E-05	7.27E-05	6.52E-05	6.41E-05	1.09E-04	9.80E-05	4.65E-03
Cd-113m	1.30E-02	1.30E-02	1.30E-02	1.30E-02	1.30E-02	1.30E-02	1.30E-02	1.30E-02	1.30E-02	1.30E-02	1.31E-02	8.50E-02
Cd-115m	6.29E-04	6.98E-04	6.59E-04	6.39E-04	6.17E-04	6.52E-04	6.19E-04	6.17E-04	6.13E-04	6.53E-04	6.40E-04	1.22E-02
Sn-123	1.23E-04	1.46E-04	1.23E-04	9.21E-04	1.20E-04	1.22E-04	1.22E-04	1.20E-04	1.20E-04	1.31E-04	1.97E-04	7.78E-03
Sb-124	1.41E-03	6.94E-03	1.62E-03	4.45E-03	8.00E-04	1.29E-03	1.18E-03	7.24E-04	6.92E-04	3.45E-03	3.18E-03	9.42E-03
Sn-125	1.61E-04	1.10E-03	1.71E-04	7.77E-04	8.12E-05	1.39E-04	1.36E-04	4.65E-05	3.86E-05	5.05E-04	4.45E-04	1.14E-02
Sb-125	1.15E-03	2.96E-03	1.43E-03	5.51E-03	7.86E-04	1.13E-03	9.48E-04	9.35E-04	9.58E-04	1.84E-03	1.63E-03	4.20E-03
Te-125m	2.43E-04	5.15E-04	2.32E-04	6.25E-03	2.00E-04	2.33E-04	1.94E-04	2.18E-04	3.85E-03	2.51E-04	5.74E-04	3.22E-03
Sn-126	2.99E-03	9.31E-03	3.17E-03	1.04E-02	2.04E-03	2.66E-03	2.46E-03	2.06E-03	2.30E-03	5.22E-03	4.21E-03	1.77E-02
Sb-126	1.58E-03	1.04E-02	1.80E-03	3.39E-03	7.20E-04	1.39E-03	1.33E-03	5.08E-04	4.55E-04	4.93E-03	3.94E-03	9.11E-03
Sb-127	3.46E-04	2.18E-03	3.96E-04	1.10E-03	1.74E-04	3.14E-04	2.95E-04	1.22E-04	1.08E-04	1.06E-03	1.07E-03	6.18E-03
Te-127	1.68E-05	2.01E-05	1.74E-05	3.74E-05	1.65E-05	1.71E-05	1.66E-05	1.64E-05	6.24E-05	1.84E-05	1.23E-04	6.24E-04
Te-127m	5.15E-04	6.20E-04	5.12E-04	3.04E-02	4.91E-04	5.07E-04	4.84E-04	5.01E-04	1.13E-02	5.18E-04	1.32E-03	8.66E-03
Sb-129	9.78E-05	5.85E-04	2.26E-04	1.58E-04	4.37E-05	1.53E-04	4.91E-05	2.59E-05	1.51E-05	3.66E-04	2.16E-04	1.57E-03
Te-129	2.95E-06	7.07E-06	7.12E-06	3.50E-06	2.29E-06	5.10E-06	2.19E-06	2.20E-06	2.77E-06	5.70E-06	1.02E-05	2.33E-04
Te-129m	8.66E-04	1.15E-03	8.91E-04	1.96E-02	8.15E-04	8.67E-04	8.27E-04	8.31E-04	1.70E-02	9.47E-04	2.59E-03	1.10E-02
I-129	1.11E-03	4.74E-04	4.62E-04	5.19E-04	5.24E-04	4.55E-04	4.30E-04	6.36E-04	7.81E+00	4.66E-04	1.59E-03	3.91E-01
Sn-130	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sn-130m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-130	3.01E-04	3.33E-04	4.51E-04	2.82E-04	1.88E-04	3.46E-04	2.38E-04	3.09E-04	1.32E-01	4.24E-04	3.48E-03	7.27E-03
Sb-131	1.37E-05	4.56E-05	8.17E-05	1.56E-05	6.11E-06	5.19E-05	3.69E-06	6.07E-06	2.61E-03	3.70E-05	1.82E-05	3.82E-04
Te-131	3.83E-06	9.39E-06	1.97E-05	3.93E-06	1.80E-06	1.26E-05	1.06E-06	2.32E-06	3.30E-03	8.00E-06	8.78E-06	3.24E-04
Te-131m	5.18E-04	2.69E-03	6.61E-04	9.84E-04	2.77E-04	5.27E-04	4.13E-04	2.53E-04	6.85E-02	1.41E-03	1.61E-03	7.23E-03
I-131	4.70E-04	1.93E-04	2.26E-04	3.75E-04	2.54E-04	1.98E-04	1.49E-04	5.65E-04	1.60E+00	2.19E-04	2.80E-03	8.05E-02
Xe-131m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb-132	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb-132m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	1.36E-03	5.96E-03	1.37E-03	1.99E-03	8.06E-04	1.20E-03	1.33E-03	8.55E-04	1.15E-01	3.25E-03	1.25E-02	1.41E-02
I-132	9.90E-05	1.22E-04	2.70E-04	9.76E-05	6.89E-05	1.93E-04	8.70E-05	9.15E-05	1.27E-02	1.44E-04	1.17E-03	1.06E-03
Sb-133	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table A-1. Ingestion dose conversion factors based on ICRP-72.

Ingestion Dose Conversion Factors (rem/μCi)

Nuclide	Adrenals	B Surface	Brain	Breast	S Wall	SI Wall	ULI Wall	LLI Wall	Kidneys	Liver	ET Region	Lung
Te-133	7.67E-06	3.47E-06	1.87E-06	2.90E-06	9.00E-04	1.49E-04	3.80E-05	1.55E-05	7.78E-06	5.13E-06	2.10E-06	4.09E-06
Te-133m	5.91E-05	3.01E-05	1.07E-05	2.04E-05	2.49E-03	1.36E-03	1.06E-03	4.17E-04	7.44E-05	4.91E-05	1.27E-05	2.84E-05
I-133	1.59E-04	1.81E-04	1.78E-04	1.34E-04	2.06E-03	2.12E-04	3.55E-04	4.83E-04	1.53E-04	1.49E-04	1.89E-04	1.68E-04
Xe-133	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-133m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-134	6.50E-05	4.25E-05	2.64E-05	3.20E-05	1.66E-03	4.64E-04	5.79E-04	1.69E-04	6.84E-05	5.44E-05	3.09E-05	4.08E-05
I-134	7.08E-05	3.92E-05	2.63E-05	3.41E-05	2.04E-03	1.03E-04	9.50E-05	5.44E-05	6.52E-05	5.11E-05	3.10E-05	4.39E-05
Cs-134	7.73E-02	7.39E-02	5.71E-02	5.22E-02	6.99E-02	7.71E-02	7.49E-02	8.34E-02	7.24E-02	7.31E-02	6.86E-02	6.51E-02
Cs-134m	2.60E-05	2.72E-05	2.20E-05	2.09E-05	4.27E-04	3.57E-05	4.06E-05	3.31E-05	2.51E-05	2.51E-05	2.40E-05	2.37E-05
I-135	1.65E-04	1.52E-04	1.29E-04	1.14E-04	2.01E-03	2.15E-04	2.81E-04	2.63E-04	1.58E-04	1.45E-04	1.45E-04	1.43E-04
Xe-135	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-135m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-135	7.12E-03	7.12E-03	7.12E-03	7.12E-03	7.40E-03	7.12E-03	8.03E-03	9.78E-03	7.12E-03	7.12E-03	7.12E-03	7.12E-03
Cs-136	1.22E-02	1.20E-02	8.69E-03	7.92E-03	1.20E-02	1.23E-02	1.20E-02	1.36E-02	1.13E-02	1.14E-02	1.06E-02	1.01E-02
Xe-137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-137	5.19E-02	5.09E-02	4.36E-02	4.15E-02	4.96E-02	5.19E-02	5.34E-02	6.19E-02	4.99E-02	5.02E-02	4.84E-02	4.69E-02
Ba-137m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-138	4.52E-05	2.56E-05	1.83E-05	2.46E-05	2.60E-03	9.61E-05	6.60E-05	3.29E-05	4.31E-05	3.38E-05	2.07E-05	2.96E-05
Cs-139	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	2.62E-06	1.09E-05	1.39E-06	1.60E-06	2.56E-03	1.96E-03	1.66E-03	3.74E-04	3.29E-06	2.54E-06	1.41E-06	1.80E-06
Cs-140	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-140	7.70E-04	6.06E-03	3.71E-04	2.78E-04	2.32E-03	6.15E-03	3.15E-02	1.06E-01	8.37E-04	5.53E-04	3.22E-04	3.99E-04
La-140	3.91E-04	4.27E-04	4.59E-06	9.27E-05	4.04E-03	1.02E-02	3.42E-02	6.45E-02	8.33E-04	5.92E-04	1.91E-05	1.31E-04
Ba-141	8.45E-06	1.01E-05	6.90E-07	2.51E-06	1.46E-03	6.48E-04	8.08E-04	4.32E-04	9.27E-06	5.66E-06	8.45E-07	3.63E-06
La-141	2.37E-06	2.13E-06	5.70E-08	6.09E-07	3.46E-03	5.07E-03	9.20E-03	5.28E-03	4.31E-06	3.72E-06	1.29E-07	8.63E-07
Ce-141	2.00E-05	1.83E-04	9.21E-07	2.81E-06	8.25E-04	2.15E-03	1.13E-02	3.20E-02	4.50E-05	8.82E-05	1.07E-06	5.23E-06
Ba-142	1.38E-05	7.01E-06	6.03E-07	3.91E-06	7.50E-04	3.66E-04	3.40E-04	9.20E-05	1.82E-05	1.16E-05	9.91E-07	5.57E-06
La-142	7.07E-05	3.24E-05	9.83E-07	1.97E-05	3.14E-03	2.65E-03	2.58E-03	6.99E-04	1.08E-04	7.00E-05	3.23E-06	2.71E-05
La-143	9.30E-07	7.38E-07	8.93E-09	2.29E-07	1.46E-03	3.20E-04	2.01E-04	3.14E-04	1.39E-06	9.76E-07	3.21E-08	3.42E-07
Ce-143	4.54E-05	8.11E-05	3.36E-07	7.80E-06	2.07E-03	4.94E-03	2.16E-02	4.31E-02	1.04E-04	8.07E-05	1.23E-06	1.26E-05
Pr-143	4.10E-08	6.39E-06	4.10E-08	4.10E-08	1.34E-03	3.32E-03	1.95E-02	5.46E-02	1.05E-05	5.08E-05	4.10E-08	4.10E-08
Ce-144	5.96E-05	1.23E-03	4.26E-05	4.50E-05	4.13E-03	1.38E-02	8.42E-02	2.46E-01	7.29E-05	3.55E-03	4.29E-05	4.81E-05
Pr-144	2.41E-07	6.70E-08	2.87E-09	6.96E-08	1.52E-03	3.56E-04	6.59E-05	3.51E-06	2.66E-07	1.58E-07	9.65E-09	1.00E-07
Pr-144m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-145	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr-145	9.90E-07	8.55E-07	3.40E-08	2.36E-07	2.60E-03	4.43E-03	1.05E-02	8.18E-03	2.18E-06	1.98E-06	5.88E-08	3.43E-07
Ce-146	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr-146	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr-147	6.18E-06	1.86E-06	3.79E-08	1.49E-06	9.35E-04	1.76E-04	5.35E-05	4.74E-05	6.44E-06	3.77E-06	1.58E-07	2.41E-06
Nd-147	3.06E-05	1.22E-04	2.60E-07	4.94E-06	1.32E-03	3.42E-03	1.76E-02	4.75E-02	7.27E-05	8.21E-05	8.00E-07	8.38E-06
Pm-147	1.11E-08	1.61E-03	8.60E-09	8.69E-09	2.64E-04	6.61E-04	4.00E-03	1.17E-02	1.19E-08	4.30E-04	8.54E-09	9.39E-09
Pr-148	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm-148	1.21E-04	1.57E-04	1.44E-06	2.81E-05	3.61E-03	9.13E-03	4.51E-02	1.15E-01	2.63E-04	2.17E-04	5.75E-06	4.01E-05
Pm-148m	5.12E-04	8.27E-04	9.76E-06	1.03E-04	2.92E-03	8.73E-03	2.16E-02	5.10E-02	1.10E-03	9.12E-04	2.19E-05	1.60E-04

Nuclide	Muscle	Ovaries	Pancreas	R Marrow	Skin	Spleen	Testes	Thymus	Thyroid	Uterus	Bld Wall	Eff Dose
Te-133	4.59E-06	8.27E-06	2.52E-05	4.52E-06	2.53E-06	1.63E-05	1.94E-06	3.11E-06	3.01E-03	7.61E-06	4.26E-05	2.68E-04
Te-133m	4.18E-05	1.55E-04	1.73E-04	4.95E-05	2.08E-05	1.13E-04	1.76E-05	2.02E-05	1.19E-02	1.23E-04	2.08E-04	1.05E-03
I-133	1.85E-04	1.81E-04	2.10E-04	1.74E-04	1.37E-04	1.79E-04	1.47E-04	1.94E-04	3.04E-01	2.12E-04	4.11E-03	1.58E-02
Xe-133	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-133m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-134	4.70E-05	9.99E-05	1.52E-04	4.99E-05	3.01E-05	1.05E-04	3.45E-05	3.61E-05	1.94E-03	8.77E-05	3.13E-04	4.00E-04
I-134	4.39E-05	5.11E-05	1.83E-04	4.27E-05	2.95E-05	1.23E-04	3.24E-05	3.78E-05	1.99E-03	5.52E-05	3.05E-04	3.98E-04
Cs-134	6.41E-02	7.97E-02	8.05E-02	6.91E-02	4.80E-02	7.24E-02	6.43E-02	6.90E-02	6.86E-02	8.09E-02	7.49E-02	7.12E-02
Cs-134m	2.33E-05	2.62E-05	2.98E-05	2.38E-05	2.00E-05	2.66E-05	2.30E-05	2.40E-05	2.40E-05	2.63E-05	2.68E-05	7.44E-05
I-135	1.56E-04	1.83E-04	2.71E-04	1.48E-04	1.11E-04	2.09E-04	1.40E-04	1.57E-04	5.92E-02	2.23E-04	2.42E-03	3.46E-03
Xe-135	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-135m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-135	7.12E-03	7.12E-03	7.12E-03	7.12E-03	7.12E-03	7.12E-03	7.12E-03	7.12E-03	7.12E-03	7.12E-03	8.07E-03	7.40E-03
Cs-136	9.93E-03	1.27E-02	1.28E-02	1.06E-02	7.16E-03	1.14E-02	9.93E-03	1.07E-02	1.06E-02	1.28E-02	1.19E-02	1.14E-02
Xe-137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-137	4.64E-02	5.30E-02	5.33E-02	4.85E-02	3.97E-02	5.00E-02	4.65E-02	4.85E-02	4.84E-02	5.35E-02	5.35E-02	5.02E-02
Ba-137m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-138	2.88E-05	3.09E-05	1.18E-04	2.79E-05	2.13E-05	8.02E-05	2.04E-05	2.54E-05	2.07E-05	3.00E-05	2.41E-05	3.40E-04
Cs-139	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	2.29E-06	6.46E-06	5.77E-06	1.09E-05	1.66E-06	4.18E-06	1.57E-06	1.54E-06	1.41E-06	5.29E-06	1.53E-05	4.46E-04
Cs-140	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-140	7.49E-04	4.19E-03	7.11E-04	4.62E-03	3.97E-04	5.86E-04	6.10E-04	3.26E-04	3.22E-04	1.85E-03	1.66E-03	9.61E-03
La-140	6.43E-04	5.15E-03	7.71E-04	9.70E-04	2.57E-04	5.89E-04	4.81E-04	6.90E-05	1.91E-05	2.39E-03	1.56E-03	7.49E-03
Ba-141	4.45E-06	1.24E-05	3.01E-05	1.07E-05	2.15E-06	1.91E-05	1.30E-06	2.03E-06	8.45E-07	1.03E-05	8.64E-06	2.59E-04
La-141	2.48E-06	1.64E-05	5.81E-06	3.51E-06	1.03E-06	3.94E-06	1.16E-06	4.54E-07	1.29E-07	1.00E-05	4.33E-06	1.32E-03
Ce-141	4.03E-05	3.75E-04	4.23E-05	7.14E-05	1.18E-05	3.28E-05	2.93E-05	2.34E-06	1.07E-06	1.68E-04	1.20E-04	2.63E-03
Ba-142	9.05E-06	3.92E-05	4.38E-05	1.24E-05	4.03E-06	2.81E-05	2.94E-06	3.10E-06	9.91E-07	2.95E-05	1.27E-05	1.31E-04
La-142	5.45E-05	2.84E-04	2.11E-04	7.02E-05	2.33E-05	1.38E-04	1.82E-05	1.48E-05	3.23E-06	2.11E-04	7.31E-05	6.73E-04
La-143	8.87E-07	6.11E-06	3.01E-06	1.22E-06	3.18E-07	1.96E-06	4.64E-07	1.75E-07	3.21E-08	3.03E-06	1.72E-06	2.07E-04
Ce-143	8.30E-05	7.46E-04	1.03E-04	1.28E-04	2.65E-05	7.43E-05	5.67E-05	5.73E-06	1.23E-06	3.34E-04	2.10E-04	4.14E-03
Pr-143	4.10E-08	4.10E-08	4.10E-08	6.39E-06	4.10E-08	4.10E-08	4.10E-08	4.10E-08	4.10E-08	4.10E-08	2.20E-07	4.33E-03
Ce-144	6.82E-05	2.78E-04	7.07E-05	7.14E-04	5.07E-05	6.23E-05	6.12E-05	4.46E-05	4.29E-05	1.40E-04	1.12E-04	1.94E-02
Pr-144	1.20E-07	3.30E-07	9.11E-07	1.26E-07	5.28E-08	5.72E-07	2.35E-08	5.39E-08	9.65E-09	2.80E-07	9.25E-08	1.87E-04
Pr-144m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-145	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr-145	1.14E-06	8.06E-06	2.40E-06	1.72E-06	4.43E-07	1.60E-06	5.61E-07	1.76E-07	5.88E-08	4.64E-06	2.14E-06	1.46E-03
Ce-146	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr-146	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr-147	2.89E-06	7.69E-06	2.46E-05	2.93E-06	1.15E-06	1.52E-05	4.49E-07	1.09E-06	1.58E-07	6.27E-06	2.00E-06	1.21E-04
Nd-147	6.72E-05	6.56E-04	6.79E-05	1.13E-04	2.04E-05	5.15E-05	5.14E-05	3.63E-06	8.00E-07	2.69E-04	1.87E-04	3.98E-03
Pm-147	1.12E-08	3.36E-08	1.21E-08	1.29E-04	9.15E-09	1.05E-08	1.01E-08	8.70E-09	8.54E-09	1.90E-08	9.66E-08	9.67E-04
Pr-148	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm-148	2.19E-04	1.83E-03	2.37E-04	3.50E-04	8.55E-05	1.84E-04	1.79E-04	2.10E-05	5.75E-06	8.14E-04	5.64E-04	9.92E-03
Pm-148m	9.37E-04	8.07E-03	9.78E-04	1.55E-03	3.39E-04	7.53E-04	8.11E-04	7.93E-05	2.19E-05	3.59E-03	2.51E-03	6.53E-03

Table A-1. Ingestion dose conversion factors based on ICRP-72.

Ingestion Dose Conversion Factors (rem/μCi)

Nuclide	Adrenals	B Surface	Brain	Breast	S Wall	SI Wall	ULI Wall	LLI Wall	Kidneys	Liver	ET Region	Lung
Pm-149	2.09E-06	5.07E-06	4.91E-08	3.71E-07	1.55E-03	3.69E-03	1.89E-02	4.23E-02	4.73E-06	9.42E-06	8.64E-08	5.81E-07
Pm-151	5.12E-05	8.00E-05	2.20E-07	8.53E-06	1.55E-03	3.64E-03	1.45E-02	2.60E-02	1.15E-04	8.08E-05	1.19E-06	1.39E-05
Sm-151	9.15E-09	2.13E-03	4.02E-09	3.19E-09	8.45E-05	2.11E-04	1.28E-03	3.76E-03	5.22E-09	5.68E-04	2.88E-09	7.11E-09
Eu-152	1.19E-03	4.26E-03	1.80E-04	2.64E-04	2.15E-03	5.79E-03	1.56E-02	3.74E-02	1.22E-03	5.86E-03	1.58E-04	5.20E-04
Sm-153	9.58E-06	4.83E-05	4.58E-08	8.87E-07	1.23E-03	2.96E-03	1.41E-02	3.02E-02	2.52E-05	2.22E-05	8.64E-08	2.11E-06
Eu-154	1.10E-03	8.61E-03	1.60E-04	2.48E-04	2.84E-03	7.56E-03	2.57E-02	6.67E-02	1.21E-03	7.15E-03	1.44E-04	4.74E-04
Eu-155	4.90E-05	2.46E-03	5.80E-06	6.93E-06	3.69E-04	1.00E-03	4.58E-03	1.29E-02	6.29E-05	7.81E-04	4.38E-06	2.05E-05
Eu-156	3.00E-04	4.33E-04	4.95E-06	7.26E-05	3.08E-03	8.39E-03	3.26E-02	8.44E-02	6.61E-04	5.07E-04	1.64E-05	1.02E-04
Tb-160	2.88E-04	8.44E-04	9.50E-06	6.37E-05	2.30E-03	6.49E-03	2.23E-02	5.80E-02	6.19E-04	5.59E-04	1.67E-05	9.49E-05
Ho-166m	3.30E-03	1.46E-02	4.64E-04	6.42E-04	3.93E-03	8.62E-03	1.92E-02	4.25E-02	2.79E-03	1.25E-02	4.04E-04	1.34E-03
Be-7	1.49E-05	2.21E-05	2.56E-06	3.26E-06	5.65E-05	1.78E-04	2.65E-04	4.74E-04	2.94E-05	1.91E-05	2.23E-06	5.26E-06
Na-24	1.28E-03	2.01E-03	9.26E-04	8.26E-04	4.41E-03	1.29E-03	1.45E-03	1.56E-03	1.17E-03	1.10E-03	1.03E-03	9.97E-04
Mn-54	1.77E-03	2.62E-03	6.16E-04	5.55E-04	1.62E-03	3.61E-03	5.38E-03	9.04E-03	1.56E-03	3.89E-03	6.05E-04	9.30E-04
Fe-55	3.17E-04	2.21E-03	3.17E-04	3.17E-04	3.42E-04	3.74E-04	6.64E-04	1.33E-03	3.17E-04	2.71E-03	3.17E-04	3.17E-04
Fe-59	3.90E-03	3.96E-03	1.68E-03	1.83E-03	4.11E-03	7.12E-03	1.47E-02	3.09E-02	3.63E-03	1.12E-02	2.02E-03	2.54E-03
Co-57	2.89E-04	4.34E-04	1.70E-04	1.50E-04	4.43E-04	9.05E-04	2.19E-03	5.20E-03	2.97E-04	6.13E-04	1.99E-04	2.18E-04
Co-58	8.58E-04	8.06E-04	3.80E-04	4.01E-04	1.65E-03	3.91E-03	7.27E-03	1.48E-02	1.05E-03	1.48E-03	4.81E-04	5.49E-04
Co-60	9.15E-03	7.61E-03	5.05E-03	5.00E-03	9.51E-03	1.56E-02	2.42E-02	4.31E-02	8.84E-03	1.66E-02	6.33E-03	6.61E-03
Cu-64	6.24E-05	5.69E-05	1.42E-04	4.06E-05	6.44E-04	7.57E-04	2.29E-03	2.79E-03	7.26E-05	1.37E-04	4.38E-05	4.69E-05
Cu-67	2.58E-04	2.95E-04	1.03E-03	2.03E-04	9.66E-04	1.22E-03	4.87E-03	1.07E-02	2.62E-04	8.41E-04	2.24E-04	2.27E-04
W-181	3.74E-05	2.39E-04	1.49E-05	6.70E-06	1.25E-04	3.02E-04	9.78E-04	2.51E-03	2.76E-04	7.93E-05	9.66E-06	1.57E-05
W-185	1.02E-05	5.46E-04	1.02E-05	1.02E-05	5.51E-04	9.56E-04	6.90E-03	2.00E-02	1.47E-03	2.61E-04	1.02E-05	1.02E-05
W-187	9.73E-05	2.53E-04	2.79E-05	3.80E-05	1.68E-03	2.93E-03	1.21E-02	2.01E-02	3.21E-04	1.53E-04	3.14E-05	4.84E-05
W-188	6.09E-05	3.55E-03	4.06E-05	3.64E-05	6.21E-04	1.69E-03	2.55E-02	1.06E-01	9.70E-03	1.72E-03	3.80E-05	4.23E-05
Au-198	1.46E-04	1.75E-04	6.38E-05	7.37E-05	1.82E-03	4.12E-03	1.76E-02	3.96E-02	2.37E-04	1.80E-04	7.01E-05	8.75E-05
Au-199	4.54E-05	7.43E-05	2.66E-05	2.74E-05	7.25E-04	1.62E-03	7.58E-03	1.78E-02	6.73E-05	5.33E-05	2.79E-05	3.14E-05
Pb-203	1.52E-04	3.81E-04	4.82E-05	4.91E-05	5.64E-04	1.27E-03	3.47E-03	6.62E-03	5.52E-04	3.41E-04	5.42E-05	7.67E-05
Th-229	2.80E-01	8.35E+01	2.80E-01	2.79E-01	2.84E-01	2.92E-01	3.55E-01	5.17E-01	1.17E+00	4.04E+00	2.80E-01	2.80E-01
Th-230	5.03E-02	4.54E+01	5.03E-02	5.03E-02	5.44E-02	6.04E-02	1.12E-01	2.30E-01	6.85E-01	5.89E-01	5.03E-02	5.03E-02
Th-234	7.85E-06	1.75E-04	2.41E-06	3.27E-06	3.69E-03	9.44E-03	5.60E-02	1.60E-01	7.01E-05	2.93E-05	2.52E-06	3.86E-06
U-233	1.05E-01	3.10E+00	1.05E-01	1.05E-01	1.09E-01	1.15E-01	1.67E-01	2.85E-01	1.08E+00	4.10E-01	1.05E-01	1.05E-01
U-234	1.02E-01	2.91E+00	1.02E-01	1.02E-01	1.06E-01	1.12E-01	1.63E-01	2.82E-01	1.06E+00	3.98E-01	1.02E-01	1.02E-01
U-235	9.50E-02	2.74E+00	9.49E-02	9.47E-02	9.90E-02	1.05E-01	1.59E-01	2.88E-01	9.83E-01	3.69E-01	9.48E-02	9.48E-02
U-237	3.67E-05	3.89E-04	3.50E-06	6.10E-06	1.01E-03	2.58E-03	1.25E-02	3.23E-02	5.18E-04	5.89E-05	3.67E-06	1.02E-05
U-238	9.08E-02	2.63E+00	9.08E-02	9.08E-02	9.44E-02	9.97E-02	1.46E-01	2.56E-01	9.40E-01	3.54E-01	9.08E-02	9.08E-02
U-240	4.08E-05	1.64E-04	2.14E-06	9.59E-06	3.14E-03	7.38E-03	2.63E-02	3.50E-02	2.78E-04	7.55E-05	3.16E-06	1.37E-05
Np-237	2.66E-02	2.01E+01	2.65E-02	2.64E-02	3.09E-02	3.76E-02	9.34E-02	2.23E-01	7.17E-02	3.20E-01	2.65E-02	2.65E-02
Np-239	3.33E-05	9.50E-05	1.90E-07	4.04E-06	1.28E-03	3.15E-03	1.45E-02	3.22E-02	7.75E-05	5.07E-05	5.28E-07	7.69E-06
Np-240	3.10E-05	1.38E-05	1.81E-07	7.06E-06	1.71E-03	1.13E-03	8.51E-04	1.88E-04	4.28E-05	2.64E-05	7.99E-07	1.11E-05
Pu-238	4.77E-02	2.74E+01	4.77E-02	4.77E-02	5.25E-02	5.96E-02	1.19E-01	2.58E-01	1.18E-01	5.77E+00	4.77E-02	4.77E-02
Pu-239	5.37E-02	3.05E+01	5.37E-02	5.37E-02	5.81E-02	6.47E-02	1.21E-01	2.50E-01	1.25E-01	6.39E+00	5.37E-02	5.37E-02
Pu-240	5.37E-02	3.05E+01	5.37E-02	5.37E-02	5.81E-02	6.48E-02	1.21E-01	2.51E-01	1.25E-01	6.39E+00	5.37E-02	5.37E-02
Pu-241	1.10E-03	6.06E-01	1.10E-03	1.10E-03	1.12E-03	1.16E-03	1.44E-03	2.10E-03	1.84E-03	1.26E-01	1.10E-03	1.10E-03
Am-241	5.67E-02	3.34E+01	5.67E-02	5.67E-02	6.16E-02	6.91E-02	1.31E-01	2.75E-01	1.71E-01	2.05E+00	5.67E-02	5.67E-02
Cm-242	8.53E-04	6.87E-01	8.53E-04	8.53E-04	6.11E-03	1.40E-02	8.01E-02	2.32E-01	1.48E-02	1.91E-01	8.53E-04	8.53E-04

Nuclide	Muscle	Ovaries	Pancreas	R Marrow	Skin	Spleen	Testes	Thymus	Thyroid	Uterus	Bld Wall	Eff Dose
Pm-149	3.70E-06	3.09E-05	4.37E-06	7.71E-06	1.25E-06	3.30E-06	2.80E-06	2.87E-07	8.64E-08	1.49E-05	1.01E-05	3.68E-03
Pm-151	8.67E-05	7.36E-04	1.13E-04	1.35E-04	2.84E-05	8.24E-05	5.99E-05	6.22E-06	1.19E-06	3.55E-04	2.20E-04	2.71E-03
Sm-151	6.79E-09	5.92E-08	6.07E-09	1.70E-04	3.61E-09	3.22E-09	2.91E-09	3.13E-09	2.88E-09	6.09E-09	8.49E-08	3.63E-04
Eu-152	7.88E-04	4.93E-03	1.22E-03	2.20E-03	3.60E-04	6.52E-04	5.09E-04	2.57E-04	1.58E-04	2.21E-03	1.55E-03	5.06E-03
Sm-153	2.45E-05	2.68E-04	2.77E-05	3.50E-05	5.79E-06	1.93E-05	1.36E-05	5.46E-07	8.64E-08	1.06E-04	6.71E-05	2.75E-03
Eu-154	7.93E-04	5.13E-03	1.17E-03	2.69E-03	3.60E-04	6.59E-04	5.37E-04	2.39E-04	1.44E-04	2.31E-03	1.62E-03	7.56E-03
Eu-155	4.35E-05	3.66E-04	6.25E-05	2.61E-04	1.31E-05	3.34E-05	2.53E-05	7.14E-06	4.38E-06	1.60E-04	1.11E-04	1.20E-03
Eu-156	5.45E-04	4.54E-03	5.68E-04	8.51E-04	2.17E-04	4.50E-04	4.49E-04	5.51E-05	1.64E-05	1.98E-03	1.41E-03	8.13E-03
Tb-160	5.18E-04	4.42E-03	5.42E-04	8.80E-04	1.96E-04	4.15E-04	4.28E-04	4.96E-05	1.67E-05	1.94E-03	1.36E-03	5.95E-03
Ho-166m	1.55E-03	7.98E-03	1.68E-02	4.30E-03	7.25E-04	1.87E-03	8.97E-04	6.36E-04	4.04E-04	3.78E-03	2.62E-03	7.33E-03
Be-7	2.52E-05	2.05E-04	2.58E-05	4.35E-05	9.38E-06	2.04E-05	2.19E-05	3.11E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Na-24	1.02E-03	1.23E-03	1.49E-03	1.47E-03	7.89E-04	1.26E-03	9.59E-04	1.01E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mn-54	1.05E-03	4.02E-03	1.60E-03	2.29E-03	5.93E-04	9.79E-04	7.42E-04	6.64E-04	2.23E-06	9.31E-05	6.58E-05	1.03E-04
Fe-55	3.17E-04	3.17E-04	3.17E-04	4.19E-03	3.17E-04	9.36E-03	3.17E-04	3.17E-04	1.03E-03	1.21E-03	1.56E-03	1.61E-03
Fe-59	2.59E-03	6.49E-03	3.98E-03	5.80E-03	1.72E-03	7.26E-03	2.20E-03	2.25E-03	6.05E-04	2.12E-03	1.58E-03	2.67E-03
Co-57	2.41E-04	7.50E-04	3.28E-04	2.84E-04	1.52E-04	2.60E-04	2.19E-04	1.95E-04	3.17E-04	3.17E-04	3.17E-04	1.23E-03
Co-58	8.64E-04	4.11E-03	1.08E-03	1.15E-03	4.68E-04	8.50E-04	7.96E-04	5.04E-04	2.02E-03	4.19E-03	3.31E-03	6.62E-03
Co-60	7.12E-03	1.59E-02	9.65E-03	7.99E-03	4.75E-03	7.73E-03	6.73E-03	6.41E-03	1.99E-04	4.88E-04	4.28E-04	7.80E-04
Cu-64	5.91E-05	1.77E-04	1.56E-04	7.09E-05	4.30E-05	6.89E-05	5.15E-05	4.44E-05	4.81E-04	2.15E-03	1.73E-03	2.77E-03
Cu-67	2.38E-04	4.26E-04	8.88E-04	2.59E-04	2.05E-04	2.51E-04	2.27E-04	2.19E-04	6.33E-03	1.13E-02	9.62E-03	1.26E-02
W-181	3.29E-05	2.43E-04	4.79E-05	8.58E-05	1.16E-05	2.43E-04	1.89E-05	8.40E-06	4.38E-05	1.14E-04	8.45E-05	4.50E-04
W-185	1.02E-05	1.04E-05	1.02E-05	1.87E-04	1.02E-05	1.27E-03	1.02E-05	1.02E-05	2.24E-04	3.29E-04	3.25E-04	1.26E-03
W-187	1.27E-04	8.26E-04	1.75E-04	2.03E-04	5.93E-05	2.68E-04	9.97E-05	3.83E-05	9.66E-06	1.05E-04	1.17E-04	2.88E-04
W-188	5.46E-05	1.77E-04	6.24E-05	1.22E-03	4.12E-05	8.36E-03	4.88E-05	3.76E-05	1.02E-05	1.03E-05	3.39E-04	1.64E-03
Au-198	1.99E-04	1.19E-03	2.30E-04	2.82E-04	1.04E-04	1.88E-04	1.73E-04	7.78E-05	3.14E-05	4.20E-04	8.72E-04	2.33E-03
Au-199	5.91E-05	3.12E-04	6.71E-05	7.65E-05	3.44E-05	5.68E-05	4.98E-05	2.90E-05	3.80E-05	9.64E-05	1.21E-03	7.72E-03
Pb-203	1.46E-04	8.64E-04	2.07E-04	2.52E-04	6.59E-05	1.56E-04	1.10E-04	6.01E-05	7.01E-05	6.06E-04	7.15E-04	3.82E-03
Th-229	2.80E-01	7.04E-01	2.80E-01	4.00E+00	2.79E-01	2.80E-01	7.13E-01	2.80E-01	2.79E-05	1.69E-04	2.55E-04	1.63E-03
Th-230	5.03E-02	3.66E-01	5.03E-02	1.56E+00	5.03E-02	5.03E-02	3.73E-01	5.03E-02	5.42E-05	4.48E-04	3.23E-04	9.14E-04
Th-234	1.43E-05	1.22E-04	1.40E-05	1.08E-04	6.22E-06	1.14E-05	1.71E-05	3.03E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-233	1.05E-01	1.06E-01	1.05E-01	3.11E-01	1.05E-01	1.05E-01	1.06E-01	1.05E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-234	1.02E-01	1.02E-01	1.02E-01	3.00E-01	1.02E-01	1.02E-01	1.02E-01	1.02E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-235	9.49E-02	9.56E-02	9.49E-02	2.81E-01	9.47E-02	9.49E-02	9.48E-02	9.48E-02	2.80E-01	2.80E-01	2.80E-01	1.85E+00
U-237	6.72E-05	6.17E-04	7.38E-05	1.37E-04	2.05E-05	5.80E-05	4.75E-05	5.56E-06	5.03E-02	5.03E-02	5.03E-02	7.91E-01
U-238	9.08E-02	9.08E-02	9.08E-02	2.76E-01	9.08E-02	9.08E-02	9.08E-02	9.08E-02	2.52E-06	5.01E-05	3.67E-05	1.26E-02
U-240	5.83E-05	4.58E-04	8.48E-05	1.05E-04	2.21E-05	6.06E-05	3.84E-05	7.52E-06	1.05E-01	1.05E-01	1.05E-01	1.90E-01
Np-237	2.65E-02	2.68E-01	2.65E-02	7.70E-01	2.64E-02	2.65E-02	2.73E-01	2.64E-02	1.02E-01	1.02E-01	1.03E-01	1.83E-01
Np-239	6.16E-05	5.51E-04	7.33E-05	9.59E-05	1.82E-05	5.57E-05	4.30E-05	2.95E-06	9.48E-02	9.51E-02	9.54E-02	1.73E-01
Np-240	2.08E-05	1.04E-04	1.01E-04	2.67E-05	7.92E-06	6.43E-05	5.23E-06	5.09E-06	3.67E-06	2.75E-04	2.44E-04	2.81E-03
Pu-238	4.77E-02	3.59E-01	4.77E-02	1.35E+00	4.77E-02	4.77E-02	3.66E-01	4.77E-02	9.08E-02	9.08E-02	9.11E-02	1.65E-01
Pu-239	5.37E-02	3.99E-01	5.37E-02	1.45E+00	5.37E-02	5.37E-02	4.06E-01	5.37E-02	3.16E-06	2.25E-04	2.47E-04	4.12E-03
Pu-240	5.37E-02	3.99E-01	5.37E-02	1.45E+00	5.37E-02	5.37E-02	4.06E-01	5.37E-02	2.65E-02	2.65E-02	2.65E-02	3.96E-01
Pu-241	1.10E-03	7.96E-03	1.10E-03	2.38E-02	1.10E-03	1.10E-03	8.11E-03	1.10E-03	5.28E-07	2.60E-04	1.74E-04	2.95E-03
Am-241	5.67E-02	6.48E-01	5.67E-02	1.14E+00	5.67E-02	5.67E-02	6.42E-01	5.67E-02	7.99E-07	8.00E-05	2.48E-05	3.04E-04
Cm-242	8.54E-04	1.22E-02	8.53E-04	4.88E-02	8.53E-04	8.53E-04	1.20E-02	8.53E-04	4.77E-02	4.77E-02	4.77E-02	8.44E-01

Table A-2. Inhalation dose conversion factors based on ICRP-72.

Inhalation Dose Conversion Factors (rem/μCi)

Nuclide	Adrenals	B Surface	Brain	Breast	S Wall	SI Wall	ULI Wall	LLI Wall	Kidneys	Liver	ET Region	Lung
Se-79	5.55E-04	5.55E-04	5.55E-04	5.55E-04	6.66E-04	7.77E-04	1.96E-03	4.81E-03	1.89E-02	8.14E-03	2.11E-02	7.40E-02
Br-82	9.62E-04	9.25E-04	7.77E-04	7.77E-04	1.33E-03	9.99E-04	1.26E-03	1.55E-03	8.14E-04	8.88E-04	5.55E-02	1.07E-02
Br-83	1.48E-05	1.48E-05	1.48E-05	1.48E-05	3.70E-04	2.00E-05	2.41E-05	1.81E-05	1.48E-05	1.48E-05	3.18E-03	1.15E-03
Kr-83m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	1.78E-05	1.85E-05	1.85E-05	1.55E-05	7.03E-04	2.59E-05	2.00E-05	1.52E-05	1.67E-05	1.63E-05	3.55E-03	4.44E-04
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	4.07E-03	1.48E-02	4.07E-03	3.70E-03	4.44E-03	4.07E-03	5.55E-03	8.51E-03	4.07E-03	4.07E-03	1.37E-02	4.07E-03
Kr-87	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-87	2.07E-03	8.14E-03	2.07E-03	2.07E-03	2.18E-03	2.07E-03	2.96E-03	4.81E-03	2.07E-03	2.07E-03	8.88E-03	2.18E-03
Kr-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-88	8.51E-06	9.62E-06	8.88E-06	8.14E-06	4.07E-04	1.74E-05	9.99E-06	8.14E-06	8.51E-06	8.14E-06	1.33E-03	1.22E-04
Kr-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	8.88E-06	1.33E-05	9.62E-06	7.77E-06	2.00E-04	1.15E-05	9.25E-06	8.51E-06	8.14E-06	7.77E-06	2.00E-03	9.62E-05
Sr-89	8.51E-04	2.59E-02	8.51E-04	8.51E-04	1.33E-03	1.67E-03	8.14E-03	2.18E-02	8.51E-04	8.51E-04	8.51E-03	9.62E-04
Rb-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-90m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-90	2.89E-03	1.78E+00	2.89E-03	2.89E-03	3.03E-03	3.18E-03	9.99E-03	2.85E-02	2.89E-03	2.89E-03	1.15E-02	3.00E-03
Y-90	1.89E-07	5.55E-06	1.89E-07	1.89E-07	1.59E-03	3.70E-03	2.04E-02	4.81E-02	1.89E-07	5.55E-06	8.14E-03	2.89E-02
Rb-91	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-91	1.37E-04	6.66E-04	1.37E-04	1.04E-04	7.03E-04	1.04E-03	3.07E-03	3.26E-03	1.41E-04	1.26E-04	1.41E-02	2.52E-04
Y-91	1.78E-05	2.33E-04	5.92E-06	1.92E-05	1.11E-03	2.78E-03	1.67E-02	4.81E-02	9.99E-06	2.37E-04	2.37E-02	2.55E-01
Y-91m	5.18E-06	4.07E-06	3.63E-06	3.33E-06	5.92E-05	2.81E-05	3.63E-05	3.59E-05	5.18E-06	4.44E-06	9.99E-04	1.85E-04
Sr-92	7.77E-05	4.44E-04	7.77E-05	6.29E-05	4.44E-04	8.14E-04	2.44E-03	1.74E-03	8.14E-05	7.40E-05	8.51E-03	1.85E-04
Y-92	8.14E-06	7.40E-06	5.55E-06	5.92E-06	2.00E-03	2.78E-03	4.81E-03	2.37E-03	9.62E-06	8.51E-06	4.81E-03	2.59E-03
Sr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-93	6.29E-06	7.03E-06	4.07E-06	4.81E-06	1.85E-03	3.66E-03	1.15E-02	1.26E-02	7.77E-06	7.77E-06	5.55E-03	5.92E-03
Zr-93	5.55E-05	1.85E+00	7.77E-05	2.74E-05	4.44E-05	1.11E-04	5.55E-04	1.63E-03	2.18E-05	1.85E-05	3.55E-03	1.07E-02
Nb-93m	3.70E-05	2.00E-04	1.74E-05	3.70E-05	8.14E-05	1.59E-04	8.88E-04	2.59E-03	2.70E-04	3.66E-04	1.52E-02	5.18E-02
Y-94	3.70E-06	3.22E-06	3.29E-06	2.85E-06	5.92E-04	1.52E-04	3.70E-05	4.44E-06	3.26E-06	2.81E-06	2.44E-03	3.07E-04
Y-95	1.96E-06	1.55E-06	1.52E-06	1.81E-06	2.78E-04	4.07E-05	7.03E-06	2.33E-06	1.26E-06	1.52E-06	1.63E-03	1.89E-04
Zr-95	5.55E-03	4.81E-02	1.41E-03	4.44E-03	2.85E-03	2.92E-03	5.92E-03	1.30E-02	2.55E-03	3.70E-03	4.07E-02	1.18E-01
Nb-95	2.04E-03	1.04E-03	2.04E-04	2.15E-03	1.26E-03	1.41E-03	3.00E-03	6.29E-03	8.14E-04	1.81E-03	2.85E-02	4.44E-02
Y-96	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zr-97	1.81E-04	3.15E-04	1.15E-04	1.41E-04	1.85E-03	4.81E-03	1.74E-02	2.48E-02	2.07E-04	2.00E-04	3.07E-02	1.33E-02
Nb-97	8.88E-06	7.03E-06	5.92E-06	5.92E-06	4.81E-04	3.59E-04	2.74E-04	5.92E-05	9.25E-06	7.77E-06	4.07E-03	7.40E-04
Nb-97m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb-98m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mo-99	8.51E-05	9.25E-05	2.66E-05	7.77E-05	7.77E-04	1.92E-03	9.25E-03	2.15E-02	1.04E-04	1.18E-04	1.48E-02	2.41E-02
Tc-99	3.59E-05	3.59E-05	3.59E-05	3.59E-05	2.07E-03	4.44E-04	2.81E-03	8.14E-03	3.59E-05	4.81E-05	2.92E-02	1.26E-01
Tc-99m	7.03E-06	1.26E-05	4.44E-06	4.44E-06	5.92E-05	7.77E-05	1.55E-04	1.07E-04	8.88E-06	7.77E-06	1.63E-03	3.44E-04
Mo-101	4.44E-06	4.07E-06	4.07E-06	3.33E-06	3.29E-04	8.88E-05	2.44E-05	4.07E-06	3.70E-06	3.33E-06	3.29E-03	3.66E-04
Tc-101	9.99E-07	1.04E-06	9.25E-07	7.40E-07	1.22E-04	2.33E-05	4.81E-06	7.77E-07	8.51E-07	7.77E-07	1.70E-03	1.63E-04
Mo-102	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc-102	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Nuclide	Muscle	Ovaries	Pancreas	R Marrow	Skin	Spleen	Testes	Thymus	Thyroid	Uterus	Bld Wall	Eff Dose
Se-79	5.55E-04	1.04E-03	2.89E-03	5.55E-04	5.55E-04	3.22E-03	1.67E-03	5.55E-04	5.55E-04	5.55E-04	6.29E-04	1.04E-02
Br-82	8.51E-04	1.04E-03	9.99E-04	8.88E-04	5.55E-04	8.88E-04	7.03E-04	1.11E-03	9.25E-04	9.62E-04	9.62E-04	3.29E-03
Br-83	1.48E-05	1.48E-05	1.52E-05	1.48E-05	1.48E-05	1.48E-05	1.48E-05	1.48E-05	1.48E-05	1.48E-05	1.70E-05	2.59E-04
Kr-83m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	1.89E-05	1.52E-05	2.70E-05	1.78E-05	1.44E-05	2.11E-05	1.30E-05	2.15E-05	1.96E-05	1.52E-05	1.41E-05	2.26E-04
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	4.07E-03	4.07E-03	4.07E-03	7.40E-03	3.70E-03	4.07E-03	4.07E-03	4.07E-03	4.07E-03	4.07E-03	5.18E-03	4.81E-03
Kr-87	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-87	2.07E-03	2.07E-03	2.07E-03	4.07E-03	2.07E-03	2.07E-03	2.07E-03	2.07E-03	2.07E-03	2.07E-03	2.78E-03	2.81E-03
Kr-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-88	8.88E-06	8.14E-06	1.04E-05	8.88E-06	8.14E-06	9.25E-06	7.77E-06	9.62E-06	9.25E-06	8.14E-06	7.77E-06	1.04E-04
Kr-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	9.62E-06	7.03E-06	1.44E-05	1.04E-05	7.03E-06	1.11E-05	5.92E-06	1.18E-05	1.04E-05	7.03E-06	6.66E-06	8.88E-05
Sr-89	8.51E-04	8.51E-04	8.51E-04	2.07E-02	8.51E-04	8.51E-04	8.51E-04	8.51E-04	8.51E-04	8.51E-04	2.92E-03	5.18E-03
Rb-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-90m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-90	2.89E-03	2.89E-03	2.89E-03	7.77E-01	2.89E-03	2.89E-03	2.89E-03	2.89E-03	2.89E-03	2.89E-03	6.29E-03	1.15E-01
Y-90	1.89E-07	1.92E-07	1.89E-07	5.55E-06	1.89E-07	1.89E-07	1.89E-07	1.89E-07	1.89E-07	1.89E-07	8.88E-07	7.03E-03
Rb-91	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-91	1.48E-04	2.66E-04	1.48E-04	6.29E-04	1.07E-04	1.30E-04	1.07E-04	1.44E-04	1.41E-04	1.96E-04	7.40E-04	1.04E-03
Y-91	1.07E-05	9.99E-06	1.44E-05	2.37E-04	7.77E-06	1.48E-05	5.18E-06	2.15E-05	1.04E-05	7.03E-06	7.40E-06	3.29E-02
Y-91m	5.18E-06	9.62E-06	1.30E-05	5.55E-06	2.29E-06	8.51E-06	4.81E-07	5.92E-06	4.07E-06	7.77E-06	2.37E-06	5.55E-05
Sr-92	8.51E-05	1.26E-04	9.25E-05	3.00E-04	6.66E-05	8.14E-05	6.29E-05	8.88E-05	8.14E-05	1.07E-04	5.55E-04	6.66E-04
Y-92	9.62E-06	3.07E-05	1.48E-05	1.07E-05	4.44E-06	1.04E-05	2.04E-06	9.62E-06	6.29E-06	2.00E-05	8.14E-06	1.07E-03
Sr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-93	8.14E-06	3.22E-05	9.25E-06	9.99E-06	3.63E-06	7.03E-06	2.63E-06	7.77E-06	4.81E-06	1.74E-05	9.62E-06	2.26E-03
Zr-93	4.81E-05	1.70E-05	1.26E-05	1.48E-01	4.07E-05	1.63E-05	8.51E-06	2.44E-05	1.37E-05	8.88E-06	4.07E-05	3.70E-02
Nb-93m	7.40E-05	2.11E-05	2.07E-05	7.40E-05	1.89E-05	4.07E-05	1.70E-05	2.22E-05	1.74E-05	1.74E-05	2.22E-05	6.66E-03
Y-94	4.07E-06	3.66E-06	9.99E-06	3.55E-06	1.92E-06	6.66E-06	2.66E-07	5.18E-06	3.63E-06	3.11E-06	9.99E-07	1.70E-04
Y-95	1.81E-06	1.04E-06	3.70E-06	1.63E-06	8.88E-07	2.66E-06	1.11E-07	2.92E-06	1.81E-06	8.51E-07	3.48E-07	9.62E-05
Zr-95	2.55E-03	2.66E-03	3.70E-03	8.88E-03	1.44E-03	3.44E-03	6.29E-04	5.18E-03	2.37E-03	1.59E-03	1.18E-03	1.85E-02
Nb-95	9.62E-04	1.33E-03	1.52E-03	1.26E-03	4.81E-04	1.48E-03	1.48E-04	2.48E-03	8.51E-04	6.29E-04	4.44E-04	6.66E-03
Y-96	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zr-97	2.26E-04	8.88E-04	2.29E-04	4.07E-04	1.07E-04	1.85E-04	9.99E-05	2.15E-04	1.37E-04	4.44E-04	2.96E-04	5.18E-03
Nb-97	9.25E-06	2.04E-05	2.04E-05	9.62E-06	4.07E-06	1.37E-05	1.11E-06	9.99E-06	6.66E-06	1.55E-05	4.81E-06	2.70E-04
Nb-97m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb-98m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mo-99	7.40E-05	3.15E-04	8.14E-05	9.99E-05	3.18E-05	7.40E-05	3.22E-05	1.04E-04	4.44E-05	1.48E-04	1.07E-04	4.81E-03
Tc-99	3.59E-05	3.59E-05	3.59E-05	3.59E-05	3.59E-05	3.59E-05	3.59E-05	3.59E-05	9.25E-04	3.59E-05	1.48E-04	1.59E-02
Tc-99m	8.88E-06	3.11E-05	1.30E-05	9.99E-06	3.33E-06	9.25E-06	2.29E-06	8.51E-06	2.96E-05	2.00E-05	1.04E-05	1.11E-04
Mo-101	4.81E-06	4.07E-06	1.22E-05	4.07E-06	2.26E-06	8.14E-06	2.74E-07	6.29E-06	4.44E-06	3.52E-06	1.15E-06	1.67E-04
Tc-101	1.11E-06	8.14E-07	2.59E-06	9.62E-07	5.18E-07	1.74E-06	1.55E-07	1.33E-06	5.55E-06	7.03E-07	3.29E-07	7.77E-05
Mo-102	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc-102	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table A-2. Inhalation dose conversion factors based on ICRP-72.

Inhalation Dose Conversion Factors (rem/μCi)

Nuclide	Adrenals	B Surface	Brain	Breast	S Wall	SI Wall	ULI Wall	LLI Wall	Kidneys	Liver	ET Region	Lung
Tc-103	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	1.48E-03	6.29E-04	1.33E-04	1.48E-03	9.62E-04	1.30E-03	4.07E-03	1.07E-02	5.18E-04	1.22E-03	2.89E-02	8.14E-02
Rh-103m	7.77E-09	1.81E-08	4.81E-09	7.40E-09	3.15E-05	1.92E-05	1.11E-05	1.74E-06	6.29E-09	1.15E-08	3.40E-05	6.66E-05
Tc-104	6.66E-06	5.92E-06	5.92E-06	5.18E-06	5.55E-04	1.30E-04	3.55E-05	6.29E-06	5.92E-06	5.18E-06	2.85E-03	2.78E-04
Mo-105	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc-105	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-105	3.29E-05	3.18E-05	2.15E-05	2.33E-05	7.03E-04	1.07E-03	2.33E-03	1.96E-03	4.07E-05	3.55E-05	9.25E-03	3.37E-03
Rh-105	1.92E-05	1.96E-05	1.07E-05	1.59E-05	2.92E-04	6.66E-04	2.89E-03	5.55E-03	1.85E-05	1.96E-05	7.77E-03	9.62E-03
Rh-105m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	4.07E-03	2.00E-03	9.25E-04	4.07E-03	4.81E-03	7.77E-03	4.07E-02	1.22E-01	1.74E-03	3.40E-03	8.14E-02	1.96E+00
Rh-106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd-107	1.07E-07	1.59E-06	1.07E-07	1.07E-07	1.89E-05	4.81E-05	2.85E-04	8.51E-04	7.03E-05	3.70E-05	4.81E-04	1.78E-02
Rh-109	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd-109	8.51E-07	3.15E-06	3.70E-07	7.40E-07	7.03E-04	1.48E-03	5.18E-03	7.03E-03	1.18E-05	6.66E-06	9.25E-03	9.25E-03
Ag-109m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag-110m	3.29E-02	1.33E-02	2.70E-03	3.52E-02	1.81E-02	7.40E-03	1.18E-02	1.92E-02	1.22E-02	3.03E-02	1.18E-01	2.63E-01
Ag-111	2.37E-05	1.74E-05	8.88E-06	2.29E-05	6.29E-04	1.55E-03	8.88E-03	2.33E-02	1.55E-05	2.07E-04	1.15E-02	4.81E-02
Cd-113m	7.77E-03	7.77E-03	7.77E-03	7.77E-03	8.14E-03	8.88E-03	1.33E-02	2.33E-02	1.26E+00	2.18E-01	1.55E-01	6.29E-01
Cd-115m	3.29E-04	2.92E-04	2.74E-04	3.11E-04	1.41E-03	2.92E-03	1.59E-02	4.44E-02	4.07E-02	7.40E-03	2.11E-02	2.15E-01
Sn-123	4.44E-04	8.88E-03	4.07E-04	4.44E-04	1.26E-03	2.59E-03	1.44E-02	4.07E-02	4.07E-04	4.44E-04	2.41E-02	2.29E-01
Sb-124	5.18E-03	7.03E-03	8.51E-04	5.18E-03	3.63E-03	4.44E-03	1.44E-02	3.59E-02	2.29E-03	4.81E-03	6.66E-02	1.63E-01
Sn-125	3.40E-04	2.37E-03	1.30E-04	3.26E-04	1.63E-03	3.70E-03	2.04E-02	5.55E-02	2.15E-04	2.92E-04	1.85E-02	7.40E-02
Sb-125	4.44E-03	3.22E-02	1.07E-03	3.70E-03	2.55E-03	2.22E-03	4.81E-03	1.07E-02	2.04E-03	5.18E-03	4.07E-02	1.18E-01
Te-125m	1.78E-04	2.18E-02	7.40E-05	1.85E-04	3.00E-04	5.92E-04	2.92E-03	8.14E-03	8.88E-04	1.92E-04	2.29E-02	1.07E-01
Sn-126	2.96E-02	1.04E-01	1.41E-02	2.33E-02	1.78E-02	1.78E-02	3.66E-02	8.14E-02	1.70E-02	2.26E-02	1.41E-01	6.66E-01
Sb-126	2.92E-03	2.59E-03	5.92E-04	2.85E-03	2.74E-03	5.18E-03	1.30E-02	2.89E-02	1.44E-03	2.66E-03	8.88E-02	6.29E-02
Sb-127	2.96E-04	5.18E-04	1.11E-04	2.78E-04	9.25E-04	2.29E-03	1.07E-02	2.85E-02	2.18E-04	3.55E-04	3.00E-02	4.44E-02
Te-127	4.07E-06	9.62E-06	4.07E-06	4.07E-06	3.33E-04	5.92E-04	1.81E-03	1.89E-03	1.26E-05	4.44E-06	4.81E-03	3.26E-03
Te-127m	2.26E-04	3.70E-02	1.67E-04	2.15E-04	3.70E-04	7.77E-04	5.92E-03	2.00E-02	2.78E-03	2.15E-04	3.63E-02	2.18E-01
Sb-129	5.92E-05	7.77E-05	4.07E-05	4.44E-05	1.04E-03	1.92E-03	4.07E-03	2.59E-03	7.03E-05	6.66E-05	1.37E-02	3.63E-03
Te-129	1.63E-06	1.89E-06	1.41E-06	1.37E-06	4.81E-04	3.40E-04	2.33E-04	4.44E-05	1.92E-06	1.55E-06	2.66E-03	6.66E-04
Te-129m	3.66E-04	1.26E-02	2.33E-04	3.40E-04	1.04E-03	2.48E-03	1.48E-02	4.07E-02	3.55E-03	3.33E-04	2.63E-02	1.81E-01
I-129	2.22E-04	7.40E-04	2.59E-04	2.04E-04	2.66E-04	2.22E-04	4.07E-04	7.40E-04	2.15E-04	2.18E-04	5.18E-03	3.22E-04
Sn-130	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sn-130m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-130	1.30E-04	2.11E-04	2.33E-04	1.18E-04	4.81E-04	1.41E-04	1.52E-04	1.81E-04	1.18E-04	1.22E-04	3.03E-02	3.00E-04
Sb-131	1.07E-05	1.04E-05	8.51E-06	7.77E-06	5.18E-04	2.33E-04	1.15E-04	5.55E-05	9.62E-06	8.51E-06	4.07E-03	6.29E-04
Te-131	2.89E-06	2.78E-06	2.11E-06	2.18E-06	3.22E-04	1.04E-04	4.07E-05	3.03E-05	2.44E-06	2.33E-06	2.63E-03	4.07E-04
Te-131m	3.07E-04	5.92E-04	1.63E-04	2.59E-04	1.07E-03	2.37E-03	7.77E-03	1.41E-02	4.07E-04	3.11E-04	3.70E-02	1.85E-02
I-131	9.25E-05	2.55E-04	3.00E-04	1.18E-04	2.66E-04	8.51E-05	1.15E-04	1.89E-04	8.14E-05	8.88E-05	1.74E-02	3.15E-04
Xe-131m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb-132	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb-132m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	8.88E-04	1.41E-03	3.70E-04	8.51E-04	1.41E-03	4.07E-03	1.52E-02	3.48E-02	7.77E-04	8.51E-04	6.29E-02	3.70E-02
I-132	5.92E-05	7.03E-05	7.03E-05	4.81E-05	4.81E-04	6.66E-05	6.66E-05	6.29E-05	5.55E-05	5.18E-05	9.99E-03	1.81E-04
Sb-133	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Nuclide	Muscle	Ovaries	Pancreas	R Marrow	Skin	Spleen	Testes	Thymus	Thyroid	Uterus	Bld Wall	Eff Dose
Tc-103	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	6.66E-04	8.88E-04	1.11E-03	8.51E-04	3.29E-04	1.04E-03	1.11E-04	1.78E-03	5.92E-04	4.07E-04	3.00E-04	1.15E-02
Rh-103m	3.40E-08	5.55E-08	4.07E-08	8.14E-09	6.29E-09	1.48E-08	4.44E-09	6.29E-09	4.81E-09	2.11E-08	1.18E-08	1.15E-05
Tc-104	7.03E-06	6.29E-06	1.67E-05	6.29E-06	3.66E-06	1.15E-05	1.04E-06	9.25E-06	3.26E-05	5.55E-06	2.41E-06	1.74E-04
Mo-105	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc-105	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-105	4.07E-05	1.41E-04	5.92E-05	4.81E-05	1.70E-05	4.07E-05	9.62E-06	3.70E-05	2.52E-05	8.51E-05	3.70E-05	9.62E-04
Rh-105	2.11E-05	7.77E-05	2.18E-05	2.55E-05	1.07E-05	1.89E-05	1.11E-05	2.18E-05	1.33E-05	4.07E-05	3.22E-05	1.67E-03
Rh-105m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	2.04E-03	1.22E-03	3.07E-03	2.44E-03	1.37E-03	2.96E-03	8.14E-04	4.81E-03	2.00E-03	9.99E-04	1.04E-03	2.44E-01
Rh-106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd-107	1.07E-07	1.07E-07	1.07E-07	5.92E-07	1.07E-07	1.07E-07	1.07E-07	1.07E-07	1.07E-07	1.07E-07	1.30E-06	2.18E-03
Rh-109	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd-109	2.07E-06	1.11E-05	1.33E-06	1.55E-06	4.81E-07	9.99E-07	3.55E-07	8.88E-07	4.44E-07	2.66E-06	2.85E-06	1.96E-03
Ag-109m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag-110m	1.44E-02	6.29E-03	2.41E-02	1.81E-02	7.77E-03	2.37E-02	8.88E-04	4.07E-02	1.37E-02	3.37E-03	2.22E-03	4.44E-02
Ag-111	1.78E-05	4.81E-05	2.15E-05	2.15E-05	1.07E-05	1.96E-05	9.62E-06	2.78E-05	1.37E-05	2.48E-05	1.92E-05	7.40E-03
Cd-113m	7.77E-03	7.77E-03	7.77E-03	7.77E-03	7.77E-03	7.77E-03	7.77E-03	7.77E-03	7.77E-03	7.77E-03	7.77E-03	1.15E-01
Cd-115m	2.92E-04	3.07E-04	3.15E-04	3.00E-04	2.81E-04	3.15E-04	2.74E-04	3.22E-04	2.89E-04	2.89E-04	2.81E-04	2.85E-02
Sn-123	4.07E-04	4.07E-04	4.44E-04	3.18E-03	4.07E-04	4.44E-04	4.07E-04	4.44E-04	4.07E-04	4.07E-04	6.66E-04	3.00E-02
Sb-124	2.55E-03	3.26E-03	4.07E-03	4.44E-03	1.44E-03	3.70E-03	5.92E-04	6.29E-03	2.41E-03	1.70E-03	1.59E-03	2.41E-02
Sn-125	2.33E-04	5.18E-04	2.78E-04	1.52E-03	1.48E-04	2.66E-04	1.15E-04	3.70E-04	1.92E-04	2.74E-04	4.07E-04	1.26E-02
Sb-125	2.22E-03	1.89E-03	3.29E-03	6.29E-03	1.30E-03	3.00E-03	7.77E-04	4.44E-03	2.04E-03	1.33E-03	1.18E-03	1.78E-02
Te-125m	1.44E-04	2.07E-04	1.07E-04	1.89E-03	7.03E-05	1.44E-04	5.55E-05	1.55E-04	1.15E-03	7.77E-05	1.74E-04	1.41E-02
Sn-126	1.74E-02	1.52E-02	2.26E-02	5.18E-02	1.18E-02	2.07E-02	9.25E-03	2.78E-02	1.70E-02	1.26E-02	1.15E-02	1.04E-01
Sb-126	1.67E-03	4.44E-03	2.29E-03	2.59E-03	8.14E-04	2.15E-03	5.55E-04	3.40E-03	1.33E-03	2.15E-03	1.67E-03	1.37E-02
Sb-127	2.52E-04	9.25E-04	2.85E-04	5.55E-04	1.26E-04	2.48E-04	1.18E-04	3.40E-04	1.70E-04	4.44E-04	4.07E-04	7.77E-03
Te-127	4.44E-06	5.55E-06	4.44E-06	9.25E-06	4.07E-06	4.44E-06	4.07E-06	4.44E-06	1.55E-05	4.81E-06	3.03E-05	7.40E-04
Te-127m	1.96E-04	2.11E-04	1.89E-04	9.99E-03	1.59E-04	1.96E-04	1.48E-04	2.07E-04	3.70E-03	1.63E-04	4.44E-04	2.92E-02
Sb-129	7.03E-05	2.26E-04	9.99E-05	9.25E-05	3.44E-05	7.40E-05	2.07E-05	7.03E-05	4.81E-05	1.44E-04	9.25E-05	1.33E-03
Te-129	1.78E-06	2.74E-06	2.78E-06	1.85E-06	1.26E-06	2.11E-06	9.99E-07	1.74E-06	1.85E-06	2.26E-06	4.81E-06	2.15E-04
Te-129m	2.92E-04	3.63E-04	3.18E-04	5.55E-03	2.37E-04	3.15E-04	2.18E-04	3.63E-04	4.81E-03	2.66E-04	7.03E-04	2.59E-02
I-129	5.55E-04	2.29E-04	2.22E-04	2.55E-04	2.55E-04	2.18E-04	2.07E-04	3.15E-04	3.70E+00	2.26E-04	7.77E-04	1.89E-01
Sn-130	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sn-130m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-130	2.22E-04	1.52E-04	1.67E-04	1.89E-04	1.30E-04	1.37E-04	1.18E-04	2.63E-04	6.66E-02	2.04E-04	1.74E-03	3.59E-03
Sb-131	1.11E-05	1.48E-05	2.55E-05	1.07E-05	5.55E-06	1.74E-05	1.85E-06	1.37E-05	2.29E-04	1.18E-05	7.03E-06	2.63E-04
Te-131	2.89E-06	3.70E-06	6.29E-06	2.74E-06	1.44E-06	4.44E-06	6.29E-07	3.59E-06	2.52E-04	2.92E-06	2.41E-06	1.70E-04
Te-131m	3.26E-04	1.22E-03	3.44E-04	4.44E-04	1.55E-04	2.96E-04	1.48E-04	3.66E-04	1.33E-02	5.92E-04	5.55E-04	5.18E-03
I-131	2.59E-04	8.88E-05	9.99E-05	2.04E-04	1.37E-04	9.25E-05	7.03E-05	3.15E-04	7.77E-01	1.04E-04	1.37E-03	4.07E-02
Xe-131m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb-132	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb-132m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	8.14E-04	2.89E-03	8.51E-04	1.04E-03	4.07E-04	7.77E-04	4.44E-04	1.04E-03	2.37E-02	1.41E-03	3.03E-03	1.11E-02
I-132	7.40E-05	5.92E-05	8.51E-05	6.66E-05	4.81E-05	6.66E-05	4.81E-05	8.51E-05	7.03E-03	7.40E-05	6.29E-04	7.40E-04
Sb-133	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table A-2. Inhalation dose conversion factors based on ICRP-72.

Inhalation Dose Conversion Factors (rem/μCi)

Nuclide	Adrenals	B Surface	Brain	Breast	S Wall	SI Wall	ULI Wall	LLI Wall	Kidneys	Liver	ET Region	Lung
Te-133	2.96E-06	2.89E-06	2.66E-06	2.33E-06	1.89E-04	4.81E-05	6.66E-05	9.62E-05	2.63E-06	2.48E-06	2.00E-03	2.33E-04
Te-133m	2.89E-05	2.52E-05	2.11E-05	2.04E-05	8.14E-04	5.18E-04	5.92E-04	5.18E-04	2.96E-05	2.52E-05	7.40E-03	1.04E-03
I-133	7.77E-05	1.15E-04	1.26E-04	7.40E-05	4.44E-04	8.51E-05	1.11E-04	1.41E-04	7.40E-05	7.40E-05	1.48E-02	2.18E-04
Xe-133	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-133m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-134	2.66E-05	2.37E-05	1.85E-05	1.81E-05	5.92E-04	4.81E-04	4.07E-04	9.62E-05	2.96E-05	2.44E-05	7.03E-03	9.25E-04
I-134	3.03E-05	3.29E-05	3.29E-05	2.33E-05	3.70E-04	3.40E-05	3.22E-05	2.66E-05	2.74E-05	2.59E-05	5.55E-03	1.41E-04
Cs-134	3.70E-02	3.55E-02	2.78E-02	2.55E-02	3.33E-02	3.70E-02	3.59E-02	4.07E-02	3.48E-02	3.52E-02	8.14E-02	3.15E-02
Cs-134m	1.33E-05	1.48E-05	1.18E-05	1.07E-05	8.88E-05	1.48E-05	1.59E-05	1.48E-05	1.26E-05	1.30E-05	2.48E-03	1.26E-04
I-135	7.77E-05	1.07E-04	1.15E-04	7.03E-05	4.07E-04	8.51E-05	9.62E-05	9.99E-05	7.40E-05	7.40E-05	1.48E-02	2.07E-04
Xe-135	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-135m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-135	3.44E-03	3.44E-03	3.44E-03	3.44E-03	3.52E-03	3.44E-03	3.70E-03	4.81E-03	3.44E-03	3.44E-03	7.40E-03	3.52E-03
Cs-136	5.92E-03	5.92E-03	4.44E-03	4.07E-03	5.55E-03	5.92E-03	5.92E-03	6.29E-03	5.55E-03	5.55E-03	7.03E-02	5.18E-03
Xe-137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-137	2.52E-02	2.44E-02	2.11E-02	2.00E-02	2.37E-02	2.52E-02	2.55E-02	2.96E-02	2.41E-02	2.41E-02	4.81E-02	2.29E-02
Ba-137m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-138	2.15E-05	2.26E-05	2.26E-05	1.81E-05	4.44E-04	2.85E-05	2.33E-05	1.78E-05	2.00E-05	1.92E-05	3.37E-03	1.33E-04
Cs-139	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	8.14E-06	5.55E-05	8.14E-06	7.77E-06	4.81E-04	3.63E-04	8.88E-04	2.04E-04	8.14E-06	8.14E-06	1.85E-03	1.33E-04
Cs-140	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-140	1.07E-03	9.99E-03	7.03E-04	4.44E-04	9.99E-04	2.52E-03	1.48E-02	4.81E-02	9.25E-04	6.29E-04	3.18E-02	7.40E-04
La-140	5.18E-04	4.81E-04	2.18E-04	4.07E-04	1.70E-03	4.07E-03	1.30E-02	2.48E-02	4.81E-04	1.41E-03	5.18E-02	1.48E-02
Ba-141	5.92E-06	2.85E-05	5.92E-06	4.81E-06	2.37E-04	1.18E-04	3.70E-04	1.78E-04	5.92E-06	5.55E-06	1.85E-03	1.07E-04
La-141	6.66E-06	4.81E-05	4.81E-06	5.55E-06	1.26E-03	1.81E-03	3.29E-03	1.92E-03	5.92E-06	8.14E-05	3.70E-03	2.63E-03
Ce-141	2.26E-04	3.70E-04	1.44E-05	2.18E-04	4.07E-04	9.25E-04	4.81E-03	1.37E-02	7.03E-05	2.96E-04	2.15E-02	1.22E-01
Ba-142	7.03E-06	1.52E-05	7.03E-06	4.81E-06	1.22E-04	7.40E-05	1.67E-04	4.44E-05	7.77E-06	6.66E-06	2.07E-03	8.14E-05
La-142	4.07E-05	3.52E-05	2.96E-05	2.92E-05	1.07E-03	8.88E-04	8.51E-04	2.37E-04	4.44E-05	4.81E-05	8.51E-03	9.99E-04
La-143	9.99E-07	1.81E-06	7.40E-07	8.14E-07	3.22E-04	7.77E-05	7.03E-05	1.18E-04	9.25E-07	7.03E-06	1.59E-03	3.15E-04
Ce-143	5.18E-05	6.66E-05	2.18E-05	4.81E-05	8.51E-04	2.00E-03	8.51E-03	1.74E-02	5.18E-05	6.66E-05	1.44E-02	1.96E-02
Pr-143	5.55E-08	8.51E-06	5.55E-08	5.55E-08	5.55E-04	1.37E-03	8.14E-03	2.26E-02	1.44E-05	7.03E-05	1.26E-02	7.03E-02
Ce-144	9.99E-04	7.40E-03	2.96E-04	9.99E-04	2.55E-03	6.29E-03	3.70E-02	1.11E-01	4.81E-04	2.15E-02	1.11E-01	1.55E+00
Pr-144	9.62E-08	8.14E-08	8.88E-08	7.77E-08	3.70E-04	8.51E-05	1.59E-05	8.51E-07	8.14E-08	7.40E-08	1.63E-03	2.41E-04
Pr-144m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-145	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr-145	6.66E-07	8.14E-07	4.44E-07	5.18E-07	9.99E-04	1.70E-03	4.07E-03	3.15E-03	1.26E-06	1.63E-06	4.44E-03	3.03E-03
Ce-146	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr-146	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr-147	2.26E-06	2.41E-06	2.00E-06	1.70E-06	2.07E-04	4.07E-05	1.48E-05	1.85E-05	1.78E-06	1.74E-06	2.15E-03	2.74E-04
Nd-147	1.55E-04	3.63E-04	1.81E-05	1.59E-04	5.92E-04	1.41E-03	7.40E-03	1.96E-02	6.29E-05	2.29E-04	1.85E-02	7.03E-02
Pm-147	2.55E-07	1.81E-02	9.99E-08	2.41E-07	1.22E-04	3.03E-04	1.85E-03	5.55E-03	1.44E-07	4.81E-03	6.66E-02	1.44E-01
Pr-148	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm-148	2.89E-04	1.85E-04	7.03E-05	3.00E-04	1.55E-03	3.70E-03	1.85E-02	4.81E-02	1.78E-04	3.00E-04	2.37E-02	4.81E-02
Pm-148m	6.29E-03	3.03E-03	5.18E-04	6.66E-03	3.70E-03	4.07E-03	9.62E-03	2.18E-02	2.33E-03	5.55E-03	7.77E-02	1.44E-01

Nuclide	Muscle	Ovaries	Pancreas	R Marrow	Skin	Spleen	Testes	Thymus	Thyroid	Uterus	Bld Wall	Eff Dose
Te-133	3.44E-06	5.55E-06	6.29E-06	3.29E-06	1.67E-06	4.44E-06	7.03E-07	4.07E-06	2.00E-04	3.33E-06	4.44E-06	1.18E-04
Te-133m	3.15E-05	6.66E-05	6.29E-05	3.18E-05	1.48E-05	4.44E-05	6.66E-06	3.44E-05	9.25E-04	4.81E-05	3.48E-05	5.18E-04
I-133	1.18E-04	8.51E-05	8.88E-05	1.04E-04	8.14E-05	7.77E-05	7.03E-05	1.33E-04	1.52E-01	1.04E-04	2.04E-03	7.77E-03
Xe-133	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-133m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-134	2.92E-05	6.66E-05	5.92E-05	3.03E-05	1.37E-05	4.07E-05	5.92E-06	3.07E-05	1.30E-04	5.18E-05	3.48E-05	4.07E-04
I-134	3.44E-05	2.66E-05	4.81E-05	3.11E-05	2.22E-05	3.70E-05	2.04E-05	4.07E-05	1.33E-03	3.00E-05	1.96E-04	2.89E-04
Cs-134	3.11E-02	3.70E-02	3.70E-02	3.33E-02	2.33E-02	3.48E-02	3.11E-02	3.33E-02	3.33E-02	4.07E-02	3.63E-02	3.55E-02
Cs-134m	1.26E-05	1.33E-05	1.41E-05	1.22E-05	1.04E-05	1.30E-05	1.18E-05	1.30E-05	1.26E-05	1.33E-05	1.37E-05	9.62E-05
I-135	1.11E-04	8.51E-05	9.99E-05	9.62E-05	7.40E-05	8.51E-05	7.03E-05	1.33E-04	3.03E-02	1.07E-04	1.22E-03	1.70E-03
Xe-135	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-135m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-135	3.44E-03	3.44E-03	3.44E-03	3.44E-03	3.44E-03	3.44E-03	3.44E-03	3.44E-03	3.44E-03	3.44E-03	4.07E-03	3.66E-03
Cs-136	4.81E-03	5.92E-03	6.29E-03	5.18E-03	3.55E-03	5.55E-03	4.81E-03	5.55E-03	5.55E-03	6.29E-03	5.92E-03	7.03E-03
Xe-137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-137	2.26E-02	2.55E-02	2.55E-02	2.33E-02	1.92E-02	2.41E-02	2.26E-02	2.33E-02	2.33E-02	2.59E-02	2.59E-02	2.48E-02
Ba-137m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-138	2.29E-05	1.78E-05	3.33E-05	2.15E-05	1.70E-05	2.66E-05	1.48E-05	2.70E-05	2.44E-05	1.78E-05	1.59E-05	1.67E-04
Cs-139	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	8.14E-06	9.25E-06	8.88E-06	5.55E-05	7.77E-06	8.51E-06	7.77E-06	8.14E-06	8.14E-06	8.88E-06	7.77E-05	2.04E-04
Cs-140	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-140	8.14E-04	2.48E-03	8.14E-04	7.03E-03	4.81E-04	6.29E-04	5.18E-04	5.92E-04	5.92E-04	1.26E-03	1.26E-03	5.92E-03
La-140	4.81E-04	2.00E-03	5.55E-04	6.66E-04	2.37E-04	4.44E-04	2.11E-04	5.55E-04	3.00E-04	9.62E-04	6.29E-04	5.55E-03
Ba-141	6.29E-06	7.03E-06	9.25E-06	2.66E-05	4.81E-06	7.40E-06	4.07E-06	7.03E-06	6.29E-06	6.29E-06	2.92E-05	1.30E-04
La-141	5.92E-06	9.62E-06	7.03E-06	1.37E-05	4.81E-06	6.29E-06	4.07E-06	6.29E-06	5.18E-06	7.40E-06	5.18E-06	8.51E-04
Ce-141	1.04E-04	1.59E-04	1.67E-04	1.37E-04	4.44E-05	1.63E-04	1.37E-05	2.74E-04	8.14E-05	7.40E-05	5.18E-05	1.55E-02
Ba-142	8.51E-06	1.44E-05	1.18E-05	1.63E-05	4.81E-06	8.51E-06	3.66E-06	8.88E-06	7.40E-06	1.07E-05	1.92E-05	9.62E-05
La-142	4.44E-05	9.62E-05	8.14E-05	4.44E-05	2.18E-05	5.92E-05	8.88E-06	4.81E-05	3.37E-05	7.40E-05	2.78E-05	5.55E-04
La-143	1.04E-06	2.59E-06	1.37E-06	1.70E-06	6.29E-07	1.07E-06	5.55E-07	1.11E-06	8.14E-07	1.44E-06	9.99E-07	1.22E-04
Ce-143	6.29E-05	2.96E-04	6.29E-05	7.77E-05	2.33E-05	5.18E-05	2.33E-05	6.29E-05	3.07E-05	1.33E-04	8.51E-05	4.07E-03
Pr-143	5.55E-08	5.55E-08	5.55E-08	8.51E-06	5.55E-08	5.55E-08	5.55E-08	5.55E-08	5.55E-08	5.55E-08	2.96E-07	1.04E-02
Ce-144	5.55E-04	3.48E-04	7.77E-04	4.44E-03	4.07E-04	7.77E-04	2.59E-04	1.15E-03	5.18E-04	3.03E-04	2.85E-04	1.96E-01
Pr-144	1.04E-07	8.51E-08	2.48E-07	8.88E-08	5.18E-08	1.67E-07	9.62E-09	1.37E-07	9.62E-08	7.40E-08	2.89E-08	1.11E-04
Pr-144m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-145	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr-145	8.51E-07	3.11E-06	1.11E-06	1.07E-06	4.07E-07	8.14E-07	2.44E-07	8.14E-07	5.18E-07	1.81E-06	9.25E-07	9.62E-04
Ce-146	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr-146	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr-147	2.52E-06	1.85E-06	5.92E-06	2.07E-06	1.11E-06	4.07E-06	1.22E-07	3.18E-06	2.22E-06	1.48E-06	5.18E-07	1.11E-04
Nd-147	8.88E-05	2.70E-04	1.22E-04	1.30E-04	3.55E-05	1.18E-04	2.18E-05	1.92E-04	6.29E-05	1.15E-04	7.77E-05	9.99E-03
Pm-147	1.59E-07	1.07E-07	2.15E-07	1.44E-03	1.22E-07	2.00E-07	9.62E-08	2.78E-07	1.44E-07	1.04E-07	9.99E-07	1.81E-02
Pr-148	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm-148	2.11E-04	7.40E-04	2.48E-04	2.78E-04	9.99E-05	2.33E-04	7.40E-05	3.63E-04	1.41E-04	3.40E-04	2.33E-04	9.62E-03
Pm-148m	2.85E-03	3.59E-03	4.81E-03	3.70E-03	1.44E-03	4.44E-03	3.70E-04	7.77E-03	2.59E-03	1.67E-03	1.15E-03	2.18E-02

Table A-2. Inhalation dose conversion factors based on ICRP-72.

Inhalation Dose Conversion Factors (rem/μCi)

Nuclide	Adrenals	B Surface	Brain	Breast	S Wall	SI Wall	ULI Wall	LLI Wall	Kidneys	Liver	ET Region	Lung
Pm-149	2.92E-06	4.81E-06	1.04E-06	2.66E-06	6.29E-04	1.48E-03	7.77E-03	1.70E-02	2.41E-06	9.62E-06	8.51E-03	1.74E-02
Pm-151	5.18E-05	6.66E-05	2.44E-05	4.44E-05	6.29E-04	1.44E-03	5.92E-03	1.04E-02	5.55E-05	5.92E-05	1.33E-02	1.04E-02
Sm-151	1.81E-06	4.07E-01	7.77E-07	6.29E-07	3.55E-05	8.88E-05	5.55E-04	1.67E-03	9.62E-07	1.07E-01	4.07E-03	1.15E-02
Eu-152	1.78E-01	7.03E-01	3.37E-02	4.81E-02	6.29E-02	6.66E-02	8.51E-02	5.55E-02	1.18E-01	9.99E-01	7.77E-02	2.29E-01
Sm-153	2.04E-05	2.81E-04	7.03E-06	1.67E-05	4.81E-04	1.15E-03	5.55E-03	1.15E-02	1.63E-05	3.11E-04	1.04E-02	1.63E-02
Eu-154	1.55E-01	1.52E+00	2.96E-02	4.44E-02	5.55E-02	5.92E-02	7.77E-02	6.29E-02	1.07E-01	1.26E+00	1.04E-01	3.70E-01
Eu-155	7.03E-03	4.44E-01	1.04E-03	1.55E-03	2.37E-03	2.55E-03	4.44E-03	6.66E-03	5.18E-03	1.37E-01	2.15E-02	7.03E-02
Eu-156	1.81E-03	5.18E-03	3.22E-04	1.52E-03	1.89E-03	3.59E-03	1.33E-02	3.37E-02	2.63E-03	7.03E-03	4.44E-02	8.51E-02
Tb-160	6.29E-03	5.18E-02	1.11E-03	4.44E-03	3.22E-03	4.07E-03	1.04E-02	2.48E-02	5.18E-03	2.00E-02	5.92E-02	1.74E-01
Ho-166m	5.55E-01	2.66E+00	8.88E-02	1.18E-01	2.74E-01	1.89E-01	2.33E-01	1.37E-01	3.48E-01	2.26E+00	1.52E-01	4.44E-01
Be-7	1.96E-04	8.51E-05	1.55E-05	2.00E-04	1.07E-04	8.51E-05	1.26E-04	2.07E-04	6.66E-05	1.63E-04	1.52E-03	9.25E-04
Na-24	6.29E-04	1.11E-03	6.29E-04	4.81E-04	1.15E-03	5.92E-04	5.92E-04	6.29E-04	5.55E-04	5.55E-04	4.81E-02	7.03E-04
Mn-54	5.92E-03	4.07E-03	9.99E-04	5.18E-03	3.26E-03	2.48E-03	3.26E-03	4.44E-03	2.81E-03	7.40E-03	2.63E-02	2.33E-02
Fe-55	3.70E-04	2.66E-03	3.70E-04	3.70E-04	3.70E-04	4.07E-04	5.18E-04	7.77E-04	3.70E-04	3.15E-03	3.70E-04	1.48E-03
Fe-59	5.18E-03	4.07E-03	1.70E-03	4.07E-03	3.70E-03	4.07E-03	7.03E-03	1.33E-02	3.55E-03	1.11E-02	4.81E-02	8.88E-02
Co-57	1.81E-03	1.37E-03	7.77E-05	1.78E-03	9.99E-04	4.07E-04	1.04E-03	2.44E-03	5.55E-04	1.59E-03	7.03E-03	2.44E-02
Co-58	4.44E-03	1.92E-03	3.70E-04	4.81E-03	2.63E-03	1.85E-03	3.44E-03	6.66E-03	1.67E-03	3.70E-03	3.37E-02	4.81E-02
Co-60	8.14E-02	3.44E-02	7.77E-03	9.25E-02	4.44E-02	1.30E-02	1.70E-02	2.11E-02	3.15E-02	7.40E-02	2.70E-01	6.66E-01
Cu-64	3.18E-05	3.15E-05	6.66E-05	2.59E-05	2.59E-04	3.00E-04	8.88E-04	1.11E-03	3.11E-05	5.92E-05	5.55E-03	2.74E-03
Cu-67	1.22E-04	1.41E-04	4.44E-04	1.04E-04	4.07E-04	4.81E-04	1.96E-03	4.44E-03	1.11E-04	3.59E-04	1.11E-02	1.89E-02
W-181	3.70E-05	2.44E-04	2.04E-05	7.77E-06	4.07E-05	9.62E-05	3.52E-04	8.88E-04	3.07E-04	8.14E-05	1.59E-03	2.11E-05
W-185	1.18E-05	6.29E-04	1.18E-05	1.18E-05	1.15E-04	1.92E-04	2.48E-03	7.03E-03	1.74E-03	3.07E-04	6.29E-03	1.07E-04
W-187	6.66E-05	2.74E-04	6.66E-05	4.44E-05	3.70E-04	7.03E-04	4.07E-03	7.03E-03	2.85E-04	1.07E-04	1.44E-02	1.89E-04
W-188	5.92E-05	4.07E-03	4.44E-05	3.66E-05	1.63E-04	3.70E-04	9.62E-03	4.07E-02	1.15E-02	2.00E-03	9.99E-03	1.30E-04
Au-198	1.48E-04	1.22E-04	6.66E-05	1.33E-04	7.77E-04	1.67E-03	7.03E-03	1.59E-02	1.18E-04	1.44E-04	1.85E-02	2.15E-02
Au-199	4.07E-05	5.18E-05	1.96E-05	3.63E-05	3.03E-04	6.66E-04	3.07E-03	7.40E-03	3.29E-05	4.07E-05	1.18E-02	2.44E-02
Pb-203	1.89E-04	5.18E-04	1.07E-04	8.14E-05	2.07E-04	3.55E-04	8.14E-04	1.44E-03	7.77E-04	4.81E-04	1.04E-02	1.59E-04
Th-229	6.29E+00	1.89E+03	6.29E+00	6.29E+00	6.29E+00	6.29E+00	6.29E+00	6.66E+00	2.66E+01	9.25E+01	1.48E+03	1.85E+03
Th-230	1.11E+00	1.04E+03	1.11E+00	1.11E+00	1.11E+00	1.11E+00	1.15E+00	1.18E+00	1.63E+01	1.37E+01	2.63E+02	2.85E+02
Th-234	5.55E-05	2.89E-04	8.14E-06	5.92E-05	1.59E-03	4.07E-03	2.33E-02	6.66E-02	1.11E-04	7.77E-05	2.29E-02	2.11E-01
U-233	5.18E-01	1.59E+01	5.18E-01	5.18E-01	5.18E-01	5.18E-01	5.18E-01	5.55E-01	5.18E+00	2.07E+00	4.44E+01	1.04E+02
U-234	5.18E-01	1.44E+01	5.18E-01	5.18E-01	5.18E-01	5.18E-01	5.18E-01	5.55E-01	5.18E+00	1.96E+00	4.44E+01	9.99E+01
U-235	4.81E-01	1.37E+01	4.81E-01	4.81E-01	4.81E-01	4.81E-01	4.81E-01	5.18E-01	4.81E+00	1.81E+00	4.07E+01	8.88E+01
U-237	1.04E-04	7.40E-04	2.15E-05	8.88E-05	4.07E-04	9.99E-04	4.81E-03	1.26E-02	9.99E-04	1.07E-04	2.07E-02	5.18E-02
U-238	4.44E-01	1.30E+01	4.44E-01	4.44E-01	4.44E-01	4.44E-01	4.81E-01	4.81E-01	4.81E+00	1.78E+00	3.70E+01	8.14E+01
U-240	3.52E-05	1.37E-04	2.18E-05	2.63E-05	1.30E-03	2.78E-03	9.99E-03	1.30E-02	4.81E-04	4.44E-05	1.55E-02	1.04E-02
Np-237	4.81E+00	3.70E+03	4.81E+00	4.81E+00	4.81E+00	4.81E+00	4.81E+00	5.18E+00	1.37E+01	5.92E+01	4.81E+01	1.07E+02
Np-239	5.92E-05	2.00E-03	2.55E-05	4.81E-05	5.18E-04	1.22E-03	5.55E-03	1.22E-02	1.15E-04	1.37E-04	1.96E-02	2.63E-02
Np-240	1.63E-05	8.88E-05	1.15E-05	1.07E-05	5.55E-04	3.63E-04	2.74E-04	6.29E-05	1.74E-05	1.55E-05	8.88E-03	1.67E-03
Pu-238	8.88E+00	5.18E+03	8.88E+00	8.88E+00	8.88E+00	8.88E+00	8.88E+00	8.88E+00	2.22E+01	1.07E+03	5.55E+01	1.37E+02
Pu-239	9.99E+00	5.55E+03	9.99E+00	9.99E+00	9.99E+00	9.99E+00	9.99E+00	9.99E+00	2.37E+01	1.22E+03	5.55E+01	1.22E+02
Pu-240	9.99E+00	5.55E+03	9.99E+00	9.99E+00	9.99E+00	9.99E+00	9.99E+00	9.99E+00	2.37E+01	1.22E+03	5.55E+01	1.22E+02
Pu-241	2.07E-01	1.15E+02	2.07E-01	2.07E-01	2.07E-01	2.07E-01	2.07E-01	2.07E-01	3.55E-01	2.41E+01	2.26E-01	2.44E-01
Am-241	1.07E+01	6.29E+03	1.07E+01	1.07E+01	1.07E+01	1.07E+01	1.07E+01	1.07E+01	3.22E+01	3.70E+02	5.55E+01	1.37E+02
Cm-242	1.30E-01	9.99E+01	1.30E-01	1.30E-01	1.30E-01	1.30E-01	1.52E-01	2.11E-01	2.04E+00	2.63E+01	3.22E+01	1.33E+02

Nuclide	Muscle	Ovaries	Pancreas	R Marrow	Skin	Spleen	Testes	Thymus	Thyroid	Uterus	Bld Wall	Eff Dose
Pm-149	2.85E-06	1.26E-05	3.11E-06	5.55E-06	1.15E-06	2.66E-06	1.18E-06	3.48E-06	1.63E-06	5.92E-06	4.07E-06	3.44E-03
Pm-151	6.29E-05	2.92E-04	6.66E-05	7.77E-05	2.41E-05	5.55E-05	2.44E-05	6.29E-05	3.26E-05	1.41E-04	8.88E-05	2.55E-03
Sm-151	8.88E-07	6.29E-07	1.04E-06	3.22E-02	6.66E-07	5.92E-07	5.18E-07	6.29E-07	5.55E-07	5.18E-07	1.55E-05	1.48E-02
Eu-152	5.18E-02	5.18E-02	1.33E-01	2.59E-01	3.26E-02	4.81E-02	1.37E-02	4.81E-02	3.07E-02	3.70E-02	2.44E-02	1.55E-01
Sm-153	2.15E-05	1.04E-04	2.29E-05	1.07E-04	7.77E-06	1.78E-05	7.77E-06	2.18E-05	9.62E-06	4.44E-05	3.52E-05	2.96E-03
Eu-154	4.44E-02	4.44E-02	1.15E-01	3.37E-01	2.89E-02	4.44E-02	1.22E-02	4.44E-02	2.78E-02	3.37E-02	2.18E-02	1.96E-01
Eu-155	1.81E-03	1.81E-03	5.55E-03	3.70E-02	8.51E-04	1.70E-03	3.11E-04	1.85E-03	9.62E-04	1.22E-03	7.40E-04	2.55E-02
Eu-156	8.88E-04	2.00E-03	1.41E-03	2.52E-03	4.81E-04	1.18E-03	2.37E-04	1.74E-03	7.03E-04	9.25E-04	7.03E-04	1.41E-02
Tb-160	2.48E-03	2.92E-03	4.44E-03	1.07E-02	1.41E-03	3.37E-03	5.18E-04	4.81E-03	2.07E-03	1.63E-03	1.15E-03	2.70E-02
Ho-166m	1.41E-01	1.41E-01	3.00E+00	5.55E-01	8.51E-02	2.33E-01	3.59E-02	1.26E-01	7.77E-02	1.04E-01	6.66E-02	4.44E-01
Be-7	8.88E-05	9.25E-05	1.48E-04	1.15E-04	4.44E-05	1.37E-04	1.04E-05	2.37E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Na-24	6.29E-04	5.92E-04	6.29E-04	8.14E-04	4.44E-04	5.55E-04	4.81E-04	7.03E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mn-54	2.66E-03	2.44E-03	4.44E-03	4.07E-03	1.48E-03	4.07E-03	6.29E-04	6.29E-03	8.14E-05	4.44E-05	3.00E-05	2.15E-04
Fe-55	3.70E-04	3.70E-04	3.70E-04	4.81E-03	3.70E-04	1.11E-02	3.70E-04	3.70E-04	7.03E-04	5.92E-04	7.40E-04	1.89E-03
Fe-59	2.92E-03	3.70E-03	4.44E-03	5.55E-03	1.89E-03	7.40E-03	1.70E-03	4.81E-03	2.44E-03	1.52E-03	1.15E-03	5.55E-03
Co-57	7.40E-04	2.85E-04	1.37E-03	8.88E-04	3.22E-04	1.30E-03	3.37E-05	2.29E-03	3.70E-04	3.70E-04	3.70E-04	1.48E-03
Co-58	2.04E-03	1.81E-03	3.37E-03	2.59E-03	1.07E-03	3.29E-03	2.07E-04	5.55E-03	2.66E-03	2.81E-03	2.29E-03	1.52E-02
Co-60	3.63E-02	8.51E-03	5.92E-02	4.44E-02	2.04E-02	6.29E-02	1.89E-03	1.04E-01	7.03E-04	1.55E-04	1.07E-04	3.70E-03
Cu-64	3.37E-05	7.03E-05	6.66E-05	3.66E-05	2.15E-05	3.22E-05	2.04E-05	3.52E-05	1.89E-03	8.51E-04	5.92E-04	7.77E-03
Cu-67	1.11E-04	1.70E-04	3.70E-04	1.18E-04	8.88E-05	1.15E-04	9.25E-05	1.22E-04	3.63E-02	5.92E-03	3.70E-03	1.15E-01
W-181	2.55E-05	9.25E-05	3.70E-05	7.77E-05	1.11E-05	2.70E-04	1.11E-05	1.41E-05	2.96E-05	4.44E-05	3.37E-05	6.29E-04
W-185	1.18E-05	1.22E-05	1.18E-05	2.22E-04	1.18E-05	1.48E-03	1.18E-05	1.18E-05	1.07E-04	1.33E-04	1.33E-04	2.70E-03
W-187	9.25E-05	2.96E-04	8.51E-05	1.33E-04	5.55E-05	2.44E-04	6.29E-05	7.40E-05	1.44E-05	4.44E-05	8.14E-05	1.59E-04
W-188	4.81E-05	8.88E-05	5.92E-05	1.41E-03	4.07E-05	9.99E-03	4.07E-05	4.07E-05	1.18E-05	1.18E-05	4.07E-04	8.14E-04
Au-198	1.37E-04	4.81E-04	1.52E-04	1.70E-04	7.03E-05	1.33E-04	7.03E-05	1.70E-04	7.03E-05	1.67E-04	8.88E-04	1.18E-03
Au-199	3.70E-05	1.26E-04	4.44E-05	4.44E-05	2.00E-05	3.70E-05	2.07E-05	4.81E-05	4.07E-05	5.92E-05	1.18E-03	3.11E-03
Pb-203	1.33E-04	2.70E-04	1.81E-04	2.37E-04	8.14E-05	1.44E-04	9.25E-05	1.26E-04	9.62E-05	2.44E-04	2.85E-04	4.07E-03
Th-229	6.29E+00	1.48E+01	6.29E+00	9.25E+01	6.29E+00	5.92E+00	1.48E+01	6.29E+00	2.66E-05	6.66E-05	1.04E-04	3.52E-03
Th-230	1.11E+00	8.51E+00	1.11E+00	3.70E+01	1.11E+00	1.11E+00	8.51E+00	1.11E+00	1.18E-04	1.89E-04	1.74E-04	5.55E-04
Th-234	3.03E-05	5.92E-05	4.44E-05	1.70E-04	1.52E-05	4.44E-05	1.63E-05	7.03E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-233	5.18E-01	5.18E-01	5.18E-01	1.55E+00	5.18E-01	5.18E-01	5.18E-01	5.18E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-234	5.18E-01	5.18E-01	5.18E-01	1.48E+00	5.18E-01	5.18E-01	5.18E-01	5.18E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-235	4.81E-01	4.81E-01	4.81E-01	1.41E+00	4.81E-01	4.81E-01	4.81E-01	4.81E-01	6.29E+00	6.29E+00	6.29E+00	2.63E+02
U-237	7.03E-05	2.44E-04	8.51E-05	1.59E-04	2.81E-05	8.14E-05	2.37E-05	1.18E-04	1.11E+00	1.11E+00	1.11E+00	5.18E+01
U-238	4.44E-01	4.44E-01	4.44E-01	1.37E+00	4.44E-01	4.44E-01	4.44E-01	4.44E-01	2.48E-05	2.41E-05	1.89E-05	2.92E-02
U-240	4.44E-05	1.78E-04	4.81E-05	8.14E-05	2.00E-05	3.70E-05	1.78E-05	4.07E-05	5.18E-01	5.18E-01	5.18E-01	1.33E+01
Np-237	4.81E+00	5.18E+01	4.81E+00	1.44E+02	4.81E+00	4.81E+00	5.18E+01	4.81E+00	5.18E-01	5.18E-01	5.18E-01	1.30E+01
Np-239	5.55E-05	2.41E-04	6.29E-05	1.96E-04	2.59E-05	5.18E-05	4.44E-05	6.29E-05	4.81E-01	4.81E-01	4.81E-01	1.15E+01
Np-240	1.78E-05	3.59E-05	3.70E-05	2.00E-05	8.14E-06	2.52E-05	3.70E-06	1.89E-05	4.44E-05	1.15E-04	1.89E-04	7.03E-03
Pu-238	8.88E+00	6.66E+01	8.88E+00	2.55E+02	8.88E+00	8.88E+00	7.03E+01	8.88E+00	4.44E-01	4.44E-01	4.44E-01	1.07E+01
Pu-239	9.99E+00	7.40E+01	9.99E+00	2.74E+02	9.99E+00	9.99E+00	7.77E+01	9.99E+00	2.59E-05	8.88E-05	3.37E-04	3.03E-03
Pu-240	9.99E+00	7.40E+01	9.99E+00	2.74E+02	9.99E+00	9.99E+00	7.77E+01	9.99E+00	4.81E+00	4.81E+00	4.81E+00	8.51E+01
Pu-241	2.07E-01	1.52E+00	2.07E-01	4.44E+00	2.07E-01	2.07E-01	1.55E+00	2.07E-01	3.52E-05	1.11E-04	1.15E-04	4.07E-03
Am-241	1.07E+01	1.22E+02	1.07E+01	2.15E+02	1.07E+01	1.07E+01	1.22E+02	1.07E+01	1.30E-05	2.74E-05	1.37E-05	5.18E-04
Cm-242	1.30E-01	1.78E+00	1.30E-01	7.03E+00	1.30E-01	1.30E-01	1.78E+00	1.30E-01	8.88E+00	8.88E+00	8.88E+00	1.70E+02

APPENDIX B

CODE LISTING

FIIDOS, VERSION 4.3

```
      program main
      include 'fiparms.f'
      include 'varblock.f'
c .....
c start of program
c .....
      open(unit=1,file='fiidos.out',status='unknown')
c .....
c subroutine input is used to read and check the input data provided
c by the user for consistency and any possible error conditions.  If
c succesful, rest of program should run without any difficulties.
c .....
      write(*,*) ' Reading input file.'
      call input
c .....
c subroutine fisfrc is used to convert the weapon yield in kilotons into the
c relative number of fission for each fissionable material-neutron energy set
c .....
      write(*,*) ' Calculating fission yields.'
      call fisfrc
c .....
c set up ORIGEN2 input deck and run ORIGEN2
c .....
      write(*,*) ' Writing ORIGEN2 input.'
      call orgsrc
      write(*,*) ' Calling ORIGEN2.'
      call ORIGEN2
c .....
c final dose calculation loop is controlled by setting the time index
c (tmindx) to the desired value of the measurement index or exposure
c index.  The measurement index will vary from 1 to nmeas, while the
c exposure index will vary from nmeas+1 to nmeas+nexp.  Each exposure
c is linked to a particular measurement index via xcmeas.
c .....
      do 40 i=1,nexp
      tcncnew=xtexp(i)
       write(*,50) (8,l=1,70),i,nexp,xtexp(i),xdur(i)
       tmindx=xcmeas(i)
       call rri
       if(xitrm(i).gt.3) go to 30
       call rges
  30   continue
       call sfcalc
       tmindx=i+nmeas
       call rri
       tmindx=i
       istidx=0
       isttm=tmindx
       call dose
       istidx=1
c .....
c Handle integrated doses (itpm=2)
c .....
       if(itpm.eq.2) then
        do 31 k=1,sss
         tdsum(k)=0.0
         td1sum(k)=0.0
         td2sum(k)=0.0
         td3sum(k)=0.0
          td4sum(k)=0.0
  31    continue
        do 32 k=1,ppp
         sumexf(k)=0.0
  32    continue
  33    continue
        if(timest(istidx).le.xtexp(isttm))then
         istidx=istidx+1
```

```
         go to 33
        endif
        oldtcnc=xtexp(isttm)
  34    continue
        tcncnew=timest(istidx)
        tmindx=istidx-40
        if(tcncnew.ge.xtexp(isttm+nexp))then
         tcncnew=xtexp(isttm+nexp)
         tmindx=isttm+nexp+nmeas
        endif
        call rri
        tmindx=i
        call dose
        if(tcncnew.eq.xtexp(isttm+nexp))go to 35
        oldtcnc=tcncnew
        istidx=istidx+1
        go to 34
  35    continue
       endif
c
       if(iout4.eq.1) call outputf
  40  continue
      tmindx=nexp+1
      write(*,*) ' '
      write(*,*) ' Writing output file data.'
      call outputf
  50  format(70a1,'  Processing exposure number ',i2,' of ',i2,
     ;', texp=',g10.4,' dur=',g10.4,\)
c .....
c close up output file and end program
c .....
 998  write(*,*)' FIIDOS finished'
      write(1,999)
 999  format(/' end')
      close(unit=1)
      stop
      end
c .....
c block data initialization routine
c .....
      block data init
      include 'fiparms.f'
      include 'varblock.f'
      data tddcfsum,tddcf1sum /sss*0.,sss*0.,sss*0.,sss*0./
      data tddcf2sum,tddcf3sum /sss*0.,sss*0.,sss*0.,sss*0./
      data tddcf4sum /sss*0.,sss*0./
      data afp,afracc /www*0.,www*0./
      data aactin,aactp,akrxer,actinp /xxx*0.,yyy*0.,vvv*0.,xxx*0./
      data actpp /yyy*0./
      data sumfrac /ppp*0./
      data spec,sactp,sactin,skrxer /ooo*0.,ooo*0.,ooo*0.,ooo*0./
      data sfracc,gamma,gref /ooo*0.,ooo*0.,nnn*0./
      data alphaemit /
     ;1.0,1.0,0.0,1.0,1.0,1.0,0.0,1.0,0.0,1.0,
     ;0.0,0.0,1.0,1.0,1.0,0.0,1.0,1.0,0.0,0.0/
      data timest /
     ;2.78e-7,5.98e-7,1.29e-6,2.78e-6,5.98e-6,1.29e-5,
     ;2.78e-5,5.98e-5,1.29e-4,2.78e-4,5.98e-4,1.29e-3,
     ;2.78e-3,5.98e-3,1.29e-2,2.78e-2,5.98e-2,1.29e-1,
     ;2.78e-1,5.98e-1,1.29e+0,2.78e+0,5.98e+0,1.29e+1,
     ;2.78e+1,5.98e+1,1.29e+2,2.78e+2,5.98e+2,1.29e+3,
     ;2.78e+3,5.98e+3,1.29e+4,2.78e+4,5.98e+4,1.29e+5,
     ;2.78e+5,5.98e+5,1.29e+6,2.78e+6/
      end
```

```
c
c  fiparms.for - This file contains the variables dimension data to define
c                the problem size for the fiidos primary routines.  This
c                enables a more straightforward path when additional
c                nuclides are added to fiidos or if some array sizes need to
c                be adjusted to accomodate a specific problem.
c
      integer zzz,yyy,xxx,www,vvv
      integer uuu,ttt,sss
      integer ppp,ooo,nnn
      real rzero
c
c                           Maximum number of measurements + exposures
c                           Should be ORIGEN2 AAA-50
      parameter (zzz=100)
c                           Number of acitvation product nuclides
      parameter (yyy=20)
c                           Number of actinide nuclides
      parameter (xxx=20)
c                           Total number of FP nuclides (also for fractionation)
      parameter (www=150)
c                           Number of noble gas nuclides (krypton and xenon)
      parameter (vvv=20)
c                           Number of standard time steps for ORIGEN
c                           storage vectors; must be less than JJJJ in
c                           params.f (zzz+uuu must be less than JJJ)
      parameter (uuu=40)
c                           Number of nuclides in DCF files
c                           (wwww+xxxx+yyyy)
      parameter (ttt=190)
c                           Maximum number of organs in DCF files (+1)
      parameter (sss=40)
c                           Number of entries for Pu retention output
      parameter (ppp=30)
c                           Number of gamma energy groups
      parameter (ooo=18)
c                           Number of gamma radiation exposure factors
      parameter (nnn=21)
c                           Set zero for real variables
      parameter (rzero=0.0)
c
```

```
      integer xitrm,xitmi,xcmeas,xitdcf,tindex,tmindx
      integer nplut,numorgans,edosnum
      character*80 title,dcfidinfo
       character*11 orgnames
c
      common /doses/  td(zzz,sss),td1(zzz,sss),td2(zzz,sss),
     ;                td3(zzz,sss),td4(zzz,sss),
     ;                tdold(sss),td1old(sss),td2old(sss),td3old(sss),
     ;                td4old(sss),
     ;                tdsum(sss),td1sum(sss),td2sum(sss),td3sum(sss),
     ;                td4sum(sss),
     ;                tddcfsum(2,sss),tddcf1sum(2,sss),
     ;                tddcf2sum(2,sss),tddcf3sum(2,sss),
     ;                tddcf4sum(2,sss),
     ;                dcf(sss),osrnd(ttt,sss),alphaemit(xxx)
       common /organs/ numorgans(2),edosnum(2),dcfidinfo(2),
     ;                orgnames(2,sss)
      common /flags/  itpm,ikrxer,iactp,iactin,ifrac,iplut,xitrm(zzz),
     ;                xitmi(zzz),xcmeas(zzz),xitdcf(zzz)
      common /fract/  nfrac,id(www),ffrac(www)
      common /fusion/ fie,fue,xnu1(3),xnu14(3),xnufu,alpha(3),beta(3)
      common /inp/    nexp,xbr(zzz),xdur(zzz),xkfac(zzz),xtexp(zzz)
      common /inv/    afp(www),aactin(xxx),aactp(yyy),acttot,
     ;                akrxer(vvv),afracc(www),actinp(xxx),actpp(yyy)
      common /look/   lookfp(www),lookap(yyy),lookan(xxx)
      common /meas/   nmeas,nplut,xtmeas(zzz),xrimes(zzz),xactmes(zzz),
     ;                sf
      common /plutm/  exfrac(zzz,ppp),sumfrac(ppp),sumexf(ppp),
     ;                oldexf(ppp)
      common /outf/   iout1,iout2,iout3,iout4,iout5
      common /spect/  spec(ooo),gref(nnn),sactp(ooo),sactin(ooo),
     ;                skrxer(ooo),sfracc(ooo),gamma(ooo)
      common /time/   times(zzz),xtra(zzz),tindex(zzz),tyrs(ppp),tmindx,
     ;                tcncnew,oldtcnc,timest(uuu),isttm,istidx
      common /title/  title
      common /yield/  ykt(6),yfis(6),twyf,yfisf(6),cmvkt
```

```
      subroutine input
      include 'fiparms.f'
      include 'varblock.f'
c .....
c local variables
c .....
      integer txitrm,txitmi,txcmeas,txitdcf,origord(zzz)
      real lowdiff,lowtime
c
c ....
c this subroutine obtains and checks the input data from the fiidos user
c as much as possible - most random errors cause the program to crash
c by trying to read incompatible data formats.  miscellaneous number
c errors may be caught before they cause trouble
c if users never made mistrakes, most of this subroutine wouldn't be here
c ....
c array title     - title of the problem
c variable  itpm  - index for type of problem. the two types of problems are:
c                   (1) discreet exposure cases; n measurement times and
c                       m exposure times, generally m >= n
c                   (2) integrated case; 1 measurement time and
c                       1 long term exposure time
c variable  iout1 - index for output control
c                   (0) suppress output
c                   (1) print relative gamma emission spectrum at the time
c                       of measurement or the measured activity of radio-
c                       logical material, and the radiological contamination
c                       scaling factor
c variable  iout2 - index for output control
c                   (0) suppress output
c                   (1) print the relative radionuclide inventories for
c                       fission products, activation products, and actinide
c                       elements at the time of exposure
c variable  iout3 - index for output control
c                   (0) suppress output
c                   (1) print the dose to each organ from each radionuclide.
c variable  iout4 - index for output control
c                   (0) suppress output
c                   (1) print intermediate organ dose results for each
c                       exposure incident
c variable iout5  - index for table creation
c                   (0) suppress output
c                   (1) create tables of organ doses for fission products,
c                       activation products, actinides, and total as a
c                       function of time - good for importing into spread-
c                       sheet software for further analysis.  Four
c                       tables will be created for each set of dose
c                       conversion factors used.
c variable nmeas  - number of measurement times
c array xitrm(i)  - index for type of i th radiological measurement
c                   the six types of measurement are:
c                   (1) radiation intensity - above contaminated surface
c                   (2) radiation intensity - inside debris cloud
c                   (3) radiation intensity - below debris cloud
c                   (4) gross activity - airborne concentration
c                   (5) gross activity - surface concentration
c                   (6) gross activity - inhalation or ingestion intake
c array xtmeas(i) - time at which i th radiological measurement was made
c array xrimes(i) - i th radiation intensity measurement, for itrm = 1-3;
c                   i th radionuclide index, if measured single species when
c                   xitrm = 6
c array xitmi(i)  - index for i th type of radiation intensity measurement
c                   device; the five types are:
c                   (1) tissue free-in-air
c                   (2) air, free-in-air
c                   (3) film badge, free-in-air
c                   (4) film badge, in-situ(midplane)
```

```
c                    (5) film badge, in-situ(isotropic)
c array xactmes(i)- i th measured gross activity
c variable nexp   - number of exposure incidents
c array xtexp(i)  - time at which i th exposure occurred
c array xcmeas(i) - index for correspondence to measurement time
c                   possible values are:
c                   (1) Use nearest measurement time > exposure time
c                   (0) Use nearest measurement time < exposure time (default)
c                   (-n) Use n th measurement time
c array xdur(i)   - duration of i th exposure
c array xbr(i)    - breathing rate during i th exposure
c array xkfac(i)  - ratio of airborne to surface activity during i th exposure
c array xitdcf(i) - index for type of dose conversion factor for i th exposure
c                 - there are nine types:
c                   (1)  inhalation dcf (ornl tm-190)
c                   (2)  ingestion dcf (ornl tm-190)
c                   (3)  inhalation (large particles) dcf (ornl tm-190)
c                   (4)  inhalation dcf (icrp-30)
c                   (5)  ingestion dcf (icrp-30)
c                   (6)  inhalation (20 um large particles) dcf (icrp-30)
c                   (7)  inhalation dcf (icrp-30)
c                   (8)  ingestion dcf (icrp-30)
c                   (9)  inhalation (10 um large particles) dcf (icrp-30)
c                   (10) inhalation dcf (icrp-72)
c                   (11) ingestion dcf (icrp-72)
c array  ykt(i)   - yield in kilotons from fm-ne set i. the six fm-ne sets are:
c                   (1) u-235, fast neut.     (2) u-235,14-mev neut.
c                   (3) u-238, fast neut.     (4) u-238,14-mev neut.
c                   (5)pu-239, fast neut.     (6)pu-239,14-mev neut.
c                    because these yields are not usually known or reported
c                    an alternative input is available and suggested
c                   (1) -1 ; for a flag       (2) total yield
c                   (3) u-235 total yield     (4) u-238 total yield
c                   (5) pu-239 total yield    (6) total fusion yield
c variable iactp  - index for treatment of activation products. the options are:
c                   (0) do not include activation products
c                   (1) include activation products
c array  actpp(i) - activation product production for i th radionuclide (ci/kt).
c                   production data must be provided for twenty radionuclides
c                   (1) be-7     (2) na-24    (3) mn-54    (4) fe-55
c                   (5) fe-59    (6) co-57    (7) co-58    (8) co-60
c                   (9) cu-64    (10)cu-67    (11) w-181   (12) w-185
c                   (13) w-187   (14) w-188   (15)au-198   (16)au-199
c                   (17)pb-203   (18)mn-56    (19)not used (20)not used
c variable iactin - index for treatment of actinide elements. the options are:
c                   (0) do not include actinide elements
c                   (1) include actinide elements
c array actinp(i) - actinide element production for i th radionuclide (ci/kt).
c                   production data must be provided for twenty radionuclides
c                   (1) th-229    (2) th-230    (3) th-234    (4)  u-233
c                   (5)  u-234    (6)  u-235    (7)  u-237    (8)  u-238
c                   (9)  u-240    (10)np-237    (11)np-239    (12)np-240
c                   (13)pu-238    (14)pu-239    (15)pu-240    (16)pu-241
c                   (17)am-241    (18)cm-242    (19)not used  (20)not used
c variable ikrxer - index for treatment of krypton and xenon. the options are:
c                   (0) do not modify inventory
c                   (1) remove krypton and xenon
c variable ifrac  - index for treament of fractionation of fission products.
c                   the two choices are:
c                   (0) do not modify inventory
c                   (1) modify inventory for fractionation
c variable nfrac  - the number of radiological nuclides to be modified by
c                   fractionation
c array id(i)     - index for the identification of the i th fission product
c                   radionuclide to be changed. indices of fission product
c                   radionuclides are listed in subroutine fraci.
c array ffrac(i)  - fraction of basic inventory of radionuclide i that is to
```

```
c                   be present in fractionated fallout material
c variable iplut  - index for treatment of plutonium bioassay
c                   (0) Suppress calculation
c                   (1) Perform plutonium bioassay calculation
c variable nplut  - number of entries for plutonium calculation (max 30)
c array tyrs(i)   - time after exposure (yrs) for pu239 conc in urine
c
10    continue
c .....
c problem identification and control data
c .....
      open(unit=2,file='input.dat',status='old')
      read(2,20) title
 20   format(a80)
      read(2,*) itpm
      if(itpm.gt.2.or.itpm.lt.1)then
       write(*,*) ' Error reading input file. Bad value of itpm.'
       write(*,*) ' Program quitting'
       close(unit=1)
       close(unit=2)
       stop
      endif
      read(2,*) iout1
      if(iout1.gt.1.or.iout1.lt.0)then
       write(*,*) ' Error reading input file. Bad value of iout1.'
       write(*,*) ' Program quitting'
       close(unit=1)
       close(unit=2)
       stop
      endif
      read(2,*) iout2
      if(iout2.gt.1.or.iout2.lt.0)then
       write(*,*) ' Error reading input file. Bad value of iout2.'
       write(*,*) ' Program quitting'
       close(unit=1)
       close(unit=2)
       stop
      endif
      read(2,*) iout3
      if(iout3.gt.1.or.iout3.lt.0)then
       write(*,*) ' Error reading input file. Bad value of iout3.'
       write(*,*) ' Program quitting'
       close(unit=1)
       close(unit=2)
       stop
      endif
      read(2,*) iout4
      if(iout4.gt.1.or.iout4.lt.0)then
       write(*,*) ' Error reading input file. Bad value of iout4.'
       write(*,*) ' Program quitting'
       close(unit=1)
       close(unit=2)
       stop
      endif
      read(2,*) iout5
      if(iout5.gt.1.or.iout5.lt.0)then
       write(*,*) ' Error reading input file. Bad value of iout5.'
       write(*,*) ' Program quitting'
       close(unit=1)
       close(unit=2)
       stop
      endif
 30   continue
c .....
c radiological measurement data
c .....
      read(2,*) nmeas
```

```
      if(nmeas.le.0) then
       write(*,*) ' Number of measurements cannot be zero or negative.'
       write(*,*) ' Program quitting.'
       close(unit=1)
       close(unit=2)
       stop
      endif
      if(itpm.eq.2.and.nmeas.gt.33) then
       write(*,*) ' Number of measurements must be less than 33 when'
       write(*,*) ' itpm = 2.  Program quitting.'
       close(unit=1)
       close(unit=2)
       stop
      endif
      if(nmeas.gt.50) then
       write(*,*) ' Number of measurements > 50.  Problem will not run'
       write(*,*) ' if nmeas+nexp>100.'
       if(nmeas.gt.zzz) then
        write(*,*) ' Program quitting.'
        close(unit=1)
        close(unit=2)
        stop
       endif
      endif
      do 40 i=1,nmeas
       read(2,*) xitrm(i),xtmeas(i),xrimes(i),xitmi(i),xactmes(i)
       origord(i)=i
       if(xitrm(i).lt.1.or.xitrm(i).gt.6.or.
     ;    xitmi(i).lt.0.or.xitmi(i).gt.5) then
        write(*,*) ' Error reading input file. Bad itrm or itmi value.'
        write(*,*) ' Last value of tmeas read was ',xtmeas(i)
        write(*,*) ' Program quitting'
        close(unit=1)
        close(unit=2)
        stop
       endif
       if(xtmeas(i).lt.2.78e-7) then
        write(*,*) ' Times shorter than 2.78e-7 hours not permitted.'
        write(*,*) ' Adjusting time ',xtmeas,' to 2.78e-7 hours.'
        xtmeas(i)=2.78e-7
       endif
       if(xtmeas(i).gt.1.e7) then
        write(*,*) ' Calculations for times longer than 1000 years'
        write(*,*) ' are not reliable, but the problem will run.'
       endif
 40   continue
c .....
c sort measurement data in chronologic order
c .....
      if(nmeas.gt.1) then
       do 42 i=1,nmeas
        do 41 j=1,nmeas-1
         if(xtmeas(j).gt.xtmeas(j+1))then
          txitrm=xitrm(j)
          txtmeas=xtmeas(j)
          txrimes=xrimes(j)
          txitmi=xitmi(j)
          txactmes=xactmes(j)
          torigord=origord(j)
c
          xitrm(j)=xitrm(j+1)
          xtmeas(j)=xtmeas(j+1)
          xrimes(j)=xrimes(j+1)
          xitmi(j)=xitmi(j+1)
          xactmes(j)=xactmes(j+1)
          origord(j)=origord(j+1)
c
```

```
           xitrm(j+1)=txitrm
           xtmeas(j+1)=txtmeas
           xrimes(j+1)=txrimes
           xitmi(j+1)=txitmi
           xactmes(j+1)=txactmes
           origord(j+1)=torigord
          endif
 41      continue
 42     continue
       endif
c .....
c dose calculation data and determination of relevant measurement
c .....
       read(2,*) nexp
       if(nexp.le.0) then
        write(*,*) ' Number of exposures cannot be zero or negative.'
        write(*,*) ' Program quitting.'
        close(unit=1)
        close(unit=2)
        stop
       endif
       if(itpm.eq.2.and.nexp.gt.33) then
        write(*,*) ' Number of exposures must be less than 33 when'
        write(*,*) ' itpm = 2.  Program quitting.'
        close(unit=1)
        close(unit=2)
        stop
       endif
       if(nexp+nmeas.gt.100) then
        write(*,*) ' nmeas+nexp exceeds max value of 100.'
        write(*,*) ' Program quitting'
        close(unit=1)
        close(unit=2)
        stop
       endif
       do 60 i=1,nexp
        lowtime = 1e7
        txcmeas = 0
        read(2,*) xtexp(i),xcmeas(i),xdur(i),xbr(i),xkfac(i),xitdcf(i)
        if(xcmeas(i).gt.1) then
         write(*,*) ' Error reading input file. Bad cmeas number.'
         write(*,*) ' Last value of texp read was ',xtexp(i)
         write(*,*) ' Program quitting'
         close(unit=1)
         close(unit=2)
         stop
        endif
        if(xitdcf(i).lt.1.or.xitdcf(i).gt.2) then
         write(*,*) ' Error reading input file. Bad itdcf number.'
         write(*,*) ' Last value of texp read was ',xtexp(i)
         write(*,*) ' Program quitting'
         close(unit=1)
         close(unit=2)
         stop
        endif
        if(abs(xcmeas(i)).gt.nmeas) then
         write(*,*) ' Error in exposure/measurement correspondence.'
         write(*,*) ' Last value of texp read was ',xtexp(i)
         write(*,*) ' Program quitting'
         close(unit=1)
         close(unit=2)
         stop
        endif
        if(xtexp(i).lt.2.78e-7) then
         write(*,*) ' Times shorter than 2.78e-7 hours not permitted.'
         write(*,*) ' Adjusting time ',xtexp,' to 2.78e-7 hours.'
         xtexp(i)=2.78e-7
```

```
      endif
      if(xtexp(i).gt.1.e7) then
       write(*,*) ' Calculations for times longer than 1000 years'
       write(*,*) ' are not reliable, but the problem will run.'
       write(*,*) ' Some elements may underflow in ORIGEN, causing'
       write(*,*) ' problems for FIIDOS in the dose calculation.'
      endif
c .....
c determine corresponding measurement time (for xcmeas(i)=0 or 1)
c .....
      if(xcmeas(i).eq.0) then
       do 50 j=1,nmeas
        lowdiff=xtexp(i)-xtmeas(j)
        if(lowdiff.gt.rzero.and.lowdiff.lt.lowtime) then
         lowtime=lowdiff
         txcmeas=j
        endif
 50    continue
       if(txcmeas.eq.0) then
        write(*,*) ' Warning! No measurement times earlier than ',
     ;  xtexp(i)
        write(*,*) ' Adjusting to find closest later time.'
        xcmeas(i)=1
       endif
      endif
c
      if(xcmeas(i).eq.1) then
       do 51 j=1,nmeas
        lowdiff=xtmeas(j)-xtexp(i)
        if(lowdiff.gt.rzero.and.lowdiff.lt.lowtime) then
         lowtime=lowdiff
         txcmeas=j
        endif
 51    continue
c
       if(txcmeas.eq.0) then
        write(*,*) ' Warning! No measurement times later than ',
     ;  xtexp(i)
        write(*,*) ' Adjusting correspondence to closest earlier time.'
        xcmeas(i)=0
        do 52 j=1,nmeas
         lowdiff=xtexp(i)-xtmeas(j)
         if(lowdiff.gt.rzero.and.lowdiff.lt.lowtime) then
          lowtime=lowdiff
          txcmeas=j
         endif
 52     continue
       endif
      endif
c
      if(txcmeas.eq.0.and.xcmeas(i).ge.0) then
       write(*,*) ' Bizarre error in exposure-measurement time',
     ; 'correspondence!'
       write(*,*) ' Program quitting.'
       close(unit=1)
       close(unit=2)
       stop
      endif
      if(xcmeas(i).ge.0)xcmeas(i)=txcmeas
      if(xcmeas(i).lt.0)then
       do 53 j=1,nmeas
        if((abs(xcmeas(i)).eq.origord(j)).and.(xcmeas(i).lt.0))
     ;    xcmeas(i)=j
 53    continue
      endif
 60   continue
c .....
```

```
c sort exposure data in chronologic order
c .....
      if(nexp.gt.1) then
       do 72 i=1,nexp
        do 71 j=1,nexp-1
         if(xtexp(j).gt.xtexp(j+1))then
          txtexp=xtexp(j)
          txcmeas=xcmeas(j)
          txdur=xdur(j)
          txbr=xbr(j)
          txkfac=xkfac(j)
          txitdcf=xitdcf(j)
c
          xtexp(j)=xtexp(j+1)
          xcmeas(j)=xcmeas(j+1)
          xdur(j)=xdur(j+1)
          xbr(j)=xbr(j+1)
          xkfac(j)=xkfac(j+1)
          xitdcf(j)=xitdcf(j+1)
c
          xtexp(j+1)=txtexp
          xcmeas(j+1)=txcmeas
          xdur(j+1)=txdur
          xbr(j+1)=txbr
          xkfac(j+1)=txkfac
          xitdcf(j+1)=txitdcf
         endif
 71     continue
 72    continue
      endif
c .....
c check measurement and exposure data for various incompatibilities
c .....
c integrated exposures (itpm=2) not allowed with itrm=6
      if(itpm.eq.2) then
       do 73 i=1,nexp
        if(xitrm(i).eq.6) then
         write(*,*) ' You cannot use an integrated exposure (itpm=2)'
         write(*,*) ' with a gross activity ingestion/inhalation ',
     ;             '(itrm=6).'
         write(*,*) ' Program quitting.'
         close(unit=1)
         close(unit=2)
         stop
        endif
 73    continue
      endif
c cannot have multiple exposures to a single ingestion
      do 75 i=1,nmeas
       if(xitrm(i).eq.6) then
        itrmexp=0
        do 74 j=1,nexp
         if(xcmeas(j).eq.i) itrmexp=itrmexp+1
 74     continue
        if(itrmexp.gt.1) then
         write(*,*) ' You cannot have multiple exposures to a single'
         write(*,*) ' gross activity ingestion or inhalation (itrm=6).'
         write(*,*) ' Program quitting.'
         close(unit=1)
         close(unit=2)
         stop
        endif
       endif
 75   continue
c .....
c shot data
c .....
```

```
      read(2,*) (ykt(i),i=1,6)
      read(2,*) iactp
      if(iactp.gt.1.or.iactp.lt.0)then
       write(*,*) ' Error reading input file. Bad value of iactp.'
       write(*,*) ' Program quitting.'
       close(unit=1)
       close(unit=2)
       stop
      endif
      if(iactp.eq.0) go to 80
      read(2,*) (actpp(i),i=1,20)
 80   continue
      read(2,*) iactin
      if(iactin.gt.1.or.iactin.lt.0)then
       write(*,*) ' Error reading input file. Bad value of iactin.'
       write(*,*) ' Program quitting.'
       close(unit=1)
       close(unit=2)
       stop
      endif
      if(iactin.eq.0) go to 90
      read(2,*) (actinp(i),i=1,20)
 90   continue
c .....
c fallout data
c .....
      read(2,*) ikrxer
      if(ikrxer.gt.1.or.ikrxer.lt.0)then
       write(*,*) ' Error reading input file. Bad value of ikrxer.'
       write(*,*) ' Program quitting.'
       close(unit=1)
       close(unit=2)
       stop
      endif
      read(2,*) ifrac
      if(ifrac.gt.1.or.ifrac.lt.0)then
       write(*,*) ' Error reading input file. Bad value of ifrac.'
       write(*,*) ' Program quitting.'
       close(unit=1)
       close(unit=2)
       stop
      endif
      if(ifrac.eq.0) go to 120
      open(unit=3,file='frac.gam',status='unknown')
      nfrac=0
 105  read(2,*,end=110) id(nfrac+1)
      read(2,*) ffrac(nfrac+1)
      read(2,*)(gamma(j),j=1,ooo)
      write(3,*)(gamma(j),j=1,ooo)
      nfrac=nfrac+1
      go to 105
 110  continue
      close(unit=3)
 120  continue
c .....
c plutonium data
c .....
      read(2,*)iplut
      if(iplut.gt.1.or.iplut.lt.0)then
       write(*,*) ' Error reading input file. Bad value of iplut.'
       write(*,*) ' Program quitting.'
       close(unit=1)
       close(unit=2)
       stop
      endif
      if(iplut.eq.0) go to 140
      read(2,*)nplut
```

```
      if(nplut.gt.ppp) then
       write(*,*) ' Number of entries for Pu retention currently'
       write(*,*) ' limited to ',ppp
       write(*,*) ' Program quitting.'
       close(unit=1)
       close(unit=2)
       stop
      endif
      read(2,*) (tyrs(i),i=1,nplut)
 140  continue
      close(unit=2)
c .....
c write output file header info
c .....
      write(1,500) title,itpm,iout1,iout2,iout3,iout4,iout5
      write(1,510) nmeas
      write(1,520) (xitrm(i),i=1,nmeas)
      write(1,530) (xtmeas(i),i=1,nmeas)
      write(1,540) (xrimes(i),i=1,nmeas)
      write(1,550) (xitmi(i),i=1,nmeas)
      write(1,560) (xactmes(i),i=1,nmeas)
      write(1,570) nexp
      write(1,580) (xtexp(i),i=1,nexp)
      write(1,590) (xcmeas(i),i=1,nexp)
      write(1,600) (xdur(i),i=1,nexp)
      write(1,610) (xbr(i),i=1,nexp)
      write(1,620) (xkfac(i),i=1,nexp)
      write(1,630) (xitdcf(i),i=1,nexp)
      write(1,650) iactp
      write(1,670) iactin
      write(1,690) ikrxer
      write(1,700) ifrac
      if(ifrac.ne.1) go to 230
      write(1,710) nfrac
      write(1,720) (id(i),i=1,nfrac)
      write(1,730) (ffrac(i),i=1,nfrac)
 230  write(1,740) iplut
      if(iplut.ne.1) go to 240
      write(1,750) nplut
      write(1,760) (tyrs(i),i=1,nplut)
c
c .....
c Set up integrated exposures if itpm=2 (Not echoed in output file)
c .....
 240  if(itpm.eq.2) then
       do 300 i=1,nexp
          xtexp(i+nexp)=xtexp(i)+xdur(i)
          xcmeas(i+nexp)=xcmeas(i)
          xdur(i+nexp)=xdur(i)
          xbr(i+nexp)=xbr(i)
          xkfac(i+nexp)=xkfac(i)
          xitdcf(i+nexp)=xitdcf(i)
 300   continue
      endif
c .....
c format block
c .....
 500  format(34x,'fiidos   input'/
     ;8x,'title:',3x,a80,/
     ;8x,80('-')/
     ;8x,'itpm    problem type            single/integrated    1/2',i10/
     ;8x,'iout1   print spectrum              no/yes           0/1',i10/
     ;8x,'iout2   print inventory             no/yes           0/1',i10/
     ;8x,'iout3   print dose inventory        no/yes           0/1',i10/
     ;8x,'iout4   print intermediate doses    no/yes           0/1',i10/
     ;8x,'iout5   print dose tables           no/yes           0/1',i10)
 510  format(/
```

```
     ;8x,'nmeas   number of measurement calculations              ',i10)
 520  format(
     ;8x,'itrm    rad measurement indices                         ',
     ;10i10,19(/64x,10i10))
 530  format(
     ;8x,'tmeas   time of rad measurements                        ',
     ;5x,1p10g10.3,19(/69x,1p10g10.3))
 540  format(
     ;8x,'rimes   rad intensity (itrm=1-3); index nuclide (itrm=6)',
     ;5x,1p10g10.3,19(/69x,1p10g10.3))
 550  format(
     ;8x,'itmi    meas index tis/air/fb/fb-man/fb-man 1/2/3/4/5   ',
     ;10i10,19(/64x,10i10))
 560  format(
     ;8x,'actmes  activity measurement (itrm=4-6)                 ',
     ;5x,1p10g10.3,19(/69x,1p10g10.3))
 570  format(/
     ;8x,'nexp    number of exposure calculations                 ',i10)
 580  format(
     ;8x,'texp    exposed @ h+(hr)                                ',
     ;5x,1p10g10.3,19(/69x,1p10g10.3))
 590  format(
     ;8x,'icmeas  rad exposure to measurement indices (re-sorted) ',
     ;10i10,19(/64x,10i10))
 600  format(
     ;8x,'dur     duration (hr)                                   ',
     ;5x,1p10g10.3,19(/69x,1p10g10.3))
 610  format(
     ;8x,'br      breathing rate (m**3/hr)                        ',
     ;5x,1p10g10.3,19(/69x,1p10g10.3))
 620  format(
     ;8x,'kfac    resuspension factors (m**-1)                    ',
     ;5x,1p10g10.3,19(/69x,1p10g10.3))
 630  format(
     ;8x,'itdcf   dose conversion factor set index 1/2            ',
     ;10i10,19(/64x,10i10))
 650  format(/
     ;8x,'iactp   activation products         no/yes          0/1',i10)
 670  format(
     ;8x,'iactin  actinides                   no/yes          0/1',i10)
 690  format(
     ;8x,'ikrxer  noble gases removed         no/yes          0/1',i10)
 700  format(
     ;8x,'ifrac   fractionation               no/yes          0/1',i10)
 710  format(
     ;8x,'nfrac   number of fission products to be fractionated   ',i10)
 720  format(/8x,'isotope id''s',5x,5i10/(25x,5i10))
 730  format(/8x,'fractionation factor ',1p5g10.3/(29x,5g10.3))
 740  format(/
     ;8x,'iplut   plutonium bioassay          no/yes          0/1',i10)
 750  format(
     ;8x,'nplut   number of entries for plutonium bioassay        ',i10)
 760  format(
     ;8x,'tyrs    times after shot for Pu conc in urine           ',
     ;5x,1p10g10.3)
 770  format(//34x,'fiidos output')
 900  continue
      write(1,770)
      return
      end
```

```
      subroutine fisfrc
      include 'fiparms.f'
      include 'varblock.f'
c  this subroutine calulates the total weapon yield in number of fissions and
c  the fraction of that yield from each fissionable-neutron energy set.
c .....
c  variable ykttot  - total yield of device both fusion and fission (new input)
c  variables ykt235,ykt238,ykt239- fission yield of u235,u238,pu239 (new input)
c  variables yktfus - fusion yield                                  (new input)
c  array ykt(i)     - yield in kilotons from fm-ne set i            (old input)
c  array yfis(i)    - yield in fissions from fm-ne set i
c  variable twyf    - total weapon yield in fissions.
c  array yfisf(i)   - fraction of total weapon yield from fm-ne set i.(results)
c  variable cmvkt   - conversion factor of fissions per kt
c  variable fif     - fission fraction of yield (derived)
c  variable fie     - energy recovered per fission
c  variable fue     - energy recovered per fusion
c  variable xnu1    - neutrons released from 1 mev fission
c  variable xnu14   - neutrons released from 14 mev fission
c  variable xnufu   - neutrons released from fusion
c  variable fifi1   - probability of a fission neutron causing a 1 mev fission
c  variable fufi14  - probability of a fusion neutron causing a 14 mev fission
c  variable fufi1   - probability of a fusion neutron causing a 1 mev fission
c  variable alpha   - ratio of fufi14/fifi1
c  variable beta    - ratio of fufi1/fifi1
c  variable frac1   - fraction of yield from fissions from 1 mev neutrons
c  variable frac14  - fraction of yield from fissions from 14 mev neutrons
c  variable fracfu  - fraction of yield from fusion
c .....
      twyf=0.0
      frac14=0.0
      frac1=0.0
      fracfu=0.0
      if(ykt(1).ge.0) go to 20
c
c option to determine the fission fractions from fusion/fission ratios
c uses new input
      ykttot=ykt(2)
      ykt235=ykt(3)
      ykt238=ykt(4)
      ykt239=ykt(5)
      yktfus=ykt(6)
      if(abs(ykttot-ykt235-ykt238-ykt239-yktfus).gt.0.02*ykttot)
     ;write(*,*)' recheck fission/fusion yield inputs ; do not add up'
      fif=(ykt235+ykt238+ykt239)/ykttot
      do 10 i=1,3
      a=(1-fif)*fie/fue*xnufu*(xnu14(i)-xnu1(i))*alpha(i)
      b=fif*xnu1(i)+(1-fif)*fie/fue*xnufu*(alpha(i)+beta(i))
      c=-fif
      if(xnu14(i).ne.xnu1(i).and.a.ne.0)fifi1=(-b+sqrt(b*b-4*a*c))/(2*a)
      if(xnu14(i).eq.xnu1(i).or .a.eq.0)fifi1=-c/b
      frac14=(1-fif)*fie/fue*xnufu*alpha(i)*fifi1
      frac1=fif-frac14
      fracfu=(1-fif)
      if(i.eq.1)ykt(1)=ykt235*frac1
      if(i.eq.1)ykt(2)=ykt235*frac14
      if(i.eq.2)ykt(3)=ykt238*frac1
      if(i.eq.2)ykt(4)=ykt238*frac14
      if(i.eq.3)ykt(5)=ykt239*frac1
      if(i.eq.3)ykt(6)=ykt239*frac14
 10   continue
c
 20   do 30 i=1,6
          yfis(i)=ykt(i)*cmvkt
          twyf   =twyf + yfis(i)
 30   continue
 40   do 50 i=1,6
```

```
          yfisf(i)=yfis(i)/twyf
 50   continue
c ....
      return
      end
c .....
      block data init1
      common /fusion/ fie,fue,xnu1(3),xnu14(3),xnufu,alpha(3),beta(3)
      common /yield/  ykt(6),yfis(6),twyf,yfisf(6),cmvkt
      data cmvkt /1.45e+23/
      data fie,fue,  xnu1,       xnu14,  xnufu,   alpha,       beta/
     ;  180.,17.6,2.5,2.5,3.0,4.5,4.4,4.8, 1. ,.93,3.5,.94,.29,.83,.18/
      end
```

```
      subroutine orgsrc
      include 'fiparms.f'
      include 'varblock.f'
c  this subroutine writes out the input file for the origen2 code
c  it uses the data read in by input.dat
c .....
c  array   a - first section of origen2 input
c  array   b - second section of origen2 input
c  array   c - third section of origen2 input
c  array ahe - curies of actinides           (heavy elements)
c  array ale - curies of activation products (light elements)
c  array ihe - origen2 actinide identification number
c  array ile - origen2 activation product identification number
c .....
      character*80 a(45),b(41),c
c
      equivalence (yfisf(1),u235ff),(yfisf(3),u238ff),(yfisf(5),pu239ff)
      equivalence (yfisf(2),u23514),(yfisf(4),u23814),(yfisf(6),pu23914)
c
      dimension ahe(100),ihe(100),ale(100),ile(100)
      dimension idactp(20),dactp(20),idactin(20),dactin(20)
c
      data idactp/04070,110240,250540,260550,260590,270570,
     ; 270580,270600,290640,290670,741810,741850,741870,
     ; 741880,791980,791990,250560,000000,000000,000000/
      data idactin/902290,902300,902340,922330,922340,922350,
     ;922370,922380,922400,932370,932390,932400,942380,
     ;942390,942400,942410,952410,962420,000000,000000/
      data dactp/1.,1.28E-05,2.57E-08,8.45E-09,1.78E-07,1.,
     ;1.13E-07,4.17E-09,1.52E-05,3.11E-06,6.62E-08,1.07E-07,8.06E-06,
     ;1.16E-07,2.97E-06,2.55E-06,7.46E-05,1.,1.,1./
      data dactin/2.99E-12,2.85E-13,3.33E-07,1.39E-13,8.98E-14,3.12E-17,
     ;1.19E-06,4.92E-18,1.37E-05,1.03E-14,3.41E-06,1.78E-04,2.50E-10,
     ;9.13E-13,3.36E-12,1.53E-09,5.08E-11,4.92E-08,1.,1./
      data a/
     ;'-1',
     ;'-1',
     ;'-1',
     ;'BAS      1E14 FISSIONS',
     ;'LIB    0 1 2 3 0 0 0 9 3 0 1 15',
     ;'PHO    101 102 103 10',
     ;'CUT  7 0.0 25 -1. 26 -1. 27 .1 -1',
     ;'OPTL  8 8 8 8 8 8 5 17*8',
     ;'OPTA  8 8 8 8 8 8 5 17*8',
     ;'OPTF  8 8 8 8 8 8 5 17*8',
     ;'RDA    title for run',
     ;'TIT     test of inventory mix',
     ;'RDA    put cinder u235 ff inventory in vector -1',
     ;'INP    -1 2 -1 -1 1 1',
     ;'RDA    put cinder u238 ff inventory in vector -2',
     ;'INP    -2 2 -1 -1 1 1',
     ;'RDA    put cinder pu239 ff inventory in vector -3',
     ;'INP    -3 2 -1 -1 1 1',
     ;'RDA    put endf6 u235 14 inventory in vector -4',
     ;'INP    -4 2 -1 -1 1 1',
     ;'RDA    put endf6 u238 14 inventory in vector -5',
     ;'INP    -5 2 -1 -1 1 1',
     ;'RDA    put endf6 pu239 14 inventory in vector -6',
     ;'INP    -6 2 -1 -1 1 1',
     ;'RDA    move fraction of cinder u235 ff inventory to vector 1',
     ;'MOV    -1 1 0 1.0',
     ;'RDA    add fraction of cinder u238 ff inventory to vector 1',
     ;'ADD    -2 1 0 1.0',
     ;'RDA    add fraction of cinder pu239 ff inventory to vector 1',
     ;'ADD    -3 1 0 1.0',
     ;'RDA    move fraction of endf6 u235 14 inventory to vector 1',
     ;'ADD    -4 1 0 1.0',
```

```
     ;'RDA    add fraction of endf6 u238 14 inventory to vector 1',
     ;'ADD    -5 1 0 1.0',
     ;'RDA    add fraction of endf6 pu239 14 inventory to vector 1',
     ;'ADD    -6 1 0 1.0',
     ;'RDA    put actinide inventory in vector -7',
     ;'INP    -7 2 -1 -1 1 1',
     ;'RDA    add fraction of actinide inventory to vector -7',
     ;'ADD    -7 1 0 1.0',
     ;'RDA    put activated light element inventory in vector -8',
     ;'INP    -8 2 -1 -1 1 1',
     ;'RDA    add fraction of light element inventory to vector -8',
     ;'ADD    -8 1 0 1.0',
     ;'HED    1  CHARGE'/
      data b/
     ;'RDA    decay inv in vector 1 to .001s, put results in vector -1',
     ;'DEC     2.778E-7  1 -1 3 0 ',
     ;'DEC     5.985E-7 -1 -2 3 0 ',
     ;'DEC     1.289E-6 -2 -3 3 0 ',
     ;'DEC     2.778E-6 -3 -4 3 0 ',
     ;'DEC     5.985E-6 -4 -5 3 0 ',
     ;'DEC     1.289E-5 -5 -6 3 0 ',
     ;'DEC     2.778E-5 -6 -7 3 0 ',
     ;'DEC     5.985E-5 -7 -8 3 0 ',
     ;'DEC     1.289E-4 -8 -9 3 0 ',
     ;'DEC     2.778E-4 -9 -10 3 0 ',
     ;'DEC     5.985E-4 -10 -11 3 0 ',
     ;'DEC     1.289E-3 -11 -12 3 0 ',
     ;'DEC     2.778E-3 -12 -13 3 0 ',
     ;'DEC     5.985E-3 -13 -14 3 0 ',
     ;'DEC     1.289E-2 -14 -15 3 0 ',
     ;'DEC     2.778E-2 -15 -16 3 0 ',
     ;'DEC     5.985E-2 -16 -17 3 0 ',
     ;'DEC     1.289E-1 -17 -18 3 0 ',
     ;'DEC     2.778E-1 -18 -19 3 0 ',
     ;'DEC     5.985E-1 -19 -20 3 0 ',
     ;'DEC     1.289E+0 -20 -21 3 0 ',
     ;'DEC     2.778E+0 -21 -22 3 0 ',
     ;'DEC     5.985E+0 -22 -23 3 0 ',
     ;'DEC     1.289E+1 -23 -24 3 0 ',
     ;'DEC     2.778E+1 -24 -25 3 0 ',
     ;'DEC     5.985E+1 -25 -26 3 0 ',
     ;'DEC     1.289E+2 -26 -27 3 0 ',
     ;'DEC     2.778E+2 -27 -28 3 0 ',
     ;'DEC     5.985E+2 -28 -29 3 0 ',
     ;'DEC     1.289E+3 -29 -30 3 0 ',
     ;'DEC     2.778E+3 -30 -31 3 0 ',
     ;'DEC     5.985E+3 -31 -32 3 0 ',
     ;'DEC     1.289E+4 -32 -33 3 0 ',
     ;'DEC     2.778E+4 -33 -34 3 0 ',
     ;'DEC     5.985E+4 -34 -35 3 0 ',
     ;'DEC     1.289E+5 -35 -36 3 0 ',
     ;'DEC     2.778E+5 -36 -37 3 0 ',
     ;'DEC     5.985E+5 -37 -38 3 0 ',
     ;'DEC     1.289E+6 -38 -39 3 0 ',
     ;'DEC     2.778E+6 -39 -40 3 0 '/
c
c .....
c use data from fiidos
c .....
      ntimes=nmeas+nexp
      if(itpm.eq.2)ntimes=ntimes+nexp
      do 10 n=1,nmeas
       times(n)=xtmeas(n)
 10   continue
      do 20 n=1,nexp
       times(n+nmeas)=xtexp(n)
       if(itpm.eq.2)times(n+nmeas+nexp)=xtexp(n+nexp)
```

```
 20   continue
c
      if(iactp.ne.0) then
       nactp=yyy
       do 30 i=1,nactp
        ile(i)=idactp(i)
        ale(i)=actpp(i)
 30    continue
      else
       nactp=1
       ile(1)=0
       ale(1)=0.
      endif
c
      if(iactin.ne.0) then
       nactin=xxx
       do 40 i=1,nactin
        ihe(i)=idactin(i)
        ahe(i)=actinp(i)
 40    continue
      else
       nactin=1
       ihe(1)=0
       ahe(1)=0.
      endif
c .....
c set up desired decay times based on standard decay times
c .....
      intmax=1
      do 50 nt=1,ntimes
       bigind=3*log10(times(nt)/2.778e-7)+.99999
       tindex(nt)=min(bigind,40.)
       xtra(nt)=times(nt)-2.778e-7*10.**((tindex(nt)-1.)/3.)
       intmax=max(tindex(nt),intmax)
 50   continue
      open(unit=3,file='orgsrc.dat',status='old')
      open(unit=2,file='tape5.inp')
c
      write(2,90)(a(i),i=1,11)
      write(2,100)title
      write(2,90)(a(i),i=13,25)
      write(2,101)u235ff*1.e-6
      write(2,90)a(27)
      write(2,102)u238ff*1.e-6
      write(2,90)a(29)
      write(2,103)pu239ff*1.e-6
      write(2,90)a(31)
      write(2,104)u23514*1.e-6
      write(2,90)a(33)
      write(2,105)u23814*1.e-6
      write(2,90)a(35)
      write(2,106)pu23914*1.e-6
      if(nactin.ne.0)then
      write(2,90)(a(i),i=37,40)
      endif
      if(nactp.ne.0)then
      write(2,90)(a(i),i=41,44)
      endif
      write(2,90)a(45)
      write(2,90)(b(nt),nt=1,intmax+1)
      do 60 nt=1,ntimes
       write(2,108)xtra(nt),-1*tindex(nt),-1*(nt+40),3,1
 60   continue
      write(2,107)
      write(2,108)xtra(1),-1*tindex(1),2,3,1
      write(2,109)2,times(1)
      write(2,110)2
```

```
 70   read(3,90,end=80)c
      write(2,90)c
      go to 70
 80   continue
      write(2,111)
     ; (ihe(i),ahe(i)/dactin(i)*3.7e10/6.023e23/1.45e+9,i=1,nactin),0,0.
      write(2,113)
      write(2,112)
     ; (ile(i),ale(i)/dactp(i)*3.7e10/6.023e23/1.45e+9,i=1,nactp),0,0.
      write(2,113)
      write(2,114)
c
90    format(a80)
95    format(1p,e10.3,i5,e10.3)
100   format('TIT     ',a80)
101   format('MOV    -1 1 0 ',1pg10.3)
102   format('ADD    -2 1 0 ',1p,g10.3)
103   format('ADD    -3 1 0 ',1p,g10.3)
104   format('ADD    -4 1 0 ',1pg10.3)
105   format('ADD    -5 1 0 ',1p,g10.3)
106   format('ADD    -6 1 0 ',1p,g10.3)
107   format('RDA     DUMMY DECAY')
108   format('DEC    ',g12.5,4i6)
109   format('HED    ',i3,1x,1pg8.2,'H')
110   format('OUT    ',i3,'  1  -1   0')
111   format(('2',4(1x,i6,1p,e12.5)))
112   format(('1',4(1x,i6,1p,e12.5)))
113   format(' 0')
114   format('END')
c
      close(unit=3)
      close(unit=2)
      return
      end
```

```
      subroutine rri
      include 'fiparms.f'
      include 'varblock.f'
c  calculates the relative radionuclide inventory for the purpose of
c  providing data to be used to modify the relative gamma emission spectum
c ....
c    indices for control of inventory treatment
c  variable  ikrxer - index for treatment of noble gases
c  variable  iactp  - index for treatment of activation products
c  variable  iactin - index for treatment of actinides
c  variable  ifrac  - index for treatment of fractionation of fission products
c   0) no treatment           1) treatment required
c .....
c calculate gross fission product inventory
c .....
      call gfpi
c .....
c remove krypton and xenon if desired
c .....
      if(ikrxer.eq.1) call krxeri
c .....
c add activation products if desired
c .....
      if(iactp.eq.1) call actpi
c .....
c add actinides if desired
c .....
      if(iactin.eq.1) call actini
c .....
c fractionate results if desired
c .....
      if(ifrac.eq.1) call fraci
      return
      end
```

```
        subroutine gfpi
       include 'fiparms.f'
       include 'varblock.f'
c  this subroutine accepts the relative radiological inventory of fission
c  products from calculations of origen2.
c .....
c  array     afp(i)  -relativve inventory of fission products
c                      given in units of curies per 10**14 fissions.
c  variable  acttot - total activity from all radionuclides
c  array lookfp(i) - lookup fission product # i in origen2 inventory
c  array xnew(i,j) - origen2 inventory isotope j; time i
c  array dis(i)    - decay constant for origen2 isotope i (sec-1)
c  array q(i)      - energy per disintegration (watts)
c  variable ertfpf - energy rate for fiidos fiss prod inventory
c  variable e50fpf - 50 yr cum energy from fiidos fiss prod inventory
c  variable ertfpo - energy rate for origen2 fiss prod inventory
c  variable e50fpo - 50 yr cum energy from origen2 fiss prod inventory
c .....
c commons from origen2
       INCLUDE 'params.f'
       DIMENSION XNEW(AAAA,BBBB),COEFF(CCCC,BBBB),NPROD(CCCC,BBBB),
      $MMAX(BBBB),KAP(BBBB)
       COMMON /BIG/NUCL(BBBB),Q(BBBB),FG(0004),TOCAP(BBBB),GENNEU(GGGG),
      $ALPHAN(GGGG),SPONF(GGGG),SFNU(GGGG),FISS(GGGG),NUCAB(BBBB),
      $AMPC(BBBB),WMPC(BBBB),XSTORE(JJJJ,BBBB),DIS(BBBB),B(BBBB),
      $ABUND(KKKK),NON0(BBBB),KD(BBBB),LOC(DDDD),NGF(BBBB),NGN(BBBB),
      $NGR(LLLL),GGR(LLLL),AA(DDDD),LOCA(DDDD),NFUDFP(FFFF,OOOO)
       COMMON /NUDSCR/DUM1(CCCC,BBBB),DUM2(HHHH,BBBB),S(2),CIMN(BBBB),
      $ CSUM(BBBB),NONP(BBBB),NQ(BBBB),XP(BBBB),XPAR(BBBB),XTEMP(BBBB),
      $ D(BBBB),AP(IIII),LOCP(IIII),LONG(BBBB)
       EQUIVALENCE (DUM1(1,1),COEFF(1,1)),(DUM2(1,1),NPROD(1,1)),
      $(NONP(1),MMAX(1)),(KAP(1),NQ(1)),(XNEW(1,1),DUM1(1,1))
c .....
       ertfpf=0.
       e50fpf=0.
       do 10 i=1,www
       mmm=lookfp(i)
       value=XSTORE(tmindx+40,mmm)
       afp(i)=value*DIS(mmm)*1.6283e13
       ertfpf=ertfpf+value*Q(mmm)/1.6e-13
       if(DIS(mmm).ne.0)
      $ e50fpf=e50fpf+value*Q(mmm)/1.6e-13/DIS(mmm)*
      $ (1-exp(-1.*DIS(mmm)*50.*365.*24.*3600.))
 10    continue
c
       ertfpo=0.
       e50fpo=0.
       do 20 mmm=818,1598
       value=XSTORE(tmindx+40,mmm)
       ertfpo=ertfpo+value*Q(mmm)/1.6e-13
       if(DIS(mmm).ne.0)
      $ e50fpo=e50fpo+value*Q(mmm)/1.6e-13/DIS(mmm)*
      $ (1-exp(-1.*DIS(mmm)*50.*365.*24.*3600.))
 20    continue
c .....
c  calculate total activity
c .....
       acttot=0.0
       do 30 i=1,www
       acttot=acttot+afp(i)
 30    continue
       return
       end
c .....
       blockdata lookdata
       include 'fiparms.f'
       include 'varblock.f'
```

```
      data lookfp/
     +870,896,904,905,911,919,920,921,928,934,
     +935,941,942,946,947,948,956,957,958,959,
     +965,966,967,968,974,975,982,983,985,986,
     +993,1000,1001,1002,1008,1016,1017,1018,1029,1037,
     +1038,1039,1052,1053,1059,1060,1067,1068,1069,1077,
     +1083,1084,1085,1086,1087,1093,1094,1103,1122,1124,
     +1126,1135,1143,1161,1181,1259,1268,1276,1278,1279,
     +1288,1289,1299,1300,1301,1318,1319,1320,1321,1327,
     +1328,1331,1338,1339,1340,1341,1342,1346,1347,1348,
     +1349,1353,1354,1355,1356,1358,1359,1365,1366,1369,
     +1370,1374,1375,1376,1377,1385,1391,1392,1393,1398,
     +1399,1406,1407,1411,1412,1413,1418,1419,1420,1425,
     +1426,1434,1435,1436,1442,1443,1444,1451,1452,1460,
     +1461,1468,1469,1470,1471,1477,1479,1480,1489,1503,
     +1504,1513,1522,1530,1539,1545,1569,1597,1599,1600/
      data lookap/
     +1600, 38,118,124,128, 1600 ,130,132,147,150,
     +605,610,613,614,656,657,120, 3*1600/
      data lookan/
     +738,739,743,753,754,755,757,758,760,765,
     +767,768,773,774,775,776,784,793, 2*1600/
      end
```

```
      subroutine krxeri
      include 'fiparms.f'
      include 'varblock.f'
c  this subroutine removes krypton and xenon (noble gases) from inventory and
c  records amount of removed inventory so that gamma energy spectrum can be
c  modified.
c .....
c  array afp(i)   - amount of radionuclide i determined for time of concern.
c  array akrxer(j)- amount of noble gas j removed from inventory
c                   at time of concern.
c  array noble(j) - radionuclide position corresponding to j th noble gas.
c .....
      dimension noble(13)
      data noble/4,7,8,10,12,14,87,96,97,103,104,107,110/
c .....
 10   continue
      do 20 j=1,13
      akrxer(j)=afp(noble(j))
      afp(noble(j))=0.0
      acttot=acttot-akrxer(j)
 20   continue
      return
      end
```

```
      subroutine actpi
      include 'fiparms.f'
      include 'varblock.f'
c  this subroutine accepts the relative radionuclide inventory
c  of activation products from calculations of origen2.
c .....
c                 the twenty radionuclides are:
c                   (1) be-7     (2) na-24    (3) mn-54    (4) fe-55
c                   (5) fe-59    (6) co-57    (7) co-58    (8) co-60
c                   (9) cu-64    (10)cu-67    (11) w-181   (12) w-185
c                   (13) w-187   (14) w-188   (15)au-198   (16)au-199
c                   (17)pb-203   (18)mn-56    (19)not used (20)not used
c  array aactp(i)  - relative inventory of activation product radionuclides
c                    given in units of curie per 10**14 fissions.
c  array lookap(i) - lookup activation product # i in origen2 inventory
c  array xnew(i,j) - origen2 inventory isotope j; time i
c  array dis(i)    - decay constant for origen2 isotope i (sec-1)
c  array q(i)      - energy per disintegration (watts)
c  variable ertapf - energy rate for fiidos act prod inventory
c  variable e50apf - 50 yr cum energy from fiidos act prod inventory
c  variable ertapo - energy rate for origen2 act prod inventory
c  variable e50apo - 50 yr cum energy from origen2 act prod inventory
c .....
c common from origen2
      INCLUDE 'params.f'
      DIMENSION XNEW(AAAA,BBBB),COEFF(CCCC,BBBB),NPROD(CCCC,BBBB),
     $MMAX(BBBB),KAP(BBBB)
      COMMON /BIG/NUCL(BBBB),Q(BBBB),FG(0004),TOCAP(BBBB),GENNEU(GGGG),
     $ALPHAN(GGGG),SPONF(GGGG),SFNU(GGGG),FISS(GGGG),NUCAB(BBBB),
     $AMPC(BBBB),WMPC(BBBB),XSTORE(JJJJ,BBBB),DIS(BBBB),B(BBBB),
     $ABUND(KKKK),NON0(BBBB),KD(BBBB),LOC(DDDD),NGF(BBBB),NGN(BBBB),
     $NGR(LLLL),GGR(LLLL),AA(DDDD),LOCA(DDDD),NFUDFP(FFFF,OOOO)
      COMMON /NUDSCR/DUM1(CCCC,BBBB),DUM2(HHHH,BBBB),S(2),CIMN(BBBB),
     $ CSUM(BBBB),NONP(BBBB),NQ(BBBB),XP(BBBB),XPAR(BBBB),XTEMP(BBBB),
     $ D(BBBB),AP(IIII),LOCP(IIII),LONG(BBBB)
      EQUIVALENCE (DUM1(1,1),COEFF(1,1)),(DUM2(1,1),NPROD(1,1)),
     $(NONP(1),MMAX(1)),(KAP(1),NQ(1)),(XNEW(1,1),DUM1(1,1))
c .....
      ertapf=0.
      e50apf=0.
      do 10 i=1,yyy
      mmm=lookap(i)
      value=XSTORE(tmindx+40,mmm)
      aactp(i)=value*DIS(mmm)*1.6283e13
      ertapf=ertapf+value*Q(mmm)/1.6e-13
      if(DIS(mmm).ne.0)
     $ e50apf=e50apf+value*Q(mmm)/1.6e-13/DIS(mmm)*
     $ (1-exp(-1.*DIS(mmm)*50.*365.*24.*3600.))
 10   continue
c
      ertapo=0.
      e50apo=0.
      do 20 mmm=1,688
      value=XSTORE(tmindx+40,mmm)
      ertapo=ertapo+value*Q(mmm)/1.6e-13
      if(DIS(mmm).ne.0)
     $ e50apo=e50apo+value*Q(mmm)/1.6e-13/DIS(mmm)*
     $ (1-exp(-1.*DIS(mmm)*50.*365.*24.*3600.))
 20   continue
c .....
c  calculate total activity
c .....
      do 30 i=1,yyy
      acttot=acttot+aactp(i)
 30   continue
      return
      end
```

```
      subroutine actini
      include 'fiparms.f'
      include 'varblock.f'
c  this subroutine calculates the relative radionuclide inventory of
c  actinide elements from calculations of origen2.
c .....
c              the twenty radionuclides are:
c                  (1) th-229    (2) th-230    (3) th-234    (4)  u-233
c                  (5)  u-234    (6)  u-235    (7)  u-237    (8)  u-238
c                  (9)  u-240    (10)np-237    (11)np-239    (12)np-240
c                  (13)pu-238    (14)pu-239    (15)pu-240    (16)pu-241
c                  (17)am-241    (18)cm-242    (19)not used  (20)not used
c  array aactin(i) - relative inventory of actinide radionuclides given
c                    in units of curie per 10**14 fissions.
c  array lookan(i) - lookup actinide # i in origen2 inventory
c  array xnew(i,j) - origen2 inventory isotope i; time j
c  array dis(i)    - decay constant for origen2 isotope i (sec-1)
c  array q(i)      - energy per disintegration (watts)
c  variable ertanf - energy rate for fiidos actinide inventory
c  variable e50anf - 50 yr cum energy from fiidos actinide inventory
c  variable ertano - energy rate for origen2 actinide inventory
c  variable e50ano - 50 yr cum energy from origen2 actinide inventory
c .....
c commons from origen2
      INCLUDE 'params.f'
      DIMENSION XNEW(AAAA,BBBB),COEFF(CCCC,BBBB),NPROD(CCCC,BBBB),
     $MMAX(BBBB),KAP(BBBB)
      COMMON /BIG/NUCL(BBBB),Q(BBBB),FG(0004),TOCAP(BBBB),GENNEU(GGGG),
     $ALPHAN(GGGG),SPONF(GGGG),SFNU(GGGG),FISS(GGGG),NUCAB(BBBB),
     $AMPC(BBBB),WMPC(BBBB),XSTORE(JJJJ,BBBB),DIS(BBBB),B(BBBB),
     $ABUND(KKKK),NON0(BBBB),KD(BBBB),LOC(DDDD),NGF(BBBB),NGN(BBBB),
     $NGR(LLLL),GGR(LLLL),AA(DDDD),LOCA(DDDD),NFUDFP(FFFF,OOOO)
      COMMON /NUDSCR/DUM1(CCCC,BBBB),DUM2(HHHH,BBBB),S(2),CIMN(BBBB),
     $ CSUM(BBBB),NONP(BBBB),NQ(BBBB),XP(BBBB),XPAR(BBBB),XTEMP(BBBB),
     $ D(BBBB),AP(IIII),LOCP(IIII),LONG(BBBB)
      EQUIVALENCE (DUM1(1,1),COEFF(1,1)),(DUM2(1,1),NPROD(1,1)),
     $(NONP(1),MMAX(1)),(KAP(1),NQ(1)),(XNEW(1,1),DUM1(1,1))
c .....
      ertanf=0.
      e50anf=0.
      do 10 i=1,xxx
      mmm=lookan(i)
      value=XSTORE(tmindx+40,mmm)
      aactin(i)=value*DIS(mmm)*1.6283e13
      ertanf=ertanf+value*Q(mmm)/1.6e-13
      if(DIS(mmm).ne.0)
     $ e50anf=e50anf+value*Q(mmm)/1.6e-13/DIS(mmm)*
     $ (1-exp(-1.*DIS(mmm)*50.*365.*24.*3600.))
 10   continue
c
      ertano=0.
      e50ano=0.
      do 20 mmm=689,817
      value=XSTORE(tmindx+40,mmm)
      ertano=ertano+value*Q(mmm)/1.6e-13
      if(DIS(mmm).ne.0)
     $ e50ano=e50ano+value*Q(mmm)/1.6e-13/DIS(mmm)*
     $ (1-exp(-1.*DIS(mmm)*50.*365.*24.*3600.))
 20   continue
c .....
c  calculate total activity
c .....
      do 30 i=1,xxx
      acttot=acttot+aactin(i)
 30   continue
      return
      end
```

```
      subroutine fraci
      include 'fiparms.f'
      include 'varblock.f'
c  this subroutine modifies the relative radionuclide inventory of fission
c  products with user supplied fractionation factors.
c .....
c                 the one hundred and fifty radionuclides are:
c          (1)  se-79    (2)  br-82    (3)  br-83    (4)  kr-83m   (5)  br-84
c          (6)  br-85    (7)  kr-85    (8)  kr-85m   (9)  rb-86    (10) kr-87
c          (11) rb-87    (12) kr-88    (13) rb-88    (14) kr-89    (15) rb-89
c          (16) sr-89    (17) rb-90    (18) rb-90m   (19) sr-90    (20)  y-90
c          (21) rb-91    (22) sr-91    (23)  y-91    (24)  y-91m   (25) sr-92
c          (26)  y-92    (27) sr-93    (28)  y-93    (29) zr-93    (30) nb-93m
c          (31)  y-94    (32)  y-95    (33) zr-95    (34) nb-95    (35)  y-96
c          (36) zr-97    (37) nb-97    (38) nb-97m   (39) nb-98m   (40) mo-99
c          (41) tc-99    (42) tc-99m   (43) mo-101   (44) tc-101   (45) mo-102
c          (46) tc-102   (47) tc-103   (48) ru-103   (49) rh-103m  (50) tc-104
c          (51) mo-105   (52) tc-105   (53) ru-105   (54) rh-105   (55) rh-105m
c          (56) ru-106   (57) rh-106   (58) pd-107   (59) rh-109   (60) pd-109
c          (61) ag-109m  (62) ag-110m  (63) ag-111   (64) cd-113m  (65) cd-115m
c          (66) sn-123   (67) sb-124   (68) sn-125   (69) sb-125   (70) te-125m
c          (71) sn-126   (72) sb-126   (73) sb-127   (74) te-127   (75) te-127m
c          (76) sb-129   (77) te-129   (78) te-129m  (79)  i-129   (80) sn-130
c          (81) sb-130m  (82)  i-130   (83) sb-131   (84) te-131   (85) te-131m
c          (86)  i-131   (87) xe-131m  (88) sb-132   (89) sb-132m  (90) te-132
c          (91)  i-132   (92) sb-133   (93) te-133   (94) te-133m  (95)  i-133
c          (96) xe-133   (97) xe-133m  (98) te-134   (99)  i-134   (100)cs-134
c          (101)cs-134m  (102) i-135   (103)xe-135   (104)xe-135m  (105)cs-135
c          (106)cs-136   (107)xe-137   (108)cs-137   (109)ba-137m  (110)xe-138
c          (111)cs-138   (112)cs-139   (113)ba-139   (114)cs-140   (115)ba-140
c          (116)la-140   (117)ba-141   (118)la-141   (119)ce-141   (120)ba-142
c          (121)la-142   (122)la-143   (123)ce-143   (124)pr-143   (125)ce-144
c          (126)pr-144   (127)pr-144m  (128)ce-145   (129)pr-145   (130)ce-146
c          (131)pr-146   (132)ce-147   (133)pr-147   (134)nd-147   (135)pm-147
c          (136)pr-148   (137)pm-148   (138)pm-148m  (139)pm-149   (140)pm-151
c          (141)sm-151   (142)eu-152   (143)sm-153   (144)eu-154   (145)eu-155
c          (146)eu-156   (147)tb-160   (148)ho-166m  (149)not used (150)not used
c  array afp(i)    - relative radionuclide inventory of fission products in units
c                    of curies per 10**14 fissions.
c  array afracc(id(i))-change in the amount of relative radionuclide inventory
c                      for the i th fractionated fission product.
c  array id(i)     - fission product number for the i th fractionated fission
c                    product.
c .....
      do 10 i=1,nfrac
      afracc(i)=(ffrac(i)-1.)*afp(id(i))
      afp(id(i))=afp(id(i))*ffrac(i)
      acttot=acttot+afracc(i)
 10   continue
      return
      end
```

```
      subroutine rges
      include 'fiparms.f'
      include 'varblock.f'
c  calculates the relative radionuclide gamma energy spectrum for the purpose of
c  providing data to be used to in subroutine sfcalc.
c .....
c    indices for control of inventory treatment are:
c  variable  ikrxer - index for treatment of noble gases
c  variable  iactp  - index for treatment of activation products
c  variable  iactin - index for treatment of actinides
c  variable  ifrac  - index for treatment of fractionation of fission products
c   0) no treatment           1) treatment required
c .....
c calculate gross fission product gamma spectrum
c .....
      call gfpg
c .....
c remove krypton and xenon if desired
c .....
      if(ikrxer.eq.1) call krxerg
c .....
c add activation products if desired
c .....
      if(iactp.eq.1) call actpg
c .....
c add actinides if desired
c .....
      if(iactin.eq.1) call acting
c .....
c fractionate results if desired
c .....
      if(ifrac.eq.1) call fracg
      return
      end
```

```
      subroutine gfpg
      include 'fiparms.f'
      include 'varblock.f'
c  this subroutine accepts the relative radiological gamma energy spectrum
c  of fission products from calculations of origen2.
c .....
c  array spec(j)  - relative gamma emission spectrum for energy group j
c                   of the fission products
c  array gspec(j,k,l)-rel gammma energy spectrum from origen2
c                    energy group j; isotope type k; time loc l
c .....
c common from origen2
      common /spectra/ gspec(ooo,3,zzz)
c .....
      do 10 j=1,ooo
      spec(j)=gspec(j,3,tmindx)
 10   continue
c convert from gamma/sec to gamma/hr
      do 20 j=1,ooo
      spec(j)=spec(j)*3600.
 20   continue
      return
      end
```

```
      subroutine krxerg
      include 'fiparms.f'
      include 'varblock.f'
c  this subroutine calculates the spectrum produced by krypton and xenon (noble
c  gases) and removes it from the relative radionuclide gamma
c  spectrum at the time of concern.
c .....
c  array akrxer(i)- amount of noble gas i removed from inventory
c                   at time of concern.
c  array gamma(j) - photons per disintegration for each energy group i. read in
c                   one isotope at a time.
c  array spec(j)  - relative gamma energy spectrum for energy group j modified
c                   by subtracting the spectrum of the noble gases.
c .....
 10   continue
      open(unit=2,file='krxe.gam',status='old')
 20   continue
      do 30 j=1,ooo
      skrxer(j)=0.0
 30   continue
      do 40 i=1,13
      read(2,*)(gamma(j),j=1,ooo)
      do 40 j=1,ooo
      skrxer(j)=skrxer(j)+akrxer(i)*gamma(j)
 40   continue
      do 50 j=1,ooo
      skrxer(j)=skrxer(j)*1.332e+14
      spec(j)=spec(j)-skrxer(j)
 50   continue
      close(unit=2)
      return
      end
```

```
      subroutine actpg
      include 'fiparms.f'
      include 'varblock.f'
c  this subroutine accepts the gamma energy spectrum of activation products
c  from calculations of origen2
c  and adds it to the relative radionuclide gamma spectrum at time of concern
c .....
c                 the twenty radionuclides are:
c                   (1) be-7     (2) na-24    (3) mn-54    (4) fe-55
c                   (5) fe-59    (6) co-57    (7) co-58    (8) co-60
c                   (9) cu-64    (10)cu-67    (11) w-181   (12) w-185
c                   (13) w-187   (14) w-188   (15)au-198   (16)au-199
c                   (17)pb-203   (18)mn-56    (19)not used (20)not used
c  array sactp(j) - relative gamma energy spectrum for energy group j
c                   of the activation products.
c  array spec(j)  - relative gamma energy spectrum for energy group j which is
c                   modified by adding spectrum of the activation products.
c  array gspec(j,k,l)-rel gammma energy spectrum from origen2
c                    energy group j; isotope type k; time loc l
c common from origen2
      common /spectra/ gspec(ooo,3,zzz)
c .....
      do 10 j=1,ooo
      sactp(j)=gspec(j,1,tmindx)
 10   continue
c convert from gamma/sec to gamma/hr
      do 20 j=1,ooo
      sactp(j)=sactp(j)*3600.
      spec(j)=spec(j)+sactp(j)
 20   continue
      return
      end
```

```
      subroutine acting
      include 'fiparms.f'
      include 'varblock.f'
c  this subroutine accepts the gamma energy spectrum of actinide elements
c  from calculations of origen2.
c  and adds it to the relative radionuclide gamma spectrum at time of concern
c .....
c              the twenty radionuclides are:
c                  (1) th-229    (2) th-230    (3) th-234    (4)  u-233
c                  (5)  u-234    (6)  u-235    (7)  u-237    (8)  u-238
c                  (9)  u-240    (10)np-237    (11)np-239    (12)np-240
c                  (13)pu-238    (14)pu-239    (15)pu-240    (16)pu-241
c                  (17)am-241    (18)cm-242    (19)not used  (20)not used
c  array sactin(j) - relative gamma energy spectrum for energy group j
c                    of the actinides.
c  array spec(j)   - relative gamma energy spectrum for energy group j which
c                    is modified by adding spectrum of the actinides.
c  array gspec(j,k,l)-rel gammma energy spectrum from origen2
c                    energy group j; isotope type k; time loc l
c .....
c common from origen2
      common /spectra/ gspec(ooo,3,zzz)
c .....
      do 10 j=1,ooo
      sactin(j)=gspec(j,2,tmindx)
 10   continue
c convert from gamma/sec to gamma/hr
      do 20 j=1,ooo
      sactin(j)=sactin(j)*3600.
      spec(j)=spec(j)+sactin(j)
 20   continue
      return
      end
```

```
      subroutine fracg
      include 'fiparms.f'
      include 'varblock.f'
c  this subroutine modifies the gamma energy spectrum caused by the
c  the fractionation of fission products at the time of concern.
c .....
c                 the one hundred and fifty radionuclides are:
c          (1)  se-79    (2)  br-82    (3)  br-83    (4)  kr-83m   (5)  br-84
c          (6)  br-85    (7)  kr-85    (8)  kr-85m   (9)  rb-86    (10) kr-87
c          (11) rb-87    (12) kr-88    (13) rb-88    (14) kr-89    (15) rb-89
c          (16) sr-89    (17) rb-90    (18) rb-90m   (19) sr-90    (20)  y-90
c          (21) rb-91    (22) sr-91    (23)  y-91    (24)  y-91m   (25) sr-92
c          (26)  y-92    (27) sr-93    (28)  y-93    (29) zr-93    (30) nb-93m
c          (31)  y-94    (32)  y-95    (33) zr-95    (34) nb-95    (35)  y-96
c          (36) zr-97    (37) nb-97    (38) nb-97m   (39) nb-98m   (40) mo-99
c          (41) tc-99    (42) tc-99m   (43) mo-101   (44) tc-101   (45) mo-102
c          (46) tc-102   (47) tc-103   (48) ru-103   (49) rh-103m  (50) tc-104
c          (51) mo-105   (52) tc-105   (53) ru-105   (54) rh-105   (55) rh-105m
c          (56) ru-106   (57) rh-106   (58) pd-107   (59) rh-109   (60) pd-109
c          (61) ag-109m  (62) ag-110m  (63) ag-111   (64) cd-113m  (65) cd-115m
c          (66) sn-123   (67) sb-124   (68) sn-125   (69) sb-125   (70) te-125m
c          (71) sn-126   (72) sb-126   (73) sb-127   (74) te-127   (75) te-127m
c          (76) sb-129   (77) te-129   (78) te-129m  (79)  i-129   (80) sn-130
c          (81) sb-130m  (82)  i-130   (83) sb-131   (84) te-131   (85) te-131m
c          (86)  i-131   (87) xe-131m  (88) sb-132   (89) sb-132m  (90) te-132
c          (91)  i-132   (92) sb-133   (93) te-133   (94) te-133m  (95)  i-133
c          (96) xe-133   (97) xe-133m  (98) te-134   (99)  i-134   (100)cs-134
c          (101)cs-134m  (102) i-135   (103)xe-135   (104)xe-135m  (105)cs-135
c          (106)cs-136   (107)xe-137   (108)cs-137   (109)ba-137m  (110)xe-138
c          (111)cs-138   (112)cs-139   (113)ba-139   (114)cs-140   (115)ba-140
c          (116)la-140   (117)ba-141   (118)la-141   (119)ce-141   (120)ba-142
c          (121)la-142   (122)la-143   (123)ce-143   (124)pr-143   (125)ce-144
c          (126)pr-144   (127)pr-144m  (128)ce-145   (129)pr-145   (130)ce-146
c          (131)pr-146   (132)ce-147   (133)pr-147   (134)nd-147   (135)pm-147
c          (136)pr-148   (137)pm-148   (138)pm-148m  (139)pm-149   (140)pm-151
c          (141)sm-151   (142)eu-152   (143)sm-153   (144)eu-154   (145)eu-155
c          (146)eu-156   (147)tb-160   (148)ho-166m  (149)not used (150)not used
c  array afracc(i)- amount of relative radionuclide inventory for fiss products
c                   changed by fractionation.
c  array gamma(j) - photons per disintegration for each energy group j read in
c                   one isotope at a time.
c  array  spec(j) - relative gamma energy spectrum for energy group j modified
c                   by change in spectrum from fractionation of fiss products.
c .....
 10   continue
      open(unit=2,file='frac.gam',status='old')
 20   continue
      do 30 j=1,ooo
      sfracc(j)=0.0
 30   continue
      do 40 i=1,nfrac
      read(2,*)(gamma(j),j=1,ooo)
      do 40 j=1,ooo
      sfracc(j)=sfracc(j)+afracc(i)*gamma(j)
 40   continue
      do 50 j=1,ooo
      sfracc(j)=sfracc(j)*1.332e+14
      spec(j)=spec(j)+sfracc(j)
 50   continue
      close(unit=2)
      return
      end
```

```
      subroutine sfcalc
      include 'fiparms.f'
      include 'varblock.f'
c  this subroutine calculates the scaling factor that specifies the radiological
c  contamination in units of 10**14 fissions per m**2 or m**3.
c .....
c  variable itrm   - index for type of radiological measurement
c            the six types of measurement are
c       (1) radiation intensity above contaminated surface
c       (2) radiation intensity inside debris cloud
c       (3) radiation intensity below debris cloud
c       (4) gross activity - airborne concentration
c       (5) gross activity - surface concentration
c       (6) gross activity - inhalation or ingestion intake
c  array  spec(j)  - relative gamma emission spectrum at time of measurement
c                    (gamma/hr per 10**14 fissions).
c  variable acttot - total relative activity of radiological material
c                    (curie per 10**14 fissions).
c  array xactmes(t)- measured activity of radiological material
c                    (curie,curie per m**2, or curie per m**3) at
c                    time index t.
c  array gref(j)   - gamma radiation exposure factor for surface, in-cloud,
c                    or below-cloud measurement instrument itmi
c                    (r/hr per gamma/hr/m**2).
c  variable sf     - scaling factor (10*14 fissions per m**2 or m**3)
c  array xrimes(t) - measured radiation intensity(r/hr)at time index t
c .....
 10   continue
 20   if(xitrm(tmindx).gt.3) go to 90
c .....
c xitrm=1,2,3
c .....
 30   if(xitrm(tmindx).eq.1) open(unit=2,file='gref.sur',status='old')
      if(xitrm(tmindx).eq.2) open(unit=2,file='gref.inc',status='old')
      if(xitrm(tmindx).eq.3) open(unit=2,file='gref.blc',status='old')
 40   continue
      do 50 j=1,xitmi(tmindx)
      read(2,*)(gref(i),i=1,nnn)
 50   continue
      do 60 i=1,nnn
      gref(i)=gref(i)/1.e+4
 60   continue
      es=0.0
      do 70 i=1,15
      es=es+spec(i)*gref(nnn+1-i)
 70   continue
      es=es+ 0.55*spec(16)*gref(6)
      es=es+ 0.45*spec(16)*gref(5)
 80   continue
      sf=xrimes(tmindx)/es
      close(unit=2)
      go to 110
c .....
c  xitrm=4,5,6
c .....
 90   continue
      if(xitrm(tmindx).lt.6.or.xrimes(tmindx).eq.0.) go to 100
c logic for specific activity
      irimes=int(xrimes(tmindx))
      if(irimes.lt.151) r=acttot/afp(irimes)
      if(irimes.gt.150.and.irimes.lt.171) r=acttot/aactp(irimes-150)
      if(irimes.gt.170) r=acttot/aactin(irimes-170)
      sf=r*xactmes(tmindx)/acttot
      go to 110
 100  continue
      sf=xactmes(tmindx)/acttot
 110  continue
```

```
return
end
```

```
      subroutine dose
      include 'fiparms.f'
      include 'varblock.f'
c ....
c  this subroutine calculates the organ doses contributed by each radionuclide
c  and the total organ doses.
c ....
c  array xbr(t)   - breathing rate(m**3/hr) at time t
c  array xdur(t)  - duration of exposure(hr) at time t
c  array xkfac(t) - ratio of airborne to surface at time t
c  variable sf    - scaling factor (10**14 fissions per m**2, if itrm=1,5;
c                   10**14 fissions per m**3, if itrm=2,3,4; 10**14 fissions
c                   intake, if itrm=6)
c  array xitdcf(t)- index for type of dose conversion factor(see input)
c  array afp(i)   - relative amount of fission product radionuclides
c                   (curie per 10**14 fissions)
c  array aactp(i) - relative amount of activation product radionuclides
c                   (curie per 10**14 fissions)
c  array aactin(i)- relative amount of actinide element radionuclides
c                   (curie per 10**14 fissions)
c  array dcf(j)   - dose conversion factor(rem/curie)for inhalation or ingestion
c  array d(i,j)   - dose to organ j for radionuclide i (rem)
c  array td(i,j)  - total dose to organ j at time i
c  variable upfrac- pu239 uptake fraction for ingestion or inhalation
c                   in curies per curies
c  array exfrac(i,j) - pu239 excretion fraction in urine curies per day from
c                      exposure i, j years from shot
c  array sumfrac(i)-pu239 total excretion for multiple exposures
c  array tyrs(i)  - times after shot for excretion factors(years)
c
c .....
c array xitdcf - index for type of dose conversion factor
c    (1) inhalation dcf (currently ICRP 72)
c    (2) ingestion dcf (currently ICRP 72)
c .....
      const=xbr(tmindx)*xdur(tmindx)*xkfac(tmindx)*sf
c .....
c open DCF files
c .....
      if(xitdcf(tmindx).eq.1)
     ; open(unit=2,file='inh.dcf',status='old')
      if(xitdcf(tmindx).eq.2)
     ; open(unit=2,file='ing.dcf',status='old')
c.....
c read initial information from DCF file
c.....
      read(2,*) numorgans(xitdcf(tmindx)),edosnum(xitdcf(tmindx))
       read(2,1) dcfidinfo(xitdcf(tmindx))
       read(2,2) (orgnames(xitdcf(tmindx),i),
     ;           i=1,numorgans(xitdcf(tmindx)))
  1   format(a80)
  2   format(40a11)
c.....
c initialize total dose arrays for current time index
c.....
  3   do 10 j=1,sss
        td(tmindx,j)=0.0
        td1(tmindx,j)=0.0
        td2(tmindx,j)=0.0
        td3(tmindx,j)=0.0
        td4(tmindx,j)=0.0
        do 9 i=1,ttt
         osrnd(i,j)=0.0
  9     continue
 10   continue
c.....
c read in dcf set
```

```
c.....
      do 70 i=1,ttt
 20    read(2,*) (dcf(j),j=1,numorgans(xitdcf(tmindx))) ! Read in dcfs
       do 21 j=numorgans(xitdcf(tmindx))+1,sss
        dcf(j)=0.0
 21    continue
c total all doses by radionuclide group (fp,actp,actin) but
c separate doses from alpha emitters from doses from beta+gamma
c emitters in actinide group
 60    do 69 j=1,sss
        dcf(j)=dcf(j)*1.e+6
        if(i.le.150)then
         osrnd(i,j)=const*afp(i)*dcf(j)
         td1(tmindx,j)=td1(tmindx,j)+osrnd(i,j)
        elseif(i.le.170)then
         osrnd(i,j)=const*aactp(i-150)*dcf(j)
         td2(tmindx,j)=td2(tmindx,j)+osrnd(i,j)
        elseif(i.le.190)then
         osrnd(i,j)=const*aactin(i-170)*dcf(j)
         td3(tmindx,j)=td3(tmindx,j)+(osrnd(i,j)*
     ;                 (1.0-alphaemit(i-170)))
         td4(tmindx,j)=td4(tmindx,j)+(osrnd(i,j)*alphaemit(i-170))
        else
        endif
 69    continue
 70   continue
      close(unit=2)
      if (itpm.eq.2)go to 120
c
 80   do 81 j=1,sss
       td(tmindx,j)=td1(tmindx,j)+td2(tmindx,j)+td3(tmindx,j)+
     ;              td4(tmindx,j)
       tddcfsum(xitdcf(tmindx),j)=tddcfsum(xitdcf(tmindx),j)+
     ;                            td(tmindx,j)
       tddcf1sum(xitdcf(tmindx),j)=tddcf1sum(xitdcf(tmindx),j)+
     ;                             td1(tmindx,j)
       tddcf2sum(xitdcf(tmindx),j)=tddcf2sum(xitdcf(tmindx),j)+
     ;                             td2(tmindx,j)
       tddcf3sum(xitdcf(tmindx),j)=tddcf3sum(xitdcf(tmindx),j)+
     ;                             td3(tmindx,j)
       tddcf4sum(xitdcf(tmindx),j)=tddcf4sum(xitdcf(tmindx),j)+
     ;                             td4(tmindx,j)
 81   continue
      go to 300
c
 120  do 121 j=1,sss
       td(tmindx,j)=td1(tmindx,j)+td2(tmindx,j)+td3(tmindx,j)+
     ;              td4(tmindx,j)
 121  continue
      if(istidx.ne.0)then
       timelog=alog(oldtcnc/tcncnew)
       do 130 j=1,sss
c
        a=0.0
        if(td(tmindx,j)*tdold(j).ne.0)a=alog(tdold(j)/td(tmindx,j))/
     ;    timelog
        tdsum(j)=tdsum(j)+td(tmindx,j)/xdur(tmindx)*tcncnew/(1+a)*
     ;    (1.0-(oldtcnc/tcncnew)**(1+a))
c
        a=0.0
        if(td1(tmindx,j)*td1old(j).ne.0)a=alog(td1old(j)/td1(tmindx,j))/
     ;    timelog
        td1sum(j)=td1sum(j)+td1(tmindx,j)/xdur(tmindx)*tcncnew/(1+a)*
     ;    (1.0-(oldtcnc/tcncnew)**(1+a))
c
        a=0.0
        if(td2(tmindx,j)*td2old(j).ne.0)a=alog(td2old(j)/td2(tmindx,j))/
```

```
     ;    timelog
        td2sum(j)=td2sum(j)+td2(tmindx,j)/xdur(tmindx)*tcncnew/(1+a)*
     ;    (1.0-(oldtcnc/tcncnew)**(1+a))
c
        a=0.0
        if(td3(tmindx,j)*td3old(j).ne.0)a=alog(td3old(j)/td3(tmindx,j))/
     ;    timelog
        td3sum(j)=td3sum(j)+td3(tmindx,j)/xdur(tmindx)*tcncnew/(1+a)*
     ;    (1.0-(oldtcnc/tcncnew)**(1+a))
c
        a=0.0
        if(td4(tmindx,j)*td4old(j).ne.0)a=alog(td4old(j)/td4(tmindx,j))/
     ;    timelog
        td4sum(j)=td4sum(j)+td4(tmindx,j)/xdur(tmindx)*tcncnew/(1+a)*
     ;    (1.0-(oldtcnc/tcncnew)**(1+a))
c
        if(tcncnew.eq.xtexp(isttm+nexp))then
         td(tmindx,j)=tdsum(j)
         td1(tmindx,j)=td1sum(j)
         td2(tmindx,j)=td2sum(j)
         td3(tmindx,j)=td3sum(j)
         td4(tmindx,j)=td4sum(j)
        endif
 130   continue
      endif
c
      do 140 j=1,sss
       tdold(j)=td(tmindx,j)
       td1old(j)=td1(tmindx,j)
       td2old(j)=td2(tmindx,j)
       td3old(j)=td3(tmindx,j)
       td4old(j)=td4(tmindx,j)
 140  continue
c
      if(tcncnew.eq.xtexp(isttm+nexp))then
 150   do 151 j=1,sss
        td(tmindx,j)=td1(tmindx,j)+td2(tmindx,j)+td3(tmindx,j)+
     ;             td4(tmindx,j)
        tddcfsum(xitdcf(tmindx),j)=tddcfsum(xitdcf(tmindx),j)+
     ;                            td(tmindx,j)
        tddcf1sum(xitdcf(tmindx),j)=tddcf1sum(xitdcf(tmindx),j)+
     ;                             td1(tmindx,j)
        tddcf2sum(xitdcf(tmindx),j)=tddcf2sum(xitdcf(tmindx),j)+
     ;                             td2(tmindx,j)
        tddcf3sum(xitdcf(tmindx),j)=tddcf3sum(xitdcf(tmindx),j)+
     ;                             td3(tmindx,j)
        tddcf4sum(xitdcf(tmindx),j)=tddcf4sum(xitdcf(tmindx),j)+
     ;                             td4(tmindx,j)
 151   continue
      endif
c
 300  continue
      if(iplut.eq.0) go to 500
c
c implement jones pu239 retention and excretion function
c times are relative to the shot, not to the exposure
c
      if(xitdcf(tmindx).eq.1) then
        upfrac=.05
      else
        upfrac=1.e-5
      endif
c
      a1=4.75e-3
      a2=2.39e-4
      a3=8.55e-5
      a4=1.42e-5
```

```
      x1=5.58e-1
      x2=4.42e-2
      x3=3.80e-3
      x4=2.84e-5
      do 400 i=1,nplut
       if(itpm.eq.2.and.istidx.ne.0) then
        t=365.*tyrs(i)-tcncnew/24.
        if(t.lt.0.0) t=0.0
       else
        t=365.*tyrs(i)-xtexp(tmindx)/24.
        if(t.le.0.0) go to 395
       endif
c .....
c Calculate basic excretion fraction
c .....
       ft=(a1*exp(-x1*t)+a2*exp(-x2*t)+a3*exp(-x3*t)+a4*exp(-x4*t))
       exfrac(tmindx,i)=const*aactin(14)*upfrac*ft
       addnp=const*aactin(11)*2.35/(24360*365)*upfrac*ft
       if(upfrac.eq.0.05) exfrac(tmindx,i)=exfrac(tmindx,i)+2.4*addnp
       if(upfrac.eq.1.e-5) exfrac(tmindx,i)=exfrac(tmindx,i)+100.*addnp
c .....
c Adjust excretion if exposure time + duration exceeds measurement time
c .....
       if(itpm.eq.1.and.((xtexp(tmindx)+xdur(tmindx))/24.0.gt.365.*
     ;    tyrs(i))) then
        timedif=365.*tyrs(i)-xtexp(tmindx)/24.0
        exfrac(tmindx,i) = exfrac(tmindx,i)/xdur(tmindx)*timedif*24.0
       endif
c .....
c Handle integrated plutonium intake
c .....
       if(itpm.eq.2)then
        if(istidx.ne.0)then
         t=365.*tyrs(i)-oldtcnc/24.
         if(t.lt.0.0) go to 390
         ftold=(a1*exp(-x1*t)+a2*exp(-x2*t)+a3*exp(-x3*t)+a4*exp(-x4*t))
         if((tcncnew/24.0).gt.(365.0*tyrs(i))) then
          timedif=365.0*tyrs(i)-oldtcnc/24.0
         else
          timedif=tcncnew/24.0-oldtcnc/24.0
         endif
c
         a=0.0
         exfden=max(exfrac(tmindx,i),oldexf(i))
         if(exfden.le.0) go to 390
         if((exfrac(tmindx,i)*oldexf(i).ne.0).and.(abs(exfrac(tmindx,i)
     ;      -oldexf(i))/exfden.gt.0.001)) then
          a=alog((oldexf(i)/ftold)/(exfrac(tmindx,i)/ft))/timedif
          sumexf(i)=sumexf(i)+exfrac(tmindx,i)/a/xdur(tmindx)*
     ;              (exp(a*timedif)-1.0)*24.0
         else
          sumexf(i)=sumexf(i)+(exfrac(tmindx,i)+oldexf(i))/2/
     ;              xdur(tmindx)*timedif*24
         endif
 390     if(tcncnew.eq.xtexp(isttm+nexp)) then
          exfrac(tmindx,i)=sumexf(i)
          sumfrac(i)=sumfrac(i)+exfrac(tmindx,i)
         endif
        endif
        oldexf(i)=exfrac(tmindx,i)
c .....
c Handle standard plutonium intake
c .....
       else
        sumfrac(i)=sumfrac(i)+exfrac(tmindx,i)
       endif
 395   continue
```

```
 400  continue
c
 500  return
      end
```

```
      subroutine outputf
      include 'fiparms.f'
      include 'varblock.f'
c .....
      character*2 atorby(2)
      character*7 nucld1(100),nucld2(90)
      data atorby/'at','by'/
      data nucld1/'se-79','br-82','br-83','kr-83m','br-84','br-85',
     ;'kr-85','kr-85m','rb-86','kr-87','rb-87','kr-88','rb-88','kr-89',
     ;'rb-89','sr-89','rb-90','rb-90m','sr-90',' y-90','rb-91','sr-91',
     ;' y-91',' y-91m','sr-92',' y-92','sr-93',' y-93','zr-93','nb-93m',
     ;' y-94',' y-95','zr-95','nb-95',' y-96','zr-97','nb-97','nb-97m',
     ;'nb-98m','mo-99','tc-99','tc-99m','mo-101','tc-101','mo-102',
     ;'tc-102','tc-103','ru-103','rh-103m','tc-104','mo-105','tc-105',
     ;'ru-105','rh-105','rh-105m','ru-106','rh-106','pd-107','rh-109',
     ;'pd-109','ag-109m','ag-110m','ag-111','cd-113m','cd-115m',
     ;'sn-123','sb-124','sn-125','sb-125','te-125m','sn-126','sb-126',
     ;'sb-127','te-127','te-127m','sb-129','te-129','te-129m',' i-129',
     ;'sn-130','sb-130m',' i-130','sb-131','te-131','te-131m',' i-131',
     ;'xe-131m','sb-132','sb-132m','te-132',' i-132','sb-133','te-133',
     ;'te-133m',' i-133','xe-133','xe-133m','te-134',' i-134','cs-134'/
      data nucld2/
     ;'cs-134m',' i-135','xe-135','xe-135m','cs-135','cs-136','xe-137',
     ;'cs-137','ba-137m','xe-138','cs-138','cs-139','ba-139','cs-140',
     ;'ba-140','la-140','ba-141','la-141','ce-141','ba-142','la-142',
     ;'la-143','ce-143','pr-143','ce-144','pr-144','pr-144m','ce-145',
     ;'pr-145','ce-146','pr-146','ce-147','pr-147','nd-147','pm-147',
     ;'pr-148','pm-148','pm-148m','pm-149','pm-151','sm-151','eu-152',
     ;'sm-153','eu-154','eu-155','eu-156','tb-160','ho-166m',' ',' ',
     ;'be-7','na-24','mn-54','fe-55','fe-59','co-57','co-58','co-60',
     ;'cu-64','cu-67',' w-181',' w-185',' w-187',' w-188','au-198',
     ;'au-199','pb-203',' ',' ',' ','th-229','th-230','th-234',' u-233'
     ;,' u-234',' u-235',' u-237',' u-238',' u-240','np-237','np-239',
     ;'np-240','pu-238','pu-239','pu-240','pu-241','am-241','cm-242',
     ;' ',' '/
c .....
c print program results based on specified output options
c .....
      if(tmindx.le.nexp) then
       write(1,10)xtmeas(xcmeas(tmindx))
      else
       write(1,20)
      endif
      if(tmindx.gt.nexp) go to 450
  10  format(1x//10x,'time of measurement   ',1pg12.3,' hours')
  20  format(1x//10x,'total of all measurements and exposures')
c .....
c print gamma spectrum information, if specified by IOUT1
c .....
      if(iout1.eq.0) go to 50
      if(xitrm(xcmeas(tmindx)).le.3) write(1,30)
      if(xitrm(xcmeas(tmindx)).le.3) write(1,40)
     ;(i,spec(i)-sactp(i)-sactin(i),sactp(i),sactin(i),spec(i),
     ;skrxer(i),sfracc(i),i=1,ooo)
  30  format(8x,
     ;'spec(j)-relative gamma emission spectrum at time of measurement'
     ;/26x,'(gamma/hr per 10**14 fissions)'
     ;//1x,'group #  fission product  activation product    ',
     ;'actinides           total          noble gases    fractionated')
  40  format(1x,i5,1pg16.3,4g18.3,g16.3)
c .....
c if activity intake measured, indicate index radionuclide or gross activity
c .....
  50  if(xitrm(xcmeas(tmindx)).eq.6.and.xrimes(xcmeas(tmindx)).gt.0)
     ; go to 60
      if(xitrm(xcmeas(tmindx)).ge.4) write(1,90) xactmes(xcmeas(tmindx))
      go to 70
```

```
  60  irimes=ifix(xrimes(xcmeas(tmindx)))
      write(1,100) irimes,xactmes(xcmeas(tmindx))
  70  write(1,80) sf
  80  format(/8x,'sf',7x,
     ;'scaling factor(10**14 fissions [per m**2, m**3])',1pg10.3)
  90  format(//8x'actmes   measured gross activity (curies)',1pg26.3)
 100  format(//8x'actmes   measured activity of radionuclide #',i3,
     ;1pg20.3)
c .....
c print relative inventory, if specified by IOUT2
c .....
      if(iout2.eq.0.or.itpm.eq.2) go to 300
      write(1,200)(i,i=1,10)
      write(1,210)(j*10-10,(afp(i+j*10-10),i=1,10),j=1,15)
      write(1,210)(j*10-160,(aactp(i+j*10-160),i=1,10),j=16,17)
      write(1,210)(j*10-180,(aactin(i+j*10-180),i=1,10),j=18,19)
      write(1,220) acttot
 200  format(/' inventory of 150 fission products, 20 activation',
     ;' products, 20 actinides (ci/10**14 fissions)'/(10i12))
 210  format(0pi4,1p10g12.3)
 220  format(/8x,'acttot   total activity(curies/10**14 fissions)',
     ;1pg20.3)
c .....
c print isotopic organ doses, if specified by IOUT3
c .....
 300  if(iout3.eq.0.or.itpm.eq.2) go to 400
      numgroups=int(numorgans(xitdcf(tmindx))/12)
c
       if (numgroups.ge.1) then
        do 301 k=1,numgroups
         if (k.eq.1) then
          write(1,311)(orgnames(xitdcf(tmindx),(k-1)*12+j),j=1,12)
         else
          write(1,313)(orgnames(xitdcf(tmindx),(k-1)*12+j),j=1,12)
        endif
        write(1,312)(i,(osrnd(i,(k-1)*12+j),j=1,12),i=1,150)
        write(1,312)(i-150,(osrnd(i,(k-1)*12+j),j=1,12),i=151,170)
        write(1,312)(i-170,(osrnd(i,(k-1)*12+j),j=1,12),i=171,190)
 301   continue
      endif
       if (numgroups*12.eq.numorgans(xitdcf(tmindx))) goto 400
c
      if (numgroups.eq.0) then
        write(1,311)(orgnames(xitdcf(tmindx),j),
     ;              j=1,numorgans(xitdcf(tmindx)))
      else
        write(1,313)(orgnames(xitdcf(tmindx),numgroups*12+j),
     ;              j=1,(numorgans(xitdcf(tmindx))-(numgroups*12)))
       endif
c
      write(1,312)(i,(osrnd(i,numgroups*12+j),
     ;              j=1,(numorgans(xitdcf(tmindx))-(numgroups*12))),
     ;              i=1,150)
      write(1,312)(i-150,(osrnd(i,numgroups*12+j),
     ;              j=1,(numorgans(xitdcf(tmindx))-(numgroups*12))),
     ;              i=151,170)
      write(1,312)(i-170,(osrnd(i,numgroups*12+j),
     ;              j=1,(numorgans(xitdcf(tmindx))-(numgroups*12))),
     ;              i=171,190)
       goto 400
 311  format(//19x,'dose commitment in rem from each radionuclide'//
     ;' iso #',1a11,11a12)
 312  format(1x,i3,1x,1p12g12.3)
 313  format(/' iso #',1a11,11a12)
c .....
c print intermediate organ doses, if specified by IOUT4
c .....
```

```
 400  if(iout2.eq.0.and.itpm.eq.1)write(1,220)acttot
      write(1,410) atorby(1),xtexp(tmindx),xdur(tmindx)
c
 401   write(1,411)(orgnames(xitdcf(tmindx),i),td1(tmindx,i),
     ;             td2(tmindx,i),td3(tmindx,i),td4(tmindx,i),
     ;             td(tmindx,i),i=1,numorgans(xitdcf(tmindx)))
 410  format(//11x,'total dose commitments in rem for intake ',a2,
     ;' time =',1pg10.3,' hours'/
     ;11x,'with duration time =',1pg10.3,' hours'//10x,
     ;' fission products  activation products  actinides(g+b) ',
     ;'   actinides(a)       total')
 411  format(a11,2x,1pg11.3,1pg18.3,1pg19.3,1pg17.3,1pg16.3)
c .....
c print relative contribution to eff dose from radionuclide if >1%
c .....
       if (edosnum(xitdcf(tmindx)).eq.0) goto 500
 419  write(1,431)
      do 420 i=1,100
       if(osrnd(i,edosnum(xitdcf(tmindx))).gt.
     ;    td(tmindx,edosnum(xitdcf(tmindx)))/100.)
     ;  write(1,432) nucld1(i),osrnd(i,edosnum(xitdcf(tmindx))),
     ;               100.*osrnd(i,edosnum(xitdcf(tmindx)))/
     ;               td(tmindx,edosnum(xitdcf(tmindx)))
 420  continue
      do 430 i=101,190
       if(osrnd(i,edosnum(xitdcf(tmindx))).gt.
     ;    td(tmindx,edosnum(xitdcf(tmindx)))/100.)
     ;  write(1,432) nucld2(i-100),osrnd(i,edosnum(xitdcf(tmindx))),
     ;               100.*osrnd(i,edosnum(xitdcf(tmindx)))/
     ;               td(tmindx,edosnum(xitdcf(tmindx)))
 430  continue
      go to 500
 431  format(//' radionuclides contributing > 1% to effective dose',
     ;       ' equivalent'//' nuclide      rem      percent')
 432  format(1x,a7,1pg13.3,0pf7.1)
c
 450  write(1,451)
      do 460 j=1,2
       if(tddcfsum(j,numorgans(j)).gt.1e-10) then
         write(1,*) ' '
         write(1,*) ' '
         write(1,*) ' Doses from Specified DCF File'
          write(1,454) dcfidinfo(j)
         write(1,452)
         write(1,453)(orgnames(j,i),tddcf1sum(j,i),tddcf2sum(j,i),
     ;                 tddcf3sum(j,i),tddcf4sum(j,i),tddcfsum(j,i),
     ;                 i=1,numorgans(j))
       endif
 460  continue
 451  format(//11x,'total dose commitments in rem for all intakes',
     ;' by DCF set')
 452  format(/10x,
     ;' fission products  activation products  actinides(g+b) ',
     ;'   actinides(a)       total')
 453  format(a11,2x,1pg11.3,1pg18.3,1pg19.3,1pg17.3,1pg16.3)
 454  format(' DCF File Info:  ',a80)
c .....
c print plutonium excretion information, if specified
c .....
 500  if (iplut.eq.0)  go to 600
      if (tmindx.gt.nexp) then
       write(1,593)
      else
       if(xitdcf(tmindx).ne.2 .and. xitdcf(tmindx).ne.5 )
     ;  write(1,590)'inhalation',.05
       if(xitdcf(tmindx).eq.2 .or.  xitdcf(tmindx).eq.5 )
     ;  write(1,590)'ingestion ',1.0e-5
```

```
      endif
      write(1,591) (tyrs(i),i=1,nplut)
      if (tmindx.gt.nexp) then
       write(1,592) (sumfrac(i),i=1,nplut)
      else
       write(1,592) (exfrac(tmindx,i),i=1,nplut)
      endif
 590  format(/5x,'pu239 fraction in urine from ',a10,' exposure     ',
     ;'  uptake fraction=',1pe9.3)
 591  format(/' time after shot (yrs)     ',1p10g10.2)
 592  format(/' conc (ci/day) or (ci/1.4l)',1p10g10.2)
 593  format(/5x,'pu239 fraction in urine from all exposures')
c .....
c print table output file, if specified by IOUT5
c NOTE: Table output limited in versions 4.2 and later to alpha emitters
c       and gamma plus beta emitters only - no radionuclide groupings
c       or bioassay results are provided in the tables.  If such data is
c       needed, use version 4.1
c .....
 600  if(tmindx.le.nexp.or.iout5.ne.1) go to 700
      open(unit=4,file='fiidost.out',status='unknown')
c
      do 620 k=1,2
        if(tddcfsum(k,numorgans(k)).gt.1e-10) then
        write(4,690) '   alpha emitters   ',dcfidinfo(k)
        write(4,691) (orgnames(k,j),j=1,numorgans(k))
        do 613 i=1,nexp
         if(xitdcf(i).eq.k) write(4,694) xtexp(i),(td4(i,j),
     ;                                  j=1,numorgans(k))
 613    continue
        write(4,690) 'gamma+beta emitters ',dcfidinfo(k)
        write(4,691) (orgnames(k,j),j=1,numorgans(k))
        do 614 i=1,nexp
         if(xitdcf(i).eq.k) write(4,694) xtexp(i),(td(i,j)-td4(i,j),
     ;                                  j=1,numorgans(k))
 614    continue
       endif
 620  continue
c
 670  close(unit=4)
c
 680  format(23x,'FIIDOS Data Tables')
 681  format(1x,'Total dose commitments in rem for all intakes',
     ;' by DCF set and type of nuclide (with totals)')
 682  format(/11x,a12,' Doses from Inhalation and/or Ingestion')
 683  format(//5x,'Pu239 fraction in urine from all exposures')
 684  format(/' time after shot (yrs)   ',1p,50(',  ',g7.2))
 685  format(10x,'      exp tm            concentrations (ci/day)',
     ;' or (ci/1.4l)')
 686  format(15x,1pg10.4,1p,40(',',g9.2))
 687  format(13x,'   total    ',1p,40(',',g9.2))
c
 690  format(//19x,'Dose commitment in rem from ',a20,'.',
     ;       /19x,'DCF File Info:  ',a80)
 691  format(/,2x,'exp tm   ',40(', ',a10))

 694  format(1x,1pg10.4,1p,40(',',g11.3))
 695  format(1x,' total    ',1p,40(',',g11.3))
c
 700  continue
      return
      end
```

APPENDIX C

SAMPLE PROBLEMS

SAMPLE PROBLEMS

A set of six, small example problems has been devised to illustrate the utility of FIIDOS. The first four problems all address the same radiation exposure scenario, but each problem uses a different type of radiological measurement and the time of the measurement is not necessarily coincident with the time of the exposure. All of the first four scenarios use the ICRP-72 inhalation dose conversion factor table. These are nearly identical to the example problems given in the previous FIIDOS manual, with only minor changes that reflect the effect the incorporation of ORIGEN into FIIDOS has had on the results. The set thus shows the capability of FIIDOS to utilize different types of radiological measurement information. The fifth example problem is used to show the results from the same gross activity intake used in the fourth example problem, but using the ICRP-72 ingestion dose conversion factor table. The last example problem is a complete fission product, activation product, and actinide problem. It also illustrates the Pu-239 excretion calculation.

The radiation exposure scenario addressed by the first four examples involves a 15-minute inhalation exposure to deposited fallout four hours after the detonation. The weapon yield is 10 KT, all from U-235 fast neutron fission. No activation products or actinide elements are considered. The fallout is considered to be depleted of the fission gases krypton and xenon, but no other fractionation effects are considered. The specified breathing rate is 1.2 m^3/hr. The airborne activity-surface activity ratio, or resuspension factor is 10^{-5} m^{-1}. ICRP-72 inhalation dose conversion factors are used throughout.

The table below shows the radiological measurements used for each example problem.

Problem	Type of Radiological Measurement	Value	Time
One	Radiation Intensity	10.0 R/hr	H+1 Hour
Two	Airborne Activity Concentration	6.914 μCi/m^3	H+1 Hour
Three	Surface Activity Concentration	0.132 Ci/m^2	H+4 Hour
Four	Inhalation Activity Intake	0.3974 μCi	H+4 Hour

The FIIDOS computer program output for the four example problems is given in Figures C-1 through C-4. All example problems have produced the same calculated organ doses using different types of radiological measurements.

The four example problems produced the same results because the problem input data are consistent. Figure C-5 shows the FIIDOS output from the calculation that was used to develop the consistent input data for the example problem set. The calculation was performed as a multiple exposure problem with exposure times of H+l hour and H+4 hour and a measurement time of H+1 hour. The calculation was keyed to a radiation intensity above a contaminated surface of 10 R/hr at H+1 hour; the radiological measurement for Example Problem 1.

As seen in Figure C-5, at H+1 hour, the radiological contamination scaling factor, is 2.54 x 10^{14} fissions/m^2 (carried out to greater precision, actual value is 2.541 x 10^{14} fissions/m^2), and the total activity of the fallout material is 0.272 Ci/10^{14} fissions (actual value to greater precision is 0.2721 Ci/10^{14} fissions). The gross surface activity is thus 0.6914 Ci/m^2. With a resuspension factor of 10^{-5} m^{-1}, the gross airborne activity is 6.914 x 10^{-6} Ci/m^3 at H+1 hour, the radiological measurement for Example Problem 2.

As seen in Figure C-5, at H+4 hour, the radiological contamination scaling factor is 2.54 x 10^{14} fissions/m^2, and the total activity of the fallout material is 0.05214 Ci/10^{14} fissions. The gross surface activity is thus 0.13247 Ci/m^2 at H+4 hour, the radiological measurement for Example Problem 3 (though only 3 digits of precision are shown).

As given above, at H+4 hour the gross surface activity is 0.13247 Ci/m^2. With a resuspension factor of 10^{-5} m^{-1}, the gross airborne activity is 1.3247 x 10^{-6} Ci/m^3. For a 0.25-hour exposure with a breathing rate of 1.2 m^3/hr, the gross activity intake is thus 0.3974 x 10^{-6} Ci, the radiological measurement for Example Problem 4.

The input data in Example Problem 4 is convenient for illustrating the effects of assuming different pathways and using different dose conversion factors. Figure C-5 shows the output of Example Problem 5, which is identical to Example Problem 4 except that the mode of intake was changed to ingestion. Table 18 shows the committed organ doses calculated for the intake of 0.3974 μCi of fission products via ingestion or inhalation using the 11 sets of dose conversion factors that have been incorporated into the various versions of FIIDOS over the years. Currently, only ICRP-72 dose conversion factors are used.

Example Problem 6 shows a full example with all types of radionuclides present. The output is given in Figure C-7. In general, if the problem is concerned with a complete set of fission product inventories, the change in results with the current version of FIIDOS versus the original version is within a few percent. However, the amount of specific isotopes can change significantly. Thus if the problem is governed by either a specific isotope input or an isotope for dose, then more significant changes are possible.

```
                           fiidos   input
title:      FIIDOS VERSION 4.3 EXAMPLE PROBLEM ONE
------------------------------------------------------------------------------
itpm    problem type            single/integrated    1/2         1
iout1   print spectrum              no/yes           0/1         0
iout2   print inventory             no/yes           0/1         0
iout3   print dose inventory        no/yes           0/1         0
iout4   print intermediate doses    no/yes           0/1         1
iout5   print dose tables           no/yes           0/1         0

nmeas   number of measurement calculations                       1
itrm    rad measurement indices                                  1
tmeas   time of rad measurements                               1.00
rimes   rad intensity (itrm=1-3); index nuclide (itrm=6)       10.0
itmi    meas index tis/air/fb/fb-man/fb-man 1/2/3/4/5            2
actmes  activity measurement (itrm=4-6)                        0.00

nexp    number of exposure calculations                          1
texp    exposed @ h+(hr)                                       4.00
icmeas  rad exposure to measurement indices (re-sorted)          1
dur     duration (hr)                                         0.250
br      breathing rate (m**3/hr)                               1.20
kfac    resuspension factors (m**-1)                          1.000E-05
itdcf   dose conversion factor set index 1/2                     1

iactp   activation products         no/yes           0/1         0
iactin  actinides                   no/yes           0/1         0
ikrxer  noble gases removed         no/yes           0/1         1
ifrac   fractionation               no/yes           0/1         0

iplut   plutonium bioassay          no/yes           0/1         1
nplut   number of entries for plutonium bioassay                 3
tyrs    times after shot for Pu conc in urine                  50.0      55.0      60.0
```

```
                           fiidos output


  time of measurement       1.00     hours

sf       scaling factor(10**14 fissions [per m**2, m**3])  2.54

acttot   total activity(curies/10**14 fissions)          5.214E-02


   total dose commitments in rem for intake at time =  4.00     hours
   with duration time = 0.250     hours
```

	fission products	activation products	actinides(g+b)	actinides(a)	total
adrenals	1.940E-05	0.00	0.00	0.00	1.940E-05
bone surf	6.665E-05	0.00	0.00	0.00	6.665E-05
brain	1.655E-05	0.00	0.00	0.00	1.655E-05
breast	1.577E-05	0.00	0.00	0.00	1.577E-05
st wall	3.192E-04	0.00	0.00	0.00	3.192E-04
si wall	4.332E-04	0.00	0.00	0.00	4.332E-04
uli wall	1.109E-03	0.00	0.00	0.00	1.109E-03
lli wall	1.226E-03	0.00	0.00	0.00	1.226E-03
kidneys	1.897E-05	0.00	0.00	0.00	1.897E-05
liver	2.182E-05	0.00	0.00	0.00	2.182E-05
et region	3.062E-03	0.00	0.00	0.00	3.062E-03
lung	1.066E-03	0.00	0.00	0.00	1.066E-03
muscle	2.120E-05	0.00	0.00	0.00	2.120E-05
ovaries	4.477E-05	0.00	0.00	0.00	4.477E-05
pancreas	2.386E-05	0.00	0.00	0.00	2.386E-05
r marrow	5.019E-05	0.00	0.00	0.00	5.019E-05
skin	1.308E-05	0.00	0.00	0.00	1.308E-05
spleen	1.977E-05	0.00	0.00	0.00	1.977E-05
testes	1.176E-05	0.00	0.00	0.00	1.176E-05
thymus	2.342E-05	0.00	0.00	0.00	2.342E-05
thyroid	3.033E-03	0.00	0.00	0.00	3.033E-03
uterus	2.950E-05	0.00	0.00	0.00	2.950E-05
ubld wall	1.108E-04	0.00	0.00	0.00	1.108E-04
eff dose	5.270E-04	0.00	0.00	0.00	5.270E-04

Figure C-1. Example Problem 1 - Inhalation Intake Based on Radiation Intensity

radionuclides contributing > 1% to effective dose equivalent

nuclide	rem	percent
sr-91	1.861E-05	3.5
sr-92	2.052E-05	3.9
y-92	2.930E-05	5.6
y-93	4.289E-05	8.1
zr-97	6.272E-05	11.9
mo-99	1.596E-05	3.0
ru-105	5.592E-06	1.1
i-131	2.292E-05	4.3
te-132	2.524E-05	4.8
i-133	8.737E-05	16.6
i-134	1.031E-05	2.0
i-135	4.197E-05	8.0
ba-139	5.746E-06	1.1
la-141	2.730E-05	5.2
la-142	1.463E-05	2.8
ce-143	2.606E-05	4.9
ce-144	6.025E-06	1.1
pr-145	1.535E-05	2.9

pu239 fraction in urine from inhalation exposure   uptake fraction=5.000E-02

time after shot (yrs)	50.	55.	60.
conc (ci/day) or (ci/1.4l)	0.0	0.0	0.0

total of all measurements and exposures

total dose commitments in rem for all intakes by DCF set

Doses from Specified DCF File
DCF File Info: ICRP-72 Inhalation DCFs - Max dose from all particle sizes - 3-28-2006

	fission products	activation products	actinides(g+b)	actinides(a)	total
adrenals	1.940E-05	0.00	0.00	0.00	1.940E-05
bone surf	6.665E-05	0.00	0.00	0.00	6.665E-05
brain	1.655E-05	0.00	0.00	0.00	1.655E-05
breast	1.577E-05	0.00	0.00	0.00	1.577E-05
st wall	3.192E-04	0.00	0.00	0.00	3.192E-04
si wall	4.332E-04	0.00	0.00	0.00	4.332E-04
uli wall	1.109E-03	0.00	0.00	0.00	1.109E-03
lli wall	1.226E-03	0.00	0.00	0.00	1.226E-03
kidneys	1.897E-05	0.00	0.00	0.00	1.897E-05
liver	2.182E-05	0.00	0.00	0.00	2.182E-05
et region	3.062E-03	0.00	0.00	0.00	3.062E-03
lung	1.066E-03	0.00	0.00	0.00	1.066E-03
muscle	2.120E-05	0.00	0.00	0.00	2.120E-05
ovaries	4.477E-05	0.00	0.00	0.00	4.477E-05
pancreas	2.386E-05	0.00	0.00	0.00	2.386E-05
r marrow	5.019E-05	0.00	0.00	0.00	5.019E-05
skin	1.308E-05	0.00	0.00	0.00	1.308E-05
spleen	1.977E-05	0.00	0.00	0.00	1.977E-05
testes	1.176E-05	0.00	0.00	0.00	1.176E-05
thymus	2.342E-05	0.00	0.00	0.00	2.342E-05
thyroid	3.033E-03	0.00	0.00	0.00	3.033E-03
uterus	2.950E-05	0.00	0.00	0.00	2.950E-05
ubld wall	1.108E-04	0.00	0.00	0.00	1.108E-04
eff dose	5.270E-04	0.00	0.00	0.00	5.270E-04

pu239 fraction in urine from all exposures

time after shot (yrs)	50.	55.	60.
conc (ci/day) or (ci/1.4l)	0.0	0.0	0.0

end

Figure C-1. Example Problem 1 - Inhalation Intake Based on Radiation Intensity (concluded).

```
                          fiidos   input
title:      FIIDOS VERSION 4.3 EXAMPLE PROBLEM TWO
--------------------------------------------------------------------------------
itpm    problem type            single/integrated    1/2         1
iout1   print spectrum              no/yes           0/1         0
iout2   print inventory             no/yes           0/1         0
iout3   print dose inventory        no/yes           0/1         0
iout4   print intermediate doses    no/yes           0/1         1
iout5   print dose tables           no/yes           0/1         0

nmeas   number of measurement calculations                       1
itrm    rad measurement indices                                  4
tmeas   time of rad measurements                               1.00
rimes   rad intensity (itrm=1-3); index nuclide (itrm=6)       0.00
itmi    meas index tis/air/fb/fb-man/fb-man 1/2/3/4/5            0
actmes  activity measurement (itrm=4-6)                       6.914E-06

nexp    number of exposure calculations                          1
texp    exposed @ h+(hr)                                       4.00
icmeas  rad exposure to measurement indices (re-sorted)          1
dur     duration (hr)                                         0.250
br      breathing rate (m**3/hr)                               1.20
kfac    resuspension factors (m**-1)                          1.000E-05
itdcf   dose conversion factor set index 1/2                     1

iactp   activation products         no/yes           0/1         0
iactin  actinides                   no/yes           0/1         0
ikrxer  noble gases removed         no/yes           0/1         1
ifrac   fractionation               no/yes           0/1         0

iplut   plutonium bioassay          no/yes           0/1         1
nplut   number of entries for plutonium bioassay                 3
tyrs    times after shot for Pu conc in urine                  50.0      55.0      60.0


                          fiidos output


  time of measurement       1.00     hours


actmes   measured gross activity (curies)                6.914E-06

sf       scaling factor(10**14 fissions [per m**2, m**3]) 2.541E-05

acttot   total activity(curies/10**14 fissions)          5.214E-02


   total dose commitments in rem for intake at time =  4.00     hours
   with duration time = 0.250     hours
```

	fission products	activation products	actinides(g+b)	actinides(a)	total
adrenals	1.940E-10	0.00	0.00	0.00	1.940E-10
bone surf	6.665E-10	0.00	0.00	0.00	6.665E-10
brain	1.655E-10	0.00	0.00	0.00	1.655E-10
breast	1.577E-10	0.00	0.00	0.00	1.577E-10
st wall	3.192E-09	0.00	0.00	0.00	3.192E-09
si wall	4.332E-09	0.00	0.00	0.00	4.332E-09
uli wall	1.109E-08	0.00	0.00	0.00	1.109E-08
lli wall	1.226E-08	0.00	0.00	0.00	1.226E-08
kidneys	1.897E-10	0.00	0.00	0.00	1.897E-10
liver	2.182E-10	0.00	0.00	0.00	2.182E-10
et region	3.062E-08	0.00	0.00	0.00	3.062E-08
lung	1.066E-08	0.00	0.00	0.00	1.066E-08
muscle	2.120E-10	0.00	0.00	0.00	2.120E-10
ovaries	4.476E-10	0.00	0.00	0.00	4.476E-10
pancreas	2.386E-10	0.00	0.00	0.00	2.386E-10
r marrow	5.019E-10	0.00	0.00	0.00	5.019E-10
skin	1.308E-10	0.00	0.00	0.00	1.308E-10
spleen	1.977E-10	0.00	0.00	0.00	1.977E-10
testes	1.176E-10	0.00	0.00	0.00	1.176E-10
thymus	2.342E-10	0.00	0.00	0.00	2.342E-10
thyroid	3.032E-08	0.00	0.00	0.00	3.032E-08
uterus	2.950E-10	0.00	0.00	0.00	2.950E-10
ubld wall	1.108E-09	0.00	0.00	0.00	1.108E-09
eff dose	5.269E-09	0.00	0.00	0.00	5.269E-09

Figure C-2. Example Problem 2 - Intake Based on Inhalation of Airborne Activity.

radionuclides contributing > 1% to effective dose equivalent

nuclide	rem	percent
sr-91	1.861E-10	3.5
sr-92	2.052E-10	3.9
y-92	2.930E-10	5.6
y-93	4.289E-10	8.1
zr-97	6.271E-10	11.9
mo-99	1.595E-10	3.0
ru-105	5.592E-11	1.1
i-131	2.292E-10	4.3
te-132	2.524E-10	4.8
i-133	8.736E-10	16.6
i-134	1.031E-10	2.0
i-135	4.197E-10	8.0
ba-139	5.745E-11	1.1
la-141	2.729E-10	5.2
la-142	1.463E-10	2.8
ce-143	2.606E-10	4.9
ce-144	6.024E-11	1.1
pr-145	1.535E-10	2.9

pu239 fraction in urine from inhalation exposure uptake fraction=5.000E-02

time after shot (yrs)	50.	55.	60.
conc (ci/day) or (ci/1.4l)	0.0	0.0	0.0

total of all measurements and exposures

total dose commitments in rem for all intakes by DCF set

Doses from Specified DCF File
DCF File Info: ICRP-72 Inhalation DCFs - Max dose from all particle sizes - 3-28-2006

	fission products	activation products	actinides(g+b)	actinides(a)	total
adrenals	1.940E-10	0.00	0.00	0.00	1.940E-10
bone surf	6.665E-10	0.00	0.00	0.00	6.665E-10
brain	1.655E-10	0.00	0.00	0.00	1.655E-10
breast	1.577E-10	0.00	0.00	0.00	1.577E-10
st wall	3.192E-09	0.00	0.00	0.00	3.192E-09
si wall	4.332E-09	0.00	0.00	0.00	4.332E-09
uli wall	1.109E-08	0.00	0.00	0.00	1.109E-08
lli wall	1.226E-08	0.00	0.00	0.00	1.226E-08
kidneys	1.897E-10	0.00	0.00	0.00	1.897E-10
liver	2.182E-10	0.00	0.00	0.00	2.182E-10
et region	3.062E-08	0.00	0.00	0.00	3.062E-08
lung	1.066E-08	0.00	0.00	0.00	1.066E-08
muscle	2.120E-10	0.00	0.00	0.00	2.120E-10
ovaries	4.476E-10	0.00	0.00	0.00	4.476E-10
pancreas	2.386E-10	0.00	0.00	0.00	2.386E-10
r marrow	5.019E-10	0.00	0.00	0.00	5.019E-10
skin	1.308E-10	0.00	0.00	0.00	1.308E-10
spleen	1.977E-10	0.00	0.00	0.00	1.977E-10
testes	1.176E-10	0.00	0.00	0.00	1.176E-10
thymus	2.342E-10	0.00	0.00	0.00	2.342E-10
thyroid	3.032E-08	0.00	0.00	0.00	3.032E-08
uterus	2.950E-10	0.00	0.00	0.00	2.950E-10
ubld wall	1.108E-09	0.00	0.00	0.00	1.108E-09
eff dose	5.269E-09	0.00	0.00	0.00	5.269E-09

pu239 fraction in urine from all exposures

time after shot (yrs)	50.	55.	60.
conc (ci/day) or (ci/1.4l)	0.0	0.0	0.0

end

Figure C-2. Example Problem 2 - Intake Based on Inhalation of Airborne Activity (concluded).

```
                         fiidos   input
title:      FIIDOS VERSION 4.3 EXAMPLE PROBLEM THREE
----------------------------------------------------------------------------
itpm    problem type            single/integrated    1/2         1
iout1   print spectrum              no/yes           0/1         0
iout2   print inventory             no/yes           0/1         0
iout3   print dose inventory        no/yes           0/1         0
iout4   print intermediate doses    no/yes           0/1         1
iout5   print dose tables           no/yes           0/1         0

nmeas   number of measurement calculations                       1
itrm    rad measurement indices                                  5
tmeas   time of rad measurements                              4.00
rimes   rad intensity (itrm=1-3); index nuclide (itrm=6)      0.00
itmi    meas index tis/air/fb/fb-man/fb-man 1/2/3/4/5            0
actmes  activity measurement (itrm=4-6)                      0.132

nexp    number of exposure calculations                          1
texp    exposed @ h+(hr)                                      4.00
icmeas  rad exposure to measurement indices (re-sorted)          1
dur     duration (hr)                                        0.250
br      breathing rate (m**3/hr)                              1.20
kfac    resuspension factors (m**-1)                         1.000E-05
itdcf   dose conversion factor set index 1/2                     1

iactp   activation products         no/yes           0/1         0
iactin  actinides                   no/yes           0/1         0
ikrxer  noble gases removed         no/yes           0/1         1
ifrac   fractionation               no/yes           0/1         0

iplut   plutonium bioassay          no/yes           0/1         1
nplut   number of entries for plutonium bioassay                 3
tyrs    times after shot for Pu conc in urine                 50.0      55.0      60.0
```

```
                         fiidos output


  time of measurement       4.00     hours


actmes   measured gross activity (curies)                0.132

sf       scaling factor(10**14 fissions [per m**2, m**3])  2.54

acttot   total activity(curies/10**14 fissions)          5.214E-02


   total dose commitments in rem for intake at time =  4.00     hours
   with duration time = 0.250     hours
```

	fission products	activation products	actinides(g+b)	actinides(a)	total
adrenals	1.940E-05	0.00	0.00	0.00	1.940E-05
bone surf	6.665E-05	0.00	0.00	0.00	6.665E-05
brain	1.655E-05	0.00	0.00	0.00	1.655E-05
breast	1.577E-05	0.00	0.00	0.00	1.577E-05
st wall	3.192E-04	0.00	0.00	0.00	3.192E-04
si wall	4.332E-04	0.00	0.00	0.00	4.332E-04
uli wall	1.109E-03	0.00	0.00	0.00	1.109E-03
lli wall	1.226E-03	0.00	0.00	0.00	1.226E-03
kidneys	1.897E-05	0.00	0.00	0.00	1.897E-05
liver	2.182E-05	0.00	0.00	0.00	2.182E-05
et region	3.062E-03	0.00	0.00	0.00	3.062E-03
lung	1.066E-03	0.00	0.00	0.00	1.066E-03
muscle	2.120E-05	0.00	0.00	0.00	2.120E-05
ovaries	4.477E-05	0.00	0.00	0.00	4.477E-05
pancreas	2.386E-05	0.00	0.00	0.00	2.386E-05
r marrow	5.019E-05	0.00	0.00	0.00	5.019E-05
skin	1.308E-05	0.00	0.00	0.00	1.308E-05
spleen	1.977E-05	0.00	0.00	0.00	1.977E-05
testes	1.176E-05	0.00	0.00	0.00	1.176E-05
thymus	2.342E-05	0.00	0.00	0.00	2.342E-05
thyroid	3.033E-03	0.00	0.00	0.00	3.033E-03
uterus	2.950E-05	0.00	0.00	0.00	2.950E-05
ubld wall	1.108E-04	0.00	0.00	0.00	1.108E-04
eff dose	5.270E-04	0.00	0.00	0.00	5.270E-04

Figure C-3. Example Problem 3 - Intake Based on Inhalation of Resuspended Surface Activity.

```
radionuclides contributing > 1% to effective dose equivalent

 nuclide      rem      percent
 sr-91      1.861E-05    3.5
 sr-92      2.052E-05    3.9
  y-92      2.930E-05    5.6
  y-93      4.289E-05    8.1
 zr-97      6.272E-05   11.9
 mo-99      1.596E-05    3.0
 ru-105     5.592E-06    1.1
  i-131     2.292E-05    4.3
 te-132     2.524E-05    4.8
  i-133     8.737E-05   16.6
  i-134     1.031E-05    2.0
  i-135     4.197E-05    8.0
 ba-139     5.746E-06    1.1
 la-141     2.730E-05    5.2
 la-142     1.463E-05    2.8
 ce-143     2.606E-05    4.9
 ce-144     6.025E-06    1.1
 pr-145     1.535E-05    2.9

     pu239 fraction in urine from inhalation exposure       uptake fraction=5.000E-02

 time after shot (yrs)        50.       55.       60.

 conc (ci/day) or (ci/1.4l)   0.0       0.0       0.0


          total of all measurements and exposures


           total dose commitments in rem for all intakes by DCF set


  Doses from Specified DCF File
 DCF File Info:  ICRP-72 Inhalation DCFs - Max dose from all particle sizes - 3-28-2006

           fission products  activation products  actinides(g+b)    actinides(a)       total
  adrenals     1.940E-05          0.00               0.00            0.00           1.940E-05
  bone surf    6.665E-05          0.00               0.00            0.00           6.665E-05
  brain        1.655E-05          0.00               0.00            0.00           1.655E-05
  breast       1.577E-05          0.00               0.00            0.00           1.577E-05
  st wall      3.192E-04          0.00               0.00            0.00           3.192E-04
  si wall      4.332E-04          0.00               0.00            0.00           4.332E-04
  uli wall     1.109E-03          0.00               0.00            0.00           1.109E-03
  lli wall     1.226E-03          0.00               0.00            0.00           1.226E-03
  kidneys      1.897E-05          0.00               0.00            0.00           1.897E-05
  liver        2.182E-05          0.00               0.00            0.00           2.182E-05
  et region    3.062E-03          0.00               0.00            0.00           3.062E-03
  lung         1.066E-03          0.00               0.00            0.00           1.066E-03
  muscle       2.120E-05          0.00               0.00            0.00           2.120E-05
  ovaries      4.477E-05          0.00               0.00            0.00           4.477E-05
  pancreas     2.386E-05          0.00               0.00            0.00           2.386E-05
  r marrow     5.019E-05          0.00               0.00            0.00           5.019E-05
  skin         1.308E-05          0.00               0.00            0.00           1.308E-05
  spleen       1.977E-05          0.00               0.00            0.00           1.977E-05
  testes       1.176E-05          0.00               0.00            0.00           1.176E-05
  thymus       2.342E-05          0.00               0.00            0.00           2.342E-05
  thyroid      3.033E-03          0.00               0.00            0.00           3.033E-03
  uterus       2.950E-05          0.00               0.00            0.00           2.950E-05
  ubld wall    1.108E-04          0.00               0.00            0.00           1.108E-04
  eff dose     5.270E-04          0.00               0.00            0.00           5.270E-04

     pu239 fraction in urine from all exposures

 time after shot (yrs)        50.       55.       60.

 conc (ci/day) or (ci/1.4l)   0.0       0.0       0.0

 end
```

Figure C-3. Example Problem 3 - Intake Based on Inhalation of Resuspended Surface Activity (concluded).

```
                          fiidos   input
title:      FIIDOS VERSION 4.3 EXAMPLE PROBLEM FOUR
-----------------------------------------------------------------------------
itpm    problem type            single/integrated    1/2        1
iout1   print spectrum              no/yes           0/1        0
iout2   print inventory             no/yes           0/1        0
iout3   print dose inventory        no/yes           0/1        0
iout4   print intermediate doses    no/yes           0/1        1
iout5   print dose tables           no/yes           0/1        0

nmeas   number of measurement calculations                      1
itrm    rad measurement indices                                 6
tmeas   time of rad measurements                             4.00
rimes   rad intensity (itrm=1-3); index nuclide (itrm=6)     0.00
itmi    meas index tis/air/fb/fb-man/fb-man 1/2/3/4/5           0
actmes  activity measurement (itrm=4-6)                     3.974E-07

nexp    number of exposure calculations                         1
texp    exposed @ h+(hr)                                     4.00
icmeas  rad exposure to measurement indices (re-sorted)         1
dur     duration (hr)                                        1.00
br      breathing rate (m**3/hr)                             1.00
kfac    resuspension factors (m**-1)                         1.00
itdcf   dose conversion factor set index 1/2                    1

iactp   activation products         no/yes           0/1        0
iactin  actinides                   no/yes           0/1        0
ikrxer  noble gases removed         no/yes           0/1        1
ifrac   fractionation               no/yes           0/1        0

iplut   plutonium bioassay          no/yes           0/1        1
nplut   number of entries for plutonium bioassay                3
tyrs    times after shot for Pu conc in urine                50.0      55.0      60.0


                          fiidos output


  time of measurement       4.00     hours


actmes   measured gross activity (curies)                3.974E-07

sf       scaling factor(10**14 fissions [per m**2, m**3]) 7.622E-06

acttot   total activity(curies/10**14 fissions)          5.214E-02

   total dose commitments in rem for intake at time =  4.00     hours
   with duration time =  1.00     hours
```

	fission products	activation products	actinides(g+b)	actinides(a)	total
adrenals	1.940E-05	0.00	0.00	0.00	1.940E-05
bone surf	6.665E-05	0.00	0.00	0.00	6.665E-05
brain	1.655E-05	0.00	0.00	0.00	1.655E-05
breast	1.577E-05	0.00	0.00	0.00	1.577E-05
st wall	3.192E-04	0.00	0.00	0.00	3.192E-04
si wall	4.332E-04	0.00	0.00	0.00	4.332E-04
uli wall	1.109E-03	0.00	0.00	0.00	1.109E-03
lli wall	1.226E-03	0.00	0.00	0.00	1.226E-03
kidneys	1.897E-05	0.00	0.00	0.00	1.897E-05
liver	2.182E-05	0.00	0.00	0.00	2.182E-05
et region	3.062E-03	0.00	0.00	0.00	3.062E-03
lung	1.066E-03	0.00	0.00	0.00	1.066E-03
muscle	2.120E-05	0.00	0.00	0.00	2.120E-05
ovaries	4.477E-05	0.00	0.00	0.00	4.477E-05
pancreas	2.386E-05	0.00	0.00	0.00	2.386E-05
r marrow	5.019E-05	0.00	0.00	0.00	5.019E-05
skin	1.308E-05	0.00	0.00	0.00	1.308E-05
spleen	1.977E-05	0.00	0.00	0.00	1.977E-05
testes	1.176E-05	0.00	0.00	0.00	1.176E-05
thymus	2.342E-05	0.00	0.00	0.00	2.342E-05
thyroid	3.033E-03	0.00	0.00	0.00	3.033E-03
uterus	2.950E-05	0.00	0.00	0.00	2.950E-05
ubld wall	1.108E-04	0.00	0.00	0.00	1.108E-04
eff dose	5.270E-04	0.00	0.00	0.00	5.270E-04

Figure C-4. Example Problem 4 - Intake Based on Inhalation of Gross Activity.

radionuclides contributing > 1% to effective dose equivalent

nuclide	rem	percent
sr-91	1.861E-05	3.5
sr-92	2.052E-05	3.9
y-92	2.930E-05	5.6
y-93	4.289E-05	8.1
zr-97	6.272E-05	11.9
mo-99	1.596E-05	3.0
ru-105	5.592E-06	1.1
i-131	2.292E-05	4.3
te-132	2.524E-05	4.8
i-133	8.737E-05	16.6
i-134	1.031E-05	2.0
i-135	4.197E-05	8.0
ba-139	5.746E-06	1.1
la-141	2.730E-05	5.2
la-142	1.463E-05	2.8
ce-143	2.606E-05	4.9
ce-144	6.025E-06	1.1
pr-145	1.535E-05	2.9

pu239 fraction in urine from inhalation exposure   uptake fraction=5.000E-02

time after shot (yrs)	50.	55.	60.
conc (ci/day) or (ci/1.4l)	0.0	0.0	0.0

total of all measurements and exposures

total dose commitments in rem for all intakes by DCF set

Doses from Specified DCF File
DCF File Info: ICRP-72 Inhalation DCFs - Max dose from all particle sizes - 3-28-2006

	fission products	activation products	actinides(g+b)	actinides(a)	total
adrenals	1.940E-05	0.00	0.00	0.00	1.940E-05
bone surf	6.665E-05	0.00	0.00	0.00	6.665E-05
brain	1.655E-05	0.00	0.00	0.00	1.655E-05
breast	1.577E-05	0.00	0.00	0.00	1.577E-05
st wall	3.192E-04	0.00	0.00	0.00	3.192E-04
si wall	4.332E-04	0.00	0.00	0.00	4.332E-04
uli wall	1.109E-03	0.00	0.00	0.00	1.109E-03
lli wall	1.226E-03	0.00	0.00	0.00	1.226E-03
kidneys	1.897E-05	0.00	0.00	0.00	1.897E-05
liver	2.182E-05	0.00	0.00	0.00	2.182E-05
et region	3.062E-03	0.00	0.00	0.00	3.062E-03
lung	1.066E-03	0.00	0.00	0.00	1.066E-03
muscle	2.120E-05	0.00	0.00	0.00	2.120E-05
ovaries	4.477E-05	0.00	0.00	0.00	4.477E-05
pancreas	2.386E-05	0.00	0.00	0.00	2.386E-05
r marrow	5.019E-05	0.00	0.00	0.00	5.019E-05
skin	1.308E-05	0.00	0.00	0.00	1.308E-05
spleen	1.977E-05	0.00	0.00	0.00	1.977E-05
testes	1.176E-05	0.00	0.00	0.00	1.176E-05
thymus	2.342E-05	0.00	0.00	0.00	2.342E-05
thyroid	3.033E-03	0.00	0.00	0.00	3.033E-03
uterus	2.950E-05	0.00	0.00	0.00	2.950E-05
ubld wall	1.108E-04	0.00	0.00	0.00	1.108E-04
eff dose	5.270E-04	0.00	0.00	0.00	5.270E-04

pu239 fraction in urine from all exposures

time after shot (yrs)	50.	55.	60.
conc (ci/day) or (ci/1.4l)	0.0	0.0	0.0

end

Figure C-4. Example Problem 4 - Intake Based on Inhalation of Gross Activity (concluded).

```
                          fiidos   input
      title:      FIIDOS VERSION 4.3 EXAMPLE PROBLEM BASIS
      --------------------------------------------------------------------------------
      itpm    problem type           single/integrated    1/2        1
      iout1   print spectrum             no/yes           0/1        0
      iout2   print inventory            no/yes           0/1        0
      iout3   print dose inventory       no/yes           0/1        0
      iout4   print intermediate doses   no/yes           0/1        1
      iout5   print dose tables          no/yes           0/1        0

      nmeas   number of measurement calculations                      1
      itrm    rad measurement indices                                 1
      tmeas   time of rad measurements                              1.00
      rimes   rad intensity (itrm=1-3); index nuclide (itrm=6)      10.0
      itmi    meas index tis/air/fb/fb-man/fb-man 1/2/3/4/5           2
      actmes  activity measurement (itrm=4-6)                       0.00

      nexp    number of exposure calculations                         2
      texp    exposed @ h+(hr)                                      1.00      4.00
      icmeas  rad exposure to measurement indices (re-sorted)         1         1
      dur     duration (hr)                                        0.250     0.250
      br      breathing rate (m**3/hr)                              1.20      1.20
      kfac    resuspension factors (m**-1)                         1.000E-05 1.000E-05
      itdcf   dose conversion factor set index 1/2                    1         1

      iactp   activation products        no/yes           0/1        0
      iactin  actinides                  no/yes           0/1        0
      ikrxer  noble gases removed        no/yes           0/1        1
      ifrac   fractionation              no/yes           0/1        0

      iplut   plutonium bioassay         no/yes           0/1        1
      nplut   number of entries for plutonium bioassay                3
      tyrs    times after shot for Pu conc in urine                 50.0      55.0      60.0


                          fiidos output


        time of measurement       1.00     hours

      sf       scaling factor(10**14 fissions [per m**2, m**3])  2.54

      acttot   total activity(curies/10**14 fissions)          0.272


         total dose commitments in rem for intake at time =  1.00     hours
         with duration time = 0.250     hours
```

	fission products	activation products	actinides(g+b)	actinides(a)	total
adrenals	4.360E-05	0.00	0.00	0.00	4.360E-05
bone surf	1.129E-04	0.00	0.00	0.00	1.129E-04
brain	3.869E-05	0.00	0.00	0.00	3.869E-05
breast	3.454E-05	0.00	0.00	0.00	3.454E-05
st wall	9.737E-04	0.00	0.00	0.00	9.737E-04
si wall	7.640E-04	0.00	0.00	0.00	7.640E-04
uli wall	1.607E-03	0.00	0.00	0.00	1.607E-03
lli wall	1.536E-03	0.00	0.00	0.00	1.536E-03
kidneys	4.317E-05	0.00	0.00	0.00	4.317E-05
liver	4.592E-05	0.00	0.00	0.00	4.592E-05
et region	8.817E-03	0.00	0.00	0.00	8.817E-03
lung	1.648E-03	0.00	0.00	0.00	1.648E-03
muscle	4.773E-05	0.00	0.00	0.00	4.773E-05
ovaries	8.396E-05	0.00	0.00	0.00	8.396E-05
pancreas	6.603E-05	0.00	0.00	0.00	6.603E-05
r marrow	9.222E-05	0.00	0.00	0.00	9.222E-05
skin	2.965E-05	0.00	0.00	0.00	2.965E-05
spleen	5.161E-05	0.00	0.00	0.00	5.161E-05
testes	2.422E-05	0.00	0.00	0.00	2.422E-05
thymus	5.304E-05	0.00	0.00	0.00	5.304E-05
thyroid	3.066E-03	0.00	0.00	0.00	3.066E-03
uterus	6.189E-05	0.00	0.00	0.00	6.189E-05
ubld wall	1.857E-04	0.00	0.00	0.00	1.857E-04
eff dose	8.805E-04	0.00	0.00	0.00	8.805E-04

Figure C-5. Basis for Example Problem Set Input.

radionuclides contributing > 1% to effective dose equivalent

nuclide	rem	percent
sr-91	2.315E-05	2.6
sr-92	4.421E-05	5.0
y-92	1.442E-05	1.6
y-93	5.249E-05	6.0
y-94	1.583E-05	1.8
zr-97	7.093E-05	8.1
mo-99	1.647E-05	1.9
tc-101	1.087E-05	1.2
ru-105	8.887E-06	1.0
sb-131	1.284E-05	1.5
te-131	1.408E-05	1.6
i-131	1.211E-05	1.4
te-132	2.592E-05	2.9
te-133m	3.572E-05	4.1
i-133	7.165E-05	8.1
te-134	5.471E-05	6.2
i-134	4.167E-05	4.7
i-135	5.760E-05	6.5
cs-138	3.145E-05	3.6
ba-139	2.461E-05	2.8
ba-141	1.041E-05	1.2
la-141	4.065E-05	4.6
la-142	5.577E-05	6.3
ce-143	2.624E-05	3.0
pr-145	2.173E-05	2.5

pu239 fraction in urine from inhalation exposure   uptake fraction=5.000E-02

time after shot (yrs)	50.	55.	60.
conc (ci/day) or (ci/1.4l)	0.0	0.0	0.0

time of measurement   1.00   hours

sf   scaling factor(10**14 fissions [per m**2, m**3]) 2.54

acttot   total activity(curies/10**14 fissions)   5.214E-02

total dose commitments in rem for intake at time = 4.00   hours
with duration time = 0.250   hours

	fission products	activation products	actinides(g+b)	actinides(a)	total
adrenals	1.940E-05	0.00	0.00	0.00	1.940E-05
bone surf	6.665E-05	0.00	0.00	0.00	6.665E-05
brain	1.655E-05	0.00	0.00	0.00	1.655E-05
breast	1.577E-05	0.00	0.00	0.00	1.577E-05
st wall	3.192E-04	0.00	0.00	0.00	3.192E-04
si wall	4.332E-04	0.00	0.00	0.00	4.332E-04
uli wall	1.109E-03	0.00	0.00	0.00	1.109E-03
lli wall	1.226E-03	0.00	0.00	0.00	1.226E-03
kidneys	1.897E-05	0.00	0.00	0.00	1.897E-05
liver	2.182E-05	0.00	0.00	0.00	2.182E-05
et region	3.062E-03	0.00	0.00	0.00	3.062E-03
lung	1.066E-03	0.00	0.00	0.00	1.066E-03
muscle	2.120E-05	0.00	0.00	0.00	2.120E-05
ovaries	4.477E-05	0.00	0.00	0.00	4.477E-05
pancreas	2.386E-05	0.00	0.00	0.00	2.386E-05
r marrow	5.019E-05	0.00	0.00	0.00	5.019E-05
skin	1.308E-05	0.00	0.00	0.00	1.308E-05
spleen	1.977E-05	0.00	0.00	0.00	1.977E-05
testes	1.176E-05	0.00	0.00	0.00	1.176E-05
thymus	2.342E-05	0.00	0.00	0.00	2.342E-05
thyroid	3.033E-03	0.00	0.00	0.00	3.033E-03
uterus	2.950E-05	0.00	0.00	0.00	2.950E-05
ubld wall	1.108E-04	0.00	0.00	0.00	1.108E-04
eff dose	5.270E-04	0.00	0.00	0.00	5.270E-04

Figure C-5. Basis for Example Problem Set Input (continued).

radionuclides contributing > 1% to effective dose equivalent

nuclide	rem	percent
sr-91	1.861E-05	3.5
sr-92	2.052E-05	3.9
y-92	2.930E-05	5.6
y-93	4.289E-05	8.1
zr-97	6.272E-05	11.9
mo-99	1.596E-05	3.0
ru-105	5.592E-06	1.1
i-131	2.292E-05	4.3
te-132	2.524E-05	4.8
i-133	8.737E-05	16.6
i-134	1.031E-05	2.0
i-135	4.197E-05	8.0
ba-139	5.746E-06	1.1
la-141	2.730E-05	5.2
la-142	1.463E-05	2.8
ce-143	2.606E-05	4.9
ce-144	6.025E-06	1.1
pr-145	1.535E-05	2.9

pu239 fraction in urine from inhalation exposure   uptake fraction=5.000E-02

time after shot (yrs)	50.	55.	60.
conc (ci/day) or (ci/1.4l)	0.0	0.0	0.0

total of all measurements and exposures

total dose commitments in rem for all intakes by DCF set

Doses from Specified DCF File
DCF File Info: ICRP-72 Inhalation DCFs - Max dose from all particle sizes - 3-28-2006

	fission products	activation products	actinides(g+b)	actinides(a)	total
adrenals	6.300E-05	0.00	0.00	0.00	6.300E-05
bone surf	1.796E-04	0.00	0.00	0.00	1.796E-04
brain	5.524E-05	0.00	0.00	0.00	5.524E-05
breast	5.031E-05	0.00	0.00	0.00	5.031E-05
st wall	1.293E-03	0.00	0.00	0.00	1.293E-03
si wall	1.197E-03	0.00	0.00	0.00	1.197E-03
uli wall	2.716E-03	0.00	0.00	0.00	2.716E-03
lli wall	2.762E-03	0.00	0.00	0.00	2.762E-03
kidneys	6.214E-05	0.00	0.00	0.00	6.214E-05
liver	6.774E-05	0.00	0.00	0.00	6.774E-05
et region	1.188E-02	0.00	0.00	0.00	1.188E-02
lung	2.715E-03	0.00	0.00	0.00	2.715E-03
muscle	6.893E-05	0.00	0.00	0.00	6.893E-05
ovaries	1.287E-04	0.00	0.00	0.00	1.287E-04
pancreas	8.989E-05	0.00	0.00	0.00	8.989E-05
r marrow	1.424E-04	0.00	0.00	0.00	1.424E-04
skin	4.273E-05	0.00	0.00	0.00	4.273E-05
spleen	7.139E-05	0.00	0.00	0.00	7.139E-05
testes	3.599E-05	0.00	0.00	0.00	3.599E-05
thymus	7.646E-05	0.00	0.00	0.00	7.646E-05
thyroid	6.099E-03	0.00	0.00	0.00	6.099E-03
uterus	9.139E-05	0.00	0.00	0.00	9.139E-05
ubld wall	2.965E-04	0.00	0.00	0.00	2.965E-04
eff dose	1.407E-03	0.00	0.00	0.00	1.407E-03

pu239 fraction in urine from all exposures

time after shot (yrs)	50.	55.	60.
conc (ci/day) or (ci/1.4l)	0.0	0.0	0.0

end

Figure C-5. Basis for Example Problem Set Input (concluded).

```
                          fiidos   input
        title:      FIIDOS VERSION 4.3 EXAMPLE PROBLEM FIVE
        -----------------------------------------------------------------------------
        itpm    problem type            single/integrated    1/2         1
        iout1   print spectrum              no/yes           0/1         0
        iout2   print inventory             no/yes           0/1         0
        iout3   print dose inventory        no/yes           0/1         0
        iout4   print intermediate doses    no/yes           0/1         1
        iout5   print dose tables           no/yes           0/1         0

        nmeas   number of measurement calculations                       1
        itrm    rad measurement indices                                  6
        tmeas   time of rad measurements                               4.00
        rimes   rad intensity (itrm=1-3); index nuclide (itrm=6)       0.00
        itmi    meas index tis/air/fb/fb-man/fb-man 1/2/3/4/5            0
        actmes  activity measurement (itrm=4-6)                       3.974E-07

        nexp    number of exposure calculations                          1
        texp    exposed @ h+(hr)                                       4.00
        icmeas  rad exposure to measurement indices (re-sorted)          1
        dur     duration (hr)                                          1.00
        br      breathing rate (m**3/hr)                               1.00
        kfac    resuspension factors (m**-1)                           1.00
        itdcf   dose conversion factor set index 1/2                     2

        iactp   activation products         no/yes           0/1         0
        iactin  actinides                   no/yes           0/1         0
        ikrxer  noble gases removed         no/yes           0/1         1
        ifrac   fractionation               no/yes           0/1         0

        iplut   plutonium bioassay          no/yes           0/1         1
        nplut   number of entries for plutonium bioassay                 3
        tyrs    times after shot for Pu conc in urine                  50.0      55.0      60.0


                          fiidos output


          time of measurement       4.00     hours


        actmes   measured gross activity (curies)                3.974E-07

        sf       scaling factor(10**14 fissions [per m**2, m**3]) 7.622E-06

        acttot   total activity(curies/10**14 fissions)          5.214E-02


           total dose commitments in rem for intake at time =  4.00     hours
           with duration time =  1.00     hours
```

	fission products	activation products	actinides(g+b)	actinides(a)	total
adrenals	3.017E-05	0.00	0.00	0.00	3.017E-05
bone surf	6.645E-05	0.00	0.00	0.00	6.645E-05
brain	1.508E-05	0.00	0.00	0.00	1.508E-05
breast	1.618E-05	0.00	0.00	0.00	1.618E-05
st wall	1.050E-03	0.00	0.00	0.00	1.050E-03
si wall	1.227E-03	0.00	0.00	0.00	1.227E-03
uli wall	3.019E-03	0.00	0.00	0.00	3.019E-03
lli wall	3.164E-03	0.00	0.00	0.00	3.164E-03
kidneys	7.360E-05	0.00	0.00	0.00	7.360E-05
liver	6.117E-05	0.00	0.00	0.00	6.117E-05
et region	1.655E-05	0.00	0.00	0.00	1.655E-05
lung	2.007E-05	0.00	0.00	0.00	2.007E-05
muscle	2.953E-05	0.00	0.00	0.00	2.953E-05
ovaries	1.102E-04	0.00	0.00	0.00	1.102E-04
pancreas	5.406E-05	0.00	0.00	0.00	5.406E-05
r marrow	5.793E-05	0.00	0.00	0.00	5.793E-05
skin	1.813E-05	0.00	0.00	0.00	1.813E-05
spleen	4.002E-05	0.00	0.00	0.00	4.002E-05
testes	2.250E-05	0.00	0.00	0.00	2.250E-05
thymus	1.865E-05	0.00	0.00	0.00	1.865E-05
thyroid	6.294E-03	0.00	0.00	0.00	6.294E-03
uterus	6.994E-05	0.00	0.00	0.00	6.994E-05
ubld wall	2.031E-04	0.00	0.00	0.00	2.031E-04
eff dose	8.608E-04	0.00	0.00	0.00	8.608E-04

Figure C-6. Example Problem 5 - Intake Based on Ingestion of Gross Activity.

radionuclides contributing > 1% to effective dose equivalent

nuclide	rem	percent
sr-91	4.311E-05	5.0
sr-92	4.869E-05	5.7
y-92	4.997E-05	5.8
y-93	8.115E-05	9.4
zr-97	9.250E-05	10.7
i-131	4.533E-05	5.3
te-132	3.206E-05	3.7
i-133	1.777E-04	20.6
i-134	1.421E-05	1.7
i-135	8.533E-05	9.9
ba-139	1.259E-05	1.5
la-141	4.234E-05	4.9
la-142	1.774E-05	2.1
ce-143	2.651E-05	3.1
pr-145	2.330E-05	2.7

pu239 fraction in urine from ingestion exposure uptake fraction=1.000E-05

time after shot (yrs)	50.	55.	60.
conc (ci/day) or (ci/1.4l)	0.0	0.0	0.0

total of all measurements and exposures

total dose commitments in rem for all intakes by DCF set

Doses from Specified DCF File
DCF File Info: ICRP-72 Ingestion DCFs (From FGR-13) - 5-24-2001

	fission products	activation products	actinides(g+b)	actinides(a)	total
adrenals	3.017E-05	0.00	0.00	0.00	3.017E-05
bone surf	6.645E-05	0.00	0.00	0.00	6.645E-05
brain	1.508E-05	0.00	0.00	0.00	1.508E-05
breast	1.618E-05	0.00	0.00	0.00	1.618E-05
st wall	1.050E-03	0.00	0.00	0.00	1.050E-03
si wall	1.227E-03	0.00	0.00	0.00	1.227E-03
uli wall	3.019E-03	0.00	0.00	0.00	3.019E-03
lli wall	3.164E-03	0.00	0.00	0.00	3.164E-03
kidneys	7.360E-05	0.00	0.00	0.00	7.360E-05
liver	6.117E-05	0.00	0.00	0.00	6.117E-05
et region	1.655E-05	0.00	0.00	0.00	1.655E-05
lung	2.007E-05	0.00	0.00	0.00	2.007E-05
muscle	2.953E-05	0.00	0.00	0.00	2.953E-05
ovaries	1.102E-04	0.00	0.00	0.00	1.102E-04
pancreas	5.406E-05	0.00	0.00	0.00	5.406E-05
r marrow	5.793E-05	0.00	0.00	0.00	5.793E-05
skin	1.813E-05	0.00	0.00	0.00	1.813E-05
spleen	4.002E-05	0.00	0.00	0.00	4.002E-05
testes	2.250E-05	0.00	0.00	0.00	2.250E-05
thymus	1.865E-05	0.00	0.00	0.00	1.865E-05
thyroid	6.294E-03	0.00	0.00	0.00	6.294E-03
uterus	6.994E-05	0.00	0.00	0.00	6.994E-05
ubld wall	2.031E-04	0.00	0.00	0.00	2.031E-04
eff dose	8.608E-04	0.00	0.00	0.00	8.608E-04

pu239 fraction in urine from all exposures

time after shot (yrs)	50.	55.	60.
conc (ci/day) or (ci/1.4l)	0.0	0.0	0.0

end

Figure C-6. Example Problem 5 - Intake Based on Ingestion of Gross Activity (concluded).

Table C-1 Organ dose commitments calculated using different sets of dose conversion factors

Organ Dose Commitments (rem) - Example Problem 4

FIIDOS	Ingestion				Inhalation Small Particles			Inhalation Large Particles			Opt. Size
	TM-190	ICRP-30	FGR-11	ICRP-72	TM-190	ICRP-30	FGR-11	TM-190	ICRP-30	FGR-11	ICRP-72
adrenals	3.31E-5	2.92E-5	-	3.02E-5	3.71E-5	2.63E-5	-	4.53E-5	3.23E-5	-	1.94E-5
bone surf	2.89E-5	4.25E-5	2.60E-5	6.65E-5	4.78E-5	6.09E-5	4.52E-5	5.68E-5	8.48E-5	6.50E-5	6.67E-5
brain	-	-	-	1.51E-5		-	-	-	-	-	1.66E-5
breast	-	-	2.47E-5	1.62E-5	-	-	1.71E-5	-	-	2.30E-5	1.58E-5
st wall	1.03E-3	1.04E-3	-	1.05E-3	1.50E-4	1.66E-4	-	3.34E-4	4.05E-4	-	3.19E-4
si wall	1.39E-3	1.25E-3	-	1.23E-3	2.17E-4	2.22E-4	-	4.82E-4	5.30E-4	-	4.33E-4
uli wall	3.01E-3	2.95E-3	-	3.02E-3	5.58E-4	5.84E-4	-	1.29E-3	1.40E-3	-	1.11E-3
lli wall	3.06E-3	3.06E-3	-	3.16E-3	7.21E-4	7.37E-4	-	1.68E-3	1.73E-3	-	1.23E-3
kidneys	9.07E-5	6.49E-5	-	7.36E-5	4.11E-5	2.24E-5	-	6.12E-5	3.55E-5	-	1.90E-5
liver	1.08E-4	6.09E-5	-	6.12E-5	5.89E-5	3.64E-5	-	7.46E-5	5.16E-5	-	2.18E-5
et region	-	-	-	1.66E-5	-	-	-				3.06E-3
lung	4.76E-5	2.08E-5	1.57E-5	2.01E-5	2.04E-3	1.34E-3	1.52E-3	1.22E-3	2.31E-5	5.40E-4	1.07E-3
muscle	-	-	-	2.95E-5	-	-	-	-	-	-	2.12E-5
ovaries	-	-	9.71E-5	1.10E-4	-	-	2.80E-5	-	-	2.02E-5	4.48E-5
pancreas	5.41E-5	5.60E-5	-	5.41E-5	4.23E-5	2.88E-5	-	5.78E-5	4.01E-5	-	2.39E-5
r marrow	4.14E-5	4.61E-5	3.37E-5	5.79E-5	4.25E-5	4.25E-5	2.85E-5	5.64E-5	6.60E-5	4.19E-5	5.02E-5
skin	-	-	-	1.81E-5	-	-	-	-	-	-	1.31E-5
spleen	4.14E-5	4.08E-5	-	4.00E-5	3.76E-5	2.83E-5	-	5.06E-5	3.78E-5	-	1.98E-5
testes	2.40E-5	2.15E-5	9.71E-5	2.25E-5	2.06E-5	1.54E-5	2.80E-5	3.38E-5	2.69E-5	2.02E-5	1.18E-5
thymus	3.52E-5	2.12E-5	-	1.87E-5	5.32E-5	3.07E-5	-	5.32E-5	2.83E-5	-	2.34E-5
thyroid	1.25E-2	7.29E-3	7.29E-3	6.29E-3	6.34E-3	4.18E-3	4.17E-3	1.18E-2	7.51E-3	7.42E-3	3.03E-3
uterus	-	-	-	6.99E-5	-	-	-	-	-	-	2.95E-5
ubld wall	3.88E-5	3.90E-5	-	2.03E-4	1.92E-5	1.96E-5	-	3.50E-5	3.68E-5	-	1.11E-4
	-	-	-	-	-	-	-				-
bone	2.57E-5	-	-	-	5.10E-5	-	-	6.60E-5	-	-	-
res lymp	4.76E-5	-	-	-	4.07E-3	-	-	1.33E-3	-	-	-
y marrow	2.78E-5	-	-	-	2.88E-5	-	-	4.55E-5	-	-	-
remainder	-	-	1.79E-3	-	-	-	3.77E-4	-	-	8.31E-4	-
tbody	6.56E-5	-	-	-	6.27E-5	-	-	8.41E-5	-	-	-
eff dose	-	7.39E-4	7.92E-4	8.61E-4	-	4.03E-4	4.34E-4	-	4.93E-4	5.44E-4	5.27E-4

- = Not considered in dose factor set

```
                          fiidos   input
title:   RESIDENCE ISLAND - FIIDOS VERSION 4.3 EXAMPLE PROBLEM SIX
--------------------------------------------------------------------------------
itpm    problem type            single/integrated    1/2        1
iout1   print spectrum              no/yes           0/1        0
iout2   print inventory             no/yes           0/1        1
iout3   print dose inventory        no/yes           0/1        0
iout4   print intermediate doses    no/yes           0/1        1
iout5   print dose tables           no/yes           0/1        0

nmeas   number of measurement calculations                      1
itrm    rad measurement indices                                 1
tmeas   time of rad measurements                              16.0
rimes   rad intensity (itrm=1-3); index nuclide (itrm=6)      1.00
itmi    meas index tis/air/fb/fb-man/fb-man 1/2/3/4/5           2
actmes  activity measurement (itrm=4-6)                       0.00

nexp    number of exposure calculations                         1
texp    exposed @ h+(hr)                                      16.0
icmeas  rad exposure to measurement indices (re-sorted)         1
dur     duration (hr)                                         1.00
br      breathing rate (m**3/hr)                              1.20
kfac    resuspension factors (m**-1)                         6.000E-06
itdcf   dose conversion factor set index 1/2                    1

iactp   activation products         no/yes           0/1        1
iactin  actinides                   no/yes           0/1        1
ikrxer  noble gases removed         no/yes           0/1        1
ifrac   fractionation               no/yes           0/1        0

iplut   plutonium bioassay          no/yes           0/1        1
nplut   number of entries for plutonium bioassay                3
tyrs    times after shot for Pu conc in urine                 50.0      55.0      60.0


                          fiidos output


  time of measurement       16.0     hours

sf       scaling factor(10**14 fissions [per m**2, m**3])  9.91
```

inventory of 150 fission products, 20 activation products, 20 actinides (ci/10**14 fissions)

	1	2	3	4	5	6	7	8	9	10
0	1.877E-12	1.416E-07	1.364E-05	0.00	8.641E-12	0.00	0.00	0.00	3.988E-09	0.00
10	2.182E-17	0.00	9.683E-05	0.00	7.553E-21	1.281E-05	0.00	0.00	7.269E-08	2.611E-08
20	0.00	6.617E-04	9.581E-06	4.204E-04	1.341E-04	7.055E-04	0.00	8.153E-04	1.204E-12	7.725E-16
30	0.00	4.724E-29	1.710E-05	2.201E-07	0.00	8.585E-04	9.206E-04	8.147E-04	2.614E-10	3.730E-04
40	1.476E-12	2.934E-04	1.917E-21	5.058E-20	3.846E-27	3.876E-27	0.00	2.664E-05	2.659E-05	1.232E-17
50	0.00	0.00	3.285E-04	3.608E-04	9.357E-05	1.455E-06	1.455E-06	1.572E-13	0.00	1.919E-04
60	1.920E-04	1.032E-10	1.782E-05	3.540E-10	1.097E-07	1.498E-07	1.753E-08	5.651E-06	1.167E-07	7.036E-10
70	5.333E-12	8.269E-07	5.533E-05	3.153E-05	4.987E-08	1.740E-04	1.954E-04	2.804E-06	5.174E-14	0.00
80	0.00	2.850E-06	1.078E-14	2.532E-05	1.125E-04	8.147E-05	0.00	0.00	0.00	2.615E-04
90	2.805E-04	0.00	2.236E-08	9.889E-08	9.242E-04	0.00	0.00	4.052E-09	4.392E-07	1.441E-09
100	1.004E-07	7.917E-04	0.00	0.00	7.628E-13	2.737E-06	0.00	1.112E-07	1.050E-07	0.00
110	9.031E-11	1.220E-32	8.479E-06	0.00	8.245E-05	2.157E-05	1.271E-17	4.121E-04	2.995E-05	6.959E-29
120	1.157E-05	3.528E-22	4.850E-04	1.880E-05	2.962E-06	2.964E-06	4.147E-08	0.00	4.255E-04	2.409E-23
130	7.861E-14	0.00	2.837E-23	3.824E-05	1.841E-08	0.00	1.738E-10	9.906E-11	9.763E-05	8.098E-05
140	1.361E-09	7.610E-15	2.986E-05	4.795E-12	1.761E-08	1.010E-06	9.202E-11	8.733E-16	0.00	0.00
0	0.00	3.964E-04	0.00	0.00	0.00	0.00	0.00	8.272E-05	0.00	0.00
10	0.00	3.833E-06	0.00	1.024E-05	0.00	0.00	0.00	0.00	0.00	0.00
0	0.00	2.267E-20	2.618E-14	0.00	1.380E-12	4.830E-14	1.287E-05	1.379E-12	9.396E-06	7.872E-15
10	5.663E-06	9.479E-06	8.980E-10	6.897E-08	2.743E-12	8.779E-09	2.569E-14	0.00	0.00	0.00

```
acttot   total activity(curies/10**14 fissions)          1.262E-02


   total dose commitments in rem for intake at time =  16.0     hours
   with duration time =  1.00     hours
```

	fission products	activation products	actinides(g+b)	actinides(a)	total
adrenals	7.932E-05	4.985E-04	2.835E-07	4.975E-05	6.279E-04
bone surf	2.785E-04	2.377E-04	7.352E-05	2.766E-02	2.825E-02
brain	5.391E-05	6.372E-05	1.823E-07	4.975E-05	1.676E-04
breast	6.611E-05	5.598E-04	2.557E-07	4.975E-05	6.760E-04
st wall	7.048E-04	2.948E-04	1.957E-06	4.975E-05	1.051E-03

Figure C-7. Example Problem 6 - Residence Island.

si wall	1.234E-03	9.354E-05	3.648E-06	4.975E-05	1.381E-03
uli wall	3.910E-03	1.250E-04	1.368E-05	4.975E-05	4.099E-03
lli wall	5.918E-03	1.740E-04	2.535E-05	4.975E-05	6.167E-03
kidneys	7.358E-05	2.103E-04	1.521E-06	1.180E-04	4.034E-04
liver	8.503E-05	4.542E-04	1.527E-05	6.080E-03	6.635E-03
et region	9.910E-03	2.965E-03	4.353E-05	2.768E-04	1.320E-02
lung	6.363E-03	3.953E-03	6.643E-05	6.099E-04	1.099E-02
muscle	7.982E-05	2.320E-04	2.587E-07	4.975E-05	3.618E-04
ovaries	2.097E-04	6.707E-05	1.416E-06	3.686E-04	6.468E-04
pancreas	8.349E-05	3.674E-04	2.907E-07	4.975E-05	5.010E-04
r marrow	1.926E-04	2.863E-04	3.076E-06	1.364E-03	1.846E-03
skin	4.490E-05	1.328E-04	1.851E-07	4.975E-05	2.276E-04
spleen	7.138E-05	3.948E-04	2.674E-07	4.975E-05	5.162E-04
testes	4.165E-05	2.479E-05	1.028E-06	3.870E-04	4.545E-04
thymus	9.302E-05	6.317E-04	3.041E-07	4.975E-05	7.748E-04
thyroid	1.698E-02	2.340E-04	2.110E-07	4.975E-05	1.726E-02
uterus	1.187E-04	5.176E-05	3.582E-07	4.975E-05	2.206E-04
ubld wall	3.721E-04	4.377E-05	5.846E-07	4.975E-05	4.662E-04
eff dose	2.485E-03	7.332E-04	1.258E-05	9.217E-04	4.153E-03

radionuclides contributing > 1% to effective dose equivalent

nuclide	rem	percent
sr-91	4.894E-05	1.2
y-92	5.403E-05	1.3
y-93	1.314E-04	3.2
zr-97	3.174E-04	7.6
mo-99	1.281E-04	3.1
rh-105	4.288E-05	1.0
te-131m	4.158E-05	1.0
i-131	2.367E-04	5.7
te-132	2.072E-04	5.0
i-133	5.126E-04	12.3
i-135	9.619E-05	2.3
ce-143	1.409E-04	3.4
na-24	5.340E-05	1.3
co-60	6.773E-04	16.3
pu-239	9.108E-04	21.9

pu239 fraction in urine from inhalation exposure   uptake fraction=5.000E-02

time after shot (yrs)	50.	55.	60.
conc (ci/day) or (ci/1.4l)	2.08E-18	1.98E-18	1.88E-18

total of all measurements and exposures

total dose commitments in rem for all intakes by DCF set

Doses from Specified DCF File
DCF File Info: ICRP-72 Inhalation DCFs - Max dose from all particle sizes - 3-28-2006

	fission products	activation products	actinides(g+b)	actinides(a)	total
adrenals	7.932E-05	4.985E-04	2.835E-07	4.975E-05	6.279E-04
bone surf	2.785E-04	2.377E-04	7.352E-05	2.766E-02	2.825E-02
brain	5.391E-05	6.372E-05	1.823E-07	4.975E-05	1.676E-04
breast	6.611E-05	5.598E-04	2.557E-07	4.975E-05	6.760E-04
st wall	7.048E-04	2.948E-04	1.957E-06	4.975E-05	1.051E-03
si wall	1.234E-03	9.354E-05	3.648E-06	4.975E-05	1.381E-03
uli wall	3.910E-03	1.250E-04	1.368E-05	4.975E-05	4.099E-03
lli wall	5.918E-03	1.740E-04	2.535E-05	4.975E-05	6.167E-03
kidneys	7.358E-05	2.103E-04	1.521E-06	1.180E-04	4.034E-04
liver	8.503E-05	4.542E-04	1.527E-05	6.080E-03	6.635E-03
et region	9.910E-03	2.965E-03	4.353E-05	2.768E-04	1.320E-02
lung	6.363E-03	3.953E-03	6.643E-05	6.099E-04	1.099E-02
muscle	7.982E-05	2.320E-04	2.587E-07	4.975E-05	3.618E-04
ovaries	2.097E-04	6.707E-05	1.416E-06	3.686E-04	6.468E-04
pancreas	8.349E-05	3.674E-04	2.907E-07	4.975E-05	5.010E-04
r marrow	1.926E-04	2.863E-04	3.076E-06	1.364E-03	1.846E-03
skin	4.490E-05	1.328E-04	1.851E-07	4.975E-05	2.276E-04
spleen	7.138E-05	3.948E-04	2.674E-07	4.975E-05	5.162E-04
testes	4.165E-05	2.479E-05	1.028E-06	3.870E-04	4.545E-04
thymus	9.302E-05	6.317E-04	3.041E-07	4.975E-05	7.748E-04

Figure C-7. Example Problem 6 - Residence Island (continued).

```
 thyroid      1.698E-02         2.340E-04          2.110E-07        4.975E-05       1.726E-02
 uterus       1.187E-04         5.176E-05          3.582E-07        4.975E-05       2.206E-04
 ubld wall    3.721E-04         4.377E-05          5.846E-07        4.975E-05       4.662E-04
 eff dose     2.485E-03         7.332E-04          1.258E-05        9.217E-04       4.153E-03

    pu239 fraction in urine from all exposures

time after shot (yrs)        50.       55.       60.

conc (ci/day) or (ci/1.4l)  2.08E-18  1.98E-18  1.88E-18

end
```

Figure C-7. Example Problem 6 - Residence Island (concluded).

DISTRIBUTION LIST

DTRA-TR-07-11

Additional copies are available at:
http://www.dtra.mil/rd/programs/nuclear_personnel/pubs.cfm

DEPARTMENT OF DEFENSE

Defense Technical Information Center
8725 John J. Kingman Road, Suite 0944
Fort Belvoir, VA 22060-6201
ATTN: DTIC/OCA

Defense Threat Reduction Agency
8725 John J. Kingman Road, RD-NTSN
Fort Belvoir, VA 22060-6201

DEPARTMENT OF VETERANS AFFAIRS

Department of Veterans Affairs
Chief, Public Health & Environmental Hazards
VA Central Office (13)
810 Vermont Ave., NW
Washington, DC 20420

DEPARTMENT OF HEALTH AND HUMAN SERVICES

National Institute of Occupational Safety and Health
Director, Compensation Analysis and Support
Robert A. Taft Laboratories
4676 Columbia Parkway
Cincinnati, OH 45226-1998

DEPARTMENT OF LABOR

U. S. Department of Labor, DEEOIC
200 Constitution Avenue NW, Room C-3321
Washington, DC 20210

FEDERAL AGENCY ADVISORY BOARDS

Veterans' Advisory Board on Dose Reconstruction
7910 Woodmont Avenue, Suite 400
Bethesda, MD 20814-3095

Advisory Board on Radiation and Worker Health
4676 Columbia Parkway, MS: C-46
Cincinnati, OH 45226

DEPARTMENT OF DEFENSE CONTRACTORS

ITT Industries
ITT Systems Corporation
1680 Texas Street, SE
Kirtland AFB, NM 87117-5669
ATTN: DTRIAC
ATTN: DARE

L3 Communications
11410 Isaac Newton Square North, Suite 103
Reston, VA 20190-5005

SAIC
8301 Greensboro Drive, M/S E-5-5
McLean, VA 22102

SENES Oak Ridge, Inc.
102 Donner Drive
Oak Ridge, TN 37830

Oak Ridge Associated Universities
4850 Smith Road, Suite 200
Cincinnati, OH 45212

S. Cohen and Associates
6858 Old Dominion Drive, Suite 301
McLean, VA 22101