INL/EXT-09-15275

Revision 1

Radiological Safety Analysis Computer (RSAC) Program Version 7.2 Users' Manual

Bradley J. Schrader

October 2010

The INL is a U.S. Department of Energy National Laboratory
operated by Battelle Energy Alliance

INL/EXT-09-15275
Revision 1

Radiological Safety Analysis Computer (RSAC) Program Version 7.2 Users' Manual

Bradley J. Schrader

October 2010

Idaho National Laboratory
Idaho Falls, Idaho 83415

Prepared for the
U.S. Department of Energy
National Nuclear Security Administration
Office of Field Support
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

ABSTRACT

The Radiological Safety Analysis Computer (RSAC) Program Version 7.2 (RSAC-7) is the newest version of the RSAC legacy code. RSAC-7 calculates the consequences of a release of radionuclides to the atmosphere. Users generates a fission product inventory from either reactor operating history or a nuclear criticality event. RSAC-7 models the effects of high-efficiency particulate air filters or other cleanup systems and calculates the decay and ingrowth during transport through processes, facilities, and the environment. Doses are calculated for inhalation, air immersion, ground surface, ingestion, and cloud gamma pathways. RSAC-7 is used as a tool to evaluate accident conditions in emergency response scenarios, radiological sabotage events, and safety basis accident consequences.

This users' manual contains the mathematical models and operating instructions for RSAC-7. Instructions, screens, and examples are provided to guide the user through the functions provided by RSAC-7. This program is designed for users who are familiar with radiological dose assessment methods.

INTENTIONALLY BLANK

CONTENTS

FIGURES

TABLES

1. INTRODUCTION

Radioactive releases from nuclear facilities may contribute to radiation exposure through a number of pathways: external exposures by direct radiation from plumes or deposited radionuclides or internal exposures from inhalation or ingestion of radioactive material. The Radiological Safety Analysis Computer (RSAC) Program calculates the consequences of a release of radionuclides to the atmosphere. RSAC 7.2 is the current release and RSAC-7 is the version. Using a personal computer, RSAC 7 users generate a fission product inventory; calculate inventory decay and ingrowth; fractionate the inventory during transport through processes, facilities, and the environment; model the downwind dispersion of the activity; and calculate doses to downwind individuals.

A fission product inventory is calculated from reactor operating history and is used to simulate a nuclear criticality accident. Radionuclide inventories are also directly input into RSAC-7.2 if desired. Source term modeling allows for complete progeny ingrowth and decay during all accident phases. RSAC-7.2 release scenario modeling allows fractionation of the inventory by chemical group or element. RSAC-7.2 also models the effects of high-efficiency particulate air (HEPA) filters or other cleanup systems. RSAC-7's meteorological capabilities include Gaussian plume diffusion for Pasquill-Gifford, Hilsmeier-Gifford, and Markee models. RSAC-7.2 possesses the unique ability to model Class F fumigation conditions. Optionally, users supply plume standard deviations (σs) or atmospheric diffusion (χ/Qs) to the code as input data. See Appendix A

for mathematical models. RSAC-7.2 also includes corrections for deposition (wet and dry) plume rise (jet and buoyant), resuspension, and release in a room and building wake. Doses are calculated through inhalation, immersion, ground surface, and ingestion pathways, and cloud gamma dose from semi-infinite plume model and finite plume model.

RSAC-7 calculates internal dose using the dose conversion factors and methodology from both International Commission for Radiological Protection (ICRP) 26/30 and ICRP 60/68/72. In addition to the calculation of lifetime dose, RSAC-7 calculates the acute 24-hour dose from radiological sabotage events.

RSAC-7 is an excellent tool to evaluate accident conditions in emergency response scenarios and to evaluate safety basis accident conditions.

1.1 RSAC History

RSAC was originally developed and written in assembly language (MAP) for the IBM 7044/44 in 1966 by R. L. Coates and N. R. Horton[11] for support of the Advanced Test Reactor dose consequence calculations. In 1968, a FORTRAN version of the program was prepared by L. C. Richardson[29]. Since 1968, RSAC has undergone substantial revision.

In 1973, RSAC-2 was issued by D. R. Wenzel (Wenzel 1973)[38] to:

- Add input and output options
- Change the inhalation dose calculations (lung and gastro-intestinal tract)
- Change the numerical integration methods for cloud gamma dose calculations
- Change the gamma-ray buildup factor model
- Revise radionuclide yields and half-lives in the standard library
- Refine output format for ease of reading
- reduce computer memory requirements.

In 1982, RSAC-3 was issued (Wenzel 1982)[39] to:

- Add a 50-mile population dose calculation
- Use the U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.109 for ingestion dose calculations
- Use the ICRP Lung Dynamics Model for inhalation dose calculations
- Use the Dolphin and Eve Gastro-intestinal Tract Model
- Improve error detection.

After undergoing an extensive verification and validation, RSAC-4 (Wenzel 1990)[40] was enhanced and issued in 1990 to:

- Convert the program to FORTRAN 77
- Execute RSAC-4 on a personal computer
- Use internal dose conversion factors from DOE/EH-0071 and external dose-rate conversion factors from DOE/EH-0070
- Add dose summary tables
- Add an ingestion dose model for an acute release
- Increase the number of organs in the dose calculations
- Include water immersion dose calculations
- Program calculated plume rise for either jet or buoyant plume
- Revise fission yields and half-lives
- Add radionuclides to the standard library
- Update the photon data library
- Enhance error diagnostics
- Include verification and validation necessary to meet the additional requirements for software imposed by American Society of Mechanical Engineers (ASME)- Nuclear Quality Assurance (NQA)-1-2000, "Quality Assurance Requirements for Nuclear Facility Applications[2]."

In 1994, RSAC-5 (Wenzel 1994) [41]was issued to:

- Add an option to calculate cloud-gamma doses expressed in external dose equivalent
- Add a variable particle size option for inhalation dose calculations
- Resolve the over depletion for ground level releases during stable meteorology that was observed in earlier versions of RSAC
- Add a reflective meteorological model to better model diffusion below the mixing depth
- Include additional radionuclides to more accurately model the U-235 fission chain
- Add a dose summing option
- Incorporate a simplified notation for radionuclide identification
- Include a capability to read radionuclide inventories from external files

- Correct errors observed in earlier versions of RSAC for the finite-plume model integration for cloud-gamma dose calculations and large plumes
- Add meteorological diffusion using Pasquill-Gifford parameters
- Include an option to simulate the release of fission products from an operating reactor
- Update forage and vegetation yields
- Include an option to read ingestion transfer parameters from an external file
- Refine the model for ingestion dose calculations from an acute release.

After major modifications, RSAC-6 was released in 2001 to:

- Add radionuclides to the program library
- Use internal dose conversion factors from Federal Guidance Report (FGR)-11 and external dose-rate conversion factors from FGR-12
- Calculate doses at distances of less than 100 meters
- Correct minor errors identified in the program
- Printout radionuclides in a logical order
- Add default lung clearance classes to provide the maximum dose based on each element
- Allow entry of radionuclide input in either upper or lower case characters
- Eliminate a discontinuity in the leakage function
- Add an option to allow the user to enter a respirable fraction for inhalation dose calculations
- Add an option to allow the user to enter an occupancy factor for ground surface dose calculations
- Incorporate editorial changes in program output
- Enhance the method to estimate the building wake effect
- Evaluate the instantaneous release to a room
- Evaluate the resuspension of particulate activity
- Enhance the method for evaluation of dry deposition
- Perform calculation of an effective σ_y and σ_z when χ/Q is directly input.

RSAC-7.2 is the current release of of RSAC-7 and was released in 2010. This revision of RSAC:

- Added internal dose conversion factors from ICRP 68 and 72
- Added acute dose conversion factors for a 24-hour exposure from a sabotage event
- Corrected minor errors in the printing and display features
- Added the capability to perform joint frequency meteorological conditions to calculate both 50% and 95% metrological conditions for input into RSAC
- Established an internal validation process to assure proper verification of installation parameters
- Established 20 new examples for execution of the enhanced capabilities of RSAC-7
- Added input units of curies, grams, and Becquerel to the direct input model.

1.2 Summary of RSAC-7.2 Capabilities

RSAC-7.2 consists of nine subroutines. Each subroutine performs a type of calculation and operates together with or independently of the others, depending on the analysis being performed. Historically, these subroutines have been referred to as a series. For consistency with earlier versions, this nomenclature has been retained. Both the series number and the subroutine function are indentified. These series are identified by input series lines in multiples of 1000. A summary of each of the program series follows.

1.2.1 1000 Series – Fission Product Calculation and Inventory Decay

RSAC-7.2 allows the user to establish an inventory of fission products (and subsequent decay products) by simulating the operation of a thermal reactor. The user can simulate steady-state, transient, or cyclic reactor operation. A refueling option is also available. After establishing the reactor operating history, the user can then specify the fractional release of the radionuclide inventory by individual element, by groups of elements (solids, halogens, noble gases, cesium, or ruthenium), or by a single release fraction for the entire inventory.

RSAC-7.2 calculates inventories for fission products only. The nuclear data library (see Appendix B

) contains selected activation products, actinides, and the daughters of actinides in addition to the fission products. Inventories for activation products and actinides are not calculated by RSAC-7; however, they can be added to the inventory by using the radionuclide direct input section of the program. Subsequent sections of the program calculate the radioactive decay and doses from these additional radionuclides.

The model used by RSAC-7.2 to calculate fission product inventories is simple compared to the model used in the Oak Ridge isotope generation 2 (ORIGEN2) program (Croff 1980[13], RSICC 1991[31]). RSAC-7.2 is simple to run and requires less computer time than ORIGEN2. In general, the RSAC-7.2 model calculates fission product inventories well. However, it does not calculate inventories for activation products or actinides. While the RSAC-7.2 model corrects for depletions of fission products by neutron activation, it does not calculate all of the subsequent radionuclides that are produced by the neutron activation of fission products. When irradiation times are long, the burnup is relatively high, or the enrichment of the fuel is low, inventories of radionuclides produced primarily by the activation of fission products (Cs-134, Pm-147, Sm-151, Eu-154, and Eu-155) can differ from ORIGEN2-calculated inventories by more than 20%. When doses from these radionuclides are significant compared to the other fission products, users should use a more sophisticated computer program such as ORIGEN2 and import the final inventory using the 2000 Series direct radionuclide input option. RSAC-7.2 can then be used to calculate inventory decay and simulate additional reactor operation or fuel handling accidents such as a criticality.

The 1000 Series of RSAC-7.2 can be reentered as many times as desired to modify the radionuclide inventory. One of the options in this series is to fractionate the radionuclide inventory and to simulate removal of activity by cleanup systems such as HEPA filters. The inventory can be fractionated for a chemical group, element, or the entire inventory.

1.2.2 2000 Series – Direct Radionuclide Input

This series allows users to input a radionuclide inventory from an external file or to directly input the amounts of radionuclides to be used in subsequent calculations. The direct radionuclide input option should be used to add activation products and other radionuclides not generated by the 1000 series source term generation function.

1.2.3 3000 Series – Dose Summary Option

This series allows doses from different exposure pathways and multiple RSAC-7.2 calculations within the same input run to be summarized, added, and reported in summary tables. This option has strict operating guidelines (see Section 4.1, *Dose Summary Option Control Line [3000]*).

1.2.4 5000 Series – Meteorological Data Input

This series allows the user to specify meteorological conditions at the time of release and to calculate diffusion, dispersion, and depletion factors.

This input series of RSAC-7.2 must normally be entered before any dose calculations are requested. After establishing basic meteorological parameters (such as stack height, wind velocity, and mixing layer depth), the user specifies points of interest for dose calculations at downwind and/or crosswind positions.

RSAC-7.2 models the release of radioactivity from containment structures using exponential functions (see Appendix A

). Instantaneous and continuous releases are modeled using a single exponential function. Complex release scenarios can be modeled using a series of up to 10 exponential functions. These functions calculate the radionuclide inventory decay while it is held up by the containment structure before it is released.

Atmospheric diffusion parameters can be input directly by the user or calculated by RSAC-7. RSAC-7.2 calculates plume standard deviations (σs) developed for three different conditions. Hilsmeier-Gifford σs (Clawson et al. 1989[10]) were developed for desert terrains and releases from a few to 15 minutes. Markee σs (Clawson et al. 1989[10]) were also developed for a desert terrain; however, they were developed for releases from 15 to 60 minutes in duration. Pasquill-Gifford σs are presented in Nuclear Regulatory Commission (NRC) Regulatory Guide 1.145 (NRC 1982)[26] and by Slade (1968)[34] from the Prairie Grass experiments for effluent releases with durations of 10 to 60 minutes.

Other meteorological options available in RSAC-7.2 are corrections for plume rise using models by Briggs (1969),[7] building wake corrections (Ramsdell, 1997),[28] and plume depletion using modeling of Markee (1967)[23] and Chamberlain (1953).[8]

1.2.5 6000 Series – Radionuclide Inventory Decay for Printout

This series allows the user to calculate the radioactive decay of the entire radionuclide inventory or of selected radionuclides for printout. Decay of the radionuclide inventory for subsequent dose calculations is not done in this series, but in the 1000 Series. If downwind distances have been previously specified in the meteorological section of the program (5000 Series), decay times are calculated for each downwind position. Alternately, the user can directly specify decay times in this series. Radionuclide inventory printout options are then available. Inventories for activation products and actinides are printed only when 2000 Series input has been used to enter these radionuclides.

1.2.6 7000 Series – Internal/External Dose Calculations

This series allows the user to perform a variety of dose calculations. The radionuclide source term for these calculations is the radionuclide inventory created and operated on in the 1000 and 2000 Series. An internal dose can be calculated for up to 23 organs in addition to the committed effective dose equivalent (CEDE) for the inhalation or ingestion pathways. Internal doses are calculated using dose conversion factors from Federal Guidance Report No. 11 (Eckerman 1988)[16]. Ingestion doses from a chronic release are calculated using models described in NRC Regulatory Guide 1.109 (NRC 1977a)[24]. Because of the lack of a consensus model, equations for calculating ingestion doses from an acute release have been developed specifically for RSAC-7. Standard ingestion constants are provided in the program; however, the user can alter any of the constants. External dose can also be calculated for up to 23 organs in addition to the external effective dose equivalent (EDE) for the ground surface and for air immersion pathways. The air immersion model should be used with caution to ensure that the plume has diffused to the ground level and that the plume size is large compared to the mean free path of the gamma rays. Otherwise, using the air immersion model can result in significant error in the dose calculation. External doses are calculated using dose-rate conversion factors from Federal Guidance Report No. 12 (Eckerman 1993).[15] External exposure from a release to a room and internal exposure from resuspension are also available.

1.2.7 9000 Series – Cloud Gamma Dose Calculation

RSAC-7.2 calculates cloud gamma doses (in addition to the air immersion model provided in the 7000 Series input) using either a finite plume model or a semi-infinite cloud gamma model. The finite plume model is accurate for any plume size, location, or release point. However, compared to the air immersion or semi-infinite models, it requires longer computer time to perform calculations. When the plume has diffused to ground level and is large compared to the mean free path of the gamma rays, both the semi-infinite and the air immersion models give accurate results. However, as noted in the 7000 Series discussion in this section, significant errors can result when the proper conditions for these simplified models do not exist. Whenever in doubt, the user should use the finite plume cloud gamma model. By comparing the results of the finite plume model with the semi-infinite plume model, users can establish when the simplified models can be used.

2. RSAC-7.2 Software Management

The purpose of RSAC 7 software management is to outline and explain the management of the RSAC-7.2 software project. RSAC-7.2 is the newest version of the RSAC legacy program. It was developed by modifying RSAC-7.1; however, as a result of major modifications to the program, RSAC-7.2 is considered a new software project and not a maintenance upgrade of RSAC-7.1. Therefore, the existing software management plan (SMP) for Version 6.2 was left unchanged, and a new SMP for Version 7 was developed.

The modifications that was made to RSAC-7.2, along with other added capabilities, is described in more detail in the technical and functional requirements document. The purpose was to create RSAC-7.2 with sufficient quality so that it could confidently be released on an international scale to NQA-1-2000, “Quality Assurance Requirements for Nuclear Facility Applications,” Subpart 2.7, “Quality Assurance Requirements for Computer Software for Nuclear Facility Applications.[2]” In addition to the requirements of NQA-1-2000, NQA-1-2008 “Quality Assurance Requirements for Nuclear Facility Applications,” Subpart 2.7, “Quality Assurance Requirements for Computer Software for Nuclear Facility Applications,[27]” was also used as a basis for establishing software requirements. Where a difference existed between the documents, the most conservative process or method was selected.

The SMP for version 7 applies to all point releases. As in 7.0.x, 7.2.x, 7.4.x, 7.6.x etc. The released versions are controlled as even point releases. During the testing phase the versions are controlled as odd point releases. All releases of RSAC-7 are required to follow this SMP and the other implementing documents of this plan.

This chapter provides the software management (SM) and software quality assurance (SQA) requirements of DOE O 414.1C, Quality Assurance, dated 6-17-05, for RSAC-7. This chapter supplements the quality assurance program (QAP) requirements of Title 10 Code of Federal Regulations (CFR) 830, Subpart A, Quality Assurance, for DOE nuclear facilities and activities. The SQA requirements for DOE, including the National Nuclear Security Administration (NNSA), and its contractors are necessary to implement effective quality assurance (QA) processes and achieve safe nuclear facility operations.

DOE promulgated the software requirements and this guidance to control or eliminate the hazards and associated vulnerability posed by security software. Software failures or unintended output can lead to unexpected program failures and undue risks to the DOE/NNSA mission, the environment, the public, and the workers. This standard includes software application practices covered by appropriate national and international consensus standards and various processes currently in use at DOE facilities. This guidance is considered to be of sufficient rigor and depth to ensure acceptable reliability of safety software at DOE/NNSA facilities.

This chapter should be used by organizations to help determine and support the steps necessary to address possible design or functional implementation deficiencies that might exist and to reduce operational hazards-related risks to an acceptable level. Attributes such as the facility life-cycle stage and the hazardous nature of each facility’s operations should be considered when using this standard. Alternative methods to those described in this standard may be used provided they result in compliance with applicable requirements. Another objective of this guidance is to encourage robust software quality methods to enable the development of high quality applications. This section describes the installation procedures for loading RSAC-7.2 onto a personal computer. The minimum hardware and software requirements are listed.

This section also identifies the point-of-contact for questions about the program and a summary of quality assurance activities conducted to ensure the integrity of RSAC.

2.1 Hardware and Software Requirements

RSAC-7.2 runs on an personal computer or compatible computer running Windows XP, Vista, and Windows 7. Although the code does run on earlier versions of Windows operating systems, it has not been validated on those earlier versions of Windows. The computational program is written in FORTRAN, and the user interface is written in VisualBasic.

2.2 Loading Instructions and Validation of Installation

Place the RSAC-7.2 CD in the CD reader. Double click on "My Computer." Double click on the drive letter for your CD reader. Double click on "Setup" and answer the questions. You will be requested to have a key to install the software. A readme file is included with the software that can assist with installation if necessary. Once the program has been installed and opened, a screen will open that requires a response (see Figure 2-1).

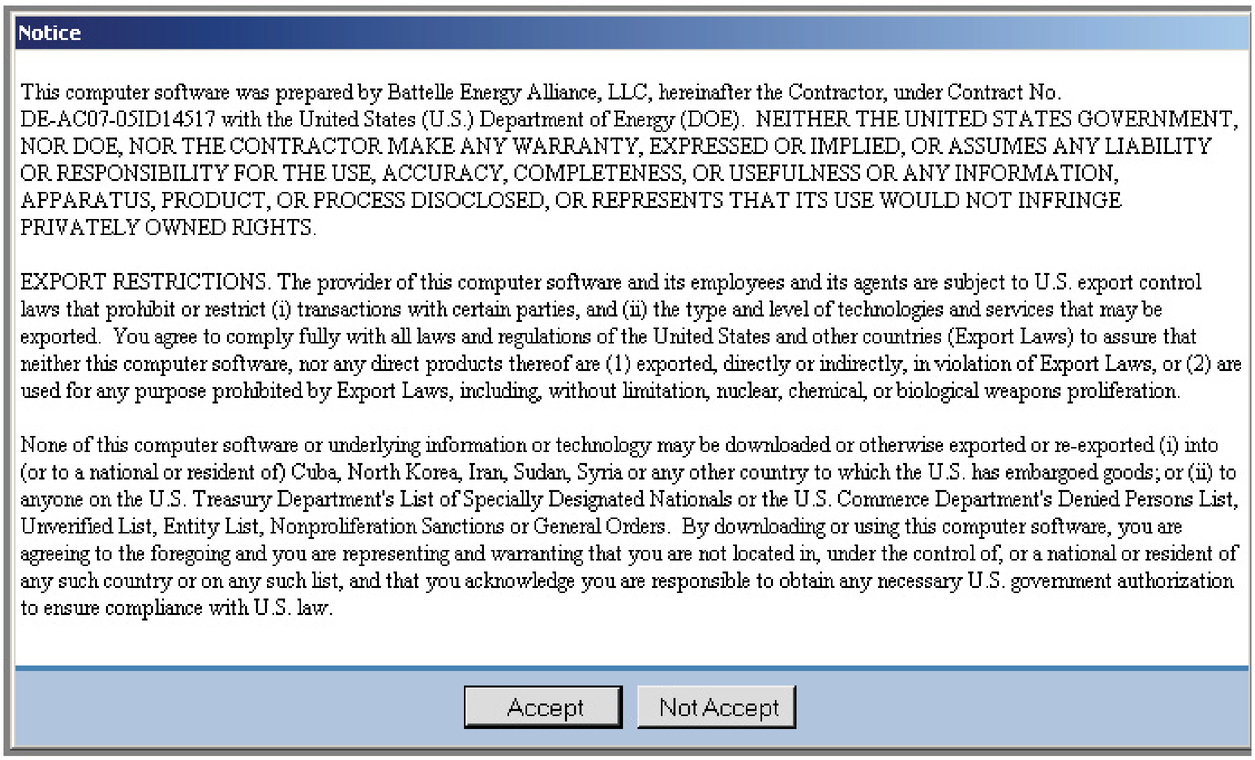


Figure 2-1. Installation screen acceptance notice.

The terms of the license must be accepted each time the software is opened in order to continue with use of the software. The next step validates the installation by clicking on the RSAC QC selection under the help menu. Once the selection is made, acceptance of the verification is required (see Figure 2-2).

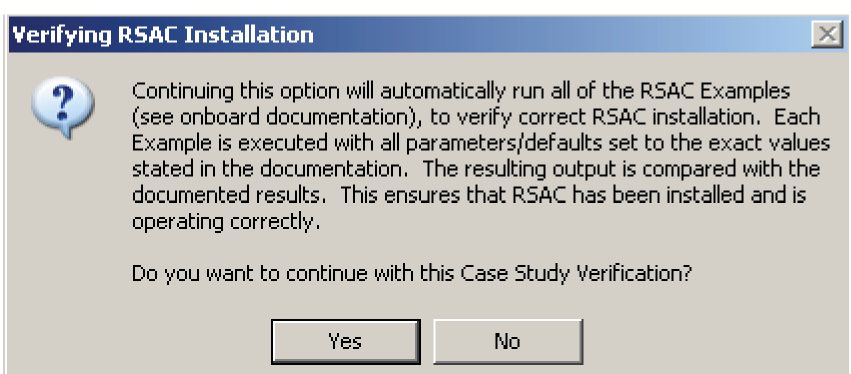


Figure 2-2. Verifying RSAC installation view.

If yes is selected, the installation validation will continue, and all 20 examples are excuted and compared against the verified and validated results. If Figure 2-3appears, the installation was successfully verified. This QC check should be performed each time a change is made to the operating system. This assures that the change has not affected the RSAC execution capabilities.

If no is selected then the installation will abort and the user is returned to the main screen.

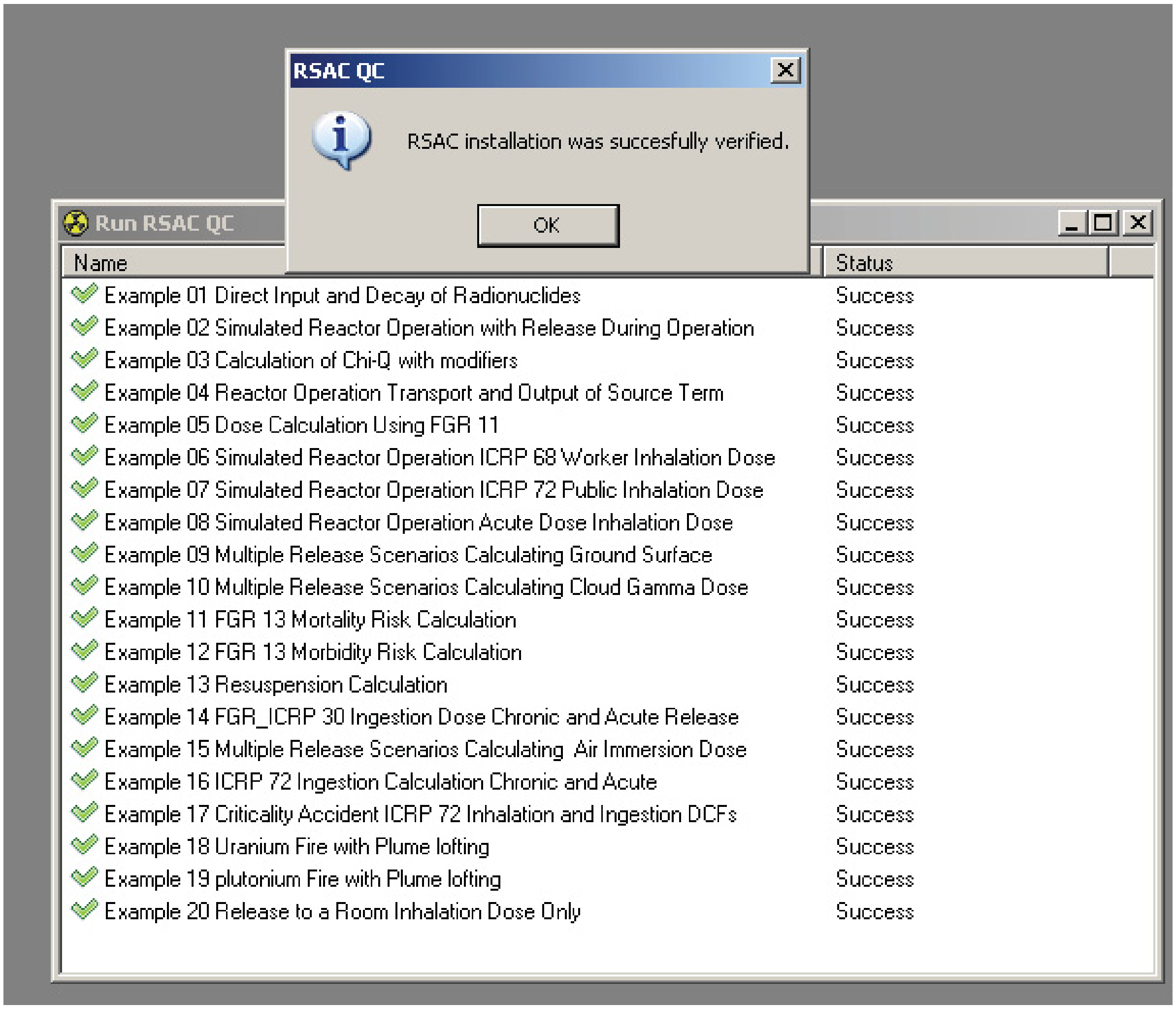


Figure 2-3. Successful verification screen display.

If the screen shown in Figure 2-3 does not display, an error screen will display with a request that the user no longer use the software and to notify the RSAC program point of contact of the problem through the bug reporting system.

2.3 Point-of-Contact and Issues Reporting

A method to report bugs, provide suggestions, and look for program updates has been imbedded in the Help menu of RSAC-7.2. . Click on the Help menu and select website from the drop down menu to be directly linked to the Idaho National Laboratory RSAC website. The RSAC website has links to report bugs, provide suggestions, look up product information, and obtain downloads for program updates and manuals.

To obtain a copy of RSAC-7.2 or to resolve problems encountered when running RSAC-7.2, contact:

Dr. Bradley .J. Schrader P.E., CHP

Idaho National Laboratory

P.O. Box 1625

Idaho Falls, ID 83415-3214

(208) 526-0912

email: Bradley.Schrader@inl.gov

2.4 Software Management and Quality Assurance

The scope of the Department of Energy Quality Assurance (QA) Rule, 10 CFR 830 Subpart A, is stated as “This subpart establishes quality assurance requirements for contractors conducting activities, including providing items or services, that affect, or may affect, nuclear safety of DOE nuclear facilities.” The scope of the QA Rule encompasses the contractor’s conduct of activities as they relate to software (items or services). Therefore, the RSAC software application for nuclear safety, safeguards and security, and emergency preparedness are within its scope. DOE O 414.1C establishes the Software Quality Assurance (SQA) requirements to be implemented under the Rule for RSAC.

DOE O 414.1C requires that an appropriate level of quality infrastructure be established and a commitment made to maintain this infrastructure for the software. The RSAC SQA program establishes the appropriate software life-cycle practices, including design concepts, to ensure that the software functions reliably and performs correctly the intended work specified for that software. The RSAC SQA program is fully documented and available for review from the RSAC program point of contact. The software management program has 10 software quality work activities that ensure that the safety software performs its intended functions. The RSAC SQA plan documents the implementation strategies and appropriate standards for these 10 activities, which are:

1. Software project management and quality planning.
2. Software risk management.
3. Software configuration management (SCM).
4. Procurement and supplier management.
5. Software requirements identification and management.
6. Software design and implementation.
7. Software security.
8. Verification and validation (V&V).
9. Problem reporting and corrective action.
10. Training of personnel in the design, development, use, and evaluation of security software.

RSAC nuclear safety software is controlled in a traceable, planned, and orderly manner. The software quality work activities defined in this section provide the basis for planning, implementing, maintaining, and operating safety software.

2.4.1 Configuration Control

Configuration control is maintained by issuing copies of RSAC-7.2 with a unique serial number. Only binary copies of RSAC-7.2 and its libraries are issued to users to prevent user changes to the program that would invalidate the extensive V&V.

2.4.2 Verification and Validation

RSAC-7.2 has been subjected to extensive independent V&V for use in performing safety-related dose calculations to support safety analysis reports and emergency response conditions (INEEL 2001).[21] RSAC V&V files are contained in seven volumes in excess of 10,000 pages. The files are maintained by the Idaho National Laboratory (INL) and are available for review. The INL maintains a Software Management Plan and a Software Quality Assurance Plan per DOE recommendations.

2.4.3 Restrictions or Limitations

The RSAC is based on the Gaussian model of dispersion. As such, RSAC is best suited for specific types of conditions, which should be considered before applying RSAC. The conditions are:

- **Plume Duration** – RSAC is best suited for “short” duration plumes, ranging from approximately several minutes to several days. It should be understood that plume meander has a significant effect on releases longer than an hour. Meteorological conditions change and will cause plume variations from that approximated using the Gaussian model.
- **Source Distance** – RSAC does not model dispersion close to the source (less than 100 meters from the source), especially where the influence of structures or other obstacles is still significant. Although the selection of distances inside of 100 meters can be performed, the results should be understood as only a conservative approximation. Dispersion influenced by several, collocated facilities, within several hundred meters of each other should be modeled with care. Similarly, RSAC should be applied with caution at distances greater than 10 to 15 miles, especially if meteorological conditions are likely to be different from those at the source of the release. Long-range projections of dose conditions are better calculated with mesoscale, regional models that are able to account for multiple weather observations. Nevertheless, some applications may require 50-mile or greater radius analysis to meet requirements, e.g., Environmental Impact Statements (EISs) or Probabilistic Safety Assessments (PSAs).
- **Terrain** – Gaussian models are inherently flat-earth models, and perform best over regions of transport where there is minimal variation in terrain. Because of this, there is inherent conservatism (and simplicity) if the environs have significant nearby buildings, tall vegetation, or grade variations not taken into account in the dispersion parameterization.
- **Momentum** – RSAC does not account for momentum-driven releases from detonation type events.
- **Briggs Algorithm** – In plumes arising from fire-related source terms, the user should exercise caution with the models that use the Briggs algorithm, such as RSAC. The Briggs approach for accounting for sensible energy in a plume is valid for “open-field” releases (not impacted by buildings and other obstacles), or if used in combination with building wake effects.
- **Dose Conversion**– The user should ensure that the dose conversion factors used in RSAC are applicable to the radionuclides in the source term and the physicochemical characteristics. For example, plutonium nitrates and oxides have different time scales for dosimetric effects in the body. Thus, the appropriate lung absorption type should be used in the dose conversion factor file used in the RSAC run. In all cases RSAC will default to the lung absorption type that results in the highest dose.

INTENTIONALLY BLANK

3. EXECUTING RSAC-7

RSAC-7.2 can be executed directly using a user-supplied ASCII input file or the windows graphical user interface can be used to build input files. For those familiar with RSAC inputs and a DOS-based environment, the same input-output techniques used since RSAC-2 (1973)[38] can be applied and is not discussed here. Further information on this command line process can be found in the user manuals of all earlier versions. However for a complete description of the command line inputs for RSAC-7.2 see chapter 4.

3.1 Using RSAC 7

As previously discussed in section 2.2, the software installation should be validated upon installation and when any changes are made to the computer/operating system that may affect the accurate execution of RSAC.

3.1.1 Main Window

The RSAC main window (see Figure 3-1) provides access to all of the programs tools and features.

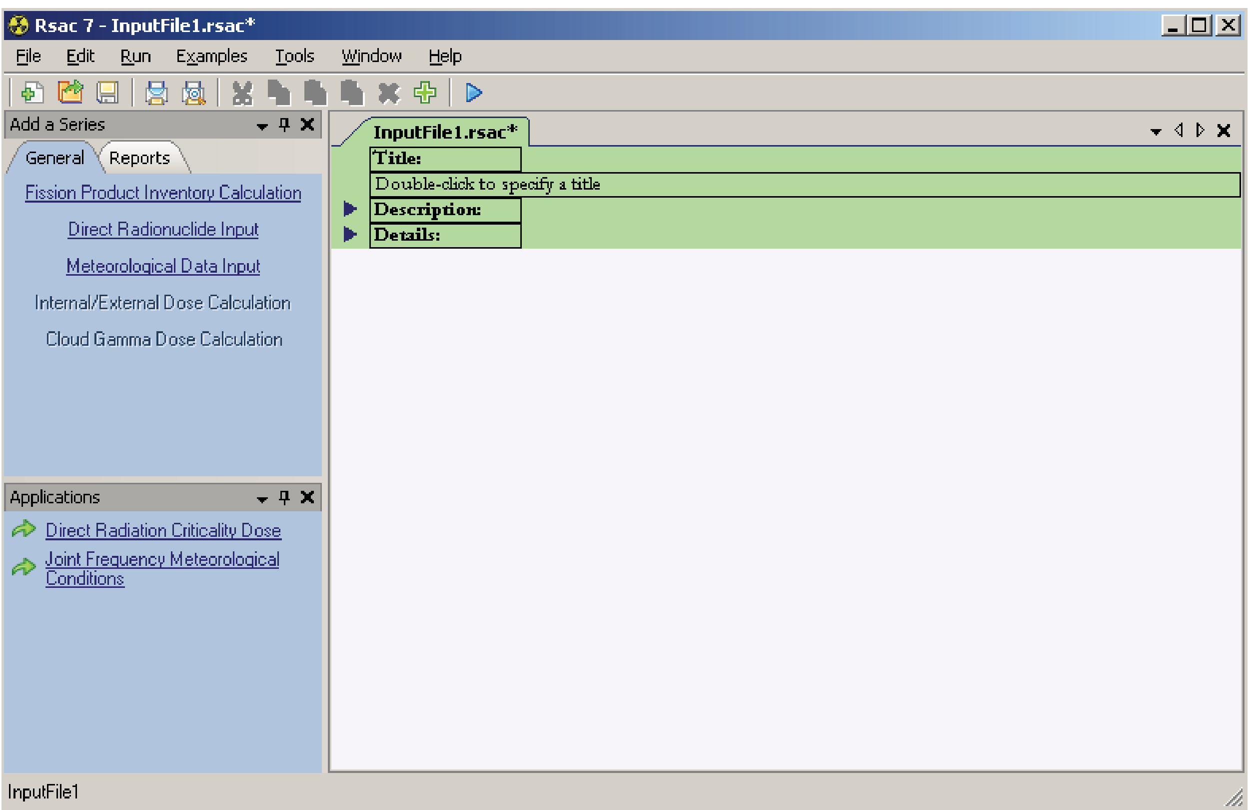


Figure 3-1. RSAC main window.

Some of the most commonly used components are shown in Figure 3-2.

Figure 3-2. Toolbar display.

The toolbar provides shortcuts for:

- Opening files
- Printing
- Using the cut, copy, paste, insert, and delete series
- Running the currently open file with RSAC.

The Add a Series menu (see Figure 3-3) allows selecting a series to add to the open file. It works similar to a tab control. Click on General to add a series or Reports to generate a report.

Note: Some series may be disabled until its prerequisites are met.

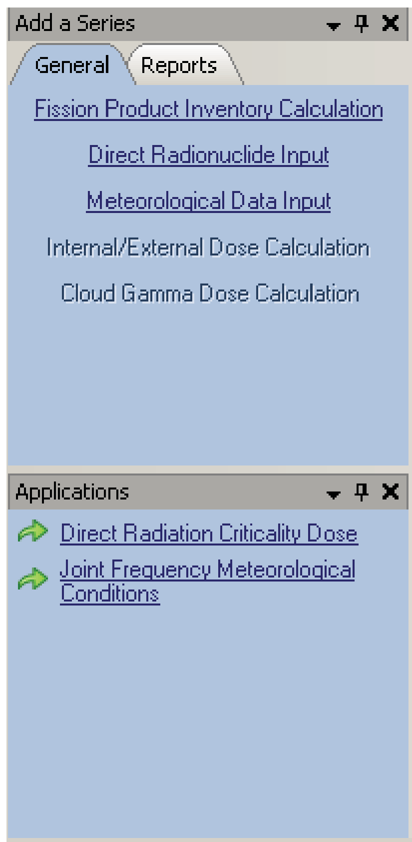


Figure 3-3. Add a Series menu display.

The file summary (see Figure 3-4) displays the following:

- Quick view of what series are in the file
- Cut, Copy, Paste, Insert, and Delete series
- The option to open a series in edit mode

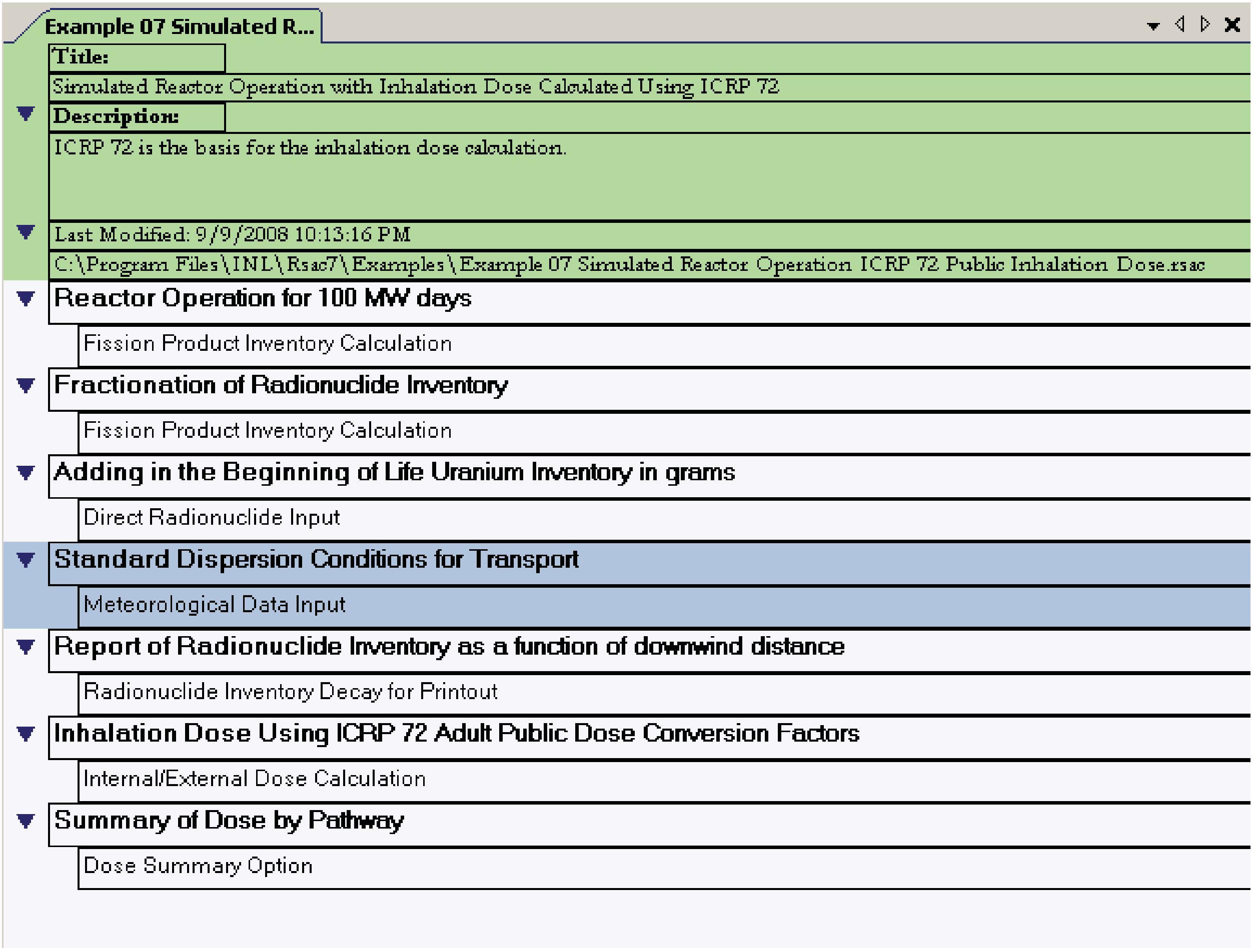


Figure 3-4. File summary display.

The file information (see Figure 3-5) located at the bottom of the screen shows the full path of the currently open file and the date and time it was last modified.

Figure 3-5. File information display.

3.1.2 Other Tools and Features

Other tools and features that are accessible under the drop-down menu at the top of the window are:

- **Create Text File -** Creates a text file from the currently open file
- **Edit Text and ASCII Files -** Opens the selected file in Notepad for editing
- **Browse File -** Browse the currently open file in text format
- **Run Batch -** Allows running a batch of mixed file types with RSAC
- **Run History -** Views history database of all files run with RSAC
- **View Existing -** Opens existing run output files for viewing

- **Options** - Controls user settings for WinRp
- **Website** - Opens the RSAC website in Internet Explorer
- **RSAC Manual** - Opens the RSAC pdf manual, Adobe Acrobat Reader is required.

3.1.3 Options

Certain features of WinRp can be controlled in the options dialog (see Figure 3-6). To open the Options Dialog, click the Tools menu then click Options.

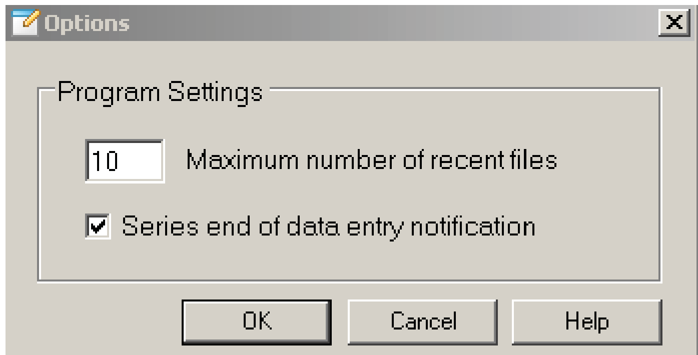


Figure 3-6. Options Dialog display.

3.1.4 Series Main Window

The series main window (See Figure 3-7) provides a summary of all data that have been entered for the current series. Data can be reviewed then saved, edited, or discarded using the buttons on the lower right corner of the window.

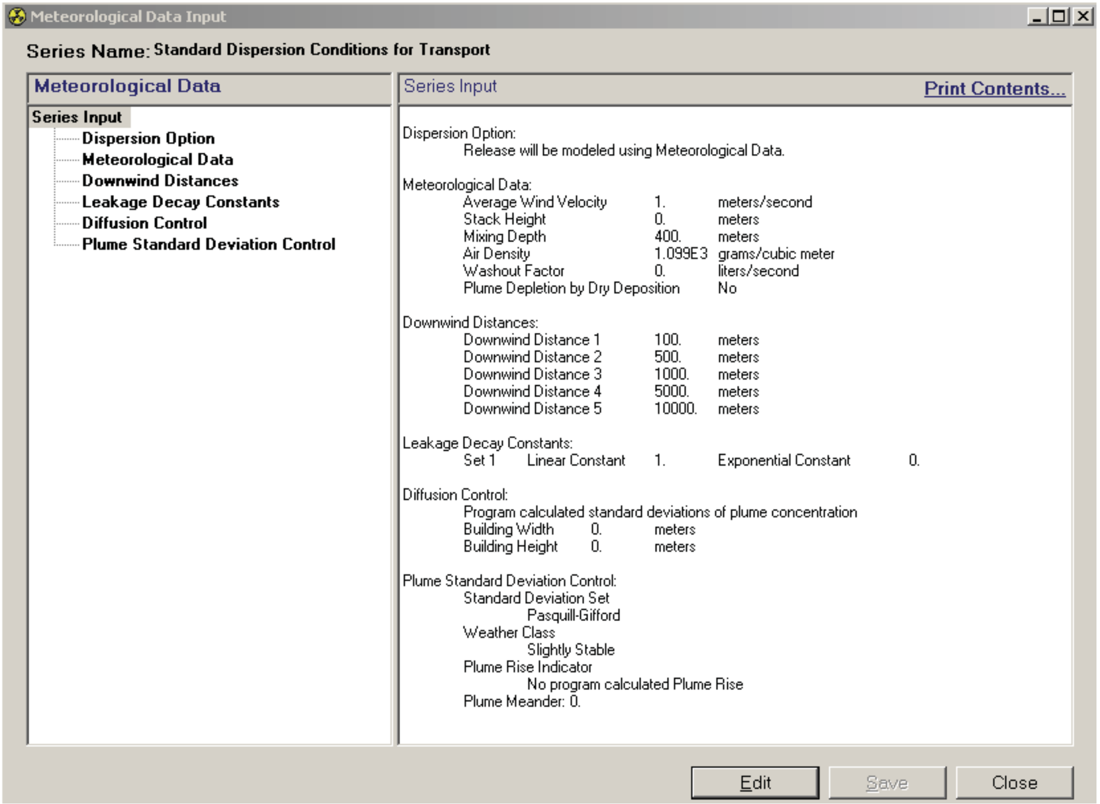


Figure 3-7. Series Main Window.

The navigation pane (see Figure 3-8) on the left side of the series main window gives a brief outline of what data have been entered into the Series.

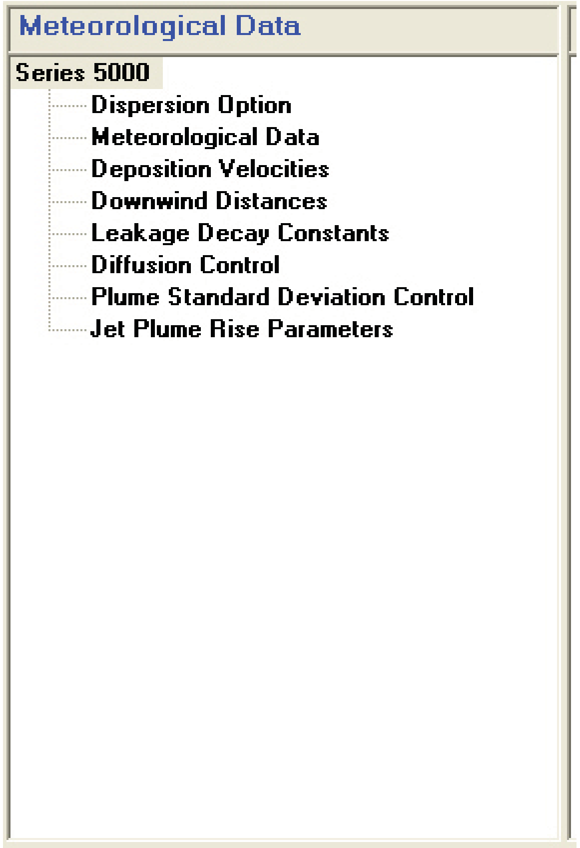


Figure 3-8. Navigation Pane.

The contents pane (see Figure 3-9) will display the data for the selected item in the navigation pane. Thus, when a subitem is selected in the navigation pane the corresponding data for that item are displayed in the contents pane. This provides quick access to the specific data that are in question. The Print Contents link in the upper right corner will print the current data in the contents pane to the chosen printer.

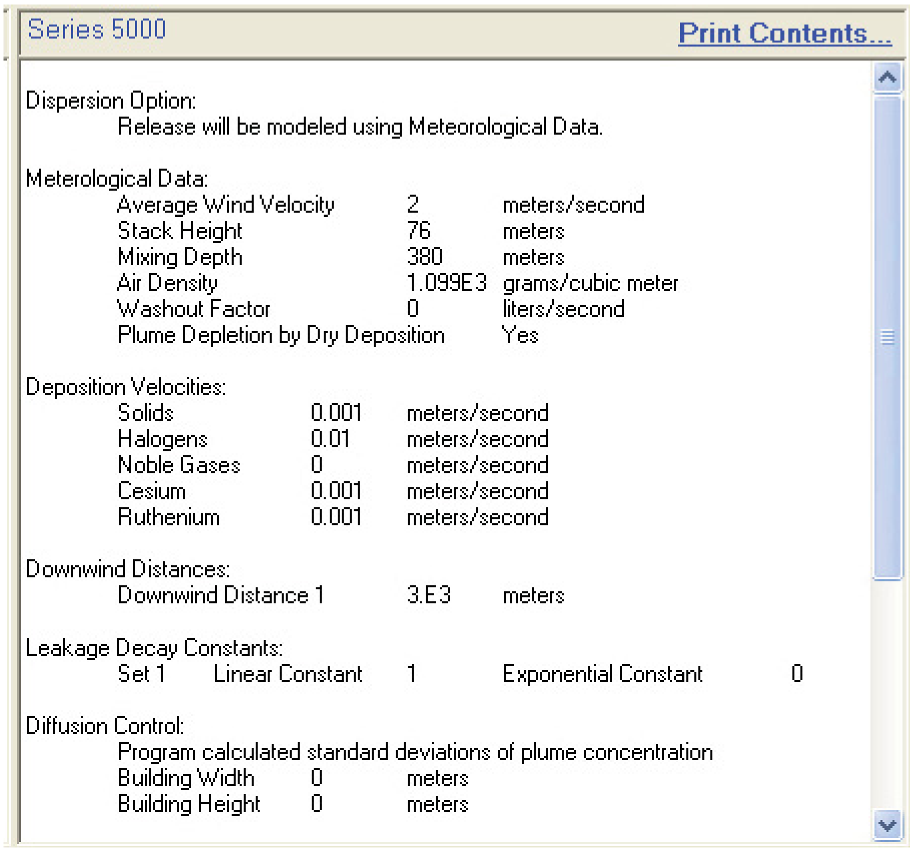


Figure 3-9. Contents pane.

3.1.5 Adding a Series

To add or append a new series to the file, use the Add Series Menu (see Figure 3-10) on the main window and click the name of the desired series.

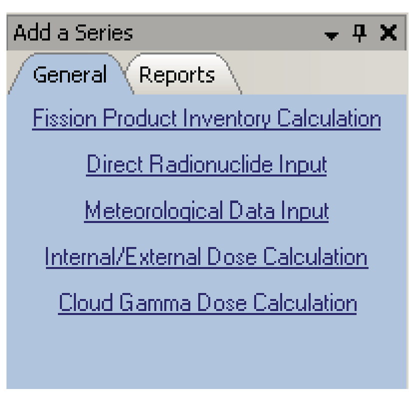


Figure 3-10. Add Series Menu.

When the series name is clicked, the main series window will appear with the series title window on top of it (see Figure 3-11).

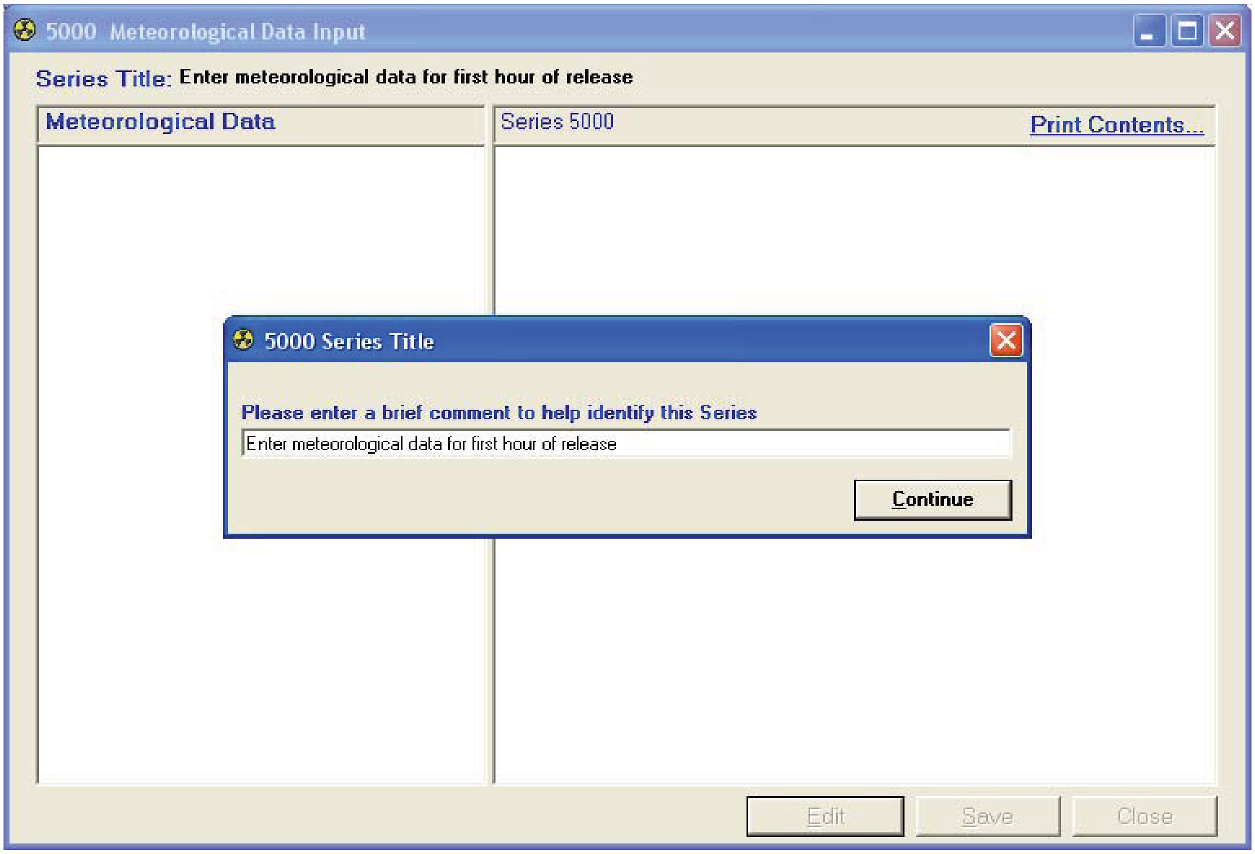


Figure 3-11. Series main window with title input.

The series title is used to identify the series in the file summary on the main window to make future editing sessions easier. Once the series title has been entered, the data entry screens are shown in sequence to allow input of the data for that series. When all the data have been entered for that series, the series main window becomes active again allowing review of the data and the option to save or discard the data.

To cancel data entry for a series, click the X in the upper right corner of the current data entry screen and click yes in response to the confirmation. The series main window becomes active again allowing the click of the cancel button.

3.1.6 Editing a Series

To edit a series in the open file, use the file summary on the main window and double-click the series to edit. The series main window will appear similar to Figure 3-12.

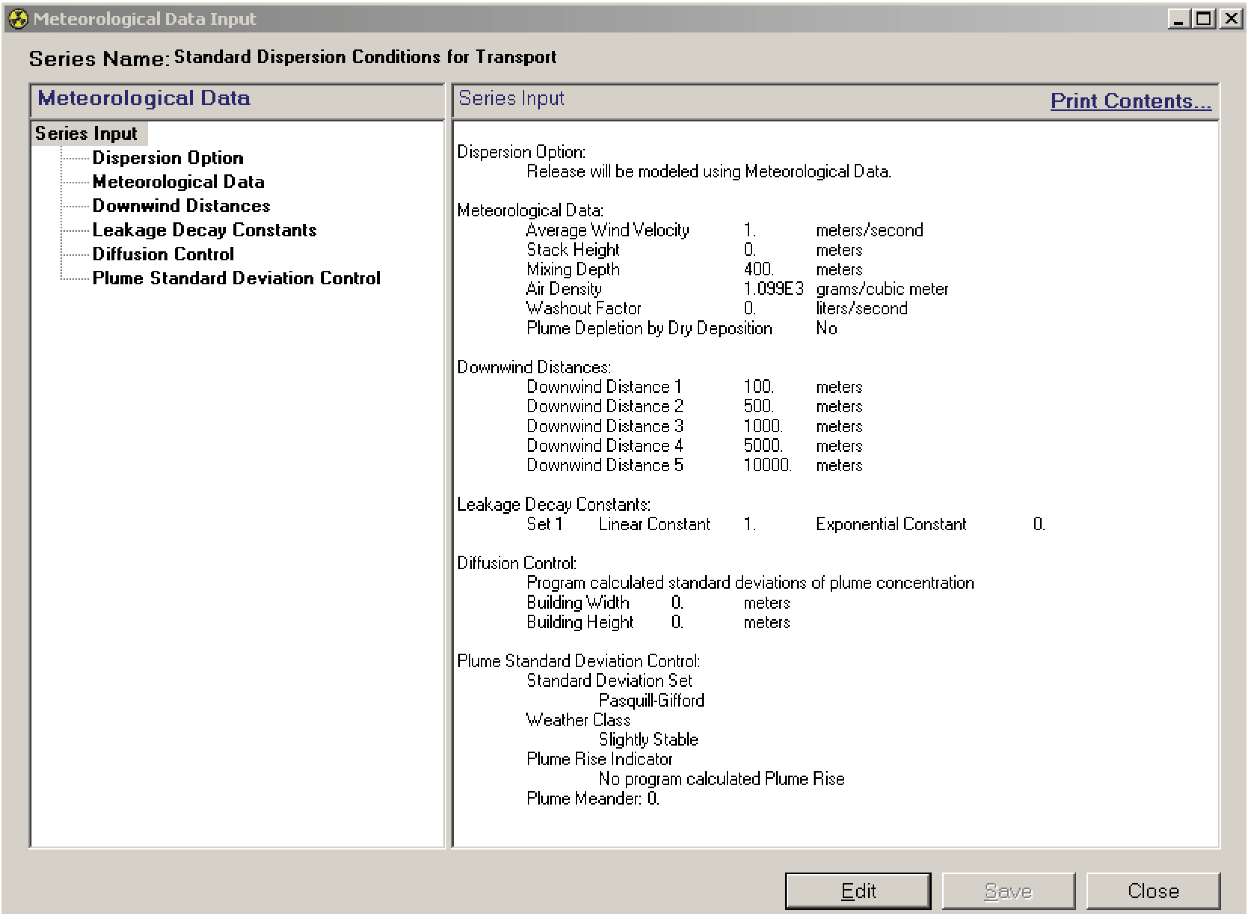


Figure 3-12. Series main window in edit mode.

The series main window shows the data that were entered in for the series. To edit the data, click the edit button and each data entry screen is shown in sequence for editing. Once through the whole series, the data can be reviewed and saved or discarded. If the data are discarded the original data will remain in the file.

To cancel the edit of a series, click the X in the upper right corner of the current data entry screen and click yes in response to the confirmation. The original data is then reloaded into the series main window.

3.1.7 Run Results

The run results window (see Figure 3-13) gives an explorer-like view of the run output from RSAC allowing the user to explore the results of several files at a time.

Figure 3-13. Run results window.

Each file that was run with RSAC appears as the top level item in the left navigation pane. The file is broken down into sections that are identified in the output, which will be the subitems under the file. The item that is currently selected in the navigation pane is displayed in the right pane.

- To view the contents of the whole file click the top level item that has the same name as the file. The whole contents of the file will then be displayed in the right pane. To view just one section of the file, click on the sections item in the navigation pane that is listed under the file.

3.2 Series Data Entry

The following section steps through the data entry options are available in each series to build an input file for RSAC. If at any time a comment button is active during series input, a comment screen is available for use (see Figure 3-14). Information can be cut and paste into the comment screen from any windows based program or it can be directly typed into the form.

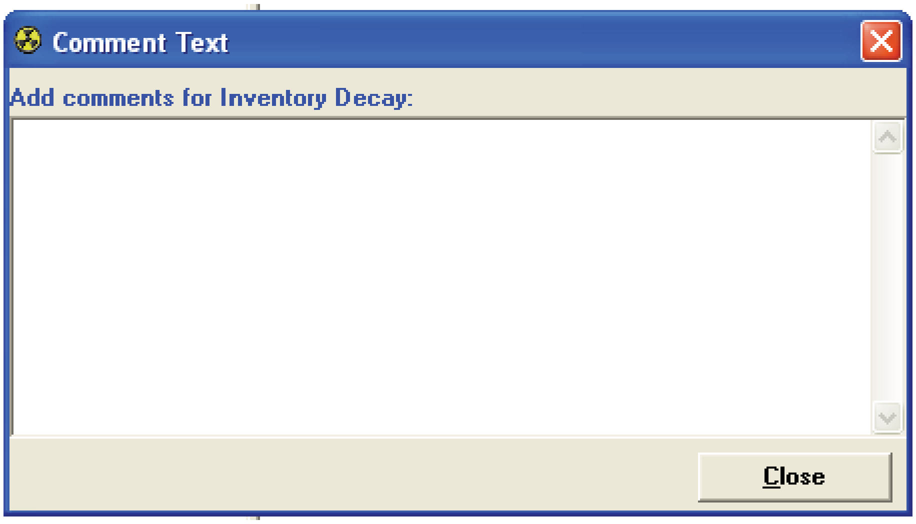


Figure 3-14. Comment entry screen.

3.2.1 1000 Series – Fission Product Inventory Calculation

Screen 1 - Input Type: The first data entry screen for the 1000 series is the Input Type (see Figure 3-15). Select the type of input to be generated. Only one type can be selected at a time. The option chosen determines the sequence of screens that follow screen 1.

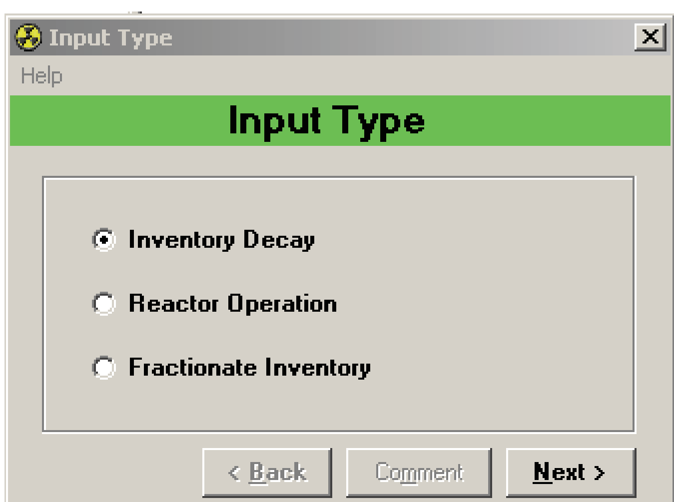


Figure 3-15. Screen 1, Input type screen.

Screen 2A (Optional) - Inventory Decay: This screen appears only if *Inventory Decay* is chosen on screen 1. Indicate the inventory decay time (see Figure 3-16). An inventory must have been input previously for this to function properly. A pull down menu is available to allow for a variety of input options.

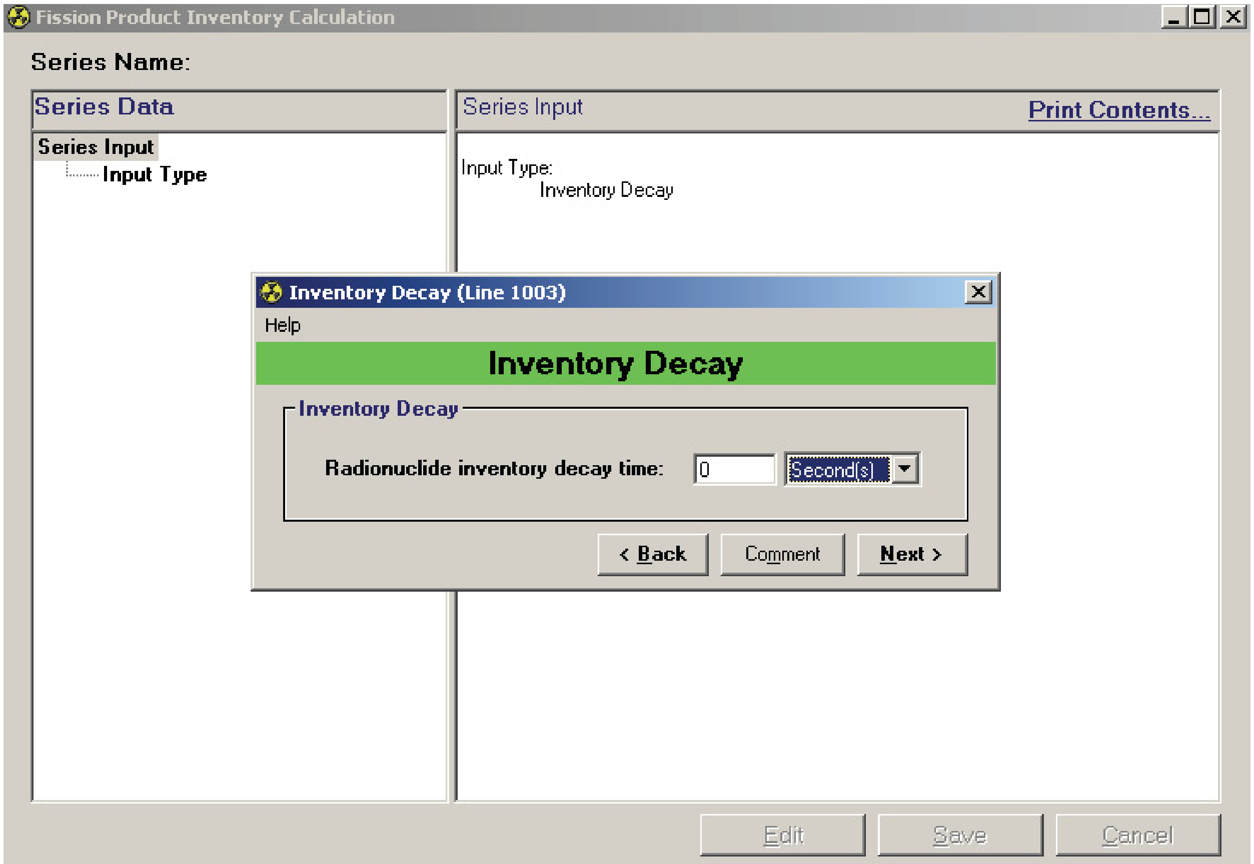


Figure 3-16. Screen 2A (Optional), Inventory Decay.

Next, notification of input completion for the 1000 series is given (see Figure 3-17). Click the OK button to end data entry for the series and review the data input.

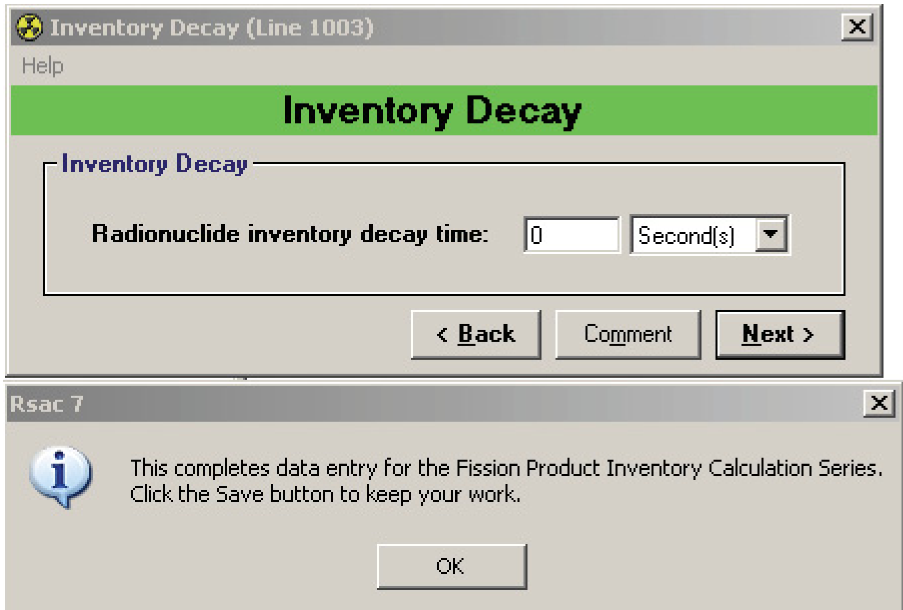


Figure 3-17. Input Completion Notification screen.

Screen 2B (Optional) - Reactor Operation: Shown only if *Reactor Operation* is selected on screen 1, see Figure 3-18.

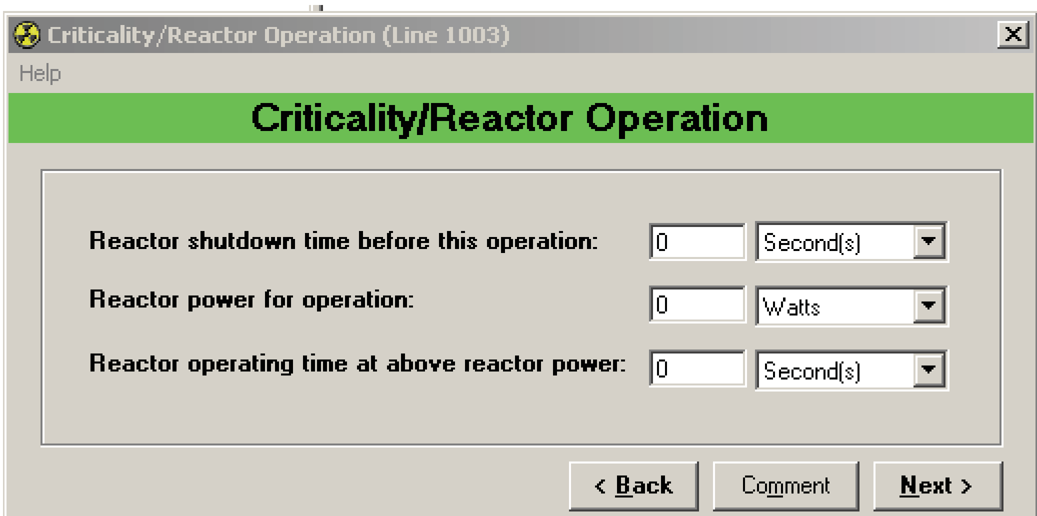


Figure 3-18. Screen 2B (Optional), Reactor Operation.

Screen 3A - Release During Reactor Operation: This screen appears after optional screen 2B *Reactor Operation* (see Figure 3-19). If **YES** is clicked, the *Release During Fission Product* screen will appear next.

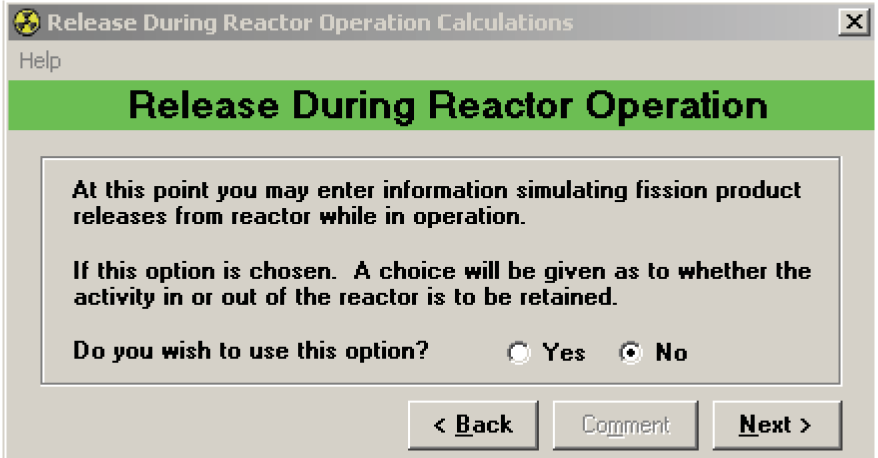


Figure 3-19. Screen 3A, Release During Reactor Operation.

Screen 4A - Release During Fission Product: On this screen (see Figure 3-20), enter the inventory to be retained for subsequent calculations. Specifically, supply the following:

- Number of reactor incremental release steps
- Radionuclide leak rate from the reactor for each of the following: solids, halogens, noble gases, cesium, and ruthenium.

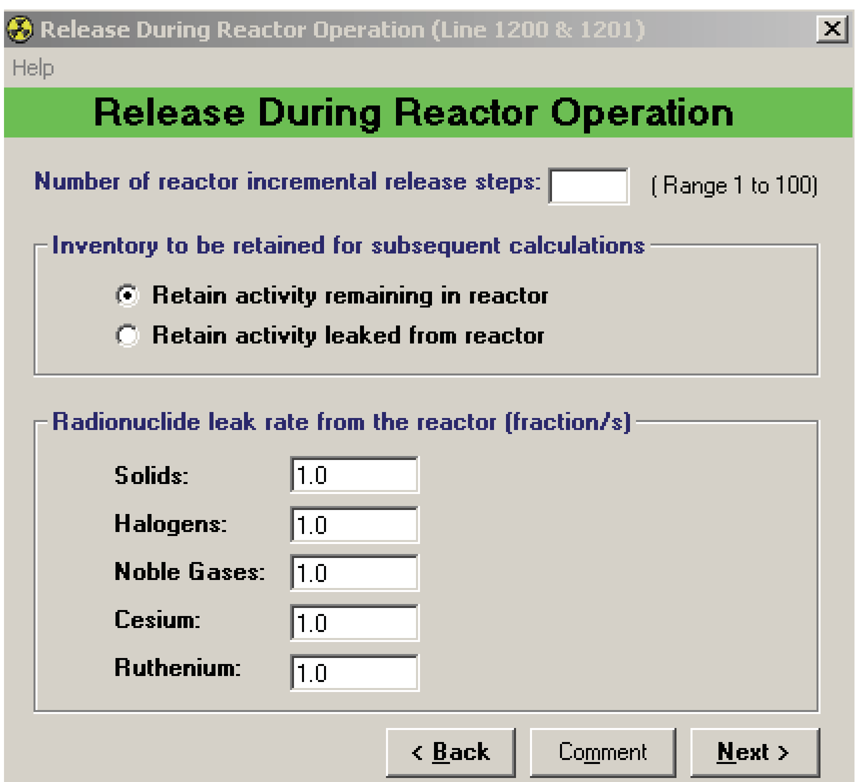


Figure 3-20. Screen 4A, Release During Fission Product.

Screen 2C (Optional) - Fractionate Inventory: This screen appears only if *Fractionate Inventory* is selected on screen 1 (see Figure 3-21). Select the option of what type of fractionation should be performed.

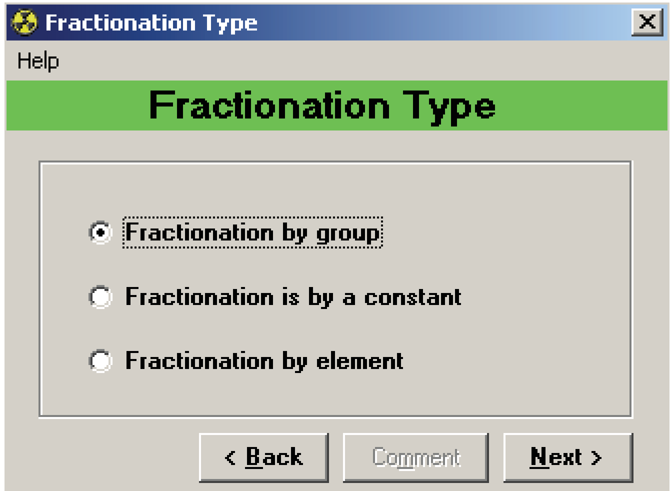


Figure 3-21. Screen 2C (Optional), Fractionate Inventory.

Screen 3B (Optional) – Fractionation by Group: This screen appears only if *Fractionation by group* is selected on the Fractionate Inventory screen 2C (see Figure 3-22).

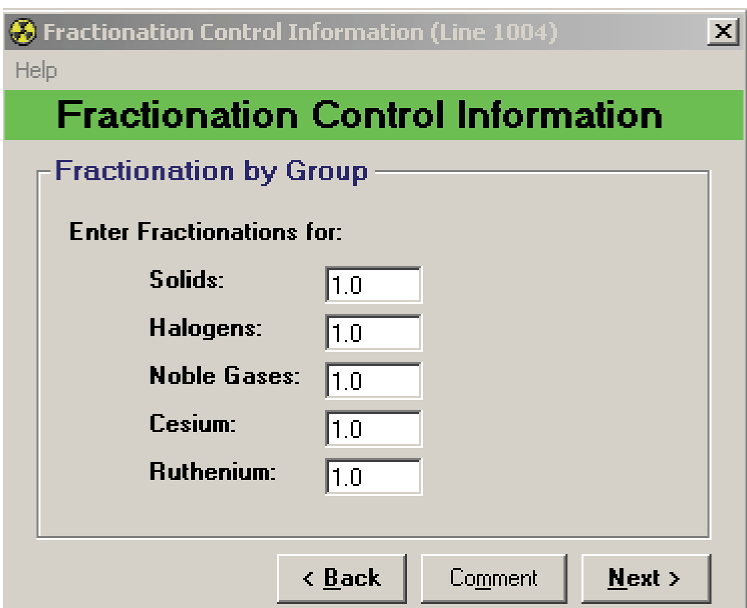


Figure 3-22. Screen 3B (Optional), Fractionation by Group.

Screen 3C(Optional) – Fractionation by Constant: This screen appears only if *Fractionation is by a constant* is selected on the Fractionate Inventory screen 2 (see Figure 3-23).

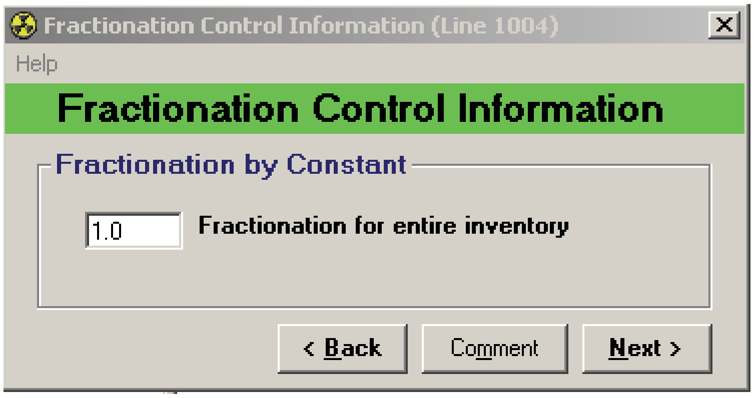


Figure 3-23. Screen 3C (Optional), Fractionation by a Constant.

Screen 3D (Optional) – Fractionation by Element: This screen appears only if *Fractionation by element* is selected on the Fractionate Inventory screen 2C (see Figure 3-24). Provide the fractionation for elements that are not individual fractionated on the next screen.

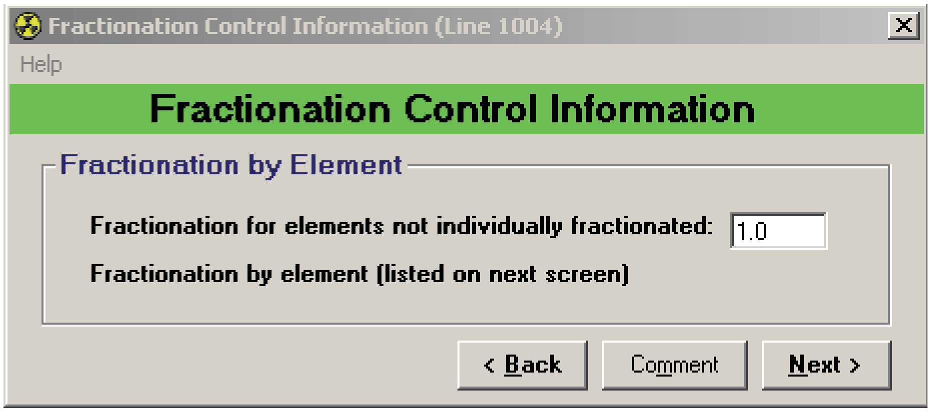


Figure 3-24. Screen 3D (Optional), Fractionation by Element.

Screen 4B - Element Fractionation Specification: This screen specifies individual element fractionations (see Figure 3-25). To enter a fractionation for an element use one of the following methods. Use the <↑> and <↓> to select the desired element in the list; scroll through the list and select the desired element; type the symbol to quickly select the desired element. Then click the Enter Fractionation button below the list or double-click the element to supply a value. Once the value has been supplied click the OK button to accept the value or click the Cancel button to discard the supplied value.

NOTE To supply the same fractionation to multiple elements hold the <shift> or <ctrl> keys while selecting element then click the Enter Fractionation button. To discard a fractionation already entered, select the element from the list and click the Clear Selected button.

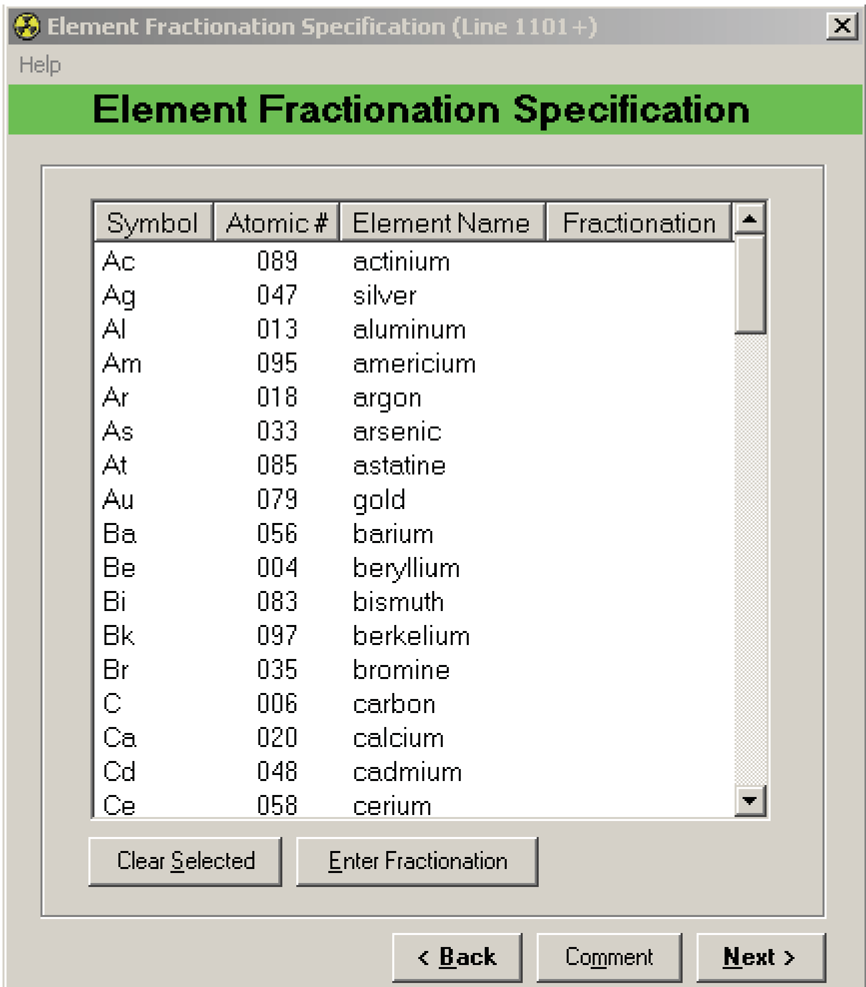


Figure 3-25. Screen 4B, Element Fractionation Specification.

3.2.2 2000 Series – Direct Radionuclide Input

Screen 1 - Series Title: Enter a brief comment about the 2000 Series that is being appended and click on Continue (see Figure 3-26). This comment is used to distinguish between series and can make future editing sessions easier. This comment will also appear in the generated RSAC-7.2 input file.

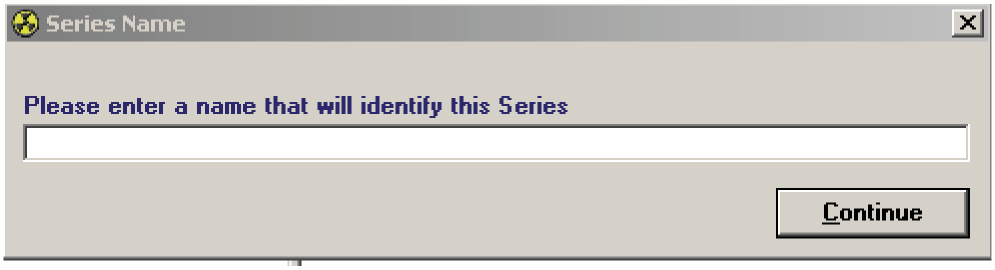


Figure 3-26. Screen 1, Series Title.

Screen 2 - Radionuclide Input Options: Use the mouse to select the appropriate option for your problem (see Figure 3-27).

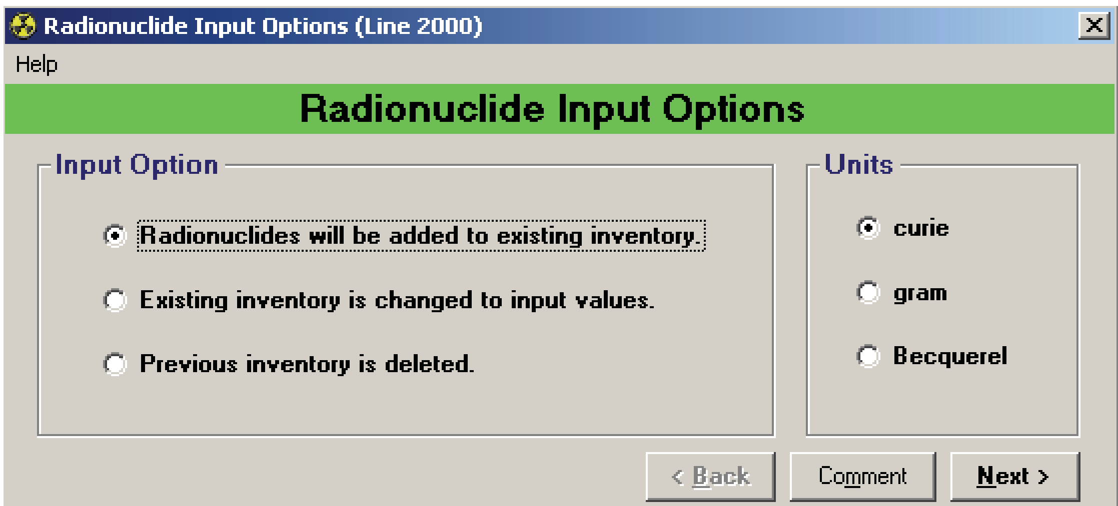


Figure 3-27. Screen 2, Radionuclide Input Options.

- First selection - Retain the previous radionuclide inventory and to add the inventory for the radionuclides selected on the subsequent screens to the previous values.
- Second selection - Retain the previous radionuclide inventory and to change the inventory for the radionuclides selected on the subsequent screens to the new values entered.
- Third selection – Initializes the inventory. You will be entering the radionuclide inventory and any previous radionuclide inventory is deleted. If this option is selected, the warning in Figure 3-28 is displayed. It is very important to understand that if a 1000 series was used to generate a fission product inventory previously, this option will delete the inventory from memory. Use this option with caution.
- A new option in RSAC 7.2 is to allow input in various units. Make sure the appropriate unit of input is selected.

Figure 3-28. Previous Inventory Deleted Warning.

Screen 3 - Direct Radionuclide Input: This screen (see Figure 3-29) determines whether the radionuclides will be selected and values input directly or if an external file will be used as the source for radionuclide input.

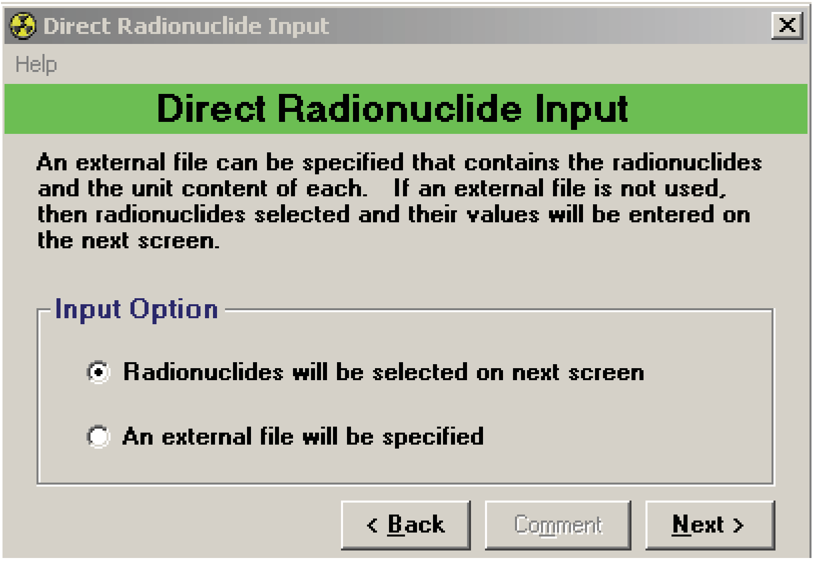


Figure 3-29. Screen 3, Direct Radionuclide Input.

Screen 4A (Optional) - Radionuclide Curie Input: This screen appears only when *Radionuclides will be selected on next screen* is chosen on screen 3. On this screen (see Figure 3-30), select the radionuclide and input the activity desired by using one of the following methods. Use the <↑> and <↓> to select the desired radionuclide in the list; scroll through the list and select the desired radionuclide; type the symbol to quickly select the desired radionuclide. Then click the Enter Curie button below the list or double-click the radionuclide to supply a value. Once the value has been supplied, click the OK button to accept the value or click the Cancel button to discard the supplied value.

NOTE 1: To supply the same curie to multiple radionuclides hold the <shift> or <ctrl> keys while selecting radionuclide then click the Enter Curie button. To discard a Curie already entered, select the radionuclide from the list and click the Clear Selected button.

NOTE 2: If the selection mode changes from curies to grams or Becquerel's, the input screen is basically the same other than the name on the enter key.

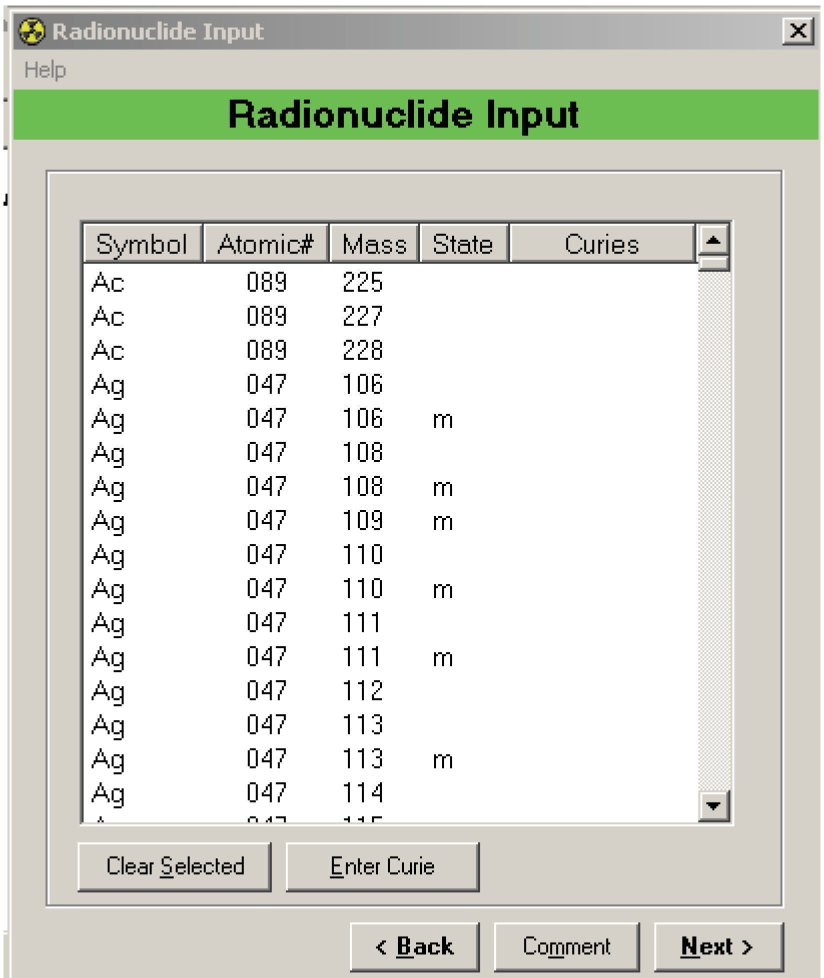


Figure 3-30. Screen 4A (Optional) Radionuclide Curie Input.

Screen 4B (Optional) - External File for Radionuclide Entry: This screen appears only when *An external file will be specified* is chosen on screen 3 (see Figure 3-31). Enter the name of the file that contains the list of radionuclides and curie content. Use the Select File button to locate the file.

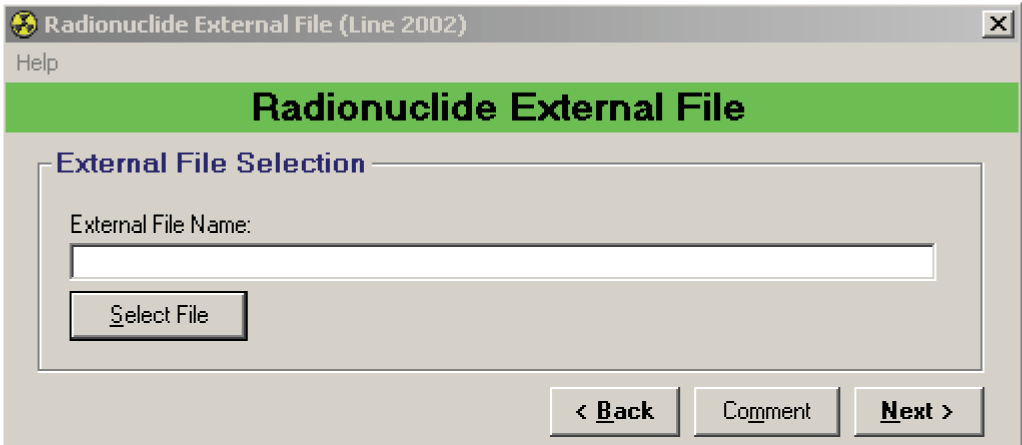


Figure 3-31. Screen 4B (Optional), External File for Radionuclide Entry.

Screen 5 - Series Complete Notification: When finished with the data entry screens, a completed notification appears (see Figure 3-32). Click OK to return to the series main window (see Figure 3-11) to review and save entered data.

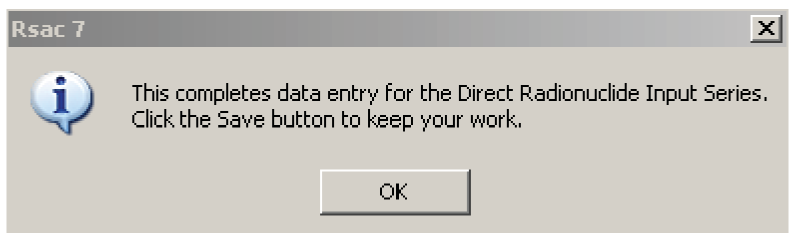


Figure 3-32. Screen 5, Series Complete Notification.

3.2.3 3000 Series – Dose Summary Option

The dose summary option cannot be initialized until meteorological data (5000 Series) has been entered. The initiation of the dose summary option is automatically performed. In addition, downwind distances cannot be changed using subsequent 5000 Series input after the dose summary option has been initiated.

The 3000 series is accessed by clicking on the Reports Tab (see Figure 3-33).

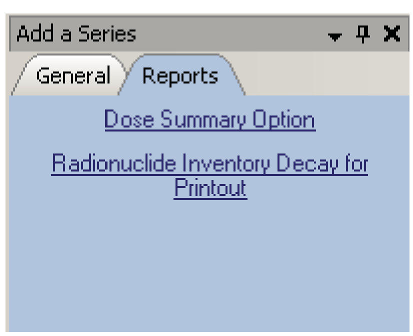


Figure 3-33. Reports Tab screen.

Screen 2 - Dose Summary Options: After the series title screen is dismissed the following selections are available (see Figure 3-34).

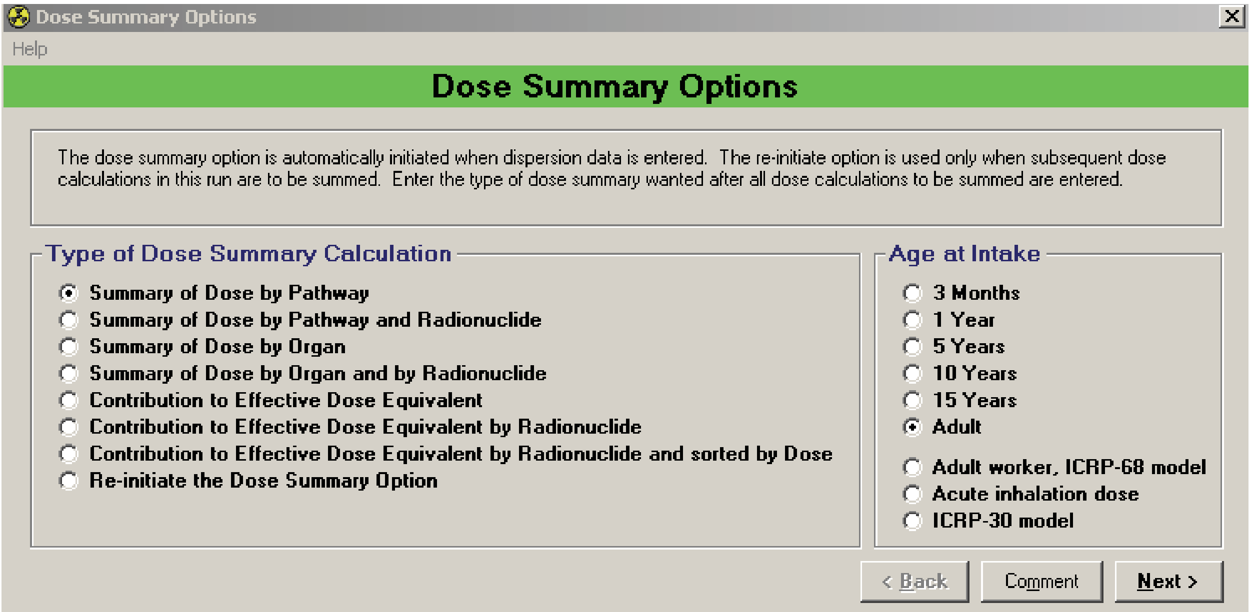


Figure 3-34. Screen 2, Dose Summary Options.

One or all of the options may be selected and may be selected for a specific age group.

- Summary of Dose by Pathway - Summarizes the CEDE for each pathway and totals the dose.
- Summary of Dose by Pathway and Radionuclide - Summarizes the CEDE for each radionuclide and each pathway. It does not summarize for the plume gamma pathway.
- Summary of Dose by Organ – Requires the selection of organs on optional screen 3 (see Figure 3-35). Click the organ in the list to select it and click again to unselect the organ. An X will appear in the selected column to indicate the organ is selected. If the Clear Selected button is clicked, then all organs are unselected.

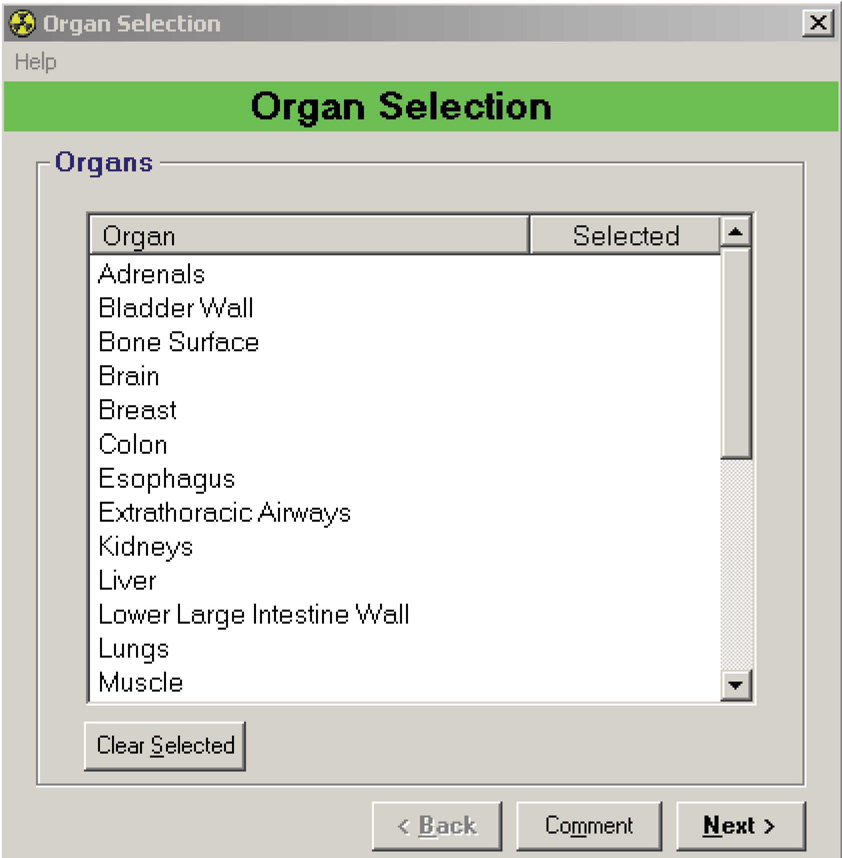


Figure 3-35. Screen 3 (Optional), Organ Selection.

- Summary of Dose by Organ and Radionuclide – Same as the previous option but radionuclides are added to the summary. The organ selection optional screen 3(see Figure 3-35) is shown with a note that it is summarized by organ and radionuclide.
- Summary of Dose from Contribution to Effective Dose Equivalent - This summary function shows in order of distance the pathway to EDE.
- Summary of Dose from Contribution to EDE and Radionuclide – Same as the previous report and sorted alphabetically by radionuclide.
- Summary of Dose from Contribution to EDE and Radionuclide Sorted by Dose – Same as the previous report except the order is from highest dose to lowest by radionuclide.

3.2.4 5000 Series – Dispersion Control Input

Screen 2 - Dispersion Options: After the series title screen the Dispersion options screen is displayed (see Figure 3-36). Select the type of dispersion control desired and click on the next button.

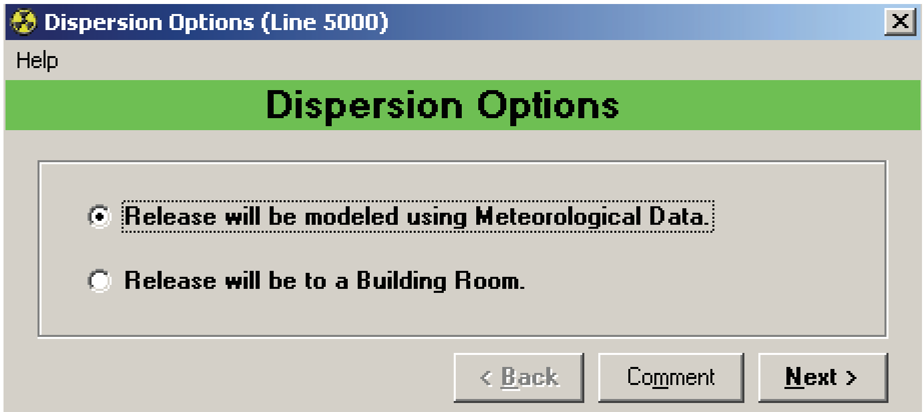


Figure 3-36. Screen 2, Dispersion Options.

- Option **1** - The release will be modeled using meteorological data.
- Option **2** - The release will be to a room. If this option is selected, only the inhalation pathway can be evaluated.

Screen 3 (Optional) - General Meteorological Information: This screen appears only if option 1 was chosen on screen 2. Enter the Meteorological Conditions and click on next (see Figure 3-37). If questions arise on what the inputs are or how the default values were chosen, move the cursor over the item in question and right-click, then click on Display Help. Select Help and the information will be displayed (see Figure 3-38).

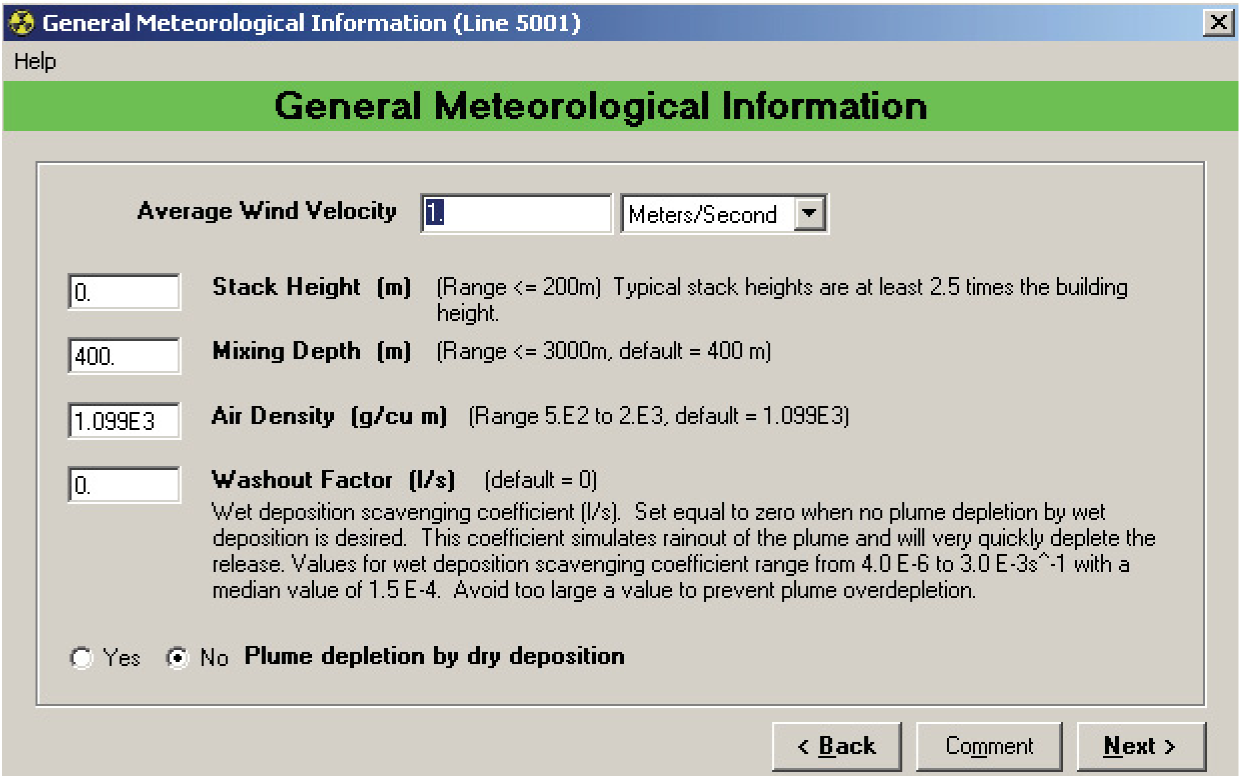


Figure 3-37. Screen 3 (Optional), General Meteorological Information.

Mixing Depth:

The third selection is the mixing depth. This depth acts as an effective ceiling to the release. Mixing depths are difficult to determine. The default value is 400 meters. Other values are identified below.

Season	Morning	Afternoon
Spring	480	2330
Summer	260	2900
Autumn	330	1550
Winter	400	730
Annual	370	2090

Figure 3-38. Help Information.

Screen 4 (Optional) – Dry Deposition Variables: This screen is only displayed when **YES** has been selected for *Plume depletion by dry deposition* on screen 3 (see Figure 3-39). It is important to understand that if plume depletion is not requested, the options for calculation of ingestion and ground surface dose will not be available. If the RSAC-7.2 default variables are chosen, then the Deposition Velocities will be those defined in Figure 3-39. Ensure that the deposition velocities are selected based on facility-specific recommendations.

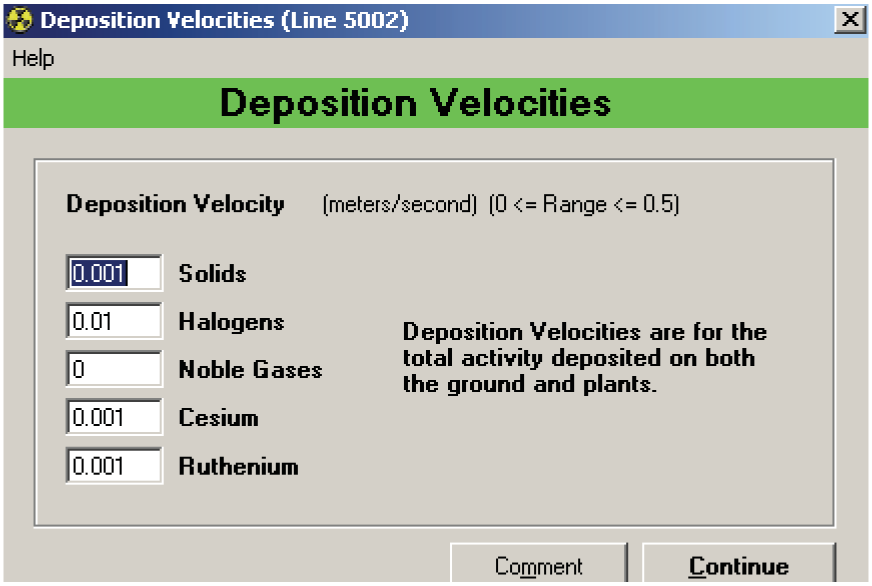


Figure 3-39. Screen 4 (Optional), Dry Deposition Variables.

Screen 5 - Downwind Distances: Enter one or more unique downwind distances (see Figure 3-40). If a duplicate distance is entered, you will be alerted and the field in error will automatically be highlighted. Be careful when editing downwind distances because the direct input of χ/Q values and the direct input of standard deviations must correspond to downwind distances.

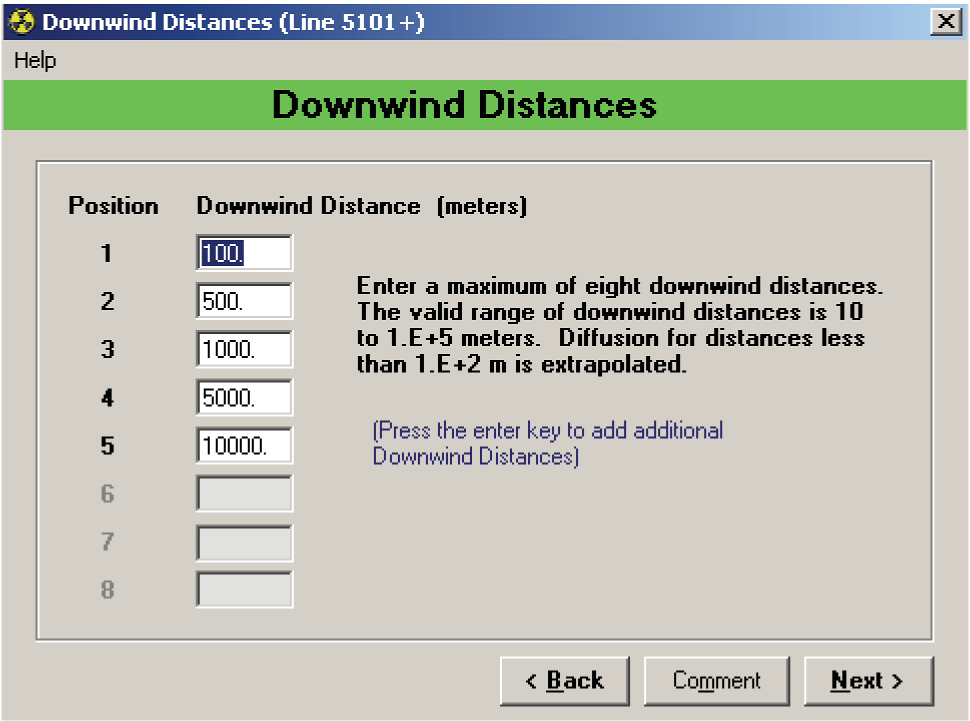


Figure 3-40. Screen 5, Downwind Distances.

Screen 6 - Leakage Decay Constants: Enter linear or exponential constants (s) (see Figure 3-41). Up to 10 sets of constants can be entered. The leakage decay constants must be entered in sets of two.

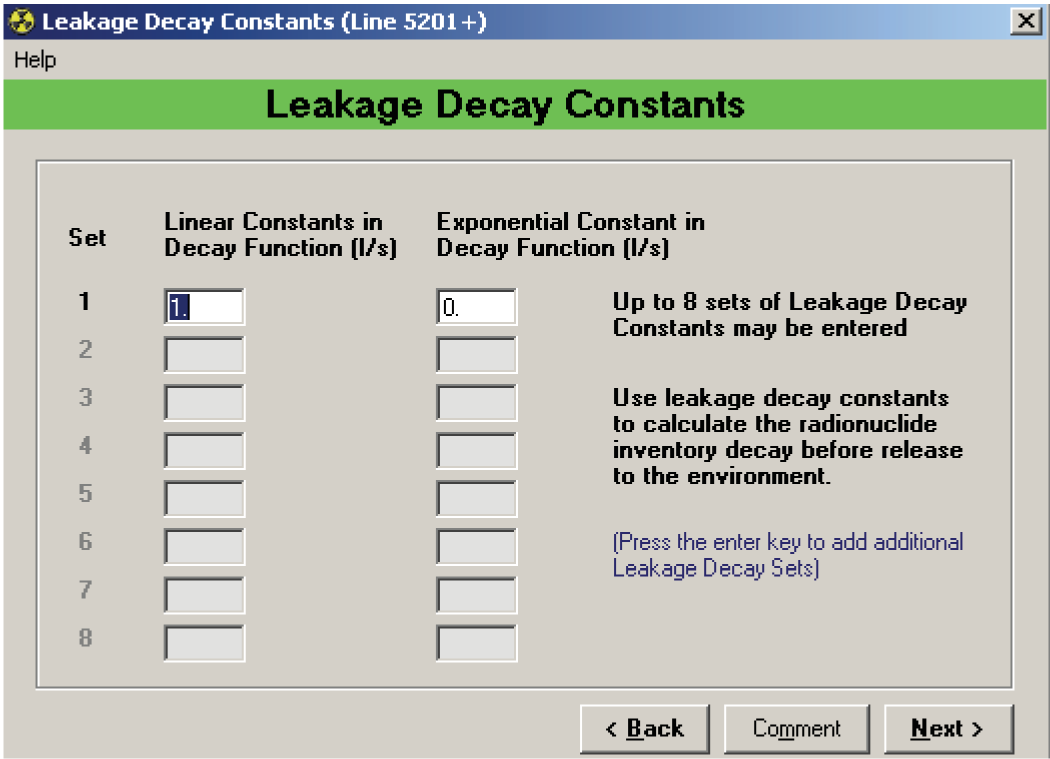


Figure 3-41. Screen 6, Leakage Decay Constants.

Screen 7 - Crosswind Distance: Select **Yes** if you want to enter crosswind distances; otherwise, select **No** (see Figure 3-42). If yes is selected, the input fields will become active allowing up to 15 crosswind distances to be entered.

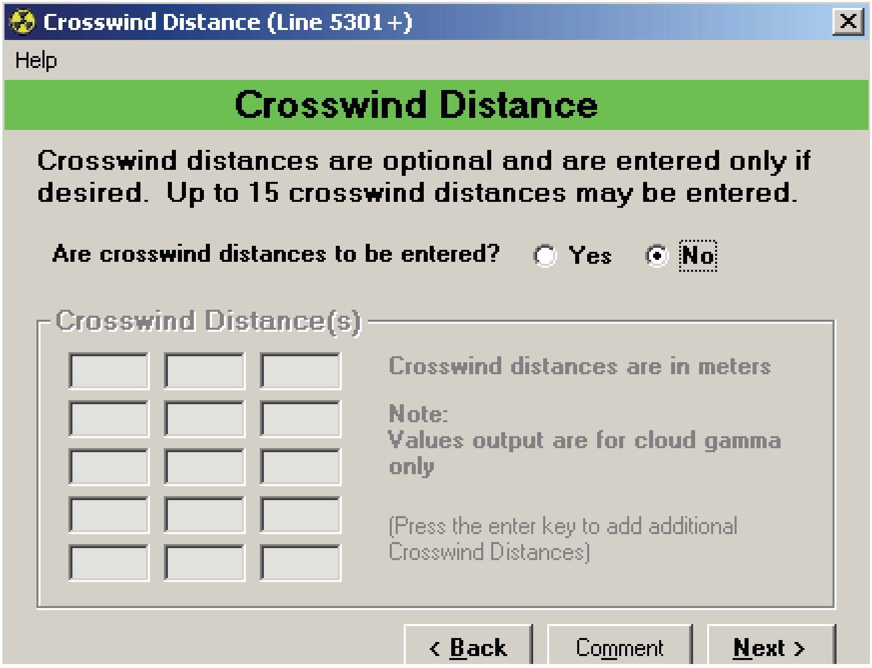


Figure 3-42. Screen 7, Crosswind Distance.

Screen 7 - Diffusion Coefficient Control: The following options are available for diffusion coefficient control (see Figure 3-43):

- If option **1** is selected, then the *Coefficient of Standard Deviation screen* will appear next. Enter the values for σ_y and σ_z. Standard deviations must be entered in sets of two.
- If option **2** is selected, then the *Plume Standard Deviation Control* screen will appear next. Enter the type of sigma weather class and plume rise indicator on a sequence of input screens.
- If option **3** is selected, then the *Direct χ/Q Input* screen will appear next. Enter the χ/Q associated with the downwind distance.

NOTE: Building wake control is only available if stack height was equal to zero on screen 3 (see Figure 3-43).

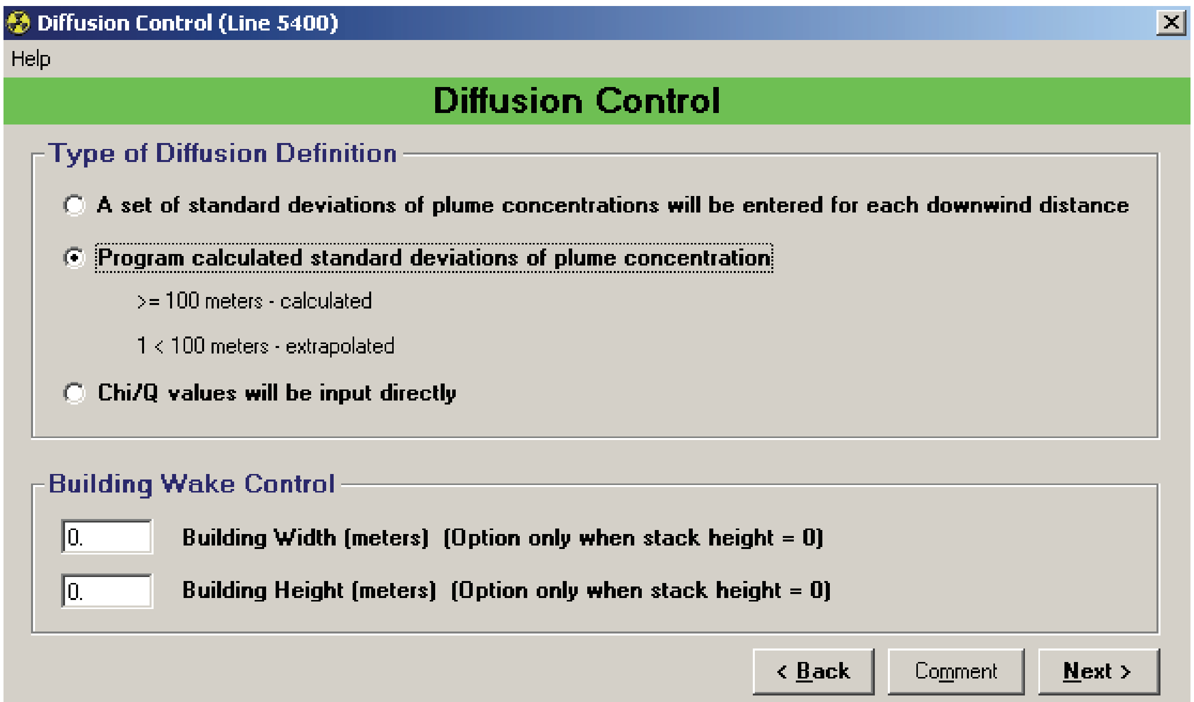


Figure 3-43. Screen 8, Diffusion Coefficient Control.

Screen 10A (Optional) - Coefficient of Standard Deviation: This screen appears only if option 1 was chosen on screen 9 (see Figure 3-44).

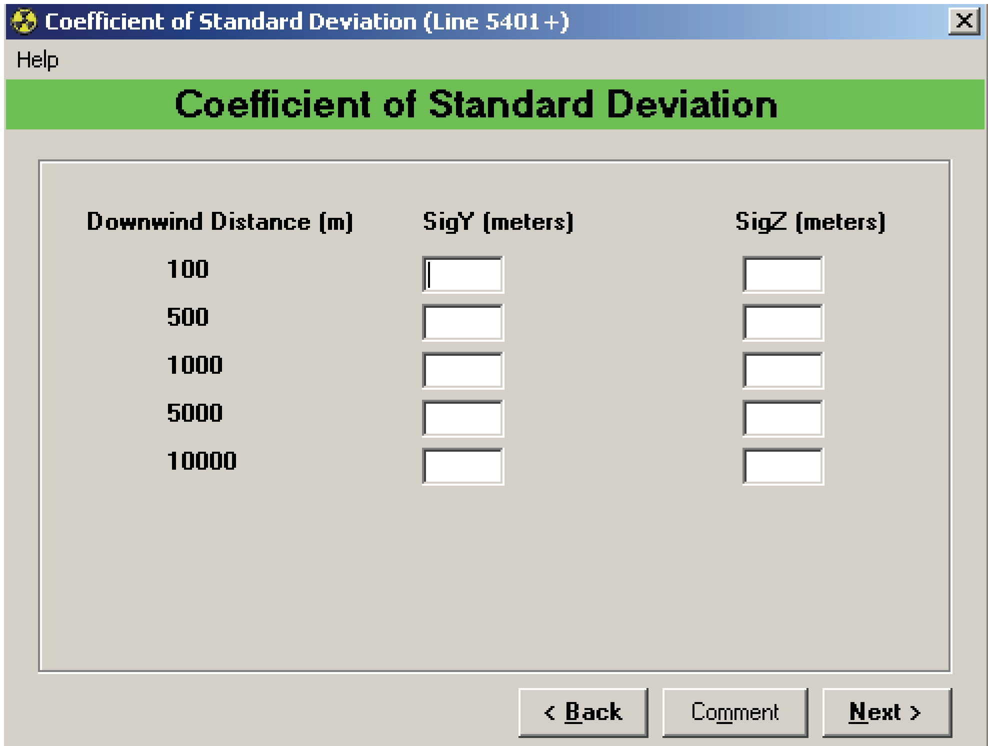


Figure 3-44. Screen 10A (Optional), Coefficient of Standard Deviation.

Screen 10B (Optional) - Plume Standard Deviation Control: This screen appears only if option 2 was chosen on screen 9 (see Figure 3-45).

NOTE: *Weather class* F Extremely Stable (Fumigation) *is only available if stack height was equal to zero on screen 3. Plume meander is a factor that allows for additional spreading of the plume. Also known as a spreading ratio it is a factor greater than 1 that adjusts the calculated Chi/Q values to account for very low wind speed spreading.*

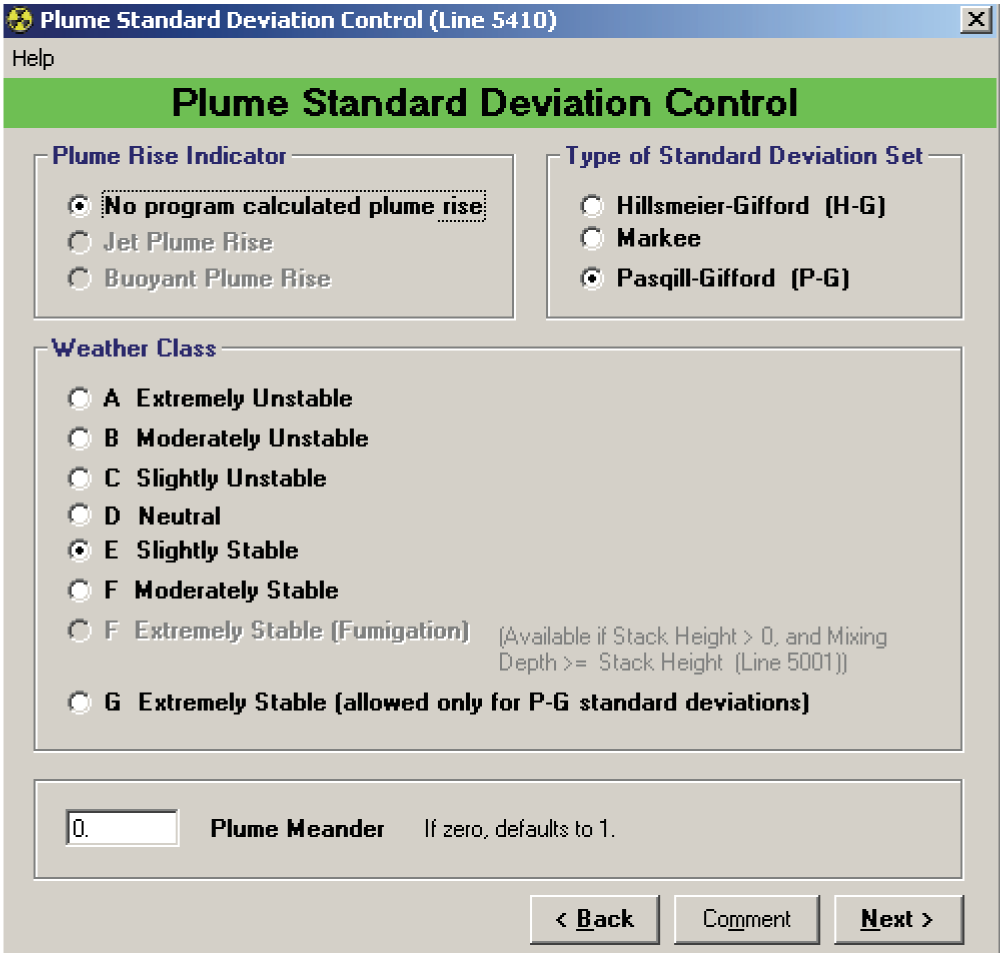


Figure 3-45. Screen 10B (Optional), Plume Standard Deviation Control.

Screen 10C (Optional) - Direct Chi/Q Input: This screen appears only if option 3 was chosen on screen 9 (see Figure 3-46).

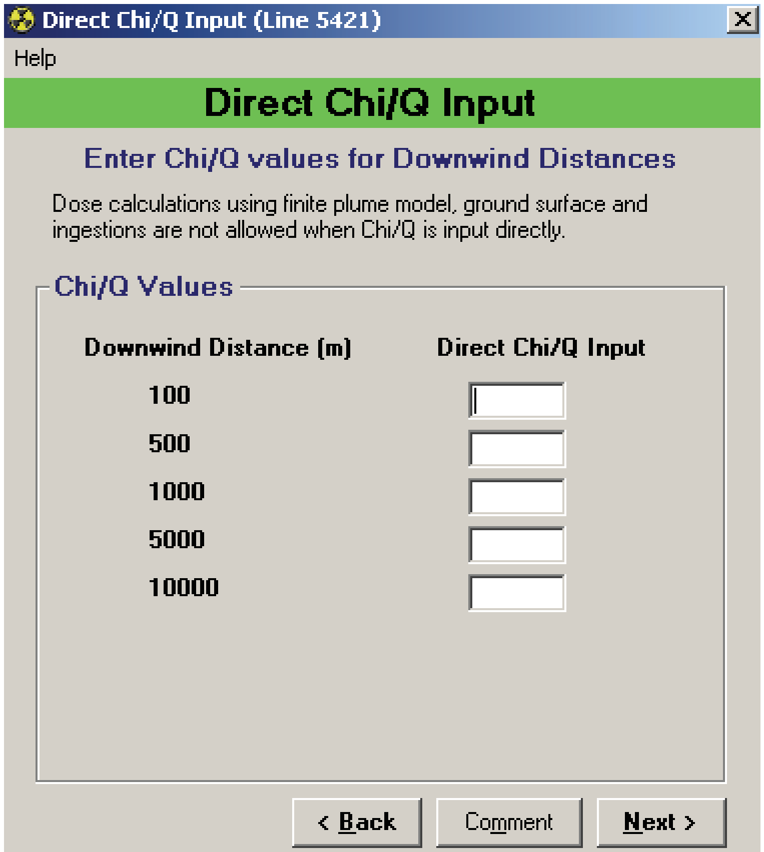


Figure 3-46. Screen 10C (Optional), Direct Chi/Q Input.

Screen 11A (Optional) - Jet Plume Rise Parameters: This screen appears only if *Jet Plume Rise* was chosen on *Plume Standard Deviation Control* screen 10B (see Figure 3-47).

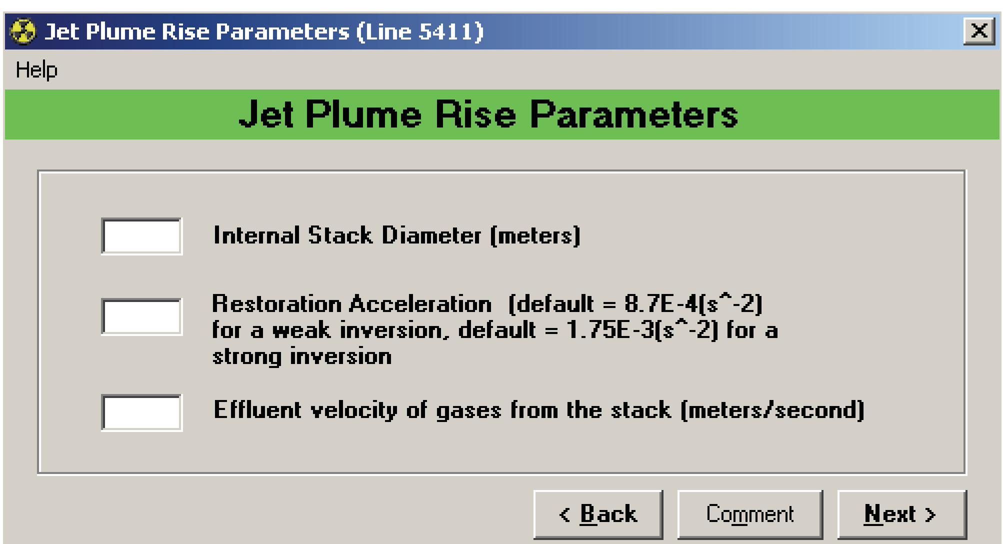


Figure 3-47. Screen 11A (Optional), Jet Plume Rise Parameters.

Screen 11B (Optional) - Buoyant Plume Rise Parameters: This screen appears only if *Buoyant Plume Rise* was chosen on *Plume Standard Deviation Control* screen 10B (see Figure 3-48).

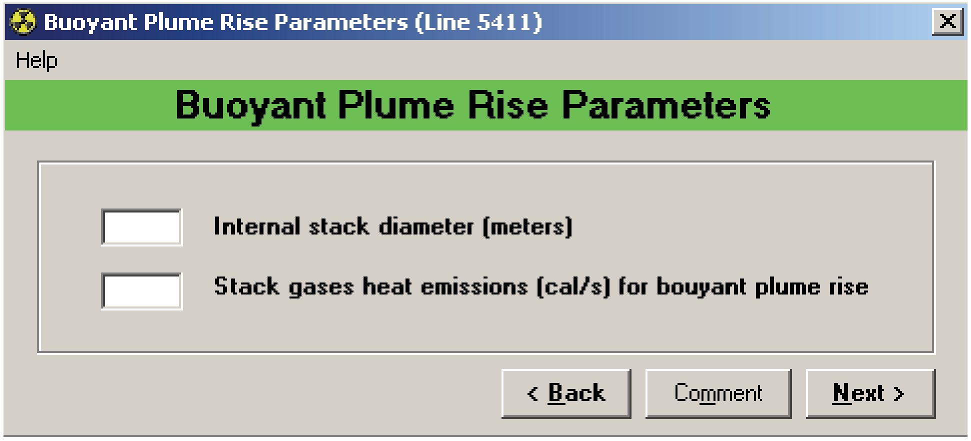


Figure 3-48. Screen 11B (Optional), Buoyant Plume Rise Parameters.

3.2.5 6000 Series – Radionuclide Inventory Decay and Printout

To append a new 6000 series in the current file, click on the *Reports* tab (see Figure 3-49).

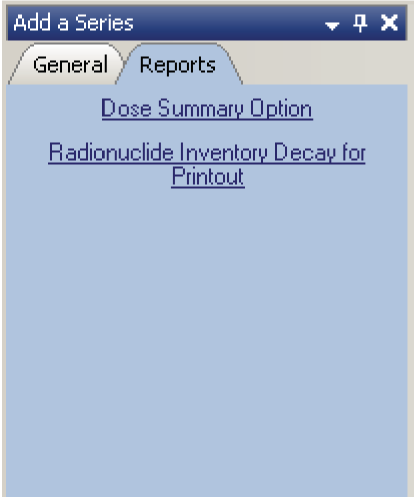


Figure 3-49. Reports Tab screen.

Screen 2 - Radionuclide Decay Control: This screen is shown after the series title screen for the 6000 series (see Figure 3-50). In this data entry screen sequence , the following information must be provided:

- If all or selected radionuclide decay will be calculated
- If inventories are to be printed
- Which units of measure
- If the exponential leakage decay option is desired.

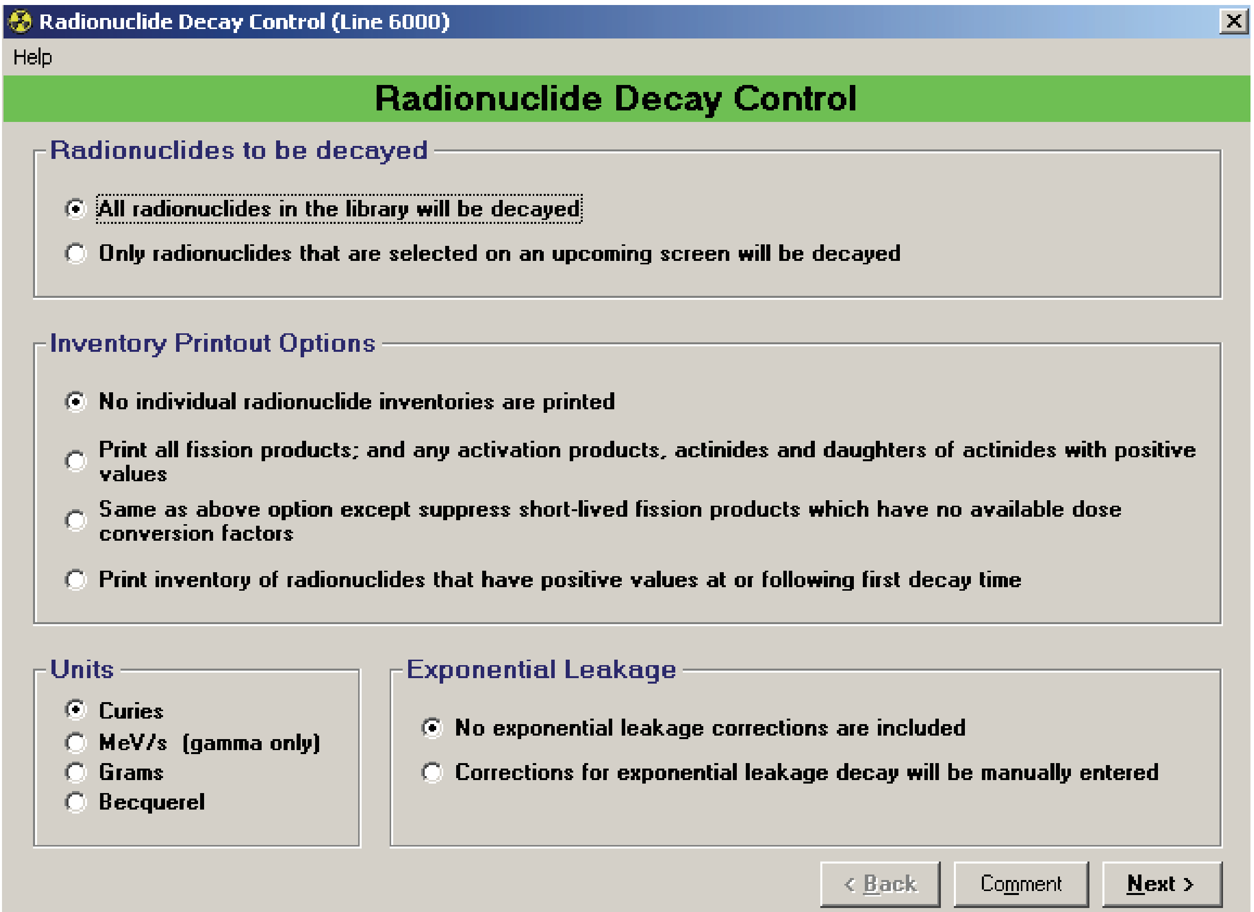


Figure 3-50. Screen 2, Radionuclide Decay Control.

Screen 3 (Optional) - Exponential Leakage Decay: This screen appears only if *Corrections for exponential leakage decay will be manually entered* was chosen on screen 2 (see Figure 3-51). Enter the decay time(s) for the exponential decay function. After clicking next, a prompt will appear asking if you want to change the *Leakage Decay constants* (see Figure 3-52). If the constants have been previously entered and do not need to be changed, click on **No** to proceed; otherwise click **Yes** to change the *Leakage Decay constants*.

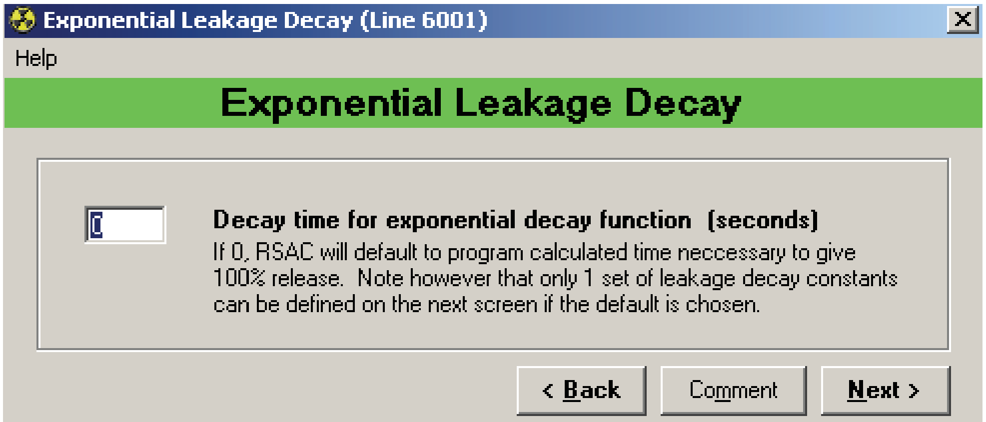


Figure 3-51. Screen 3 (Optional), Exponential Leakage Decay.

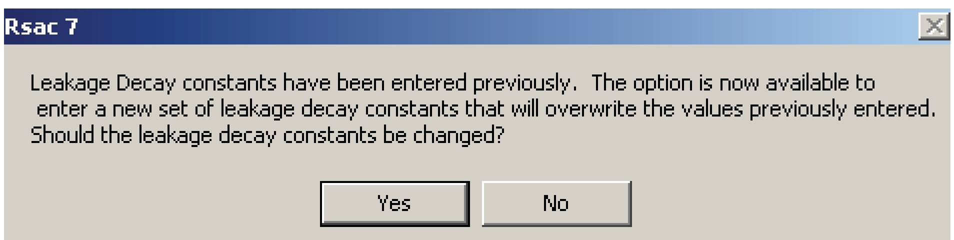


Figure 3-52. Leakage Decay Constants Prompt screen.

Screen 4 (Optional) - Leakage Decay Constants: If **Yes** was chosen on the Leakage Decay Constants Prompt then the screen in Figure 3-53 appears to enter linear and exponential constants (s^{-1}). Up to eight sets of constants can be entered. After entering a set of constants, press the <enter> key to allow entry of another set.

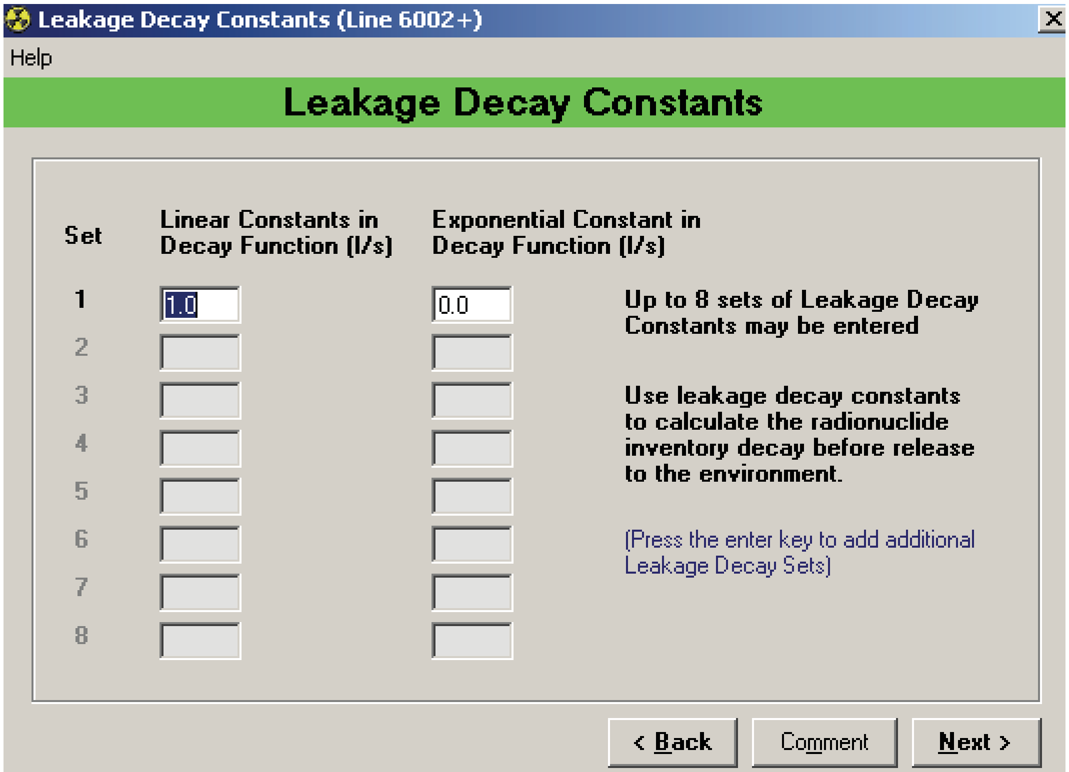


Figure 3-53. Screen 4 (Optional), Leakage Decay Constants.

Screen 5 (Optional) - Radionuclide Selection: This screen appears only if *Only radionuclides that are selected on an upcoming screen will be decayed* was chosen on screen 2. On this screen (see Figure 3-54), select the radionuclide using one of the following methods. Scroll through the list and click on the desired radionuclide; type the symbol to quickly select the desired radionuclide. To unselect a radionuclide, click it in the list a second time. To clear all selected, click the Clear Selected button.

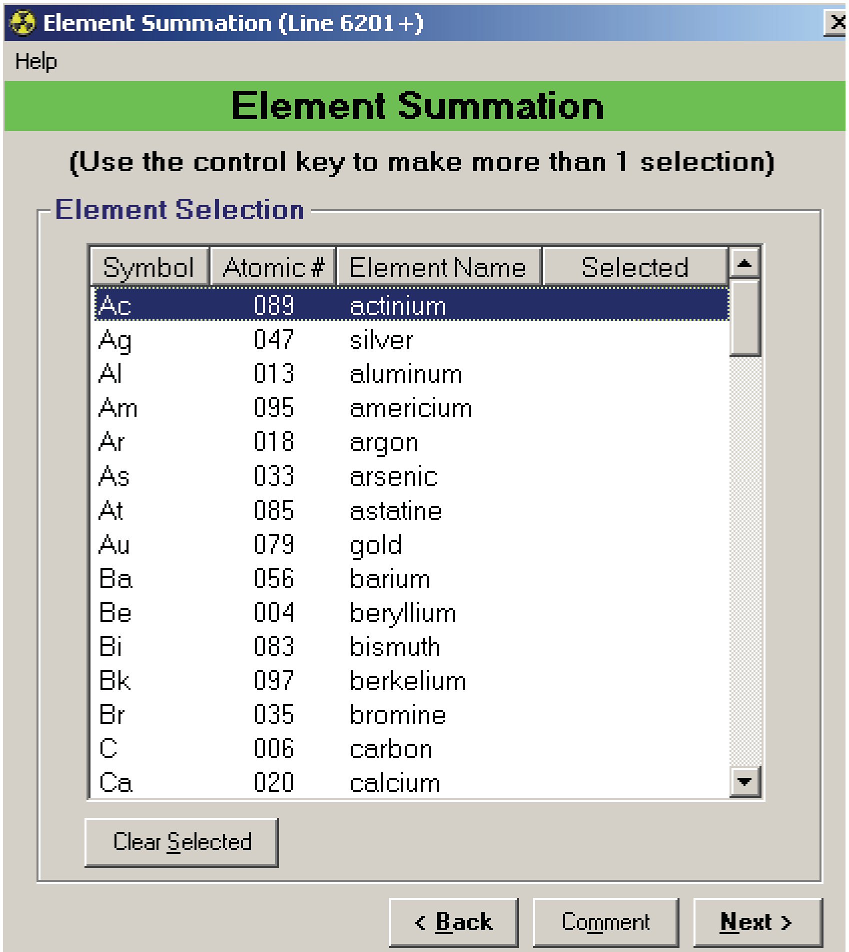


Figure 3-54. Screen 5 (Optional), Radionuclide Selection.

Screen 6 - Decay Times: The screen asks if you want to enter decay times directly (see Figure 3-55). If **Yes** is selected, the decay times input section will be enabled allowing input of decay times. A maximum of eight decay times can be entered. However, when you want to see all of the output data on an unshifted screen or printed on a standard 80-column page, enter a maximum of three decay times.

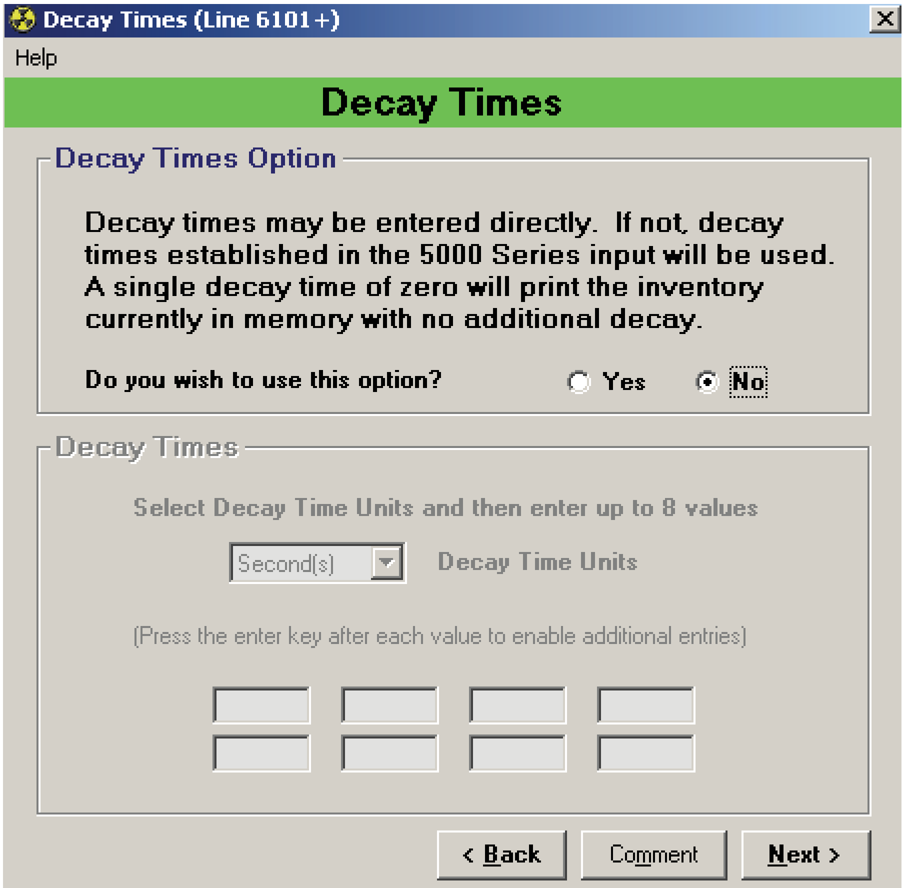


Figure 3-55. Screen 6, Decay Times.

Screen 7 (Optional) - Summation Control: Shown only if *All radionuclides in the library will be decayed* was chosen on screen 2. This screen (see Figure 3-56) will determine if you would like a summation of the radionuclide inventory by group (solids, halogens, noble gases, cesium, and ruthenium) and if the radionuclide inventory should be summed by element.

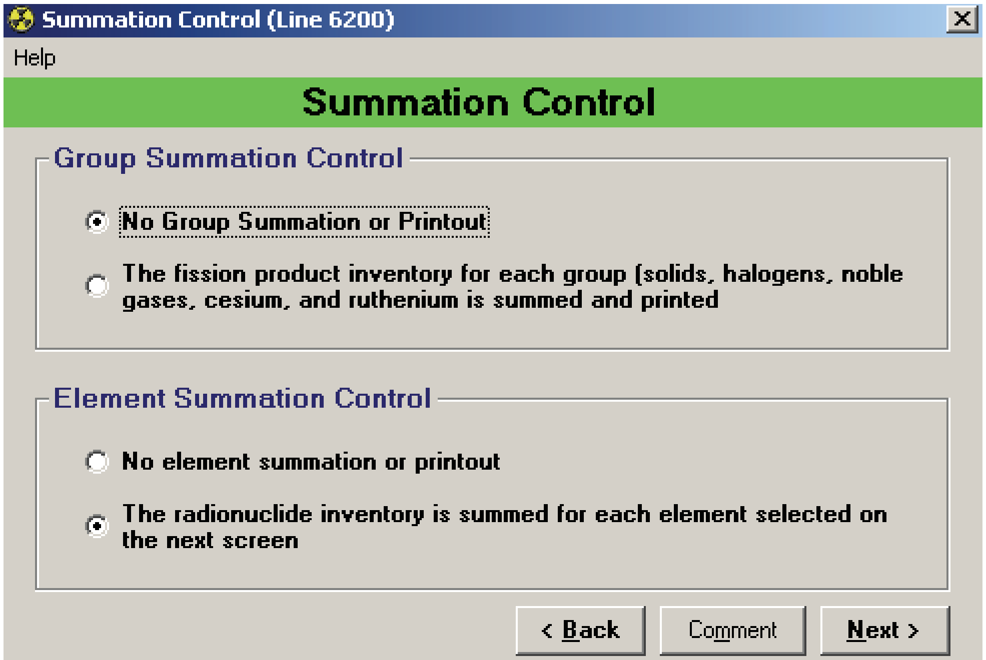


Figure 3-56. Screen 7 (Optional), Summation Control.

Screen 8 (Optional) - Element Summation: This screen appears only if *The radionuclide inventory is summed of each element selected on the next screen* is chosen on screen 7. On this screen (see Figure 3-57), select the element using one of the following methods. Scroll through the list and click on the desired element; type the symbol to quickly select the desired element. To unselect an element click it in the list a second time. To clear all selected, click the Clear Selected button.

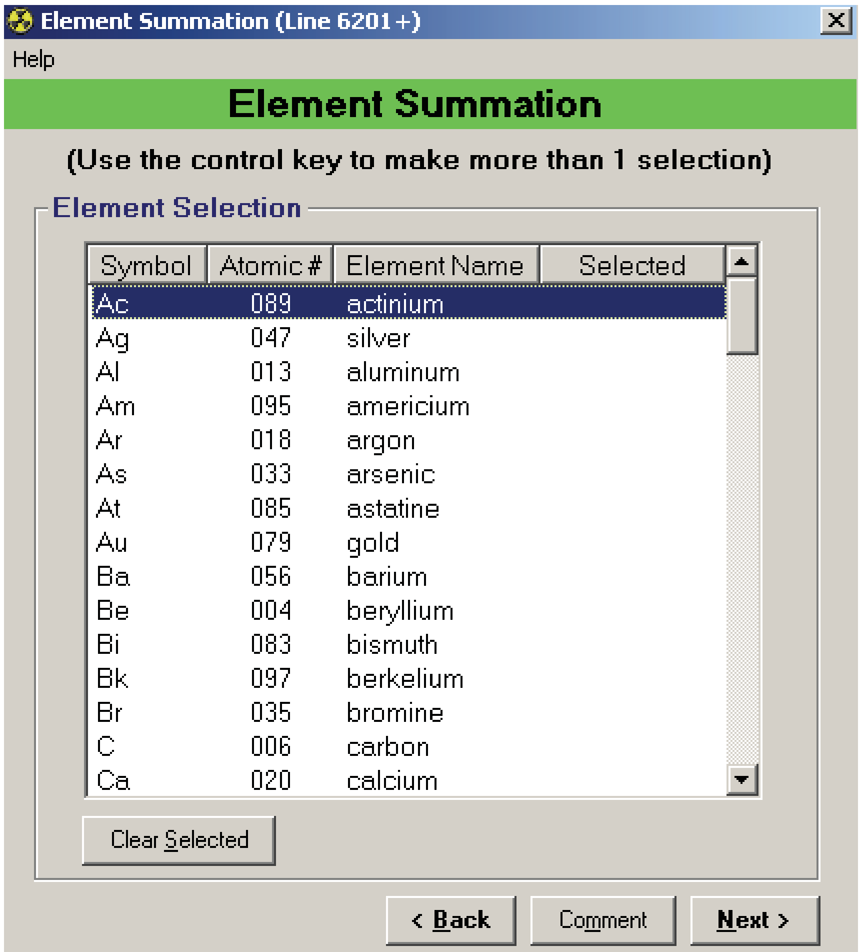


Figure 3-57. Screen 8 (Optional), Element Summation.

3.2.6 7000 Series – Internal/External Dose Calculation

Screen 2 - Dose Control Selection: After the series title screen the Dose Control Calculation screen is displayed (see Figure 3-58). In this data entry screen you will be asked to select the type of dose calculation or risk evaluation per Federal Guidance Report 13.

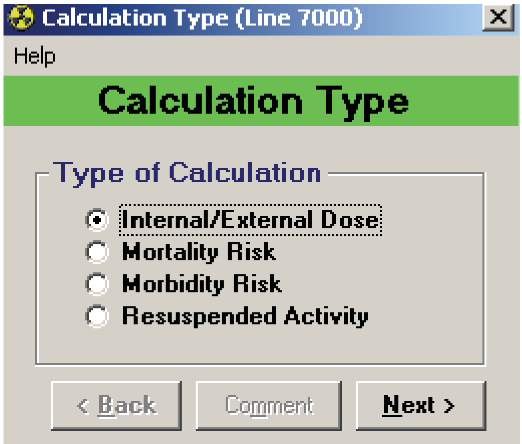


Figure 3-58. Dose Selection Screen.

Based on the type of calculation chosen, a different screen sequence will be presented (see Figure 3-59).

- Type of dose calculation – Internal/External
- Amount of printed output
- Dose unit
- If all elements are to be used in the calculation
- If all organs are to be included in the dose calculation.

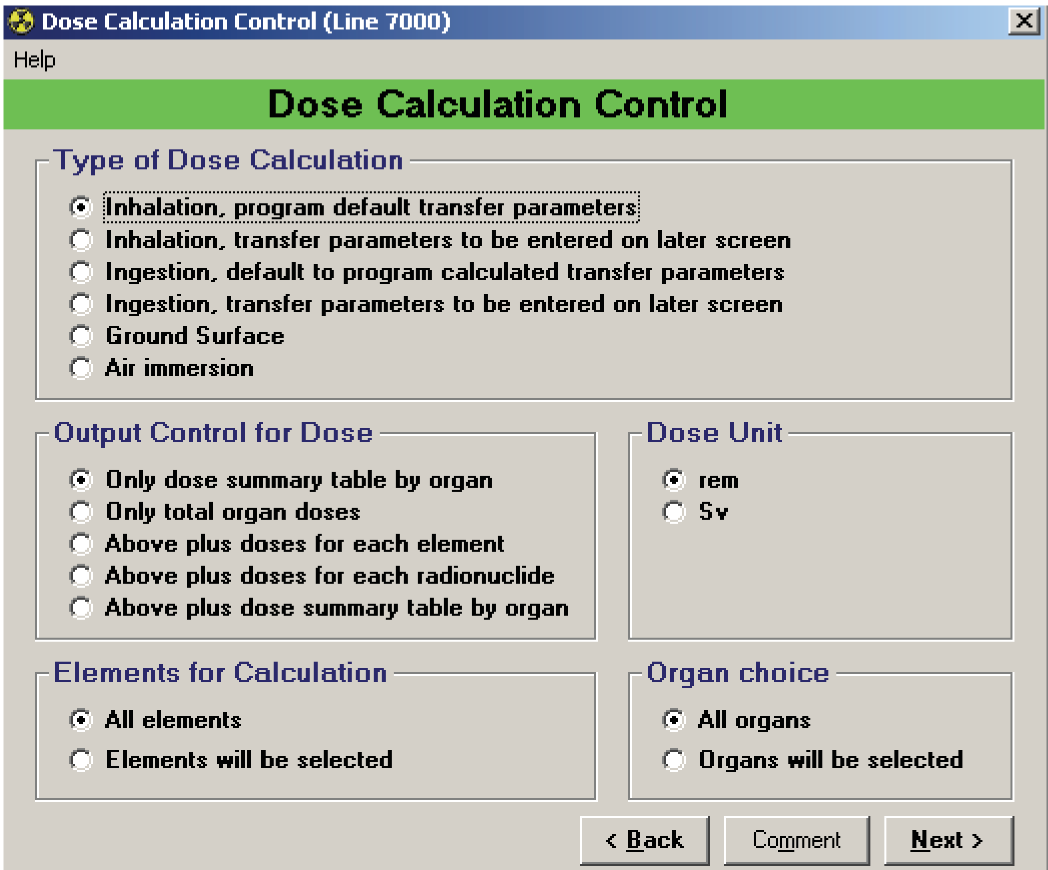


Figure 3-59. Screen 2, Dose Control Calculation.

Screen 3A (Optional) - Inhalation Dose Control: This screen appears only when option 1, 2, 7, or 8 is chosen for the *Type of Dose Calculation* on screen 2. Enter the breathing rate (m^3/s) and decay time (s) for exponential decay function (see Figure 3-60).

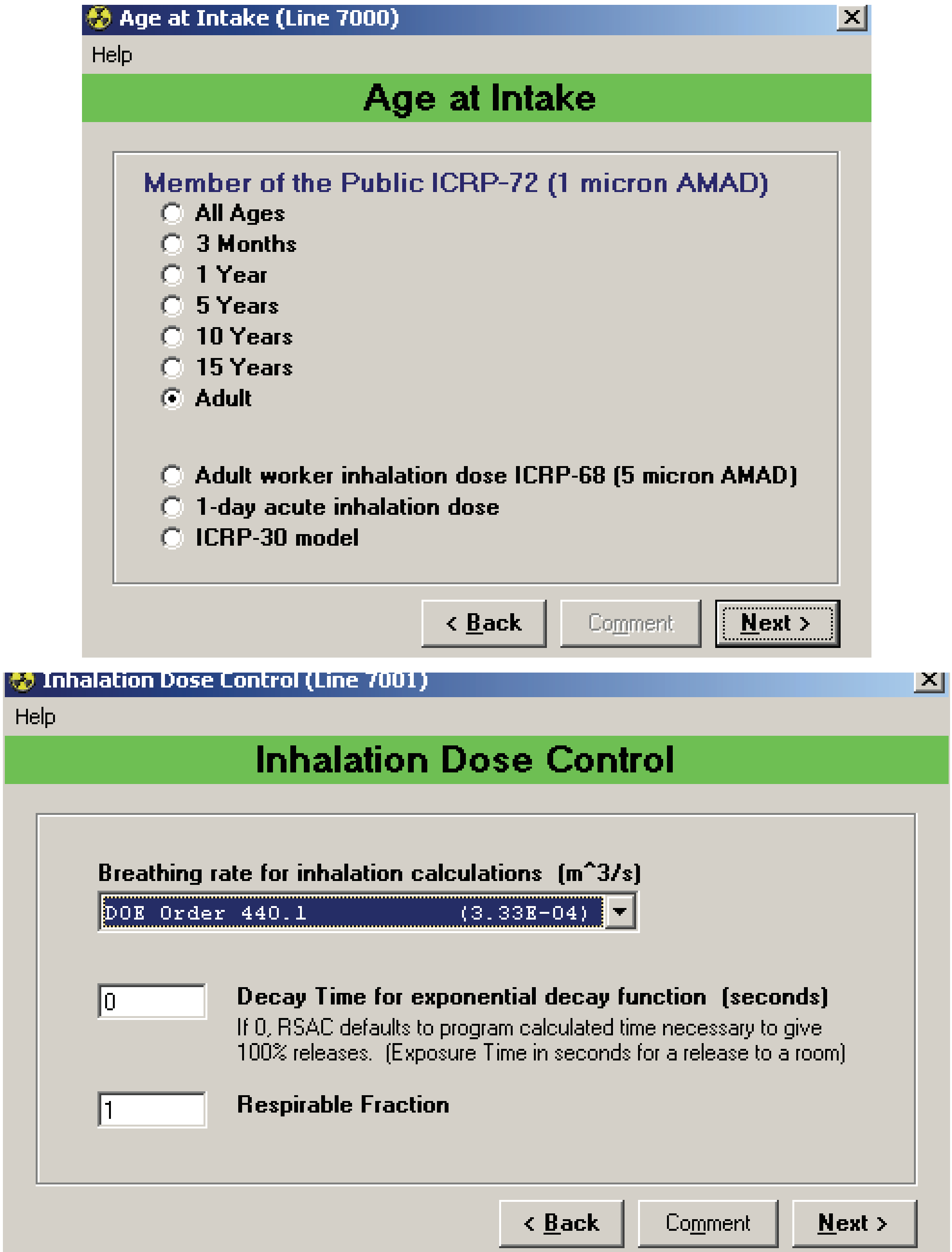


Figure 3-60. Screen 3A (Optional), Inhalation Dose Control.

Screen 4A (Optional) - Inhalation Parameters Dose Calculation: This screen appears only if option 2 or 8 is chosen for the *Type of Dose Calculation* on screen 2. Enter activity median aerodynamic diameter (AMAD) (μ) and whether default lung clearance classes are to be used (see Figure 3-61). If user input of lung clearance classes is chosen, the *Clearance Class Entry* screen will appear next.

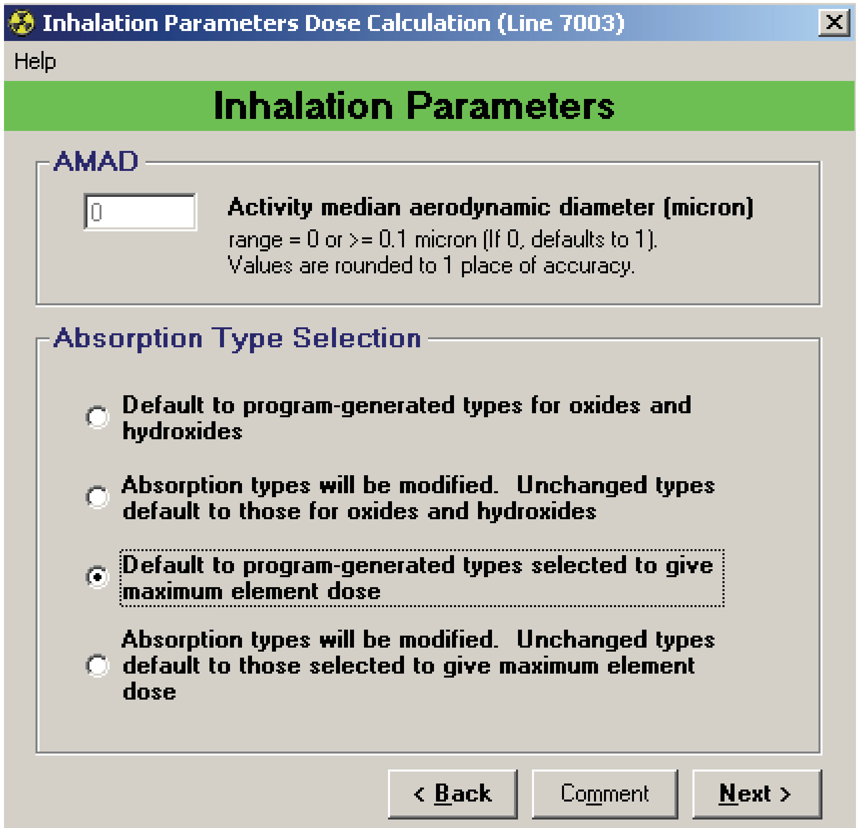


Figure 3-61. Screen 4A (Optional), Inhalation Parameters Dose Calculation.

Screen 5A (Optional) – Absorption Type Entry: Shown only if option 2 or 4 is chosen for *Absorption Type Entry* on screen 4A (see Figure 3-62). Scroll through the list and click on the desired element. A pop-up screen will appear showing the valid lung clearance classes for the chosen element. Select the desired lung clearance class and click on Continue.

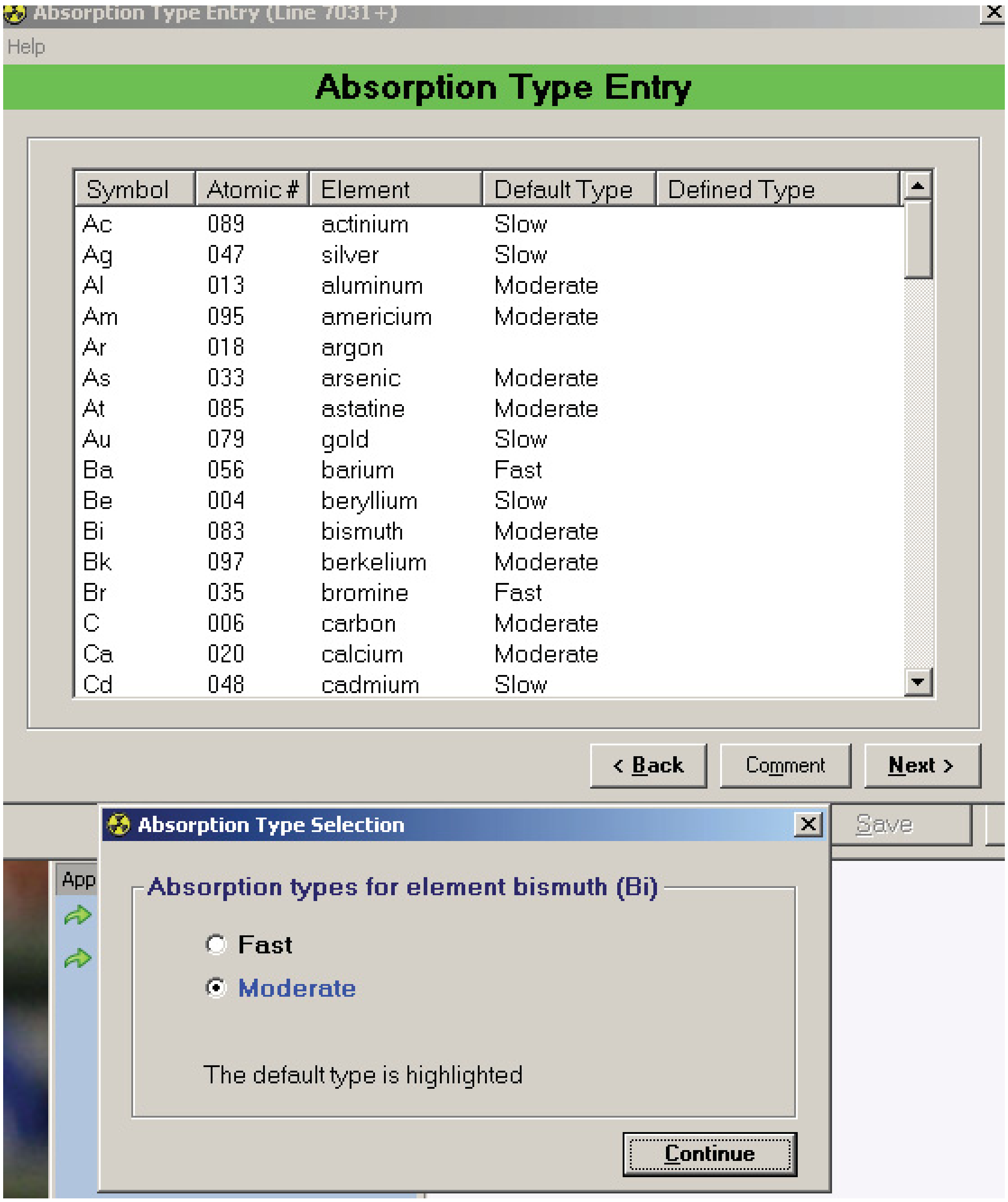


Figure 3-62. Screen 5A (Optional), Clearance Class Entry.

Mortality Risk Calculation- This screen appears when mortality risk is selected on the opening screen (see Figure 3-63).

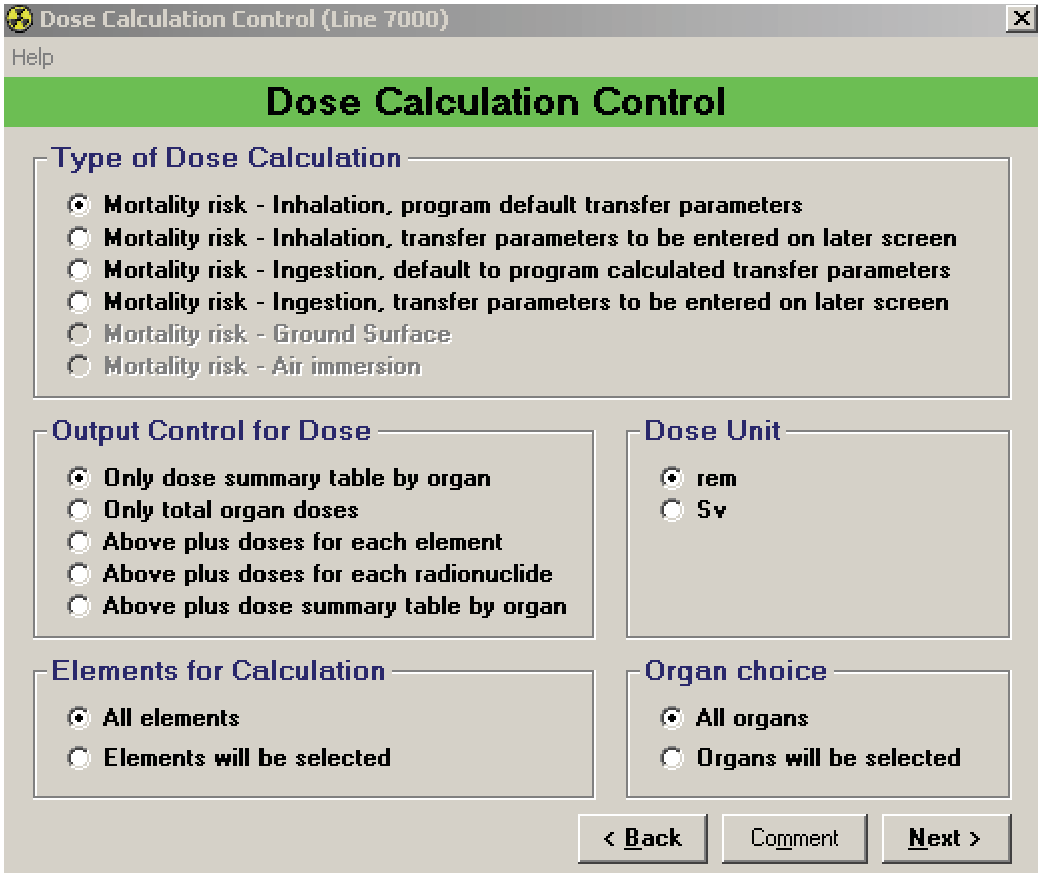


Figure 3-63. Mortality Risk Calculation screen.

All optional screens for inhalation/ingestion transfer parameters and output control are generated and controlled the same as for dose calculation. The primary difference is that summary output controls are specific to the risk calculation function and should be calculated separate from a dose calculation.

Morbidity Risk Calculation- This screen appears when mortality risk is selected on the opening screen (see Figure 3-64).

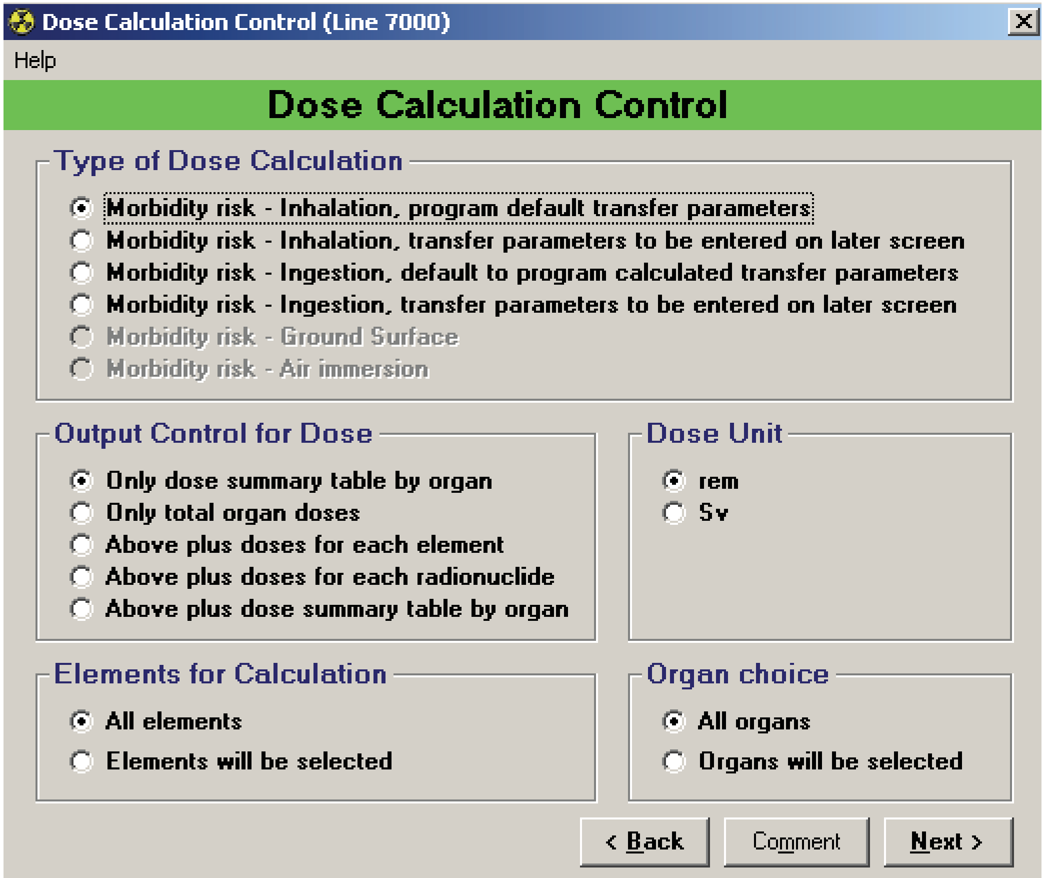


Figure 3-64. Morbidity Risk Calculation screen.

Screen 6 (Optional) - Resuspension of Activity: This screen appears onlyif option 7 or 8 is chosen for Type of Dose Calculation on screen 2 (see Figure 3-65).

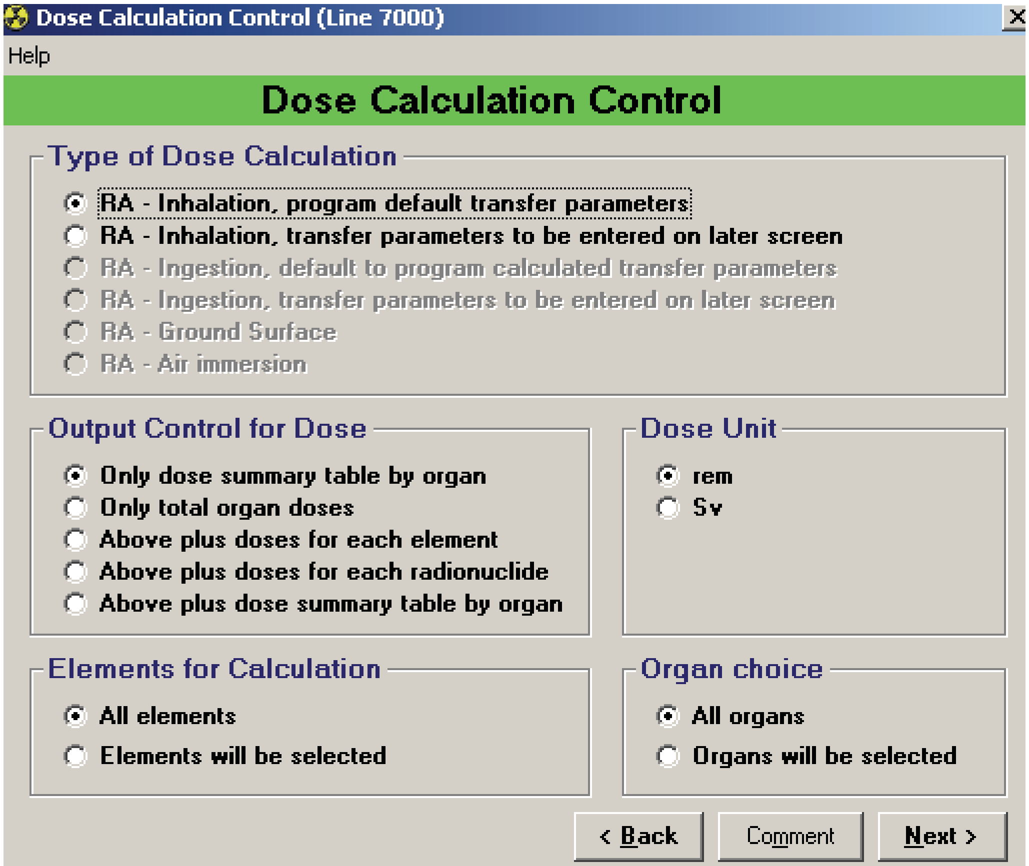


Figure 3-65. Screen 6 (Optional), Resuspension of Activity.

Screen 3B (Optional) - Ingestion Dose Parameters: This screen appears only if option 3 or 4 is chosen for *Type of Dose Calculation* on screen 2 (see Figure 3-66). Enter decay time (s) for exponential decay function and the plant midpoint of operating life (y).

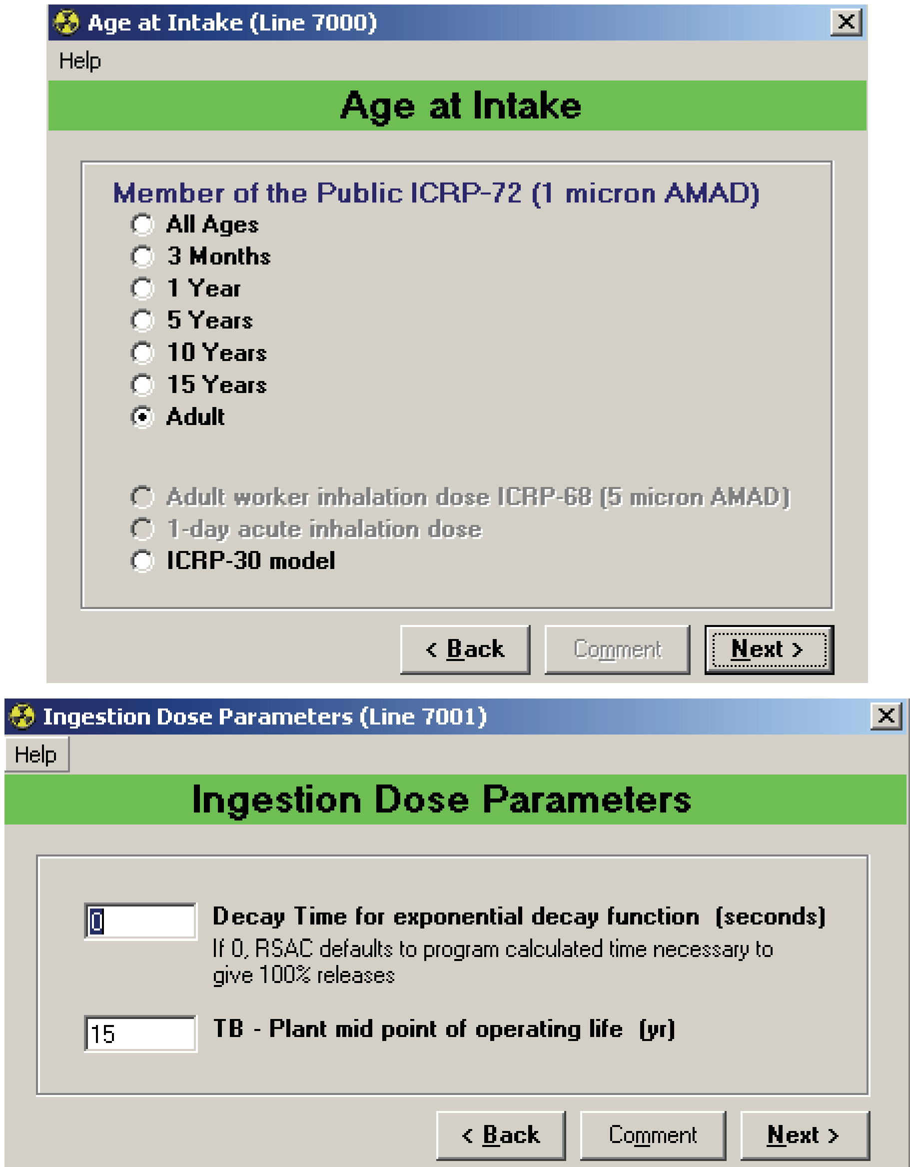


Figure 3-66. Screen 3B (Optional) - Ingestion Dose Parameters.

Screen 4B (Optional) - Ingestion Dose Control: This screen appears only if option 4 is chosen for *Type of Dose Calculation* on screen 2 (see Figure 3-67). Use this sequence of screens to choose whether to use default ingestion transfer parameters; whether the release is chronic, acute, or if ingestion parameters are to be user entered; the time period crops are exposed to contamination during the growing season when the release is not chronic; and the harvest duration period following the end of an acute release period. When you select to enter ingestion parameters, a series of screens will appear that contain the RSAC-7.2 default ingestion parameters.

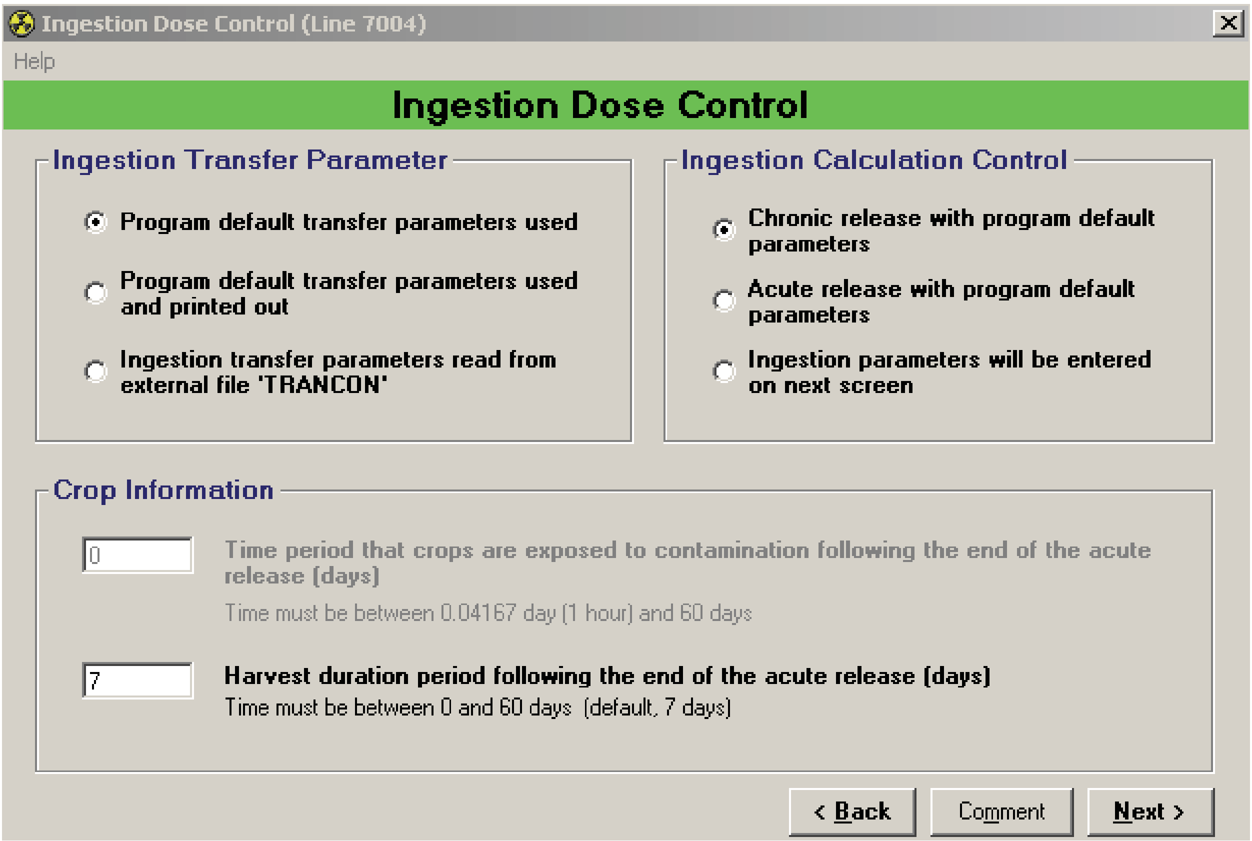


Figure 3-67. Screen 4B (Optional), Ingestion Dose Control.

Screen 5B (Optional) - Ingestion Dose Constants: This screen appears only if *Ingestion parameters will be entered on next screen* is chosen on screen 4B (see Figures 3-68 through 3-72).

NOTE: All tabs will need to be reviewed before continuing.

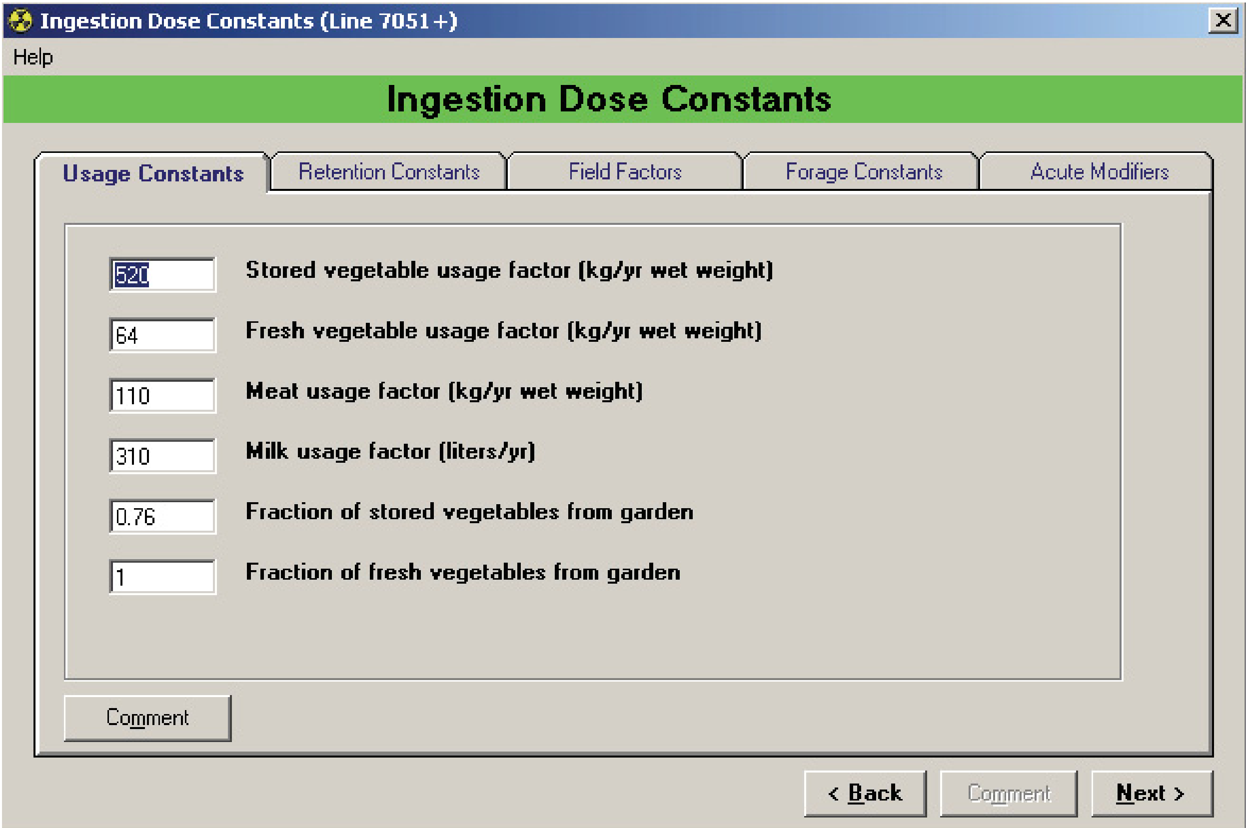


Figure 3-68. Screen 5B (Optional), Usage Constants Tab.

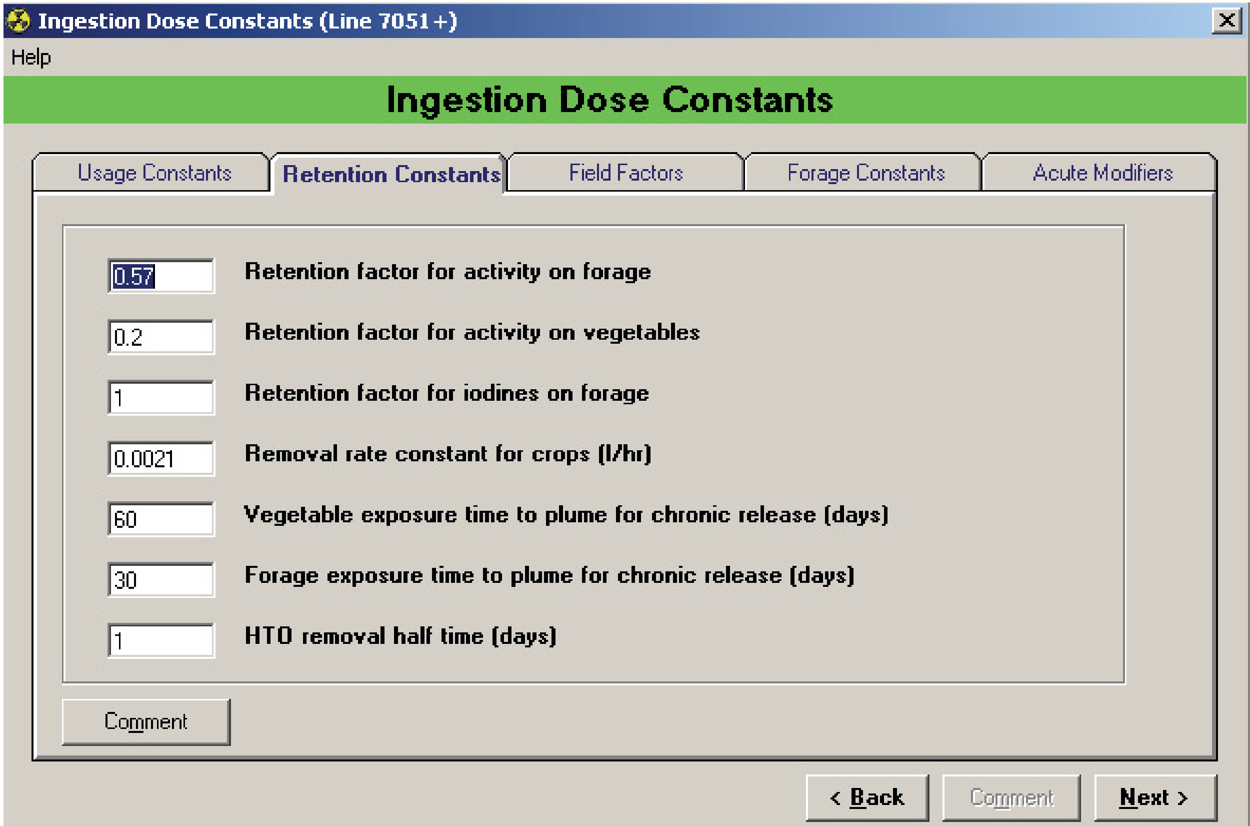


Figure 3-69. Screen 5B (Optional), Retention Constants Tab.

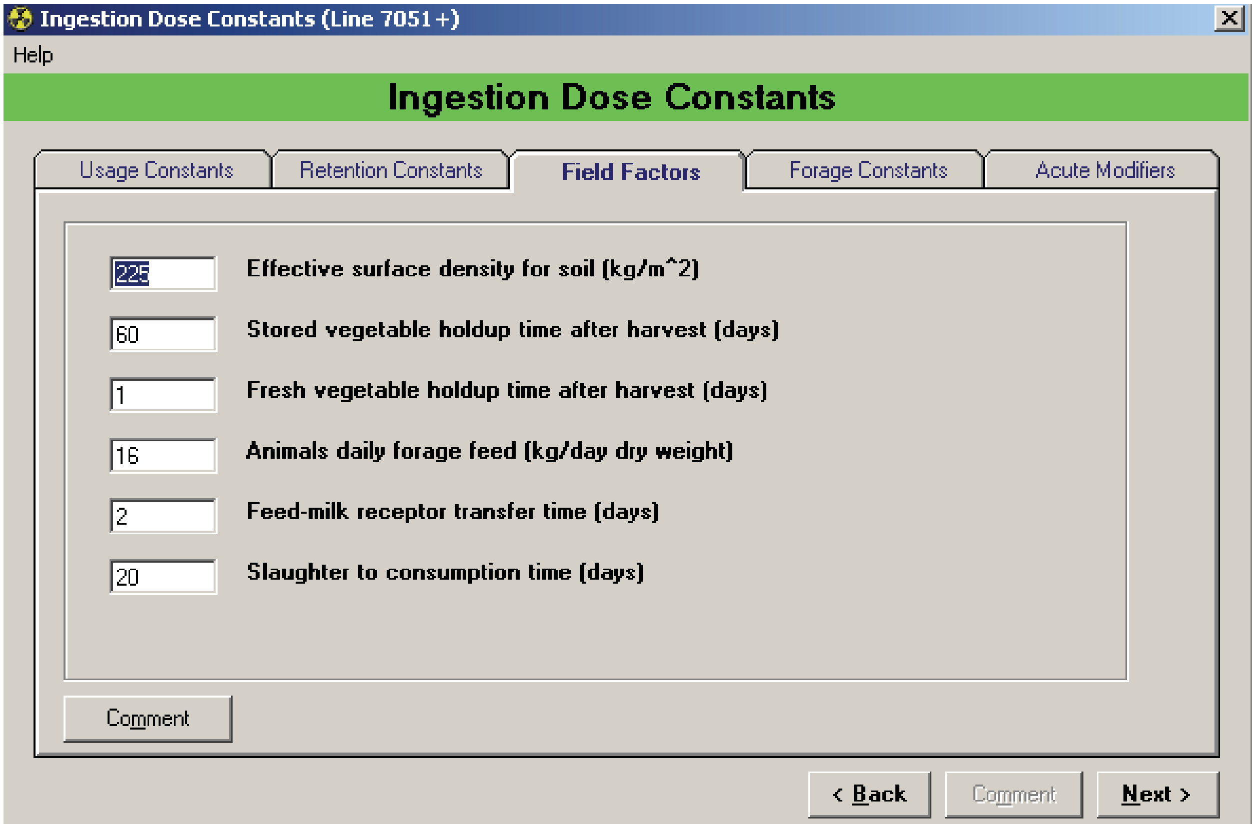


Figure 3-70. Screen 5B (Optional), Field Factors Tab.

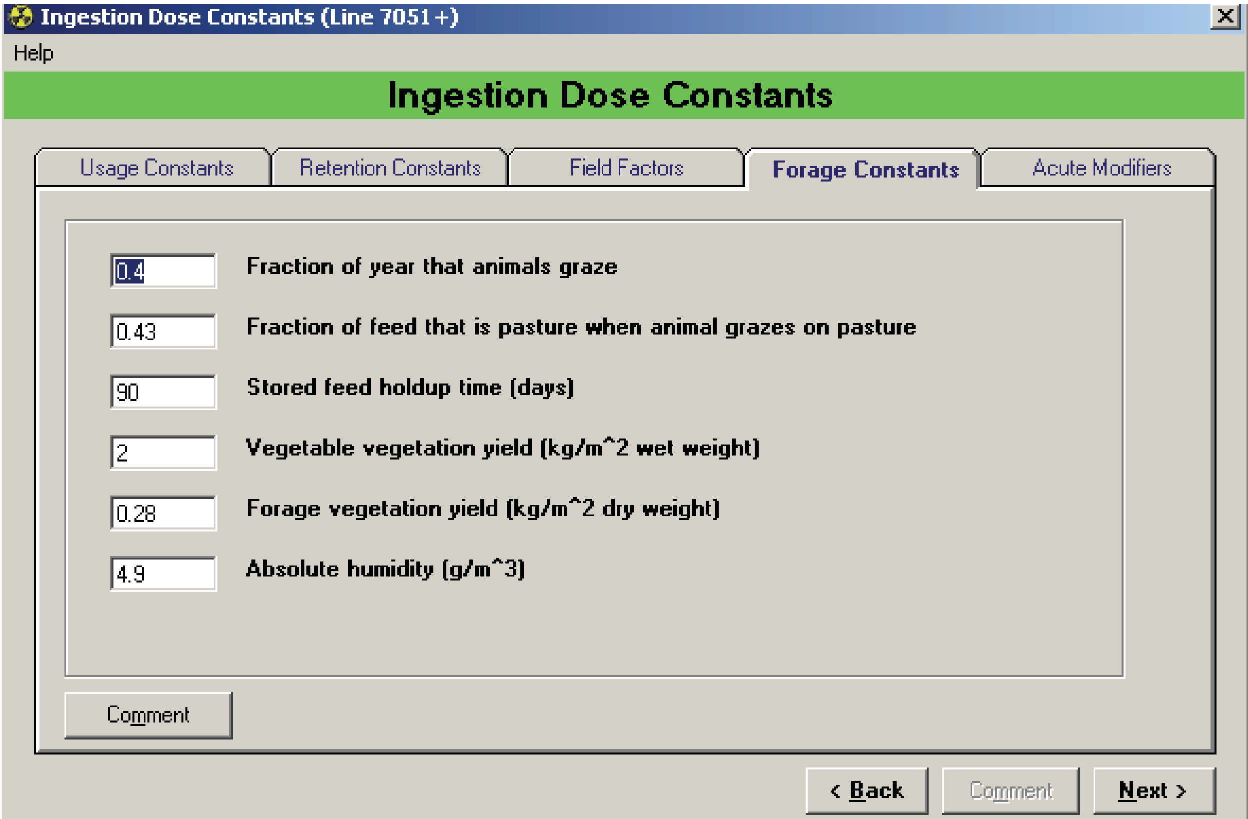


Figure 3-71. Screen 5B (Optional), Forage Constants Tab.

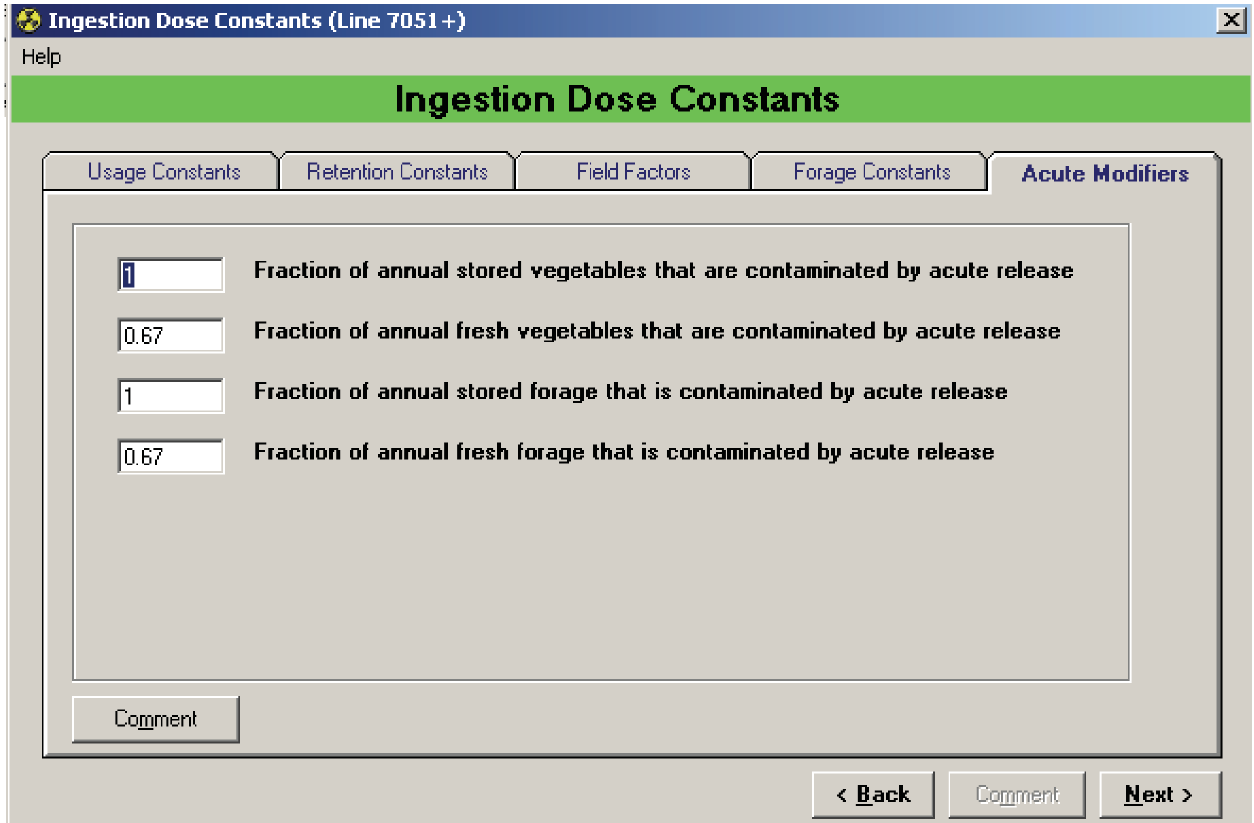


Figure 3-72. Screen 5B (Optional), Acute Modifiers.

Screen 3C (Optional) - Ground Surface Dose Parameters: Shown only if option 5 is chosen for *Type of Dose Calculation* on screen 2. Enter the decay time (s) for exponential calculations, exposure time of the receptor to contaminated ground surface, and the building shielding factor (see Figure 3-73).

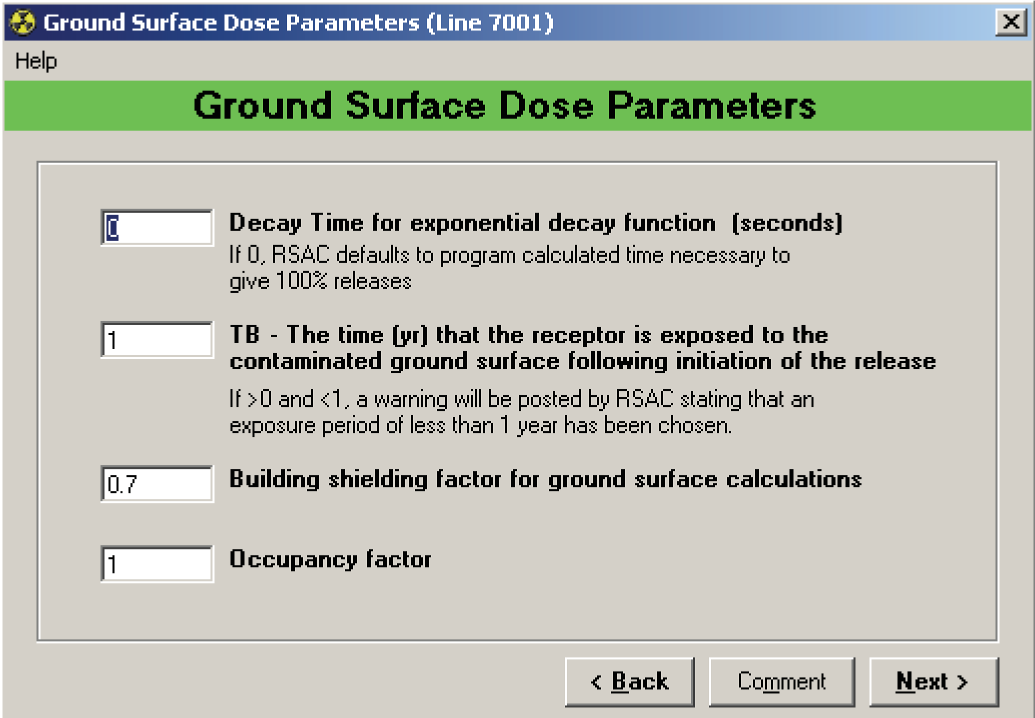


Figure 3-73. Screen 3C (Optional), Ground Surface Dose Parameters.

Screen 3D (Optional) - Air Immersion Dose Parameters: This screen appears only if option 6 is chosen for *Type of Dose Calculation* on screen 2. Enter decay time (s) for exponential decay functions (see Figure 3-74).

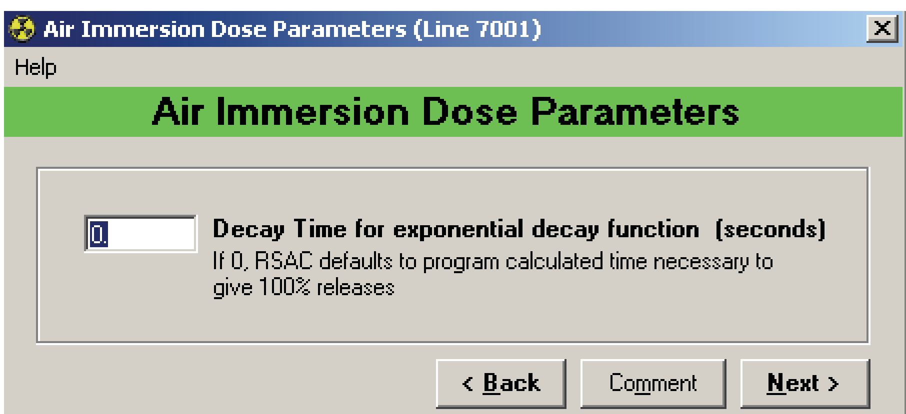


Figure 3-74. Screen 3D (Optional), Air Immersion Dose Parameters.

Screen (Optional) - Internal/External Organ Selection: This screen appears only if *Organs will be listed on a upcoming screen* is chosen on screen 2. On this screen (see Figure 3-75), select the organ using one of the following methods. Scroll through the list and click on the desired organ; type the organ name to quickly select the desired organ. To unselect an organ click it in the list a second time. To clear all selected, click the Clear Selected button.

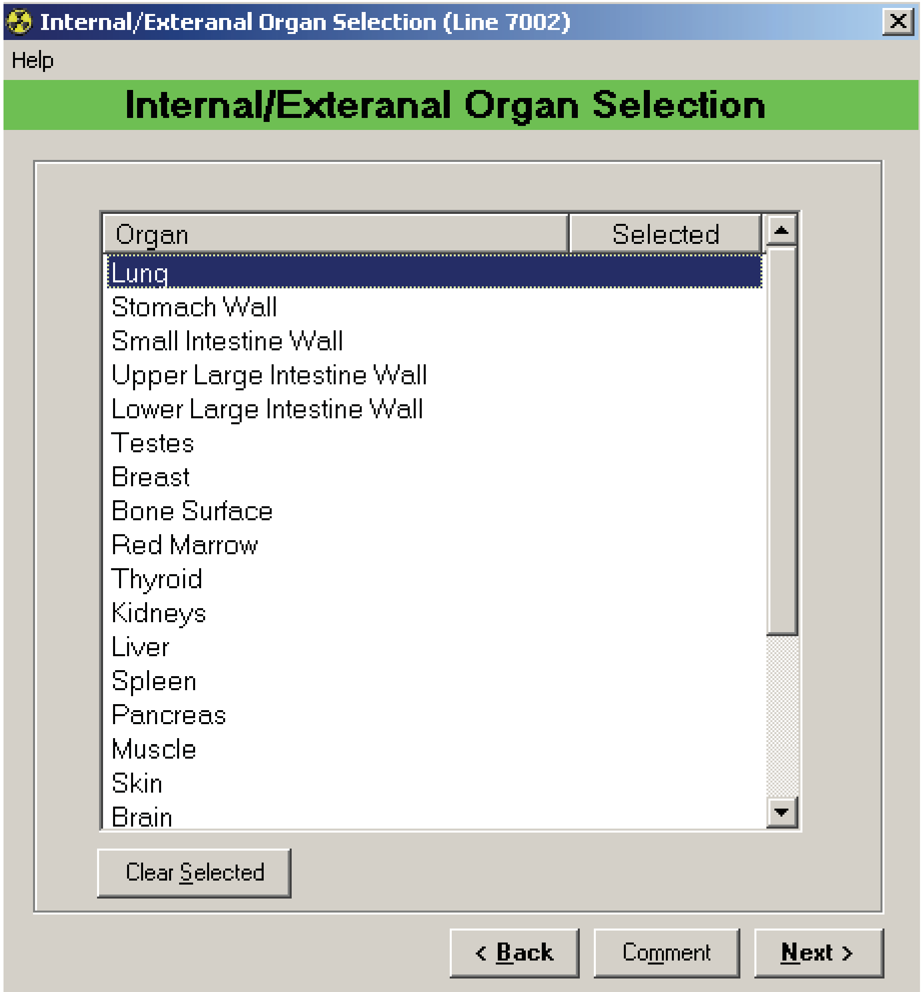


Figure 3-75. Screen (Optional), Internal/External Organ Selection.

Screen (Optional) - Element Selection: This screen appears only if *Elements will be listed on a upcoming screen* is chosen on screen 2. On this screen (see Figure 3-76), select the element using one of the following methods. Scroll through the list and click on the desired element; type the symbol to quickly select the desired element. To unselect an element click it in the list a second time. To clear all selected, click the Clear Selected button.

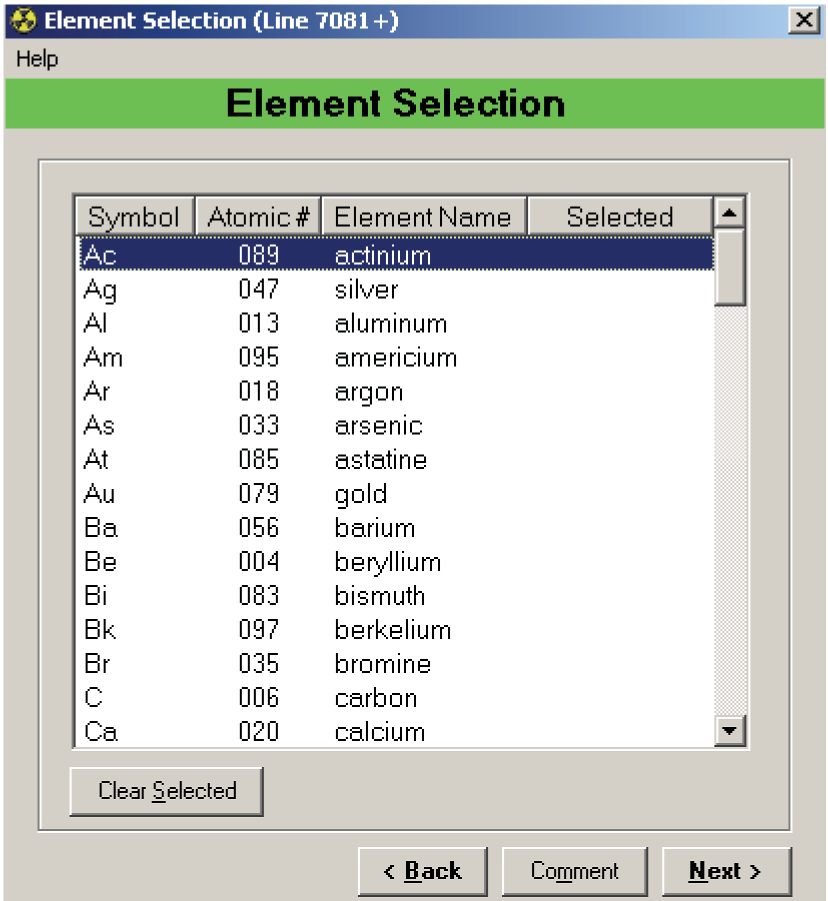


Figure 3-76. Screen (Optional), Element Selection.

3.2.7 9000 Series – Cloud Gamma Dose Calculation

Screen 2 - Cloud Gamma Dose Calculation: After the series title screen the cloud gamma does calculation screen appear asking whether calculations are to be made using the finite or semi-infinite plume model (see Figure 3-77). By checking which calculation should be used the inputs for the exponential decay function will be enabled.

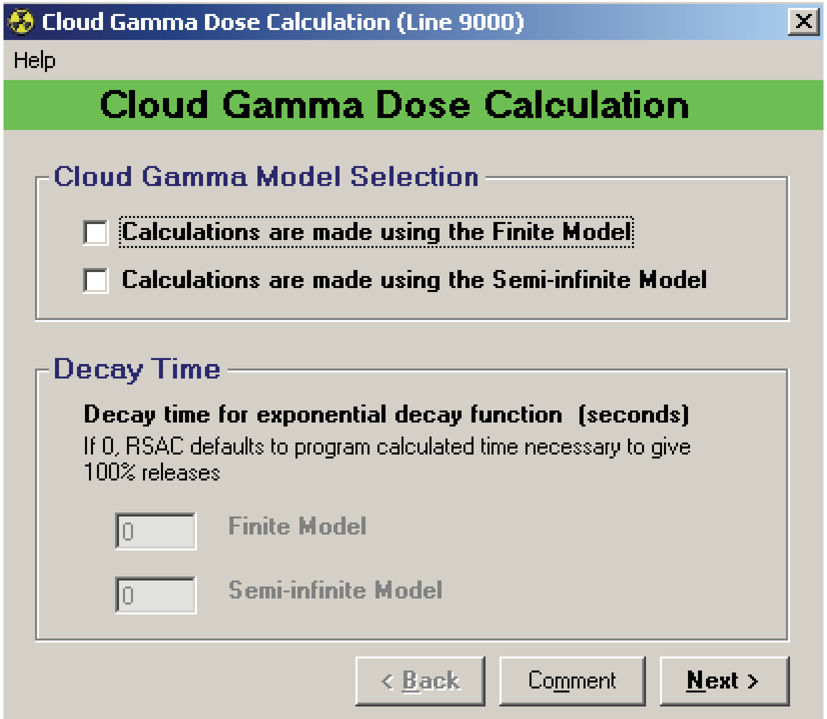


Figure 3-77. Screen 2, Cloud Gamma Dose Control.

3.3 Critdos Subroutine

CRITDOS calculates the prompt neutron doses using the NRC Regulatory Guide 3.33 (RG 3.33) equations. Both unshielded and shielded direct doses are calculated based on the total fission yield of the postulated criticality, the distance from the criticality to the receptor, equivalent concrete thickness of the shield, and the system being analyzed (i.e., neutron escape fraction based on the system size).

The gamma and neutron attenuation factors given in RG 3.33 vary according to the thickness of the concrete. That is, the first few inches of concrete are not as effective at attenuating radiation as the remaining thickness of concrete. Equations have been derived and put into CRITDOS that take this into account. In addition, the equations for concrete shielding that is less than 12 in. thick have been modified to make them more realistic (i.e., best estimate rather than conservative).

The equations for calculating a dose, in rem, from RG 3.33 are based on 10% of the neutrons escaping from the system. The equations in CRITDOS have been modified to allow the user two additional options for neutron escaping from the system. In addition to the 0.10 escape fraction, which is representative of a large moderated system, the user can choose a moderated system with an escape fraction of 0.30 or a small unreflected metal system with an escape fraction of 0.70.

To run the Critdos subroutine click on the Critdos tab and click the *Launch Critdos* link (see Figure 3-78).

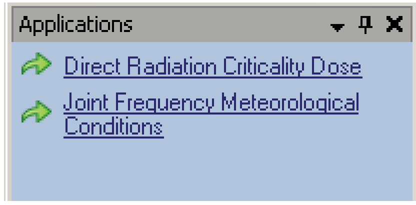


Figure 3-78. Applications Tab.

Screen 1 - Data Input: Use this screen to supply the following information (see Figure 3-79): The title that will appear on each page of output: The total fissions; Distance in feet; Concrete thickness in inches; and the System type.

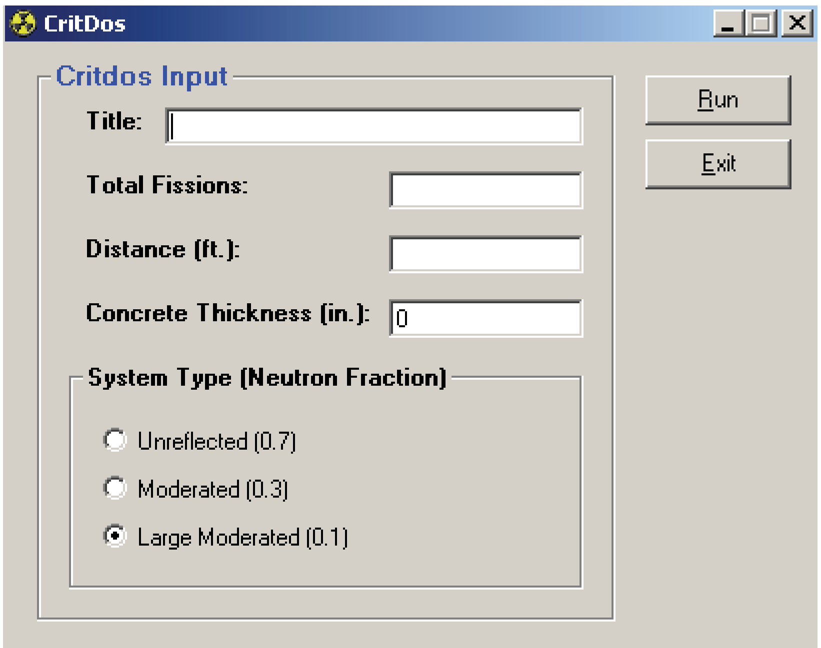


Figure 3-79. Screen 1, Data Input.

Screen 2 - Program Output: Displays the output results from Critdos (see Figure 3-80).

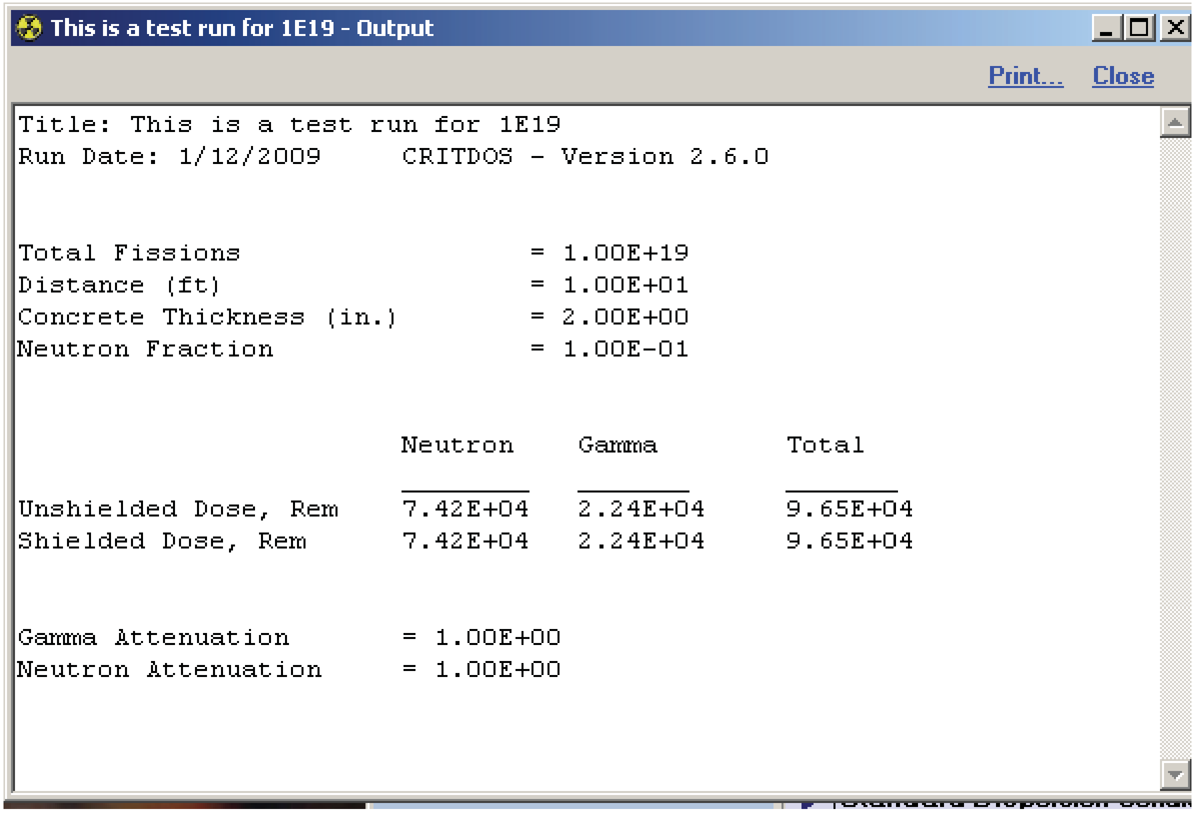


Figure 3-80. Screen 2, Program Output.

3.4 MetCond Subroutine

The metCond subroutine uses a joint frequency distribution to define the meteorological conditions where normalized concentrations (χ/Q) are exceeded no more than 5% and 50% of the time. The metCond subroutine defines this condition on data as summarized by the National Weather Service (NWS) meteorological data, CD-144 format. The input is a joint frequency distribution of 6 windspeeds, 16 wind directions, and 6 stability categories (Pasquill - Gifford: A through F) for the station and time period desired. The computational program is written in FORTRAN, and the user interface is written in VisualBasic for DOS. The joint frequency data for a significant number of locations have been provided integral to the software. If your specific location is not available, the data are available from the NWS and can be directly added to the library.

Joint Frequency Meteorological Conditions

A description of the facility and its reason for selection is placed in the top frame (see Figure 3-81). This program reads standard STAR data obtainable from most airports and consists of a reduction of hourly readings to a form that can be evaluated in a joint frequency model. The output is a metrological stability class and wind speed that represents the conditions where 95% of the time will result in lower dose to a receptor.

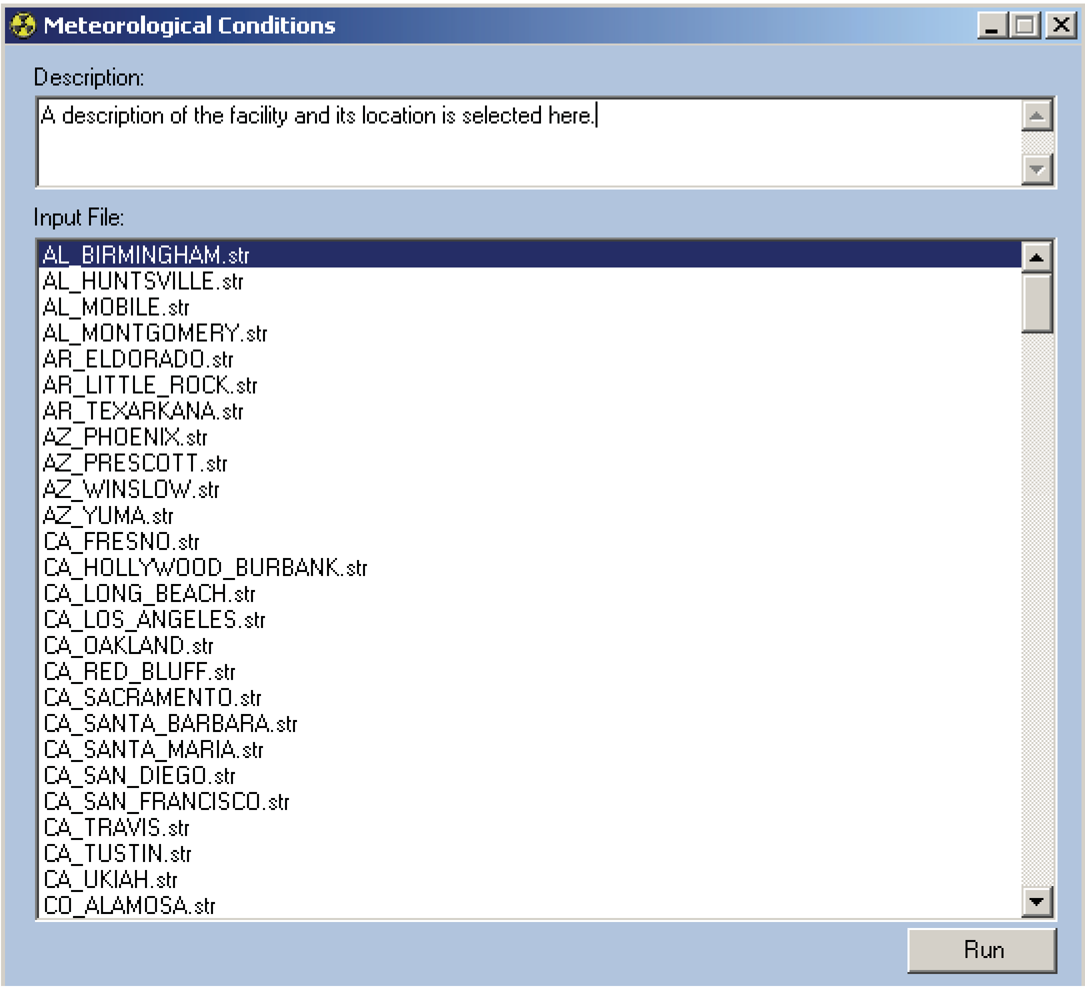


Figure 3-81. Meteorological Conditions screen.

A joint frequency table is generated as shown in Figure 3-82.

SUMMARY TABLE			WINDSPEED (m/s)			
SC	1.04	2.46	4.47	6.93	9.61	13.91
A	0.01217	0.00488	0.00000	0.00000	0.00000	0.00000
B	0.03829	0.02166	0.00972	0.00000	0.00000	0.00000
C	0.01991	0.02998	0.04009	0.00937	0.00187	0.00058
D	0.03847	0.06103	0.11962	0.17756	0.07013	0.02500
E	0.11610	0.13765	0.06599	0.00000	0.00000	0.00000
F	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
G	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
TOTAL	1.000					

Figure 3-82. Generated joint frequency table.

From that data two points of interest are reported (see Figure 3-83).

```
50TH PERCENTILE OCCURS IN STABLILTY CLASS C, 2.46 m/s WINDSPEED


 95TH PERCENTILE TABLE          WINDSPEED (m/s)

  SC     1.04     2.46     4.47     6.93     9.61    13.91
    A   0.01217  0.00488  0.00000  0.00000  0.00000  0.00000

    B   0.03829  0.02166  0.00972  0.00000  0.00000  0.00000

    C   0.01991  0.02998  0.04009  0.00937  0.00187  0.00058

    D   0.03847  0.06103  0.11962  0.17756  0.07013  0.02500

    E   0.06603  0.13765  0.06599  0.00000  0.00000  0.00000

    F   0.00000  0.00000  0.00000  0.00000  0.00000  0.00000

    G   0.00000  0.00000  0.00000  0.00000  0.00000  0.00000


95TH PERCENTILE OCCURS IN STABLILTY CLASS E, 1.04 m/s WINDSPEED

THE TABLE CAN BE USED TWO WAYS.

    FIRST  - ASSUME 100% OF THE RELEASE IS THAT MET/STABILITY CLASS
             FOR EITHER 50th OR 95th PERCENTILE CONDITIONS
             WHICHEVER IS APPICABLE.

    SECOND - CALCULATE A DOSE CONSEQUENCE FOR EACH OF THE CONDITIONS
             THEN MULTIPLY THE VALUES OF THE TABLE BY THE RESULTS OF THE
             APPROPRIATE MET/STABILITY CLASS PERCENTAGE.   SUM THE VALUES
             TO GENERATE A DOSE CONSEQUENCE FOR A 95% JOINT FREQUENCY TABLE

    THE MOST CONSERVATIVE METHOD IS TO ASSUME 100% OF THE RELEASE AT
    THE 95% CONDITIONS.  EITHER WAY CAN BE DIRECTLY INPUT INTO RSAC7.
```

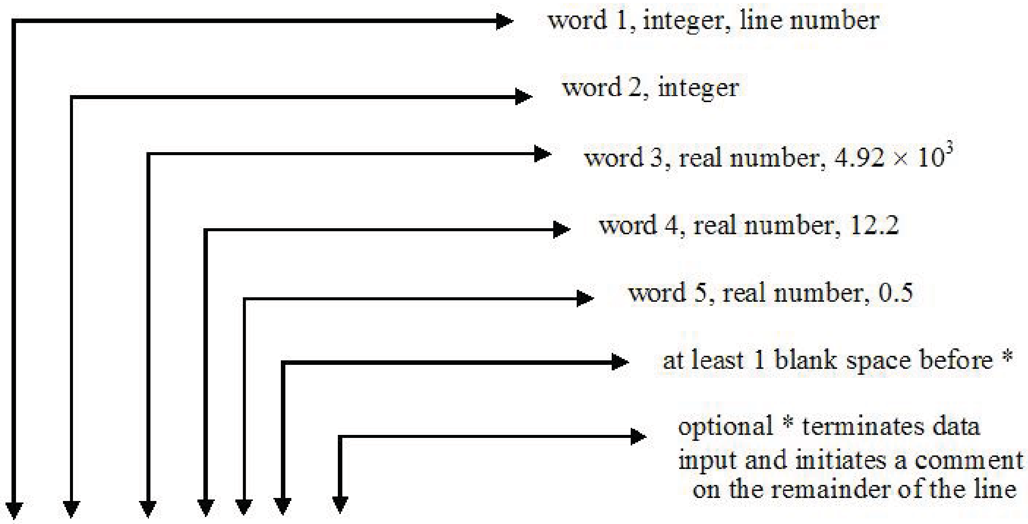
Figure 3-83. Table generated from two points of interest.

INTENTIONALLY BLANK

4. Reading the RSAC-7.2 INPUT File

4.1 RSAC-7.2 Input

A typical RSAC-7.2 input line includes



5400,1,4.92+3,12.2,.5 *YOUR COMMENT ON LINE

Other variations of this same line include

5400, 1, 4.92E3, 12.2, 5.E-1 *YOUR COMMENT ON LINE

5400 1 492+4 1.22E+1 5.-1 *YOUR COMMENT ON LINE

A comma or a blank space can be used as delimiters between entries. Each integer or real number entry is referred to as a "word." The first word of every line is referred to as the "line number," which is used to check input sequences.

As shown in the third word of the last variation above (492 + 4), when a real number does not contain a decimal point, the decimal point is assumed to appear before the first digit. However, you are encouraged to place a decimal point in real numbers. The following RSAC-7.2 input descriptions assume that all words are real numbers unless otherwise noted. Changes from RSAC-6 to RSAC-7.2 are noted in red.

The input descriptions in this section include word, program name, entry, and description information. The word column presents the location of the entry. The program name column identifies the name given to the variable in the source program and is not input on a line. The entry and description columns provide the entry numbers or type of entry and their corresponding descriptions.

To insert a comment line, type a # sign in the first column. There is no limit to the number of comment lines you can insert. Comment lines are printed in the RSAC-7.2 ASCII input file and appear in the list of input printed at the beginning of each output file.

The example runs in Section 5 will help you learn how to prepare ASCII input for the RSAC-7.2 program.

4.2 Calculation Title Line

Column	Entry
1	*
2-72	Page heading (alphanumeric)

RSAC-7.2 ignores all lines of input until it reads a line that contains an asterisk in column 1. This allows the program to start the next problem if an error is found in the input. If output is not received from an RSAC-7.2 run, check to see if a line contains an asterisk in column 1.

4.2.1 1000 Series – Fission Product Inventory Calculation and Inventory Decay

Use a *Fission Product Calculation and Inventory Decay Control Line (1000)* to initiate fission product inventory calculations or inventory decay calculations of a directly input radionuclide inventory. Input the following lines to describe the reactor operating history and the fractionation of the fission product inventory. This calculation generates a fission product inventory only. It does not calculate the actinides available for release. These should be directly input using a 2000 series and may be added to the calculated fission product inventory. If subsequent decay is required, an additional 1000 series should be used to calculate the decay of inventory. The 6000 series does not calculate a decayed inventory for subsequent release. It will only decay the inventory for printout purposes.

4.2.1.1 Fission Product Inventory Calculation and Inventory Decay Control Line (1000)

Word	Variable Name	Entry	Description
1		1000	

4.2.1.2 Inventory Control/Initial Reactor Data Line (1001)

The required Inventory Control/Initial Reactor Data Line (1001) must immediately follow the Fission Product Inventory Calculation and Inventory Decay Control Line (1000). Use the control word on this line to indicate whether you are

a) calculating a new fission product inventory (actinides are not calculated) or
b) modifying a previously calculated radionuclide inventory.

If you want to calculate a new fission product inventory, enter the reactor power, and operating time on this line. The next line may be a *Refueling Line (1002), Decay/Cycle Line (1003)*, or *Fractionation Line (1004)* to modify the release calculation.

If you are modifying a directly input radionuclide inventory, the remaining words on this line are ignored (but must be present) and the next line must be a *Refueling Line (1002), Decay/Cycle Line (1003)*, or *Fractionation Line (1004)*.

Word	Variable Name	Entry	Description
1		1001	
2		Integer	Control word:
		0	Calculations start with no previous radionuclide inventory.
		1	Previous radionuclide inventory is retained and the next line must be a *Refueling Line (1002)*, *Decay/Cycle Line (1003)*, or *Fractionation Line (1004)*. The values for the remaining words on this line are ignored; however, values for each of the following words must be present.

Word	Variable Name	Entry	Description
3	POWER		Reactor power (W) or 0.0 if word 2 = 1 If megawatt days (MWd) of an operating cycle are known use the following conversion to generate the inputs for words 3 and 4. If operating power and MWd are known: 8.64 E10 W-s/MWd, then divide through by the average power (W) for the cycle, and the resultant will give the reactor operating time in seconds. If operating time and MWd are known: 8.64 E10 W-s/MWd, then divide through by the operating time (seconds) for the cycle, and the resultant will give an average reactor power in watts.
4	TROP		Reactor operating time at the above power (s) or 0.0 if word 2 = 1.

4.2.1.3 Refueling Line (1002)

Word	Variable Name	Entry	Description
1		1002	
2			The fraction of radionuclide inventory remaining after refueling. This is the same total inventory fractionation as performed when word 2 of *Fractionation Control Line (1004)* is equal to 2.

The *Decay/Cycle Line (1003*) is used to calculate the inventory decay as generated with an *Inventory Control/Initial Reactor Data Line (1001)* or a 2000 series directly input radionuclide inventory. This is the only location in the program where the radionuclide inventory decay can be calculated. A 6000 series decay does not calculate an inventory decay for subsequent release. If a subsequent reactor cycle is required then words 3 and 4 can be used to cycle the reactor.

4.2.1.4 Decay/Cycle Line (1003)

Word	Variable Name	Entry	Description
1		1003	
2	TTROP		Decay time or reactor shutdown time before this cycle (s).
3	POWER		Reactor power for cycle (W). If zero, TROP below is set to zero, and the next entry is ignored.
4	TROP		Reactor operating time at above reactor power for this cycle (s). This quantity is set to zero if reactor power above is zero.

4.2.1.5 Fractionation Control Line (1004)

Use this line to release a fraction of the radionuclide inventory and simulate removal of activity by cleanup systems such as HEPA filters. Use the control word on this line to determine whether the type of fractionation is by group, by a constant value, or by element. Specify fractionation by the following groups: solids, halogens, noble gases, cesium, and ruthenium. Enter the fractionation value for each group on this line. If the constant fractionation option is used, the entire radionuclide inventory is fractionated by the next value entered on this line. If fractionation by element is chosen, enter a fractionation value for those elements not described by an *Element Fractionation Lines (1101+)* on this line. Enter the *Element Fractionation Lines (1101+)*, describing the fractionation of each desired element.

Word	Entry	Description
1	1004	
2	-1	Fractionation by group as specified by the next five words.
		Fractionation for solids.
4		Fractionation for halogens.
5		Fractionation for noble gases.
6		Fractionation for cesium.
7		Fractionation for ruthenium.
2		Fractionation is by a constant specified by the next word.
3	FRAC	Fractionation for entire radionuclide inventory.
2	1	Fractionation by element. Following lines will be *Element Fractionation Lines (1101+)*.
3	FRAC	Fractionation for elements not described by *Element Fractionation Lines (1101+)*.

4.2.1.6 Element Fractionation Lines (1101+)

Use these lines only if you want fractionation by element.

Word	Entry	Description
1	Integer	11XX (XX = 01, 02,..., etc.)
2	Integer	Atomic number of element.
3		Fractionation for above element.
.		.
.		.
2N	Integer	N^{th} atomic number
2N + 1	x	N^{th} fractionation

Enter additional sets of two values on this and following lines until all desired elements have been described. The number of sets per line is optional.

4.2.1.7 Release During Simulated Reactor Operations Line (1200)

Use this optional control line to simulate radionuclide releases from a reactor while it is operating. Insert a *Release During Fission Product Calculation Line (1200)* immediately following either the *Initial Reactor Data Line (1001)* or the *Cycle Line (1003)* to modify the reactor operations requested by the *(1001)* or *(1003)* lines.

A *Reactor Linear Leak Rates Line (1201)* must immediately follow a *(1200)* line. Activity is removed from the reactor incrementally using the number of chosen steps (1 to 100) over the entire reactor operating cycle requested by a *(1001)* or *(1003)* line. The number of steps should reflect the need for resolution of the release. The more steps, the more exact the totals will be for the shorter lived radionuclides.

RSAC-7.2 has two memory buffers for storing radionuclide inventories: main and hold. The activity remaining in the reactor is stored in a main memory buffer, and the activity released from the reactor is stored in the hold memory buffer. You can choose whether the activity leaked from the reactor (hold buffer) or that remaining in the reactor following operations (main buffer) is used in further calculations. When you choose the option to retain the activity remaining in the reactor after encountering a *(1999)* line, the main memory buffer is retained for further calculations and the hold buffer is deleted. Normally the activity leaked from the reactor (hold buffer) is used for release calculations.

When you choose the option to retain the activities released from the reactor during each step increment are summed to give the total amount of each radionuclide released from the reactor during the total operating period. After activity is entered into the hold memory buffer, it cannot be decayed until after a *Fission Product Calculation and Inventory Decay End Line (1999)* is encountered When you choose the option to retain the activity released from the reactor, the hold memory buffer is copied to the main memory buffer for subsequent calculations, and the radionuclide inventory that was remaining in the reactor is deleted.

After a *(1200)* line is encountered, it remains in effect on all subsequent reactor cycle operations (*Cycle Line [1003*]) until either another *(1200)* line or a *Fission Product Calculation and Inventory Decay End Line (1999)* is encountered.

When the *(1200)* line option is used, all subsequent fractionations of the radionuclide inventory using *(1004)* lines (until a *[1999]* line is encountered) are made on the inventory chosen to be retained for subsequent calculations. If desired you can make even further decay (and fractionation) by exiting the 1000 Series with a *(1999)* line and reentering the 1000 Series with another *(1000)* line.

Word	Variable Name	Entry	Description
1		1200	
2	NCS	Integer	Number of reactor release steps (≤100)
3	KEEPFLAG	Integer	Inventory to be retained for subsequent calculations:
		0	Retain activity remaining in reactor
		1	Retain activity remaining in reactor

4.2.1.8 Reactor Linear Leak Rates Line (1201)

You must insert the *Reactor Linear Leak Rates Lines (1201)* immediately following a *(1200)* line to establish the leak rates for the different groups of fission products. Calculation of the Linear Leak Rate is performed by dividing the fraction of the group to be released from the reactor by the total reactor operating time of the cycle in seconds.

Word	Variable Name	Entry	Description
1		1201	Radionuclide leak rate from the operating reactor (fraction/s)
2	RR(1)		Solids
3	RR(2)		Halogens

Word	Variable Name	Entry	Description
4	RR(3)		Noble gases
5	RR(4)		Cesium
6	RR(5)		Ruthenium

4.2.1.9 Fission Product Calculation and Inventory Decay End Line (1999)

Use this line to end the fission product inventory calculation or inventory decay requested by the last *Fission Product Calculation and Inventory Decay Line (1000)*.

Word	Entry
1	1999

4.2.2 2000 Series – Direct Radionuclide Input

Use the *Radionuclide Direct Input Control Line (2000)* to initiate directly entering the radionuclide inventory in curies instead of using a fission product inventory. All radionuclides are identified by the radionuclide identification number (NUCL) or by entering the element symbol followed by the atomic number.

4.2.2.1 Radionuclide Direct Input Control Line (2000)

This control line has one data word that identifies whether an existing radionuclide inventory should be deleted, changed, or appended. If the option to change or append the file is chosen, the previous radionuclide inventory can be from another directly calculated (1000 series), input or another external file. It is important to understand that if an inventory decay is required, it must be done in a 1000 series decay (1003) line. A 6000 series decay calculation is for display and print purposes only and will not calculate the active inventory decay.

Word	Entry	Description
1	2000	
2	0	Radionuclide inventory input option is chosen. Any previous radionuclide inventory is deleted. Radionuclide entry lines or an external file (2002) may be identified. If direct input of radionuclides and their respective activities is desired then the requirements of Radionuclide Entry Lines must be followed. If an external file is requested the requirements of line (2002) must be followed.
	1	Same as for entry 0 except the previous radionuclide inventory is retained and the activity of the chosen radionuclide is changed to that indicated on either the Radionuclide Entry Lines or an external file.
	-1	Same as for entry 0 except the previous radionuclide inventory is retained and the activity of the chosen radionuclide is added to that indicated on either the Radionuclide Entry Lines or an external file.
3	0	curie
	1	gram
	2	Bq

4.2.2.2 Radionuclide Entry Lines

Radionuclide Entry Lines are present only when an external file *(2002)* line option is not selected. Following the last entry of an inventory for a radionuclide, you must enter an *Input End Line (2999)*.

Word	Variable Name	Entry	Description
1	NUCL	Integer	Radionuclide identification number (see 4000 Series, *Radionuclide Data Change Line*). An alternate entry can be made by replacing NUCL with the element symbol (in capital letters) followed by the mass number and metastable state indicator. Examples of allowable styles include Cs137, Cs-137, Cs 137 Ba137m, Ba-137m, Ba 137m CS137, CS-137, CS 137 BA137M, BA-137M, BA 137M
2			The amount in curies, grams, or Bq as specified in the 2000 line of this radionuclide.

Make additional line entries until all desired radionuclides have been entered into the radionuclide inventory. Only one radionuclide and associated curies per line is allowed. Line numbers are not required.

4.2.2.3 External Radionuclide File Control Line (2002)

This optional line allows you to specify an external file for inputting radionuclide inventories. This line may follow Line *(2000)*. Data in the external file have the same format as that on the *Radionuclide Entry Lines* with one exception. The first line in the external file is used to identify the data set and is printed on the RSAC-7.2 output file. The program stops reading radionuclide inventories from an external file when it encounters either a blank line or the end of the file. An *Input End Line (2999)* must immediately follow a *(2002)* line.

Word	Variable Name	Entry	Description
1		2002	
2	EXTFILE		Enter the name of the external file containing the radionuclide inventory input. The name entered must be a valid DOS filename with no extensions.

4.2.2.4 Radionuclide Direct Input End Line (2999)

Use this line to end the direct input of radionuclide inventory input.

Word	Entry
1	2999

4.2.3 3000 Series – Dose Summary Option

Use this option to summarize, add, and report in summary tables doses from different exposure pathways and multiple RSAC-7.2 calculations.

4.2.3.1 Dose Summary Option Control Line (3000)

RSAC-7.2 automatically initiates the dose summary. Following dose calculations for the pathways desired, enter additional *(3000)* lines to request dose summaries. Changes can be made in the 5000 Series (Dispersion Control Input) following initiation of the 3000 Series option; however, downwind distances cannot be changed.

Word	Name	Entry	Description
1		3000	
2	ISUMTYPE	Integer	Type of calculation:
		1	Re-initiate the dose/cancer risk summary option (used only to zero dose history for stacked cases in the same run).
		2	Summary of dose by pathway.
		3	Summary of dose by pathway and radionuclide.
		4	Summary of dose/cancer risk by organ/cancer (requires a *[3001]* Line to follow).
		5	Summary of dose/cancer risk by organ and radionuclide (requires a *[3001]* Line to follow).
		6	Contribution to the effective dose.
		7	Contribution to E-50/cancer risk by radionuclide.
		8	Contribution to E-50/cancer risk by radionuclide sorted by dose.
3	INAGE	Inhalation/Ingestion intake age	Mortality/Morbidity age group

ICRP-72 model

1	3 months	0 – 5 years
2	1 year	5 - 15 years
3	5 years	15 – 25 years
4	10 years	25 – 70 years
5	15 years	0 – 100 years
6	Adult	
7	Adult Worker, ICRP-68 model	
8	Acute inhalation dose	
9	ICRP-30 model	

4.2.3.2 Dose Summary Organ Selection (3001)

This line is present only if word 2 on the *(3000)* line is 4 or 5. Dose summaries for up to four organs can be entered. When additional dose summaries for organs are desired, add additional *(3000)* and *(3001)* lines.

Word	Variable Name	Entry	Description
1		3001	
2	INORGAN(1)	Integer	Organ number
.	.	.	
.	.	.	
4	INORGAN(4)		

	ICRP-72 Dose	ICRP-30 Dose	Cancer Risk Mortality/Morbidity	Acute Dose
1	Adrenals	Lung	Bladder	Small Intestine
2	Bladder Wall	Stomach Wall	Bone	Bone Marrow
3	Bone Surface	SI Wall	Breast	Lung
4	Brain	ULI Wall	Colon	Alveolar Interstitial Region
5	Breast	LLI Wall	Esophagus	
6	Colon	Testes	Kidney	
7	Esophagus	Breast	Leukemia	
8	ET Airways	Bone Surface	Liver	
9	Kidneys		Red Marrow	Lung
10	Liver	Thyroid	Ovary	
11	LLI Wall	Kidneys	Residual	
12	Lungs	Liver	Skin	
13	Muscle	Spleen	Stomach	
14	Ovaries	Pancreas	Thyroid	
15	Pancreas	Muscle	Total	
16	Red Marrow	Skin		
17	SI Wall	Brain		
18	Skin	Thymus		
19	Spleen	Bladder Wall		
20	Stomach Wall	Adrenals		
21	Testes	Esophagus		
22	Thymus	Ovaries		
23	Thyroid	Uterus		
24	ULI Wall			
25	Uterus			
26	Effective			

4.2.4 5000 Series – Dispersion Control Input

The 5000 Series creates the conditions under which the release parameters will be evaluated.

4.2.4.1 Dispersion Control Line (5000)

Use a *Dispersion Control Line (5000)* to initiate input of meteorological or room release data.

Word	Entry	Description
1	5000	
2	0	Release will be modeled using meteorological dispersion data. A 5001 line will immediately follow the 5000 line.
	1	Release will be into a building/room. A 5500 line will immediately follow the 5000 line.

4.2.4.2 General Meteorological Information Line (5001)

Word	Variable Name	Entry	Description
1		5001	
2	UBAR		Average wind velocity (m/s)
3	S H		Stack height (m). Typical stack heights are at least 2.5 times the building height.
4	H		Mixing layer depth (m). If zero, defaults to 400 m.
5	ADEN		Air density (g/m^3). If zero, defaults to 1.099E+3 (average density for 5000 ft. altitude).
6	AMBDA		Wet deposition scavenging coefficient (1/s). Set equal to zero when no plume depletion by wet deposition is desired. This coefficient simulates rainout of the plume and will very quickly deplete the release. Values for wet deposition scavenging coefficient range from 4.0 E-6 to 3.0 E-3 s^{-1} with a median value of 1.5 E-4. Avoid too large a value to prevent plume overdepletion.
7	SW1	Integer	Plume depletion by dry deposition:
		0	No
		1	Yes

4.2.4.3 Deposition Velocities Line (5002)

Entering this line is optional. However, the line must be present if you are making ingestion or ground surface dose calculations.

Word	Variable Name	Entry	Description
1		5002	Deposition velocity (m/s) for:
2	DV(1)		Solids
3	DV(2)		Halogens
4	DV(3)		Noble gases
5	DV(4)		Cesium
6	DV(5)		Ruthenium

4.2.4.4 Downwind Distance Lines (5101+)

Word	Variable Name	Entry	Description
1		Integer	510X (X = 1,2,..., etc.)
2	DIE(1)		Downwind distance (m)
.	.		
.	.		
.	.		
N	DIE(N)		

Enter a maximum of eight downwind distances. The valid range of downwind distances is 10 to 1.E+5 m. Diffusion for distances less than 1.E+2 m is extrapolated.

4.2.4.5 Leakage Decay Constants Lines (5201+)

Use leakage decay constants to calculate the radionuclide inventory decay before release to the environment. When the radionuclide inventory decay has already been corrected to the actual amount to be released, treat the release as an instantaneous release as described below to avoid double decay.

Word	Variable Name	Entry	Description
1		Integer	52XX (XX = 01, 02, ..., etc.)
2	K1(1)		Linear constant in the leakage rate function (s^{-1})
3	K2(1)		Exponential constant in leakage rate function (s^{-1})

Enter additional sets of two values on this and following lines up to a maximum of 10 sets.

Values of K1 and K2 can be either positive or negative. If a constant leakage is desired, set K2 = 0 and K1 = the reciprocal of the time that it takes for the activity to be released to the atmosphere. The use of one set of leakage constants is normally sufficient for most calculations.

When an instantaneous release is desired, enter only one set of leakage constants and set K1 = 1., K2 = 0., and the exposure time to the plume to 1 second.

When decay correction is desired for a constant release, set K1 = the reciprocal of the release time (s), K2 = 0., and the decay time for the leakage rate function = the time (s) over which the release occurs [see Appendix A, Equation (A-28)].

When an exponential release as a function of time is desired, set K2 = 1/T_h, where T_h is the release half-time (s) for the exponential decay function. K1 can be calculated using the following equation:

$$K1 = \frac{L_f \, K2}{1. - e^{-K2\,T}}$$

where L_f is the fraction of the total source volume to be released over the time T (s).

Decay times for the leakage rate function used with these constants are entered on lines *(6001)*, *(7001)*, *(8020)*, and *(9000)* lines. An option is provided for the program to automatically calculate the necessary decay times to give a 100% release if only one set of constants is entered (K1 > 0 and K1 > K2). When these conditions are not met, you must directly enter the decay time for the leakage rate function. It is important not to decay the radionuclide inventory twice before its release to the atmosphere. This can inadvertently occur when the total activity of each radionuclide to be released to the atmosphere over an extended period of time is entered directly into RSAC-7.2 rather than using RSAC-7.2 to calculate the radionuclide inventory. When this is the case, no additional decay of the activity before release is desired even though the total activity entered may represent a release over an extended period of time.

4.2.4.6 Crosswind Distance Lines (5301+)

You can omit these lines if no crosswind calculations are desired.

Word	Variable Name	Entry	Description
1		Integer	53XX (XX = 01, 02,..., etc.)
2	ELB(1)		Crosswind distance (m)
.			
.			
.			
N	ELB(N-1)		

Additional values on this and following lines are entered up to a maximum of 15 crosswind distances.

4.2.4.7 Diffusion Control Line (5400)

Word	Variable Name	Entry	Description
1		5400	
2	NTRL	1	A set of standard deviations of plume concentrations is entered on the *Standard Deviation Lines (5401+)* for each downwind distance.
		2	Program-calculated standard deviations of plume concentration. A *(5410)* line will immediately follow this line.
		3	χ/Q values are input directly. The remainder of this line is ignored, and χ/Q values are read from *(542X)* lines.
3	DUMMY		Building width (m) (Smallest representative width).
4	DUMMZ		Building height (m) (Smallest representative height).

4.2.4.8 Standard Deviation Lines (5401+)

Enter these lines only if word 2 on the *Diffusion Control Line (5400)* is equal to 1.

Word	Variable Name	Entry	Description
1		Integer	540X (X = 1, 2, ..., etc.)
2	SIGY(1)		The horizontal dispersion standard deviation for the first downwind distance (m).
3	SIGZ(1)		The vertical dispersion standard deviation for the first downwind distance (m).
.			
.			
.			
N			

Enter additional sets of standard deviations on this and following lines for the additional downwind distance until values have been entered corresponding to each downwind position entered on the *(5100+)* lines above. A set of standard deviations must be entered for each downwind distance.

4.2.4.9 Plume Standard Deviation Control Line (5410)

Enter this line only if word 2 on the Diffusion Control Line (5400) is 2. See Appendix C for information on the different sets of σs that are available. Hilsmeier-Gifford σs (Clawson et al. 1989[10]) should be used for desert terrains (such as the INL) for effluent releases from a few minutes to 15 minute in duration. Markee σs (Clawson et al. 1989[10]) should be used for desert terrains for effluent releases from 15 to 60 minute in duration. Pasquill-Gifford σs were developed from the Prairie Grass experiments for effluent releases from 10 to 60 minutes in duration. The Pasquill-Gifford σs are presented in Regulatory Guide 1.145 (NRC 1982[26]) and by Slade (1968[34]). Carefully evaluate the appropriateness of using the program-generated σs for effluent releases of different durations than noted above. When you consider the program-generated σs inappropriate, word 2 on the *Diffusion Control Line (5400)* should be set to 1, and σs should be entered directly using the *(540X)* lines.

Word	Variable Name	Entry	Description
1		5410	
2	ITS	1	Hilsmeier-Gifford (H-G) σs
		2	Markee σs
		3	Pasquill-Gifford (P-G) σs
3	IWC	Integer	Weather class: See Appendix C for Classification of Atmospheric Stability
		1	A Extremely Unstable
		2	B Moderately Unstable
		3	C Slightly Unstable
		4	D Neutral
		5	E Slightly Stable
		6	F Moderately Stable
		7	F Fumigation [SH>O and H>=SH on a *(5001)* line]
		8	G Extremely Stable (allowed only for P-G σs)
4	IPLRS	Integer	Plume rise indicator:
		0	No plume rise (ground level release)
		1	Jet plume rise. (Elevated Release) Requires a *(5411)* line.
		2	Buoyant plume rise. (Fire, Convection Rise) Requires a *(5411)* line

Add a 5th word to Line 5410

Word	Description
5	Plume meander. If 0, defaults to 1.

4.2.4.10 Plume Rise Control Line (5411)

The *(5411)* line is present only when word 4 on the *(5410)* line is not equal to 0.

Word	Variable Name	Entry	Description
1		5411	Plume rise parameters:
2	SDIA		Internal stack diameter (m).
3	RS		Restoring acceleration (s^{-2}). If zero, defaults to program calculated values of 8.7E-4 (s^{-2}) for a weak inversion and 1.75E-3 (s^{-2}) for a strong inversion.
4	WO		Effluent velocity of gases from the stack (m/s).
5	QH		Stack gasses heat emission (cal/s) for buoyant plume rise. Enter zero for jet plume.

4.2.4.11 Direct χ/Q Input Lines (5421+)

Enter these lines only if word 2 on the *Diffusion Control Line (5400)* is 3. Cloud gamma calculations using the finite plume model and plume depletion by ground deposition are not allowed when using this option.

Word	Variable Name	Entry	Description
1		Integer	542X (X = 1,2,..., etc.)
2		CQ	χ/Q for the lst downwind distance
.		.	
.		.	
.		.	
N		CQ	χ/Q for the N^{th} downwind distance

Enter additional values on this and following line for each downwind distance entered on the *(5101)* line. A (5999) line must immediately follow the input of the (542X)lines.

4.2.4.12 Dispersion to Building/Room Line (5500)

Enter the volume in cubic meters of the building/room in which the release will occur. Input the exposure time for an individual in the room on a 7001 line.

Word	Variable Name	Entry	Description
1		5500	
2	ROOMVOL		Volume ($m^{3)}$

4.2.4.13 Meteorological Data End Line (5999)

Use this line to end the meteorological data input and calculations as requested by the *Meteorological Control Line (5000)*.

Word	Entry
1	5999

4.2.5 6000 Series – Radionuclide Inventory Decay for Printout

This series is used only to calculate the radionuclide inventory decay for printout. Radionuclide decay for subsequent dose calculations must be calculated in the 1000 Series. Use the *Decay Control Line (6000)* to initiate radionuclide inventory decay calculations. Decay of either the entire radionuclide inventory or selected radionuclides can be calculated. Decay times can be entered directly with *Decay Times Lines (6101+)* or they can be established from the 5000 Series meteorological downwind data lines. Individual radionuclides selected are printed. If desired, rather than printing the entire radionuclide inventory you can select other printout options.

4.2.5.1 Decay Control Line (6000)

Word	Variable Name	Entry	Description
1		6000	
2	NCH	Integer	Printout control:
		0	Decay of radionuclides in the RSAC-7.2 library will be calculated.
		1	Only radionuclides selected following a *(6021)* line will be printed.
3	ISW2	Integer	Printout options:
		0	No individual radionuclide inventories are printed.
		-1	Print all fission products and any activation products, actinides, and daughters of actinides with positive values.
		1	Same as -1 option except suppress short-lived fission products that have no available dose conversion factors.
		2	Print inventory of radionuclides that have positive values at or following the first requested decay time.
4	ISW	Integer	Units control word:
		0	Curies
		1	MeV/s (gamma only)
		2	Grams
5	LEAK	Integer	Exponential leakage option
		0	No exponential leakage corrections are included.
		1	Correction for exponential leakage decay included. A *(6001)* line must immediately follow this line. This option provides an inventory of the radionuclides reaching a downwind location

following a release that varies exponentially as a function of time.

4.2.5.2 Decay Time for Leakage Rate Function (6001)

Use this line only when LEAK on the *(6000)* line is equal to 1

Word	Variable Name	Entry	Description
1		6001	
2	T		Decay time (s) for the exponential decay function. If zero, defaults to the time necessary to give 100% release.

4.2.5.3 Leakage Decay Constants (6002+)

Use these lines only when the exponential leakage option is requested (i.e., LEAK = 1). You can omit these lines if leak rate exponentials have been previously entered with *(5201+)* lines.

Word	Variable Name	Entry	Description
1		Integer	60XX (XX = 02, 03,..., etc.)
2	K1(1)		Linear constant in leak rate function (s^{-1})
3	K2(1)		Exponential constant in leak rate function (s^{-1})

Enter additional sets of two values on this and following lines up to a maximum of 10 sets.

4.2.5.4 Radionuclide Selection Option Line (6021)

This line is required only if NCH (word 2) entered on the *Decay Control Line (6000)* is equal to 1. This line is followed by additional lines described as following:

Word	Variable Name	Entry	Description
1	NUCL	Integer	Radionuclide identification number (see Series 4000, *Radionuclide Data Change Line*). An alternate entry can be made by replacing NUCL with the element symbol followed by the mass number and metastable state indicator. Examples of allowable styles include: Cs137, Cs-137, Cs 137 Ba137m, Ba-137m, Ba 137m CS137, CS-137, CS 137 BA137M, BA-137M, BA 137M

Make additional line entries until all desired radionuclides have been entered into the radionuclide inventory. A *(6101)* or *(6999)* line must follow last radionuclide identification entered.

4.2.5.5 Decay Times Lines (6101+)

You can omit these lines if decay times have been established using the *(5001+)* lines.

Word	Variable Name	Entry	Description
1		Integer	61XX (XX = 01, 02, ..., etc.)
2	IUNIT	Integer	Decay time unit: 1 = Second 2 = Minute 3 = Hour 4 = Day 5 = Year
3	TIME(2)		Decay time
.	.		
.	.		
.	.		
N	TIME(N-1)		

Enter additional values on this and following lines up to a maximum of eight values. When you want to see all of the output data on an unshifted screen or printed on a standard 80-column page, a maximum of three decay times should be entered on each 6000 Series input.

4.2.5.6 Summation Control Line (6200)

This line is present only if the entire radionuclide inventory decay is calculated and it can be deleted if desired. A summation of the radionuclide inventory by group (solids, halogens, noble gases, cesium, and ruthenium) and/or by element can be printed. If summation by element is requested, enter the *Element Summation Lines (6201+)* next, selecting the elements to be summed.

Word	Entry	Description
1	6200	
2		Group summation control word:
	0	No summation or printout.
	1	The fission product inventory for each group (solids, halogens, noble gases, cesium, and ruthenium) is summed and printed.
3	Integer	Element summation control word:
	0	No summation or printout.
	1	The radionuclide inventory is summed for each element selected by the *Element Summation Lines (6201+)* that follow.

4.2.5.7 Element Summation Lines (6201+)

These lines are required only if the entire radionuclide inventory decay is calculated and if the element summation option on the *Summation Control Line (6200)* is chosen. Enter any number of these lines.

Word	Entry	Description
1	Integer	62XX (XX = 01, 02, ..., etc.).
2	Integer	Atomic number of element to be summed.

Enter additional words on this and following lines until the desired elements have been selected for summation.

4.2.5.8 Decay End Line (6999)

Use this line to end the fission product inventory decay and printout as requested by the *Decay Control Line (6000)*.

Word	Entry
1	6999

4.2.6 7000 Series – Internal/External Dose Calculation

Use the initial line of this series to establish the type of dose calculation to be made and the amount of output data. Air-immersion doses are calculated using dose-rate conversion factors from Federal Guidance Report 12 (Eckerman 1993[15)]) developed for a semi-infinite plume. Use **caution** to ensure that the plume size is large compared to the mean free path of the gamma rays. If there is any doubt, make cloud gamma calculations (see 9000 Series in this section) using both the finite plume model and the semi-infinite plume model and ensure that the doses are converged.

4.2.6.1 Dose Calculation Control Line 1 (7000)

Word	Variable Name	Entry	Description
1		7000	
2	IMOD	Integer	Type of calculation:
		1	Inhalation, program default parameters.
		2	Inhalation, user-supplied parameters on the *(7003)* line.
		3	Ingestion, default to program calculated chronic parameters.
		4	Ingestion with user supplied parameters on the *(7004)* line.
		5	Ground surface.
		6	Air immersion (see caution above).
			Mortality risk, add 10 to the above values of IMOD.
			Morbidity risk, add 20 to the above values of IMOD.
			Resuspended Activity, enter IMOD as a negative value.
3	ISW	Integer	Output control:
		-2	Only dose summaries by organ.
		-1	Only total organ doses.
		0	Above plus doses for each element.
		1	Above plus doses for each radionuclide.
		2	Above plus dose summary tables by organ.

Word	Variable	Type	Description
4	IDU	Integer	Dose unit:
		1	rem
		2	Sv
5	NCH	Integer	Number of elements for which calculation is done:
		0	All elements.
		1	As indicated on *Optional Element Selection Lines (7081+)*.
6	IONC	Integer	Organ number choice:
		1	Default to all organs.
		2	As indicated on the *Optional Selection of Organs Line (7002)*.
7	AGE	Inhalation/Ingestion intake age	Mortality/Morbidity age group

		ICRP-72 model
0	All ages	All age groups
1	3 months	0 – 5 years
2	1 year	5 - 15 years
3	5 years	15 – 25 years
4	10 years	25 – 70 years
5	15 years	0 – 110 years
6	Adult	
7	Adult Worker, ICRP-68 model (inhalation only)	
8	Acute inhalation dose (inhalation only)	
9	ICRP-30 model	

If word two, IMOD, was entered as ‘ground surface’ or ‘air immersion’ calculation, then the final word in this line, ‘age,’ is not used in any calculations. However, this word must be present. It is suggested that you use ‘0’ for this value, though integers 1-9 would have the same results.

A special test option has been added to print out the actual dose conversion factors used in RSAC-7. This is initiated by putting -201 in word 4 of Line 7001 for the variable TB. This should be very useful for performing V&V. The place to look closely is for the elements with special chemical forms.

4.2.6.2 Dose Calculation Control Line 2 (7001)

Variable

Word	Name	Entry	Description
1		7001	
2	BREATH		Breathing rate (m^3/s) for inhalation calculations. If zero, defaults to 3.33E-4. Use 2.66E-4 for 24-h average breathing rate.
3	TINHA		Release to atmosphere: Decay time (s) for the exponential decay function (see Appendix A, Section A-2.4, "Leakage Rate Function"). If zero, defaults to the time necessary to give 100% release. Release to building: Time that receptor is exposed (s). If zero, defaults to 60 s.
4	TB		Values for the term "TB" depend the type of calculation being made: For acute releases: TB is the number of years that crops are grown on the contaminated soil. TB should be 1. year for dose during the year of intake. Values greater than 1. year give the dose from growing crops on the contaminated soil for the specified number of years. If zero, defaults to 15 years. Ingestion from chronic release: For chronic releases, TB is the years of long-term buildup of activity in the soil. TB should be equal to the plant mid-point of operating life (y). If zero, defaults to 15 years. Ground surface: TB is the time in years that the receptor is exposed to the contaminated ground surface following initiation of the release. If > 0 and <1, a warning will be given that an exposure period of <1 year has been chosen. If zero, defaults to 1 year.
5	BS		Building shielding factor for ground surface dose calculations. If zero, defaults to 0.7.
6	OCFACT		Occupancy factor for ground surface dose calculations (entry of word is optional). If zero, defaults to 1.0.

4.2.6.3 *Optional Selection of Organs Line (7002)*

Word	Variable Name	Entry	Description
1		7002	User selection of organs
2	IO(1)	Integer	Organ number:
.	.		
.	.		
.	.		
N+1	IO(N)		

	ICRP-72 Dose	ICRP-30 Dose	Mortality/ Morbidity Cancer Risk	Acute Dose
1	Adrenals	Lung	Bladder	Small Intestine
2	Bladder Wall	Stomach Wall	Bone	Bone Marrow
3	Bone Surface	SI Wall	Breast	Lung
4	Brain	ULI Wall	Colon	Alveolar Interstitial Region
5	Breast	LLI Wall	Esophagus	
6	Colon	Testes	Kidney	
7	Esophagus	Breast	Leukemia	
8	ET Airways	Bone Surface	Liver	
9	Kidneys	Red Marrow	Lung	
10	Liver	Thyroid	Ovary	
11	LLI Wall	Kidneys	Residual	
12	Lungs	Liver	Skin	
13	Muscle	Spleen	Stomach	
14	Ovaries	Pancreas	Thyroid	
15	Pancreas	Muscle	Total	
16	Red Marrow	Skin		
17	SI Wall	Brain		
18	Skin	Thymus		
19	Spleen	Bladder Wall		
20	Stomach Wall	Adrenals		
21	Testes	Esophagus		
22	Thymus	Ovaries		
23	Thyroid	Uterus		
24	LLI Wall	Effective		
25	Uterus			
26	Effective			

Line 7003

AMAD only is used with the ICRP-30 model. A value must be present, but it is ignored in other calculations. Default to 0.

4.2.6.4 *Optional Inhalation Dose Calculation Control Line (7003)*

This line is present only if IMOD (word 2) on the *(7000)* line is 1. It is important to understand that when the default recommended or maximum parameter is selected, it is for the element and all associated nuclides. For example, the maximum value for ICRP 72 adult with respect to plutonium is defined as Fast. This is true for the majority of the plutonium radionuclides. However, if Pu-234, Pu-235, and a few others are being evaluated, it is not the maximum clearance type. For those nuclides, Slow is the maximum type. Therefore, it is very important that you understand the nuclide and the appropriate clearance class/type for your specific application. A option has been added to output all of the clearance class values by changing the third word values to a negative number. See Appendix D

for the default values for all options.

Word	Variable Name	Entry	Description
1		7003	User-supplied inhalation parameters.
2	AMAD		Activity median aerodynamic diameter (μm). If zero, defaults to 1. AMAD must be ≥0.1 μm.
3	ICCI		Clearance class indicator:
		1	Default to program-generated classes for ICRP 72 recommended values and oxides and hydroxides where no recommendations exist.
		2	User input of classes on *(703X)* lines. Unchanged classes default to those for selection (1).
		3	Default to program-generated classes selected to give maximum element dose.
		4	User input of classes on (703X) lines. Unchanged classes default to those selected to give maximum element dose.
			Add a negative (-) sign in front of word 3 and the values used for all selected clearance classes, including changes made on 703X lines, will be output.

4.2.6.5 *Optional Ingestion Dose Calculation Control Line (7004)*

This line is present only if IMOD (word 2) on the *(7000)* line is 3.

Word	Variable Name	Entry	Description
1		7004	

2	ITRAN	Integer	Ingestion transfer parameter control: 0 = Program default transfer parameters used. 1 = Program default transfer parameters are used and printed out. 2 = Read ingestion transfer parameters from external file TRANCON.
3	ITYPE	Integer	User control for ingestion calculations 0 = Chronic release with program default parameters. 1 = Acute release with program default parameters. 2 = User-supplied ingestion parameters on *(705X)* lines.
4	ATIME		Time period (d) that crops are exposed to contamination during the growing season. A time period of ≥60 days signifies a chronic release with vegetable and forage exposure times to the plume as indicated in Series 7000, Ingestion Constants Line 3 (7052). A time period of <60 days signifies an acute release. ITYPE = 0. Variable not used. ITYPE = 1. Time must be between 0.04167 day (1. hour) and <60. day. ITYPE = 2. If zero or > 60., defaults to 60. days. Otherwise, must not be <0.04167.
5	THD		Harvest duration time period (0. ≤ THD < 60.) following an acute release (d). If zero, defaults to 7 days. When the sum of ATIME and THD exceeds ETV (see *[7052]* line), the program automatically decreases the value input for THD to give a sum of ETV days for produce calculations. The program also automatically calculates a value for THD for forage calculations so that the sum of ATIME and THD do not exceed the value of ETM (see [*7052]* line).

4.2.6.6 Optional Clearance Class by Element Lines (7031+)

These lines are present only if ICCI (word 3) on the (7003) line is equal to 2. Make entries in pairs of two: the element's atomic number followed by the clearance class code. Refer to Appendix D

for valid clearance classes.

Word	Variable Name	Entry	Description		
1		Integer	703X (X = 1, 2, ..., etc.).		
2	NN	Integer	Atomic number for element.		
3	ICI(NN)	Integer	ICRP-72	ICRP 68	ICRP-30
		1	Type F	Type F	Class D
		2	Type M	Type M	Class W
		3	Type S	Type S	Class Y

Enter as many pairs of entries and up to eight pairs per line.

4.2.6.7 Optional Ingestion Dose Constants Lines (7051+)

These lines are present only if ITYPE (word 3) on the *(7004)* line is equal to 2.

Ingestion Constants Line 1 (7051)

Word	Variable Name	Description	Default Value	Variable Name
1		7051		
2	UFSV	Stored vegetable usage factor (kg/yr wet weight)	520.	U^v
3	UFFV	Fresh vegetable usage factor (kg/yr wet weight)	64.	U^L
4	UFMP	Meat usage factor (kg/yr wet weight)	110.	U^F
5	UFM	Milk usage factor (L/yr)	310.	U^m
6	FG	Fraction of stored vegetables from garden	0.76	f_g
7	FY	Fraction of fresh vegetables from garden	1.0	f_l

Ingestion Constants Line 2 (7052)

Word	Variable Name	Description	Default Value	Variable Name
1		7052		
2	RF1	Retention factor for activity on forage	0.57	r
3	RF2	Retention factor for activity on vegetables	0.2	r
4	RFI	Retention factor for iodines on forage	1.0	r
5	RRC	Removal rate constant for crops (1/h)	0.0021	λ_w
6	ETV	Vegetable exposure time to plume for chronic release (d)	60.	t_e
7	ETM	Forage exposure time to plume for chronic release (d)	30.	t_e
8	HRHT	HTO removal half time (d)	1.	λ_p

Ingestion Constants Line 3 (7053)

Word	Variable Name	Description	Default Value	Variable Name
1		7053		
2	SD	Effective surface density for soil (kg/m^2)	225.	P
3	THS	Stored vegetable holdup time after harvest (d)	60.	t_h

4	THF	Fresh vegetable holdup time after harvest (d)	1.	t_h
5	QF	Animals daily forage feed (kg/day dry weight)	16.	Q_F
6	TRAN	Feed-milk receptor transfer time (d)	2.	t_f
7	TSLA	Slaughter to consumption time (d)	20.	t_c

Ingestion Constants Line 4 (7054)

Word	Variable Name	Description	Default Value	Variable Name
1		7054		
2	FPAST	Fraction of year that animals graze	0.4	f_p
3	FS	Fraction of feed that is pasture when animal grazes on pasture	.43	f_s
4	THSF	Stored feed holdup time (d)	90.	t_h
5	VYV	Vegetable vegetation yield (kg/m^2 wet weight)	2.	Y_v
6	VYM	Forage vegetation yield (kg/m^2 dry weight)	0.28	Y_v
7	HUM	Absolute humidity (g/m^3)	4.9	H

4.2.6.8 Optional Acute Ingestion Constants Line 4 (7055)

This line can be omitted; however, when it is not entered, all acute ingestion constants are set equal to 1.

Word	Variable Name	Description	Default Value	Variable Name
1		7055		
2	AFG	Fraction of annual stored vegetables that are contaminated by acute release	0.5[a] 1.0[b]	F_a
3	AFY	Fraction of annual fresh vegetables that are contaminated by acute release	0.33[a] 0.67[b]	F_a
4	AFFS	Fraction of annual stored forage that is contaminated by acute release	0.5[a] 1.0[b]	F_a
5	AFFF	Fraction of annual fresh forage that is contaminated by acute release	0.33[a] 0.67[b]	F_a

a. Crops exposed to contamination between 1 hour and <30 days.

b. Crops exposed to contamination between 30 days and <60 days.

4.2.6.9 Optional Element Selection Lines (7081+)

These lines are present only if word 5 (NCH) on the *(7000)* line is greater than zero.

Word	Variable Name	Entry	Description
1		Integer	708X (X = 1, 2, ..., etc.).
2	NUMBER(1)	Integer	Atomic number of element.
.	.		
.	.		
N	NUMBER(N)		

Enter additional values on this and following lines until the number of elements indicated on the *(7000)* line have been entered.

4.2.6.10 Resuspension Control Line (7090)

Enter the parameters for evaluating inhalation dose from resuspended activity. Ingestion and External dose from resuspension of activity is not calculated due to its negligible contribution to CEDE.

Word	Variable Name	Entry	Description
1		7090	
2	TSD		Time since deposition (days).
3	RET		Exposure time to resuspended activity.
4	ARL		Linear constant in the resuspension rate function (d^{-1}). Defaults to 4.9 E-8 (d^{-1}).
5	BRE		Exponential constant in the resuspension rate function (d^{-1}). Defaults to 4.1 E-3 (d^{-1}).

4.2.6.11 Dose Calculation End Line (7999)

Use this line to end the input for the calculations requested by a *Dose Calculation Control Line 1 (7001)*.

Word		Entry
1	7999	
2		

4.2.7 9000 Series – Cloud Gamma Dose Calculation

Use a *(9000)* control line to initiate a cloud gamma dose calculation.

Word	Variable Name	Entry	Description
1		9000	
2	IT	0	All calculations are made using the finite plume model
		1	All calculations are made using the semi-infinite model
3	T		Decay time for the leakage rate function (s). If zero defaults to the time necessary to give 100% (see *[5201+]* lines).

5. EXAMPLE RSAC-7.2 RUNS

RSAC-7.2 has 20 examples that are useful in helping the user learn how to run RSAC-7. These examples are also used to validate the installation. The examples available are as follows:

1. **Direct Input and Decay of Nuclides**: This example shows the various ways nuclides can be input and decayed for output viewing.
2. **Simulated Reactor Operation with Release During Operation**: This example generates a fission product inventory from a simulated reactor operation of 50 MW for 50 days. In addition the simulation of a fuel failure fractionates the calculated inventory. The decay and output of two scenarios is shown. The first scenario is for the activity retained in the reactor and the second is the activity released from the reactor.
3. **Calculation of Chi/Q with modifiers**: This example is a demonstration of the various conditions that can be modeled to establish Chi/Q values.
4. **Reactor Operation Transport and Output of Source Term**: This example combines the techniques of Examples 1-3, then outputs the transported source term using the report function.
5. **Dose Calculation Using FGR 11**: This example evaluates all the pathways using the same dose conversion factors used in RSAC 6.
6. **Simulated Reactor Operation ICRP 68 Worker Inhalation Dose**: This example evaluates all the pathways with the exception of ingestion using the facility worker dose conversion factors from ICRP 68.
7. **Simulated Reactor Operation ICRP 72 Public Inhalation Dose**: This example evaluates all the pathways using the Adult dose conversion factor from ICRP 72 for inhalation and ingestion.
8. **Simulated Reactor Operation Acute Dose Inhalation**: This example evaluates the 24 hour acute dose from a release from an operating reactor.
9. **Multiple Release Scenarios Calculating Ground Surface**: This example demonstrates the capabilities of RSAC with respect to various release conditions while calculating ground surface dose.
10. **Multiple Release Scenarios Calculating Cloud Gamma Dose**: This example demonstrates the capabilities of RSAC with respect to various release conditions while calculating cloud gamma dose.
11. **FGR 13 Mortality Risk Calculation**: This example evaluates mortality risk from release of an operating reactor.
12. **FGR 13 Morbidity Risk Calculation**: This example evaluates morbidity risk from release of an operating reactor.
13. **Resuspension Calculation**: This example evaluates inhalation dose from resuspension.
14. **FGR_ICRP 30 Ingestion Dose Chronic and Acute Release**: This example demonstrates both models of ingestion (Chronic and Acute) using FGR 11 values.
15. **Multiple Release Scenarios Calculating Air Immersion Dose**: This example demonstrates the capabilities of RSAC with respect to various release conditions while calculating air immersion dose.
16. **ICRP 72 Ingestion Dose Chronic and Acute Release**: This example demonstrates both models of ingestion (Chronic and Acute) using ICRP 72 Adult values.

17. **Criticality Accident ICRP 72 Inhalation and Ingestion DCFs**: This example demonstrates the complete evaluation of a 1.0 E18 fissions/sec for 10 seconds. All pathways are evaluated using the ICRP 72 Adult values for ingestion and inhalation.
18. **Uranium Fire with Plume Lofting**: This example evaluates the release of uranium from a fire with plume lofting to show how important it is to identify where the plume reaches the ground.
19. **Plutonium Fire with Plume Lofting**: This example evaluates the release of plutonium from a fire with plume lofting to show how important it is to identify where the plume reaches the ground. This example is similar to example 18.
20. **Release to a Room Inhalation Dose Only**: This example demonstrates how RSAC can calculate the inhalation dose from a release to a volume.

The examples are added to demonstrate the capabilities of RSAC-7.2 and validate the 127 executable commands within the software. The examples are write only, but can be saved as another name and edited. The output of example 1 is documented here for information purposes only.

Example 1
Direct Input and Decay of Radionuclides

Radiological Safety Analysis Computer Program (RSAC 7.1.0 preview)

Name: INL **Company:** Idaho National Laboratory **Serial:** 0001

Computer: INL413668 **Run Date:** 10/28/2010 **Run Time:** 09:58:24

File: Example 07 Simulated Reactor Operation ICRP 72 Public Inhalation Dose.rsac

Input

```
* Simulated Reactor Operation with Inhalation Dose Calculated Using ICRP 72
# ICRP 72 is the basis for the inhalation dose calculation.
#
#
# Reactor Operation for 100 MW days
1000
1001,1,0.,0.
1003,0.,1.00E+07,8640000.
1999
# Fractionation of Radionuclide Inventory
1000
1001,1,0.,0.
1004,-1,0.1,0.25,1.,0.1,0.1
1999
# Adding in the Beginning of Life Uranium Inventory in grams
2000,-1,1
U-233,100.
U-234,100.
U-235,10000.
U-238,1.e7
2999
# Standard Dispersion Conditions for Transport
5000,0
5001,1.,0.,400.,1.099E3,0.,1
5002,0.001,0.01,0.,0.001,0.001
5101,100.,500.,1000.,5000.,10000.
5201,1.,0.
5400,2,0.,0.
5410,3,5,0,0.
5999
# Inhalation Dose Using ICRP 72 Adult Public Dose Conversion Factors
7000,2,-2,1,0,1,6
7001,3.33E-04,0.,0,0,1.
7003,0.,-3
7999
# Ground Surface
7000,5,-2,1,0,1,0
7001,0,0.,1.,0.7,1.
7999
# Air Immersion
7000,6,-2,1,0,1,0
7001,0,0.,0,0
7999
# Ingestion Calculation
7000,4,-2,1,0,1,6
Rsac7.exe     RSAC-7 INPUT     10/28/2010     09:58
7001,0,0.,15.,0
7004,0,0,0.,7.
7999
# Cloud Gamma
9000,0,0.
# Summary of Dose by Pathway
3000,2,6
10000
```

```
Fission Product Calculation

    RADIONUCLIDE INVENTORY HAS BEEN DECAYED FOR  0.000E+00 SECONDS
    THE REACTOR HAS OPERATED AT  1.000E+07 WATTS FOR   8.640E+06 SECONDS
          BURNUP =  1.000E+03 MWD
    TOTAL RADIONUCLIDE REMAINING =  1.727E+18  D/S OR  4.668E+07 CI

Fission Product Calculation

    FRACTIONATION BY ELEMENT GROUP
      SOLIDS = 1.000E-01   HALOGENS = 2.500E-01   NOBLE GASES = 1.000E+00
      CESIUM = 1.000E-01   RUTHENIUM = 1.000E-01
    TOTAL RADIONUCLIDE REMAINING =  3.785E+17  D/S OR  1.023E+07 CI

Direct Radionuclide Input

        PREVIOUS INVENTORY INCREASED BY THE FOLLOWING VALUES
     NUCLIDE          HALF LIFE       GRAM      CURIE
  922330   U233    1.592E+05  yr    1.000E+02 9.638E-01
  922340   U234    2.455E+05  yr    1.000E+02 6.223E-01
  922350   U235    7.038E+08  yr    1.000E+04 2.161E-02
  922380   U238    4.468E+09  yr    1.000E+07 3.362E+00

Meteorological Data

        MEAN WIND SPEED = 1.000E+00 (m/s)   STACK HEIGHT = 0.000E+00 (m)
    MIXING LAYER HEIGHT = 4.000E+02 (m)      AIR DENSITY = 1.099E+03 (g/cu m)
    WET DEPOSITION SCAVENGING COEFFICIENT = 0.000E+00 (1/s)
    DRY DEPOSITION VELOCITIES (m/s)
         SOLIDS = 1.000E-03    HALOGENS = 1.000E-02   NOBLE GASES = 0.000E+00
         CESIUM = 1.000E-03   RUTHENIUM = 1.000E-03
    THERE IS 1 SET OF LEAKAGE CONSTANTS (K1,K2)
          1.000E+00       0.000E+00
    PLUME MEANDER FACTOR = 1.00E+00
    PASQUILL CLASS E METEOROLOGY,  P-G   SIGMA VALUES
    NO BUILDING WAKE CORRECTION MADE
      DOWNWIND DISTANCE     STACK        SIGY        SIGZ        CHI/Q
                          HEIGHT (m)     (m)         (m)        (s/m^3)
         1.000E+02         0.000E+00   6.695E+00   3.489E+00   1.363E-02
         5.000E+02         0.000E+00   2.864E+01   1.296E+01   8.574E-04
         1.000E+03         0.000E+00   5.356E+01   2.134E+01   2.785E-04
         5.000E+03         0.000E+00   2.291E+02   5.641E+01   2.463E-05
         1.000E+04         0.000E+00   4.285E+02   7.769E+01   9.562E-06
    PLUME DEPLETION BY FALLOUT IS INCLUDED
      FRACTION OF PLUME REMAINING AIRBORNE FOLLOWING DEPLETION BY DEPOSITION
        DOWNWIND DISTANCE     SOLIDS   HALOGENS    CESIUM    RUTHENIUM
            1.000E+02       9.527E-01  6.161E-01  9.527E-01  9.527E-01
            5.000E+02       9.402E-01  5.400E-01  9.402E-01  9.402E-01
            1.000E+03       9.331E-01  5.004E-01  9.331E-01  9.331E-01
            5.000E+03       9.129E-01  4.018E-01  9.129E-01  9.129E-01
            1.000E+04       8.971E-01  3.377E-01  8.971E-01  8.971E-01

Inhalation Dose Calculation

         USING DOSE CONVERSION FACTORS FROM ICRP-72 FOR MEMBERS OF THE PUBLIC
    RESPIRABLE FRACTION =  1.000E+00
    BREATHING RATE =  3.330E-04 (m^3/s)
    RELEASE TIME FOR EXPONENTIAL DECAY FUNCTION =  1.000E+00 (s)
    INTERNAL EXPOSURE TIME PERIOD  =  5.000E+01 (yr)
    LUNG ABSORPTION TYPES SELECTED TO GIVE MAXIMUM DOSE
    LUNG CEARANCE TYPES USED IN CALCULATIONS
      ELEMENT     TYPE
       1    H       F
       4   Be       S
       6    C       S
       9    F       S
      11   Na       F
```

```
12   Mg      M
13   Al      M
14   Si      S
15    P      M
16    S      S
17   Cl      M
19    K      F
20   Ca      S
21   Sc      S
22   Ti      S
23    V      M
24   Cr      S
25   Mn      M
26   Fe      S
27   Co      S
28   Ni      S
29   Cu      S
30   Zn      S
31   Ga      M
32   Ge      M
33   As      M
34   Se      S
35   Br      M
37   Rb      F
38   Sr      S
39    Y      S
40   Zr      S
41   Nb      S
42   Mo      S
43   Tc      S
44   Ru      S
45   Rh      S
46   Pd      S
47   Ag      S
48   Cd      F
49   In      M
50   Sn      M
51   Sb      S
52   Te      S
53    I      F
55   Cs      S
56   Ba      S
57   La      M
58   Ce      S
59   Pr      S
60   Nd      S
61   Pm      S
62   Sm      M
63   Eu      M
64   Gd      M
65   Tb      M
66   Dy      M
67   Ho      M
68   Er      M
69   Tm      M
70   Yb      S
71   Lu      S
72   Hf      M
73   Ta      S
74    W      F
75   Re      M
76   Os      S
77   Ir      S
78   Pt      F
79   Au      S
80   Hg      M
81   Tl      F
82   Pb      S
83   Bi      M
84   Po      S
85   At      M
87   Fr      F
```

```
    88   Ra       S
    89   Ac       S
    90   Th       S
    91   Pa       S
    92    U       S
    93   Np       F
    94   Pu       F
    95   Am       F
    96   Cm       F
    97   Bk       M
    98   Cf       M
    99   Es       M
   100   Fm       M
  INHALATION DOSE CALCULATIONS FOR ADULT AGE
   INHALATION EQUIVALENT DOSE ORDERED BY ORGAN (rem)   FOR ADULT AGE
              DOWNWIND DISTANCES (m)
  ORGAN   NO.  1.00E+02  5.00E+02  1.00E+03  5.00E+03  1.00E+04
--------  ---  --------  --------  --------  --------  --------
ADRENALS   1   2.90E+03  1.80E+02  5.79E+01  4.93E+00  1.86E+00
  B_WALL   2   6.95E+03  4.29E+02  1.38E+02  1.14E+01  4.20E+00
BSURFACE   3   4.61E+03  2.86E+02  9.21E+01  7.86E+00  2.97E+00
   BRAIN   4   1.06E+03  6.59E+01  2.12E+01  1.77E+00  6.57E-01
  BREAST   5   2.80E+03  1.74E+02  5.60E+01  4.78E+00  1.80E+00
   COLON   6   2.94E+04  1.82E+03  5.86E+02  4.95E+01  1.84E+01
ESOPHAGU   7   3.41E+03  2.11E+02  6.80E+01  5.79E+00  2.18E+00
  ET_AIR   8   6.24E+04  3.86E+03  1.23E+03  9.71E+01  3.46E+01
 KIDNEYS   9   2.09E+03  1.30E+02  4.17E+01  3.54E+00  1.33E+00
   LIVER  10   3.80E+03  2.36E+02  7.59E+01  6.49E+00  2.45E+00
LLI_WALL  11   4.15E+04  2.58E+03  8.29E+02  7.06E+01  2.65E+01
   LUNGS  12   2.74E+05  1.70E+04  5.47E+03  4.70E+02  1.78E+02
  MUSCLE  13   1.91E+03  1.18E+02  3.81E+01  3.22E+00  1.20E+00
 OVARIES  14   2.26E+03  1.40E+02  4.49E+01  3.79E+00  1.41E+00
PANCREAS  15   2.51E+03  1.56E+02  5.01E+01  4.22E+00  1.58E+00
R_MARROW  16   2.84E+03  1.76E+02  5.67E+01  4.83E+00  1.82E+00
 SI_WALL  17   6.36E+03  3.94E+02  1.26E+02  1.02E+01  3.64E+00
    SKIN  18   1.22E+03  7.56E+01  2.43E+01  2.05E+00  7.68E-01
  SPLEEN  19   2.40E+03  1.49E+02  4.78E+01  4.05E+00  1.52E+00
 ST_WALL  20   5.33E+03  3.32E+02  1.06E+02  8.11E+00  2.79E+00
  TESTES  21   9.64E+02  5.97E+01  1.92E+01  1.61E+00  6.01E-01
  THYMUS  22   3.41E+03  2.11E+02  6.80E+01  5.79E+00  2.18E+00
 THYROID  23   2.63E+05  1.63E+04  5.22E+03  4.41E+02  1.64E+02
ULI_WALL  24   2.03E+04  1.26E+03  4.03E+02  3.37E+01  1.24E+01
  UTERUS  25   1.70E+03  1.06E+02  3.39E+01  2.84E+00  1.06E+00
   INHALATION EQUIVALENT DOSE ORDERED BY DOSE (rem)   FOR ADULT AGE
              DOWNWIND DISTANCES (m)
  ORGAN   NO.  1.00E+02  5.00E+02  1.00E+03  5.00E+03  1.00E+04
--------  ---  --------  --------  --------  --------  --------
   LUNGS  12   2.74E+05  1.70E+04  5.47E+03  4.70E+02  1.78E+02
 THYROID  23   2.63E+05  1.63E+04  5.22E+03  4.41E+02  1.64E+02
  ET_AIR   8   6.24E+04  3.86E+03  1.23E+03  9.71E+01  3.46E+01
LLI_WALL  11   4.15E+04  2.58E+03  8.29E+02  7.06E+01  2.65E+01
   COLON   6   2.94E+04  1.82E+03  5.86E+02  4.95E+01  1.84E+01
ULI_WALL  24   2.03E+04  1.26E+03  4.03E+02  3.37E+01  1.24E+01
  B_WALL   2   6.95E+03  4.29E+02  1.38E+02  1.14E+01  4.20E+00
 SI_WALL  17   6.36E+03  3.94E+02  1.26E+02  1.02E+01  3.64E+00
 ST_WALL  20   5.33E+03  3.32E+02  1.06E+02  8.11E+00  2.79E+00
BSURFACE   3   4.61E+03  2.86E+02  9.21E+01  7.86E+00  2.97E+00
   LIVER  10   3.80E+03  2.36E+02  7.59E+01  6.49E+00  2.45E+00
ESOPHAGU   7   3.41E+03  2.11E+02  6.80E+01  5.79E+00  2.18E+00
  THYMUS  22   3.41E+03  2.11E+02  6.80E+01  5.79E+00  2.18E+00
ADRENALS   1   2.90E+03  1.80E+02  5.79E+01  4.93E+00  1.86E+00
R_MARROW  16   2.84E+03  1.76E+02  5.67E+01  4.83E+00  1.82E+00
  BREAST   5   2.80E+03  1.74E+02  5.60E+01  4.78E+00  1.80E+00
PANCREAS  15   2.51E+03  1.56E+02  5.01E+01  4.22E+00  1.58E+00
  SPLEEN  19   2.40E+03  1.49E+02  4.78E+01  4.05E+00  1.52E+00
 OVARIES  14   2.26E+03  1.40E+02  4.49E+01  3.79E+00  1.41E+00
 KIDNEYS   9   2.09E+03  1.30E+02  4.17E+01  3.54E+00  1.33E+00
  MUSCLE  13   1.91E+03  1.18E+02  3.81E+01  3.22E+00  1.20E+00
  UTERUS  25   1.70E+03  1.06E+02  3.39E+01  2.84E+00  1.06E+00
    SKIN  18   1.22E+03  7.56E+01  2.43E+01  2.05E+00  7.68E-01
   BRAIN   4   1.06E+03  6.59E+01  2.12E+01  1.77E+00  6.57E-01
  TESTES  21   9.64E+02  5.97E+01  1.92E+01  1.61E+00  6.01E-01
```

INHALATION EFFECTIVE DOSE ORDERED BY DOSE (rem) FOR ADULT AGE

ORGAN	NO.	DOWNWIND DISTANCES (m) 1.00E+02	5.00E+02	1.00E+03	5.00E+03	1.00E+04
ADRENALS	1	1.45E+02	9.01E+00	2.90E+00	2.47E-01	9.29E-02
B_WALL	2	3.47E+02	2.15E+01	6.88E+00	5.71E-01	2.10E-01
BSURFACE	3	4.61E+01	2.86E+00	9.21E-01	7.86E-02	2.97E-02
BRAIN	4	5.32E+01	3.30E+00	1.06E+00	8.85E-02	3.29E-02
BREAST	5	1.40E+02	8.70E+00	2.80E+00	2.39E-01	9.02E-02
COLON	6	3.53E+03	2.19E+02	7.03E+01	5.94E+00	2.21E+00
ESOPHAGU	7	1.70E+02	1.06E+01	3.40E+00	2.89E-01	1.09E-01
ET_AIR	8	3.12E+03	1.93E+02	6.15E+01	4.85E+00	1.73E+00
KIDNEYS	9	1.05E+02	6.49E+00	2.09E+00	1.77E-01	6.64E-02
LIVER	10	1.90E+02	1.18E+01	3.79E+00	3.24E-01	1.23E-01
LLI_WALL	11	2.08E+03	1.29E+02	4.14E+01	3.53E+00	1.32E+00
LUNGS	12	3.29E+04	2.04E+03	6.57E+02	5.65E+01	2.14E+01
MUSCLE	13	9.55E+01	5.92E+00	1.90E+00	1.61E-01	6.02E-02
OVARIES	14	1.13E+02	6.99E+00	2.25E+00	1.89E-01	7.06E-02
PANCREAS	15	1.26E+02	7.79E+00	2.50E+00	2.11E-01	7.91E-02
R_MARROW	16	3.41E+02	2.12E+01	6.81E+00	5.79E-01	2.18E-01
SI_WALL	17	3.18E+02	1.97E+01	6.30E+00	5.09E-01	1.82E-01
SKIN	18	1.22E+01	7.56E-01	2.43E-01	2.05E-02	7.68E-03
SPLEEN	19	1.20E+02	7.44E+00	2.39E+00	2.03E-01	7.60E-02
ST_WALL	20	1.07E+03	6.63E+01	2.12E+01	1.62E+00	5.58E-01
TESTES	21	4.82E+01	2.99E+00	9.59E-01	8.07E-02	3.01E-02
THYMUS	22	1.70E+02	1.06E+01	3.40E+00	2.89E-01	1.09E-01
THYROID	23	1.31E+04	8.13E+02	2.61E+02	2.20E+01	8.21E+00
ULI_WALL	24	1.01E+03	6.28E+01	2.02E+01	1.68E+00	6.18E-01
UTERUS	25	8.52E+01	5.28E+00	1.69E+00	1.42E-01	5.28E-02
E_50	26	5.24E+04	3.25E+03	1.05E+03	8.91E+01	3.35E+01

Ground Surface Dose Calculation

```
    OCCUPANCY FACTOR =  1.000E+00
    TIME RECEPTOR IS EXPOSED TO CONTAMINATED SOIL =  1.000E+00 (yr)
    BUILDING SHIELDING FACTOR =  7.000E-01
    RELEASE TIME FOR EXPONENTIAL DECAY FUNCTION =  1.000E+00 s
    GROUND SURFACE DOSE                          CHI/Q =  1.363E-02 (s/m^3)
      DOWNWIND DISTANCE =  1.00E+02 (m)    PLUME TRAVEL TIME = 1.00E+02 (s)
    GROUND SURFACE DOSE                          CHI/Q =  8.574E-04 (s/m^3)
      DOWNWIND DISTANCE =  5.00E+02 (m)    PLUME TRAVEL TIME = 5.00E+02 (s)
    GROUND SURFACE DOSE                          CHI/Q =  2.785E-04 (s/m^3)
      DOWNWIND DISTANCE =  1.00E+03 (m)    PLUME TRAVEL TIME = 1.00E+03 (s)
    GROUND SURFACE DOSE                          CHI/Q =  2.463E-05 (s/m^3)
      DOWNWIND DISTANCE =  5.00E+03 (m)    PLUME TRAVEL TIME = 5.00E+03 (s)
    GROUND SURFACE DOSE                          CHI/Q =  9.562E-06 (s/m^3)
      DOWNWIND DISTANCE =  1.00E+04 (m)    PLUME TRAVEL TIME = 1.00E+04 (s)
```

GROUND SURFACE EFFECTIVE DOSE ORDERED BY ORGAN (rem)

ORGAN	NO.	DOWNWIND DISTANCES (M) 1.00E+02	5.00E+02	1.00E+03	5.00E+03	1.00E+04
Lungs	1	5.41E+04	3.35E+03	1.08E+03	9.10E+01	3.41E+01
S Wall	2	5.14E+04	3.18E+03	1.02E+03	8.64E+01	3.23E+01
SI Wall	3	5.03E+04	3.12E+03	1.00E+03	8.47E+01	3.17E+01
ULI Wall	4	5.10E+04	3.16E+03	1.01E+03	8.59E+01	3.21E+01
LLI Wall	5	5.22E+04	3.23E+03	1.04E+03	8.79E+01	3.29E+01
Testes	6	5.92E+04	3.67E+03	1.18E+03	9.98E+01	3.73E+01
Breast	7	5.68E+04	3.52E+03	1.13E+03	9.57E+01	3.58E+01
BSurface	8	8.09E+04	5.01E+03	1.61E+03	1.36E+02	5.11E+01
R Marrow	9	5.50E+04	3.41E+03	1.09E+03	9.26E+01	3.47E+01
Thyroid	10	5.55E+04	3.44E+03	1.11E+03	9.36E+01	3.50E+01
Kidney	11	5.19E+04	3.22E+03	1.03E+03	8.74E+01	3.27E+01
Liver	12	5.16E+04	3.19E+03	1.03E+03	8.68E+01	3.25E+01
Spleen	13	5.17E+04	3.20E+03	1.03E+03	8.71E+01	3.26E+01
Pancreas	14	4.84E+04	2.99E+03	9.62E+02	8.14E+01	3.05E+01
Muscle	15	4.75E+04	2.94E+03	9.46E+02	8.00E+01	2.99E+01
Skin	16	3.84E+05	2.38E+04	7.65E+03	6.51E+02	2.45E+02
Brain	17	5.10E+04	3.16E+03	1.02E+03	8.59E+01	3.22E+01
Thymus	18	5.08E+04	3.15E+03	1.01E+03	8.56E+01	3.20E+01
U Bladd	19	5.21E+04	3.23E+03	1.04E+03	8.77E+01	3.28E+01
Adrenal	20	5.86E+04	3.63E+03	1.17E+03	9.86E+01	3.69E+01

```
  Esophagu  21   4.64E+04  2.87E+03  9.22E+02  7.80E+01  2.92E+01
  Ovaries   22   5.11E+04  3.17E+03  1.02E+03  8.61E+01  3.22E+01
  Uterus    23   5.00E+04  3.09E+03  9.94E+02  8.41E+01  3.15E+01
GROUND SURFACE  EFFECTIVE DOSE ORDERED BY DOSE (rem)
                DOWNWIND DISTANCES (M)
    ORGAN   NO.  1.00E+02  5.00E+02  1.00E+03  5.00E+03  1.00E+04
  --------  ---  --------  --------  --------  --------  --------
  Skin      16   3.84E+05  2.38E+04  7.65E+03  6.51E+02  2.45E+02
  BSurface   8   8.09E+04  5.01E+03  1.61E+03  1.36E+02  5.11E+01
  Testes     6   5.92E+04  3.67E+03  1.18E+03  9.98E+01  3.73E+01
  Adrenal   20   5.86E+04  3.63E+03  1.17E+03  9.86E+01  3.69E+01
  Breast     7   5.68E+04  3.52E+03  1.13E+03  9.57E+01  3.58E+01
  Thyroid   10   5.55E+04  3.44E+03  1.11E+03  9.36E+01  3.50E+01
  R Marrow   9   5.50E+04  3.41E+03  1.09E+03  9.26E+01  3.47E+01
  Lungs      1   5.41E+04  3.35E+03  1.08E+03  9.10E+01  3.41E+01
  LLI Wall   5   5.22E+04  3.23E+03  1.04E+03  8.79E+01  3.29E+01
  U Bladd   19   5.21E+04  3.23E+03  1.04E+03  8.77E+01  3.28E+01
  Kidney    11   5.19E+04  3.22E+03  1.03E+03  8.74E+01  3.27E+01
  Spleen    13   5.17E+04  3.20E+03  1.03E+03  8.71E+01  3.26E+01
  Liver     12   5.16E+04  3.19E+03  1.03E+03  8.68E+01  3.25E+01
  S Wall     2   5.14E+04  3.18E+03  1.02E+03  8.64E+01  3.23E+01
  Ovaries   22   5.11E+04  3.17E+03  1.02E+03  8.61E+01  3.22E+01
  Brain     17   5.10E+04  3.16E+03  1.02E+03  8.59E+01  3.22E+01
  ULI Wall   4   5.10E+04  3.16E+03  1.01E+03  8.59E+01  3.21E+01
  Thymus    18   5.08E+04  3.15E+03  1.01E+03  8.56E+01  3.20E+01
  SI Wall    3   5.03E+04  3.12E+03  1.00E+03  8.47E+01  3.17E+01
  Uterus    23   5.00E+04  3.09E+03  9.94E+02  8.41E+01  3.15E+01
  Pancreas  14   4.84E+04  2.99E+03  9.62E+02  8.14E+01  3.05E+01
  Muscle    15   4.75E+04  2.94E+03  9.46E+02  8.00E+01  2.99E+01
  Esophagu  21   4.64E+04  2.87E+03  9.22E+02  7.80E+01  2.92E+01
GROUND SURFACE  EFFECTIVE DOSE EQUIVALENT (rem)
                DOWNWIND DISTANCES (M)
    ORGAN   NO.  1.00E+02  5.00E+02  1.00E+03  5.00E+03  1.00E+04
  --------  ---  --------  --------  --------  --------  --------
  Lungs      1   6.49E+03  4.02E+02  1.29E+02  1.09E+01  4.09E+00
  S Wall     2   3.08E+03  1.91E+02  6.13E+01  5.19E+00  1.94E+00
  SI Wall    3   3.02E+03  1.87E+02  6.01E+01  5.08E+00  1.90E+00
  ULI Wall   4   3.06E+03  1.90E+02  6.09E+01  5.15E+00  1.93E+00
  LLI Wall   5   3.13E+03  1.94E+02  6.23E+01  5.27E+00  1.97E+00
  Testes     6   1.48E+04  9.17E+02  2.95E+02  2.49E+01  9.33E+00
  Breast     7   8.52E+03  5.28E+02  1.70E+02  1.44E+01  5.37E+00
  BSurface   8   2.43E+03  1.50E+02  4.83E+01  4.09E+00  1.53E+00
  R Marrow   9   6.60E+03  4.09E+02  1.31E+02  1.11E+01  4.16E+00
  Thyroid   10   1.67E+03  1.03E+02  3.32E+01  2.81E+00  1.05E+00
  Kidney    11   3.12E+03  1.93E+02  6.20E+01  5.24E+00  1.96E+00
  Liver     12   3.09E+03  1.92E+02  6.15E+01  5.21E+00  1.95E+00
  Spleen    13   3.10E+03  1.92E+02  6.18E+01  5.23E+00  1.96E+00
  Pancreas  14   2.90E+03  1.80E+02  5.77E+01  4.88E+00  1.83E+00
  Muscle    15   2.85E+03  1.77E+02  5.68E+01  4.80E+00  1.80E+00
  Skin      16   3.84E+03  2.38E+02  7.65E+01  6.51E+00  2.45E+00
  Brain     17   3.06E+03  1.90E+02  6.09E+01  5.16E+00  1.93E+00
  Thymus    18   3.05E+03  1.89E+02  6.07E+01  5.14E+00  1.92E+00
  U Bladd   19   3.13E+03  1.94E+02  6.22E+01  5.26E+00  1.97E+00
  Adrenal   20   3.51E+03  2.18E+02  6.99E+01  5.92E+00  2.21E+00
  Esophagu  21   2.78E+03  1.72E+02  5.53E+01  4.68E+00  1.75E+00
  Ovaries   22   1.28E+04  7.92E+02  2.54E+02  2.15E+01  8.06E+00
  Uterus    23   3.00E+03  1.86E+02  5.96E+01  5.05E+00  1.89E+00
  EXT EDE   24   5.65E+04  3.50E+03  1.12E+03  9.52E+01  3.56E+01
```

```
Air Immersion Dose Equivalent Calculation'>
```

```
    RELEASE TIME FOR EXPONENTIAL DECAY FUNCTION =  1.000E+00 s
    AIR IMMERSION DOSE                         CHI/Q =  1.363E-02 (m^3 m)
      DOWNWIND DISTANCE =  1.00E+02 (m)    PLUME TRAVEL TIME = 1.00E+02 (s)
    AIR IMMERSION DOSE                         CHI/Q =  8.574E-04 (m^3 m)
      DOWNWIND DISTANCE =  5.00E+02 (m)    PLUME TRAVEL TIME = 5.00E+02 (s)
    AIR IMMERSION DOSE                         CHI/Q =  2.785E-04 (m^3 m)
      DOWNWIND DISTANCE =  1.00E+03 (m)    PLUME TRAVEL TIME = 1.00E+03 (s)
    AIR IMMERSION DOSE                         CHI/Q =  2.463E-05 (m^3 m)
      DOWNWIND DISTANCE =  5.00E+03 (m)    PLUME TRAVEL TIME = 5.00E+03 (s)
    AIR IMMERSION DOSE                         CHI/Q =  9.562E-06 (m^3 m)
```

```
    DOWNWIND DISTANCE =  1.00E+04 (m)    PLUME TRAVEL TIME = 1.00E+04 (s)
AIR IMMERSION EFFECTIVE DOSE ORDERED BY ORGAN (rem)
              DOWNWIND DISTANCES (M)
  ORGAN   NO.  1.00E+02  5.00E+02  1.00E+03  5.00E+03  1.00E+04
 -------- ---  --------  --------  --------  --------  --------
Lungs      1   1.08E+04  6.43E+02  1.93E+02  1.05E+01  2.83E+00
S Wall     2   9.69E+03  5.79E+02  1.73E+02  9.41E+00  2.54E+00
SI Wall    3   8.87E+03  5.30E+02  1.59E+02  8.59E+00  2.31E+00
ULI Wall   4   9.13E+03  5.45E+02  1.63E+02  8.85E+00  2.38E+00
LLI Wall   5   8.99E+03  5.37E+02  1.61E+02  8.71E+00  2.34E+00
Testes     6   1.07E+04  6.41E+02  1.92E+02  1.05E+01  2.83E+00
Breast     7   1.22E+04  7.26E+02  2.17E+02  1.18E+01  3.20E+00
BSurface   8   1.69E+04  1.01E+03  3.01E+02  1.67E+01  4.63E+00
R Marrow   9   1.06E+04  6.33E+02  1.89E+02  1.03E+01  2.76E+00
Thyroid   10   1.10E+04  6.60E+02  1.98E+02  1.07E+01  2.90E+00
Kidney    11   9.74E+03  5.82E+02  1.74E+02  9.46E+00  2.55E+00
Liver     12   9.82E+03  5.87E+02  1.76E+02  9.53E+00  2.57E+00
Spleen    13   9.85E+03  5.88E+02  1.76E+02  9.56E+00  2.58E+00
Pancreas  14   9.03E+03  5.39E+02  1.61E+02  8.76E+00  2.36E+00
Muscle    15   8.79E+03  5.25E+02  1.57E+02  8.52E+00  2.29E+00
Skin      16   2.16E+04  1.30E+03  3.96E+02  2.30E+01  6.39E+00
Brain     17   1.15E+04  6.86E+02  2.05E+02  1.11E+01  3.00E+00
Thymus    18   1.03E+04  6.13E+02  1.84E+02  9.97E+00  2.69E+00
U Bladd   19   9.16E+03  5.47E+02  1.64E+02  8.89E+00  2.39E+00
Adrenal   20   1.05E+04  6.28E+02  1.88E+02  1.02E+01  2.76E+00
Esophagu  21   9.18E+03  5.49E+02  1.64E+02  8.90E+00  2.39E+00
Ovaries   22   8.93E+03  5.34E+02  1.60E+02  8.65E+00  2.32E+00
Uterus    23   8.69E+03  5.19E+02  1.55E+02  8.42E+00  2.26E+00
AIR IMMERSION EFFECTIVE DOSE ORDERED BY DOSE (rem)
              DOWNWIND DISTANCES (M)
  ORGAN   NO.  1.00E+02  5.00E+02  1.00E+03  5.00E+03  1.00E+04
 -------- ---  --------  --------  --------  --------  --------
Skin      16   2.16E+04  1.30E+03  3.96E+02  2.30E+01  6.39E+00
BSurface   8   1.69E+04  1.01E+03  3.01E+02  1.67E+01  4.63E+00
Breast     7   1.22E+04  7.26E+02  2.17E+02  1.18E+01  3.20E+00
Brain     17   1.15E+04  6.86E+02  2.05E+02  1.11E+01  3.00E+00
Thyroid   10   1.10E+04  6.60E+02  1.98E+02  1.07E+01  2.90E+00
Lungs      1   1.08E+04  6.43E+02  1.93E+02  1.05E+01  2.83E+00
Testes     6   1.07E+04  6.41E+02  1.92E+02  1.05E+01  2.83E+00
R Marrow   9   1.06E+04  6.33E+02  1.89E+02  1.03E+01  2.76E+00
Adrenal   20   1.05E+04  6.28E+02  1.88E+02  1.02E+01  2.76E+00
Thymus    18   1.03E+04  6.13E+02  1.84E+02  9.97E+00  2.69E+00
Spleen    13   9.85E+03  5.88E+02  1.76E+02  9.56E+00  2.58E+00
Liver     12   9.82E+03  5.87E+02  1.76E+02  9.53E+00  2.57E+00
Kidney    11   9.74E+03  5.82E+02  1.74E+02  9.46E+00  2.55E+00
S Wall     2   9.69E+03  5.79E+02  1.73E+02  9.41E+00  2.54E+00
Esophagu  21   9.18E+03  5.49E+02  1.64E+02  8.90E+00  2.39E+00
U Bladd   19   9.16E+03  5.47E+02  1.64E+02  8.89E+00  2.39E+00
ULI Wall   4   9.13E+03  5.45E+02  1.63E+02  8.85E+00  2.38E+00
Pancreas  14   9.03E+03  5.39E+02  1.61E+02  8.76E+00  2.36E+00
LLI Wall   5   8.99E+03  5.37E+02  1.61E+02  8.71E+00  2.34E+00
Ovaries   22   8.93E+03  5.34E+02  1.60E+02  8.65E+00  2.32E+00
SI Wall    3   8.87E+03  5.30E+02  1.59E+02  8.59E+00  2.31E+00
Muscle    15   8.79E+03  5.25E+02  1.57E+02  8.52E+00  2.29E+00
Uterus    23   8.69E+03  5.19E+02  1.55E+02  8.42E+00  2.26E+00
AIR IMMERSION EFFECTIVE DOSE EQUIVALENT (rem)
              DOWNWIND DISTANCES (M)
  ORGAN   NO.  1.00E+02  5.00E+02  1.00E+03  5.00E+03  1.00E+04
 -------- ---  --------  --------  --------  --------  --------
Lungs      1   1.29E+03  7.72E+01  2.31E+01  1.26E+00  3.39E-01
S Wall     2   5.81E+02  3.47E+01  1.04E+01  5.64E-01  1.52E-01
SI Wall    3   5.32E+02  3.18E+01  9.52E+00  5.15E-01  1.38E-01
ULI Wall   4   5.48E+02  3.27E+01  9.80E+00  5.31E-01  1.43E-01
LLI Wall   5   5.39E+02  3.22E+01  9.65E+00  5.22E-01  1.40E-01
Testes     6   2.68E+03  1.60E+02  4.80E+01  2.61E+00  7.07E-01
Breast     7   1.82E+03  1.09E+02  3.26E+01  1.78E+00  4.81E-01
BSurface   8   5.06E+02  3.02E+01  9.04E+00  5.01E-01  1.39E-01
R Marrow   9   1.27E+03  7.59E+01  2.27E+01  1.23E+00  3.32E-01
Thyroid   10   3.31E+02  1.98E+01  5.93E+00  3.22E-01  8.71E-02
Kidney    11   5.84E+02  3.49E+01  1.05E+01  5.67E-01  1.53E-01
Liver     12   5.89E+02  3.52E+01  1.05E+01  5.72E-01  1.54E-01
Spleen    13   5.91E+02  3.53E+01  1.06E+01  5.74E-01  1.55E-01
```

```
Pancreas  14   5.42E+02  3.23E+01  9.69E+00  5.25E-01  1.42E-01
Muscle    15   5.27E+02  3.15E+01  9.43E+00  5.11E-01  1.37E-01
Skin      16   2.16E+02  1.30E+01  3.96E+00  2.30E-01  6.39E-02
Brain     17   6.89E+02  4.12E+01  1.23E+01  6.69E-01  1.80E-01
Thymus    18   6.16E+02  3.68E+01  1.10E+01  5.98E-01  1.61E-01
U Bladd   19   5.50E+02  3.28E+01  9.83E+00  5.33E-01  1.44E-01
Adrenal   20   6.31E+02  3.77E+01  1.13E+01  6.14E-01  1.66E-01
Esophagu  21   5.51E+02  3.29E+01  9.86E+00  5.34E-01  1.43E-01
Ovaries   22   2.23E+03  1.34E+02  4.00E+01  2.16E+00  5.79E-01
Uterus    23   5.21E+02  3.11E+01  9.33E+00  5.05E-01  1.36E-01
EXT EDE   24   1.10E+04  6.58E+02  1.97E+02  1.07E+01  2.90E+00
```

Ingestion Dose Calculation

```
        USING DOSE CONVERSION FACTORS FROM ICRP-72 FOR MEMBERS OF THE PUBLIC
    RELEASE TIME FOR EXPONENTIAL DECAY FUNCTION =  1.000E+00 (s)
    INTERNAL EXPOSURE TIME PERIOD =  5.000E+01 (yr)
    INGESTION CALCULATIONS MADE USING CODE CALCULATED CONSTANTS
       INGESTION CONSTANTS:
           5.20E+02  STORED VEGETABLE USAGE FACTOR (KG/YR)
           6.40E+01  FRESH VEGETABLE USAGE FACTOR (KG/YR)
           1.10E+02  MEAT USAGE FACTOR (KG/YR)
           3.10E+02  MILK USAGE FACTOR (L/YR)
           7.60E-01  FRACTION OF STORED VEGETABLES FROM GARDEN
           1.00E+00  FRACTION OF FRESH VEGETABLES FROM GARDEN
           5.70E-01  RETENTION FACTOR FOR ACTIVITY ON FORAGE
           2.00E-01  RETENTION FACTOR FOR ACTIVITY ON VEGETABLES
           1.00E+00  RETENTION FACTOR FOR IODINES
           2.10E-03  REMOVAL RATE CONSTANT FOR CROPS (1/H)
           6.00E+01  VEGETABLE EXPOSURE TIME TO PLUME FOR CHRONIC RELEASE (D)
           3.00E+01  FORAGE EXPOSURE TIME TO PLUME FOR CHRONIC RELEASE (D)
           1.00E+00  HTO REMOVAL HALF TIME (D)
           2.25E+02  EFFECTIVE SURFACE SOIL DENSITY (KG/SQ M)
           6.00E+01  STORED VEGETABLE HOLDUP TIME AFTER HARVEST (D)
           1.00E+00  FRESH VEGETABLE HOLDUP TIME AFTER HARVEST (D)
           1.60E+01  ANIMALS DAILY FORAGE FEED (KG/D)
           2.00E+00  FEED-MILK-RECEPTOR TRANSFER TIME (D)
           2.00E+01  SLAUGHTER TO CONSUMPTION TIME (D)
           4.00E-01  FRACTION OF YEAR ON PASTURE
           4.30E-01  PASTURE FEED FRACTION
           9.00E+01  STORED FEED STORAGE TIME
           2.00E+00  VEGETABLE VEGETATION YIELD (KG/SQ M)
           2.80E-01  FORAGE VEGETATION YIELD (KG/SQ M)
           4.90E+00  ABSOLUTE HUMIDITY (G/CU M)
    CHRONIC RELEASE - ANNUAL DOSE
       ACTIVITY BUILDUP IN SOIL OVER   1.500E+01 (YR)
   ICRP-72 INGESTION DOSE CALCULATIONS FOR ADULT AGE
     INGESTION EQUIVALENT DOSE ORDERED BY ORGAN (rem)   FOR ADULT AGE
               DOWNWIND DISTANCES (m)
   ORGAN   NO.  1.00E+02  5.00E+02  1.00E+03  5.00E+03  1.00E+04
 --------  ---  --------  --------  --------  --------  --------
 ADRENALS   1   5.21E+03  3.23E+02  1.04E+02  8.89E+00  3.35E+00
   B_WALL   2   3.46E+04  2.15E+03  6.90E+02  5.86E+01  2.20E+01
 BSURFACE   3   5.24E+04  3.25E+03  1.05E+03  9.06E+01  3.45E+01
    BRAIN   4   6.88E+03  4.27E+02  1.38E+02  1.18E+01  4.48E+00
   BREAST   5   4.21E+03  2.61E+02  8.42E+01  7.21E+00  2.73E+00
    COLON   6   1.59E+05  9.90E+03  3.19E+03  2.76E+02  1.05E+02
 ESOPHAGU   7   7.44E+03  4.62E+02  1.49E+02  1.28E+01  4.83E+00
   ET_AIR   8   7.36E+03  4.57E+02  1.47E+02  1.26E+01  4.78E+00
  KIDNEYS   9   6.33E+03  3.93E+02  1.27E+02  1.08E+01  4.09E+00
    LIVER  10   6.18E+03  3.83E+02  1.23E+02  1.06E+01  4.00E+00
 LLI_WALL  11   2.43E+05  1.51E+04  4.87E+03  4.21E+02  1.60E+02
    LUNGS  12   5.97E+03  3.70E+02  1.19E+02  1.02E+01  3.86E+00
   MUSCLE  13   7.59E+03  4.71E+02  1.52E+02  1.30E+01  4.93E+00
  OVARIES  14   1.29E+04  8.00E+02  2.58E+02  2.22E+01  8.42E+00
 PANCREAS  15   6.31E+03  3.91E+02  1.26E+02  1.07E+01  3.99E+00
 R_MARROW  16   2.70E+04  1.68E+03  5.41E+02  4.67E+01  1.78E+01
  SI_WALL  17   2.48E+04  1.54E+03  4.97E+02  4.28E+01  1.63E+01
     SKIN  18   4.73E+03  2.94E+02  9.45E+01  8.11E+00  3.07E+00
   SPLEEN  19   5.39E+03  3.34E+02  1.07E+02  9.14E+00  3.43E+00
  ST_WALL  20   2.72E+04  1.68E+03  5.39E+02  4.48E+01  1.64E+01
```

```
   TESTES  21   4.44E+03  2.75E+02  8.86E+01  7.59E+00  2.87E+00
   THYMUS  22   7.44E+03  4.62E+02  1.49E+02  1.28E+01  4.83E+00
  THYROID  23   1.38E+07  8.59E+05  2.77E+05  2.39E+04  9.06E+03
 ULI_WALL  24   9.33E+04  5.79E+03  1.87E+03  1.61E+02  6.15E+01
   UTERUS  25   8.43E+03  5.23E+02  1.68E+02  1.44E+01  5.46E+00
     INGESTION EQUIVALENT DOSE ORDERED BY DOSE (rem)   FOR ADULT AGE
               DOWNWIND DISTANCES (m)
   ORGAN   NO.  1.00E+02  5.00E+02  1.00E+03  5.00E+03  1.00E+04
 --------  ---  --------  --------  --------  --------  --------
  THYROID  23   1.38E+07  8.59E+05  2.77E+05  2.39E+04  9.06E+03
 LLI_WALL  11   2.43E+05  1.51E+04  4.87E+03  4.21E+02  1.60E+02
    COLON   6   1.59E+05  9.90E+03  3.19E+03  2.76E+02  1.05E+02
 ULI_WALL  24   9.33E+04  5.79E+03  1.87E+03  1.61E+02  6.15E+01
 BSURFACE   3   5.24E+04  3.25E+03  1.05E+03  9.06E+01  3.45E+01
   B_WALL   2   3.46E+04  2.15E+03  6.90E+02  5.86E+01  2.20E+01
  ST_WALL  20   2.72E+04  1.68E+03  5.39E+02  4.48E+01  1.64E+01
 R_MARROW  16   2.70E+04  1.68E+03  5.41E+02  4.67E+01  1.78E+01
  SI_WALL  17   2.48E+04  1.54E+03  4.97E+02  4.28E+01  1.63E+01
  OVARIES  14   1.29E+04  8.00E+02  2.58E+02  2.22E+01  8.42E+00
   UTERUS  25   8.43E+03  5.23E+02  1.68E+02  1.44E+01  5.46E+00
   MUSCLE  13   7.59E+03  4.71E+02  1.52E+02  1.30E+01  4.93E+00
 ESOPHAGU   7   7.44E+03  4.62E+02  1.49E+02  1.28E+01  4.83E+00
   THYMUS  22   7.44E+03  4.62E+02  1.49E+02  1.28E+01  4.83E+00
   ET_AIR   8   7.36E+03  4.57E+02  1.47E+02  1.26E+01  4.78E+00
    BRAIN   4   6.88E+03  4.27E+02  1.38E+02  1.18E+01  4.48E+00
  KIDNEYS   9   6.33E+03  3.93E+02  1.27E+02  1.08E+01  4.09E+00
 PANCREAS  15   6.31E+03  3.91E+02  1.26E+02  1.07E+01  3.99E+00
    LIVER  10   6.18E+03  3.83E+02  1.23E+02  1.06E+01  4.00E+00
    LUNGS  12   5.97E+03  3.70E+02  1.19E+02  1.02E+01  3.86E+00
   SPLEEN  19   5.39E+03  3.34E+02  1.07E+02  9.14E+00  3.43E+00
 ADRENALS   1   5.21E+03  3.23E+02  1.04E+02  8.89E+00  3.35E+00
     SKIN  18   4.73E+03  2.94E+02  9.45E+01  8.11E+00  3.07E+00
   TESTES  21   4.44E+03  2.75E+02  8.86E+01  7.59E+00  2.87E+00
   BREAST   5   4.21E+03  2.61E+02  8.42E+01  7.21E+00  2.73E+00
     INGESTION EFFECTIVE DOSE ORDERED BY DOSE (rem)   FOR ADULT AGE
               DOWNWIND DISTANCES (m)
   ORGAN   NO.  1.00E+02  5.00E+02  1.00E+03  5.00E+03  1.00E+04
 --------  ---  --------  --------  --------  --------  --------
 ADRENALS   1   2.61E+02  1.62E+01  5.20E+00  4.44E-01  1.68E-01
   B_WALL   2   1.73E+03  1.07E+02  3.45E+01  2.93E+00  1.10E+00
 BSURFACE   3   5.24E+02  3.25E+01  1.05E+01  9.06E-01  3.45E-01
    BRAIN   4   3.44E+02  2.14E+01  6.88E+00  5.91E-01  2.24E-01
   BREAST   5   2.11E+02  1.31E+01  4.21E+00  3.61E-01  1.36E-01
    COLON   6   1.91E+04  1.19E+03  3.83E+02  3.31E+01  1.26E+01
 ESOPHAGU   7   3.72E+02  2.31E+01  7.44E+00  6.38E-01  2.42E-01
   ET_AIR   8   3.68E+02  2.28E+01  7.36E+00  6.32E-01  2.39E-01
  KIDNEYS   9   3.17E+02  1.96E+01  6.33E+00  5.41E-01  2.05E-01
    LIVER  10   3.09E+02  1.92E+01  6.17E+00  5.29E-01  2.00E-01
 LLI_WALL  11   1.22E+04  7.55E+02  2.43E+02  2.10E+01  8.02E+00
    LUNGS  12   7.16E+02  4.44E+01  1.43E+01  1.23E+00  4.64E-01
   MUSCLE  13   3.80E+02  2.36E+01  7.59E+00  6.51E-01  2.46E-01
  OVARIES  14   6.44E+02  4.00E+01  1.29E+01  1.11E+00  4.21E-01
 PANCREAS  15   3.16E+02  1.96E+01  6.29E+00  5.33E-01  2.00E-01
 R_MARROW  16   3.25E+03  2.02E+02  6.50E+01  5.61E+00  2.13E+00
  SI_WALL  17   1.24E+03  7.71E+01  2.49E+01  2.14E+00  8.14E-01
     SKIN  18   4.73E+01  2.94E+00  9.45E-01  8.11E-02  3.07E-02
   SPLEEN  19   2.70E+02  1.67E+01  5.37E+00  4.57E-01  1.71E-01
  ST_WALL  20   5.44E+03  3.36E+02  1.08E+02  8.96E+00  3.29E+00
   TESTES  21   2.22E+02  1.38E+01  4.43E+00  3.79E-01  1.43E-01
   THYMUS  22   3.72E+02  2.31E+01  7.44E+00  6.38E-01  2.42E-01
  THYROID  23   6.92E+05  4.30E+04  1.38E+04  1.19E+03  4.53E+02
 ULI_WALL  24   4.67E+03  2.90E+02  9.34E+01  8.07E+00  3.07E+00
   UTERUS  25   4.21E+02  2.61E+01  8.42E+00  7.22E-01  2.73E-01
     E_50  26   7.36E+05  4.57E+04  1.47E+04  1.27E+03  4.82E+02
```

Gamma Dose Calculation

```
       EXPOSURE TIME =  1.0000E+00 (S)
      CALCULATIONS MADE USING THE FINITE MODEL
                                               EXTERNAL EDE
     DOWNWIND DISTANCE =  1.000E+02 (M)         DOSE =  3.93E+02 (REM)
```

```
    DOWNWIND DISTANCE =  5.000E+02 (M)          DOSE =  6.13E+01 (REM)
    DOWNWIND DISTANCE =  1.000E+03 (M)          DOSE =  2.91E+01 (REM)
    DOWNWIND DISTANCE =  5.000E+03 (M)          DOSE =  3.87E+00 (REM)
    DOWNWIND DISTANCE =  1.000E+04 (M)          DOSE =  1.32E+00 (REM)
```

Dose Summary

```
  ICRP-72 INHALATION DOSE CALCULATIONS MADE WITH ADULT INTAKE AGE
  ICRP-72 INGESTION DOSE CALCULATIONS MADE WITH ADULT INTAKE AGE
      USING DOSE CONVERSION FACTORS FROM ICRP-72 FOR MEMBERS OF THE PUBLIC
      FOR ADULT INTAKE AGE
      PATHWAY CONTRIBUTION TO THE EFFECTIVE DOSE (rem)
      DOWNWIND DISTANCE =  1.00E+02 (m)
     NUCLIDE      INHALATION  INGESTION   GROUND SUR  AIR IMMERS     TOTAL
  -------------   ----------  ----------  ----------  ----------  ----------
     SUBTOTALS      5.24E+04    7.36E+05    5.65E+04    1.10E+04    8.56E+05
                                     FINITE MODEL CLOUD GAMMA       3.93E+02
                                                                  ----------
                                                       TOTAL        8.56E+05
      USING DOSE CONVERSION FACTORS FROM ICRP-72 FOR MEMBERS OF THE PUBLIC
      FOR ADULT INTAKE AGE
      PATHWAY CONTRIBUTION TO THE EFFECTIVE DOSE (rem)
      DOWNWIND DISTANCE =  5.00E+02 (m)
     NUCLIDE      INHALATION  INGESTION   GROUND SUR  AIR IMMERS     TOTAL
  -------------   ----------  ----------  ----------  ----------  ----------
     SUBTOTALS      3.25E+03    4.57E+04    3.50E+03    6.58E+02    5.31E+04
                                     FINITE MODEL CLOUD GAMMA       6.13E+01
                                                                  ----------
                                                       TOTAL        5.32E+04
      USING DOSE CONVERSION FACTORS FROM ICRP-72 FOR MEMBERS OF THE PUBLIC
      FOR ADULT INTAKE AGE
      PATHWAY CONTRIBUTION TO THE EFFECTIVE DOSE (rem)
      DOWNWIND DISTANCE =  1.00E+03 (m)
     NUCLIDE      INHALATION  INGESTION   GROUND SUR  AIR IMMERS     TOTAL
  -------------   ----------  ----------  ----------  ----------  ----------
     SUBTOTALS      1.05E+03    1.47E+04    1.12E+03    1.97E+02    1.71E+04
                                     FINITE MODEL CLOUD GAMMA       2.91E+01
                                                                  ----------
                                                       TOTAL        1.71E+04
      USING DOSE CONVERSION FACTORS FROM ICRP-72 FOR MEMBERS OF THE PUBLIC
      FOR ADULT INTAKE AGE
      PATHWAY CONTRIBUTION TO THE EFFECTIVE DOSE (rem)
      DOWNWIND DISTANCE =  5.00E+03 (m)
     NUCLIDE      INHALATION  INGESTION   GROUND SUR  AIR IMMERS     TOTAL
  -------------   ----------  ----------  ----------  ----------  ----------
     SUBTOTALS      8.91E+01    1.27E+03    9.52E+01    1.07E+01    1.46E+03
                                     FINITE MODEL CLOUD GAMMA       3.87E+00
                                                                  ----------
                                                       TOTAL        1.47E+03
      PATHWAY CONTRIBUTION TO THE EFFECTIVE DOSE (rem)
      DOWNWIND DISTANCE =  1.00E+04 (m)
     NUCLIDE      INHALATION  INGESTION   GROUND SUR  AIR IMMERS     TOTAL
  -------------   ----------  ----------  ----------  ----------  ----------
     SUBTOTALS      3.35E+01    4.82E+02    3.56E+01    2.90E+00    5.54E+02
                                     FINITE MODEL CLOUD GAMMA       1.32E+00
                                                                  ----------
                                                       TOTAL        5.55E+02
```

Execution Time

```
           2.80E+00 SECONDS
```

6. REFERENCES

1. American National Standards Institute, Inc./American Nuclear Society (ANSI/ANS), 1987, American National Standard Guidelines for the Verification and Validation of Scientific and Engineering Computer Programs for the Nuclear Industry, ANSI/ANS-10.4.
2. American Society of Mechanical Engineers (ASME), 2000, Quality Assurance Program Requirements for Nuclear Facility Applications, ASME-NQA-1-2000.
3. Abramowitz, M and I. A. Stegum (eds.), 1964: Handbook of Mathematical Functions with Formulas, Graphs, and Mathematical Tables, AMS 55, pp. 887-890.
4. Baes, C. F. III, R. D. Sharp, A. L. Sjoreen, R. W. Shor, 1984, A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture, ORNL-5786, Oak Ridge National Laboratory, Oak Ridge Tennessee.
5. Berger, M. J. and R. G. Jaeger, 1968, Engineering Compendium on Radiation Shielding, Vol. I, New York: Springer-Verlag Inc., p. 218.
6. Boone, F. W., Y. C. Ng, J. M. Palms, 1981, "Terrestrial Pathways of Radionuclide Particulates," Health Physics, 41, pp. 735-747.
7. Briggs, G. A., 1969, Plume Rise, TID-25075, U.S. Atomic Energy Commission, Oak Ridge, Tennessee.
8. Chamberlain, A. C., 1953, Aspects of Travel and Deposition of Aerosol and Vapour Clouds, AERE-HP/R-1261, Harwell, Great Britian.
9. Chu, S. Y. F., L. P. Ekstrom and R. B. Firestone, The Lund/LBNL Nuclear Data Search, Version 2.0, Ernst O. Lawrence Berkeley National Laboratory, Berkely, California, and LUND University, Sweden, February 1999.
10. Clawson, K. L., G. E. Start, N. R. Ricks, 1989, Climatography of the Idaho National Engineering Laboratory, 2nd Edition, DOE/ID-12118, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Research Laboratories, Air Resource Laboratory, Field Research Division, Idaho Falls, Idaho, December.
11. Coates, R. L. and N. R. Horton, 1966, RSAC—A Radiological Safety Analysis Computer Program, IDO-17151, Idaho National Engineering Laboratory, Idaho Falls, Idaho.
12. Croff, A. G., R. L. Haese, N. B. Gove, 1979, Updated Decay and Photon Libraries for the Origen Code, ORNL/TM-6055, Oak Ridge National Laboratory, Oak Ridge Tennessee.
13. Croff, A. G., 1980, ORIGEN2—A Revised and Updated Version of the Oak Ridge Isotope Generation and Depletion Code, ORNL-5621, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
14. DOE, 1994, Airborne Release Fractions/Rates and Respirable Fractions for NonReactor Nuclear Facilities,DOE-HDBK-3010-94, U.S. Department of Energy, Washington, D.C.
15. Eckerman, K.F., and Ryman, J.C. 1993, External Exposures to Radionuclides in Air; Water; and Soil, Federal Guidance Report No. 12, EPA-402/R-93-081U.S. Environmental Protection Agency Washington, D.C.
16. Eckerman, K.F., Wolbarst, A.B., and Richardson, A.C.B., 1988, Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion. Federal Guidance Report No. 11, EPA-5201/1-88-020, U.S. Environmental Protection Agency, Washington, D.C.

17. Hanna, S. R., G. A. Briggs, R. P. Hosker Jr., 1982, Handbook on Atmospheric Diffusion, DOE/TIC-11223, U.S. Department of Energy, Oak Ridge, Tennessee.

18. ICRP (International Commission on Radiological Protection), 1977, Report of the Task Group on Reference Man, ICRP Publication 23, Pergamon Press, Oxford, Great Britain.

19. ICRP, 1979, Limits for Intakes of Radionuclides by Workers, Part 1, ICRP Publication 30, Pergamon Press, Oxford, Great Britain.

20. ICRP, 1983, Radionuclide Transformations, Energy and Intensity of Emissions, ICRP Publication 38, Pergamon Press, Oxford, Great Britain.

21. INEEL, 2001, Verification and Validation of RSAC-7.2, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho

22. Islitzer, N. F., 1965, Aerodynamic Effects of Large Reactor Complexes Upon Atmospheric Turbulence and Diffusion, IDO-12041, Idaho National Engineering Laboratory, Idaho Falls, Idaho.

23. Markee, E. H. Jr., 1967, "A Parametric Study of Gaseous Plume Depletion by Ground Surface Adsorption," in Proceeding of USAEC Meteorological Information Meeting, C. A. Mawson, Editor, AECL-2787, pp. 602-613.

24. NRC (U.S. Nuclear Regulatory Commission), 1977a, Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I, Regulatory Guide 1.109 Revision 1, Washington, D.C.

25. NRC, 1977b, Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors, Regulatory Guide 1.111 Revision 1, Washington, D.C.

26. NRC, 1982, Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants, Regulatory Guide 1.145, Revision 1, Washington, D.C.

27. NQA-1-2008, “Quality Assurance Requirements for Nuclear Facility Applications”, Subpart 2.7, “Quality Assurance Requirements for Computer Software for Nuclear Facility Applications.”

28. Ramsdell, J.V., Jr., Simonen, C.A., 1997, Atmospheric Relative Concentrations in Building Wakes, Report NUREG/CR-6331. U.S. Nuclear Regulatory Commission, Washington, D.C.

29. Richardson, L. C., 1968, User's Manual for the FORTRAN Version of RSAC, IDO-17261, Idaho National Engineering Laboratory, Idaho Falls, Idaho.

30. RSIC (Radiation Shielding Information Center), 1981, RSIC Data Library Collection, "DRALIST, Radioactive Decay Data for Application to Radiation Dosimetry and Radiological Assessments", DLC-80, Oak Ridge, Tennessee.

31. RSIC, 1991, RSIC Computer Code Collection, "ORIGEN 2.1, Isotope Generation and Depletion Code Matrix Exponential Method", CCC-371, Oak Ridge, Tennessee.

32. Rubinson, W., 1949, "The Equations of Radioactive Transformation in a Neutron Flux," Journal Chemical Phys, 17, pp. 542-547.

33. Sehmel, G. A., 1980: "Particle and Gas Dry Deposition: A Review," Atmospheric Environment, 14, pp. 983-1011.

34. Slade, D. H. (ed), 1968: Meteorology and Atomic Energy, AEC/TID-24190, U.S. Atomic Energy Commission, Silver Spring, Maryland.

35. SRA (Shonka Research Associates, Inc.), 1993, Software Verification and Validation Report for the WINCO RSAC-5 Code, Marietta, Georgia.

36. Till, J.E., and Meyer, H.R., eds., 1983, Radiological Assessment: A textbook on Environmental Dose Analysis, Report NUREG/CR-3332. U.S. Nuclear Regulatory Commission, Washington, D.C.

37. Turner, D. B., 1970, Workbook of Atmospheric Dispersion Estimates, Revised, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

38. Wenzel, D. R., 1973, Preliminary User's Manual for the Revised Radiological Safety Analysis Computer Program—RSAC-2, ACI-139, Allied Chemical Corporation, Idaho National Engineering Laboratory, Idaho Falls, Idaho.

39. Wenzel, D. R., 1982, RSAC-3, Radiological Safety Analysis Computer Program, ENICO-1002, Idaho National Engineering Laboratory, Idaho Falls, Idaho.

40. Wenzel, D. R., 1990, Interim Users Manual for RSAC-4, Radiological Safety Analysis Computer Program, Version 4.03, Westinghouse Idaho Nuclear Company, Inc., Idaho National Engineering Laboratory, Idaho Falls, Idaho.

41. Wenzel, D. R. 1994, The Radiological Safety Analysis Computer Program (RSAC-5) User's Manual, WINCO-1123, Revision 1, Idaho national Engineering and Environmental Laboratory, Idaho Falls, Idaho.

42. Yanskey, G. R., E. H. Markee Jr., A. P. Richter, 1966, Climatography of the National Reactor Testing Station, IDO-12045, Idaho National Engineering Laboratory, Idaho Falls, Idaho.

INTENTIONALLY BLANK

Appendix A

Mathematical Models

Appendix A

Mathematical Models

A-1. FISSION PRODUCT INVENTORY

The calculation of a fission product inventory for a given operating history is divided into two parts: fission product buildup and radionuclide decay.

A-1.1 Fission Product Buildup

The rate of buildup or fission product generation of the various radionuclides of a decay chain is described by a set of simultaneous differential equations of the first order:

$$\frac{dQ_1}{dt} = S_1 - \mu_1 Q_1 \quad \text{(A-1)}$$

$$\frac{dQ_2}{dt} = s_2 - \mu_2 Q_2 + \lambda_1 Q_1 \quad \text{(A-2)}$$

$$\frac{dQ_i}{dt} = s_i - \mu_i Q_i + \lambda_{i-1} Q_{i-1} \quad \text{(A-3)}$$

where

Q_i = the number of atoms for the i^{th} radio nuclide of the decay chain

t = operating time (s)

s_i = the source rate at which atoms are being produced by fission for the i^{th} radionuclide (atoms/s).

μ_i = $\lambda_i + \sigma_{ci}\ \emptyset$

λ_i = the decay constant for the i^{th} radionuclide (s^{-1})

σ_{ci} = neutron capture cross section for the i^{th} radionuclide (cm^{-2})

$\emptyset$ = neutron flux (n/cm^2-s)

$$S_i = (CONV)(POWER)(Yield_i) \quad \text{(A-4)}$$

where

CONV = the conversion factor from power to fission (fissions/W-s)

POWER = the reactor power (W)

$Yield_i$ = the fission yield for the i^{th} radionuclide of the decay chain (atoms/fission).

The general solution as formulated by Rubinson (1949) for the contribution to the n^{th} radionuclide from the m^{th} radionuclide precursor is

$$Q_n(t) = S_m \left(\prod_{i=m}^{n-1} (\lambda_i) \right) \sum_{i=m}^{n} \left[\frac{1 - e^{-\lambda_i t}}{\lambda_i \prod_{\substack{j=m \\ j \neq i}}^{n} (\mu_j - \mu_i)} \right] \quad \text{(A-5)}$$

By summing all the precursors of a particular nuclide, the general solution for the total number of atoms for the k^{th} radionuclide of the decay chain is obtained:

$$Q_k(t) = \sum_{m=1}^{k} \left(S_m \prod_{i=m}^{k-1} (\lambda_i) \right) \sum_{i=m}^{k} \left[\frac{1 - e^{-\lambda_i t}}{\lambda_i \prod_{\substack{j=m \\ j \neq i}}^{k} (\mu_j - \mu_i)} \right] \quad \text{(A-6)}$$

For convenience the linear operator, E_k, is defined as follows:

$$E_k = \sum_{m=1}^{k} \left(S_m \prod_{i=m}^{k-1} (\lambda_i) \right) \sum_{i=m}^{k} \left[\frac{1}{\prod_{\substack{j=m \\ j \neq i}}^{k} (\mu_j - \mu_i)} \right] \quad \text{(A-7)}$$

Therefore, the buildup equation can be written as

$$Q_k(t) = E_k\left(\frac{1-e^{-\lambda_i t}}{\lambda_i}\right) \tag{A-8}$$

A-1.2 Radionuclide Decay

The differential equations for the decay rate are similar to those for fission product buildup, except the source rate is considered to be zero. The general solution for the decay equation is

$$N_k(t) = E_k(e^{-\lambda_i t}) \tag{A-9}$$

where

$N_k(t)$ = the total number of atoms for the k[th] radionuclide of the decay chain

$$E_k(e^{-\lambda_i t}) = \sum_{m=1}^{k} Q_m \left[\prod_{i=m}^{k-1}(\lambda_i)\right] \sum_{i=m}^{k}\left[\frac{e^{-\lambda_i t}}{\prod_{\substack{j=m \\ j\neq i}}^{k}(\lambda_j - \lambda_i)}\right]$$

Q_m = the total number of atoms for the m[th] radionuclide immediately following reactor shutdown as defined above.

t = the time after reactor shutdown (s).

RSAC-7.2 automatically decays all radioactivity during transport from the point of release to the environment to the downwind receptor location. For simplicity, subsequent equations used in dose calculations do not show the operator E_k. However, RSAC-7.2 programming includes the buildup and decay of all progeny in each of the decay chains.

A-2. CONCENTRATION FUNCTION

A-2.1 Atmospheric Diffusion

Atmospheric diffusion at ground level for a continuous point source can be expressed using the time-integrated form of the universal diffusion equation (Slade 1986[34]; Clawson et al. 1989[10]) as follows:

$$\frac{\chi}{Q}(x,y,0)=\frac{1}{\pi\bar{u}\ \sigma_y\sigma_z}\ \exp\left[-\frac{1}{2}\ \left(\frac{y^2}{\sigma_y^2}+\frac{h^2}{\sigma_z^2}\right)\right] \tag{A-11}$$

where

$\frac{\chi}{Q}(x,y,0)$	=	ground-level atmospheric diffusion relative to the initial point of release (s/m^3)
x	=	distance downwind (m)
y	=	horizontal distance from plume centerline (m)
$\bar{u}$	=	average windspeed at the release level (m/s)
σ_y,σ_z	=	standard deviations of effluent concentration of the plume in the horizontal and vertical directions (m)
h	=	elevation of the point of release above the ground plane (m).

Airborne material freely diffuses the atmosphere near the ground level in what is known as the mixing depth. A stable layer exists above the mixing depth that restricts vertical diffusion. The depth of the mixed layer is a function of the heat energy exchange between the air and the ground; it is influenced by cloud cover, time of day, and season. Seasonal and annual mixing depths have been estimated for the Idaho National Laboratory (INL) (Clawson et al. 1989[10]) and are presented in Table A-1.

RSAC-7.2 treats the ground and the height of the mixing depth as plume reflectors. When σ_z becomes large compared to the mixing depth, the plume becomes uniformly distributed between the

Table A-1. Estimated seasonal and annual mixing depths (m) for mornings and afternoons at the Idaho National Laboratory (INL).

Season	Morning	Afternoon
Spring	480	2330
Summer	260	2900
Autumn	330	1550
Winter	400	730
ANNUAL	370	2090

ground and the height of the mixing depth. Atmospheric diffusion is then calculated using Equation (A-12) (Turner 1970,[37] Yanskey et al. 1966[42]).

$$\frac{\chi}{Q}(x,y,0)=\frac{1}{\sqrt{2\pi}\sigma_y H\bar{u}}\ \exp\left[-\frac{1}{2}\left(\frac{y^2}{\sigma_y^2}\right)\right] \tag{A-12}$$

where

H = height of the mixing depth (m).

An option is provided for ground-level releases to adjust the plume standard deviations to correct for an initial mixing of the effluent plume within a building wake (NUREG/CR-6331). An effective σ_y and σ_z can be used to correct for building turbulence (Ramsdell 1995[28]) using the following equations:

$$\sum_y = \left(\sigma_y^2 + \Delta\ \sigma_{y1}^2 + \Delta\ \sigma_{y2}^2\right)^{1/2} \tag{A-13}$$

$$\sum_z = \left(\sigma_z^2 + \Delta\ \sigma_{z1}^2 + \Delta\ \sigma_{z2}^2\right)^{1/2} \tag{A-14}$$

where σ_y and σ_z are the normal diffusion coefficients, $\Delta\sigma_{y1}$ and $\Delta\sigma_{z1}$ are the low wind speed corrections, and $\Delta\sigma_{y2}$ and $\Delta\sigma_{z2}$ are the building wake corrections. The values for $\Delta\sigma_{y1}$, $\Delta\sigma_{z1}$, $\Delta\sigma_{y2}$ and $\Delta\sigma_{z2}$ are calculated as follows:

$$\sigma_{y1}^2 = 9.13\times10^5\left[1-\left(1+\frac{x}{1000*\bar{u}}\right)\ \exp\left(-\frac{x}{1000*\bar{u}}\right)\right] \tag{A-15}$$

$$\sigma_{z1}^2 = 6.67\times10^2\left[1-\left(1+\frac{x}{100*\bar{u}}\right)\ \exp\left(-\frac{x}{100*\bar{u}}\right)\right] \tag{A-16}$$

where x is the distance from the release point to the receptor, in meters, and U is the wind speed in meters per second. It is appropriate to use the slant range distance for x because theses corrections are made only when the release is assumed to be at ground level and the receptor is assumed to be on the axis of the plume. The diffusion coefficients corrections that account for enhanced diffusion in the wake have a similar form. These corrections are:

$$\sigma_{y2}^2 = 5.24\times10^{-2}\left(\bar{u}\right)^2 A\left[1-\left(1+\frac{x}{10*\sqrt{A}}\right)\ \exp\left(-\frac{x}{10*\sqrt{A}}\right)\right] \tag{A-17}$$

$$\sigma_{z2}^2 = 1.17\times10^{-2}\left(\bar{u}\right)^2 A\left[1-\left(1+\frac{x}{10*\sqrt{A}}\right)\ \exp\left(-\frac{x}{10*\sqrt{A}}\right)\right] \tag{A-18}$$

where A is the smallest representative cross-sectional area of the building.

An upper limit is placed on Σ_y as a conservative measure. This limit is the standard deviation associated with a concentration uniformly distributed across a sector with width equal to the circumference of a circle with radius equal to the distance between a source and the receptor. This value is:

$$\Sigma_{y_{max}} = \frac{2\,\pi\,x}{\sqrt{12}} \tag{A-19}$$

When the release is from an elevated point during stable meteorological conditions, significant concentrations of the plume often do not reach ground level until the stability change occurs. The most common breakup of stable meteorology (inversion) is through a phenomenon known as fumigation, which can result in increased ground-level concentrations. While fumigation is often ignored in other codes, it is a well documented phenomena (NRC 1982, Slade 1968,[34] Turner 1970,[37] Yanskey et al. 1966[42]). Fumigation occurs when the nocturnal temperature inversion at the surface is being broken up by surface heating shortly after sunrise. The plume may be transported large downwind distances during the stable meteorology condition before a fumigation breakup occurs. The length of time that a fumigation condition lasts is a function of the release height and the downwind terrain. Fumigations typically last approximately 30 minutes for stacks in the 30 to 50-meter heights and approximately 60 minutes for stacks in the 75 to 100-meter heights. The inversion breakup creates moderately unstable conditions under an inversion lid, thereby, limiting vertical dispersion to the area between the ground and the base of the inversion (see Figure A-1).

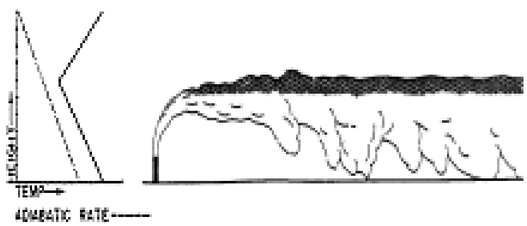


Figure A - 1. Fumigating plume.

Based on the assumption that the concentration is distributed uniformly in the vertical to the inversion base (Yanskey et al. 1966[42]), diffusion for a fumigating plume can be calculated using Equation (A-12).

Atmospheric dispersion at various heights above the ground level must be calculated to estimate cloud-gamma doses from a finite plume. The form of the time-integrated universal diffusion equation then becomes

$$\frac{\chi}{Q}(x,y,z) = \frac{1}{2\pi\bar{u}\;\sigma_y\sigma_z}\;\exp\left[-\frac{1}{2}\left(\frac{y^2}{\sigma_y^2} + \frac{(z-h)^2}{\sigma_z^2} + \frac{(z+h)^2}{\sigma_z^2}\right)\right] \tag{A-20}$$

where

z = vertical distance from the plume centerline (m)

INTENTIONALLY BLANK

A-2.2 Plume Deposition

An estimate of the amount of radioactivity that is deposited on the ground must be made to calculate ground surface, resuspension and ingestion doses.

Dry deposition calculations in RSAC-7.2 are made using a deposition velocity as defined by Chamberlain (1953)[8] as

$$V_d = -\frac{F}{\chi} \tag{A-21}$$

where

V_d = dry deposition velocity (m/s)

F = deposition flux (Ci/m^2s)

χ = airborne concentration (Ci/m^3).

The quantity of deposited radioactive material, ω, is then calculated using the following equation:

$$\omega(x,0,0) = Q \ V_d \ t \tag{A-22}$$

where

ω = surface contamination (Ci/m^2)

V_d = deposition velocity (m/s)

t = time that the ground is exposed to the plume (s).

Dry deposition velocities are a function of particle size and chemical species. Values recommended for use in RSAC-7.2 are published by Sehmel (1980).[33]

Wet deposition in RSAC-7.2 is based on the modeling summarized by Hanna et al. (1982). The modeling assumes the plume concentration (C) decreases exponentially with time:

$$C(t) = C(0)\ \exp\left[-\Lambda t\right] \tag{A-23}$$

where

Λ = scavenging coefficient (s^{-1})

t = time since precipitation began (s).

A-2.3 Plume Depletion

RSAC-7.2 has options for modeling plumes depletion by both dry and wet deposition. Plume depletion by dry deposition is based on a modified version of the Chamberlain (1953)[8] model. The Chamberlain model expressed in Pasquill notation is:

$$F_{dry}^{C} = \exp\left\{\sqrt{\frac{2}{\pi}}\frac{V_d}{\bar{u}}\int_{o}^{x}\frac{1}{\sigma_z}\ \exp\left[-\frac{1}{2}\left(\frac{h^2}{\sigma_z^2}\right)\right]dx\right\} \tag{A-24}$$

where

F_{dry}^{C} = fraction of plume depleted by dry deposition.

Because the Chamberlain model is known to indicate over depletion of the plume under stable meteorological conditions, an empirical modification has been made based upon plume depletion measurements made of releases of activity as evaluated at the INL (Markee 1967).[23] The modified Chamberlain equation is as follows:

$$F_{dry} = F_{dry}^{C}\ \exp\left[-\ln\left(x\ C_{WC}\right)\right] \tag{A-25}$$

Values for the constant C_{WC} are presented in Table A-2.

Table A-2. Values for the constant C_{WC}

Weather Class	C_{WC}
A	0.
B	0.
C	0.
D	0.
E	0.0999
F	0.198
G	0.198

When it is assumed that the rain falls completely through the plume, the fraction of the plume depleted (F_{wet}) is given by

$$F_{wet} = \frac{\Lambda}{\sqrt{2\pi}\sigma_y \bar{u}} \exp\left[-\frac{1}{2}\left(\frac{y^2}{\sigma_y^2}\right)\right] \quad \text{(A-26)}$$

The total plume depletion is:

$$F_{total} = F_{dry}^{C} \, F_{wet} \quad \text{(A-27)}$$

A-2.4 Leakage Rate Function

RSAC-7.2 can correct the radionuclide inventory for decay during holdup before leaking from a building, stack, or containment vessel to the atmosphere. Leakage is expressed in the form of a series of exponential approximations of the following form:

$$L(t - x/\bar{u}) = \sum_{j=1}^{n} K1_j \exp\left[-K2_j(t - x/\bar{u})\right] \tag{A-28}$$

where

$L(t - x/\bar{u})$ = leakage rate function (s^{-1})

t = time following the initiation of the release (s)

$x/\bar{u}$ = time required to reach any downwind receptor location (s)

n = number of exponential approximations ($1 \leq n \leq 10$)

Kl_j = linear constant (s^{-1})

$K2_j$ = exponential constant (s^{-1}).

Values of $K1_j$ and $K2_j$ can be either positive or negative. If a constant leakage rate is desired, set $K2_j$ = 0. and $K1_1$ = the reciprocal of the time that it takes for the activity to be released to the atmosphere. The use of one set of leakage constants is normally sufficient for most calculations.

It is important not to decay the radionuclide inventory twice before its release to the atmosphere. This can inadvertently occur when the total activity of each radionuclide to be released to the atmosphere over an extended period of time is entered directly into RSAC-7.2 rather than using RSAC-7.2 to calculate the radionuclide inventory. When this is the case, no additional decay of the activity before release is desired even though the total activity entered may represent a release over an extended period of time. When the total activity to be released to the atmosphere is entered directly into RSAC-7.2, the user should set $K1_1$ = 1., $K2_1$ = 0, and the time over which the activity is released to the atmosphere to 1 second.

Proper selection of the leakage constants $K1_j$ and $K2_j$ can be evaluated by integrating each of the leakage terms over the period of release. The sum of the integrated terms should equal the total release fraction before correction for radioactive decay. Additional information on the use of the RSAC-7.2 leakage function is presented in Section 4.1, *Leakage Decay Constants Lines (5201+)*.

A-2.5 Plume Rise

Plume rise in RSAC-7.2 is calculated for either jet or buoyant plumes using the methodology developed by Briggs (1969).[7] For jet plumes in neutral, windy, or lapse conditions, the jet centerline plume rise is given by

$$\Delta h = 3\frac{\omega_o}{\bar{u}}D \qquad \text{(A-29)}$$

where

Δh = plume rise above the top of the stack (m)

D = internal stack diameter (m)

w_o = efflux speed of gases from stack (m/s)

$\bar{u}$ = average windspeed at the stack level (m/s)

x = downwind distance (m).

Equation (A-29) is used up to the point that

$$\frac{\Delta h}{D} = 1.44\left(\frac{\omega_o}{\bar{u}}\right)^{2/3}\left(\frac{x}{D}\right)^{1/3} \qquad \text{(A-30)}$$

as long as $\omega_o / \bar{u} \geq 4$.

When stable meteorological conditions exist, plume rise is calculated using

$$\Delta h = 1.5\left(\frac{F_m}{\bar{u}}\right)^{1/3} s^{-1/6} \qquad \text{(A-31)}$$

where

$$F_m = \omega_o^2 \left(\frac{D}{2}\right)^2 \tag{A-32}$$

S = restoring acceleration per unit vertical displacement (s^{-2}).

RSAC-7.2 default values for S are 8.7E-04 (s^{-2}) for a weak inversion and 1.75E-03 (s^{-2}) for a strong inversion.

Plume rise for a buoyant plume is calculated using

$$\Delta h = \frac{1.6}{\bar{u}} F^{\frac{1}{3}} x^{\frac{2}{3}} \tag{A-33}$$

where

F = 3.7×10^{-5} Q_H

Q_H = stack gasses heat emission (cal/s).

Equation (A-33) is used up to a distance $x_e/x_e^* = 1$, where

x_e = downwind distance (ft)

$$x_e^* = 0.52\ F_e^{\frac{2}{5}}\ h_e^{\frac{3}{5}} \tag{A-34}$$

F_e = 4.3 x 10^{-3} Q_H

h_e = elevation of the point of release above the ground plane (ft)

Δh = 0.3048 Δh_e (m).

Beyond this distance, plume rise is calculated using

$$h_e = 1.6F_e^{\frac{1}{3}}\ \bar{u}_e^{-1}\ x_e^{*\frac{2}{3}}\left[\frac{2}{5}+\frac{16}{25}\frac{x_e}{x_e^*}+\frac{11}{5}\left(\frac{x_e}{x_e^*}\right)^2\right]\left(1+\frac{4}{5}\frac{x_e}{x_e^*}\right)^{-2} \qquad \text{(A-35)}$$

where

$\bar{u}_e$ = average windspeed at the elevation of the point of release above the ground plane (ft/s)

and allowing x_e/x_e^* to increase to a maximum value of 5.

A-3 DOSE CALCULATIONS

A-3.1 Inhalation Dose

RSAC-7.2 calculates inhalation doses using the ICRP 30 (1979)[19] model with Federal Guidance Report No. 11 dose conversion factors (DCFs). The committed dose equivalent (CDE) is calculated for individual organs and tissues over a 50-year period after inhalation. The CDE for each organ or tissue is multiplied by the appropriate ICRP 26 (1977)[18] weighting factor to calculate what is called the weighted committed dose equivalent (WCDE) in RSAC-7.2. The ICRP 26 weighting factors are presented in Table A-3. The committed effective dose equivalent (CEDE) is then the sum of the WCDEs for the organs and tissues listed in Table A-3.

RSAC-7.2 calculates CEDE for the default 1 µm activity median aerodynamic diameter (AMAD). Because of uncertainties in the ICRP 30 modeling, all final doses calculated should be reported to only one significant digit.

Table A-3. Weighting factors for stochastic risks.

Organ or tissue	*Weighting factor*
Gonads	0.25
Breast	0.15
Red bone marrow	0.12
Lungs	0.12
Thyroid	0.03
Bone surfaces	0.03
Remainder[a]	0.30

a. A weighting factor of 0.06 is applied to each of the five organs or tissues of the remaining organs receiving the greatest dose equivalents.

For particle sizes other than the default 1 μm AMAD, DCFs are corrected according to deposition in the three regions of the respiratory system; the nasal passage (NP), the trachea and bronchial tree (TB), and the pulmonary parenchyma (P). DCFs are modified according to the following equation:

$$\frac{DCF_{(New)}}{DCF_{(1\ \mu m)}} = f_{NP}\frac{D_{NP(New)}}{D_{NP_{(1\ \mu m)}}} + f_{TB}\frac{D_{TB(New)}}{D_{TB_{(1\ \mu m)}}} + f_P\frac{D_{P(New)}}{D_{TB_{(1\ \mu m)}}} \quad \text{(A-36)}$$

where

f_{NP}, f_{TB}, and f_P = fraction of the CDE in the reference tissue, resulting from deposition in the N-P, T-B, and P regions, respectively as shown in Table A-4.

D_{NP}, D_{TB}, and D_P = deposition probabilities in the respiratory regions as a function of AMAD as shown in Figure A-2.

The model is intended for use with aerosol distributions with AMADs between 0.2 and 10 μm. Provisional estimates of deposition further extending the size range are given by the dashed lines. The minimum allowable particle size is 0.1 μm AMAD. The model assumes complete deposition in the NP region for all AMAD of greater than 20 μm.

Correction is made for the chemical state of each radionuclide according to the ICRP-30 designated clearance classes of D, W and Y as shown in Table A-4 for the clearance pathways shown in Figure A-3. The allowable clearance classes for each element and the RSAC-7.2 default classes are presented in Appendix D

.

Table A-4. ICRP-30 mathematical model used to describe clearance from the respiratory system.

		Class[a]					
		D		W		Y	
Region	Compartment	T day	F	T day	F	T day	F
NP	a	0.01	0.5	0.01	0.1	0.01	0.01
(D_{NP} = 0.30)	b	0.01	0.5	0.40	0.9	0.40	0.99
TB	c	0.01	0.95	0.01	0.5	0.01	0.01
(D_{TB} = 0.08)	d	0.2	0.05	0.2	0.4	0.2	0.99
	e	0.5	0.8	50	0.15	500	0.05
P	f	NA[b]	NA	1.0	0.4	1.0	0.4
(D_P = 0.25)	g	NA	NA	50	0.4	500	0.4
	h	0.5	0.2	50	0.05	500	0.15
L	i	0.5	1.0	50	1.0	1000	0.9
	j	NA	NA	NA	NA	∞	0.1

a. D, W, and Y refer to lung retention classes with clearance half-times of 0.5, 50 and 500 days, respectively. T refers to the removal half-times, and F refers to the compartmental fractions. The values given for D_{NP}, D_{TB}, and D_P (left column) are the regional depositions for an aerosol with an AMAD of 1 µm.

b. NA = not applicable

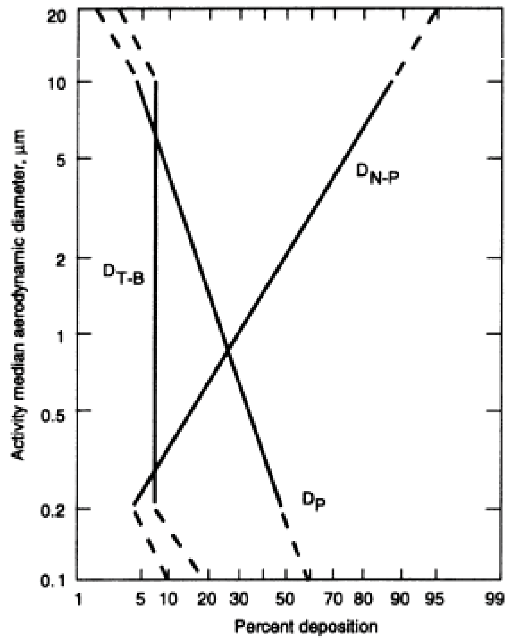


Figure A-2. Deposition of dust in the respiratory system

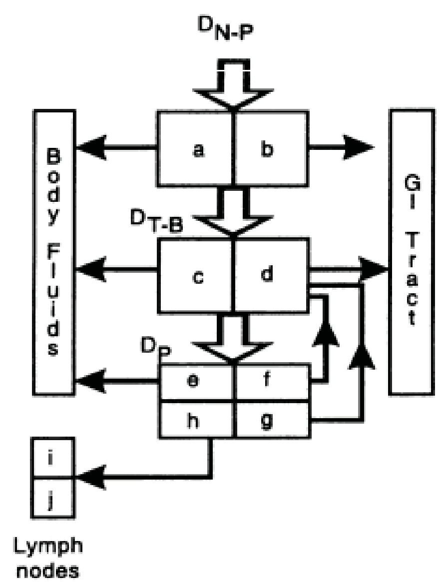


Figure A-3. Clearance pathways for the ICRP-30 model

A-3.2 Ingestion Dose

A-3.2.1 Chronic Release

The calculation of ingestion dose from a chronic release is based on the models and equations from Regulatory Guide 1.109 (NRC 1977a)[24]. Dose pathways from the ingestion of vegetation, meat, and milk have been included for activity deposited on the ground plane. The equation used to calculate the total ingestion dose from the pathways is

$$D_{ij} = DFI_{ij} \left[U^{v} f_g C_i^{v} + U^{m} C_i^{m} + U^{F} C_i^{F} + U^{L} f_1 C_i^{L} \right] \qquad \text{(A-37)}$$

where

D_{ij} = annual dose equivalent to organ j from ingestion of food contaminated from the atmospheric release and subsequent deposition of radionuclide i (rem/yr)

DFI_{ij} = ingestion dose factor for radionuclide i and organ j (rem/pCi)

U^v, U^m, U^F, U^L = usage factors for produce (nonleafy), milk, meat, and leafy vegetables (kg/yr and L/yr for milk)

f_g, f_l = respective fractions of the ingestion rates of produce and leafy vegetables that are produced in the garden of interest

$C_i^v, C_i^m, C_i^F, C_i^L$ = concentrations of radionuclide i in produce (nonleafy vegetables), milk, meat and fresh vegetables, respectively (pCi/kg).

The default dietary ingestion rates for adults (U^v, U^m, U^F, and U^L) used in RSAC-7.2 are presented in Table A-5.

Table A - 5. Default annual dietary ingestion rates for adults.

Parameter	Value	Units	Symbol
Leafy vegetables	64	kg/yr	U^L
Meat	110	kg/yr	U^F
Milk	310	L/yr	U^m
Produce	520	kg/yr	U^v

The concentration of radionuclide i in and on vegetation is a function of the rate of deposition upon the plant foliage and the rate of uptake from the soil. The equation used to estimate the concentration in and on vegetation from all radioiodines and particulate radionuclides, except tritium and carbon-14 is

$$C_i^v = d_i \left\{ \frac{r\,F_T\left[1 - e^{-\lambda_{Ei} t_e}\right]}{Y_v \lambda_{Ei}} + \frac{B_{iv}\left[1 - e^{-\lambda_i t_b}\right]}{P \lambda_i} \right\} e^{-\lambda_i t_b} \tag{A-38}$$

where

C_i^v = concentration of radionuclide i in and on vegetation (pCi/kg)

d_i = deposition rate of radionuclide i (pCi/m^2-h)

r = fraction of deposited activity retained on foliage

F_T = fraction of deposited radioactivity translocated from plant surface to edible portion of crop

λ_{Ei} = effective removal rate constant for radionuclide i from foliage surfaces (h^{-1}),

$\lambda_{Ei} = \lambda_i + \lambda_w$

λ_i = decay constant for radionuclide i (s^{-1})

λ_w = rate constant for removal of activity on plant or leaf surfaces by weathering (h^{-1})

t_e = time period that crops are exposed to contamination during the growing season (h)

Y_v = agricultural productivity (yield) (kg/m^2)

B_{iv} = concentration factor for root uptake of radionuclide i from soil to edible parts of crops (pCi/kg wet weight per pCi/kg dry soil)

t_b = period of long-term buildup for activity in soil (h)

P = effective surface density for soil (kg/m^2 dry)

t_h = holdup time between harvest and consumption by either humans or livestock (h).

The units of t_b, t_e and t_h are expressed in hours in Equation (A-38) for convenience; however, user input of t_b in Table A-6 and Section 4.1, *Dose Calculation Control Line 2 (7001)*, is in years; and t_e and t_h in Table A-6 and Section 4.1, *Ingestion Constants Line 2 (7052)* and *Ingestion Constants Line 3 (7053)* are in days.

A summary of element independent default parameters used to calculate the concentration of radioactivity in crops from chronic releases are presented in Table A-6. Element dependent parameters (Baes et al. 1984) are presented in Table A-7.

Table A-6. RSAC-7.2 default radionuclide independent parameters used to calculate concentrations in crops from chronic releases.

Parameter	Value	Units	Symbol
Fraction grown in garden			
Produce	0.76	--	f_g
Leafy vegetables	1.0	--	f_l
Fallout interception fractions			r
Pasture	0.57	--	
Vegetables	0.2	--	
Iodines on forage	1.0	--	
Removal rate constant	0.0021	h^{-1}	λ_w
Period of crop exposure during growing season			t_e
Vegetables	60.	d	
Forage	30.	d	
Vegetation yield			Y_v
Vegetables	2	kg/m^2 (dry)	
Forage	0.28	kg/m^2 (wet)	
Time of activity buildup in soil	1.315E+5 (15.)	h (yr)	t_b
Soil surface density	225.	kg/m^2	P
Time delays			t_h
Fresh vegetables	1.	d	
Stored vegetables	60.	d	
Feed-milk-person	2.	d	
Slaughter-consumption	20.	d	

Table A-7. RSAC-7.2 element-dependent parameters used to calculate concentrations in crops.

		Root uptake factors		Transfer coefficients		
	Element	Forage B_{iv1}	Produce B_{iv2}	Milk F_m	Meat F_f	Translocation factor F_T
1	H	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00
2	He	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00
3	Li	2.5E-02	1.7E-03	2.0E-02	1.0E-02	1.0E+00
4	Be	1.0E-02	6.4E-04	9.0E-07	1.0E-03	1.0E+00
5	B	4.0E+00	8.6E-01	1.5E-03	8.0E-04	1.0E+00
6	C	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00
7	N	3.0E+01	1.3E+01	2.5E-02	7.5E-02	1.0E+00
8	O	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00
9	F	6.0E-02	2.6E-03	1.0E-03	1.5E-01	1.0E+00
10	Ne	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00
11	Na	7.5E-02	2.4E-02	3.5E-02	5.5E-02	1.0E+00
12	Mg	1.0E+00	2.4E-01	4.0E-03	5.0E-03	1.0E+00
13	Al	4.0E-03	2.8E-04	2.0E-04	1.5E-03	1.0E+00
14	Si	3.5E-01	3.0E-02	2.0E-05	4.0E-05	1.0E+00
15	P	3.5E+00	1.5E+00	1.5E-02	5.5E-02	1.0E+00
16	S	1.5E+00	6.4E-01	1.5E-02	1.0E-01	1.0E+00
17	Cl	7.0E+01	3.0E+01	1.5E-02	8.0E-02	1.0E+00
18	Aa	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00
19	K	1.0E-01	2.4E-01	7.0E-03	2.0E-02	1.0E+00
20	Ca	3.5E+00	1.5E-01	1.0E-02	7.0E-04	1.0E+00
21	Sc	6.0E-03	4.3E-04	5.0E-06	1.5E-02	1.0E+00
22	Ti	5.5E-03	1.3E-03	1.0E-02	3.0E-02	1.0E+00
23	V	5.5E-03	1.3E-03	2.0E-05	2.5E-03	1.0E+00
24	Cr	7.5E-03	1.9E-03	1.5E-03	5.5E-03	1.0E+00
25	Mn	2.5E-01	2.1E-02	3.5E-04	4.0E-04	1.0E+00
26	Fe	4.0E-03	4.3E-04	2.5E-04	2.0E-02	1.0E+00
27	Co	2.0E-02	3.0E-03	2.0E-03	2.0E-02	1.0E+00
28	Ni	6.0E-02	2.6E-02	1.0E-03	6.0E-03	1.0E+00
29	Cu	4.0E-01	1.1E-01	1.5E-03	1.0E-02	1.0E+00
30	Zn	1.5E+00	3.9E-01	1.0E-02	1.0E-01	1.0E+00
31	Ga	4.0E-03	1.7E-04	5.0E-05	5.0E-04	1.0E+00
32	Ge	4.0E-01	3.4E-02	7.0E-02	7.0E-01	1.0E+00
33	As	4.0E-02	2.6E-03	6.0E-05	2.0E-03	1.0E+00
34	Se	2.5E-02	1.1E-02	4.0E-03	1.5E-02	1.0E+00
35	Br	1.5E+00	6.4E-01	2.0E-02	2.5E-02	1.0E+00
36	Kr	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00
37	Rb	1.5E-01	3.0E-02	1.0E-02	1.5E-02	1.0E+00
38	Sr	2.5E+00	1.1E-01	1.5E-03	3.0E-04	1.0E+00
39	Y	1.5E-02	2.6E-03	2.0E-05	3.0E-04	1.0E+00
40	Zr	2.0E-03	2.1E-04	3.0E-05	5.5E-03	1.0E+00
41	Nb	2.0E-02	2.1E-03	2.0E-02	2.5E-01	1.0E+00
42	Mo	2.5E-01	2.6E-02	1.5E-03	6.0E-03	1.0E+00
43	Tc	9.5E+00	6.4E-01	1.0E-02	8.5E-03	1.0E+00
44	Ru	7.5E-02	8.6E-03	6.0E-07	2.0E-03	5.0E-02
45	Rh	1.5E-01	1.7E-02	1.0E-02	2.0E-03	1.0E+00

Table A-7. RSAC-7.2 element-dependent parameters used to calculate concentrations in crops.

	Element	Root uptake factors: Forage B_{iv1}	Root uptake factors: Produce B_{iv2}	Transfer coefficients: Milk F_m	Transfer coefficients: Meat F_f	Translocation factor F_T
46	Pd	1.5E-01	1.7E-02	1.0E-02	4.0E-03	1.0E+00
48	Cd	5.5E-01	6.4E-02	1.0E-03	5.5E-04	1.0E+00
49	In	4.0E-03	1.7E-04	1.0E-04	8.0E-03	1.0E+00
50	Sn	3.0E-02	2.6E-03	1.0E-03	8.0E-02	1.0E+00
51	Sb	2.0E-01	1.3E-02	1.0E-04	1.0E-03	1.0E+00
52	Te	2.5E-02	1.7E-03	2.0E-04	1.5E-02	1.0E+00
53	I	1.5E-01	2.1E-02	1.0E-02	7.0E-03	1.0E-01
54	Xe	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00
55	Cs	8.0E-02	1.3E-02	7.0E-03	2.0E-02	5.0E-01
56	Ba	1.5E-01	6.4E-03	3.5E-04	1.5E-04	1.0E+00
57	La	1.0E-02	1.7E-03	2.0E-05	3.0E-04	1.0E+00
58	Ce	1.0E-02	1.7E-03	2.0E-05	7.5E-04	3.0E-01
59	Pr	1.0E-02	1.7E-03	2.0E-05	3.0E-04	1.0E+00
60	Nd	1.0E-02	1.7E-03	2.0E-05	3.0E-04	1.0E+00
61	Pm	1.0E-02	1.7E-03	2.0E-05	5.0E-03	1.0E+00
62	Sm	1.0E-02	1.7E-03	2.0E-05	5.0E-03	1.0E+00
63	Eu	1.0E-02	1.7E-03	2.0E-05	5.0E-03	1.0E+00
64	Gd	1.0E-02	1.7E-03	2.0E-05	3.5E-03	1.0E+00
65	Tb	1.0E-02	1.7E-03	2.0E-05	4.5E-03	1.0E+00
66	Dy	1.0E-02	1.7E-03	2.0E-05	5.5E-03	1.0E+00
67	Ho	1.0E-02	1.7E-03	2.0E-05	4.5E-03	1.0E+00
68	Er	1.0E-02	1.7E-03	2.0E-05	4.0E-03	1.0E+00
69	Tm	1.0E-02	1.7E-03	2.0E-05	4.5E-03	1.0E+00
70	Yb	1.0E-02	1.7E-03	2.0E-05	4.0E-03	1.0E+00
71	Lu	1.0E-02	1.7E-03	2.0E-05	4.5E-03	1.0E+00
72	Hf	3.5E-03	3.6E-04	5.0E-06	1.0E-03	1.0E+00
73	Ta	1.0E-02	1.1E-03	3.0E-06	6.0E-04	1.0E+00
74	W	4.5E-02	4.3E-03	3.0E-04	4.5E-02	1.0E+00
75	Re	1.5E+00	1.5E-01	1.5E-03	8.0E-03	1.0E+00
76	Os	1.5E-02	1.5E-03	5.0E-03	4.0E-01	1.0E+00
77	Ir	5.5E-02	6.4E-03	2.0E-06	1.5E-03	1.0E+00
78	Pt	9.5E-02	1.1E-02	5.0E-03	4.0E-03	1.0E+00
79	Au	4.0E-01	4.3E-02	5.5E-06	8.0E-03	1.0E+00
80	Hg	9.0E-01	8.6E-02	4.5E-04	2.5E-01	1.0E+00
81	Tl	4.0E-03	1.7E-04	2.0E-03	4.0E-02	1.0E+00
82	Pb	4.5E-02	3.9E-03	2.5E-04	3.0E-04	1.0E+00
83	Bi	3.5E-02	2.1E-03	5.0E-04	4.0E-04	1.0E+00
84	Po	2.5E-03	1.7E-04	3.5E-04	9.5E-05	1.0E+00
85	At	1.0E+00	6.4E-02	1.0E-02	1.0E-02	1.0E+00
86	Rn	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00
87	Fr	3.0E-02	3.4E-03	2.0E-02	2.5E-03	1.0E+00
88	Ra	1.5E-02	6.4E-04	4.5E-04	2.5E-04	1.0E+00
89	Ac	3.5E-03	1.5E-04	2.0E-05	2.5E-05	1.0E+00
90	Th	8.5E-04	3.6E-05	5.0E-06	6.0E-06	1.0E+00
91	Pa	2.5E-03	1.1E-04	5.0E-06	1.0E-05	1.0E+00

Table A-7. RSAC-7.2 element-dependent parameters used to calculate concentrations in crops.

	Element	Root uptake factors: Forage B_{iv1}	Root uptake factors: Produce B_{iv2}	Transfer coefficients: Milk F_m	Transfer coefficients: Meat F_f	Translocation factor F_T
92	U	8.5E-03	1.7E-03	6.0E-04	2.0E-04	1.0E+00
95	Am	5.5E-03	1.1E-04	4.0E-07	3.5E-06	3.0E-01
96	Cm	8.5E-04	6.4E-06	2.0E-05	3.5E-06	3.0E-01

Equation (A-38) is expressed in the same format as presented in Regulatory Guide 1.109 (NRC 1977a). As such, it is expressed for only a single radionuclide. However, when the radionuclide of interest is the progeny of other radionuclides, RSAC-7.2 corrects for decay chain ingrowth.

Equation (A-38) contains a translocation factor, F_T, which is not included in the original formulation of the NRC Regulatory Guide 1.109 model. This parameter corrects for the translocation of activity deposited on plant leaves to the edible portion of the crop. Translocation factors for leafy vegetables and forage are set to 1. Translocation factors to the edible portions of produce crops are taken from Boone et al. (1981).[6]

The concentration factor for root uptake, B_{iv}, is element dependent. Root uptake factors have been taken from literature developed to update the NRC Regulatory Guide 1.109 model published by Baes et al. (1984).[4] The root uptake factors in Table A-7 are dimensionless and express pCi/kg$_{plant}$ per pCi/kg$_{soil}$. The soil weight is for dry soil. Root uptake factors for forage (B_{iv1}) are for forage measured in dry weight while root uptake factors for produce (B_{iv2}) are for produce measured in wet weight.

Both C_i, the concentration of milk, and C_i, the concentration in meat, depend upon the fraction of the year that the livestock is grazing on pasture as opposed to consuming stored feed. The equation used to calculate the concentration of radionuclide i in the animal's feed is

$$C_i^{fd} = f_p f_s C_i^p + (1 - f_p) C_i^s + f_p (1 - f_s) C_i^s \tag{A-39}$$

where

C_i^{fd} = concentration of radionuclide i animals' feed (pCi/kg)

f_p = fraction of the year that animals graze on pasture

f_s = fraction of daily feed that is pasture grass when the animal grazes on pasture

C_i^p = concentration of radionuclide i on pasture grass (pCi/kg)

C_i^s = concentration of radionuclide i in stored feed (pCi/kg).

Both C_i^p and C_i^s are calculated using Equation (A-38) with appropriate constants.

The concentration of radionuclide i in milk is dependent on the concentration in the feed and the quantity of feed consumed by the animal. The equation used to calculate the concentration in milk is

$$C_i^m = F_m \, C_i^{fd} \, Q_F \, e^{-\lambda_i t_f} \tag{A-40}$$

where

C_i^m = concentration of radionuclide i in milk (pCi/L)

F_m = average fraction of the animal's daily intake of radionuclide i that appears in milk (d/L)

Q_F = amount of feed consumed by the animal (normally 16 kg/d dry weight)

t_f = average transport time of the activity from the feed into the milk and to the receptor (d).

The equation used to calculate the concentration in milk is

$$C_i^F = F_f C_i^{fd} Q_F \, \exp(-\lambda_i t_e) \tag{A-41}$$

where

C_i^F = concentration of radionuclide i in meat (pCi/kg)

F_f = average fraction of the animal's daily intake of radionuclide i that appears in each kilogram of flesh (d/kg)

t_c = average time between slaughter and consumption (d).

The equation used to calculate the concentration of tritium in vegetation from chronic releases is

$$C_T^V = 3.169 \times 10^7 \, Q_T \, \frac{\chi}{Q} \left[\frac{(0.75) \quad (0.5)}{H} \right] \tag{A-42}$$

where

C_T^V = concentration of tritium in vegetation (pCi/kg)

$$3.169 \times 10^7 = \frac{(1.0 \times 10^{12} \text{ pCi/Ci}) \ (1.0 \times 10^3 \text{ g/kg})}{3.156 \times 10^7 \text{ s/yr}} \tag{A-43}$$

Q_T = annual release of tritium (Ci/yr)

$\frac{\chi}{Q}$ = atmospheric diffusion relative to the initial point of release (s/m^3)

0.75 = fraction of total plant mass that is water

0.50 = ratio of tritium concentration in plant water to tritium concentration in atmospheric water

H = absolute humidity (g/m^3).

The equation used to calculate the concentration to carbon-14 in vegetation from chronic releases is

$$C_{14}^{v} = 3.169 \times 10^{7} \; Q_{14} \, \frac{\chi}{Q} \left[\frac{0.11}{0.16} \right] \tag{A-44}$$

where

C_{14}^{v} = concentration of carbon-14 in vegetation (pCi/kg)

Q_{14} = annual release of carbon-14 (Ci/yr)

0.11 = fraction of total plant mass that is natural carbon

0.16 = concentration of natural carbon in the atmosphere (g/m^3).

A-3.2.2 Acute Release

The ingestion equations presented in Regulatory Guide 1.109 (NRC 1977a)[24] apply to chronic releases. Unfortunately, there is no consensus model for the calculation of ingestion doses from an acute release. Therefore, it was necessary to develop the model used in RSAC-7.2. The model assumes that consumption of contaminated vegetation from an acute release occurs at a constant rate during the acute release period and during the harvest duration time that follows the acute release period. The activity on vegetation (pCi/m^2) collected during the acute release period for radionuclide i can be calculated using the following equation:

$$A_D = d_i \int_0^{t_a} e^{-\lambda_{Ei} t} dt \qquad \text{(A-45)}$$

where

A_D = activity on vegetation collected during the acute release period

d_i = deposition rate of radionuclide i (pCi/m^2-h)

t_a = acute release period (h)

λ_{Ei} = effective removal rate constant for radionuclide i from foliage surfaces (h^{-1}),

$\lambda_{Ei} = \lambda_i + \lambda_w$

Integrating Equation (A-45), the equation for A_D becomes

$$A_D = \frac{d_i}{\lambda_{Ei}} \left[1 - e^{-\lambda_{Ei} t_a}\right] \qquad \text{(A-46)}$$

Assuming that produce collection is constant during the acute release period (t_a) and during the harvest duration time period following the acute release (t_{hd}), the fraction of the uptake that is collected during the acute release period is

$$\frac{t_a}{t_a + t_{hd}} \qquad \text{(A-47)}$$

The concentration in produce collected during the acute release period is then

$$C_{iD}^{v} = \frac{r F_T F_a}{Y_v} \left(\frac{t_a}{t_a + t_{hd}} \right) A_D \qquad \text{(A-48)}$$

where

r = fraction of deposited activity retained on foliage

F_T = fraction of deposited radioactivity translocated from plant surface to edible portion of crop

F_a = fraction of annual crop that is contaminated by the acute release

Y_v = agricultural productivity (yield) (kg/m^2).

Inserting Equation (A-46) into Equation (A-48), the equation for the concentration in produce collected during the acute release period becomes

$$C_{iD}^{v} = \frac{d_i \; r \; F_T \; F_a \; t_a}{Y_v \; \lambda_{Ei} \left(t_a + t_{hd}\right)} \left[1 - e^{-\lambda_{Ei} t_a}\right] \qquad \text{(A-49)}$$

By assuming that the deposition is constant during the acute release period, the equation for calculating the activity on vegetation at the end of the release period is the same as that for the calculation of A_D. The activity on vegetation at any time following the acute release is

$$A_F = A_D \; e^{-\lambda_{Ei} t} \qquad \text{(A-50)}$$

where

A_F = activity on vegetation at any time following the acute release

t_a = hours following the end of the acute release period.

The average activity on vegetation (pCi/m^2) collected during the harvest period is calculated using the following equation:

$$A_F = \frac{A_D}{t_{hd}} \int_0^{t_{hd}} e^{-\lambda_{Ei} t} \, dt \qquad \text{(A-51)}$$

Integrating Equation (A-51), the equation for A_F becomes

$$A_F = \frac{A_D}{t_{hd} \lambda_{Ei}} \left[1 - e^{-\lambda_{Ei} t_{hd}}\right] \qquad \text{(A-52)}$$

Multiplying by the appropriate conversion factors and the fraction of the harvest collected during the period following the acute release period, the equation for calculating the activity on produce collected during the harvest period following the acute release is

$$C_{iF}^{v} = \frac{r F_T \; F_a}{Y_v} \left(\frac{A_D}{t_{hd} \lambda_{Ei}}\right) \left(\frac{t_{hd}}{t_a + t_{hd}}\right) \left[1 - e^{-\lambda_{Ei} t_{hd}}\right] \qquad \text{(A-53)}$$

Replacing A_D using Equation (A-46) and reorganizing terms, the concentration on produce collected during the harvest period following the acute release is

$$C_{iF}^{v} = \frac{d_i r F_T\ F_a\left[1 - e^{-\lambda_{Ei} t_a}\right]}{Y_v\ \lambda_{Ei}\left(t_a + t_{hd}\right)}\left[\frac{1 - e^{-\lambda_{Ei} t_{hd}}}{\lambda_{Ei}}\right] \tag{A-54}$$

The remaining term to be developed is for the concentration of activity in vegetation from the soil uptake pathway. Only slight modifications are required in the equation used for continuous releases. The equation for activity in produce (pCi/kg) for continuous releases for the soil pathway, using the subscript s to denote the soil pathway, is

$$C_{is}^{v} = d_i B_{iv}\ \frac{\left[1 - e^{-\lambda_t t_b}\right]}{P\lambda_i} \tag{A-55}$$

where

B_{iv} = concentration factor for root uptake of radionuclide i from soil to edible parts of crops (pCi/kg wet weight per pCi/kg dry soil)

P = effective surface density for soil (kg/m^2 dry)

t_b = period of long-term buildup for activity in soil (h).

This equation is changed to the acute release form by changing the soil buildup time (t_b to t_a) and adding a term to account for the effect of the acute release on future crops grown on the contaminated soil in subsequent years (β_t). The equation for the concentration of activity in vegetation from the soil uptake pathway from an acute release is then

$$C_{is}^{v} = d_i B_{iv}\ \beta_t\ \frac{\left[1 - e^{-\lambda_i t_a}\right]}{P\lambda_i} \tag{A-56}$$

where β_t is defined as

$$\beta_t = F_a + \sum_{j=2}^{N_{tb}} e^{-\lambda_i j} \tag{A-57}$$

and N_{tb} is the integer of the number of years that crops are assumed to be grown on the contaminated soil.

The total concentration in an on produce from an acute release is

$$C_i^v = \left[C_{id}^v + c_{iF}^v + C_{is}^v\right] e^{-\lambda_i t_h} \tag{A-58}$$

where

t_h = holdup time between harvest and consumption by either humans or livestock (h).

When Equations (A-48), (A-53), and (A-56) are inserted into Equation (A-58), the equation for calculating the concentration of radionuclide i in and on vegetation following an acute release becomes

$$C_i^v = d_i \left\{ \frac{rF_T F_a \left[1 - e^{-\lambda_{Ei} t_a}\right] \left[t_a + \frac{1 - e^{-\lambda_{Ei} t_{hd}}}{\lambda_{Ei}}\right]}{Y_v \lambda_{Ei} (t_a + t_{hd})} + \frac{B_{iv}\, \beta_t \left[1 - e^{-\lambda_i t_a}\right]}{P \lambda_i} \right\} e^{-\lambda_i t_h} \tag{A-59}$$

where

F_a = fraction of annual crop that is contaminated by acute release.

When t_{hd} is set equal to zero, complete harvest of the produce is assumed to occur immediately following the end of the acute release period. As t_{hd} increases in magnitude, Equation (A-59) models continued consumption from the garden for a period of time following the end of the acute release time. However, limitations are placed on the maximum value for t_{hd} so that the sum of t_a and t_{hd} do not exceed the vegetable exposure time to the plume for a chronic release (see t_e in Equation [A-38]).

It is assumed that cattle would continue to graze following an acute release of radioactivity. The value for t_{hd} used to calculate the concentration in and on forage is therefore automatically adjusted by RSAC-7.2 so that the sum of t_a and t_{hd} equals the forage exposure time for a chronic release.

Tritium is released from vegetation following an acute release with a nominal 1 day half-time. The acute tritium ingestion model assumes that the harvest occurs at a constant rate beginning when the acute release is initiated. The equation used to calculate the concentration of tritium in vegetation during and following an acute release is

$$C_{Ta}^v = 2.778 \times 10^{11}\, F_a\, Q_{Ta} \frac{\chi}{Q} \left[\frac{(0.75)(0.5)}{H(t_a + t_{hd})}\right] \left[t_a + \frac{1 - e^{-\lambda_p t_{hd}}}{\lambda_p}\right] \tag{A-60}$$

where

C_{Ta}^v = concentration of tritium in vegetation following an acute release (pCi/kg)

2.778×10^{11} = $(1.0 \times 10^{12}$ pCi/Ci$)$ $(1.0 \times 10^3$ g/kg$)$ / $(3.6 \times 10^3$ s/h$)$

F_a = fraction of annual crop that is contaminated by acute release

Q_{Ta} = acute release rate of tritium (Ci/h)

λ_p = release rate of tritium in vegetation following termination of release (h^{-1})

t_{hd} = harvest duration time after acute release (h).

The remaining variables and constants used in Equation (A-60) are as defined in Equation (A-42). The units for t_a and t_{hd} are expressed in hours in Equation (A-60) for convenience; however, user input of these variables in Section 4.1, *Optional Ingestion Dose Calculation Control Line (7004)* is in days.

The equation used to calculate concentration of carbon-14 in vegetation following an acute release is

$$C_{14a}^{v} = 2.778 \times 10^{11} \, F_a \, Q_{14a} \frac{\chi}{Q} \left[\frac{0.11}{0.16} \right] \tag{A-61}$$

where

C_{14a}^{v} = concentration of C-14 in vegetation following an acute release (pCi/kg)

F_a = fraction of annual crop that is contaminated by acute release

Q_{14a} = acute release rate of C-14 (Ci/h).

A-3.3 Ground Surface Dose

The dose from radioactivity deposited on the ground surface is calculated using dose-rate conversion factors (DRCFs) from Federal Guidance Report No. 12 (Eckerman 1993).[15] This requires integration of the activity on the ground over the exposure period. While this is a very simple integration for a single radionuclide, it can become complex when the radionuclide is the progeny of a long chain of precursors. RSAC-7.2 uses a very subtle relationship that makes this integration simple. When there is only a single radionuclide in a chain, the equation used to calculate the dose to an individual from the activity deposited on the ground is

$$D_i^G = DRCF_i \frac{\chi}{Q} V_d F_{bs} \int_0^{t_b} A_i dt \tag{A-62}$$

where

D_i^G = dose from radionuclide i deposited on the ground surface (rem)

$DRCF_i$ = dose rate conversion factor (rem-m^2/dis)

$\frac{\chi}{Q}$ = ground-level atmospheric diffusion relative to the initial point of release (s/m^3)

V_d = dry deposition velocity (m/s)

F_{bs} = building shielding factor

t_b = exposure time to radioactivity deposited on the ground surface (s)

A_i = activity of radionuclide i in the plume that reaches the downwind location of the receptor (dis/s).

A_i can be replaced using the following equation:

$$A_i = N_{i0}\, \lambda_i\, e^{\lambda_i t} \tag{A-63}$$

where

N_{i0} = number of atoms of radionuclide i released to the atmosphere

λ_i = decay constant for radionuclide i (s^{-1}).

Substituting Equation (A-63) into Equation (A-62), the equation for the dose becomes

$$D_i^G = DRCF_i \frac{\chi}{Q} V_d F_{bs} N_{i0} \lambda_i \int_0^{t_b} e^{-\lambda_i t} dt \tag{A-64}$$

This integrates to

$$D_i^G = DRCF_i \frac{\chi}{Q} V_d\ F_{bs} \left[N_{i0} - N_{i1} \right] \tag{A-65}$$

Defining N_{i1} as the number of the original atoms of radionuclide i that were in the plume that reached the downwind location of the receptor and remain undecayed at the end of the exposure, the following relationship exists:

$$N_{i1} = N_{i0}\, e^{-\lambda_i t_b} \tag{A-66}$$

Substituting Equation (A-66) into Equation (A-65), the equation can be simplified to

$$D_i^G = DRCF_i \frac{\chi}{Q} V_d\ F_{bs} \sum_{j=1}^{i} \left[N_{j0} - N_{j1} \right] \tag{A-67}$$

Thus, when the release to the atmosphere is expressed in atoms, the integration of Equation (A-62) reduces to the multiplication of the different conversion factors by the number of atoms of radionuclide i that decay during the exposure period. The generalized equation when radionuclide i is the progeny of a long decay chain is

$$D_i^G = DRCF_i \frac{\chi}{Q} V_d \; F_{bs} \; N_{i0} \left[1 - e^{-\lambda_i t_b}\right] \tag{A-68}$$

where

N_{j0} = number of atoms of radionuclide j in the plume that reaches the downwind location of the receptor

N_{j1} = number of atoms of radionuclide j that exist at the end of the exposure period, including those that ingrow from precursors in the decay chain.

The ground surface dose calculated by RSAC-7.2 is the dose that a receptor would receive if it is present for the entire exposure period. When a ground surface dose is being calculated for work area, it should be remembered that work normally occurs for only 40 hours during a 168-hour week and appropriate corrections should be made.

The time t_b has been expressed in seconds in the above equations for convenience; however, user input of the variable in Section 4.1, *Dose Calculation Control Line 2 (7001)* is in years.

A-3.4 Air Immersion Dose

RSAC-7.2 contains an option to calculate air immersion doses using Federal Guidance Report No. 12 (Eckerman 1993[15]) DRCFs. This model accurately calculates the plume gamma dose when the plume size is large compared to the mean free path of the gamma rays. However, when the plume size is small compared to the mean free path of the gamma rays, this model can overestimate doses by several decades. When the plume has not diffused to the ground level, the model can underestimate doses by several decades. Before this model is used, an evaluation should be using the finite plume cloud gamma model to ensure that the two models have reasonably converged.

The equation used to calculate the air immersion dose is

$$D_i^A = A_i \frac{\chi}{Q} DRCF_i \tag{A-69}$$

where

D_i^A = dose from radionuclide from air immersion (rem)

A_i = activity of radionuclide i decayed to the downwind location (Ci)

$\frac{\chi}{Q}$ = ground-level atmospheric diffusion relative to the initial point of release (s/m^3)

$DRCF_i$ = dose rate conversion factor ($rem\text{-}m^3/Ci\text{-}s$).

A-3.5 Cloud Gamma Dose

Two models are provided for calculating cloud gamma doses: a finite plume model and a semi-infinite model (Slade 1968[34]). The results of both models converge when the plume is relatively large and has diffused to ground level. At relatively short downwind distances the semi- infinite model overestimates the dose for ground-level releases during stable meteorological conditions and underestimates the dose from stack releases. While caution must be used when using the semi-infinite model, it requires little computer time for calculations.

A-3.5.1 Finite Plume Model

Dose calculations using the finite plume model are made using the equation:

$$D_k = \sum_{j=1}^{n} K1_j f_k \lambda_k \int_o^{\infty} k(x) E_k \left[GEXP_j(x) \right] \left[\int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \frac{\chi}{Q}(x,y,z) G_i(r) dz\, dy \right] dx \qquad \text{(A-70)}$$

where

D_k = the air entrance dose from the k^{th} radionuclide

n = number of exponential leakage approximations

Kl_j = linear approximation to leakage rate curve (s^{-1})

f_k = number of photons from the k^{th} radionuclide released per disintegration

λ_k = decay constant for the k^{th} radionuclide (s^{-1})

k(x) = cloud depletion factor

E_k = decay operator equal to:

$$\sum_{m=1}^{k} Q_m \left(\prod_{j=m}^{k-1} \lambda_i \right) \sum_{i=m}^{k} \left[\frac{1}{\prod_{\substack{j=m \\ j \neq i}}^{k} (\lambda_j - \lambda_i)} \right] \qquad \text{(A-71)}$$

where

Q_m = the total number of atoms for the m^{th} radionuclide immediately following reactor shut down

$$\mathrm{GEXP}_j(x) = \frac{e^{-\lambda_i \frac{x}{\bar{u}}}}{\lambda_i + K2_j}\left[1 - e^{-(\lambda_i + K2_j)T}\right] \quad \text{(A-72)}$$

where

× = downwind distance (m)

$\bar{u}$ = average wind velocity (m/s)

$K2_j$ = leakage rate decay constant (s^{-1})

T = period of exposure to cloud (s).

$$G_i(r) = \nu_i\ B(E_i r)\frac{e^{-\mu_i r}}{4\pi\pi^2} \quad \text{(A-73)}$$

where

r = distance from a source to the receptor

ν = flux to dose conversion factor for the i^{th} energy group (m^{-1})

$B(E_i,r)$ = dose buildup factor as a function of the i^{th} energy group and the distance traveled by the gamma ray.

μ_i = linear absorption coefficient for air for the i^{th} energy group (m^{-1}).

Buildup factors for air used in RSAC-7.2 have been developed from those published by Berger et al. (1968).[5] The Berger buildup factors for air change very rapidly in the 60 to 300 keV energy range when the travel distance exceeds four mean free paths. Traditional equations used to calculate buildup factors for shielding applications do not model buildup factors well in this energy range. The Berger buildup factors for air were therefore approximated in RSAC-7.2 using an equation of the form:

$$B(E,\mu r) = 1 + a(E)\mu r + b(E)[\mu r]^2 + c(E)[\mu r]^3 \quad \text{(A-74)}$$

A comparison of buildup factors for air calculated using Equation (A-74) with those published by Berger is presented in Table A-8.

An exact solution to Equation (A-70) does not exist. The equation is solved using numerical integration techniques. An examination of the function being integrated showed that the function can vary rapidly near the receptor. Therefore, integration is accomplished by breaking the integral in the X, Y, and Z directions each into three separate regions, each using the Gaussian quadrature for an arbitrary interval (Abramowitz and Stegum 1964[3]). This allows the regions closest to the receptor or near the plume centerline to be integrated using closely spaced mesh points while the outer regions are integrated using a coarser distribution of mesh points. When the dose is being calculated for an elevated release and at a crosswind distance from the plume centerline, up to 15 integration regions may be used. However, whenever possible, problem symmetry is used to reduce the number of integration regions and thereby the computer running time.

RSAC-7.2 integrates the activity in the plume using gamma rays distributed the nine energy groups presented in Table A-9. The RSAC-7.2 photon library was developed using photon energies from the Evaluated Nuclear Structure File (ENSDF) as presented in the Lund/LBNL Nuclear Data Search (Chu 1999[9]). Photons were energy weighted in each of the nine energy groups.

A-3.5.2 Semi-infinite Model

This model is very similar to that used to calculate air immersion doses (see Section 4.1, *Radionuclide Entry Lines*); its use requires caution. The semi-infinite model accurately calculates the plume gamma dose when the plume size is large compared to the mean free path of the gamma rays. As with the air immersion model, the semi-infinite model can overestimate doses by several decades when the plume size is small compared to the mean free path of the gamma rays. When the plume has not diffused to the ground level, the model can underestimate doses by several decades. Before this model is used, an evaluation should be using the finite plume cloud gamma model to ensure that the two models have reasonably converged.

Table A-8. Comparison of calculated buildup factors for air to Berger's buildup factors.

Energy (MeV)	Mean free paths									
	1		2		4		7		10	
	C[a]	B[b]	C[a]	B[b]	C[a]	B[b]	C[a]	B[b]	C[a]	B[b]
0.015	1.17	1.17	1.28	1.25	1.37	1.36	1.43	1.46	1.52	1.54
0.02	1.41	1.41	1.69	1.62	1.94	1.94	2.15	2.25	2.49	2.51
0.03	2.24	2.24	3.29	3.19	4.85	4.87	6.93	7.09	9.19	9.21
0.04	3.33	3033	5.87	5.86	11.53	11.50	21.17	21.10	32.00	32.20
0.05	4.25	4.25	8.65	8.72	20.85	20.80	46.59	46.10	80.80	80.70
0.06	4.75	4.75	10.69	10.80	29.22	29.40	75.55	74.60	145.00	144.00
0.08	4.81	4.81	12.14	12.00	37.96	38.20	117.75	115.00	253.00	252.00
0.1	4.48	4.48	11.51	11.40	37.18	38.50	126.22	124.00	286.00	285.00
0.15	3.72	3.72	9.47	9.20	31.03	31.70	109.44	106.00	253.00	252.00
0.2	3.27	3.27	7.80	7.73	24.42	25.60	85.07	83.90	196.50	196.00
0.3	2.85	2.85	6.25	6.22	18.01	18.60	54.32	54.40	116.00	116.00
0.4	2.60	2.60	5.39	5.37	14.66	14.90	40.38	40.30	81.50	81.50
0.5	2.44	2.44	4.83	4.82	12.47	12.50	31.42	31.30	59.50	59.50
0.6	2.33	2.33	4.43	4.45	10.93	10.90	26.14	26.00	47.80	47.70
0.8	2.18	2.18	3.90	3.94	8.91	8.86	19.53	19.30	33.50	33.40
1.0	2.08	2.08	3.56	3.60	7.63	7.59	15.72	15.60	25.80	25.70
1.5	1.92	1.92	3.05	3.09	5.89	5.85	10.96	10.80	16.70	16.60
2.0	1.81	1.81	2.74	2.78	4.94	4.92	8.66	8.53	12.70	12.50
3.0	1.68	1.68	2.40	2.41	3.95	3.93	6.36	6.32	8.81	8.80
4.0	1.59	1.59	2.18	2.19	3.38	3.38	5.20	5.20	7.03	7.03
5.0	1.52	1.52	2.03	2.03	3.03	3.03	4.51	4.51	5.97	5.97
6.0	1.47	1.47	1.92	1.92	2.78	2.78	4.02	4.04	5.26	5.26
8.0	1.39	1.39	1.76	1.75	2.43	2.44	3.40	3.43	4.38	4.38
10.0	1.33	1.33	1.64	1.64	2.21	2.21	3.01	3.01	3.78	3.79

a. C = Calculated buildup factor.
b. B = Berger's reported buildup factor.

The equation used to calculate cloud-gamma doses using the semi-infinite model (Slade 1968[34]) is

$$DG_i^S = 0.25\,\overline{E_\gamma}\,\Psi \qquad \text{(A-75)}$$

where

DG_i^S = cloud gamma dose from radionuclide I

$\overline{E_\gamma}$ = average gamma energy (MeV)

Ψ = concentration time integral (Ci-s/m^3).

Table A-9. Photon energy groups and dose conversion factors.

Energy group	Energy (MeV)/γ	Energy range (MeV)	Air entrance dose Conversion (rem-m^2/γ)	Dose ratio EDE/air entrance
1	2.5E-02	0.02 to 0.03	1.080E-14	0.1276
2	4.0E-02	0.03 to 0.05	4.800E-15	0.3443
3	7.5E-02	0.05 to 0.10	3.360E-15	0.6228
4	2.0E-01	0.10 to 0.30	9.280E-15	0.6501
5	4.0E-01	0.30 to 0.50	2.048E-14	0.6361
6	6.5E-01	0.50 to 0.80	3.328E-14	0.6528
7	9.0E-01	0.80 to 1.00	4.392E-14	0.6696
8	1.5E+00	1.00 to 2.00	6.480E-14	0.6570
9	3.7E+00	2.00 to 3.70	1.243E-13	0.7739

Appendix B

RSAC-7.2 Nuclear Data Library

Appendix B

RSAC-7.2 Nuclear Data Library

This appendix contains a table of constants used to calculate radionuclide inventories and their decay. The radionuclide column contains the radionuclide identification number and radionuclide name. The radionuclide identification number equals the sum of the radionuclide.

(atomic number × 10,000) + (mass number × 10) + (0 for ground state or 1 for metastable state).

The half-life column contains the element's half-life. The yield column provides the percent fission yield for the radionuclide. The FRACT column describes the fraction of the radionuclide decayed to the daughter indicated (IDATR). If FRACT <1.0 and the daughter indicated is not the next radionuclide in the library, an isomer is assumed. A fraction FRACT is decayed to the daughter indicated and the fraction 1-FRACT is decayed to the next radionuclide in the library.

The IDATR column contains an integer daughter indicator where

-1 = no radioactive daughter
0 = daughter is the next radionuclide in the library
≥1 = number of radionuclides in the library that are to be skipped over before the daughter is found.

The NGROUP column contains an integer element group code where

1 = solid
2 = halogen
3 = nobel gas
4 = cesium
5 = ruthenium.

The ISTART column contains an integer that points to the beginning of the chain. Subtract ISTART from the library position to find the beginning of a chain. The XSECT column contains the average neutron cross section (in barns).

Half-lives are primarily from the Evaluated Nuclear Structure File (ENSDF) as presented in the Lund/LBNL Nuclear Data Search. Pseudo radionuclides used to correct for activation of fission products were suppressed.

Activation products, actinides, and the daughters of actinides are signified by a cross section value of -1. Inventories for these radionuclides are not calculated by RSAC-7; however, you may input them directly for dose calculations.

Many short-lived fission products decay to longer-lived daughter products. Often these short-lived fission products do not have available dose conversion factors. Therefore, RSAC-7.2 only uses them to correct fission product inventories calculated by RSAC-7.2 to match those calculated by ORIGEN-2. Many of these short-lived fission products have never been observed experimentally, and their decay-related properties are derived from calculations based on nuclear systematic. These short-lived fission products, which are precursors to longer-lived daughters, are signified by a cross section value of -0.3. An option is provided in the fission product printout section of RSAC-7.2 to suppress printing these radionuclides.

Nuclide	Half Life	unit	unit	YIELD	FRACT	IDATR	NGROUP	ISTART	XSECT	Decay Chain
10030	1.23E+01	5	y	1.10E-02	1	-1	3	0	5.52E-07	H-3 > stable
40070	5.32E+01	4	d	0	1	-1	1	0	-1	Be-7 > stable
40100	1.51E+06	5	y	0	1	-1	1	0	-1	Be-10 > stable
60110	2.04E+01	2	m	0	1	-1	1	0	-1	C-11 > stable
60140	5.70E+03	5	y	1.30E-06	1	-1	1	0	9.20E-08	C-14 > stable
90180	1.10E+02	2	m	0	1	-1	2	0	-1	F-18 > stable
110220	2.60E+00	5	y	0	1	-1	1	0	-1	Na-22 > stable
110240	1.50E+01	3	h	0	1	-1	1	0	-1	Na-24 > stable
120280	2.09E+01	3	h	0	1	-1	1	0	-1	Mg-28 > stable
130260	7.17E+05	5	y	0	1	-1	1	0	-1	Al-26 > stable
140310	1.57E+02	2	m	0	1	-1	1	0	-1	Si-31 > stable
140320	1.53E+02	5	y	0	1	0	1	0	-1	Si-32 > P-32 1.0
150320	1.43E+01	4	d	0	1	-1	1	1	-1	P-32 > stable
150330	2.53E+01	4	d	0	1	-1	1	0	-1	P-33 > stable
160350	8.75E+01	4	d	0	1	-1	1	0	-1	S-35 > stable
170360	3.01E+05	5	y	0	1	-1	2	0	-1	Cl-36 > stable
170380	3.72E+01	2	m	0	1	-1	2	0	-1	Cl-38 > stable
170390	5.56E+01	2	m	0	1	0	2	0	-1	Cl-39 > Ar-39 1.0
180390	2.69E+02	5	y	0	1	-1	3	1	-1	Ar-39 > stable
180410	1.10E+02	2	m	0	1	-1	3	0	-1	Ar-41 > stable
190400	1.25E+09	5	y	0	1	-1	1	0	-1	K-40 > stable
200410	1.02E+05	5	y	0	1	-1	1	0	-1	Ca-41 > stable
190420	1.24E+01	3	h	0	1	-1	1	0	-1	K-42 > stable
190430	2.23E+01	3	h	0	1	-1	1	0	-1	K-43 > stable
210430	3.89E+00	3	h	0	1	-1	1	0	-1	Sc-43 > stable
190440	2.21E+01	2	m	0	1	-1	1	0	-1	K-44 > stable
190450	1.78E+01	2	m	0	1	0	1	0	-1	K-45 > Ca-45 1.0
200450	1.63E+02	4	d	0	1	-1	1	0	-1	Ca-45 > stable
220440	6.00E+01	5	y	0	1	1	1	0	-1	Ti-44 > Sc-44 1.0
210441	5.86E+01	3	h	0	0.9863	0	1	1	-1	Sc-44m > Sc-44 0.9863

210440	3.97E+00	3	h	0	1	-1	1	2	-1	Sc-44 > stable
220450	1.85E+02	2	m	0	1	-1	1	0	-1	Ti-45 > stable
210460	8.38E+01	4	d	0	1	-1	1	0	-1	Sc-46 > stable
200470	4.54E+00	4	d	0	1	0	1	0	-1	Ca-47 > Sc-47 1.0
210470	3.35E+00	4	d	0	1	-1	1	1	-1	Sc-47 > stable
230470	3.26E+01	2	m	0	1	-1	1	1	-1	V-47 > stable
210480	4.37E+01	3	h	0	1	-1	1	0	-1	Sc-48 > stable
240480	2.16E+01	3	h	0	1	0	1	0	-1	Cr-48 > V-48 1.0
230480	1.60E+01	4	d	0	1	-1	1	1	-1	V-48 > stable
200490	8.72E+00	2	m	0	1	0	1	0	-1	Ca-49 > Sc-49 1.0
210490	5.72E+01	2	m	0	1	-1	1	1	-1	Sc-49 > stable
240490	4.23E+01	2	m	0	1	0	1	0	-1	Cr-49 > V-49 1.0
230490	3.30E+02	4	d	0	1	-1	1	1	-1	V-49 > stable
220510	5.76E+00	2	m	0	1	-1	1	0	-0.3	Ti-51 > stable
250510	4.62E+01	2	m	0	1	0	1	0	-1	Mn-51 > Cr-51 1.0
240510	2.77E+01	4	d	0	1	-1	1	1	-1	Cr-51 > stable
260520	4.59E+01	1	s	0	1	0	1	0	-1	Fe-52 > Mn-52m 1.0
250521	2.11E+01	2	m	0	0.0175	0	1	1	-1	Mn-52m > Mn-52 0.0175
250520	5.59E+00	4	d	0	1	-1	1	2	-1	Mn-52 > stable
250530	3.70E+06	5	y	0	1	-1	1	0	-1	Mn-53 > stable
250540	3.12E+02	4	d	0	1	-1	1	0	-1	Mn-54 > stable
270550	1.75E+01	3	h	0	1	0	1	0	-1	Co-55 > Fe-55 1.0
260550	2.74E+00	5	y	0	1	-1	1	1	-1	Fe-55 > stable
250560	2.58E+00	3	h	0	1	-1	1	0	-1	Mn-56 > stable
280560	6.08E+00	4	d	0	1	0	1	0	-1	Ni-56 > Co-56 1.0
270560	7.72E+01	4	d	0	1	-1	1	1	-1	Co-56 > stable
280570	3.56E+01	3	h	0	1	0	1	0	-1	Ni-57 > Co-57 1.0
270570	2.72E+02	4	d	0	1	-1	1	1	-1	Co-57 > stable
270581	9.10E+00	3	h	0	1	0	1	0	-1	Co-58m > Co-58 1.0
270580	7.09E+01	4	d	0	1	-1	1	1	-1	Co-58 > stable
260590	4.45E+01	4	d	0	1	-1	1	0	-1	Fe-59 > stable

280590	7.60E+04	5	y	0	1	-1	1	0	-1	Ni-59 > stable
260600	1.50E+06	5	y	0	1	0	1	0	-1	Fe-60 > Co-60m 1.0
270601	1.05E+01	2	m	0	0.9975	0	1	1	-1	Co-60m > Co-60 0.9975
270600	5.28E+00	5	y	0	1	-1	1	2	-1	Co-60 > stable
290600	2.37E+01	2	m	0	1	-1	1	0	-1	Cu-60 > stable
270610	1.65E+00	3	h	0	1	-1	1	0	-1	Co-61 > stable
290610	3.33E+00	3	h	0	1	-1	1	0	-1	Cu-61 > stable
270621	1.39E+01	2	m	0	1	-1	1	0	-1	Co-62m > stable
300620	9.26E+00	3	h	0	1	0	1	0	-1	Zn-62 > Cu-62 1.0
290620	9.67E+00	2	m	0	1	-1	1	0	-1	Cu-62 > stable
280630	1.01E+02	5	y	0	1	-1	1	0	-1	Ni-63 > stable
300630	3.85E+01	2	m	0	1	-1	1	0	-1	Zn-63 > stable
280650	2.52E+00	3	h	0	1	-1	1	0	-1	Ni-65 > stable
290640	1.27E+01	3	h	0	1	-1	1	0	-1	Cu-64 > stable
310650	1.52E+01	2	m	0	1	0	1	0	-1	Ga-65 > Zn-65 1.0
300650	2.44E+02	4	d	0	1	-1	1	1	-1	Zn-65 > stable
280660	5.46E+01	3	h	0	1	0	1	0	-1	Ni-66 > Cu-66 1.0
290660	5.12E+00	2	m	0	1	-1	1	1	-0.3	Cu-66 > stable
320660	2.26E+00	3	h	0	1	0	1	0	-1	Ge-66 > Ga-66 1.0
310660	9.49E+00	3	h	0	1	-1	1	1	-1	Ga-66 > stable
290670	6.18E+01	3	h	0	1	-1	1	0	-1	Cu-67 > stable
320670	1.89E+01	2	m	0	1	0	1	0	-1	Ge-67 > Ga-67 1.0
310670	3.26E+00	4	d	0	1	-1	1	1	-1	Ga-67 > stable
320680	2.71E+02	4	d	0	1	0	1	0	-1	Ge-68 > Ga-68 1.0
310680	6.77E+01	2	m	0	1	-1	1	1	-1	Ga-68 > stable
300691	1.38E+01	3	h	0	1	0	1	0	-1	Zn-69m > Zn-69 1.0
300690	5.64E+01	2	m	0	1	-1	1	1	-1	Zn-69 > stable
330690	1.52E+01	2	m	0	1	0	1	0	-1	As-69 > Ge-69 1.0
320690	3.91E+01	3	h	0	1	-1	1	1	-1	Ge-69 > stable
310700	2.11E+01	2	m	0	1	-1	1	0	-1	Ga-70 > stable
300711	3.96E+00	3	h	0	1	-1	1	0	-1	Zn-71m > stable

330710	6.53E+01	3	h	0	1	0	1	0	-1	As-71 > Ge-71 1.0
320710	1.14E+01	4	d	0	1	-1	1	1	-1	Ge-71 > stable
340700	4.11E+01	2	m	0	1	0	1	0	-1	Se-70 > As-70
330700	5.26E+01	2	m	0	1	-1	1	0	-1	As-70 > stable
330720	2.60E+01	3	h	0	1	-1	1	0	-1	As-72 > stable
270720	9.00E-02	1	s	8.87E-07	1	0	1	0	-0.3	Co-72 > Ni-72 1.0
280720	1.57E+00	1	s	2.85E-05	1	0	1	1	-0.3	Ni-72 > Cu-72 1.0
290720	6.63E+00	1	s	3.36E-05	1	0	1	2	-0.3	Cu-72 > Zn-72 1.0
300720	4.65E+01	3	h	6.76E-06	1	0	1	3	0	Zn-72 > Ga-72 1.0
310720	1.41E+01	3	h	4.22E-08	1	-1	1	4	0	Ga-72 > stable
270730	1.16E-01	1	s	9.07E-08	1	0	1	0	-0.3	Co-73 > Ni-73 1.0
280730	8.00E-01	1	s	1.49E-05	1	0	1	1	-0.3	Ni-73 > Cu-73 1.0
290730	3.90E+00	1	s	9.86E-05	1	0	1	2	-0.3	Cu-73 > Zn-73 1.0
300730	2.35E+01	1	s	1.28E-04	1	0	1	3	-0.3	Zn-73 > Ga-73 1.0
310730	4.86E+00	3	h	6.88E-06	1	-1	1	4	0	Ga-73 > stable
340731	3.98E+01	2	m	0	0.274	1	1	0	-1	Se-73m Se-73 .726 As-73 .274
340730	7.15E+00	3	h	0	1	0	1	1	-1	Se-73 > As-73 1.0
330730	8.03E+01	4	d	0	1	-1	1	2	-1	As-73 > stable
270740	1.08E-01	1	s	7.32E-08	1	0	1	0	-0.3	Co-74 > Ni-74 1.0
280740	5.00E-01	1	s	2.42E-05	1	0	1	1	-0.3	Ni-74 > Cu-74 1.0
290740	1.63E+00	1	s	2.31E-04	1	0	1	2	-0.3	Cu-74 > Zn-74 1.0
300740	9.54E+01	1	s	3.62E-04	1	0	1	3	-0.3	Zn-74 > Ga-74 1.0
310740	8.12E+00	2	m	2.19E-05	1	-1	1	4	0	Ga-74 > stable
330740	1.78E+01	4	d	0	1	-1	1	0	-1	As-74 > stable
350741	4.60E+01	2	m	0	1	-1	1	0	-1	Br-74m > stable
350740	2.54E+01	2	m	0	1	-1	1	0	-1	Br-74 > stable
270750	8.02E-02	1	s	9.62E-09	1	0	1	0	-0.3	Co-75 > Ni-75 1.0
280750	6.00E-01	1	s	9.94E-06	1	0	1	1	-0.3	Ni-75 > Cu-75 1.0
290750	1.22E+00	1	s	2.71E-04	1	0	1	2	-0.3	Cu-75 > Zn-75 1.0
300750	1.02E+01	1	s	1.09E-03	1	0	1	3	-0.3	Zn-75 > Ga-75 1.0
310750	1.26E+02	1	s	1.79E-04	1	0	1	4	-0.3	Ga-75 > Ge-75 1.0

320751	4.77E+01	1	s	2.06E-06	1	0	1	5	-0.3	Ge-75m > Ge-75 1.0
320750	8.28E+01	2	m	2.06E-06	1	-1	1	6	4.14E-01	Ge-75 > stable
350750	9.67E+01	2	m	0	1	0	1	0	-1	Br-75 > Se-75 1.0
340750	1.19E+02	4	d	0	1	-1	1	1	-1	Se-75 > stable
280760	4.40E-01	1	s	3.26E-06	1	0	1	0	-0.3	Ni-76 > Cu-76 1.0
290760	6.41E-01	1	s	2.70E-04	1	0	1	1	-0.3	Cu-76 > Zn-76 1.0
300760	5.70E+00	1	s	2.95E-03	1	0	1	2	-0.3	Zn-76 > Ga-76 1.0
310760	3.26E+01	1	s	1.28E-03	1	-1	1	3	0	Ga-76 > stable
350760	1.62E+01	3	h	0	1	-1	1	0	-1	Br-76 > stable
330010	8.00E+22	5	y	3.40E-04	1	0	1	0	-2	pseudo
330760	1.09E+00	4	d	2.23E-07	1	-1	1	1	0	As-76 > stable
280770	1.03E-01	1	s	4.51E-07	1	0	1	0	-0.3	Ni-77 > Cu-77 1.0
290770	4.69E-01	1	s	1.17E-04	1	0	1	1	-0.3	Cu-77 > Zn-77 1.0
300770	2.08E+00	1	s	3.62E-03	1	0	1	2	-0.3	Zn-77 > Ga-77 1.0
310770	1.32E+01	1	s	5.32E-03	1	1	1	3	0	Ga-77 > Ge-77 1.0
320771	5.29E+01	1	s	4.78E-04	0.96	1	1	4	0	Ge-77m Ge-77 .04 As-77 .960
320770	1.13E+01	3	h	6.89E-04	1	0	1	5	0	Ge-77 > As-77 1.0
330770	3.88E+01	3	h	1.27E-05	1	-1	1	6	0	As-77 > stable
350770	5.70E+01	3	h	0	1	-1	1	0	-1	Br-77 > stable
280780	1.38E-01	1	s	5.06E-08	1	0	1	0	-0.3	Ni-78 > Cu-78 1.0
290780	3.42E-01	1	s	4.45E-05	1	0	1	1	-0.3	Cu-78 > Zn-78 1.0
300780	1.47E+00	1	s	4.25E-03	1	0	1	2	-0.3	Zn-78 > Ga-78 1.0
310780	5.09E+00	1	s	1.42E-02	1	0	1	3	-0.3	Ga-78 > Ge-78 1.0
320780	8.80E+01	2	m	2.00E-03	1	0	1	4	0	Ge-78 > As-78 1.0
330780	9.07E+01	2	m	2.18E-04	1	-1	1	5	0	As-78 > stable
290790	1.88E-01	1	s	5.18E-06	1	0	1	0	-0.3	Cu-79 > Zn-79 1.0
300790	9.95E-01	1	s	1.65E-03	1	0	1	1	-0.3	Zn-79 > Ga-79 1.0
310790	2.85E+00	1	s	1.52E-02	1	0	1	2	-0.3	Ga-79 > Ge-79 1.0
320790	1.90E+01	1	s	2.66E-02	1	0	1	3	-0.3	Ge-79 > As-79 1.0
330790	9.01E+00	2	m	9.41E-03	1	0	1	4	0	As-79 > Se-79m 1.0
340791	3.92E+00	2	m	8.05E-06	1	0	1	5	0	Se-79m > Se-79 1.0

340790	2.95E+05	5	y	8.03E-06	1	-1	1	6	3.63E-01	Se-79 > stable
370790	2.29E+01	2	m	0	1	0	1	0	-1	Rb-79 > Kr-79 1.0
360790	3.50E+01	3	h	0	1	-1	3	1	-1	Kr-79 > stable
290800	9.11E-02	1	s	7.03E-07	1	0	1	0	-0.3	Cu-80 > Zn-80 1.0
300800	5.40E-01	1	s	7.55E-04	1	0	1	1	-0.3	Zn-80 > Ga-80 1.0
310800	1.68E+00	1	s	2.13E-02	1	0	1	2	-0.3	Ga-80 > Ge-80 1.0
320800	2.95E+01	1	s	8.88E-02	1	0	1	3	-0.3	Ge-80 > As-80 1.0
330800	1.52E+01	1	s	1.49E-02	1	-1	1	4	0	As-80 > stable
350801	4.42E+00	3	h	0	1	0	2	0	-1	Br-80m > Br-80 1.0
350800	1.77E+01	2	m	0	1	-1	2	1	-1	Br-80 > stable
380800	1.06E+02	2	m	0	1	0	1	0	-1	Sr-80 > Rb-80 1.0
370800	3.40E+01	1	s	0	1	-1	1	1	-0.3	Rb-80 > stable
290810	7.45E-02	1	s	3.67E-08	1	0	1	0	-0.3	Cu-81 > Zn-81 1.0
300810	2.90E-01	1	s	1.32E-04	1	0	1	1	-0.3	Zn-81 > Ga-81 1.0
310810	1.22E+00	1	s	1.16E-02	1	0	1	2	-0.3	Ga-81 > Ge-81 1.0
320810	7.60E+00	1	s	1.33E-01	1	0	1	3	-0.3	Ge-81 > As-81 1.0
330810	3.33E+01	1	s	5.98E-02	1	0	1	4	0	As-81 > Se-81 1.0
340811	5.73E+01	2	m	6.85E-03	1	0	1	5	0	Se-81m > Se-81 1.0
340810	1.85E+01	2	m	2.19E-03	1	-1	1	6	0	Se-81 > stable
380810	2.23E+01	2	m	0	1	1	1	0	-1	Sr-81 > Rb-81 1.0
370811	3.05E+01	2	m	0	1	0	1	1	-1	Rb-81m > Rb-81 1.0
370810	4.57E+00	3	h	0	1	0	1	2	-1	Rb-81 > Kr-81 1.0
360810	2.29E+05	5	y	0	1	-1	3	3	-1	Kr-81 > stable
350010	1.00E+23	5	y	3.30E-02	1	3	2	0	-2	pseudo
350020	4.00E+19	5	y	2.00E-04	1	2	2	1	-2	pseudo
350030	1.00E+23	5	y	5.00E-02	1	2	2	2	-2	pseudo
350040	2.00E+19	5	y	5.00E-05	1	1	2	3	-2	pseudo
350821	6.13E+00	2	m	8.00E-05	0.976	0	2	4	0	Br-82m > Br-82 .976
350820	3.53E+01	3	h	5.92E-05	1	-1	2	5	0	Br-82 > stable
380820	2.54E+01	4	d	0	0.99974	0	1	0	-0.3	Sr-82 > Rb-82 .99974
370820	1.26E+00	2	m	0	1	-1	1	1	-0.3	Rb-82 > stable

370821	6.47E+00	3	h	0	1	-1	1	0	-1	Rb-82m > stable
300830	8.39E-02	1	s	1.02E-06	1	0	1	0	-0.3	Zn-83 > Ga-83 1.0
310830	3.10E-01	1	s	9.54E-04	1	0	1	1	-0.3	Ga-83 > Ge-83 1.0
320830	1.85E+00	1	s	9.74E-02	1	0	1	2	-0.3	Ge-83 > As-83 1.0
330830	1.34E+01	1	s	3.22E-01	0.36	1	1	3	-0.3	As-83 Se-83m .64 Se-83 .36
340831	7.01E+01	1	s	6.40E-02	1	1	1	4	0	Se-83m > Br-83 1.0
340830	2.23E+01	2	m	4.83E-02	1	0	1	5	0	Se-83 > Br-83 1.0
350830	2.40E+00	3	h	3.71E-03	1	2	2	6	0	Br-83 > Kr-83m 1.0
380830	3.24E+01	3	h	0	0.76	0	1	0	-1	Sr-83 > Rb-83 .76
370830	8.62E+01	4	d	0	0.762	0	1	1	-1	Rb-83 > Kr-83m 0.762
360831	1.83E+00	3	h	3.99E-06	1	-1	3	9	0	Kr-83m > stable
310840	8.50E-02	1	s	5.49E-05	1	0	1	0	-0.3	Ga-84 > Ge-84 1.0
320840	9.47E-01	1	s	1.91E-02	1	0	1	1	-0.3	Ge-84 > As-84 1.0
330840	4.20E+00	1	s	3.00E-01	1	0	1	2	-0.3	As-84 > Se-84 1.0
340840	3.26E+00	2	m	6.62E-01	1	1	1	3	0	Se-84 > Br-84 1.0
350841	6.00E+00	2	m	1.90E-02	1	0	2	4	0	Br-84m > stable
350840	3.18E+01	2	m	1.80E-02	1	-1	2	5	0	Br-84 > stable
370840	3.28E+01	4	d	0	1	-1	1	0	-1	Rb-84 > stable
320850	5.35E-01	1	s	6.44E-03	1	0	1	0	-0.3	Ge-85 > As-85 1.0
330850	2.02E+00	1	s	2.01E-01	0.8	0	1	1	-0.3	As-85 > Se-85 0.8
340850	3.17E+01	1	s	4.60E-01	1	1	1	2	-0.3	Se-85 > Br-85 1.0
340851	1.90E+01	1	s	4.60E-01	1	0	1	3	-0.3	Se-85m > Br-85 1.0
350850	2.90E+00	2	m	1.69E-01	0.0018	1	2	4	0	Br-85>Kr-85m.9982 Kr85 .0018
360851	4.48E+00	3	h	1.37E-02	0.211	0	3	5	0	Kr-85m > Kr-85 .211
360850	1.08E+01	5	y	2.28E-03	1	-1	3	6	1.84E-01	Kr-85 > stable
380851	6.76E+01	2	m	0	0.879	0	1	0	-1	Sr-85m > Sr-85 0.879
380850	6.48E+01	4	d	0	1	-1	1	1	-1	Sr-85 > stable
320860	2.59E-01	1	s	1.14E-03	1	0	1	0	-0.3	Ge-86 > As-86 1.0
330860	9.45E-01	1	s	1.13E-01	1	0	1	1	-0.3	As-86 > Se-86 1.0
340860	1.53E+01	1	s	######	1	0	1	2	-0.3	Se-86 > Br-86 1.0
350860	5.51E+01	1	s	2.92E-01	1	-1	2	3	0	Br-86 > stable

370860	1.86E+01	4	d	0	1	-1	1	0	-1	Rb-86 > stable
400860	1.65E+01	3	h	0	1	1	1	0	-1	Zr-86 > Y-86 1.0
390861	4.80E+01	2	m	0	1	0	1	1	-1	Y-86m > Y-86 1.0
390860	1.47E+01	3	h	0	1	-1	1	2	-1	Y-86 > stable
320870	1.26E-01	1	s	1.83E-04	1	0	1	0	-0.3	Ge-87 > As-87 1.0
330870	5.60E-01	1	s	6.44E-02	1	0	1	1	-0.3	As-87 > Se-87 1.0
340870	5.50E+00	1	s	9.34E-01	1	0	1	2	-0.3	Se-87 > Br-87 1.0
350870	5.57E+01	1	s	0	1	0	2	3	0	Br-87 > Kr-87 1.0
360870	7.63E+01	2	m	3.42E-01	1	1	3	4	5.52E+01	Kr-87 > Rb-87 1.0
380871	2.82E+00	3	h	0	0.003	0	1	0	-1	Sr-87m > Rb-87 0.003
370870	4.81E+10	5	y	1.00E-01	1	-1	1	0	7.69E-02	Rb-87 > stable
320880	1.43E-01	1	s	2.08E-06	1	0	1	0	-0.3	Ge-88 > As-88 1.0
330880	1.30E-01	1	s	2.63E-03	1	0	1	1	-0.3	As-88 > Se-88 1.0
340880	1.53E+00	1	s	3.55E-01	1	0	1	2	-0.3	Se-88 > Br-88 1.0
350880	1.63E+01	1	s	######	1	0	2	3	0	Br-88 > Kr-88 1.0
360880	2.84E+00	3	h	######	1	0	3	4	0	Kr-88 > Rb-88 1.0
370880	1.78E+01	2	m	3.20E-02	1	-1	1	5	9.20E-02	Rb-88 > stable
410880	1.45E+01	2	m	0	1	0	1	0	-1	Nb-88 > Zr-88 1.0
400880	8.34E+01	4	d	0	1	0	1	1	-1	Zr-88 > Y-88 1.0
390880	1.07E+02	4	d	0	1	-1	1	2	-1	Y-88 > stable
330890	1.29E-01	1	s	2.07E-04	1	0	1	0	-0.3	As-89 > Se-89 1.0
340890	4.10E-01	1	s	9.27E-02	1	0	1	1	-0.3	Se-89 > Br-89 1.0
350890	4.35E+00	1	s	######	1	0	2	2	-0.3	Br-89 > Kr-89 1.0
360890	3.15E+00	2	m	######	1	0	3	3	0	Kr-89 > Rb-89 1.0
370890	1.52E+01	2	m	1.70E-01	1	0	1	4	0	Rb-89 > Sr-89 1.0
380890	5.05E+01	4	d	2.58E-03	1	-1	1	5	5.26E-02	Sr-89 > stable
410891	1.18E+00	3	h	0	1	1	1	0	-1	Nb-89m > Zr-89 1.0
410890	1.90E+00	3	h	0	1	0	1	0	-1	Nb-89 > Zr-89 1.0
400890	7.84E+01	3	h	0	1	-1	1	2	-1	Zr-89 > stable
340900	5.55E-01	1	s	3.22E-02	1	0	1	0	-0.3	Se-90 > Br-90 1.0
350900	1.91E+00	1	s	######	0.88	0	2	1	-0.3	Br-90 > Kr-90 .88

360900	3.23E+01	1	s	######	1	1	3	2	0	Kr-90 > Rb-90 1.0
370901	2.58E+02	1	s	4.28E-01	0.974	1	1	3	0	Rb-90m Sr-90 .026 Rb-90 .974
370900	1.58E+02	1	s	6.76E-01	1	0	1	4	0	Rb-90 > Sr-90 1.0
380900	2.88E+01	5	y	2.82E-02	1	3	1	5	8.74E-02	Sr-90 > Y-90 1.0
390010	1.00E+23	5	y	5.20E-05	1	1	1	6	-2	pseudo
390020	5.00E+20	5	y	5.00E-07	1	0	1	7	-2	pseudo
390901	3.19E+00	3	h	1.25E-05	1	0	1	8	0	Y-90m > Y-90 1.0
390900	6.40E+01	3	h	2.30E-04	1	-1	1	9	5.92E-01	Y-90 > stable
420900	5.56E+00	3	h	0	1	0	1	0	-1	Mo-90 > Nb-90 1.0
410900	1.46E+01	3	h	0	1	-1	1	0	-1	Nb-90 > stable
340910	2.70E-01	1	s	3.22E-03	1	0	1	0	-0.3	Se-91 > Br-91 1.0
350910	5.41E-01	1	s	3.91E-01	1	0	2	1	-0.3	Br-91 > Kr-91 1.0
360910	8.57E+00	1	s	######	1	0	3	2	0	Kr-91 > Rb-91 1.0
370910	5.84E+01	1	s	######	1	0	1	3	0	Rb-91 > Sr-91 1.0
380910	9.63E+00	3	h	2.29E-01	1	1	1	4	0	Sr-91 Y-91 1.0
390911	4.97E+01	2	m	2.72E-04	1	0	1	5	0	Y-91m > Y-91 1.0
390910	5.85E+01	4	d	6.24E-04	1	-1	1	6	1.65E-01	Y-91 > stable
340920	2.48E-01	1	s	4.77E-05	1	0	1	0	-0.3	Se-92 > Br-92 1.0
350920	3.43E-01	1	s	1.89E-02	1	0	2	1	-0.3	Br-92 > Kr-92 1.0
360920	1.84E+00	1	s	######	1	0	3	2	0	Kr-92 > Rb-92 1.0
370920	4.49E+00	1	s	######	1	0	1	3	0	Rb-92 > Sr-92 1.0
380920	2.71E+00	3	h	######	1	0	1	4	0	Sr-92 > Y-92 1.0
390920	3.54E+00	3	h	9.81E-03	1	-1	1	5	0	Y-92 > stable
350930	1.02E-01	1	s	4.71E-03	1	0	2	0	-0.3	Br-93 > Kr-93 1.0
360930	1.29E+00	1	s	5.00E-01	1	0	3	1	0	Kr-93 > Rb-93 1.0
370930	5.84E+00	1	s	######	1	0	1	2	0	Rb-93 > Sr-93 1.0
380930	7.42E+00	2	m	######	1	0	1	3	0	Sr-93 > Y-93 1.0
390930	1.02E+01	3	h	9.81E-02	1	0	1	4	0	Y-93 > Zr-93 1.0
400930	1.53E+06	5	y	2.50E-01	1	2	1	5	1.029	Zr-93 > Nb-93m 1.o
410010	2.00E+23	5	y	1.20E-04	1	1	1	6	-2	pseudo
410020	2.00E+20	5	y	4.00E-06	1	0	1	7	-2	pseudo

410931	1.61E+01	5	y	9.37E-09	1	-1	1	8	0	Nb-93m > stable
420931	6.85E+00	3	h	0	1	2	1	0	-1	Mo-93m > Mo-93 1.0
430931	4.35E+01	2	m	0	0.234	1	1	0	-1	Tc-93m Tc-93 .766 Mo-93 .234
430930	2.75E+00	3	h	0	1	0	1	0	-1	Tc-93 > Mo-93 1.0
420930	4.00E+03	5	y	######	1	-1	1	3	-1	Mo-93 > stable
350940	7.00E-02	1	s	3.27E-04	1	0	2	0	-0.3	Br-94 > Kr-94 1.0
360940	2.00E-01	1	s	2.27E-01	1	0	3	1	-0.3	Kr-94 > Rb-94 1.0
370940	2.70E+00	1	s	######	1	0	1	2	-0.3	Rb-94 > Sr-94 1.0
380940	7.53E+01	1	s	######	1	0	1	3	0	Sr-94 > Y-94 1.0
390940	1.87E+01	2	m	3.52E-01	1	-1	1	4	0	Y-94 > Stable 1.0
410941	6.26E+00	2	m	4.38E-07	0.9952	0	1	0	0	Nb-94m > Nb-94 .9952
410940	2.03E+04	5	y	4.35E-07	1	-1	1	1	-1	Nb-94 > stable
440940	5.18E+01	2	m	0	1	1	1	0	-1	Ru-94 > Tc-94 1.0
430941	5.20E+01	2	m	0	1	-1	1	1	-1	Tc-94m > stable
430940	2.93E+02	2	m	0	1	-1	1	0	-1	Tc-94 > stable
350950	1.17E-01	1	s	7.33E-06	1	0	2	0	-0.3	Br-95 > Kr-95 1.0
360950	7.80E-01	1	s	1.02E-02	1	0	3	1	0	Kr-95 > Rb-95 1.0
370950	3.78E-01	1	s	8.96E-01	1	0	1	2	0	Rb-95 > Sr-95 1.0
380950	2.39E+01	1	s	######	1	0	1	3	-0.3	Sr-95 > Y-95 1.0
390950	1.03E+01	2	m	9.48E-01	1	0	1	4	0	Y-95 > Zr-95 1.0
400950	6.40E+01	4	d	2.95E-02	1	1	1	5	2.33E-01	Zr-95 > Nb-95m 1.0
410030	1.40E+18	5	y	4.50E-02	1	0	1	6	-2	pseudo > Nb-95m 1.0
410951	8.66E+01	3	h	1.29E-04	0.945	0	1	7	0	Nb-95m > Nb-95 .945
410950	3.50E+01	4	d	4.00E-05	1	-1	1	8	8.51E-01	Nb-95 > stable
430951	6.10E+01	4	d	0	0.04	0	1	0	-1	Tc-95m > Tc-95 .04
430950	2.00E+01	3	h	0	1	-1	1	1	-1	Tc-95 > stable
410040	1.00E+23	5	y	8.00E-03	1	1	1	0	-2	pseudo > Nb-96 1.0
410050	1.00E+19	5	y	1.00E-03	1	0	1	1	-2	pseudo > Nb-96 1.0
410960	2.34E+01	3	h	6.10E-04	1	-1	1	2	0	Nb-96 > stable
430961	5.15E+01	2	m	0	0.98	0	1	0	-1	Tc-96m > Tc-96 0.98
430960	4.28E+00	4	d	0	1	-1	1	1	-1	Tc-96 > stable

360970	1.49E-01	1	s	4.06E-05	1	0	3	0	-0.3	Kr-97 > Rb-97 1.0
370970	1.70E-01	1	s	3.64E-02	1	0	1	1	-0.3	Rb-97 > Sr-97 1.0
380970	4.26E-01	1	s	######	1	0	1	2	0	Sr-97 > Y-97 1.0
390970	3.75E+00	1	s	######	1	0	1	3	0	Y-97 > Zr-97 1.0
400970	1.69E+01	3	h	8.74E-01	1	0	1	4	0	Zr-97 > Nb-97m 1.0
410971	5.27E+01	1	s	6.86E-03	1	0	1	5	0	Nb-97m > Nb-97 1.0
410970	7.21E+01	2	m	1.68E-02	1	-1	1	6	0	Nb-97 > stable
430971	9.01E+01	4	d	0	1	1	1	0	-1	Tc-97m > Tc-97 1.0
440970	2.83E+00	4	d	0	0.9992	0	1	0	-1	Ru-97 > Tc-97 0.9992
430970	2.60E+06	5	y	0	1	-1	1	2	-1	Tc-97 > stable
360980	2.24E-01	1	s	4.24E-06	1	0	3	0	-0.3	Kr-98 > Rb-98 1.0
370980	9.60E-02	1	s	5.26E-03	1	0	1	1	-0.3	Rb-98 > Sr-98 1.0
380980	6.53E-01	1	s	6.98E-01	1	0	1	2	-0.3	Sr-98 > Y-98 1.0
390980	2.00E+00	1	s	######	1	0	1	3	-0.3	Y-98 > Zr-98 1.0
400980	3.07E+01	1	s	######	1	1	1	4	-0.3	Zr-98 > Nb-98 1.0
410981	5.13E+01	2	m	2.72E-02	1	-1	1	0	-0.3	Nb-98m > stable
410980	5.15E+01	2	m	4.48E-02	1	-1	1	6	0	Nb-98 > stable
430980	4.20E+06	5	y	0	1	-1	1	0	-1	Tc-98 > stable
370990	5.03E-02	1	s	4.06E-04	1	0	1	0	-0.3	Rb-99 > Sr-99 1.0
380990	2.69E-01	1	s	1.54E-01	1	0	1	1	-0.3	Sr-99 > Y-99 1.0
390990	1.47E+00	1	s	######	1	0	1	2	-0.3	Y-99 > Zr-99 1.0
400990	2.10E+00	1	s	######	1	0	1	3	0	Zr-99 > Nb-99m 1.0
410991	2.60E+00	2	m	1.49E-01	1	1	1	4	0	Nb-99m > Mo-99 1.0
410990	1.50E+01	1	s	1.37E-01	1	0	1	5	0	Nb-99 > Mo-99 1.0
420990	6.59E+01	3	h	2.87E-03	1	0	1	6	1.013	Mo-99 > Tc-99m 1.0
430991	6.02E+00	3	h	3.34E-07	1	0	1	7	0	Tc-99m > Tc-99 1.0
430990	2.11E+05	5	y	7.50E-02	1	-1	1	8	9.136	Tc-99 > stable
450991	4.70E+00	3	h	0	1	-1	1	0	-1	Rh-99m > stable
450990	1.61E+01	4	d	0	1	-1	1	0	-1	Rh-99 > stable
371000	5.10E-02	1	s	1.70E-05	1	0	1	0	-0.3	Rb-100 > Sr-100 1.0
381000	2.02E-01	1	s	2.38E-02	1	0	1	1	-0.3	Sr-100 > Y-100 1.0

391000	9.40E-01	1	s	8.57E-01	1	0	1	2	-0.3	Y-100 > Zr-100 1.0
401000	7.10E+00	1	s	######	1	1	1	3	-0.3	Zr-100 > Nb-100
411001	2.99E+00	1	s	4.69E-01	1	-1	1	4	-0.3	Nb-100m> stable
411000	1.50E+00	1	s	4.69E-01	1	-1	1	5	-0.3	Nb-100 > stable
461000	3.63E+00	4	d	0	1	-1	1	0	-1	Pd-100 > Rh-100
451000	2.08E+01	3	h	0	1	-1	1	0	-1	Rh-100 > stable
381010	1.18E-01	1	s	2.96E-03	1	0	1	0	-0.3	Sr-101 > Y-101 1.0
391010	4.48E-01	1	s	2.69E-01	1	0	1	1	-0.3	Y-101 > Zr-101 1.0
401010	2.30E+00	1	s	######	1	0	1	2	-0.3	Zr-101 > Nb-101 1.0
411010	7.10E+00	1	s	######	1	0	1	3	0	Nb-101 > Mo-101 1.0
421010	1.46E+01	2	m	1.12E-01	1	0	1	4	0	Mo-101 > Tc-101 1.0
431010	1.42E+01	2	m	2.34E-04	1	-1	1	5	0	Tc-101 > stable
461010	8.47E+00	3	h	0	0.997	0	1	0	-1	Pd-101 > Rh-101 .997
451011	4.34E+00	4	d	0	0.072	0	1	1	-1	Rh-101m> Rh-101 0.072
451010	3.30E+00	5	y	0	1	-1	1	2	-1	Rh-101 > stable
381020	6.90E-02	1	s	1.97E-04	1	0	1	0	-0.3	Sr-102 > Y-102 1.0
391020	3.60E-01	1	s	5.37E-02	1	0	1	1	-0.3	Y-102 > Zr-102 1.0
401020	2.90E+00	1	s	######	1	0	1	2	-0.3	Zr-102 > Nb-102 1.0
411020	4.30E+00	1	s	######	1	0	1	3	-0.3	Nb-102 > Mo-102 1.0
421020	1.13E+01	2	m	4.14E-01	1	1	1	4	-0.3	Mo-102 > Tc-102 1.0
431021	4.35E+00	2	m	1.29E-03	0.5	0	1	5	0	Tc-102m> Tc-102 .5
431020	5.28E+00	1	s	1.29E-03	1	-1	1	6	0	Tc-102 > stable
471020	7.70E+00	2	m	0	1	-1	1	0	-1	Ag-102 > stable
451021	3.74E+00	5	y	0	0.05	0	1	0	-1	Rh-102m> Rh-102 0.05
451020	2.07E+02	4	d	0	1	-1	1	1	-1	Rh-102 > stable
381030	1.39E-01	1	s	4.80E-06	1	0	1	0	-0.3	Sr-103 > Y-103 1.0
391030	2.30E-01	1	s	5.34E-03	1	0	1	1	-0.3	Y-103 > Zr-103 1.0
401030	1.30E+00	1	s	5.26E-01	1	0	1	2	-0.3	Zr-103 > Nb-103 1.0
411030	1.50E+00	1	s	######	1	0	1	3	-0.3	Nb-103 > Mo-103 1.0
421030	6.75E+01	1	s	9.23E-01	1	0	1	4	-0.3	Mo-103 > Tc-103 1.0
431030	5.42E+01	1	s	1.80E-02	1	2	1	5	-0.3	Tc-103 > Ru-103 1.0

471030	6.57E+01	2	m	0	1	0	1	0	-1	Ag-103 > Pd-103
461030	1.70E+01	4	d	0	1	-1	1	1	-1	Pd-103 > Stable
441030	3.92E+01	4	d	4.00E-05	0.9006	0	5	8	2.666	Ru-103 > Rh-103m .9006
451031	5.61E+01	2	m	1.05E-09	1	-1	1	9	0	Rh-103m> stable
471060	2.40E+01	2	m	0	1	-1	1	0	-1	Ag-106 > stable
471061	8.28E+00	4	d	0	1	-1	1	0	-1	Ag-106m> stable
381040	1.93E-01	1	s	8.23E-08	1	0	1	0	-0.3	Sr-104 > Y-104 1.0
391040	1.44E-01	1	s	2.54E-04	1	0	1	1	-0.3	Y-104 > Zr-104 1.0
401040	1.20E+00	1	s	8.01E-02	1	0	1	2	-0.3	Zr-104 > Nb-104 1.0
411040	4.80E+00	1	s	7.32E-01	1	0	1	3	-0.3	Nb-104 > Mo-104 1.0
421040	6.00E+01	1	s	######	1	0	1	4	-0.3	Mo-104 > Tc-104 1.0
431040	1.83E+01	2	m	5.75E-02	1	-1	1	5	0	Tc-104 > stable
481040	5.77E+01	2	m	0	1	1	1	0	-1	Cd-104 > Ag-104 1.0
471041	3.35E+01	2	m	0	0.33	0	1	0	-1	Ag-104m> Ag-104 .33
471040	6.92E+01	2	m	0	1	-1	1	2	-1	Ag-104 > stable
391050	1.74E-01	1	s	2.25E-05	1	0	1	0	-0.3	Y-105 > Zr-105 1.0
401050	6.00E-01	1	s	1.03E-02	1	0	1	1	-0.3	Zr-105 > Nb-105 1.0
411050	2.95E+00	1	s	2.03E-01	1	0	1	2	-0.3	Nb-105 > Mo-105 1.0
421050	3.56E+01	1	s	7.21E-01	1	0	1	3	-0.3	Mo-105 > Tc-105 1.0
431050	7.60E+00	2	m	9.69E-02	1	0	1	4	-0.3	Tc-105 > Ru-105 1.0
441050	4.44E+00	3	h	2.34E-03	1	1	5	5	2.91E-01	Ru-105 > Rh-105 1.0
451051	4.00E+01	1	s	7.30E-07	0.8	0	1	6	0	Rh-105m> Rh-105 .800
451050	3.54E+01	3	h	5.20E-03	1	-1	1	7	2.80E-01	Rh-105 > stable
471050	4.13E+01	4	d	0	1	-1	1	0	-1	Ag-105 > stable
401060	9.80E-01	1	s	2.48E-03	1	0	1	0	-0.3	Zr-106 > Nb-106 1.0
411060	1.02E+00	1	s	7.00E-02	1	0	1	1	-0.3	Nb-106 > Mo-106 1.0
421060	8.40E+00	1	s	2.94E-01	1	0	1	2	-0.3	Mo-106 > Tc-106 1.0
431060	3.56E+01	1	s	4.98E-02	1	0	1	3	-0.3	Tc-106 > Ru-106 1.0
441060	3.72E+02	4	d	1.20E-03	1	3	5	4	7.71E-01	Ru-106 > Rh-106 1.0
450010	1.00E+23	5	y	2.70E-02	1	0	1	5	-2	pseudo
450020	8.80E+16	5	y	9.00E-04	1	0	1	6	-2	pseudo

451061	1.31E+02	2	m	3.40E-03	1	-1	1	7	0	Rh-106m> stable 1.0
451060	3.01E+01	1	s	8.30E-03	0.7519	-1	1	8	0	Rh-106 > stable
391070	1.05E-01	1	s	3.74E-08	1	0	1	0	-0.3	Y-107 > Zr-107 1.0
401070	2.49E-01	1	s	1.19E-04	1	0	1	1	-0.3	Zr-107 > Nb-107 1.0
411070	3.30E-01	1	s	1.14E-02	1	0	1	2	-0.3	Nb-107 > Mo-107 1.0
421070	3.50E+00	1	s	1.24E-01	1	0	1	3	-0.3	Mo-107 > Tc-107 1.0
431070	2.12E+01	1	s	5.38E-02	1	0	1	4	-0.3	Tc-107 > Ru-107 1.0
441070	3.75E+00	2	m	4.94E-06	1	0	1	5	-0.3	Ru-107 > Rh-107 1.0
451070	2.17E+01	2	m	7.24E-06	1	2	1	6	0	Rh-107 > Pd-107 1.0
460010	1.10E+21	5	y	2.10E-05	1	0	1	7	-2	pseudo
461071	2.13E+01	1	s	7.64E-10	1	0	1	8	0	Pd-107m> Pd-107 1.0
461070	6.50E+06	5	y	7.40E-10	1	-1	1	9	2.816	Pd-107 > stable
481070	6.50E+00	3	h	0	1	-1	1	0	-1	Cd-107 > stable
401080	4.08E-01	1	s	2.64E-06	1	0	1	0	-0.3	Zr-108 > Nb-108 1.0
411080	1.93E-01	1	s	8.49E-04	1	0	1	1	-0.3	Nb-108 > Mo-108 1.0
421080	1.09E+00	1	s	3.27E-02	1	0	1	2	-0.3	Mo-108 > Tc-108 1.0
431080	5.17E+00	1	s	4.64E-02	1	0	1	3	-0.3	Tc-108 > Ru-108 1.0
441080	4.55E+00	2	m	1.15E-02	1	2	5	4	0	Ru-108 > Rh-108 1.0
450030	1.00E+19	5	y	2.00E-05	1	0	1	0	-2	pseudo
451081	6.00E+00	2	m	4.58E-05	1	-1	1	1	0	Rh-108m> stable
451080	1.68E+01	1	s	4.58E-05	1	-1	1	0	0	Rh-108 > stable
471081	4.38E+02	5	y	0	0.0869	0	1	0	-1	Ag-108m> Ag-108 0.089
471080	2.38E+00	2	m	0	1	-1	1	1	-1	Ag-108 > stable
401090	1.39E-01	1	s	1.75E-08	1	0	1	0	-0.3	Zr-109 > Nb-109 1.0
411090	1.90E-01	1	s	2.62E-05	1	0	1	1	-0.3	Nb-109 > Mo-109 1.0
421090	5.30E-01	1	s	4.05E-03	1	0	1	2	-0.3	Mo-109 > Tc-109 1.0
431090	8.70E-01	1	s	2.10E-02	1	0	1	3	-0.3	Tc-109 > Ru-109 1.0
441090	3.45E+01	1	s	1.89E-02	1	1	5	4	-0.3	Ru-109 > Rh-109 1.0
451091	5.00E+01	1	s	3.17E-04	1	0	1	5	-0.3	Rh-109m> Rh-109 1.0
451090	8.00E+01	1	s	3.17E-04	1	2	1	6	-0.3	Rh-109 > Pd-109 1.0
461091	4.69E+00	2	m	1.30E-06	1	1	1	7	0	Pd-109m> Pd-109 1.0

460020	1.00E+18	5	y	6.00E-03	1	0	1	8	-2	pseudo
461090	1.37E+01	3	h	1.30E-06	0.9995	0	1	9	0	Pd-109 > Ag-109m 1.0
471091	3.96E+01	1	s	1.33E-10	1	-1	1	10	0	Ag-109m> stable
491090	4.17E+00	3	h	0	1	0	1	0	-1	In-109 > Cd-109 1.0
481090	4.61E+02	4	d	0	1	-1	1	1	-1	Cd-109 > stable
470010	3.50E+19	5	y	6.10E-04	1	1	1	0	-2	pseudo
470020	4.00E+19	5	y	1.50E-02	1	1	1	1	-2	pseudo
471101	2.50E+02	4	d	4.00E-09	0.0136	0	1	2	0	Ag-110m> Ag-110 .0136
471100	2.46E+01	1	s	3.70E-09	1	-1	1	3	0	Ag-110 > stable
501100	4.11E+00	3	h	0	1	1	1	0	-1	Sn-110 > In-110 1.0
491101	6.91E+01	2	m	0	1	-1	1	1	-1	In-110m> stable
491100	4.90E+00	3	h	0	1	-1	1	0	-1	In-110 > stable
410060	6.50E+16	5	y	1.60E-08	1	0	1	0	-2	pseudo
411110	1.56E-01	1	s	1.41E-08	1	0	1	1	-0.3	Nb-111 > Mo-111 1.0
421110	3.00E-01	1	s	3.77E-05	1	0	1	2	-0.3	Mo-111 > Tc-111 1.0
431110	2.90E-01	1	s	2.49E-03	1	0	1	3	-0.3	Tc-111 > Ru-111 1.0
441110	2.12E+00	2	m	1.80E-02	1	0	5	4	-0.3	Ru-111 > Rh-111 1.0
451110	1.10E+01	1	s	5.56E-03	1	1	1	5	-0.3	Rh-111 > Pd-111 1.0
461111	5.50E+00	3	h	1.25E-04	0.27	1	1	6	-0.3	Pd-111m Pd-111 .93 Ag-111 .27
461110	2.34E+01	2	m	1.26E-04	1	0	1	7	0	Pd-111 > Ag-111m 1.0
471111	6.48E+01	1	s	1.62E-07	1	0	1	8	0	Ag-111m> Ag-111 1.0
471110	7.45E+00	4	d	1.58E-07	1	-1	1	9	3.461	Ag-111 > stable
501110	3.53E+01	2	m	0	1	0	1	0	-1	Sn-111 > In-111
491110	2.80E+00	4	d	0	1	-1	1	0	-1	In-111 > stable
480010	1.00E+20	5	y	2.10E-06	1	0	1	0	-2	pseudo
480020	1.00E+22	5	y	1.00E-10	1	0	1	1	-2	pseudo
481111	4.85E+01	2	m	2.50E-11	1	-1	1	2	0	Cd-111m> stable
421120	6.89E-01	1	s	4.16E-06	1	0	1	0	-0.3	Mo-112 > Tc-112 1.0
431120	2.80E-01	1	s	5.35E-04	1	0	1	1	-0.3	Tc-112 > Ru-112 1.0
441120	1.75E+00	1	s	9.88E-03	1	0	5	2	-0.3	Ru-112 > Rh-112 1.0
451120	2.10E+00	1	s	7.53E-03	1	0	1	3	-0.3	Rh-112 > Pd-112 1.0

461120	2.10E+01	3	h	8.99E-04	1	0	1	4	0	Pd-112 > Ag-112 1.0
471120	3.13E+00	3	h	1.70E-04	1	-1	1	5	0	Ag-112 > stable
491120	1.50E+01	2	m	0	1	-1	1	0	0	In-112 > stable
501130	1.15E+02	4	d	0	1	-1	1	0	-1	Sn-113 > Stable
491131	1.66E+00	3	h	0	1	-1	1	1	-1	In-113m> stable
421130	1.97E-01	1	s	2.70E-07	1	0	1	0	-0.3	Mo-113 > Tc-113 1.0
431130	1.30E-01	1	s	1.13E-04	1	0	1	1	-0.3	Tc-113 > Ru-113 1.0
441130	8.00E-01	1	s	5.50E-03	1	0	5	2	-0.3	Ru-113 > Rh-113 1.0
451130	2.80E+00	1	s	9.75E-03	1	0	1	3	-0.3	Rh-113 > Pd-113 1.0
461130	9.30E+01	1	s	3.02E-03	0.9	1	1	4	-0.3	Pd-113 Ag-113m .1 Ag-113 .9
471131	6.87E+01	1	s	1.52E-05	1	0	1	5	-0.3	Ag-113m> stable
471130	5.37E+00	3	h	1.52E-05	0.13	0	1	6	-0.3	Ag-113 > stable
481131	1.41E+01	5	y	0	1	-1	1	7	-1	Cd-113m> stable
481130	7.70E+15	5	y	0	1	-1	1	0	-1	Cd-113 > stable
421140	3.22E-01	1	s	1.73E-08	1	0	1	0	-0.3	Mo-114 > Tc-114 1.0
431140	1.73E-01	1	s	1.63E-05	1	0	1	1	-0.3	Tc-114 > Ru-114 1.0
441140	5.30E-01	1	s	2.04E-03	1	0	5	2	-0.3	Ru-114 > Rh-114 1.0
451140	1.85E+00	1	s	8.64E-03	1	0	1	3	-0.3	Rh-114 > Pd-114 1.0
461140	2.42E+00	2	m	6.39E-03	1	0	1	4	-0.3	Pd-114 > Ag-114 1.0
471140	4.60E+00	1	s	1.67E-04	1	-1	1	5	0	Ag-114 > stable
491141	4.95E+01	4	d	0	0.957	0	1	0	-1	In-114m> In-114 0.957
491140	7.19E+01	1	s	0	1	-1	1	1	-1	In-114 > stable
461150	5.00E+01	1	s	1.51E-02	0.73	0	1	0	-0.3	Pd-115 > Ag-115 .73
471150	2.00E+01	2	m	4.67E-04	0.0001	0	1	1	0	Ag-115 > Cd-115m .0001
481151	4.46E+01	4	d	1.46E-03	1	3	1	2	8.225	Cd-115m> stable
491150	4.41E+14	5	y	0	1	-1	1	0	-1	In-115 > stable
511150	3.21E+01	2	m	0	1	-1	1	0	-1	Sb-115 > stable
481150	5.35E+01	3	h	1.46E-02	1	0	1	0	0	Cd-115 > In-115m
491151	4.49E+00	3	h	4.05E-05	1	-1	1	1	0	In-115m > stable
491161	5.43E+01	2	m	0	1	-1	1	0	-1	In-116m> stable
521160	2.49E+00	3	h	0	1	1	1	0	-1	Te-116 > Sb-116 1.0

511161	6.03E+01	2	m	0	1	-1	1	0	-1	Sb-116m> stable
511160	1.58E+01	2	m	0	1	-1	1	0	-1	Sb-116 > stable
481171	3.36E+00	3	h	4.55E-03	1	2	1	0	0	Cd-117m > Cd-117
500010	1.00E+18	5	y	2.20E-03	1	0	1	0	-2	pseudo > pseudo
500020	1.00E+24	5	y	3.00E-04	1	4	1	1	-2	pseudo > Sb-117
481170	2.49E+00	3	h	2.56E-03	0.1	1	1	3	0	Cd-117 In-117m .1 In-117 .9
491171	1.16E+02	2	m	1.00E-02	0.47	0	1	4	9.20E-01	In-117m> In-117 .47
491170	4.32E+01	2	m	6.33E-10	1	0	1	5	9.20E-01	In-117 > Sn-117m
501171	1.36E+01	4	d	######	1	-1	1	6	0	Sn-117m> stable
511170	2.80E+00	3	h	0	1	-1	1	0	-1	Sb-117 > stable
440010	7.50E+16	5	y	3.90E-06	1	0	5	0	-2	pseudo > Ru-118
441180	6.16E-01	1	s	8.44E-07	1	0	5	1	-0.3	Ru-118 > Rh-118 1.0
451180	2.95E-01	1	s	2.32E-04	1	0	1	2	-0.3	Rh-118 > Pd-118
461180	1.90E+00	1	s	6.38E-03	1	0	1	3	-0.3	Pd-118 > Ag-118m 1.0
471181	2.00E+00	1	s	3.58E-03	0.59	1	1	4	-0.3	Ag-118m Ag-118 .41 Cd-118 .59
471180	3.76E+00	1	s	6.57E-03	1	0	1	5	-0.3	Ag-118 > Cd-118 .59
481180	5.03E+01	2	m	1.38E-03	1	1	1	6	-0.3	Cd-118 In-118 1.0
491181	4.45E+00	2	m	4.15E-06	1	-1	1	7	0	In-118m> stable 1.0
491180	5.00E+00	1	s	4.15E-06	1	-1	1	8	0	In-118 > stable
511181	5.00E+00	3	h	0	1	-1	1	0	0	Sb-118m > stable
451190	4.48E-01	1	s	4.17E-05	1	0	1	0	-0.3	Rh-119 > Pd-119 1.0
461190	9.20E-01	1	s	3.39E-03	1	0	1	1	-0.3	Pd-119 > Ag-119 1.0
471190	2.10E+00	1	s	9.26E-03	1	0	1	2	-0.3	Ag-119 > Cd-119 1.0
481190	2.69E+00	2	m	2.23E-03	0.1	1	1	3	-0.3	Cd-119 > In-119m 1.0
491191	1.80E+01	2	m	1.59E-05	0.025	0	1	4	-0.3	In-119m> stable
491190	2.40E+00	2	m	4.72E-04	1	-1	1	5	-0.3	In-119 > stable
501191	2.93E+02	4	d	2.65E-04	1	-1	1	0	0	Sn-119m > stable
511190	3.82E+01	3	h	0	1	-1	1	0	-1	Sb-119 > stable
441200	2.93E-01	1	s	3.07E-09	1	0	5	0	-0.3	Ru-120 > Rh-120 1.0
451200	1.62E-01	1	s	5.48E-06	1	0	1	1	-0.3	Rh-120 > Pd-120 1.0
461200	5.00E-01	1	s	1.14E-03	1	0	1	2	-0.3	Pd-120 > Ag-120 1.0

471200	3.20E-01	1	s	7.65E-03	1	0	1	3	-0.3	Ag-120 > Cd-120 1.0
481200	5.08E+01	1	s	8.71E-03	1	1	1	4	-0.3	Cd-120 > In-120 1.0
491201	4.62E+01	1	s	1.85E-04	1	-1	1	5	1.48E-03	In-120m> stable
491200	3.08E+00	1	s	1.85E-04	1	-1	1	6	1.48E-03	In-120 > stable
511203	5.76E+00	4	d	0	1	-1	1	0	-1	Sb-120b> stable
531201	5.30E+01	2	m	0	1	-1	1	0	-1	I-120m > stable
511200	1.59E+01	2	m	0	1	-1	1	0	-1	Sb-120 > stable
531200	8.16E+01	2	m	0	1	-1	1	0	-1	I-120 > stable
451210	2.21E-01	1	s	5.34E-07	1	0	1	0	-0.3	Rh-121 > Pd-121 1.0
461210	6.22E-01	1	s	2.92E-04	1	0	1	1	-0.3	Pd-121 > Ag-121 1.0
471210	7.80E-01	1	s	4.80E-03	1	0	1	2	-0.3	Ag-121 > Cd-121 1.0
481210	1.35E+01	1	s	1.21E-02	1	0	1	3	-0.3	Cd-121 > In-121m 1.0
491211	3.88E+00	2	m	9.58E-04	1	2	1	4	-0.3	In-121m> Sn-121 1.0
491210	2.31E+01	1	s	6.28E-04	1	1	1	5	-0.3	In-121 > Sn-121 1.0
501211	5.50E+01	5	y	8.78E-06	1	-1	1	6	0	Sn-121m> stable
501210	2.70E+01	3	h	8.75E-06	1	-1	1	7	0	Sn-121 > stable
531210	2.12E+00	3	h	0	1	1	1	0	-1	I-121 > Te-121
521211	1.54E+02	4	d	0	0.886	0	1	0	-1	Te-121m> Te-121 0.886
521210	1.92E+01	4	d	0	1	-1	1	2	-1	Te-121 > stable
511220	2.72E+00	4	d	0	1	-1	1	0	-1	Sb-122 > stable
541220	2.01E+01	3	h	0	1	0	3	0	-1	Xe-122 > I-122 1.0
531220	3.63E+00	2	m	0	1	-1	2	1	-1	I-122 > stable
451230	1.34E-01	1	s	5.12E-09	1	0	1	0	-0.3	Rh-123 > Pd-123 1.0
461230	3.10E-01	1	s	1.54E-05	1	0	1	1	-0.3	Pd-123 > Ag-123 1.0
471230	3.00E-01	1	s	1.28E-03	1	0	1	2	-0.3	Ag-123 > Cd-123 1.0
481230	2.10E+00	1	s	1.39E-02	1	2	1	3	-0.3	Cd-123 > In-123 1.0
491231	4.78E+01	1	s	3.13E-03	1	2	1	0	-0.3	In-123m > Sn-123m 1.0
501230	1.29E+02	4	d	1.62E-03	1	-1	1	1	0	Sn-123 > stable
491230	6.17E+00	1	s	3.21E-03	1	0	1	6	0	In-123 > Sn123m 1.0
501231	4.01E+01	2	m	2.94E-04	1	-1	1	7	0	Sn-123m> stable
541230	2.08E+00	3	h	0	1	0	3	0	-1	Xe-123 > I-123 1.0

531230	1.32E+01	3	h	0	1	1	2	1	-1	I-123 > Te-123 1.0
521231	1.19E+02	4	d	0	1	0	1	2	-1	Te-123m> Te-123 1.0
521230	9.20E+16	5	y	0	1	-1	1	3	-1	Te-123 > stable
511240	6.02E+01	4	d	0	1	-1	1	0	-1	Sb-124 > stable
531240	4.18E+00	4	d	0	1	-1	2	0	-1	I-124 > stable
461240	5.60E-01	1	s	3.03E-06	1	0	1	0	-0.3	Pd-124 > Ag-124 1.0
471240	1.72E-01	1	s	5.85E-04	1	0	1	1	-0.3	Ag-124 > Cd-124 1.0
481240	1.25E+00	1	s	1.41E-02	1	0	1	2	-0.3	Cd-124 > In-124 1.0
491240	3.12E+00	1	s	1.35E-02	1	-1	1	3	-0.3	In-124 > stable
511241	9.30E+01	1	s	0	1	-1	1	0	-1	Sb-124m> stable
471250	1.66E-01	1	s	1.39E-04	1	0	1	0	-0.3	Ag-125 > Cd-125 1.0
481250	6.50E-01	1	s	7.78E-03	1	1	1	1	-0.3	Cd-125 > In-125 1.0
491251	1.22E+01	1	s	7.96E-03	1	1	1	2	-0.3	In-125m> Sn-125m 1.0
491250	2.36E+00	1	s	1.35E-02	1	0	1	3	-0.3	In-125 > Sn-125m 1.0
501251	9.52E+00	2	m	5.00E-03	1	1	1	4	0	Sn-125m> Sb-125 1.0
501250	9.64E+00	4	d	1.00E-02	1	0	1	5	5.44E-01	Sn-125 > Sb-125 1.0
511250	2.76E+00	5	y	1.20E-04	1	0	1	6	7.62E-01	Sb-125 > Te-125m
521251	5.74E+01	4	d	1.38E-07	1	-1	1	0	0	Te-125m> stable
551250	4.67E+01	2	m	0	1	0	4	0	-1	Cs-125 > Xe-125 1.0
541250	1.69E+01	3	h	0	1	0	3	1	-1	Xe-125 > I-125 1.0
531250	5.94E+01	4	d	0	1	-1	2	2	-1	I-125 > stable
461260	2.87E-01	1	s	3.78E-08	1	0	1	0	-0.3	Pd-126 > Ag-126 1.0
471260	1.07E-01	1	s	5.32E-05	1	0	1	1	-0.3	Ag-126 > Cd-126 1.0
481260	5.06E-01	1	s	8.16E-03	1	0	1	2	-0.3	Cd-126 > In-126 1.0
491260	1.64E+00	1	s	4.12E-02	1	0	1	3	-0.3	In-126 > Sn-126 1.0
501260	2.30E+05	5	y	2.50E-02	1	1	1	4	4.44E-02	Sn-126 > Sb-126m 1.0
510010	1.00E+20	5	y	1.40E-04	1	1	1	5	-2	pseudo > Sb-126
511261	1.92E+01	2	m	5.02E-04	0.14	0	1	6	0	Sb-126m> Sb-126 .14
511260	1.24E+01	4	d	9.74E-04	1	-1	1	7	1.871	Sb-126 > stable
531260	1.29E+01	4	d	0	1	-1	2	0	-1	I-126 > stable
561260	1.00E+02	2	m	0	1	0	1	0	-1	Ba-126 > Cs-126 1.0

551260	1.64E+00	2	m	0	1	-1	1	1	-0.3	Cs-126 > stable
481270	3.70E-01	1	s	4.10E-03	1	1	1	0	-0.3	Cd-127 > In-127 1.0
491271	3.67E+00	1	s	2.50E-02	1	2	1	0	-0.3	In-127m> Sn-127m 1.0
491270	1.09E+00	1	s	2.49E-02	1	1	1	2	-0.3	In-127 > Sn-127m 1.0
501270	2.10E+00	3	h	4.72E-02	1	1	1	3	0	Sn-127 > Sb-127 1.0
501271	4.13E+00	2	m	5.04E-02	1	0	1	0	0	Sn-127m> Sb-127 1.0
511270	3.85E+00	4	d	7.46E-03	1	1	1	5	0	Sb-127 > Te-127 1.0
521271	1.09E+02	4	d	9.80E-05	0.976	0	1	6	2.053	Te-127m> Te-127 .976
521270	9.35E+00	3	h	4.00E-03	1	-1	1	7	0	Te-127 > stable
551270	6.25E+00	3	h	0	1	0	2	0	-1	Cs-127 > Xe-127 1.0
541270	3.64E+01	4	d	0	1	-1	3	1	-1	Xe-127 > stable
471280	5.80E-02	1	s	1.38E-06	1	0	1	0	-0.3	Ag-128 > Cd-128 1.0
481280	3.40E-01	1	s	1.82E-03	1	0	1	1	-0.3	Cd-128 > In-128 1.0
491280	8.40E-01	1	s	6.20E-02	1	0	1	2	-0.3	In-128 > Sn-128 1.0
501280	5.91E+01	2	m	3.06E-01	1	0	1	3	0	Sn-128 > Sb-128m 1.0
511281	1.04E+01	2	m	1.21E-02	1	-1	1	4	0	Sb-128m> stable
511280	9.01E+00	3	h	1.60E-02	1	-1	1	0	0	Sb-128 > stable
531280	2.50E+01	2	m	0	1	-1	2	0	-1	I-128 > stable
561280	2.43E+00	4	d	0	1	0	1	0	-1	Ba-128 > Cs-128 1.0
551280	3.62E+00	2	m	0	1	-1	4	1	-0.3	Cs-128 > stable
481290	2.70E-01	1	s	3.06E-04	1	0	1	0	-0.3	Cd-129 > In-129 1.0
491290	6.10E-01	1	s	3.94E-02	1	0	1	1	-0.3	In-129 > Sn-129m 1.0
501291	6.90E+00	2	m	3.30E-01	1	1	1	2	-0.3	Sn-129m> Sn-129 1.0
501290	2.23E+00	2	m	2.03E-01	1	0	1	3	-0.3	Sn-129 > Sb-129 1.0
511290	4.40E+00	3	h	1.14E-01	0.85	1	1	4	0	Sb-129 Te-129m .15 Te-129 .85
521291	3.36E+01	4	d	1.20E-02	0.65	0	1	5	2.90E-01	Te-129m> Te-129 .65
521290	6.96E+01	2	m	1.48E-02	1	0	1	6	0	Te-129 > I-129 1.0
531290	1.57E+07	5	y	2.50E-02	1	-1	2	7	5.272	I-129 > stable
540010	3.00E+20	5	y	1.39E-06	1	0	3	0	-2	pseudo > Xe-129m 1.0
541291	8.88E+00	4	d	5.82E-09	1	-1	3	1	0	Xe-129m> stable
551290	3.21E+01	3	h	0	1	-1	4	0	-1	Cs-129 > stable

481300	2.00E-01	1	s	8.10E-04	1	0	1	0	-0.3	Cd-130 > In-130 1.0
491300	2.90E-01	1	s	7.34E-02	0.7	0	1	1	-0.3	In-130 > In-130m 1.0
491301	1.70E+00	2	m	0	1	2	1	2	0	In-130m > Sb-130
501300	3.72E+00	2	m	8.72E-01	1	0	1	3	0	Sn-130 > Sb-130m 1.0
511301	6.30E+00	2	m	3.02E-01	1	-1	1	4	0	Sb-130m> stable
511300	3.95E+01	2	m	2.18E-01	1	-1	1	5	0	Sb-130 > stable
530010	1.00E+24	5	y	######	1	0	2	0	-2	pseudo
530020	4.00E+19	5	y	1.50E-03	1	2	2	1	-2	pseudo
530030	1.00E+24	5	y	######	1	0	2	2	-2	pseudo
530040	3.50E+19	5	y	4.00E-03	1	1	2	3	-2	pseudo > I-130 1.0
531301	8.84E+00	2	m	1.05E-04	0.83	0	2	4	0	I-130m > I-130 .83
531300	1.24E+01	3	h	1.97E-04	1	-1	2	5	0	I-130 > stable
551300	2.92E+01	2	m	0	1	-1	4	0	-1	Cs-130 > stable
481310	1.19E-01	1	s	7.70E-05	1	0	1	0	-0.3	Cd-131 > In-131 1.0
491310	2.80E-01	1	s	2.44E-02	1	0	1	1	-0.3	In-131 > Sn-131 1.0
501310	5.60E+01	1	s	9.59E-01	1	0	1	2	-0.3	Sn-131 > Sb-131 1.0
511310	2.30E+01	2	m	######	0.932	1	1	3	0	Sb-131 > Te-131 1.0
521311	3.33E+01	3	h	1.90E-01	0.778	1	1	4	0	Te-131m Te-131 .222 I-131 .778
521310	2.50E+01	2	m	1.19E-01	1	0	1	5	0	Te-131 > I-131 1.0
531310	8.03E+00	4	d	4.15E-03	0.01086	0	2	6	3.23E-01	I-131 > Xe-131 .01086
541311	1.18E+01	4	d	1.04E-06	1	-1	3	7	0	Xe-131m > Ba-131 > 1.0
561311	1.46E+01	2	m	0	1	1	1	0	-1	Ba-131m> Ba-131 1.0
571310	5.90E+01	2	m	0	1	0	1	0	-1	La-131 > Ba-131 1.0
561310	1.15E+01	4	d	0	1	0	1	2	-1	Ba-131 > Cs-131 1.0
551310	9.69E+00	4	d	0	1	-1	4	3	-1	Cs-131 > stable
481320	1.45E-01	1	s	6.14E-06	1	0	1	0	-0.3	Cd-132 > In-132 1.0
491320	2.07E-01	1	s	6.62E-03	1	0	1	1	-0.3	In-132 > Sn-132 1.0
501320	3.97E+01	1	s	5.86E-01	1	1	1	2	0	Sn-132 > Sb-132 1.0
511321	4.10E+00	2	m	######	1	1	1	3	0	Sb-132m> Te-132 1.
511320	2.79E+00	2	m	######	1	0	1	4	0	Sb-132 > Te-132
521320	3.20E+00	4	d	######	1	1	1	5	4.89E-04	Te-132 > I-132 1.0

531321	1.39E+00	3	h	0	0.86	0	2	0	-1	I-132m > I-132 .86
531320	2.30E+00	3	h	2.06E-02	1	-1	2	7	0	I-132 > stable
551320	6.48E+00	4	d	0	1	-1	4	0	-1	Cs-132 > stable
571320	4.80E+00	3	h	0	1	-1	1	0	-1	La-132 > stable
491330	1.80E-01	1	s	3.95E-04	1	0	1	0	-0.3	In-133 > Sn-133 1.0
501330	1.45E+00	1	s	1.69E-01	1	0	1	1	-0.3	Sn-133 > Sb-133 1.0
511330	2.50E+00	2	m	######	0.978	1	1	2	0	Sb-133 Te-133m .022 Te-133 .978
521331	5.54E+01	2	m	######	0.13	0	1	3	0	Te-133m> Te-133 .13
521330	1.25E+01	2	m	######	1	1	2	4	0	Te-133 > I-133 1.0
531331	9.00E+00	1	s	1.29E-01	1	0	2	5	0	I-133m > Xe-133 1.0
531330	2.08E+01	3	h	######	0.9712	1	2	6	0	I-133 .0288 Xe-133m Xe-133 .9712
541331	2.19E+00	4	d	2.67E-03	1	0	3	7	0	Xe-133m> Xe-133 1.0
541330	5.24E+00	4	d	8.79E-04	1	-1	3	8	2.44E+01	Xe-133 > stable
561331	3.89E+01	3	h	0	1	0	1	0	-1	Ba-133m> Ba-133 1.0
561330	1.05E+01	5	y	0	1	-1	1	1	-1	Ba-133 > stable
491340	1.38E-01	1	s	6.96E-06	1	0	1	0	-0.3	In-134 > Sn-134 1.0
501340	1.12E+00	1	s	1.19E-02	1	1	1	1	-0.3	Sn-134 > Sb-134 1.0
511341	1.01E+01	1	s	2.58E-01	1	1	1	2	-0.3	Sb-134m> Te-134 1.0
511340	7.80E-01	1	s	2.58E-01	1	0	1	3	0	Sb-134 > Te-134 1.0
521340	4.18E+01	2	m	######	1	0	1	4	9.20E-03	Te-134 > I-134m 1.0
531341	3.52E+00	2	m	4.52E-01	0.98	0	2	5	0	I-134m > I-134 .98
531340	5.25E+01	2	m	4.57E-01	1	-1	2	6	0	I-134 > stable
541341	2.90E-01	1	s	2.38E-02	1	-1	3	0	-0.3	Xe-134m> stable
550010	1.00E+23	5	y	8.00E-01	1	1	4	0	-2	pseudo
550020	1.90E+20	5	y	5.00E-03	1	0	4	1	-2	pseudo > Cs-134m 1.0
551341	2.91E+00	3	h	5.30E-05	1	2	4	2	0	Cs-134m> Cs-134 1.0
550030	3.00E+18	5	y	3.80E-01	1	0	4	0	-2	pseudo
550040	1.00E+19	5	y	1.00E-03	1	0	4	1	-2	pseudo > Cs-134 1.0
551340	2.07E+00	5	y	1.38E-05	1	-1	4	5	2.30E+01	Cs-134 > stable
581340	3.16E+00	4	d	0	1	0	1	6	-1	Ce-134 > La-134

571340	6.45E+00	2	m	0	1	-1	1	7	-0.3	La-134 > stable
501350	2.91E-01	1	s	1.24E-03	1	0	1	0	-0.3	Sn-135 > Sb-135 1.0
511350	1.71E+00	1	s	1.96E-01	1	0	1	1	-0.3	Sb-135 > Te-135 1.0
521350	1.90E+01	1	s	######	1	0	1	2	0	Te-135 > I-135 1.0
531350	6.58E+00	3	h	######	0.835	2	2	3	2.12E-03	I-135 > Xe-135 1.0
541351	1.53E+01	2	m	1.52E-01	1	1	3	4	0	Xe-135m> Xe-135 1.0
540020	9.00E+16	5	y	3.20E-01	1	0	3	5	-2	pseudo > Xe-135 1.0
541350	9.14E+00	3	h	9.78E-02	1	4	3	6	2.09E+05	Xe-135 > I-135 1.0
550050	6.50E+22	5	y	######	1	0	4	7	-2	pseudo
550060	1.00E+24	5	y	######	1	0	4	8	-2	pseudo > I-135m 1.0
551351	5.30E+01	2	m	6.25E-04	1	1	4	9	0	Cs-135m> Cs-135 1.0
550070	8.80E+16	5	y	######	1	0	4	10	-2	pseudo > I-135 1.0
551350	2.30E+06	5	y	9.01E-04	1	-1	4	11	2.391	Cs-135 > stable
561351	2.87E+01	3	h	0	1	-1	1	0	-1	Ba-135m > stable
581350	1.77E+01	3	h	0	1	0	1	0	-1	Ce-135 > La-135 1.0
571350	1.95E+01	3	h	0	1	-1	1	1	-1	La-135 > stable
501360	4.13E-01	1	s	5.43E-05	1	0	1	0	-0.3	Sn-136 > Sb-136 1.0
511360	8.20E-01	1	s	2.99E-02	1	0	1	1	-0.3	Sb-136 > Te-136 1.0
521360	1.75E+01	1	s	######	1	1	1	2	-0.3	Te-136 > I-136 1.0
531361	4.69E+01	1	s	######	1	-1	2	0	-0.3	I-136m > stable
531360	8.34E+01	1	s	######	1	-1	2	4	0	I-136 > stable
560010	5.00E+22	5	y	6.10E-01	1	0	1	0	-2	pseudo > Cs-136 1.0
551360	1.32E+01	4	d	7.51E-03	1	-1	4	1	0	Cs-136 > stable
601360	5.07E+01	2	m	0	1	0	1	0	-1	Nd-136 > Pr-136 1.0
591360	1.31E+01	2	m	0	1	-1	1	1	-1	Pr-136 > stable
511370	2.84E-01	1	s	2.13E-03	1	0	1	0	-0.3	Sb-137 > Te-137 1.0
521370	2.49E+00	1	s	4.20E-01	1	0	1	1	-0.3	Te-137 > I-137 1.0
531370	2.45E+01	1	s	######	1	0	2	2	-0.3	I-137 > Xe-137 1.0
541370	3.82E+00	2	m	######	1	0	3	3	0	Xe-137 > Cs-137 1.0
551370	3.01E+01	5	y	1.25E-01	0.946	0	4	4	2.56E-02	Cs-137 > Ba-137m .946
561371	2.55E+00	2	m	2.58E-04	1	-1	1	5	0	Ba-137m > stable

591370	1.28E+00	3	h	0	1	1	1	0	-1	Pr-137 > Ce-137 1.0
581371	3.44E+01	3	h	0	0.9941	1	1	1	-1	Ce-137m La-137 .9941 Ce-137 .0059
581370	9.00E+00	3	h	0	1	0	2	2	-1	Ce-137 > La-137 1.0
571370	6.00E+04	5	y	0	1	-1	3	3	-1	La-137 > stable
511380	1.30E-01	1	s	1.32E-04	1	0	1	0	-0.3	Sb-138 > Te-138 1.0
521380	1.40E+00	1	s	8.72E-02	1	0	1	1	-0.3	Te-138 > I-138 1.0
531380	6.23E+00	1	s	######	1	0	2	2	0	I-138 > Xe-138 1.0
541380	1.41E+01	2	m	######	1	1	3	3	0	Xe-138 > Cs-138 1.o
551381	2.91E+00	2	m	2.48E-01	0.75	0	4	0	0	Cs-138m> Cs-138 .75
551380	3.34E+01	2	m	3.01E-01	1	-1	4	5	0	Cs-138 > stable
571380	1.02E+11	5	y	0	1	-1	1	0	-1	La-138 > stable
591381	2.12E+00	3	h	0	1	-1	1	0	0	Pr-138m > stable
601380	5.04E+00	3	h	0	1	0	1	0	-1	Nd-138 > Pr-138 1.0
591380	1.45E+00	2	m	0	1	-1	1	1	-0.3	Pr-138 > Stable
511390	1.72E-01	1	s	5.87E-06	1	0	1	0	-0.3	Sb-139 > Te-139 1.0
521390	4.24E-01	1	s	1.30E-02	1	0	1	1	-0.3	Te-139 > I-139 1.0
531390	2.29E+00	1	s	7.23E-01	1	0	2	2	0	I-139 > Xe-139 1.0
541390	3.97E+01	1	s	######	1	0	3	3	0	Xe-139 > Cs-139 1.0
551390	9.27E+00	2	m	######	1	0	4	4	0	Cs-139 > Ba-139 1.0
561390	8.31E+01	2	m	6.71E-02	1	-1	1	5	5.52E-01	Ba-139 > stable
601391	5.50E+00	3	h	0	0.882	1	1	0	-1	Nd-139m Nd-139 .118 Pr-139 .882
601390	2.97E+01	2	m	0	1	0	1	1	-1	Nd-139 > Pr-139 1.0
591390	4.41E+00	3	h	0	1	0	1	2	-1	Pr-139 > Ce-139 1.0
581390	1.38E+02	4	d	0	1	-1	1	3	-1	Ce-139 > stable
521400	7.52E-01	1	s	1.21E-03	1	0	1	0	-0.3	Te-140 > I-140 1.0
531400	8.60E-01	1	s	2.15E-01	1	0	2	1	0	I-140 > Xe-140 1.0
541400	1.36E+01	1	s	######	1	0	3	2	0	Xe-140 > Cs-140 1.0
551400	6.37E+01	1	s	######	1	0	4	3	0	Cs-140 > Ba-140 1.0
561400	1.28E+01	4	d	4.29E-01	1	0	1	4	5.29E-01	Ba-140 > La-140 1.0
571400	1.68E+00	4	d	6.04E-03	1	-1	1	5	2.21	La-140 > stable

521410	2.36E-01	1	s	4.19E-05	1	0	1	0	-0.3	Te-141 > I-141 1.0
531410	4.30E-01	1	s	3.08E-02	1	0	2	1	0	I-141 > Xe-141 1.0
541410	1.73E+00	1	s	######	1	0	3	2	0	Xe-141 > Cs-141 1.0
551410	2.48E+01	1	s	######	1	0	4	3	1.52E-03	Cs-141 > Ba-141 1.0
561410	1.83E+01	2	m	######	1	0	1	4	0	Ba-141 > La-141 1.0
571410	3.92E+00	3	h	1.94E-02	1	0	1	5	0	La-141 > Ce-141 1.0
581410	3.25E+01	4	d	2.43E-05	1	-1	1	6	2.971	Ce-141 > stable
621411	2.26E+01	2	m	0	0.9969	0	1	0	-1	Sm-141m > Pm-141 1.0
621410	1.02E+01	2	m	0	1	0	1	1	-1	Sm-141 > Pm-141 1.0
611410	2.09E+01	2	m	0	0.999	0	1	2	-1	Pm-141 > Nd-141 .999
601410	2.49E+00	3	h	0	1	-1	1	3	-1	Nd-141 > stable
521420	4.91E-01	1	s	8.03E-07	1	0	1	0	-0.3	Te-142 > I-142 1.0
531420	1.96E-01	1	s	2.23E-03	1	0	2	1	0	I-142 > Xe-142 1.0
541420	1.22E+00	1	s	3.80E-01	1	0	3	2	0	Xe-142 > Cs-142 1.0
551420	1.68E+00	1	s	######	1	0	4	3	-0.3	Cs-142 > Ba-142 1.0
561420	1.06E+01	2	m	######	1	0	1	4	0	Ba-142 > La-142 1.0
571420	9.11E+01	2	m	1.00E-01	1	-1	1	0	0	La-142 > stable
581420	5.00E+16	5	y	0	1	-1	1	5	-1	Ce-142 > stable
591421	1.46E+01	3	h	0	0.0164	0	1	0	-1	Pr-142m > Pr-142 1.0
591420	1.91E+01	3	h	0	1	-1	1	1	-1	Pr-142 > stable
621420	7.25E+01	2	m	0	1	0	1	0	-1	Sm-142 > Pm-142 1.0
611420	4.05E+01	1	s	0	1	-1	1	1	-0.3	Pm-142 > stable
531430	3.28E-01	1	s	9.08E-05	1	0	2	0	0	I-143 > Xe-143 1.0
541430	3.00E-01	1	s	5.20E-02	1	0	3	1	0	Xe-143 > Cs-143 1.0
551430	1.78E+00	1	s	######	1	0	4	2	-0.3	Cs-143 > Ba-143 1.0
561430	1.45E+01	1	s	######	1	0	1	3	-0.3	Ba-143 > La-143 1.0
571430	1.42E+01	2	m	6.01E-01	1	0	1	4	0	La-143 > Ce-143 1.0
581430	3.30E+01	3	h	2.85E-02	1	0	1	5	1.755	Ce-143 > Pr-143 1.0
591430	1.36E+01	4	d	2.95E-06	1	-1	1	6	1.21E+01	Pr-143 > stable
611430	2.65E+02	4	d	0	1	-1	1	0	-1	Pm-143 > stable
531440	1.33E-01	1	s	3.42E-06	1	0	2	0	0	I-144 > Xe-144 1.0

541440	1.15E+00	1	s	6.57E-03	1	0	3	1	0	Xe-144 > Cs-144 1.0
551440	1.01E+00	1	s	3.11E-01	1	0	4	2	0	Cs-144 > Ba-144 1.0
561440	1.15E+01	1	s	######	1	0	1	3	0	Ba-144 > La-144 1.0
571440	4.08E+01	1	s	######	1	0	1	4	0	La-144 > Ce-144 1.0
581440	2.85E+02	4	d	6.09E-02	1	1	1	5	1.49E-01	Ce-144 > Pr-144 1.0
591441	7.20E+00	2	m	6.68E-05	0.9993	0	1	6	0	Pr-144m> Pr-144 .994
591440	1.73E+01	2	m	8.25E-05	1	-1	1	7	0	Pr-144 > stable
611440	3.63E+02	4	d	0	1	0	1	0	-1	Pm-144 > stable
601440	2.29E+15	5	y	0	1	-1	1	0	-1	Nd-144 > stable
541450	9.00E-01	1	s	1.48E-04	1	0	3	0	0	Xe-145 > Cs-145 1.0
551450	5.94E-01	1	s	7.18E-02	1	0	4	1	-0.3	Cs-145 > Ba-145 1.0
561450	4.31E+00	1	s	######	1	0	1	2	-0.3	Ba-145 > La-145 1.0
571450	2.48E+01	1	s	######	1	0	1	3	-0.3	La-145 > Ce-145 1.0
581450	3.01E+00	2	m	2.30E-01	1	0	1	4	0	Ce-145 > Pr-145
591450	5.98E+00	3	h	9.32E-04	1	-1	1	5	0	Pr-145 > stable
651490	4.12E+00	3	h	0	0.0167	3	1	0	-1	Tb-149 Gd-149 .833 Eu-145 .167
641490	9.28E+00	4	d	0	1	0	1	1	-1	Gd-149 > Eu-149
631490	9.31E+01	4	d	0	1	-1	1	2	-1	Eu-149 > stable
641450	2.30E+01	2	m	0	1	0	1	0	-1	Gd-145 > Eu-145 1.0
631450	5.93E+00	4	d	0	1	0	1	4	-1	Eu-145 > Sm-145 1.0
621450	3.40E+02	4	d	0	1	0	1	5	-1	Sm-145 > Pm-145 1.0
611450	1.77E+01	5	y	0	1	-1	1	6	-1	Pm-145 > stable
541460	9.37E-01	1	s	1.38E-05	1	0	3	0	-0.3	Xe-146 > Cs-146 1.0
551460	3.21E-01	1	s	8.10E-03	1	0	4	1	-0.3	Cs-146 > Ba-146 1.0
561460	2.22E+00	1	s	6.68E-01	1	0	1	2	-0.3	Ba-146 > La-146 1.0
571460	6.27E+00	1	s	######	1	0	1	3	-0.3	La-146 > Ce-146 1.0
581460	1.35E+01	2	m	6.73E-01	1	0	1	4	0	Ce-146 > Pr-146 1.0
591460	2.42E+01	2	m	8.54E-03	1	-1	1	5	0	Pr-146 > stable
641460	4.83E+01	4	d	0	1	0	1	0	-1	Gd-146 > Eu-146 1.0
631460	4.59E+00	4	d	0	1	1	1	1	-1	Eu-146 > Sm-146 1.0
611460	5.53E+00	5	y	0	0.359	0	1	0	-1	Pm-146 > Sm-146 0.359

621460	1.03E+08	5	y	0	1	-1	1	3	-1	Sm-146 > stable
541470	2.64E-01	1	s	2.39E-07	1	0	1	0	-0.3	Xe-147 > Cs-147 1.0
551470	2.25E-01	1	s	5.90E-04	1	0	4	1	-0.3	Cs-147 > Ba-147 1.0
561470	8.94E-01	1	s	1.30E-01	1	0	1	2	-0.3	Ba-147 > La-147 1.0
571470	4.06E+00	1	s	9.37E-01	1	0	1	3	-0.3	La-147 > Ce-147 1.0
581470	5.64E+01	1	s	######	1	0	1	4	-0.3	Ce-147 > Pr-147 1.0
591470	1.34E+01	2	m	5.38E-02	1	0	1	5	0	Pr-147 > Nd-147 1.0
601470	1.10E+01	4	d	2.96E-04	1	2	1	6	2.01E+01	Nd-147 > Pm-147 1.0
610010	1.00E+17	5	y	######	1	0	1	7	-2	pseudo > pseudo 1.0
610020	1.00E+19	5	y	1.00E-01	1	0	1	8	-2	pseudo > Pm-147 1.0
611470	2.62E+00	5	y	######	1	6	1	9	6.19E+02	Pm-147 > Sm-147 1.0
620010	7.00E+19	5	y	7.00E-01	1	5	1	0	-2	pseudo > Sm-147 1.0
651470	1.64E+00	3	h	0	1	0	1	0	0	Tb-147 > Gd-147 1.0
641470	3.81E+01	3	h	0	1	2	1	1	0	Gd-147 > Eu-147 1.0
651510	1.76E+01	3	h	0	1	0	1	0	0	Tb-151 Gd-151 1.0
641510	1.24E+02	4	d	0	1	-1	1	1	-1	Gd-151 > Stable
631470	2.41E+01	4	d	0	1	0	1	2	0	Eu-147 > Sm-147 1.0
621470	1.06E+11	5	y	1.01E-06	1	-1	1	16	0	Sm-147 > stable
551480	1.58E-01	1	s	1.81E-05	1	0	4	0	-0.3	Cs-148 > Ba-148 1.0
561480	6.07E-01	1	s	1.52E-02	1	0	1	1	-0.3	Ba-148 > La-148 1.0
571480	1.26E+00	1	s	3.42E-01	1	0	1	2	-0.3	La-148 > Ce-148 1.0
581480	5.60E+01	1	s	######	1	0	1	3	-0.3	Ce-148 > Pr-148 1.0
591480	2.29E+00	2	m	1.61E-01	1	-1	1	4	0	Pr-148 > stable
610030	8.00E+19	5	y	1.50E-01	1	0	1	0	-2	pseudo > Pm-148m 1.0
611481	4.13E+01	4	d	7.42E-07	0.042	1	1	1	0	Pm-148m pseudo .958 Pm-148 .042
610040	1.12E+20	5	y	4.20E-01	1	0	1	2	-2	pseudo > Pm-148 1.0
611480	5.37E+00	4	d	5.10E-06	1	2	1	3	0	Pm-148 > Sm-148
641480	7.46E+01	5	y	0	1	-1	1	0	-1	Gd-148 > stable
631480	5.45E+01	4	d	0	1	0	1	0	-1	Eu-148 > Sm-148
621480	7.00E+15	5	y	0	1	-1	1	1	-1	Sm-148 > stable
561490	3.44E-01	1	s	9.27E-04	1	0	1	0	-0.3	Ba-149 > La-149 1.0

571490	1.05E+00	1	s	7.02E-02	1	0	1	1	-0.3	La-149 > Ce-149 1.0
581490	5.30E+00	1	s	7.10E-01	1	0	1	2	-0.3	Ce-149 > Pr-149 1.0
591490	2.26E+00	2	m	2.89E-01	1	0	1	3	0	Pr-149 > Nd-149 1.0
601490	1.73E+00	3	h	1.81E-02	1	1	1	4	0	Nd-149 > Pm-149 1.0
610050	1.00E+18	5	y	1.70E-01	1	0	1	5	-2	pseudo > Pm-149 1.0
611490	5.31E+01	3	h	3.12E-05	1	-1	1	6	1.32E+02	Pm-149 > stable
621490	2.00E+15	5	y	0	1	-1	1	0	-1	Sm-149 > stable
610060	1.00E+17	5	y	3.73E-03	1	0	1	0	-2	pseudo > Pm-115 1.0
611500	2.68E+00	3	h	2.82E-07	1	-1	1	1	0	Pm-150 > stable
631500	3.69E+01	5	y	0	1	-1	1	0	-1	Eu-150 > stable
631503	1.28E+01	3	h	0	1	-1	1	0	-1	Eu-150b> stable
651500	3.48E+00	3	h	0	1	-1	1	0	-1	Tb-150 > stable
571510	9.54E-01	1	s	8.95E-04	1	0	1	0	-0.3	La-151 > Ce-151 1.0
581510	1.02E+00	1	s	7.58E-02	1	0	1	1	-0.3	Ce-151 > Pr-151 1.0
591510	1.89E+01	1	s	2.24E-01	1	0	1	2	-0.3	Pr-151 > Nd-151 1.0
601510	1.24E+01	2	m	1.19E-01	1	0	1	3	0	Nd-151 > Pm-151 1.0
611510	2.84E+01	3	h	1.77E-03	1	0	1	4	1.03E+02	Pm-151 > Sm-151 1.0
621510	9.00E+01	5	y	3.80E-06	1	-1	1	5	7.26E+02	Sm-151 > stable
561520	7.55E-01	1	s	1.96E-08	1	0	1	0	-0.3	Ba-152 > La-152 1.0
571520	3.09E-01	1	s	4.98E-05	1	0	1	1	-0.3	La-152 > Ce-152 1.0
581520	1.40E+00	1	s	1.36E-02	1	0	1	2	-0.3	Ce-152 > Pr-152 1.0
591520	3.63E+00	1	s	1.08E-01	1	0	1	3	-0.3	Pr-152 > Nd-152 1.0
601520	1.14E+01	2	m	1.45E-01	1	1	1	4	-0.3	Nd-152 > Pm-152 1.0
611521	7.52E+00	2	m	3.67E-03	1	0	1	5	-0.3	Pm-152m> Pm-152 1.0
611520	4.12E+00	2	m	3.67E-03	1	-1	1	6	0	Pm-152 > stable
630010	9.00E+19	5	y	1.59E-04	1	0	1	0	-2	pseudo > pseudo
630020	1.00E+19	5	y	9.70E-05	1	0	1	1	-2	pseudo > Eu-152 1.0
631520	1.35E+01	5	y	######	1	-1	1	2	1.91E+02	Eu-152 > stable
631521	9.31E+00	3	h	0	0.72	0	1	0	-1	Eu-152m > Gd-152 0.72
641520	1.08E+14	5	y	0	1	-1	1	1	-1	Gd-152 > stable
571530	4.37E-01	1	s	1.46E-06	1	0	1	0	-0.3	La-153 > Ce-153 1.0

581530	1.73E+00	1	s	1.31E-03	1	0	1	1	-0.3	Ce-153 > Pr-153 1.0
591530	4.30E+00	1	s	3.13E-02	1	0	1	2	-0.3	Pr-153 > Nd-153 1.0
601530	3.16E+01	1	s	1.17E-01	1	0	1	3	-0.3	Nd-153 > Pm-153
611530	5.25E+00	2	m	1.65E-02	1	2	1	4	-0.3	Pm-153 > Sm-153
651530	2.34E+00	4	d	0	1	4	1	0	-1	Tb-153 > Gd-153 1.0
620020	2.00E+19	5	y	4.50E-01	1	0	1	0	-2	pseudo > Sm-153 1.0
621530	4.65E+01	3	h	3.34E-04	1	-1	1	7	8.98E+01	Sm-153 > stable
640010	5.10E-02	5.68E+18	####	1	0	1	0	-2	pseudo > pseudo	
640020	1.00E+24	5	y	1.00E-03	1	0	1	1	-2	pseudo > Gd-153 1.0
641530	2.41E+02	4	d	9.70E-12	1	-1	1	10	0	Gd-153 > stable
571540	1.75E-01	1	s	3.14E-08	1	0	1	0	-0.3	La-154 > Ce-154 1.0
581540	3.59E-01	1	s	8.09E-05	1	0	1	1	-0.3	Ce-154 > Pr-154 1.0
591540	2.30E+00	1	s	5.53E-03	1	0	1	2	-0.3	Pr-154 > Nd-154 1.0
601540	2.59E+01	1	s	5.10E-02	1	1	1	3	-0.3	Nd-154 > Pm-154 1.0
611541	2.68E+00	2	m	9.40E-03	1	0	1	4	-0.3	Pm-154m> Pm-154 .10
611540	1.73E+00	2	m	9.40E-03	1	-1	1	5	-0.3	Pm-154 > stable
630030	1.75E+17	5	y	5.20E-02	1	0	1	0	-2	pseudo > pseudo
630040	1.00E+19	5	y	1.00E-03	1	0	1	1	-2	pseudo > Eu-154 1.0
631540	8.60E+00	5	y	1.73E-06	1	-1	1	2	1.29E+02	Eu-154 > stable
651540	2.15E+01	3	h	0	1	-1	1	0	-1	Tb-154 > stable
581550	7.13E-01	1	s	3.31E-06	1	0	1	0	-0.3	Ce-155 > Pr-155 1.0
591550	1.89E+00	1	s	6.84E-04	1	0	1	1	-0.3	Pr-155 > Nd-155 1.0
601550	8.90E+00	1	s	1.72E-02	1	0	1	2	-0.3	Nd-155 > Pm-155 1.0
611550	4.15E+01	1	s	1.57E-02	1	0	1	3	-0.3	Pm-155 > Sm-155 1.0
621550	2.23E+01	2	m	2.59E-03	1	1	1	4	0	Sm-155 > Eu-155 1.0
630050	1.00E+18	5	y	######	1	0	1	0	-2	pseudo > Eu-155 1.0
631550	4.75E+00	5	y	2.00E-08	1	-1	1	6	3.66E+02	Eu-155 > stable
671550	4.80E+01	2	m	0	1	0	1	0	-1	Ho-155 > Dy-155 1.0
661550	9.90E+00	3	h	0	1	0	1	1	-1	Dy-155 > Tb-155 1.0

651550	5.32E+00	4	d	0	1	-1	1	2	-1	Tb-155 > stable
581560	1.16E+00	1	s	9.13E-08	1	0	1	0	-0.3	Ce-156 > Pr-156 1.0
591560	5.10E-01	1	s	5.08E-05	1	0	1	1	-0.3	Pr-156 > Nd-156 1.0
601560	5.47E+00	1	s	3.50E-03	1	0	1	2	-0.3	Nd-156 > Pm-156 1.0
611560	2.67E+01	1	s	8.04E-03	1	1	1	3	-0.3	Pm-156 > Sm-156 1.0
630070	2.30E+17	5	y	7.70E-02	1	0	1	0	-2	pseudo > Sm-156 1.0
621560	9.40E+00	3	h	3.34E-03	0.001	0	1	5	0	Sm-156 > Eu-156 1.0
631560	1.52E+01	4	d	4.54E-05	1	-1	1	6	7.38E+02	Eu-156 > stable
651561	5.00E+00	3	h	0	1	0	1	0	-1	Tb-156m > Tb-156 1.0
651560	5.35E+00	4	d	0	1	-1	1	1	-1	Tb-156 > stable
581570	3.62E-01	1	s	2.45E-09	1	0	1	0	-0.3	Ce-157 > Pr-157 1.0
591570	6.78E-01	1	s	3.10E-06	1	0	1	1	-0.3	Pr-157 > Nd-157 1.0
601570	4.15E+00	1	s	5.94E-04	1	0	1	2	-0.3	Nd-157 > Pm-157 1.0
611570	1.06E+01	1	s	3.47E-03	1	0	1	3	-0.3	Pm-157 > Sm-157 1.0
621570	4.82E+02	1	s	3.53E-03	0.001	0	1	4	-0.3	Sm-157 > Eu-157 .001
631570	1.52E+01	3	h	8.12E-03	1	-1	1	5	4.61E+02	Eu-157 > stable
671570	1.26E+01	2	m	0	1	0	1	0	-1	Ho-157 > Dy-157 1.0
661570	8.14E+00	3	h	0	1	0	1	1	-1	Dy-157 > Tb-157 1.0
651570	7.10E+01	5	y	0	1	-1	1	2	-1	Tb-157 > stable
591580	2.63E-01	1	s	1.28E-07	1	0	1	0	-0.3	Pr-158 > Nd-158 1.0
601580	7.89E+00	1	s	6.66E-05	1	0	1	1	-0.3	Nd-158 > Pm-158 1.0
611580	4.80E+00	1	s	1.04E-03	1	0	1	2	-0.3	Pm-158 > Sm-158 1.0
621580	5.30E+00	2	m	2.58E-03	1	0	1	3	-0.3	Sm-158 > Eu-158 1.0
631580	4.59E+01	2	m	2.58E-04	1	-1	1	4	0	Eu-158 > stable
651580	1.80E+02	5	y	0	1	-1	1	0	-1	Tb-158 > stable
591590	3.14E-01	1	s	2.10E-09	1	0	1	0	-0.3	Pr-159 > Nd-159 1.0
601590	1.41E+00	1	s	3.08E-06	1	0	1	1	-0.3	Nd-159 > Pm-159 1.0
611590	4.23E+00	1	s	1.43E-04	1	0	1	2	-0.3	Pm-159 > Sm-159 1.0
621590	1.14E+01	1	s	9.04E-04	1	0	1	3	-0.3	Sm-159 > Eu-159 1.0
631590	1.81E+01	2	m	2.62E-04	1	1	1	4	0	Eu-159 > Gd-159 1.0
640030	5.00E+18	5	y	2.20E-04	1	0	1	0	-2	pseudo > Gd-159 1.0

641590	1.85E+01	3	h	1.22E-05	1	-1	1	6	0	Gd-159 > stable
671590	3.31E+01	2	m	0	1	0	1	0	-1	Ho-159 > Dy-159 1.0
661590	1.44E+02	4	d	0	1	-1	1	1	-1	Dy-159 > stable
651600	7.23E+01	4	d	0	1	-1	1	0	-1	Tb-160 > stable
651610	6.91E+00	4	d	0	1	-1	1	0	-1	Tb-161 > stable
681610	3.21E+00	3	h	0	1	0	1	0	-1	Er-161 > Ho-161 1.0
671610	2.48E+00	3	h	0	1	-1	1	1	-1	Ho-161 > stable
671621	6.70E+01	2	m	0	0.61	0	1	0	-1	Ho-162m> Ho-162 .61
671620	1.50E+01	2	m	0	1	-1	1	1	-1	Ho-162 > stable
701620	1.89E+01	2	m	0	1	0	1	0	-1	Yb-162 > Tm-162 1.0
691620	2.43E+01	1	s	0	1	-1	1	1	-1	Tm-162 > stable
671641	3.75E+01	2	m	0	1	0	1	0	-1	Ho-164m> Ho-164 1.0
671640	2.90E+01	2	m	0	1	-1	1	1	-1	Ho-164 > stable
661650	2.33E+00	3	h	0	1	-1	1	0	-1	Dy-165 > stable
681650	1.04E+01	3	h	0	1	-1	1	0	-1	Er-165 > stable
661660	8.16E+01	3	h	0	1	0	1	0	-1	Dy-166 > Ho-166 1.0
671660	2.68E+01	3	h	0	1	-1	1	1	-1	Ho-166 > stable
671661	1.20E+03	5	y	0	1	-1	1	0	-1	Ho-166m> stable
701660	5.67E+01	3	h	0	1	0	1	0	-1	Yb-166 > Tm-166 1.0
691660	7.70E+00	3	h	0	1	-1	1	1	-1	Tm-166 > stable
671670	3.10E+00	3	h	0	1	-1	1	0	-1	Ho-167 > stable
701670	1.75E+01	2	m	0	1	0	1	0	-1	Yb-167 > Tm-167 1.0
691670	9.25E+00	4	d	0	1	-1	1	1	-1	Tm-167 > stable
681690	9.39E+00	4	d	0	1	-1	1	0	-1	Er-169 > stable
711690	3.41E+01	3	h	0	1	0	1	0	-1	Lu-169 > Yb-169 1.0
701690	3.20E+01	4	d	0	1	-1	1	1	-1	Yb-169 > stable
691700	1.29E+02	4	d	0	1	-1	1	0	-1	Tm-170 > stable
721700	1.60E+01	3	h	0	1	0	1	0	-1	Hf-170 > Lu-170 1.0
711700	2.01E+00	4	d	0	1	-1	1	1	-1	Lu-170 > stable
681710	7.52E+00	3	h	0	1	0	1	0	-1	Er-171 > Tm-171 1.0
691710	1.92E+00	5	y	0	1	-1	1	1	-1	Tm-171 > stable

711710	8.24E+00	4	d	0	1	-1	1	0	-1	Lu-171 > stable
681720	4.93E+01	3	h	0	1	0	1	0	-1	Er-172 > Tm-172 1.0
691720	6.36E+01	3	h	0	1	-1	1	1	-1	Tm-172 > stable
731720	3.67E+01	2	m	0	1	0	1	0	-1	Ta-172 > Hf-172 1.0
721720	1.87E+00	5	y	0	1	0	1	1	-1	Hf-172 > Lu-172 1.0
711720	6.70E+00	4	d	0	1	-1	1	2	-1	Lu-172 > stable
691730	8.24E+00	3	h	0	1	-1	1	0	-1	Tm-173 > stable
731730	3.14E+00	3	h	0	1	0	1	0	-1	Ta-173 > Hf-173 1.0
721730	2.36E+01	3	h	0	1	0	1	1	-1	Hf-173 > Lu-173 1.0
711730	1.37E+00	5	y	0	1	-1	1	2	-1	Lu-173 > stable
711741	1.42E+02	4	d	0	0.993	0	1	0	-1	Lu-174m> Lu-174 0.993
711740	3.31E+00	5	y	0	1	-1	1	1	-1	Lu-174 > stable
731740	1.14E+00	3	h	0	1	-1	1	1	-1	Ta-174 > stable
691750	1.52E+01	2	m	0	1	0	1	0	-1	Tm-175 > Yb-175 1.0
701750	4.19E+00	4	d	0	1	-1	1	1	-1	Yb-175 > stable
731750	1.05E+01	3	h	0	1	0	1	0	-1	Ta-175 > Hf-175 1.0
721750	7.00E+01	4	d	0	1	-1	1	1	-1	Hf-175 > stable
711761	3.64E+00	3	h	0	1	-1	1	0	-1	Lu-176m> stable
711760	3.76E+10	5	y	0	1	-1	1	0	-1	Lu-176 > stable
741760	2.50E+00	3	h	0	1	0	1	0	-1	W-176 > Ta-176 1.0
731760	8.09E+00	3	h	0	1	-1	1	1	-1	Ta-176 > stable
701770	1.91E+00	3	h	0	1	1	1	0	-1	Yb-177 > Lu-177 1.0
711771	1.60E+02	4	d	0	0.22	0	1	1	-1	Lu-177m > Lu-177 0.22
711770	6.65E+00	4	d	0	1	-1	1	2	-1	Lu-177 > stable
721771	5.14E+01	2	m	0	1	-1	1	0	-1	Hf-177m>Hf-177 1.0
751770	1.40E+01	2	m	0	1	0	1	0	-1	Re-177 > W-177 1.0
741770	1.32E+02	2	m	0	1	0	1	1	-1	W-177 > Ta-177 1.0
731770	5.66E+01	3	h	0	1	-1	1	2	-1	Ta-177 > stable
701780	7.40E+01	2	m	0	1	0	1	0	-1	Yb-178 > Lu-178 1.0
711780	2.84E+01	2	m	0	1	-1	1	1	-1	Lu-178 > stable
711781	2.31E+01	2	m	0	1	-1	1	0	-1	Lu-178m stable

721781	3.10E+01	5	y	0	1	-1	1	0	-1	Hf-178m> stable
731781	2.36E+00	3	h	0	1	-1	1	0	-1	Ta-178m> stable
751780	1.32E+01	2	m	0	1	0	1	0	-1	Re-178 > W-178 1.0
741780	2.16E+01	4	d	0	1	0	1	1	-1	W-178 > Ta-178 1.0
731780	9.31E+00	2	m	0	1	-1	1	2	-0.3	Ta-178 > stable
711790	4.59E+00	3	h	0	1	-1	1	0	-1	Lu-179 > stable
721791	2.51E+01	4	d	0	1	-1	1	0	-1	Hf-179m> stable 1.0
741790	3.71E+01	2	m	0	1	0	1	0	-1	W-179 > Ta-179 1.0
731790	1.82E+00	5	y	0	1	-1	1	1	-1	Ta-179 > stable
721801	5.50E+00	3	h	0	1	-1	1	0	-1	Hf-180m> stable
731801	1.20E+15	5	y	0	1	-1	1	0	-1	Ta-180m> stable
731800	8.15E+00	3	h	0	1	-1	1	0	-1	Ta-180 > stable
761800	2.15E+01	2	m	0	1	0	1	0	-1	Os-180 > Re-180 1.0
751800	2.44E+00	2	m	0	1	-1	1	1	-0.3	Re-180 > stable
721810	4.24E+01	4	d	0	1	-1	1	0	-1	Hf-181 > stable
761810	1.05E+02	2	m	0	1	0	1	0	-1	Os-181 > Re-181 1.0
751810	1.99E+01	3	h	0	1	0	1	1	-1	Re-181 > W-181 1.0
741810	1.21E+02	4	d	0	1	-1	1	2	-1	W-181 > stable
721821	6.15E+01	2	m	0	0.54	2	1	0	-1	Hf-182m Hf-182 .46 Ta-182 .54
721820	9.00E+06	5	y	0	1	1	1	1	-1	Hf-182 > Ta-182 1.0
731821	2.64E-01	3	h	0	1	0	1	0	-1	Ta-182m>Ta-182 1.0
731820	1.15E+02	4	d	0	1	-1	1	3	-1	Ta-182 > stable
771820	1.20E+01	2	m	0	1	1	1	0	-1	Ir-182 > Os-182 1.0
751823	6.40E+01	3	h	0	1	-1	1	0	-1	Re-182b> stable
761820	2.21E+01	3	h	0	1	0	1	1	-1	Os-182 > Re-182a 1.0
751822	6.40E+01	3	h	0	1	-1	1	0	-1	Re-182a> stable
721830	1.07E+00	3	h	0	1	0	1	0	-1	Hf-183 > Ta-183 1.0
731830	5.10E+00	4	d	0	1	-1	1	1	-1	Ta-183 > stable
721840	4.12E+00	3	h	0	1	0	1	0	-1	Hf-184 > Ta-184 1.0
731840	8.70E+00	3	h	0	1	-1	1	1	-1	Ta-184 > stable
751841	1.69E+02	4	d	0	0.747	0	1	0	-1	Re-184m> Re-184 0.747

751840	3.54E+01	4	d	0	1	-1	1	1	-1	Re-184 > stable
771840	3.09E+00	3	h	0	1	-1	1	1	-1	Ir-184 > stable
731850	4.94E+01	2	m	0	1	0	1	0	-1	Ta-185 > W-185 1.0
741850	7.51E+01	4	d	0	1	-1	1	1	-1	W-185 > stable
771850	1.44E+01	3	h	0	1	0	1	0	-1	Ir-185 > Os-185 1.0
761850	9.36E+01	4	d	0	1	-1	1	1	-1	Os-185 > stable
731860	1.05E+01	2	m	0	1	-1	1	0	-1	Ta-186 > stable
751861	2.00E+05	5	y	0	1	0	1	0	-1	Re-186m> Re-186 1.0
751860	3.72E+00	4	d	0	0.922	-1	1	1	-1	Re-186 >Os-186 .922
771861	1.90E+00	3	h	0	1	-1	1	0	-1	Ir-186m> stable
781860	2.20E+00	3	h	0	1	0	1	0	-1	Pt-186 > Ir-186 1.0
771860	1.66E+01	3	h	0	1	-1	1	1	-1	Ir-186 > stable
741870	2.40E+01	3	h	0	1	0	1	0	-1	W-187 > Re-187 1.0
751870	4.33E+10	5	y	0	1	-1	1	1	-1	Re-187 > stable
771870	1.05E+01	3	h	0	1	-1	1	0	-1	Ir-187 > stable
741880	6.98E+01	4	d	0	1	1	1	0	-1	W-188 > Re-188 1.0
751881	1.86E+01	2	m	0	1	0	1	0	-1	Re-188m> Re-188 1.0
751880	1.70E+01	3	h	0	1	-1	1	2	-1	Re-188 > stable
781880	1.01E+01	4	d	0	1	0	1	0	-1	Pt-188 > Ir-188 1.0
771880	4.15E+01	3	h	0	1	-1	1	1	-1	Ir-188 > stable
781890	1.08E+01	3	h	0	1	0	1	0	-1	Pt-189 > Ir-189 1.0
771890	1.32E+01	4	d	0	1	1	1	1	-0.3	Ir-189 > Ir-189m 1.0
751890	2.43E+01	3	h	0	0.241	0	1	0	-1	Re-189 > Ir-189m 0.241
771891	1.33E-02	1	s	0	1	-1	1	3	-1	Ir-189m> stable
761901	9.90E+00	2	m	0	1	-1	1	4	-1	Os-190m> stable
771904	3.25E+00	3	h	0	0.05	0	1	0	-1	Ir-190n Ir-190m0.05
771901	1.12E+00	3	h	0	1	0	1	1	-1	Ir-190m> Ir-190 1.0
771900	1.18E+01	4	d	0	1	-1	1	2	-1	Ir-190 > stable
761911	1.31E+01	3	h	0	1	0	1	0	-1	Os-191m> Os-191 1.0
761910	1.54E+01	4	d	0	1	-1	1	1	-1	Os-191 > stable
781910	2.80E+00	4	d	0	1	-1	1	0	-1	Pt-191 > stable

771921	1.45E+00	2	m	0	1	0	1	0	-1	Ir-192m> Ir-192 1.0
771920	7.38E+01	4	d	0	1	-1	1	1	-1	Ir-192 > stable
761930	3.01E+01	3	h	0	1	-1	1	0	-1	Os-193 > stable 1.0
771931	1.05E+01	4	d	0	1	-1	1	0	-1	Ir-193m> stable
801931	1.18E+01	3	h	0	1	2	1	0	-1	Hg-193m> Au-193
791931	1.77E+01	3	h	0	0.997	1	1	1	-0.3	Au-193m Hg-193.03Au-193.997
801930	3.80E+00	3	h	0	1	0	1	2	-1	Hg-193 > Au-193 1.0
791930	1.76E+01	3	h	0	1	1	1	3	-1	Au-193 > Pt-193 1.0
781931	4.33E+00	4	d	0	1	0	1	4	-1	Pt-193m> Pt-193 1.0
781930	5.00E+01	5	y	0	1	-1	1	5	-1	Pt-193 > stable
761940	6.00E+00	5	y	0	1	0	1	0	-1	Os-194 > Ir-194 1.0
771940	1.93E+01	3	h	0	1	-1	1	1	-1	Ir-194 > stable
771941	1.71E+02	4	d	0	1	-1	1	0	-1	Ir-194m> stable
811941	3.28E+01	2	m	0	1	0	1	0	-1	Tl-194m> Tl-194
811940	3.30E+01	2	m	0	1	0	1	1	-1	Tl-194 > Hg-194 1.0
801940	4.44E+02	5	y	0	1	0	1	2	-1	Hg-194 > Au-194 1.0
791940	3.80E+01	3	h	0	1	-1	3	3	-1	Au-194 > stable
771951	3.80E+00	3	h	0	0.05	0	1	0	-1	Ir-195m>Ir-195
771950	2.50E+00	3	h	0	1	-1	1	1	-1	Ir-195 > stable
781951	4.01E+00	4	d	0	1	-1	1	0	-1	Pt-195m> stable
821951	1.50E+01	2	m	0	1	1	1	0	-1	Pb-195m> Tl-195 1.0
791951	3.05E+01	1	s	0	1	3	1	1	-1	Au-195m> Au-195 1.0
811950	1.16E+00	3	h	0	1	1	1	2	-1	Tl-195 > Hg-195 1.0
801951	4.16E+01	3	h	0	0.458	1	1	3	-1	Hg-195m Hg-195 .542 Au-195 .458
801950	1.05E+01	3	h	0	1	0	1	4	-1	Hg-195 > Au-195
791950	1.87E+02	4	d	0	1	-1	1	5	-1	Au-195 > stable
781971	9.54E+01	2	m	0	0.967	0	1	0	-1	Pt-197m > Pt-197 0.967
781970	1.99E+01	3	h	0	1	-1	1	1	-1	Pt-197 > stable
811970	2.84E+00	3	h	0	1	1	1	0	-1	Tl-197 > Hg-197
801971	2.38E+01	3	h	0	0.93	0	1	0	-1	Hg-197m> Hg-197 0.93

801970	6.41E+01	3	h	0	1	-1	1	2	-1	Hg-197 > stable
791981	2.27E+00	4	d	0	1	0	1	0	-1	Au-198m> Au-198 1.0
791980	2.70E+00	4	d	0	1	-1	1	1	-1	Au-198 > stable
821980	2.40E+00	3	h	0	1	1	1	1	-1	Pb-198 > Tl-198
811981	1.87E+00	3	h	0	0.47	0	1	0	-1	Tl-198m Tl-198 .47
811980	5.30E+00	3	h	0	1	-1	1	2	-1	Tl-198 > stable
781990	3.08E+01	2	m	0	1	0	1	0	-1	Pt-199 > Au-199 1.0
791990	3.14E+00	4	d	0	1	-1	1	0	0	Au-199 > stable
801991	4.27E+01	2	m	0	1	-1	1	0	-1	Hg-199m> stable
821990	9.00E+01	2	m	0	1	0	1	0	-1	Pb-199 > Tl-199 1.0
811990	7.42E+00	3	h	0	1	-1	1	1	-1	Tl-199 > stable
832000	3.64E+01	2	m	0	1	0	1	0	-1	Bi-200 > Pb-200 1.0
822000	2.15E+01	3	h	0	1	3	1	1	-1	Pb-200 > Tl-200 1.0
782000	1.25E+01	3	h	0	1	1	1	0	-1	Pt-200 > Au-200 1.0
792001	1.87E+01	3	h	0	0.18	0	1	0	-1	Au-200m> Au-200 .18
792000	4.84E+01	2	m	0	1	0	1	2	-1	Au-200 > stable
812000	2.61E+01	3	h	0	1	-1	1	5	-1	Tl-200 > stable
842050	1.74E+00	3	h	0	0.04	4	1	0	-1	Po-205 Bi-205 99.96 Pb-201 .04
832050	1.53E+01	4	d	0	1	0	1	1	-1	Bi-205 > Pb-205 1.0
822050	1.73E+07	5	y	0	1	-1	1	2	-1	Pb-205 > stable
792010	2.60E+01	2	m	0	1	-1	1	0	-1	Au-201 > stable
832010	1.03E+02	2	m	0	1	0	1	0	-1	Bi-201 > Pb-201 1.0
822010	9.33E+00	3	h	0	1	0	1	5	-1	Pb-201 > Tl-201 1.0
812010	7.29E+01	3	h	0	1	-1	1	6	-1	Tl-201 > stable
832020	1.71E+00	3	h	0	1	1	1	0	-1	Bi-202 Pb-202 1.0
822021	3.54E+00	3	h	0	0.095	1	1	0	-1	Pb-202m Pb-202 .905 Tl-202 .095
822020	5.25E+04	5	y	0	1	0	1	2	-1	Pb-202 > Tl-202 1.0
812020	1.23E+01	4	d	0	1	-1	1	3	-1	Tl-202 > stable
802030	4.66E+01	4	d	0	1	-1	1	1	-1	Hg-203 > stable
842030	3.67E+01	2	m	0	1	1	1	0	-1	Po-203 > Bi-203 1.0

852070	1.80E+00	3	h	0	0.914	6	1	0	-1	At-207 Po-207 .914 Bi-203 .086
832030	1.18E+01	3	h	0	1	0	1	2	-1	Bi-203 > Pb-203 1.0
822030	5.19E+01	3	h	0	1	-1	1	0	-1	Pb-203 > stable
812040	3.78E+00	5	y	0	1	-1	1	0	-1	Tl-204 > stable
832101	3.04E+06	5	y	0	1	0	1	0	-1	Bi-210m> Tl-206 1.0
812060	4.20E+00	2	m	0	1	-1	1	1	-1	Tl-206 > stable
832060	6.24E+00	4	d	0	1	-1	1	0	-1	Bi-206 > stable
842070	5.80E+00	3	h	0	1	0	1	7	-1	Po-207 > Bi-207 1.0
832080	3.68E+05	5	y	0	1	-1	1	0	-0.3	Bi-208 > stable
1002520	2.54E+01	3	h	0	1	1	1	0	-1	Fm-252 > Cf-248 1.0 start 4N
982520	2.65E+00	5	y	0	1	0	1	0	-1	Cf-252 > Cm-248 1.0
962480	3.48E+05	5	y	0	1	0	1	2	-1	Cm-248 > Pu-244 1.0
942440	8.11E+07	5	y	0	1	0	1	3	-1	Pu-244 > U-240 1.0
922400	1.41E+01	3	h	0	1	1	1	4	-1	U-240 > Np-240 1.0
932401	7.22E+00	2	m	0	0.9989	13	1	5	-1	Np-240m > Np-240 .0011 Pu-240 .9989
932400	6.19E+01	2	m	0	1	12	1	6	-1	Np-240 > Pu-240 1.0
912320	1.31E+00	4	d	0	1	5	1	0	-1	PA-232 > U-232 1.0
982440	1.94E+01	2	m	0	1	0	1	0	-1	Cf-244 > Cm-240 1.0
962400	2.70E+01	4	d	0	1	1	1	1	-1	Cm-240 > Pu-236 ~1.0
932363	2.25E+01	3	h	0	0.52	10	1	0	-1	Np-236b Pu-236 .48 U-236 .52
942360	2.86E+00	5	y	0	1	1	1	4	-1	Pu-236 > U-232 1.0
932320	1.47E+01	2	m	0	1	0	1	0	-1	Np-232 > U-232 1.0
922320	6.89E+01	5	y	0	1	12	1	6	-1	U-232 > Th-228 1.0
952441	2.60E+01	2	m	0	1	2	1	0	-1	Am-244m > Cm-244 ~1.0
952440	1.01E+01	3	h	0	1	1	1	0	-1	Am-244 Cm-244 1.0
982480	3.34E+02	4	d	0	1	0	1	1	-1	Cf-248 Cm-244 1.0
962440	1.81E+01	5	y	0	1	1	1	3	-1	Cm-244 Pu-240 1.0
952400	5.08E+01	3	h	0	1	0	1	0	-1	Am-240 Pu-240 1.0
942400	6.56E+03	5	y	0	1	1	1	19	-1	Pu-240 > U-236 1.0

932362	1.53E+05	5	y	0	0.911	0	1	0	-1	Np-236a U-236 .911 sk(Pu-236)
922360	2.34E+07	5	y	0	1	0	1	21	-1	U-236 > Th-232 1.0
902320	1.41E+10	5	y	0	1	0	1	22	-1	Th-232 > Ra-228 1.0
882280	5.75E+00	5	y	0	1	0	1	23	-1	Ra-228 > Ac-228 1.0
892280	6.15E+00	3	h	0	1	1	1	24	-1	Ac-228 > Th-228 1.0
912280	2.20E+01	3	h	0	0.98	0	1	0	-1	Pa-228 Th-228 .98 sk(Ac-224 .02)
902280	1.91E+00	5	y	0	1	0	1	26	-1	Th-228 > Ra-224 1.0
892240	2.78E+00	3	h	0	1	0	1	0	-1	Ac-224 Ra-224 .909 sk(Fr-220) .091
882240	3.66E+00	4	d	0	1	0	1	28	-1	Ra-224 > Rn-220 1.0
862200	5.56E+01	1	s	0	1	0	3	29	-1	Rn-220 > Po-216 1.0
842160	1.45E-01	1	s	0	1	0	1	30	-1	Po-216 > Pb-212 1.0
822120	1.06E+01	3	h	0	1	0	1	31	-1	Pb-212 > Bi-212 1.0
832120	6.06E+01	2	m	0	0.3593	0	1	32	-1	Bi-212 > Tl-208 .3593 sk(Po-212)
812080	3.05E+00	2	m	0	1	-1	1	33	-1	Tl-208 > stable
842120	2.99E-07	1	s	0	1	-1	1	0	-1	Po-212 > stable
101257 0	5.52E+00	3	h	0	1	0	1	0	-1	Md-257 Fm-257 .85 sk(Es-253 .15) start 4N+1
100257 0	1.01E+02	4	d	0	1	0	1	1	-1	Fm-257 > Cf-253 1.0
982530	1.78E+01	4	d	0	0.0031	2	1	2	-1	Cf-253 Cm-249 .0031 Es-253 .9969
962490	6.42E+01	2	m	0	1	2	1	3	-1	Cm-249 > Bk-249 1.0
100253 0	3.00E+00	4	d	0	1	0	1	4	-1	Fm-253 Es-253 .88 sk(Cf-249 .121)
992530	2.05E+01	4	d	0	1	0	1	5	-1	Es-253 > Bk-249 1.0
972490	3.20E+02	4	d	0	1	0	1	6	-1	Bk-249 > Cf-249 1.0
982490	3.51E+02	5	y	0	1	3	1	7	-1	Cf-249 > Cm-245 1.0
942450	1.05E+01	3	h	0	1	0	1	8	-1	Pu-245 >Am-245 1.0
952450	2.05E+00	3	h	0	1	1	1	9	-1	Am-245 > Cm-245 1.0
972450	4.94E+00	4	d	0	1	0	1	0	-1	Bk-245 > Cm-245 ~1.0
962450	8.50E+03	5	y	0	1	0	1	11	-1	Cm-245 > Pu-241 1.0

942410	1.43E+01	5	y	0	1	1	1	12	-1	Pu-241 > Am-241 1.0
962410	3.28E+01	4	d	0	0.99	0	1	0	-1	Cm-241 Am-241 .99 sk(Pu-237 .01)
952410	4.33E+02	5	y	0	1	3	1	14	-1	Am-241 > Np-237 1.0
922370	6.75E+00	4	d	0	1	2	1	15	-1	U-237 > Np-237 1.0
952370	7.30E+01	2	m	0	1	0	1	0	-1	Am-237 > Pu-237 ~1.0
942370	4.52E+01	4	d	0	1	0	1	0	-1	Pu-237 sk(U-233) Np-237 1.0
932370	2.14E+06	5	y	0	1	0	1	18	-1	Np-237 > Pa-233 1.0
912330	2.70E+01	4	d	0	1	1	1	19	-1	Pa-233 > U-233 1.0
932330	3.62E+01	2	m	0	1	0	1	0	-1	Np-233 > U-233 1.0
922330	1.59E+05	5	y	0	1	0	1	21	-1	U-233 > Th-229 1.0
902290	7.34E+03	5	y	0	1	1	1	22	-1	Th-229 > Ra-225 1.0
872250	4.00E+00	2	m	0	1	0	1	0	-0.3	Fr-225 > Ra-225 1.0
882250	1.49E+01	4	d	0	1	0	1	24	-1	Ra-225 > Ac-225 1.0
892250	1.00E+01	4	d	0	1	0	1	25	-1	Ac-225 > Fr-221 1.0
872210	4.90E+00	2	m	0	1	0	1	26	-1	Fr-221 > At-217 1.0
852170	3.23E-02	1	s	0	1	0	1	27	-1	At-217 > Bi-213 1.0
832130	4.56E+01	2	m	0	0.0209	1	1	28	-1	Bi-213 > Po-213 .9784 Tl-209 .0209
842130	4.20E-06	1	s	0	1	1	1	29	-1	Po-213 > Pb-209 1.0
812090	2.20E+00	2	m	0	1	0	1	30	-1	Tl-209 > Pb-209 1.0
822090	3.25E+00	3	h	0	1	-1	1	31	-1	Pb-209 > stable
101258 0	5.15E+01	4	d	0	1	4	1	0	-1	Md-258 > Es-254 1.0 start 2N+2
982460	3.57E+01	3	h	0	1	2	1	0	-1	Cf-246 > Cm-242 1.0
952421	1.41E+02	5	y	0	0.9952	0	1	0	-1	Am-242m sk(Np-238) Am-242 .9952
952420	1.60E+01	3	h	0	0.173	14	1	1	-1	Am-242 Cm-242 .827 Pu-242 .173
962420	1.63E+02	4	d	0	1	17	1	2	-1	Cm-242 > Pu-238 1.0
992540	2.76E+02	4	d	0	1	4	1	5	-1	Es-254 > Bk-250 1.0
992541	3.93E+01	3	h	0	1	0	1	6	-1	Es-254m Fm-254 ~1. sk(Bk-250)
100254 0	3.24E+00	3	h	0	1	4	1	1	-1	Fm-254 > Cf-250 1.0

982540	6.05E+01	4	d	0	0.0031	0	1	0	-1	Cf-254 > Cm-250 .0031
962500	9.00E+03	5	y	0	0.11	3	1	1	-1	Cm-250 Pu-246 .11 Bk-250 .14
972500	3.21E+00	3	h	0	1	1	1	10	-1	Bk-250 > Cf-250 1.0
992500	8.60E+00	3	h	0	1	0	1	0	-1	Es-250 > Cf-250 1.0
982500	1.31E+01	5	y	0	1	4	1	12	-1	Cf-250 > Cm-246 1.0
942460	1.08E+01	4	d	0	1	1	1	8	-1	Pu-246 > Am-246 1.0
952461	2.50E+01	2	m	0	1	2	1	0	-1	Am-246m > Cm-246 1.0
952460	3.90E+01	2	m	0	1	1	1	10	-1	Am-246 > Cm-246 1.0
972460	1.80E+00	4	d	0	1	0	1	0	-1	Bk-246 > Cm-246 1.0
962460	4.76E+03	5	y	0	0.9997	0	1	12	-1	Cm-246 > Pu-242 =1.0
942420	3.74E+05	5	y	0	1	4	1	13	-1	Pu-242 > U-238 1.0
932380	2.12E+00	4	d	0	1	2	1	0	-1	Np-238 > Pu-238 1.0
962380	2.40E+00	3	h	0	0.9116	0	1	0	-1	Cm-238 Am-238 .9616 sk(Pu-234)
952380	9.80E+01	2	m	0	1	0	1	0	-1	Am-238 > Pu-238 ~1.0
942380	8.77E+01	5	y	0	1	6	1	22	-1	Pu-238 > U-234 1.0
922380	4.47E+09	5	y	0	1	3	1	23	-1	U-238 > Th-234 1.0
912340	6.70E+00	3	h	0	1	3	1	24	-1	Pa-234 > U-234 1.0
942340	8.80E+00	3	h	0	1	0	1	0	-1	Pu-234 Np-234 .94 sk(U-230)
932340	4.40E+00	4	d	0	1	2	1	0	-1	Np-234 > U-234 1.0
902340	2.41E+01	4	d	0	0.998	0	1	27	-1	Th-234 > Pa-234m .998 sk(Pa-234)
912341	1.16E+00	2	m	0	0.9987	0	1	28	-0.3	Pa-234m > U-234 .9987 sk(Pa-234)
922340	2.46E+05	5	y	0	1	4	1	29	-1	U-234 > Th-230 1.0
912300	1.74E+01	4	d	0	0.095	0	1	30	-1	Pa-230 U-230 0.095 sk(Th-230)
922300	2.08E+01	4	d	0	1	1	1	31	-1	U-230 > Th-226 1.0
892260	2.94E+01	3	h	0	0.83	0	1	0	-1	Ac-226 Th-226 .88 sk(Ra-226)
902260	3.06E+01	2	m	0	1	1	1	33	-1	Th-226 > Ra-222 1.0
902300	7.54E+04	5	y	0	1	0	1	34	-1	Th-230 > Ra-226 1.0
882260	1.60E+03	5	y	0	1	1	1	35	-1	Ra-226 > Rn-222 1.0

872220	1.42E+01	2	m	0	1	1	1	0	-1	Fr-222 > Ra-222 1.0
862220	3.82E+00	4	d	0	1	1	3	37	-1	Rn-222 > Po-218
882220	3.62E+01	1	s	0	1	2	1	38	-1	Ra-222 sk(Rn-218) 1.0>Po-214 1.0
842180	3.98E+00	2	m	0	1	0	1	39	-1	Po-218 > Pb-214 .9998 sk(Ac-218)
822140	2.68E+01	2	m	0	1	1	1	40	-1	Pb-214 > Bi-214 1.0
862180	3.50E-02	1	s	0	1	1	1	41	-1	Rn-218 > Po-214 1.0
832140	1.99E+01	2	m	0	0.9998	0	1	42	-1	Bi-214 > .9998 Po-214 sk(Po-214)
842140	1.64E-04	1	s	0	1	1	1	43	-1	Po-214 > Pb-210 1.0
812100	1.30E+00	2	m	0	1	0	1	0	-1	Tl-210 > Pb-210 1.0
822100	2.22E+01	5	y	0	1	0	1	45	-1	Pb-210 > Bi-210 1.0
832100	5.01E+00	4	d	0	1	0	1	46	-1	Bi-210 > Po-210 1.0
842100	1.38E+02	4	d	0	1	-1	1	47	-1	Po-210 > stable
992550	3.98E+01	4	d	0	1	0	1	0	-0.3	Es-255 Fm-255 .92 sk(Bk-251) start 4N+3
1002550	2.01E+01	3	h	0	1	1	1	0	-1	Fm-255 > Cf-251 1.0
992510	3.30E+01	3	h	0	1	0	1	0	-1	Es-251 > Cf-251 1.0
982510	8.98E+02	5	y	0	1	0	1	3	-1	Cf-251 > Cm-247 1.0
962470	1.56E+07	5	y	0	1	0	1	4	-1	Cm-247 > Pu-243 1.0
942430	4.96E+00	3	h	0	1	1	1	5	-1	Pu-243 > Am-243 1.0
972470	1.38E+03	5	y	0	1	0	1	0	-1	Bk-247 > Am-243 1.0
952430	7.37E+03	5	y	0	1	1	1	7	-1	Am-243 > Np-239 1.0
922390	2.35E+01	2	m	0	1	0	1	0	-1	U-239 > Np-239 1.0
932390	2.36E+00	4	d	0	1	2	1	1	-1	Np-239 > Pu-239 1.0
952390	1.19E+01	3	h	0	1	1	1	1	-1	Am-239 > Pu-239 ~1.0
962430	2.91E+01	5	y	0	0.998	0	1	2	-1	Cm-243 Pu-239 .998 sk(Am-243)
942390	2.41E+04	5	y	0	1	2	1	12	-1	Pu-239 > U-235 1.0
942350	2.53E+01	2	m	0	1	0	1	0	-1	Pu-235 > Np-235 ~1.0
932350	3.96E+02	4	d	0	0.9999	0	1	0	-1	Np-235 > U-235 0.9999
922350	7.04E+08	5	y	0	1	0	1	15	-1	U-235 > Th-231 1.0

902310	2.55E+01	3	h	0	1	1	1	16	-1	Th-231 > Pa-231 1.0
922310	4.20E+00	4	d	0	1	0	1	17	-1	U-231 > Pa-231 1.0
912310	3.28E+04	5	y	0	1	5	1	18	-1	Pa-231 > Ac-227 1.0
882270	4.22E+01	2	m	0	1	4	1	0	-1	Ra-227 > Ac-227 1.0
912270	3.83E+01	2	m	0	0.15	4	1	0	-1	Pa-227 Th-227 .15 Ac-223 .85
892230	2.10E+00	2	m	0	1	0	1	1	-0.3	Ac-223 > Fr-219 1.0
852150	1.00E-04	1	s	0	1	10	1	3	-0.3	At-215 > Bi-211 1.0
892270	2.18E+01	5	y	0	0.9862	0	1	24	-1	Ac-227 > Th-227 .9862 sk(Fr-223)
902270	1.87E+01	4	d	0	1	1	1	25	-1	Th-227 > Ra-223 1.0
872230	2.18E+01	2	m	0	0.9999	0	1	0	-1	Fr-223 > Ra-223 .9999
882230	1.14E+01	4	d	0	1	0	1	27	-1	Ra-223 > Rn-219 1.0
862190	3.96E+00	1	s	0	1	0	3	28	-1	Rn-219 > Po-215 1.0
842150	1.78E-03	1	s	0	1	0	1	29	-1	Po-215 > Pb-211 1.0
822110	3.61E+01	2	m	0	1	3	1	30	-1	Pb-211 > Bi-211 1.0
852110	7.21E+00	3	h	0	0.582	1	2	0	-1	At-211 Bi-207 0.417 Po-211 .583
832070	3.29E+01	5	y	0	1	-1	1	32	-1	Bi-207 > stable
842110	5.16E-01	1	s	0	1	1	1	33	-1	Po-211 > Tl-207
832110	2.14E+00	2	m	0	0.99724	0	1	13	-1	Bi-211> Tl-207 .99727 sk(Po-211)
812070	4.77E+00	2	m	0	1	-1	1	35	-1	Tl-207 > stable

Appendix C
Meteorological Diffusion Parameters

Appendix C

Meteorological Diffusion Parameters

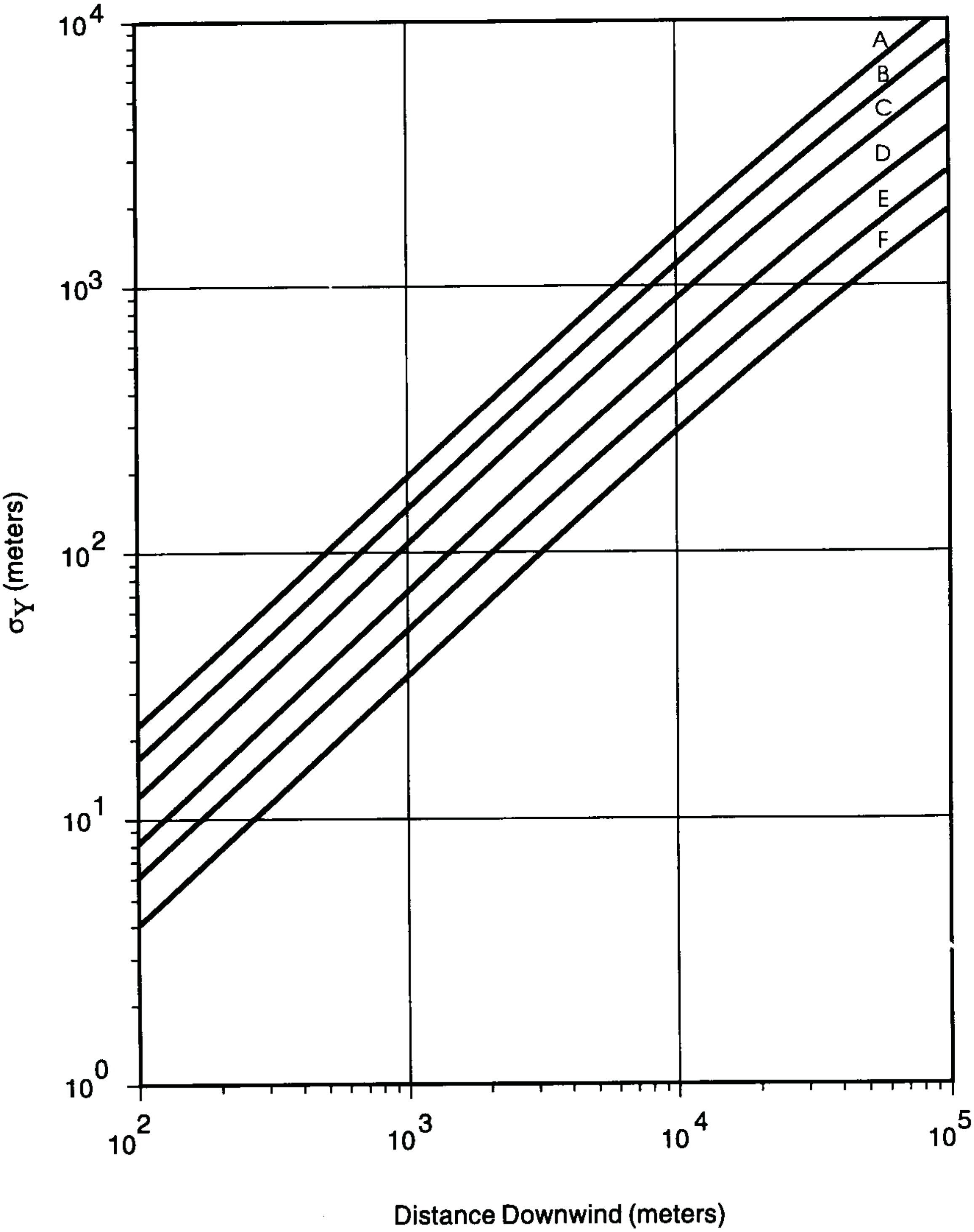


Figure C-1. σ_y versus distance downwind by stability class (Hilsmeier-Gifford).

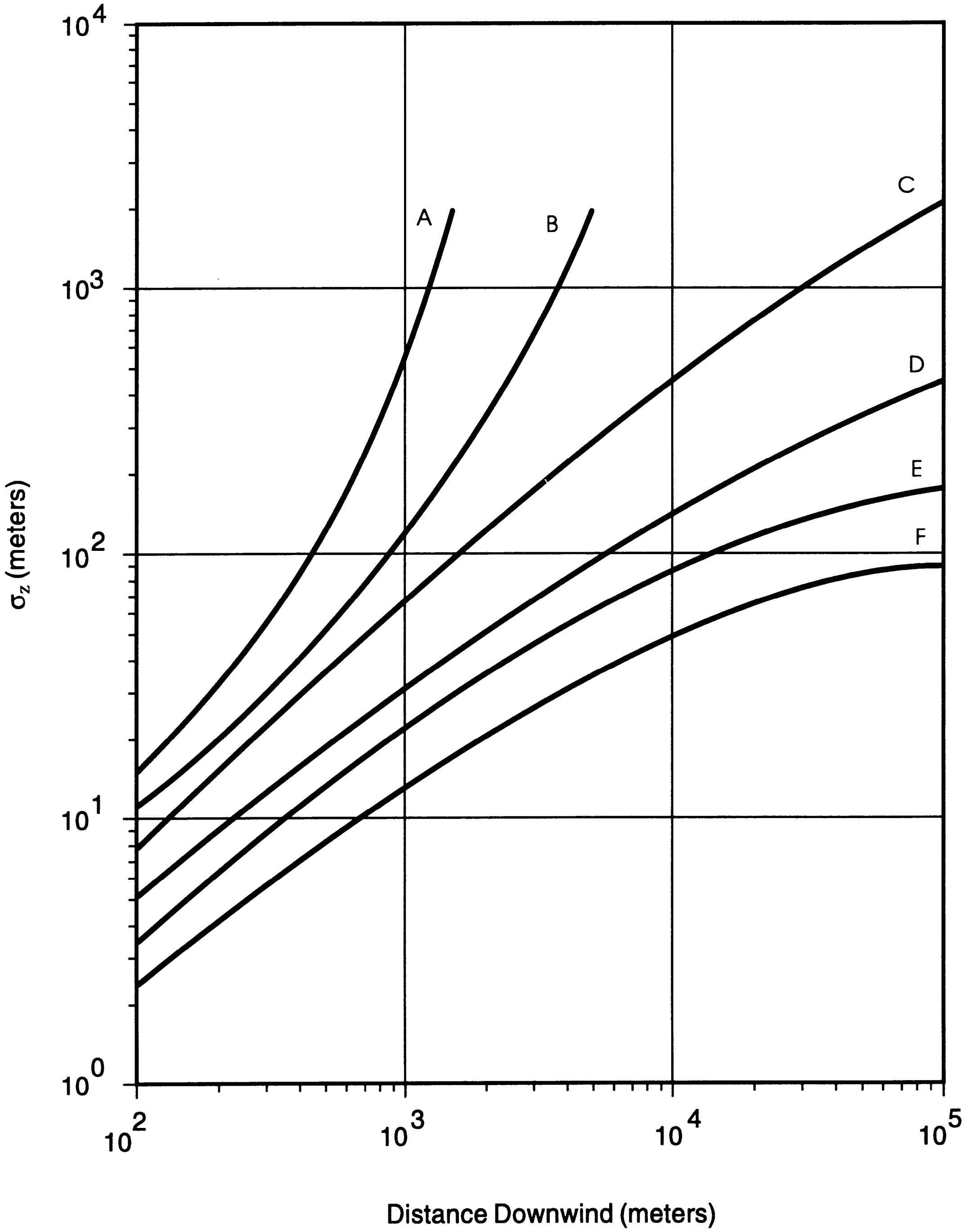


Figure C-2. σ_z versus distance downwind by stability class (Hilsmeier-Gifford).

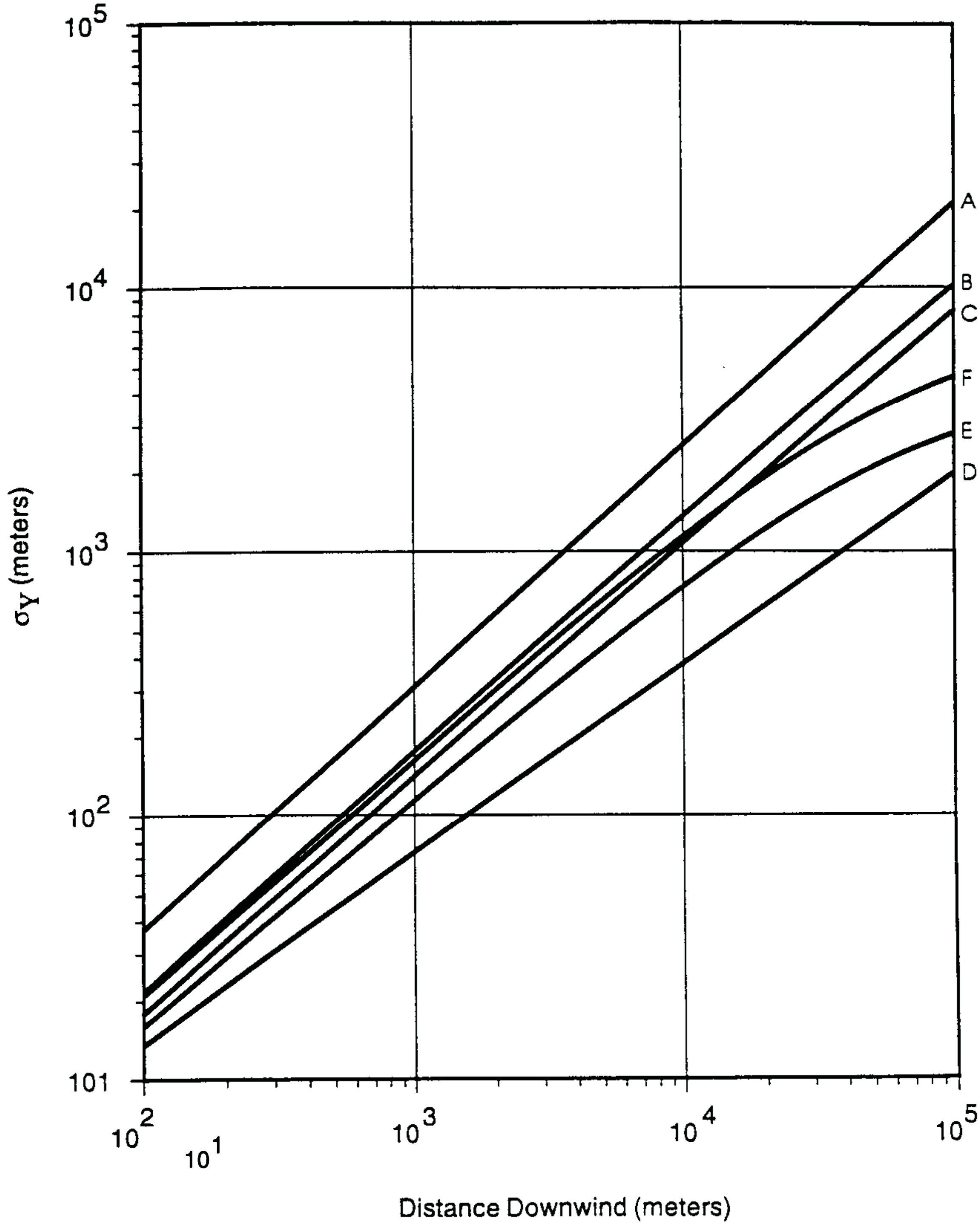


Figure C-3. σ_y versus distance downwind by stability class (Markee).

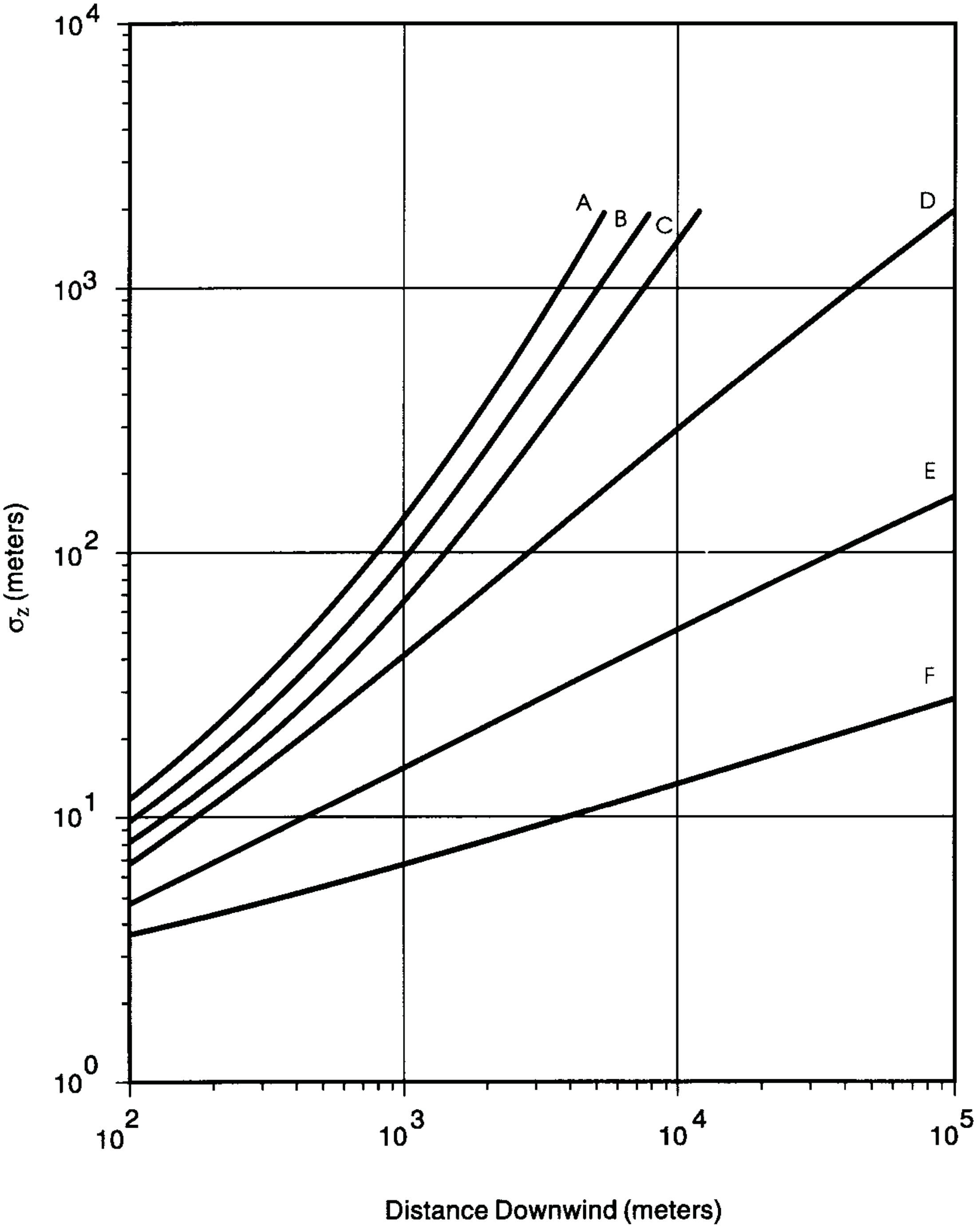


Figure C-4. σ_z versus distance downwind by stability class (Markee).

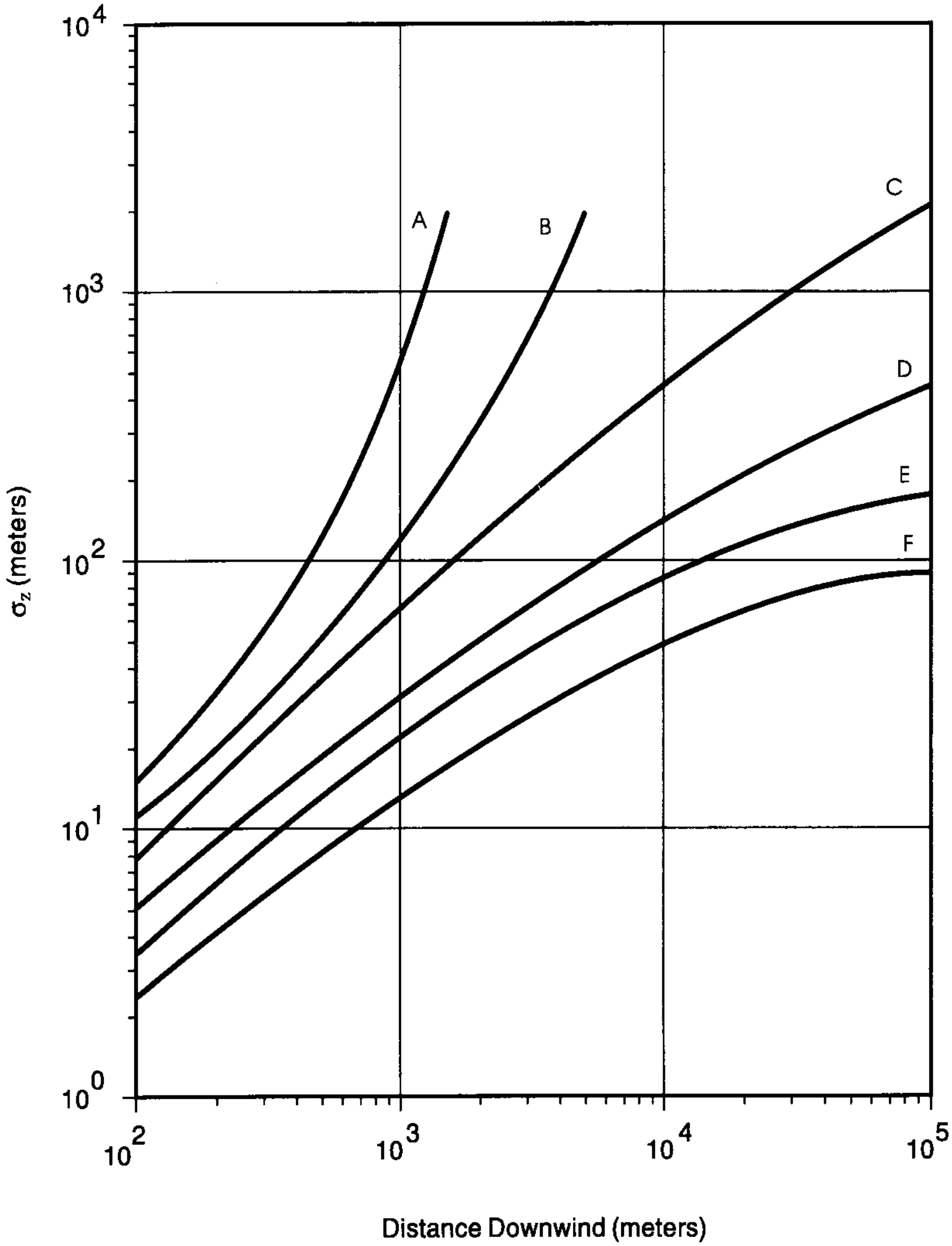


Figure C-5. σ_y versus distance downwind by stability class (Pasquill-Gifford).

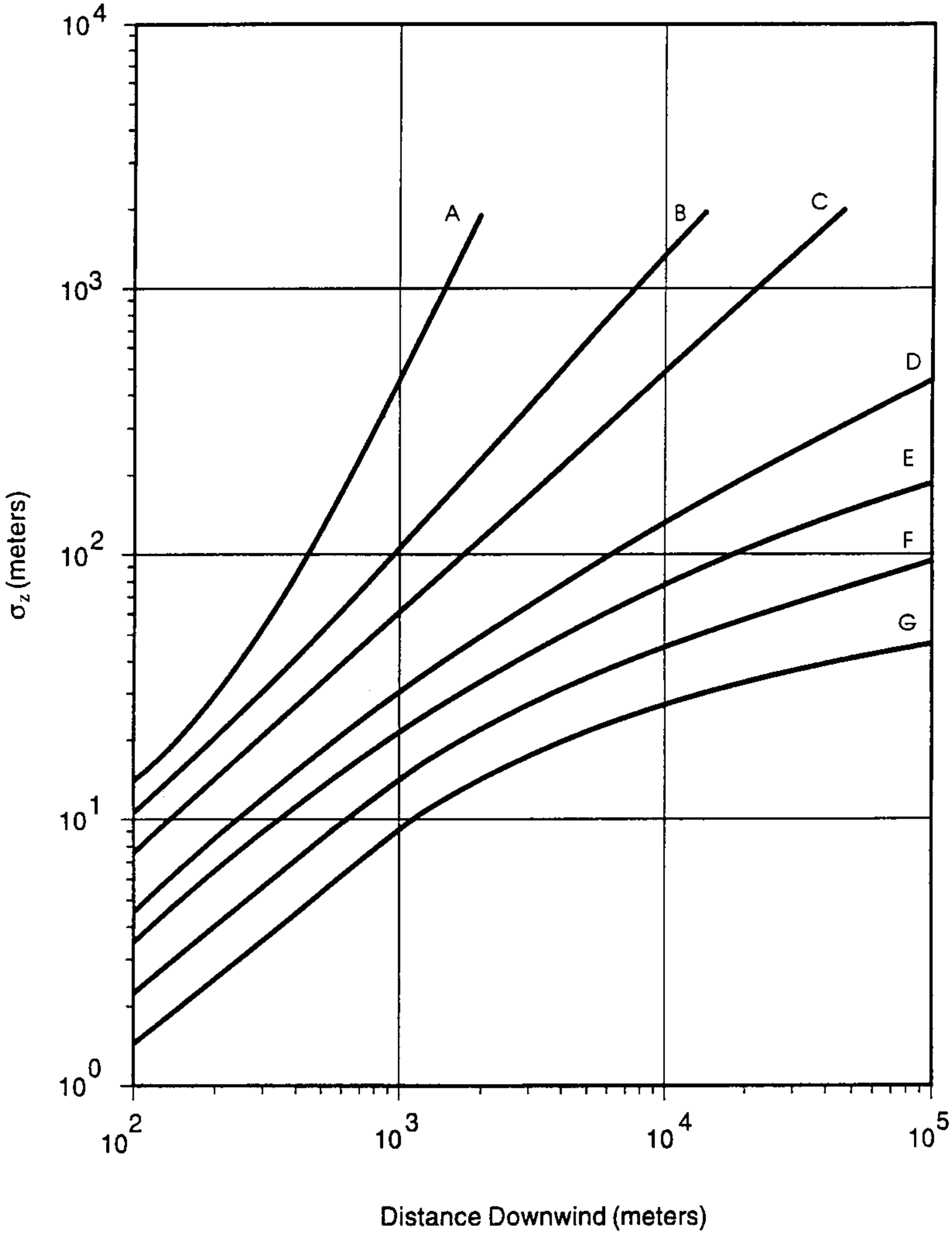


Figure C-6. σ_z versus distance downwind by stability class (Pasquill-Gifford).

CLASSIFICATION OF ATMOSPHERIC STABILITY

(Till and Meyer, 1983)

BY VERTICAL TEMPERATURE DIFFERENCE

Stability classification	Pasquill categories	Temperature change with height (°C/100 m)
Extremely unstable	*A*	$\Delta T/\Delta z \leq -1.9$
Moderately unstable	*B*	$-1.9 < \Delta T/\Delta z \leq -1.7$
Slightly unstable	*C*	$-1.7 < \Delta T/\Delta z \leq -1.5$
Neutral	*D*	$-1.5 < \Delta T/\Delta z \leq -0.5$
Slightly stable	*E*	$-0.5 < \Delta T/\Delta z \leq 1.5$
Moderately stable	*F*	$1.5 < \Delta T/\Delta z \leq 4.0$
Extremely stable	*G*	$4.0 < \Delta T/\Delta z$

BY STANDARD DEVIATION OF HORIZONTAL WIND DIRECTION

Stability classification	Pasquill categories	σ_θ[a] (deg)
Extremely unstable	*A*	$\sigma_\theta \geq 22.5$
Moderately unstable	*B*	$22.5 > \sigma_\theta \geq 17.5$
Slightly unstable	*C*	$17.5 > \sigma_\theta \geq 12.5$
Neutral	*D*	$12.5 > \sigma_\theta \geq 7.5$
Slightly stable	*E*	$7.5 > \sigma_\theta \geq 3.8$
Moderately stable	*F*	$3.8 > \sigma_\theta \geq 2.1$
Extremely stable	*G*	$2.1 > \sigma_\theta$

[a]Determined for a 15-min to 1-h period for horizontal diffusion.

Appendix D
Lung Clearance Classes

Appendix D

ICRP 30 / FGR 11

Lung Clearance Classes[a] for Oxides or Hydroxides

Z	Element	Allowable Clearance Classes			Z	Element	Allowable Clearance Classes		
1	H[b]	HTO			41	Nb		W	Y
4	Be			Y	42	Mo	D		Y
6	C[b]	CO	ORG	CO_2	43	Tc	D	W	
9	F	D	W	Y	44	Ru	D	W	Y
11	Na	D			45	Rh	D	W	Y
12	Mg	D	W		46	Pd	D	W	Y
13	Al	D	W		47	Ag	D	W	Y
14	Si	D	W	Y	48	Cd	D	W	Y
15	P	D	W		49	In	D	W	
16	S	D	W	V[c]	50	Sn	D	W	
17	Cl	D	W	Y	51	Sb	D	W	
19	K	D			52	Te	D	W	
20	Ca		W		53	I	D		
21	Sc			Y	55	Cs	D		
22	Ti	D	W	Y	56	Ba	D		
23	V	D	W		57	La	D	W	
24	Cr	D	W	Y	58	Ce		W	Y
25	Mn	D	W		59	Pr		W	Y
26	Fe	D	W		60	Nd		W	Y
27	Co		W	Y	61	Pm		W	Y
28	Ni	D	W	V	62	Sm		W	
29	Cu	D	W	Y	63	Eu		W	
30	Zn			Y	64	Gd	D	W	
31	Ga	D			65	Tb		W	
32	Ge	D	W		66	Dy		W	
33	As		W		67	Ho		W	
34	Se	D	W		68	Er		W	
35	Br	D	W		69	Tm		W	
37	Rb	D			70	Yb		W	Y
38	Sr	D		Y	71	Lu		W	Y
39	Y		W	Y	72	Hf	D	W	
40	Zr	D	W	Y	73	Ta		W	Y

ICRP 30 / FGR 11
Lung Clearance Classes for Oxides or Hydroxides

Z	Element	Allowable Clearance Classes			Z	Element	Allowable Clearance Classes		
74	W	D			88	Ra		W	
75	Re	D	W		89	Ac	D	W	Y
76	Os	D	W	Y	90	Th		W	Y
77	Ir	D	W	Y	91	Pa		W	Y
78	Pt	D			92	U	D	W	Y
79	Au	D	W	Y	93	Np		W	
80	Hg	D	W	V	94	Pu		W	Y
81	Tl	D			95	Am		W	
82	Pb	D			96	Cm		W	
83	Bi	D	W		97	Bk		W	
84	Po	D	W		98	Cf		W	Y
85	At	D	W		99	Es		W	
87	Fr	D			100	Fm		W	

a. Default lung clearance classes are underlined. D = day class, W = week class, and Y = year class.
b. Chemical species rather than clearance classes are indicated for hydrogen and carbon.
c. V = vapor.

ICRP 30 / FGR 11
Lung Clearance Classes for Maximum Element Dose

Z	Element	Allowable Clearance Classes			Z	Element	Allowable Clearance Classes		
1	H	HTO			41	Nb		W	Y
4	Be			Y	42	Mo	D		Y
6	C	CO	ORG	CO_2	43	Tc	D	W	
9	F	D	W	Y	44	Ru	D	W	Y
11	Na	D			45	Rh	D	W	Y
12	Mg	D	W		46	Pd	D	W	Y
13	Al	D	W		47	Ag	D	W	Y
14	Si	D	W	Y	48	Cd	D	W	Y
15	P	D	W		49	In	D	W	
16	S	D	W	V[c]	50	Sn	D	W	
17	Cl	D	W	Y	51	Sb	D	W	
19	K	D			52	Te	D	W	
20	Ca		W		53	I	D		
21	Sc			Y	55	Cs	D		
22	Ti	D	W	Y	56	Ba	D		
23	V	D	W		57	La	D	W	
24	Cr	D	W	Y	58	Ce		W	Y
25	Mn	D	W		59	Pr		W	Y
26	Fe	D	W		60	Nd		W	Y
27	Co		W	Y	61	Pm		W	Y
28	Ni	D	W	V	62	Sm		W	
29	Cu	D	W	Y	63	Eu		W	
30	Zn			Y	64	Gd	D	W	
31	Ga	D	W		65	Tb		W	
32	Ge	D	W		66	Dy		W	
33	As		W		67	Ho		W	
34	Se	D	W		68	Er		W	
35	Br	D	W		69	Tm		W	
37	Rb	D			70	Yb		W	Y
38	Sr	D		Y	71	Lu		W	Y
39	Y		W	Y	72	Hf	D	W	
40	Zr	D	W	Y	73	Ta		W	Y

ICRP 30 / FGR 11
Lung Clearance Classes for Maximum Element Dose

Z	Element	Allowable Clearance Classes			Z	Element	Allowable Clearance Classes		
74	W	D			88	Ra		W	
75	Re	D	W		89	Ac	D	W	Y
76	Os	D	W	Y	90	Th		W	Y
77	Ir	D	W	Y	91	Pa		W	Y
78	Pt	D			92	U	D	W	Y
79	Au	D	W	Y	93	Np		W	
80	Hg	D	W	V	94	Pu		W	Y
81	Tl	D			95	Am		W	
82	Pb	D			96	Cm		W	
83	Bi	D	W		97	Bk		W	
84	Po	D	W		98	Cf		W	Y
85	At	D	W		99	Es		W	
87	Fr	D			100	Fm		W	

ICRP 68
Recommended Lung Clearance Classes[a]

Z	Element	Allowable Clearance Classes			Z	Element	Allowable Clearance Classes		
1	H[b]	HTO		OBT	41	Nb		M	S
4	Be		M	S	42	Mo	F		S
6	C[b]	CO	ORG	CO_2	43	Tc	F	M	
9	F	F	M	S	44	Ru	F	M	S
11	Na	F			45	Rh	F	M	S
12	Mg	F	M		46	Pd	F	M	S
13	Al	F	M		47	Ag	F	M	S
14	Si	F	M	S	48	Cd	F	M	S
15	P	F	M		49	In	F	M	
16	S	F	M	V[c]	50	Sn	F	M	
17	Cl	F	M		51	Sb	F	M	
19	K	F			52	Te	F	M	
20	Ca		M		53	I	F		
21	Sc			S	55	Cs	F		
22	Ti	F	M	S	56	Ba	F		
23	V	F	M		57	La	F	M	
24	Cr	F	M	S	58	Ce		M	S
25	Mn	F	M		59	Pr		M	S
26	Fe	F	M		60	Nd		M	S
27	Co		M	S	61	Pm		M	S
28	Ni	F	M		62	Sm		M	
29	Cu	F	M	S	63	Eu		M	
30	Zn			S	64	Gd	F	M	
31	Ga	F	M		65	Tb		M	
32	Ge	F	M		66	Dy		M	
33	As		M		67	Ho		M	
34	Se	F	M		68	Er		M	
35	Br	F	M		69	Tm		M	
37	Rb	F			70	Yb		M	S
38	Sr	F		S	71	Lu		M	S
39	Y		M	S	72	Hf	F	M	
40	Zr	F	M	S	73	Ta		M	S

ICRP 68
Recommended Lung Clearance Classes

<table>
<tr><th>Z</th><th>Element</th><th colspan="3">Allowable Clearance Classes</th><th>Z</th><th>Element</th><th colspan="3">Allowable Clearance Classes</th></tr>
<tr><td>74</td><td>W</td><td><u>F</u></td><td></td><td></td><td>88</td><td>Ra</td><td></td><td><u>M</u></td><td></td></tr>
<tr><td>75</td><td>Re</td><td>F</td><td><u>M</u></td><td></td><td>89</td><td>Ac</td><td>F</td><td>M</td><td><u>S</u></td></tr>
<tr><td>76</td><td>Os</td><td>F</td><td>M</td><td><u>S</u></td><td>90</td><td>Th</td><td></td><td>M</td><td><u>S</u></td></tr>
<tr><td>77</td><td>Ir</td><td>F</td><td>M</td><td><u>S</u></td><td>91</td><td>Pa</td><td></td><td>M</td><td><u>S</u></td></tr>
<tr><td>78</td><td>Pt</td><td><u>F</u></td><td></td><td></td><td>92</td><td>U</td><td>F</td><td><u>M</u></td><td>S</td></tr>
<tr><td>79</td><td>Au</td><td>F</td><td>M</td><td><u>S</u></td><td>93</td><td>Np</td><td></td><td><u>M</u></td><td></td></tr>
<tr><td>80</td><td>Hg</td><td>F</td><td><u>M</u></td><td>V</td><td>94</td><td>Pu</td><td></td><td><u>M</u></td><td>S</td></tr>
<tr><td>81</td><td>Tl</td><td><u>F</u></td><td></td><td></td><td>95</td><td>Am</td><td></td><td><u>M</u></td><td></td></tr>
<tr><td>82</td><td>Pb</td><td><u>F</u></td><td></td><td></td><td>96</td><td>Cm</td><td></td><td><u>M</u></td><td></td></tr>
<tr><td>83</td><td>Bi</td><td>F</td><td><u>M</u></td><td></td><td>97</td><td>Bk</td><td></td><td><u>M</u></td><td></td></tr>
<tr><td>84</td><td>Po</td><td>F</td><td><u>M</u></td><td></td><td>98</td><td>Cf</td><td></td><td>M</td><td></td></tr>
<tr><td>85</td><td>At</td><td><u>F</u></td><td>M</td><td></td><td>99</td><td>Es</td><td></td><td><u>M</u></td><td></td></tr>
<tr><td>87</td><td>Fr</td><td><u>F</u></td><td></td><td></td><td>100</td><td>Fm</td><td></td><td><u>M</u></td><td></td></tr>
</table>

a. Default lung clearance classes are underlined. F = Fast, M = Medium class, and S = Slow
b. Chemical species rather than clearance classes are indicated for hydrogen and carbon.
c. V = vapor.

ICRP 68 Lung Clearance Classes for Maximum Element Dose

Z	Element	Allowable Clearance Classes			Z	Element	Allowable Clearance Classes		
1	H[b]		HTO	OBT	41	Nb		M	S
4	Be		M	S	42	Mo	F		S
6	C[b]	CO	CO_2	ORG	43	Tc	F	M	
9	F	F	M	S	44	Ru	F	M	S
11	Na	F			45	Rh	F	M	S
12	Mg	F	M		46	Pd	F	M	S
13	Al	F	M		47	Ag	F	M	S
14	Si	F	M	S	48	Cd	F	M	S
15	P	F	M		49	In	F	M	
16	S	F	M	V[c]	50	Sn	F	M	
17	Cl	F	M		51	Sb	F	M	
19	K	F			52	Te	F	M	
20	Ca		M		53	I	F		
21	Sc			S	55	Cs	F		
22	Ti	F	M	S	56	Ba	F		
23	V	F	M		57	La	F	M	
24	Cr	F	M	S	58	Ce		M	S
25	Mn	F	M		59	Pr		M	S
26	Fe	F	M		60	Nd		M	S
27	Co		M	S	61	Pm		M	S
28	Ni	F	M		62	Sm		M	
29	Cu	F	M	S	63	Eu		M	
30	Zn			S	64	Gd	F	M	
31	Ga	F	M		65	Tb		M	
32	Ge	F	M		66	Dy		M	
33	As		M		67	Ho		M	
34	Se	F	M		68	Er		M	
35	Br	F	M		69	Tm		M	
37	Rb	F			70	Yb		M	S
38	Sr	F		S	71	Lu		M	S
39	Y		M	S	72	Hf	F	M	
40	Zr	F	M	S	73	Ta		M	S

ICRP 68 Lung Clearance Classes for Maximum Element Dose

Z	Element	Allowable Clearance Classes			Z	Element	Allowable Clearance Classes		
74	W	F			88	Ra		M	
75	Re	F	M		89	Ac	F	M	S
76	Os	F	M	S	90	Th		M	S
77	Ir	F	M	S	91	Pa		M	S
78	Pt	F			92	U	F	M	S
79	Au	F	M	S	93	Np		M	
80	Hg	F	M	V	94	Pu		M	S
81	Tl	F			95	Am		M	
82	Pb	F			96	Cm		M	
83	Bi	F	M		97	Bk		M	
84	Po	F	M		98	Cf		M	
85	At	F	M		99	Es		M	
87	Fr	F			100	Fm		M	

a. Default lung clearance classes are underlined. F = Fast, M = Medium class, and S = Slow
b. Chemical species rather than clearance classes are indicated for hydrogen and carbon.
c. V = vapor.

ICRP 72
Recommended Lung Clearance Classes[a]

Z	Element	Allowable Clearance Classes			Z	Element	Allowable Clearance Classes		
1	H[b]		HTO	OBT	41	Nb	F	M	S
4	Be		M	S	42	Mo	F	M	S
6	C[b]	CO	CO_2	ORG	43	Tc	F	M	S
9	F	F	M	S	44	Ru	F	M	S
11	Na	F			45	Rh	F	M	S
12	Mg	F	M		46	Pd	F	M	S
13	Al	F	M		47	Ag	F	M	S
14	Si	F	M	S	48	Cd	F	M	S
15	P	F	M		49	In	F	M	
16	S	F	M	V[c]	50	Sn	F	M	
17	Cl	F	M		51	Sb	F	M	S
19	K	F			52	Te	F	M	S
20	Ca	F	M	S	53	I	F	M	S
21	Sc			S	55	Cs	F	M	S
22	Ti	F	M	S	56	Ba	F	M	S
23	V	F	M		57	La	F	M	
24	Cr	F	M	S	58	Ce	F	M	S
25	Mn	F	M		59	Pr		M	S
26	Fe	F	M	S	60	Nd		M	S
27	Co	F	M	S	61	Pm		M	S
28	Ni	F	M	S	62	Sm		M	
29	Cu	F	M	S	63	Eu		M	
30	Zn	F	M	S	64	Gd	F	M	
31	Ga	F	M		65	Tb		M	
32	Ge	F	M		66	Dy		M	
33	As		M		67	Ho		M	
34	Se	F	M	S	68	Er		M	
35	Br	F	M		69	Tm		M	
37	Rb	F			70	Yb		M	S
38	Sr	F	M	S	71	Lu		M	S
39	Y		M	S	72	Hf	F	M	
40	Zr	F	M	S	73	Ta		M	S

ICRP 72
Recommended Lung Clearance Classes

Z	Element	Allowable Clearance Classes			Z	Element	Allowable Clearance Classes		
74	W	F			88	Ra	F	M	S
75	Re	F	M		89	Ac	F	M	S
76	Os	F	M	S	90	Th	F	M	S
77	Ir	F	M	S	91	Pa		M	S
78	Pt	F			92	U	F	M	S
79	Au	F	M	S	93	Np	F	M	S
80	Hg	F	M	V	94	Pu	F	M	S
81	Tl	F			95	Am	F	M	S
82	Pb	F	M	S	96	Cm	F	M	S
83	Bi	F	M		97	Bk		M	
84	Po	F	M	S	98	Cf		M	
85	At	F	M		99	Es		M	
87	Fr	F			100	Fm		M	

a. Default lung clearance classes are underlined. F = Fast, M = Medium class, and S = Slow. Highlighted classes are taken from ICRP 72 Table 2, recommended default absorption Type for particulate aerosol, when no specific information is available.
b. Chemical species rather than clearance classes are indicated for hydrogen and carbon.
c. V = vapor.

ICRP 72
Maximum Lung Clearance Classes[a]

Z	Element	Allowable Clearance Classes			Z	Element	Allowable Clearance Classes		
							F		
1	H[b]	F	M	S	41	Nb		M	S
4	Be		M	S	42	Mo	F	M	S
6	C[b]	CO	CO_2	ORG	43	Tc	F	M	S
9	F	F	M	S	44	Ru	F	M	S
11	Na	F			45	Rh	F	M	S
12	Mg	F	M		46	Pd	F	M	S
13	Al	F	M		47	Ag	F	M	S
14	Si	F	M	S	48	Cd	F	M	S
15	P	F	M		49	In	F	M	
16	S	F	M	V[c]	50	Sn	F	M	
17	Cl	F	M		51	Sb	F	M	S
19	K	F			52	Te	F	M	S
20	Ca	F	M	S	53	I	F	M	S
21	Sc			S	55	Cs	F	M	S
22	Ti	F	M	S	56	Ba	F	M	S
23	V	F	M		57	La	F	M	
24	Cr	F	M	S	58	Ce	F	M	S
25	Mn	F	M		59	Pr		M	S
26	Fe	F	M	S	60	Nd		M	S
27	Co	F	M	S	61	Pm		M	S
28	Ni	F	M	S	62	Sm		M	
29	Cu	F	M	S	63	Eu		M	
30	Zn	F	M	S	64	Gd	F	M	
31	Ga	F	M		65	Tb		M	
32	Ge	F	M		66	Dy		M	
33	As		M		67	Ho		M	
34	Se	F	M	S	68	Er		M	
35	Br	F	M		69	Tm		M	
37	Rb	F			70	Yb		M	S
38	Sr	F	M	S	71	Lu		M	S
39	Y		M	S	72	Hf	F	M	
40	Zr	F	M	S	73	Ta		M	S

ICRP 72
Maximum Dose Lung Clearance Classes

Z	Element	Allowable Clearance Classes			Z	Element	Allowable Clearance Classes		
74	W	<u>F</u>			88	Ra	F	M	<u>S</u>
75	Re	F	<u>M</u>		89	Ac	F	M	<u>S</u>
76	Os	F	M	<u>S</u>	90	Th	F	M	<u>S</u>
77	Ir	F	M	<u>S</u>	91	Pa		M	<u>S</u>
78	Pt	<u>F</u>			92	U	F	M	<u>S</u>
79	Au	F	M	<u>S</u>	93	Np	<u>F</u>	M	S
80	Hg	F	<u>M</u>	V	94	Pu	<u>F</u>	M	S
81	Tl	<u>F</u>			95	Am	<u>F</u>	M	S
82	Pb	F	M	<u>S</u>	96	Cm	<u>F</u>	M	S
83	Bi	F	<u>M</u>		97	Bk		<u>M</u>	
84	Po	F	M	<u>S</u>	98	Cf		M	
85	At	F	<u>M</u>		99	Es		<u>M</u>	
87	Fr	<u>F</u>			100	Fm		<u>M</u>	

a. Default lung clearance classes are underlined. F = Fast, M = Medium class, and S = Slow
b. Chemical species rather than clearance classes are indicated for hydrogen and carbon.
c. V = vapor.