RSAC 6.2 With WinRP 2.0 User Manual

Brad Schrader

September 2005

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September 2005

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ABSTRACT

The Radiological Safety Analysis Computer Program (RSAC-6.2) calculates the consequences of a release of radionuclides to the atmosphere. Using a personal computer, a user can generate a fission product inventory from either reactor operating history or a nuclear criticality accident. RSAC-6.2 models the effects of high-efficiency particulate air filters or other cleanup systems and calculates decay and ingrowth during transport through processes, facilities, and the environment. Doses are calculated for resuspension, inhalation, immersion, ground surface, and ingestion pathways. WinRP 2.0, a windows based overlay to RSAC-6.2, assists users in creating and running RSAC-6.2 input files.

This users' manual contains the mathematical models and operating instructions for RSAC-6.2 and WinRP 2.0. Instructions, screens, and examples are provided to guide the user through the functions provided by RSAC-6.2 and WinRP 2.0. These programs are designed for users who are familiar with radiological dose assessment methods.

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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; internal exposures from inhalation or ingestion of radioactive material. The Radiological Safety Analysis Computer Program (RSAC-6.2) calculates the consequences of a release of radionuclides to the atmosphere. Using a personal computer, a user can generate a fission product inventory; calculate inventory decay and ingrowth; 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 can be calculated from reactor operating history and can be used to simulate a nuclear criticality accident. Radionuclide inventories can also be directly input into RSAC-6.2 if desired. Source term modeling allows for complete progeny ingrowth and decay during all accident phases. RSAC-6.2 release scenario modeling allows fractionation of the inventory by chemical group or element. RSAC-6.2 also models the effects of high-efficiency particulate air (HEPA) filters or other cleanup systems. RSAC-6.2's meteorological capabilities include Gaussian plume diffusion for Pasquill-Gifford, Hilsmeier-Gifford, and Markee models. RSAC-6.2 possesses the unique ability to model Class F fumigation conditions. Optionally, users can supply plume standard deviations (σ s) or atmospheric diffusion (χ/Q s) to the code as input data. RSAC-6.2 also includes corrections for deposition (wet and dry) plume rise (jet and buoyant), resuspension, 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. A fifty-mile population dose, using Regulatory Guide 1.109 modeling, is also available.

WINRP 2.0, a windows based overlay to RSAC-6.2, assists users in creating, running and viewing RSAC-6.2 input files. WINRP 2.0 is written in Visual Basic and runs on any personal computer that supports the RSAC-6.2 code. With WINRP 2.0, a user can modify input files easily. It also allows the user to insert, edit, add, copy, move, or delete sets of instructions for RSAC-6.2. WINRP 2.0 stores each problem set in a separate file. WINRP 2.0 checks all fields to ensure that data are in an appropriate range for the variable and that there is consistency in an input series.

RSAC 6.2 is an excellent tool to evaluate accident conditions in emergency response scenarios and to evaluate of 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 (Coates and Horton 1966). In 1968, a FORTRAN version of the program was prepared by L. C. Richardson (Richardson 1968). Since 1968, RSAC has undergone substantial revision.

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

- add a fifty-mile population dose calculations
- use the U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.109 (NRC 1977a) for ingestion dose calculations
- use the International Commission for Radiological Protection (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) was enhanced and issued in 1990 to

- convert the program 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 validation and verification necessary to meet the additional requirements for software imposed by ASME-NQA-1, "Quality Assurance Program Requirements for Nuclear Facilities" (ASME 1989).

In 1994, RSAC-5 was issued (Wenzel 1994) 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

The sixth and current version, RSAC-6.2, is a major revision to the program. Numerous areas were updated to

- add additional radionuclides to the program library
- use internal dose conversion factors from Federal Guidance Report No. 11 (Eckerman 1988) and external dose-rate conversion factors from Federal Guidance Report No. 12 (Eckerman 1993)
- provision to calculate doses at distances of less than 100 m
- correction of minor errors identified in the program
- printout of radionuclides in a logical order
- add of default lung clearance classes to provide the maximum dose based on each element
- entry of radionuclide input in either upper or lower case characters
- elimination of a discontinuity in the leakage function
- addition of an option to allow the user to enter a respirable fraction for inhalation dose calculations
- addition of an option to allow the user to enter an occupancy factor for ground surface dose calculations
- incorporation of editorial changes in program output.
- enhanced method for estimation of the building wake effect
- evaluate the instantaneous release to a room
- evaluate the resuspension of particulate activity
- enhanced method for evaluation of dry deposition
- perform calculation of an effective σ_y and σ_z when X/Q is directly input

1.2 Summary of RSAC-6.2 Capabilities

RSAC-6.2 consists of nine program series. Each program series performs a type of calculation and operates together with or independently of the others, depending on the analysis being performed. These series are identified by input series lines of multiples of 1000. A summary of each of the program series follows.

1000 Series—Fission Product Inventory Calculation

RSAC-6.2 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-6.2 calculates inventories for fission products only. The RSAC-6.2 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-6.2; 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-6.2 to calculate fission product inventories is simple compared to the model used in the ORIGEN2 program (Croff 1980, RSICC 1991). RSAC-6.2 is simple to run and requires less computer time than ORIGEN2. In general, the RSAC-6.2 model calculates fission product inventories well. However, it does not calculate inventories for activation products or actinides. While the RSAC-6.2 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 input to RSAC-6.2. RSAC-6.2 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-6.2 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

The capability of RSAC-6.2 to model the fission product inventory as a function of time during a hypothetical criticality accident is shown in Figure 1-1. The fission product inventories for solids, halogens, and noble gases are shown individually as a function of time. The RSAC-6.2 input for

analyzing this accident is presented in Example 8 in Section 5. The assumptions used in the example are for demonstration purposes only and should not be applied directly to other criticality accidents calculations unless determined to be applicable. Initially, the radionuclide inventory in the aged reactor fuel involved in the criticality accident is constant. The criticality occurs during a short duration, during which large quantities of short-lived fission products are produced. The solid fission products are fractionated by a factor of 0.001 and the halogens are fractionated by a factor of 0.25 to indicate the activity released to a process off-gas system. All of the noble gases are assumed to be released. While the solids initially begin to decay, the ingrowth from the short-lived noble gases increases the activity of the solids by approximately a decade. The solids then decrease by three decades when passing through the first HEPA filter. The solids activity then increases by approximately two decades during the transport time to the final two HEPAs. The final two HEPAs decrease the activity of the solids by approximately five decades, after which decay of the short-lived noble gases again builds up the activity of the solids. After about 20 minutes during downwind transport, the solids activity reaches a maximum and slowly begins to decrease.

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.

3000 Series—Dose Summary Option

This series allows doses from different exposure pathways and multiple RSAC-6.2 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)*].

Figure 1.1 - Changing inventory during criticality accident.

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-6.2 must normally be entered before any dose calculations are requested. (The 8000 Series, Fifty-Mile Radius Dose, is an exception to this rule.) 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-6.2 models the release of radioactivity from containment structures using exponential functions. 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-6.2. RSAC-6.2 calculates plume standard deviations (σ s) developed for three different conditions (see Appendix C). Hilsmeier-Gifford σ s (Clawson et al. 1989) were developed for desert terrains and releases from a few to 15 minutes. Markee σ s (Clawson et al. 1989) were also been developed for a desert terrain; however, they were developed for releases from 15 to 60 minutes in duration. Pasquill-Gifford σ s are presented in the NRC Regulatory Guide 1.145 (NRC 1982) and by Slade (1968) from the Prairie Grass experiments for effluent releases with durations of 10 to 60 minutes.

Other meteorological options available in RSAC-6.2 are corrections for plume rise using models by Briggs (1969), building wake corrections (Ramsdell, 1997), and plume depletion using modeling of Markee (1967) and Chamberlain (1953).

6000 Series—Decay of Radionuclide Inventory 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.

7000 Series—Internal/External Dose Calculation

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). Ingestion doses from a chronic release are calculated using models described in Regulatory Guide 1.109 (NRC 1977a). Because of the lack of a consensus model, equations for calculating ingestion doses from an acute release have

been developed specifically for RSAC-6.2. 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).

External exposure from a release to a room and internal exposure from resuspension are also available.

8000 Series—Fifty-Mile Radius Dose Calculation

This series permits the user to calculate committed population doses within a fifty-mile radius of a nuclear facility. The same internal and external dose models available in the 7000 Series are available in the 8000 Series. The user must supply population and diffusion/dispersion coefficients for five 10-mile radii in each of the 16 compass sectors as input.

9000 Series—Cloud Gamma Dose Calculation

RSAC-6.2 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. Appendix A, Section A-3.4, “Air Immersion Dose,” contains discussion on the magnitude of errors that can result when either the air immersion or semi-infinite models are inappropriately used. 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. INSTALLING RSAC-6.2

This section describes the installation procedures for loading RSAC-6.2 onto a personal computer. The minimum hardware and software requirements are listed.

The 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-6.2 runs on an IBM personal computer or compatible computer running Windows 2000 or XP. Although the code does run on earlier versions of Windows operating systems, it has not been validated using earlier versions of Windows.

2.2 Loading Instructions

Place the RSAC-6.2 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 required to have a key to install the software. There is a readme file included with the software that can assist with installation if necessary.

2.3 Point-of-Contact

For information on how to obtain a copy of RSAC-6.2 or to resolve problems encountered running RSAC-6.2, contact

B.J. Schrader
Idaho National Laboratory
P.O. Box 1625
Idaho Falls, ID 83415
(208) 526-3399
email: Bradley.Schrader@inl.gov

2.4 Quality Assurance

In January 2000, the Defense Nuclear Facilities Safety Board (DNFSB) issued Technical Report 25, (TECH-25), *Quality Assurance for Safety-Related Software at Department of Energy Defense Nuclear Facilities* (DNFSB, 2000). TECH-25 identified issues regarding the state of software quality assurance (SQA) in the Department of Energy (DOE) Complex for software used to make safety analysis decisions and to control safety-related systems.

Instances were noted in which computer codes were either inappropriately applied or were executed with incorrect input data. Of particular concern were inconsistencies in the exercise of

SQA from site to site, and from facility to facility, and in the variability of guidance and training in the appropriate use of accident analysis software.

During the subsequent 2000 to 2002 period, survey information on SQA programs, processes, and procedures was collected as well as the initial elements to a response plan. However, to expedite implementation of corrective actions in this area, the DNFSB issued Recommendation 2002-1, *Quality Assurance for Safety-Related Software at Department of Energy Defense Nuclear Facilities* (DNFSB, 2002). As part of its Recommendation to DOE, the DNFSB enumerated many of the points noted earlier in TECH-25, but noted specific concerns regarding the quality of the software used to analyze and guide safety-related decisions, the quality of the software used to design or develop safety-related controls, and the proficiency of personnel using the software.

DOE has developed a series of actions that address the Board's concerns, contained in the Implementation Plan for the DNFSB Recommendation, *Implementation Plan for Defense Nuclear Facilities Safety Board Recommendation 2002-1*. Two of the actions include:

- (i) identification of a set of accident analysis software that is widely used in the DOE Complex, and
- (ii) issuance of code-specific guidance reports on the use of the "toolbox" codes for DOE facility accident analysis, identifying applicable regime in accident analysis, default inputs, and special conditions for use.

Safety analysis software was designated for the DOE "toolbox" by the DOE Office of Environment, Safety and Health (DOE/EH) in March 2003 (DOE/EH, 2003). The supporting basis for this designation was provided by a DOE-chartered Safety Analysis Software Group in a technical report entitled, *Selection of Computer Codes for DOE Safety Analysis Applications*, (DOE, 2002b) (See <http://www.deprep.org/archive/rec/2002-1/NNSACCodes1.pdf>).

RSAC is not a part of the toolbox. However the guidelines for toolbox codes was implemented in the verification/validation and documentation of the 6.2 version.

- Applicability guidance for Documented Safety Analysis (DSA)-type analysis, specifically tailored for DOE safety analysis
- Appropriate regimes, recommended configurations
- Overcoming known vulnerabilities and avoiding code errors
- Valid ranges of input parameters consistent with code capability and DOE safety basis applications
- Default input value recommendations for site-independent parameters, and
- Citations of currently available SQA documentation.

2.4.1 Configuration Control

Configuration control is maintained by issuing copies of RSAC-6.2 with a unique serial number. Only binary copies of RSAC-6.2 and its libraries are issued to users to prevent user changes to the program that would invalidate the extensive validation and verification.

2.4.2 Verification and Validation

RSAC-6.2 has been subjected to extensive independent verification and validation (V&V) for use in performing safety-related dose calculations to support safety analysis reports and emergency response conditions (INEEL 2001). This V&V is an extension of the V&V performed on RSAC-5 by Shonka Research Associates, Inc. (SRA 1993). SRA conducted this verification and validation in accordance with the guidelines presented in ANSI/ANS-10.4, “American National Standard Guidelines for the Verification and Validation of Scientific and Engineering Programs for the Nuclear Industry” (ANSI/ANS 1987). The same standards were used to V&V RSAC-6.2. V&V RSAC is performed and maintained by the Idaho National Laboratory. The INL maintains a Software Management Plan and a Software Quality Assurance Plan in accordance with 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. Conditions that should be considered before applying RSAC include:

- RSAC is best suited for “short” duration plumes, ranging from approximately several minutes to several days.
- 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. 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 ten to fifteen 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 fifty-mile or greater radius analysis to meet requirements, e.g. Environmental Impact Statements (EISs) or Probabilistic Safety Assessments (PSAs).
- 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 a significant nearby buildings, tall vegetation, or grade variations not taken into account in the dispersion parameterization.
- RSAC does not account for momentum-driven releases from detonation type events.
- In plumes arising from fire-related source terms, the user should exercise caution with the models such as RSAC that use the Briggs algorithm. 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 factor applicability – 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.

3. EXECUTING RSAC-6.2

RSAC can be run directly using a user-supplied ASCII input file or WINRP 2.0 can be used to build input files.

3.1 Using WinRP 2.0

Windows RSAC Plus (WinRp) is the windows overlay for RSAC. Version 2.0 is the current version. It provides a windows interface for creating run files, editing run files, and executing the calculations with RSAC. WinRp also includes the following tools and features:

- Printing of run files
- Batch runs of mixed file types
- Review of the run output
- Run file summary
- Review of data entered before saving the series
- Other useful features.

3.1.1 Main Window

The WinRp main window (Figure 3.1) provides access to all of the programs tools and features.

Figure 3.1 - winRp Main window

Some of the most commonly used components are:

(Toolbar)

The toolbar provides shortcuts for:

- Opening files
- Printing
- Cut, Copy, Paste, Insert, and Delete series
- Run the currently open file with RSAC

(Add Series Menu)

The Add Series menu allows selecting which series to add to the open file. It works similar to a tab control, just click on Add series, Fifty-Mile Radius, or Reports to show a list of series to add. Then click the series name to add it to the file. Note that some series may be disabled until its prerequisites are met.

(File Summary)

The file summary provides the following:

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

(File information)

The file information shows the full path of the currently open file and the date and time it was last modified.

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 WinRp Options

The options dialog (Figure 3.2) is where certain features of WinRp can be controlled. To open the options dialog click the Tools menu then Options.

Figure 3.2 - Options Dialog

- Series End of Data Entry Notification -- Unchecking this option will disable the notification given when data entry for that series is complete.
- Use Run Output Directory -- This option affects where the run output for the current file will be stored. When checked WinRp will save the output in the specified run output directory. When unchecked the output will be saved to the same location as the currently open file.
- Run Output Directory -- To specify a different run output directory click the Change button and select the desired directory. Note: The Run Batch window will also use this as the default output directory.

3.1.4 Series Main Window

The series main window (Figure 3.3) provides a summary of all data that has 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 3.3 - Series Main window

The navigation pane (Figure 3.4) on the left side of the series main window, gives a brief outline of what data has been entered into the Series.

Figure 3.4 - Navigation Pane

The contents pane (Figure 3.5) will display the data for the selected item in the navigation pane. Thus, when a sub item is selected in the navigation pane the corresponding data for that item is displayed in the contents pane. This provides quick access to the specific data that in question. Using the [Print Contents](#) link in the upper right corner will print the current data in the contents pane to the chosen printer.

Series 5000 [Print Contents...](#)

Dispersion Option:
Release will be modeled using Meteorological Data.

Meteorological Data:

Average Wind Velocity	2	meters/second
Stack Height	76	meters
Mixing Depth	380	meters
Air Density	1.099E3	grams/cubic meter
Washout Factor	0	liters/second
Plume Depletion by Dry Deposition	Yes	

Deposition Velocities:

Solids	0.001	meters/second
Halogens	0.01	meters/second
Noble Gases	0	meters/second
Cesium	0.001	meters/second
Ruthenium	0.001	meters/second

Downwind Distances:

Downwind Distance 1	3.E3	meters
---------------------	------	--------

Leakage Decay Constants:

Set 1	Linear Constant	1	Exponential Constant	0
-------	-----------------	---	----------------------	---

Diffusion Control:

Program calculated standard deviations of plume concentration		
Building Width	0	meters
Building Height	0	meters

Figure 3.5 - Contents Pane

3.1.5 Adding a Series

To add or append a new series to the file use the Add Series Menu (Figure 3.6) on the main window and click the name of the desired series.

[Add Series](#) [Fifty-Mile Radius](#) [Reports](#)

1000	Fission Product Inventory Calculation
2000	Direct Radionuclide Input
5000	Meteorological Data Input
7000	Internal/External Dose Calculation
9000	Cloud Gamma Dose Calculation

Figure 3.6 - Add Series Menu

When the series name is clicked the main series window will appear with the series title window on top of it (Figure 3.7).

Figure 3.7 - 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 will be shown in sequence to allow input of the data for that series. When all the data has been entered for that series, the series main window will be come 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 will become 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 3.8.

5000 Meteorological Data Input

Series Title: Input of meteorological parameters

Meteorological Data

Series 5000

- Dispersion Option
- Meteorological Data
- Deposition Velocities
- Downwind Distances
- Leakage Decay Constants
- Diffusion Control
- Plume Standard Deviation Control
- Jet Plume Rise Parameters

Series 5000

Dispersion Option:
Release will be modeled using Meteorological Data.

Meteorological Data:

Average Wind Velocity	2	meters/second
Stack Height	76	meters
Mixing Depth	380	meters
Air Density	1.099E3	grams/cubic meter
Washout Factor	0	liters/second
Plume Depletion by Dry Deposition	Yes	

Deposition Velocities:

Solids	0.001	meters/second
Halogens	0.01	meters/second
Noble Gases	0	meters/second
Cesium	0.001	meters/second
Ruthenium	0.001	meters/second

Downwind Distances:

Downwind Distance 1	3.E3	meters
---------------------	------	--------

Leakage Decay Constants:

Set 1	Linear Constant	1	Exponential Constant	0
-------	-----------------	---	----------------------	---

Diffusion Control:

Program calculated standard deviations of plume concentration

Building Width	0	meters
Building Height	0	meters

Buttons: Edit, Save, Close

Figure 3.8 - Series Main window in Edit Mode

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

3.1.7 Run Batch

The run batch window (Figure 3.9) allows running a batch of mixed file types (WinRp, ASCII, Text) with RSAC. To open the run batch window click on the Run menu then Run Batch

Figure 3.9 – Run Batch window

To add files to the batch click the Add File button, a dialog will then appear for file selection. Use the "Files of type" drop down list to change the type of file to add. Select the desired number of files and click the Open button. The file(s) will then be added to the batch.

To remove files from the batch, select desired file(s) to remove holding the <ctrl> or <shift> to select multiple files, then click the remove button.

The output directory is the location that the output from RSAC will be stored. To change this location click the Change Directory button and select the desired output directory. Note: This is not affected by the "Use run output directory" option under the program Options dialog. Output files from the run will be saved as "<file name> out####.txt". For example if the name of the file is RunFile.rsac then the output file will be "RunFile out0001.txt". If that file already exists then the number will be increased by 1.

Once all files have been added to the batch click the run button to execute the batch with RSAC. After the run is complete a results window will appear allowing review and printout of the output.

3.1.8 Run Results

The run results window (Figure 3.10) 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 3.10 – Run Results window

Each file that was run with RSAC will appear as the top level item in the left navigation pane. The file will be broken down into sections that are identified in the output, which will be the sub items 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 which 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.

The action menu on the top of the right pane provides features to enhance the results from RSAC and provide control of the results window:

- Close: Clicking this link will close the run results window.
- Print: Clicking this link will print the output currently displayed in the right pane.
- Graph & Plots: These menu items are currently disabled, but in future versions they will provide graphs of relevant data from the RSAC output.

3.1.9 Run History

The run history window (Figure 3.11) shows a list of all files contained in the history database which have been run with RSAC from WinRp. The listing provides the name of the file, the run date, run time, and the type of file. The window also gives the ability to view any of the files in the history database. To open the run history window click on the Run menu then History.

File Name	File Type	Run Date	Run Time
Test 1	WinRp	8/11/2002	06:42:49 PM
Example 7 Comparison on cloud gamma dose models	WinRp	8/11/2002	06:42:50 PM
Example 5 Air immersion dose calculation	WinRp	8/11/2002	06:42:50 PM
Example 4 Ground surface dose calculation	WinRp	8/11/2002	06:42:50 PM
Example 2 Calculation of inhalation dose	WinRp	8/11/2002	06:42:50 PM
Example 9 Dose calc with changing meteorological conditions	WinRp	8/11/2002	06:42:50 PM
Example 1 Fission product inventory	WinRp	8/11/2002	06:42:50 PM
Example 8 Hypothetical criticality accident	WinRp	8/11/2002	06:42:50 PM
Example 6 Fifty mile radius for chronic release	WinRp	8/11/2002	06:42:50 PM
Example 3 Ingest dose calc from acute release	WinRp	8/11/2002	06:42:50 PM
Example9	Ascii	8/11/2002	06:42:51 PM
Example1	Ascii	8/11/2002	06:42:51 PM
Example5	Ascii	8/11/2002	06:42:52 PM
Example4	Ascii	8/11/2002	06:42:52 PM
Example7	Ascii	8/11/2002	06:42:52 PM
Example6	Ascii	8/11/2002	06:42:52 PM
Example8	Ascii	8/11/2002	06:42:52 PM
Example3	Ascii	8/11/2002	06:42:52 PM
Example2	Ascii	8/11/2002	06:42:52 PM
fermiout	Text	8/11/2002	06:42:53 PM
Test 1	WinRp	8/11/2002	06:49:42 PM

Figure 3.11 - Run History window

To view the files in the run history select the desired files from the list using the ctrl or shift key to select multiple files then click the View Selected link on the action menu. Right-clicking in the list will also provide a View Selected pop-up menu.

The action menu at the top of the window provides the following:

- Clear History: Clears all files in the history database.
- Close: Closes the run history window.
- View Selected: Opens the Run Results window with the selected files from the history.

3.2 Series Data Entry

The following section steps through the data entry options available in each series to build an input file for RSAC. If at anytime a comment button is active during series input, a comment screen is available for use (Figure 3.12). 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 3.12 - Comment Entry

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 (Figure 3.13). 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 3.13 - Screen 1, Input Type

Screen 2A (Optional) - Inventory Decay: Shown only if *Inventory Decay* is chosen on screen 1. Indicate the inventory decay time (Figure 3.14). You must have input an inventory previously for this to function properly. A pull down menu is available to allow for a variety of input options.

Figure 3.14 - Screen 2A (Optional), Inventory Decay

Next, notification of input completion for the 1000 series is given (Figure 3.15). Click the OK button to end data entry for the series and review the data input.

Figure 3.15 - Input Completion Notification

Screen 2B (Optional) - Reactor Operation: Shown only if *Reactor Operation* is selected on screen 1, see Figure 3.16.

Criticality/Reactor Operation (Line 1003)

Help

Criticality/Reactor Operation

Reactor shutdown time before this operation: Second(s)

Reactor power for operation: Watts

Reactor operating time at above reactor power: Second(s)

< Back Comment Next >

Figure 3.16 – Screen 2B (Optional), Reactor Operation

Screen 3A - Release During Reactor Operation: Shown after optional screen 2B *Reactor Operation* (Figure 3.17). If you respond **YES**, the *Release During Fission Product* screen will appear next.

Release During Reactor Operation Calculations

Help

Release During Reactor Operation

At this point you may enter information simulating fission product releases from reactor while in operation.

If this option is chosen. A choice will be given as to whether the activity in or out of the reactor is to be retained.

Do you wish to use this option? ☒ Yes ☐ No

< Back Comment Next >

Figure 3.17 – Screen 3A, Release During Reactor Operation

Screen 4A - Release During Fission Product: On this screen (Figure 3.18), 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.

Release During Reactor Operation (Line 1200 & 1201)

Help

Release During Reactor Operation

Number of reactor incremental release steps: 99 (Range 1 to 100)

Inventory to be retained for subsequent calculations

☒ Retain activity remaining in reactor
☐ Retain activity leaked from reactor

Radionuclide leak rate from the reactor (fraction/s)

Solids: 1.0
Halogens: 1.0
Noble Gases: 1.0
Cesium: 1.0
Ruthenium: 1.0

< Back Comment Next >

Figure 3.18 - Screen 4A, Release During Fission Product

Screen 2C (Optional) - Fractionate Inventory: Shown only if *Fractionate Inventory* is selected on screen 1 (Figure 3.19). Select the option of what type of fractionation should be performed.

Fractionation Type

Help

Fractionation Type

☒ Fractionation by group
☐ Fractionation is by a constant
☐ Fractionation by element

< Back Comment Next >

Figure 3.19 - Screen 2C (Optional), Fractionate Inventory

Screen 3B (Optional) – Fractionation by Group: Shown only if *Fractionation by group* is selected on the Fractionate Inventory screen 2C (Figure 3.20).

Fractionation Control Information (Line 1004)

Help

Fractionation Control Information

Fractionation by Group

Enter Fractionations for:

Solids:

Halogens:

Noble Gases:

Cesium:

Ruthenium:

< Back Comment Next >

Figure 3.20 - Screen 3B (Optional), Fractination by Group

Screen 3C(Optional) – Fractionation by Constant: Shown only if *Fractionation is by a constant* is selected on the Fractionate Inventory screen 2 (Figure 3.21).

Fractionation Control Information (Line 1004)

Help

Fractionation Control Information

Fractionation by Constant

Fractionation for entire inventory

< Back Comment Next >

Figure 3.21 - Screen 3C (Optional), Fractionation by a Constant

Screen 3D (Optional) – Fractionation by Element: Shown only if *Fractionation by element* is selected on the Fractionate Inventory screen 2C (Figure 3.22). Provide the fractionation for elements that are not individual fractionated on the next screen.

Figure 3.22 - Screen 3D (Optional), Fractionation by Element

Screen 4B - Element Fractionation Specification: This screen is where individual element fractionations are specified (Figure 3.23). 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 3.23 - 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 (Figure 3.24). This comment is used to distinguish between series and can make future editing sessions easier. This comment will also appear in the generated RSAC-6.2 input file.

Figure 3.24 - Screen 1, Series Title

Screen 2 - Radionuclide Input Options: Use the mouse to select the appropriate option for your problem (Figure 3.25).

Figure 3.25 - 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 3.26 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.

Figure 3.26 - Previous Inventory Deleted Warning

Screen 3 - Direct Radionuclide Input: This screen (Figure 3.27) 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 3.27 - Screen 3, Direct Radionuclide Input

Screen 4A (Optional) - Radionuclide Curie Input: Shown only when *Radionuclides will be selected on next screen* is chosen on screen 3. On this screen (Figure 3.28), select the radionuclide and input the activity desired 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: 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.

Figure 3.28 – Screen 4A (Optional) Radionuclide Curie Input

Screen 4B (Optional) - External File for Radionuclide Entry: Shown only when *An external file will be specified* is chosen on screen 3 (Figure 3.29). 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 3.29 – Screen 4B (Optional), External File for Radionuclide Entry

Screen 5 - Series Complete Notification: When finished with the data entry screens, you will be

notified that data entry is complete (Figure 3.30). Click OK to return to the series main window (Figure 3.31) to review and save entered data.

Figure 3.30 – Screen 5, Series Complete Notification

Figure 3.31 – 2000 Series Main window

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 (Figure 3.32).

Figure 3.32 - Reports Tab

Screen 2 - Dose Summary Options: After the series title screen is dismissed the following selections are available (Figure 3.33).

Figure 3.33 - Screen 2, Dose Summary Options

One or all of the options may be selected.

- Summary of Dose by Pathway - Summarizes the CEDE for each pathway and totals the dose to provide a TEDE see Figure 3.34.

```

Radiological Safety Analysis Computer Program (RSAC 6.2)
Windows RSAC Plus (WinPp 2.0.0)
Name: Brad Schrader      Company: INEEL
Serial: H4JY6-52RR0-E    Run Date: 06/29/2005    Run Time: 09:18:49
File: Crit Accident Generic Calculation.rsac

*** PATHWAY CONTRIBUTION TO THE EDE (rem), DOWNWIND DISTANCE = 3.00E+03 (m)

      NUCLIDE      INHALATION  INGESTION  GROUND SUR  AIR IMMERS  TOTAL
      -----      -
      SUBTOTALS    4.03E-03    8.61E-02    4.17E-03    -          9.43E-02
                        FINITE MODEL CLOUD GAMMA    3.08E-02
                                                    -----
                                                    TOTAL    1.25E-01

EXECUTION time = 1.03E+00 SECONDS
  
```

Figure 3.34 - Summary of Dose by Pathway

- Summary of Dose by Pathway and Radionuclide - Summarizes the CEDE for each radionuclide and each pathway (Figure 3.35). It does not summarize for the plume gamma pathway.

```

Radiological Safety Analysis Computer Program (RSAC 6.2)
Windows RSAC Plus (WinRp 2.0.0)
Name: Brad Schrader      Company: INEEL
Serial: H4JY6-52RR0-E    Run Date: 06/29/2005      Run Time: 09:20:28
File: Crit Accident Generic Calculation.rsac
  
```

*** PATHWAY CONTRIBUTION TO THE EDE (rem), DOWNWIND DISTANCE = 3.00E+03 (m)

NUCLIDE	INHALATION	INGESTION	GROUND SUR	AIR IMMERS	TOTAL
611510 Pm-151	3.61E-13	8.62E-17	1.98E-14	-	3.81E-13
621510 Sm-151	1.55E-10	1.92E-11	1.65E-15	-	1.74E-10
631520 Eu-152	3.38E-10	9.37E-11	1.05E-10	-	5.37E-10
621530 Sm-153	7.89E-14	4.73E-17	1.57E-15	-	8.06E-14
641530 Cd-153	2.65E-16	9.25E-17	4.67E-17	-	4.04E-16
631540 Eu-154	1.52E-07	4.75E-08	3.87E-08	-	2.38E-07
621550 Sm-155	4.38E-15	0.00E+00	6.95E-17	-	4.45E-15
631550 Eu-155	7.52E-08	2.55E-08	6.36E-09	-	1.07E-07
621560 Sm-156	1.48E-14	9.87E-20	2.45E-16	-	1.51E-14
631560 Eu-156	8.63E-15	4.77E-15	2.88E-15	-	1.63E-14
631570 Eu-157	2.74E-12	1.67E-16	1.02E-13	-	2.84E-12
631580 Eu-158	9.29E-13	0.00E+00	8.02E-14	-	1.01E-12
641590 Cd-159	3.34E-14	4.90E-18	7.33E-16	-	3.41E-14
942380 Pu-238	7.01E-09	6.04E-11	9.52E-16	-	7.07E-09
922340 U-234	8.68E-19	1.45E-17	1.20E-21	-	1.53E-17
902300 Th-230	0.00E+00	0.00E+00	-	-	0.00E+00
882260 Ra-226	0.00E+00	0.00E+00	-	-	0.00E+00
942390 Pu-239	3.83E-08	3.34E-10	2.09E-15	-	3.87E-08
922350 U-235	1.40E-21	2.43E-20	6.45E-24	-	2.58E-20
SUBTOTALS	4.03E-03	8.61E-02	4.17E-03	-	9.43E-02
FINITE MODEL CLOUD GAMMA					3.08E-02
TOTAL					1.25E-01

EXECUTION time = 1.01E+00 SECONDS

Figure 3.35 - Summary of Dose by Pathway and Radionuclide

- Summary of Dose by Organ – Requires the selection of organs on optional screen 3 (Figure 3.36). 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 you click the Clear Selected button then all organs will be unselected. An example of the summary is shown in Figure 3.37.

Figure 3.36 - Screen 3 (Optional), Organ Selection

```

Radiological Safety Analysis Computer Program (RSAC 6.2)
Windows RSAC Plus (WinRp 2.0.0)
Name: Brad Schrader      Company: INEEL
Serial: H4JY6-52RR0-E    Run Date: 06/29/2005    Run Time: 09:33:26
File: Crit Accident Generic Calculation.rsac

*** SUM OF ORGAN DOSE (rem), DOWNWIND DISTANCE = 3.00E+03 (m)

      NUCLEIDE      LLI Wall      Breast      Thyroid      Spleen
      -----      -
      TOTALS      4.60E-03      5.39E-03      2.92E+00      4.98E-03

      EXECUTION time = 1.05E+00 SECONDS
  
```

Figure 3.37 - Summary of Dose by Organ

- Summary of Dose by Organ and Radionuclide – Same as previous option but adds the radionuclides to the summary. The organ selection optional screen 3 will be shown with a note that it is summarized by organ and radionuclide (Figure 3.38). An example of the summary is shown in Figure 3.39.

Figure 3.38 – Screen 3 (Optional), Organ selection with Note

```

Radiological Safety Analysis Computer Program (RSAC 6.2)
Windows RSAC Plus (WinRp 2.0.0)
Name: Brad Schrader      Company: INEEL
Serial: H4JY6-52RR0-E    Run Date: 06/29/2005      Run Time: 09:34:43
File: Crit Accident Generic Calculation.rsac
  
```

*** SUM OF ORGAN DOSE (rem), DOWNWIND DISTANCE = 3.00E+03 (m)

NUCLIDE	ULI Wall	BSurface	Liver	Brain
611510 Pm-151	1.01E-12	4.86E-14	3.97E-14	1.73E-14
621510 Sm-151	6.49E-11	2.70E-09	7.20E-10	5.54E-17
631520 Eu-152	4.63E-10	1.63E-09	2.22E-09	9.43E-11
621530 Sm-153	1.81E-13	2.85E-14	2.87E-14	1.07E-15
641530 Gd-153	3.74E-16	3.99E-15	1.13E-15	3.08E-17
631540 Eu-154	2.08E-07	1.16E-06	9.44E-07	3.48E-08
621550 Sm-155	2.12E-16	1.26E-15	5.55E-16	5.57E-17
631550 Eu-155	8.98E-08	1.12E-06	3.56E-07	4.80E-09
621560 Sm-156	2.62E-14	9.82E-15	1.02E-14	2.02E-16
631560 Eu-156	2.79E-14	1.03E-14	1.12E-14	2.64E-15
631570 Eu-157	7.59E-12	5.55E-13	7.62E-13	8.63E-14
631580 Eu-158	2.53E-13	1.70E-13	1.86E-13	7.29E-14
641590 Gd-159	8.37E-14	3.86E-14	4.29E-14	6.06E-16
942380 Pu-238	1.98E-12	1.27E-07	2.34E-08	2.54E-17
922340 U-234	3.38E-18	2.14E-16	4.88E-19	1.47E-22
902300 Th-230	0.00E+00	0.00E+00	0.00E+00	-
882260 Ra-226	0.00E+00	0.00E+00	0.00E+00	-
942390 Pu-239	9.25E-12	7.03E-07	1.26E-07	2.98E-16
922350 U-235	6.24E-21	3.56E-19	8.39E-22	5.49E-24
TOTALS	4.55E-03	6.99E-03	4.76E-03	3.78E-03

EXECUTION time = 1.03E+00 SECONDS

Figure 3.39 – Summary of Dose by Organ and Radionuclide

- Summary of Dose from Contribution to EDE - See Figure 3.40 for an example

```
*** SUM OF CONTRIBUTIONS TO THE EDE (rem), DOWNWIND DISTANCE = 3.00E+03 (m)
```

NUCLIDE	***CEDE	Ext EDE	EDE	Percent
TOTALS	9.01E-02	3.49E-02	1.25E-01	1.00E+02

EXECUTION time = 1.03E+00 SECONDS

Figure 3.40 - Summary of Dose from Contribution to EDE

- Summary of Dose from Contribution to EDE and Radionuclide - See Figure 3.41 for an example.

```

Radiological Safety Analysis Computer Program (RSAC 6.2)
Windows RSAC Plus (WinRp 2.0.0)
Name: Brad Schrader      Company: INEEL
Serial: H4JY6-S2RR0-E    Run Date: 06/29/2005      Run Time: 09:40:00
File: Crit Accident Generic Calculation.rsac

```

***CEDE	Ext EDE	EDE	Percent		
631550 Eu-155	1.01E-07	6.36E-09	1.07E-07	8.57E-05	
621560 Sm-156	1.48E-14	2.45E-16	1.51E-14	1.21E-11	
631560 Eu-156	1.34E-14	2.88E-15	1.63E-14	1.30E-11	
631570 Eu-157	2.74E-12	1.02E-13	2.84E-12	2.27E-09	
631580 Eu-158	9.29E-13	8.02E-14	1.01E-12	8.07E-10	
641590 Gd-159	3.34E-14	7.33E-16	3.41E-14	2.73E-11	
942380 Pu-238	7.07E-09	9.52E-16	7.07E-09	5.65E-06	
922340 U-234	1.53E-17	1.20E-21	1.53E-17	1.23E-14	
942390 Pu-239	3.87E-08	2.09E-15	3.87E-08	3.09E-05	
922350 U-235	2.57E-20	6.45E-24	2.58E-20	2.06E-17	
872230 Fr-223	0.00E+00	1.92E-26	1.92E-26	1.54E-23	
CLOUD GAMMA	-	3.08E-02	3.08E-02	2.46E+01	
TOTALS	9.01E-02	3.49E-02	1.25E-01	1.00E+02	

```

EXECUTION time = 1.06E+00 SECONDS

```

Figure 3.41 - Summary of Dose from Contribution of EDE and Radionuclide

- Summary of Dose from Contribution to EDE and Radionuclide Sorted by Dose - Highest to Lowest, see Figure 3.42 for an example.

```
*** SUM OF CONTRIBUTIONS TO THE EDE (rem), DOWNWIND DISTANCE = 3.00E+03 (m)
SORTED BY PERCENT OF EDE
```

NUCLIDE	***CEDE	Ext EDE	EDE	Percent
531310 I-131	8.70E-02	3.62E-04	8.74E-02	6.99E+01
CLOUD GAMMA	-	3.08E-02	3.08E-02	2.46E+01
531340 I-134	2.08E-03	3.67E-03	5.75E-03	4.60E+00
531330 I-133	4.57E-04	6.29E-05	5.20E-04	4.16E-01
531320 I-132	2.78E-04	4.53E-05	3.23E-04	2.58E-01
521330 Te-133	9.19E-05	2.03E-05	1.12E-04	8.97E-02
551370 Cs-137	8.87E-05	1.30E-09	8.87E-05	7.10E-02
380900 Sr- 90	3.64E-05	1.84E-10	3.64E-05	2.91E-02

Figure 3.42 - Summary of Dose from Contribution to EDE and Radionuclide Sorted by Dose

3.2.4 5000 Series - Dispersion Control Input

Screen 2 - Dispersion Options: After the series title screen the Dispersion options screen is displayed (Figure 3.43). Select the type of dispersion control desired and click on the next button.

Figure 3.43 – 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: Shown only if option 1 was chosen on screen 2. Enter the Meteorological Conditions and click on next (Figure 4.44). If questions arise on what the inputs are or how the default values were chosen, move your cursor over the item in question and right-click and click on Display Help. Select Help and the information will be displayed (Figure 4.45).

General Meteorological Information (Line 5001)

Help

General Meteorological Information

Average Wind Velocity Meters/Second

Stack Height (m) (Range <= 200m) Typical stack heights are at least 2.5 times the building height.

Mixing Depth (m) (Range <= 3000m, default = 400 m)

Air Density (g/cu m) (Range 5.E2 to 2.E3, default = 1.099E3)

Washout Factor (l/s) (default = 0)
Wet deposition scavenging coefficient (l/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 with a median value of 1.5 E-4. Avoid too large a value to prevent plume overdepletion.

☒ Yes ☐ No **Plume depletion by dry deposition**

< Back Comment Next >

Figure 3.44 – 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 3.45 – Help Information

Screen 4 (Optional) – Dry Deposition Variables: This screen is only shown when YES has been selected for *Plume depletion by dry deposition* on screen 3 (Figure 3.46). It is important to understand that if you don't request plume depletion the options for calculation of ingestion and ground surface dose will not be available. If the RSAC-6 default variables are chosen the then Deposition Velocities will be those defined in Figure 3.47.

Dry Deposition Variables (Line 5002 & 5003)

Help

Dry Deposition Variables

Dry Deposition Variables

☒ **RSAC-6 default variables**
☐ **User-defined variables (next screen)**

>

Figure 3.46 - Screen 4 (Optional), Dry Deposition Variables

Deposition Velocities

Deposition Velocity (meters/second) (0 <= Range <= 0.5)

<input type="text" value="0.001"/>	Solids	Deposition Velocities are for the total activity deposited on both the ground and plants.
<input type="text" value="0.01"/>	Halogens	
<input type="text" value="0"/>	Noble Gases	
<input type="text" value="0.001"/>	Cesium	
<input type="text" value="0.001"/>	Ruthenium	

>

Figure 3.47 - Default Deposition Velocities

Screen 5 (Optional) - Plume Depletion by Dry Deposition Variables: Shown only if User-defined variables is chosen on screen 4 (Figure 3.48).

Dry Deposition Variables (Line 5003)

Help

Plume Depletion by Dry Deposition Variables

Dry Deposition Variables

Particle Diameter

☒ 1.0 (μm)

Min Max Step

☐ .1

Particle Density

(g/cm³)

Chemical Form

☐ Highly Reactive

☒ Slightly Reactive

☐ Non-Reactive

Micrometeorological Effects

Temperature (°C)

Monon-Obukhov (m)

Size Distribution Type

☒ Urban Dust

☐ Transuranics

☐ Smoke

Canopy Structure

☒ Water

☐ Grasslands

☐ Agricultural Areas

☐ Forests

☐ Urban Settlements

Terrain

Terrain Amplification Factor

Friction Velocity

< Back Comment Next >

Figure 3.48 - Screen 5 (Optional), Plume Depletion by Dry Deposition Variables

Screen 6 - Downwind Distances: Enter one or more unique downwind distances (Figure 3.49). 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.

Downwind Distances (Line 5101+)

Help

Downwind Distances

Position	Downwind Distance (meters)
1	3000
2	
3	
4	
5	
6	
7	
8	

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

(Press the enter key to add additional Downwind Distances)

< Back Comment Next >

Figure 3.49 - Screen 6, Downwind Distances

Screen 7 - Leakage Decay Constants: Enter linear or exponential constants (s) (Figure 3.50). Up to 10 sets of constants can be entered. The leakage decay constants must be entered in sets of two.

Leakage Decay Constants (Line 5201+)

Help

Leakage Decay Constants

Set	Linear Constants in Decay Function (l/s)	Exponential Constant in Decay Function (l/s)
1	1	0.
2		
3		
4		
5		
6		
7		
8		

Up to 8 sets of Leakage Decay Constants may be entered

Use leakage decay constants to calculate the radionuclide inventory decay before release to the environment.

(Press the enter key to add additional Leakage Decay Sets)

< Back Comment Next >

Figure 3.50 - Screen 7, Leakage Decay Constants

Screen 8 - Crosswind Distance: Select **Yes** if you want to enter crosswind distances; otherwise, select **No** (Figure 3.51). If yes is selected, the input fields will become active allowing up to 15 crosswind distances to be entered.

Crosswind Distance (Line 5301+)

Help

Crosswind Distance

Crosswind distances are optional and are entered only if desired. Up to 15 crosswind distances may be

Are crosswind distances to be entered? ☒ Yes ☐ No

Crosswind Distance(s)

Crosswind distances are in meters

(Press the enter key to add additional Crosswind Distances)

< Back Comment Next >

Figure 3.51 - Screen 8, Crosswind Distance

Screen 9 - Diffusion Coefficient Control: The following options are available for diffusion coefficient control (Figure 3.52):

- If you select option **1**, 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 you select option **2**, 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 you select option **3**, 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 (Figure 3.53).

Diffusion Control (Line 5400)

Help

Diffusion Control

Type of Diffusion Definition

☐ A set of standard deviations of plume concentrations will be entered for each downwind distance
☒ Program calculated standard deviations of plume concentration
☐ Chi/Q values will be input directly

>= 100 meters - calculated
 1 < 100 meters - extrapolated

Building Wake Control

Building Width (meters) (Option only when stack height = 0)
 Building Height (meters) (Option only when stack height = 0)

>

Figure 3.52 - Screen 9, Diffusion Coefficient Control

Building Wake Control

Building Width (meters) (Option only when stack height = 0)
 Building Height (meters) (Option only when stack height = 0)

Figure 3.53 - Building wake Control

Screen 10A (Optional) - Coefficient of Standard Deviation: Shown only if option 1 was chosen on screen 9 (Figure 3.54).

The screenshot shows a software window titled "Coefficient of Standard Deviation (Line 5401+)" with a standard Windows-style title bar (minimize, maximize, close buttons). Below the title bar is a "Help" button. The main content area has a purple header bar with the text "Coefficient of Standard Deviation". Below this, there are three input fields arranged horizontally. The first field is labeled "Downwind Distance (m)" and contains the value "3000". The second field is labeled "SigY (meters)" and is empty. The third field is labeled "SigZ (meters)" and is empty. At the bottom of the window, there are three buttons: "< Back", "Comment", and "Next >".

Figure 3.54 - Screen 10A (Optional), Coefficient of Standard Deviation

Screen 10B (Optional) - Plume Standard Deviation Control: Shown only if option 2 was chosen on screen 9 (Figure 3.55). Note: Weather class *F Extremely Stable (Fumigation)* is only available if stack height was equal to zero on screen 3.

Plume Standard Deviation Control (Line 5410)

Help

Plume Standard Deviation Control

Plume Rise Indicator

- ☐ No program calculated plume rise
- ☒ **Jet Plume Rise**
- ☐ Buoyant Plume Rise

Type of Standard Deviation Set

- ☐ Hillsmeier-Gifford (H-G)
- ☒ **Markee**
- ☐ Pasquill-Gifford (P-G)

Weather Class

- ☐ A Extremely Unstable
- ☐ B Moderately Unstable
- ☐ C Slightly Unstable
- ☐ D Neutral
- ☐ E Slightly Stable
- ☐ F Moderately Stable
- ☒ **F Extremely Stable (Fumigation)** (Available if Stack Height > 0, and Mixing Depth >= Stack Height (Line 5001))
- ☐ G Extremely Stable (allowed only for P-G standard deviations)

< **Back** **Comment** **Next** >

Figure 3.55 - Screen 10B (Optional), Plume Standard Deviation Control

Screen 10C (Optional) - Direct Chi/Q Input: Shown only if option 3 was chosen on screen 9 (Figure 3.56).

Direct Chi/Q Input (Line 5421)

Help

Direct Chi/Q Input

Enter Chi/Q values for Downwind Distances

Dose calculations using finite plume model, ground surface and ingestions are not allowed when Chi/Q is input directly.

Chi/Q Values

Downwind Distance (m)	Direct Chi/Q Input
3000	<input type="text"/>

< Back Comment Next >

Figure 3.56 - Screen 10C (Optional), Direct Chi/Q Input

Screen 11A (Optional) - Jet Plume Rise Parameters: Shown only if *Jet Plume Rise* was chosen on *Plume Standard Deviation Control* screen 10B (Figure 3.57).

Jet Plume Rise Parameters (Line 5411)

Help

Jet Plume Rise Parameters

Internal Stack Diameter (meters)

Restoration Acceleration (default = $8.7E-4[s^{-2}]$ for a weak inversion, default = $1.75E-3[s^{-2}]$ for a strong inversion)

Effluent velocity of gases from the stack (meters/second)

< Back Comment Next >

Figure 3.57 - Screen 11A (Optional), Jet Plume Rise Parameters

Screen 11B (Optional) - Buoyant Plume Rise Parameters: Shown only if *Buoyant Plume Rise* was

chosen on *Plume Standard Deviation Control* screen 10B (Figure 3.58).

Figure 3.58 - 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 (Figure 3.59).

Figure 3.59 - Reports Tab

Screen 2 - Radionuclide Decay Control: This screen is shown after the series title screen for the 6000 series (Figure 3.60). In this data entry screen sequence you will be asked to provide the following information:

- 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

Radionuclide Decay Control (Line 6000)

Help

Radionuclide Decay Control

Radionuclides to be decayed

- ☒ All radionuclides in the library will be decayed
- ☐ Only radionuclides that are selected on an upcoming screen will be decayed

Inventory Printout Options

- ☒ No individual radionuclide inventories are printed
- ☐ Print all fission products; and any activation products, actinides and daughters of actinides with positive values
- ☐ Same as above option except suppress short-lived fission products which have no available dose conversion factors
- ☐ Print inventory of radionuclides that have positive values at or following first decay time

Units

- ☒ Curies
- ☐ MeV/s (gamma only)
- ☐ Grams

Exponential Leakage

- ☒ No exponential leakage corrections are included
- ☐ Corrections for exponential leakage decay will be manually entered

< Back Comment Next >

Figure 3.60 - Screen 2, Radionuclide Decay Control

Screen 3 (Optional) - Exponential Leakage Decay: Shown only if *Corrections for exponential leakage decay will be manually entered* was chosen on screen 2 (Figure 3.61). 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* (Figure 3.62). 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*.

Exponential Leakage Decay (Line 6001)

Help

Exponential Leakage Decay

Decay time for exponential decay function (seconds)

If 0, RSAC will default to program calculated time necessary to give 100% release. Note however that only 1 set of leakage decay constants can be defined on the next screen if the default is chosen.

< Back Comment Next >

Figure 3.61 - Screen 3 (Optional), Exponential Leakage Decay

Figure 3.62 - Leakage Decay Constants Prompt

Screen 4 (Optional) - Leakage Decay Constants: If **Yes** was chosen on the Leakage Decay Constants Prompt then the screen in Figure 3.63 will be shown to enter linear and exponential constants (s^{-1}). Up to 8 sets of constants can be entered. After entering a set of constants, press the <enter> key to allow entry of another set.

Set	Linear Constants in Decay Function (l/s)	Exponential Constant in Decay Function (l/s)
1	1.0	0.0
2		
3		
4		
5		
6		
7		
8		

Up to 8 sets of Leakage Decay Constants may be entered

Use leakage decay constants to calculate the radionuclide inventory decay before release to the environment.

(Press the enter key to add additional Leakage Decay Sets)

< Back Comment Next >

Figure 3.63 - Screen 4 (Optional), Leakage Decay Constants

Screen 5 (Optional) - Radionuclide Selection: Shown only if Only *radionuclides that are selected on an upcoming screen will be decayed* was chosen on screen 2. On this screen (Figure 3.64), 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 3.64 - Screen 5 (Optional), Radionuclide Selection

Screen 6 - Decay Times: The screen asks if you want to enter decay times directly (Figure 3.65). 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 3.65 - 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 (Figure 3.66) 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 3.66 - Screen 7 (Optional), Summation Control

Screen 8 (Optional) - Element Summation: Shown only if *The radionuclide inventory is summed of each element selected on the next screen* is chosen on screen 7. On this screen (Figure 3.67), 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 3.67 - Screen 8 (Optional), Element Summation

3.2.6 7000 Series - Internal/External Dose Calculation

Screen 2 - Dose Control Calculation: After the series title screen the Dose Control Calculation screen is displayed (Figure 3.68). In this data entry screen you will be asked to provide the following information:

- Type of dose calculation
- 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

Based on the type of calculation chosen, a different screen sequence will be presented.

Dose Calculation Control (Line 7000)

Help

Dose Calculation Control

Type of Dose Calculation

- ☒ ICRP-30 Inhalation, program default parameters
- ☐ ICRP-30 Inhalation, parameters to be entered on later screen
- ☐ Ingestion, default to program calculated parameters
- ☐ Ingestion with parameters entered on later screen
- ☐ Ground Surface
- ☐ Air immersion
- ☐ Resuspended activity - ICRP-30 Inhalation default parameters
- ☐ Resuspended activity - ICRP-30 Inhalation user-defined parameters

Dose Unit

- ☒ rem
- ☐ Sv

Elements for Calculation

- ☒ All elements
- ☐ Elements will be listed on a upcoming screen

Organ choice

- ☒ Default to all organs
- ☐ Organs will be listed on a upcoming screen

Output Control for Dose

- ☒ Only dose summaries
- ☐ Dose summaries plus total organ doses
- ☐ Dose summaries plus doses for each element
- ☐ Dose summaries plus doses for each radionuclide
- ☐ Dose summaries plus total crosswind doses for each organ

< Back Comment Next >

Figure 3.68 - Screen 2, Dose Control Calculation

Screen 3A (Optional) - Inhalation Dose Control: Shown 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 (Figure 3.69).

Inhalation Dose Control (Line 7001)

Help

Inhalation Dose Control

Breathing rate for inhalation calculations (m^3/s)

DOE Order 440.1 (3.33E-04)

Decay Time for exponential decay function (seconds)
If 0, RSAC defaults to program calculated time necessary to give 100% releases. (Exposure Time in seconds for a release to a room)

0

Respirable Fraction

1

< Back Comment Next >

Figure 3.69 - Screen 3A (Optional), Inhalation Dose Control

Screen 4A (Optional) - Inhalation Parameters Dose Calculation: Shown 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 (Figure 3.70). If user input of lung clearance classes is chosen, the *Clearance Class Entry* screen will appear next.

Inhalation Parameters Dose Calculation (Line 7003)

Help

Inhalation Parameters

AMAD

Activity median aerodynamic diameter (micron)
range = 0 or ≥ 0.1 micron (If 0, defaults to 1)

Clearance Class Selection

- ☐ Default to program-generated classes for oxides and hydroxides
- ☐ Clearance classes will be modified. Unchanged classes default to those for oxides and hydroxides
- ☒ Default to program-generated classes selected to give maximum element dose
- ☐ Clearance classes will be modified. Unchanged classes default to those selected to give maximum element dose

< Back Comment Next >

Figure 3.70 - Screen 4A (Optional), Inhalation Parameters Dose Calculation

Screen 5A (Optional) - Clearance Class Entry: Shown only if option 2 or 4 is chosen for *Clearance Class Selection* on screen 4A (Figure 3.71). 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 3.71 - Screen 5A (Optional), Clearance Class Entry

Screen 6 (Optional) - Resuspension of Activity: Only shown if option 7 or 8 is chosen for Type of Dose Calculation on screen 2 (Figure 3.72).

Resuspension of Activity

Time since deposition (days)

Exposure time to resuspended activity (days)

Linear constant in the resuspension rate function (1/d)
If 0, defaults to 4.9E-8

Exponential constant in the resuspension rate function (1/d)
If 0, defaults to 4.1E-3

< Back Comment Next >

Figure 3.72 - Screen 6 (Optional), Resuspension of Activity

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

Ingestion Dose Parameters (Line 7001)

Help

Ingestion Dose Parameters

Decay Time for exponential decay function (seconds)
If 0, RSAC defaults to program calculated time necessary to give 100% releases

TB - Plant mid point of operating life (yr)

< **Back** **Comment** **Next >**

Figure 3.73 - Screen 3B (Optional) - Ingestion Dose Parameters

Screen 4B (Optional) - Ingestion Dose Control: Shown only if option 4 is chosen for *Type of Dose Calculation* on screen 2 (Figure 3.74). 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-6.2 default ingestion parameters.

Ingestion Dose Control (Line 7004)

Help

Ingestion Dose Control

Ingestion Transfer Parameter

- ☒ Program default transfer parameters used
- ☐ Program default transfer parameters used and printed out
- ☐ Ingestion transfer parameters read from external file 'TRANCON'

Ingestion Calculation Control

- ☒ Chronic release with program default parameters
- ☐ Acute release with program default parameters
- ☐ Ingestion parameters will be entered on next screen

Crop Information

Time period that crops are exposed to contamination following the end of the acute release (days)
Time must be between 0.04167 day (1 hour) and 60 days

Harvest duration period following the end of the acute release (days)
Time must be between 0 and 60 days (default, 7 days)

< **Back** **Comment** **Next >**

Figure 3.74 - Screen 4B (Optional), Ingestion Dose Control

Screen 5B (Optional) - Ingestion Dose Constants: Shown only if *Ingestion parameters will be entered on next screen* is chosen on screen 4B (Figures 3.75, 3.76, 3.77, 3.78, 3.79). Note: All tabs will need to be reviewed before continuing.

The screenshot shows a software window titled "Ingestion Dose Constants (Line 7051+)" with a "Help" button. The main title bar is "Ingestion Dose Constants". Below the title bar are five tabs: "Usage Constants" (selected), "Retention Constants", "Field Factors", "Forage Constants", and "Acute Modifiers". The "Usage Constants" tab contains six input fields with the following labels and values:

Input Field Value	Label
520	Stored vegetable usage factor (kg/yr wet weight)
64	Fresh vegetable usage factor (kg/yr wet weight)
110	Meat usage factor (kg/yr wet weight)
310	Milk usage factor (liters/yr)
0.76	Fraction of stored vegetables from garden
1	Fraction of fresh vegetables from garden

Below the input fields is a "Comment" button. At the bottom right of the window are three buttons: "< Back", "Comment", and "Next >".

Figure 3.75 - Screen 5B (Optional), Usage Constants Tab

The screenshot shows a software window titled "Ingestion Dose Constants (Line 7051+)" with a standard Windows-style title bar (minimize, maximize, close buttons). Below the title bar is a "Help" button. The main area has a purple header with the text "Ingestion Dose Constants". Below this header are five tabs: "Usage Constants", "Retention Constants" (which is selected and highlighted in blue), "Field Factors", "Forage Constants", and "Acute Modifiers". The "Retention Constants" tab contains a list of seven parameters, each with a text input field and a label:

- Retention factor for activity on forage: Input field contains "0.57".
- Retention factor for activity on vegetables: Input field contains "0.2".
- Retention factor for iodines on forage: Input field contains "1".
- Removal rate constant for crops (l/hr): Input field contains "0.0021".
- Vegetable exposure time to plume for chronic release (days): Input field contains "60".
- Forage exposure time to plume for chronic release (days): Input field contains "30".
- HTO removal half time (days): Input field contains "1".

Below the list of parameters is a "Comment" button. At the bottom right of the window are three buttons: "< Back", "Comment", and "Next >".

Figure 3.76 - Screen 5B (Optional), Retention Constants Tab

Ingestion Dose Constants (Line 7051+)

Help

Ingestion Dose Constants

Usage Constants Retention Constants **Field Factors** Forage Constants Acute Modifiers

<input type="text" value="225"/>	Effective surface density for soil (kg/m ²)
<input type="text" value="60"/>	Stored vegetable holdup time after harvest (days)
<input type="text" value="1"/>	Fresh vegetable holdup time after harvest (days)
<input type="text" value="16"/>	Animals daily forage feed (kg/day dry weight)
<input type="text" value="2"/>	Feed-milk receptor transfer time (days)
<input type="text" value="20"/>	Slaughter to consumption time (days)

Figure 3.77 - Screen 5B (Optional), Field Factors Tab

The screenshot shows a software window titled "Ingestion Dose Constants (Line 7051+)" with a standard Windows-style title bar (minimize, maximize, close buttons). Below the title bar is a "Help" button. The main area has a tabbed interface with five tabs: "Usage Constants", "Retention Constants", "Field Factors", "Forage Constants" (which is selected and highlighted in blue), and "Acute Modifiers". The "Forage Constants" tab contains a list of six parameters, each with a text input field and a label:

Value	Description
0.4	Fraction of year that animals graze
0.43	Fraction of feed that is pasture when animal grazes on pasture
90	Stored feed holdup time (days)
2	Vegetable vegetation yield (kg/m ² wet weight)
0.28	Forage vegetation yield (kg/m ² dry weight)
4.9	Absolute humidity (g/m ³)

Below the list is a "Comment" text box. At the bottom right of the window are three buttons: "< Back", "Comment", and "Next >".

Figure 3.78 - Screen 5B (Optional), Forage Constants Tab

Ingestion Dose Constants (Line 7051+)

Help

Ingestion Dose Constants

Usage Constants Retention Constants Field Factors Forage Constants **Acute Modifiers**

Fraction of annual stored vegetables that are contaminated by acute release

Fraction of annual fresh vegetables that are contaminated by acute release

Fraction of annual stored forage that is contaminated by acute release

Fraction of annual fresh forage that is contaminated by acute release

Figure 3.79 - 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 (Figure 3.80).

Ground Surface Dose Parameters (Line 7001)

Help

Ground Surface Dose Parameters

Decay Time for exponential decay function (seconds)
If 0, RSAC defaults to program calculated time necessary to give 100% releases

TB - The time (yr) that the receptor is exposed to the contaminated ground surface following initiation of the release
If >0 and <1, a warning will be posted by RSAC stating that an exposure period of less than 1 year has been chosen.

Building shielding factor for ground surface calculations

Occupancy factor

< Back Comment Next >

Figure 3.80 - Screen 3C (Optional), Ground Surface Dose Parameters

Screen 3D (Optional) - Air Immersion Dose Parameters: Shown only if option 6 is chosen for *Type of Dose Calculation* on screen 2. Enter decay time (s) for exponential decay functions (Figure 3.81).

Air Immersion Dose Parameters (Line 7001)

Help

Air Immersion Dose Parameters

Decay Time for exponential decay function (seconds)
If 0, RSAC defaults to program calculated time necessary to give 100% releases

< Back Comment Next >

Figure 3.81 - Screen 3D (Optional), Air Immersion Dose Parameters

Screen (Optional) - Internal/External Organ Selection: Shown only if *Organs will be listed on a upcoming screen* is chosen on screen 2. On this screen (Figure 3.82), 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 3.82 - Screen (Optional), Internal/External Organ Selection

Screen (Optional) - Element Selection: Shown only if *Elements will be listed on a upcoming screen* is chosen on screen 2. On this screen (Figure 3.83), 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 3.83 - screen (Optional), Element Selection

3.2.7 8000 Series - Fifty-Mile Radius Dose Calculation

Screen 2 - Radionuclide Input: After the series title screen the Radionuclide Input screen is displayed (Figure 3.84). Use The *Radionuclide Data Selection* options to indicate whether radionuclides for dose calculations will be obtained from previous 1000 or 2000 Series entries or will be selected from the list. Select the radionuclide and input the activity desired 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: 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: Up to 100 radionuclides can be input.

Radionuclide Input (Line 8001)

Help

Radionuclide Input

Radionuclide Data Selection

☒ Doses will be calculated from radionuclide inventory currently in memory from previous 1000 Series calculation or 2000 entry. Existing inventory may not contain more than 100 radionuclides with inventories greater than 0.

☐ Radionuclides will be selected below.

Curie Input

Symbol	Atomic#	Mass	State	Curies
Ac	089	225		
Ac	089	227		
Ac	089	228		
Ag	047	106		
Ag	047	106	m	
Ag	047	108		
Ag	047	108	m	
Ag	047	109	m	
Ag	047	110		
Ag	047	110	m	
Ag	047	111		
Ag	047	111	m	

Clear Selected Enter Curie

< Back Comment Next >

Figure 3.84 - Screen 2, Radio nuclide Input

Screen 3 - Model Control: The selected options on this screen will determine the sequence that subsequent screens will be displayed (Figure 3.85). The following information will assist you in preparing your selections:

- Clearance Class Selection - Indicate whether you want to default to program-generated lung clearance classes or modify them on an upcoming screen.
- Dose Unit - Indicate whether the doses will be expressed in rem or Sv.
- Input control for ingestion - Indicate whether the dose will be from a chronic release or if the ingestion dose calculations will be controlled by parameters you supply.
- Input control for building shielding/exposure factors - Indicate whether the program default values are to be used or if you will provide shielding/exposure values.

You will be asked to also provide an average breathing rate, the plant midpoint of operation life, and the time that the receptor is exposed to the contaminated ground surface following initiation of the release.

Model Control (Line 8011)

Help

Model Control

Clearance Class Selection

- ☒ Default to program-generated classes for oxides and hydroxides.
- ☐ Clearance classes will be modified. Unchanged classes default to those for oxides and hydroxides.
- ☐ Default to program generated classes selected to give maximum element dose.
- ☐ Clearance classes will be modified. Unchanged classes default to those selected to give maximum element dose.

Input Control for Ingestion

- ☒ Chronic ingestion dose with program default parameters.
- ☐ Ingestion dose controlled with user supplied parameters.

Building Shielding/Exposure Factors

- ☒ Program supplied standard parameters
- ☐ User supplied factors to be entered

Dose Unit

- ☒ rem
- ☐ Sv

Model Control

Average Breathing Rate (m³/second) Defaults to 2.66E-4 for 24-hour Average Breathing Rate.

Plant mid point of operation life (yr)

TBG - The time (yr) that the receptor is exposed to the contaminated ground surface following initiation of the release.
If >0 and <1, a warning will be posted by RSAC stating that an exposure period of less than 1 year has been chosen.

< Back Comment Next >

Figure 3.85 – Screen 3, Model Control

Screen 4 - Dose Organ Selection: On this screen (Figure 3.86), select the organs to be included in the dose calculation by 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. Note: A maximum of four organs can be selected. Doses can be calculated for additional organs by repeating the 8000 Series input.

Organ Control (Line 8012)

Help

Organ Control

Select at least 1 but not more than 4 organs

Fifty-mile dose calculations can be made for up to a maximum of four organs at a time. Calculations for additional organs can be made by repeating the 8000 Series lines.

Organs

Organ	Selected
Lungs	☒
Stomach Wall	☐
Small Intestine Wall	☐
Upper Large Intestine Wall	☐
Lower Large Intestine Wall	☐
Testes	☐
Breast	☐
Bone Surface	☐
Red Marrow	☐
Thyroid	☐
Kidneys	☐
Liver	☐

Clear Selected

< Back Comment Next >

Figure 3.86 - Screen 4, Dose Organ Selection

Screen 5 (Optional) - Building Shielding/Exposure: Shown only if *User supplied factors to be entered* was chosen for *Input control for building shielding/exposure factors* on screen 3. Enter the building shielding factor for deposition calculations and the exposure factor for air immersion calculations (Figure 3.87).

Building Shielding/Exposure Factors (Line 8013)

Help

Building Shielding/Exposure Factors

Building Shielding Factors for Deposition Calculations (0 >= Range <= 1)

Exposure Factor for Air Immersion Calculations (0 >= Range <= 1)

< Back Comment Next >

Figure 3.87 - Screen 5 (Optional), Building Shielding/Exposure

Screen 6 (Optional) - Ingestion Dose Control: Shown only if *Ingestion dose controlled with user supplied parameters* is chosen for *Input Control for Ingestion* on screen 3. The following information is required for this screen (Figure 3.88):

- Ingestion Transfer Parameter - Indicate whether program default transfer parameters are to be used, if they are to be printed, or if they are to be read from the external file **TRANCON**.
- Ingestion calculation control - Indicate whether the release will be chronic, acute, or if you will enter ingestion parameters.
- Crop Information - Enter the time period that crops are exposed to contamination during the growing season. If the choice in the *Ingestion calculation control* above was that the release is acute or if ingestion parameters would be entered by the user, the user will be requested to provide the harvest duration period following the end of the release time.

Ingestion Dose Control (Line 8014)

Help

Ingestion Dose Control

Ingestion Transfer Parameter

- ☒ Program default transfer parameters used
- ☐ Program default transfer parameters used and printed out
- ☐ Ingestion transfer parameters read from external file 'TRANCON'

Ingestion Calculation Control

- ☒ Chronic release with program default parameters
- ☐ Acute release with program default parameters
- ☐ Ingestion parameters will be entered on an upcoming screen

Crop Information

Time period that crops are exposed to contamination following the end of the acute release (days)
Time must be between 0.04167 day (1 hour) and 60 days

Harvest duration period following the end of the acute release (days)
Time must be between 0 and 60 days (default, 7 days)

< Back Comment Next >

Figure 3.88 - Screen 6 (Optional), Ingestion Dose Control

Screen 7 - Exponential Leakage Rates: Indicate whether you will use program-calculated values or specify constants for the exponential leakage decay function (Figure 3.89). If exponential rates will be specified the input below will be come active allowing user entry.

Exponential Leakage Rates (Line 8020)

Help

Exponential Leakage Rates

Type of Release

Exponential leak rates can be specified or defaulted to program calculated values necessary to give 100% release

☒ Use program calculated values
☐ Exponential rates will be specified

Exponential Leakage Decay Time

0 Decay time for exponential decay function (seconds)
 If 0, RSAC defaults to program calculated time necessary to give 100% releases

< Back Comment Next >

Figure 3.89 - Screen 7, Exponential Leakage Rates

Screen 8 (Optional) - Leakage Decay Constants: Shown only if Exponential rates will be specified is chosen on screen 7. Enter linear and exponential constants (s^{-1}) (Figure 3.90). Normally only one set of constants is entered; however, up to 8 sets of constants can be entered.

Leakage Decay Constants (Line 8021)

Help

Leakage Decay Constants

Set	Linear Constants in Decay Function (1/s)	Exponential Constant in Decay Function (1/s)
1	1.0	0.0
2		
3		
4		
5		
6		
7		
8		

Up to 8 sets of Leakage Decay Constants may be entered

Use leakage decay constants to calculate the radionuclide inventory decay before release to the environment.

(Press the enter key to add additional Leakage Decay Sets)

< Back Comment Next >

Figure 3.90 - Screen 8 (Optional), Leakage Decay Constants

Screen 9 (Optional) - Clearance Class Entry: Shown only if clearance classes were chosen to be modified on screen 3 (Figure 3.91). 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 3.91 - Screen 9 (Optional), Clearance Class Entry

Screen 10 - External Files: Use this screen to specify whether an external file containing χ/Q , population, and wind velocity data will be used or if WINRP 2.0 will be used to enter the information (Figure 3.92). If **Yes**, supply the file name by clicking the Select File button. If **No**, you will be advised that subsequent screens require entry of almost 200 data points and you will be given a chance to reconsider the option. If you choose to continue, 16 screens for each of the 16 compass sectors will be provided. On each of the screens, provide the average wind velocity toward the sector and the population and χ/Q for each of the five radii (Figure 3.93). Two additional screens will then appear.

External File for Population and Dispersion (Line 8050)

Help

External File

External File Option

An external file can be specified that contains X/Q, population, and wind velocity information for all 16 sectors (see manual for details). If no external file is to be specified X/Q, population, and wind velocity information will be entered on the following screens.

Would you like to specify an external file? ☐ Yes ☒ No

File Name:

< Back Comment Next >

Figure 3.92 - Screen 10, External Files

Sector Information (Lines 8051+, 8071+, and 8091+)

Help

Sector Information

Wind Velocity, Population, and X/Q for Sectors of Compass

Values for 16 sectors will be needed

Sector #1: N

(m/s) Wind Velocity toward **Sector #1: N**

Miles	Population	X/Q (s/m ³) (0 < X/Q <= .01)
0-10	<input type="text"/>	<input type="text"/>
10-20	<input type="text"/>	<input type="text"/>
20-30	<input type="text"/>	<input type="text"/>
30-40	<input type="text"/>	<input type="text"/>
40-50	<input type="text"/>	<input type="text"/>

Compass Rose Diagram: N, NNW, NW, WNW, W, WSW, SW, SSW, S, SSE, SE, ESE, E, NNE, NE.

Next Sector < Back Comment Next >

Figure 3.93 - Screen 11 (Optional), Sector Information

Screen 12 (Optional) - Meteorological Data for Site Boundary: Shown only if an external file was not specified on screen 10. Use this screen to provide the sector number that contains the maximum exposed individual, the χ/Q for the maximum exposed individual, the distance to the maximum exposed individual, and the average wind velocity toward the maximum exposed individual (Figure 3.94).

Meteorological Data for Site Boundary (Line 8110)

Help

Meteorological Data for Site Boundary

1 Sector Number that contains maximum exposed individual

X/Q for maximum exposed individual (s/m3) (0 < Range < 1.)

Distance to maximum exposed individual (m) (must be >= 10)

Average Wind Velocity toward maximum exposed individual (m/s)

< Back Comment Next >

Figure 3.94 - Screen 12 (Optional), Meteorological Data for Site Boundary

Screen 13 (Optional) - External File Generator: Shown only if an external file was not specified on screen 10. This screen offers the option to create an external 8000 Series file with the data that have just been entered (Figure 3.95). If you will be making additional 8000 Series calculations using the same population and meteorological data, an external file eliminates the need to reenter all of the data or reedit the entire 8000 Series. An ASCII text is created that can be read by RSAC-6.2 and WINRP 2.0

Create External File

Help

Create External File

The option is available to create an external 8000 Series file with the data that has just been entered. This option is useful if the same data will be used in future Fifty Mile Dose Calculations.

Save to External File

< Back Comment Next >

Figure 3.95 - Screen 13 (Optional), External File Generator

Screen 14 - Deposition Velocities: Enter the deposition velocity of solids, halogens, noble gases, cesium, and ruthenium (Figure 3.96).

Deposition Velocities
(meters/second) (0 <= Range <= 0.5)

<input type="text" value="0.001"/>	Solids	Deposition Velocities are for the total activity deposited on both the ground and plants.
<input type="text" value="0.01"/>	Halogens	
<input type="text" value="0"/>	Noble Gases	
<input type="text" value="0.001"/>	Cesium	
<input type="text" value="0.001"/>	Ruthenium	

< **Back** **Comment** **Next >**

Figure 3.96 - screen 14, Deposition Velocities

Screens 15 (Optional) - Ingestion Constants: Shown only if Ingestion parameters will be entered on upcoming screen was chosen on screen 6. The screens will initially contain the RSAC-6.2 default ingestion parameters (Figure 3.97). Review each tab and make adjustments as needed before continuing.

Ingestion Constants (Lines 8201+)

Help

Ingestion Constants

Usage Constants Retention Constants Field Factors Forage Constants Acute Modifiers

<input type="text" value="520"/>	Stored vegetable usage factor (kg/yr wet weight)
<input type="text" value="64"/>	Fresh vegetable usage factor (kg/yr wet weight)
<input type="text" value="110"/>	Meat usage factor (kg/yr wet weight)
<input type="text" value="310"/>	Milk usage factor (liters/yr)
<input type="text" value="0.76"/>	Fraction of stored vegetables from garden
<input type="text" value="1"/>	Fraction of fresh vegetables from garden

Comment

< **Back** **Comment** **Next >**

Figure 3.97 - screen 15 (Optional), Ingestion Constants

3.2.8 9000 Series - Cloud Gamma Dose Calculation

Screen 2 - Cloud Gamma Dose Calculation: After the series title screen the cloud gamma dose calculation screen appear asking whether calculations are to be made using the finite or semi-infinite

plume model (Figure 3.98). By checking which calculation should be used the inputs for the exponential decay function will be enabled.

Figure 3.98 – Screen 2, Cloud Gamma Dose Control

3.3 Using Critdos

To run Critdos click on the Critdos tab and click the *Launch Critdos* link (Figure 3.99).

Figure 3.99 – Critdos Tab

Screen 1 - Data Input: Use this screen to supply the following information (Figure 3.100): Title that will appear on each page of output; The total fissions; Distance in feet; Concrete thickness in inches; and the system type.

Figure 3.100 - Screen 1, Data Input

Screen 2 - Program Output: Displays the output results from Critdos (Figure 3.101).

Figure 3.101 - Screen 2, Program Output

4. Reading the RSAC-6.2 INPUT File

4.1 RSAC-6.2 Input

A typical RSAC-6.2 input line includes

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

You can use a comma or a blank space 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-6.2 input descriptions assume that all words are real numbers unless otherwise noted.

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-6.2 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-6.2 program.

Calculation Title Line

Column Entry

1

*

2-72

Page heading (alphanumeric)

RSAC-6.2 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-6.2 run, check to see if a line contains an asterisk in column 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.

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

<u>Word</u>	Variable	<u>Entry</u>	<u>Description</u>
	<u>Name</u>		
1		1000	

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 lines 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)*.

<u>Word</u>	Variable	<u>Entry</u>	<u>Description</u>
	<u>Name</u>		
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 <i>Refueling Line (1002)</i> , <i>Decay/Cycle Line (1003)</i> , or <i>Fractionation Line (1004)</i> . The values for the remaining words on this line are ignored; however, values for each of the following words must be present.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
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.

Refueling Line (1002)

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

Decay/Cycle Line (1003)

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
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.

Variable

<u>Word</u>	<u>Name</u>	<u>Entry</u>	<u>Description</u>
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.

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.

<u>Word</u>	<u>Entry</u>	<u>Description</u>
1	1004	
2	-1	Fractionation by group as specified by the next five words.
3		Fractionation for solids.
4		Fractionation for halogens.
5		Fractionation for noble gases.
6		Fractionation for cesium.
7		Fractionation for ruthenium.
2	0	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 <i>Element Fractionation Lines (1101+)</i> .
3	FRAC	Fractionation for elements not described by <i>Element Fractionation Lines (1101+)</i> .

Element Fractionation Lines (1101+)

Use these lines only if you want fractionation by element.

<u>Word</u>	<u>Entry</u>	<u>Description</u>
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		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.

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-6.2 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 chose 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 chose 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.

Variable

<u>Word</u>	<u>Name</u>	<u>Entry</u>	<u>Description</u>
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 leaked from reactor

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.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
1		1201	Radionuclide leak rate from the operating reactor (fraction/s)
2	RR(1)		Solids
3	RR(2)		Halogens
4	RR(3)		Noble gases
5	RR(4)		Cesium
6	RR(5)		Ruthenium

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)*.

<u>Word</u>	<u>Entry</u>
1	1999

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.

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.

<u>Word</u>	<u>Entry</u>	<u>Description</u>
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.

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)*.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
1	NUCL	Integer	Radionuclide identification number (see 4000 Series, <i>Radionuclide Data Change Line</i>). 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 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.

External Radionuclide File Control Line (2002)

This optional line allows you to specify an external file for inputting radionuclide inventories. This line will immediately follow a (2001) line if that option is selected; otherwise, it will 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-6.2 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.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
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.

Radionuclide Direct Input End Line (2999)

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

<u>Word</u>	<u>Entry</u>
1	2999

3000 Series—Dose Summary Option

Use this option to summarize, add, and report in summary tables doses from different exposure pathways and multiple RSAC-6.2 calculations.

Dose Summary Option Control Line (3000)

RSAC-6.2 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.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
1		3000	
2	ISUMTYPE	Integer	Type of calculation:
		1	Re-initiate the dose summary option.
		2	Summary of dose by pathway.
		3	Summary of dose by pathway and radionuclide.
		4	Summary of dose by organ [requires a (3001) Line to follow].
		5	Summary of dose by organ and radionuclide [requires a (3001) line to follow].
		6	Contribution to EDE.
		7	Contribution to EDE by radionuclide.
		8	Contribution to EDE by radionuclide sorted by dose.

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.

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

Internal

1	LUNGS
2	S WALL
3	SI WALL
4	ULI WALL
5	LLI WALL
6	TESTES
7	BREAST
8	BSURFACE
9	R MARROW
10	THYROID
11	KIDNEYS
12	LIVER
13	SPLEEN
14	PANCREAS
15	MUSCLE
16	SKIN
17	BRAIN
18	THYMUS
19	BL WALL
20	ADRENALS
21	ESUPHAGUS
22	OVARIES
23	UTERUS

5000 Series—Dispersion Control Input

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

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

<u>Word</u>	<u>Entry</u>	<u>Description</u>
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.

General Meteorological Information Line (5001)

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
1		5001	
2	UBAR		Average wind velocity (m/s)
3	SH		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

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.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
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

Downwind Distance Lines (5101+)

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
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.

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.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
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-6.2 rather than using RSAC-6.2 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.

Crosswind Distance Lines (5301+)

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

Variable		Entry	Description
Word	Name		
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.

Diffusion Control Line (5400)

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
1		5400	
2	NTRL	1	A set of standard deviations of plume concentrations is entered on the <i>Standard Deviation Lines (5401+)</i> 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).

Standard Deviation Lines (5401+)

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

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
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.

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 σ s that are available. Hilsmeier-Gifford σ s (Clawson et al. 1989) should be used for desert terrains (such as the Idaho National Engineering Laboratory) for effluent releases from a few minutes to 15 minute in duration. Markee σ s (Clawson et al. 1989) should be used for desert terrains for effluent releases from 15 to 60 minute in duration. Pasquill-Gifford σ s were developed from the Prairie Grass experiments for effluent releases from 10 to 60 minutes in duration. The Pasquill-Gifford σ s are presented in Regulatory Guide 1.145 (NRC 1982) and by Slade (1968). Carefully evaluate the appropriateness of using the program-generated σ s for effluent releases of different durations than noted above. When you consider the program-generated σ s inappropriate, word 2 on the *Diffusion Control Line (5400)* should be set to 1, and σ s should be entered directly using the (540X) lines.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
1		5410	
2	ITS	1	Hilsmeier-Gifford (H-G) σ s
		2	Markee σ s
		3	Pasquill-Gifford (P-G) σ s
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 $H \geq SH$ on a (5001) line]
		8	G Extremely Stable (allowed only for P-G σ s)
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

Plume Rise Control Line (5411)

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

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
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.

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.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
1		Integer	542X (X = 1,2,..., etc.)
2		CQ	χ/Q for the 1st 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.

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.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
1		5500	
2	ROOMVOL		Volume (m^3)

Meteorological Data End Line (5999)

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

<u>Word</u>	<u>Entry</u>
1	5999

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.

Decay Control Line (6000)

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
1		6000	
2	NCH	Integer	Printout control:
		0	Decay of radionuclides in the RSAC-6.2 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.

Decay Time for Leakage Rate Function (6001)

Use this line only when LEAK on the (6000) line is equal to 1. See Appendix A, Section A-2.4 for limitations on the use of this function.

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

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.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
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.

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:

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
1	NUCL	Integer	Radionuclide identification number (see Series 4000, <i>Radionuclide Data Change Line</i>). 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.

Decay Times Lines (6101+)

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

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
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.

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.

<u>Word</u>	<u>Entry</u>	<u>Description</u>
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 <i>Element Summation Lines (6201+)</i> that follow.

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.

<u>Word</u>	<u>Entry</u>	<u>Description</u>
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.

Decay End Line (6999)

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

<u>Word</u>	<u>Entry</u>
1	6999

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) 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.

Dose Calculation Control Line 1 (7000)

<u>Word</u>	<u>Variable</u>		<u>Description</u>
	<u>Name</u>	<u>Entry</u>	
1		7000	
2	IMOD	Integer	Type of calculation:
		0	ICRP-30 Inhalation, program default parameters.
		1	ICRP-30 Inhalation, user-supplied parameters on the (7003) line.
		2	Ingestion, default to program calculated chronic parameters.
		3	Ingestion with user supplied parameters on the (7004) line.
		4	Ground surface.
		5	Air immersion (see caution above).
		6	Resuspended Activity - ICRP-30 Inhalation, program default parameters.
		7	Resuspended Activity - ICRP-30 Inhalation, user-supplied parameters on the (7003) line.
3	ISW	Integer	Output control:
		-2	Only dose summaries.
		-1	Above plus total organ doses.
		0	Above plus doses for each element.
		1	Above plus doses for each radionuclide.
		2	Above plus total crosswind doses for each organ.

<u>Word</u>	<u>Name</u>	<u>Variable Entry</u>	<u>Description</u>
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 <i>Optional Element Selection Lines (7081+)</i> .
6	IONC	Integer	Organ number choice: 1 Default to all organs. 2 As indicated on the <i>Optional Selection of Organs Line (7002)</i> .

Dose Calculation Control Line 2 (7001)

<u>Word</u>	<u>Name</u>	<u>Variable Entry</u>	<u>Description</u>
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, "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.

<u>Word</u>	<u>Name</u>	Variable <u>Entry</u>	<u>Description</u>
			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 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.

Optional Selection of Organs Line (7002)

<u>Word</u>	Variable <u>Name</u>	<u>Entry</u>	<u>Description</u>
1		7002	User selection of organs
2	IO(1)	Integer	Organ number:
.	.		
.	.		
.	.		
N+1	IO(N)		
			Internal / External
		1	LUNG
		2	S WALL
		3	SI WALL
		4	ULI WALL
		5	LLI WALL
		6	TESTES
		7	BREAST
		8	BSURFACE
		9	R MARROW
		10	THYROID
		11	KIDNEYS
		12	LIVER
		13	SPLEEN
		14	PANCREAS
		15	MUSCLE
		16	SKIN
		17	BRAIN
		18	THYMUS
		19	BL WALL / U BLADD

Variable

<u>Word</u>	<u>Name</u>	<u>Entry</u>	<u>Description</u>
			Internal / External
		20	ADRENALS
		21	ESUPHAGUS
		22	OVARIES
		23	UTERUS
		24	CEDE ^a / EDE

- a. When $AMAD \neq 1$. [word 2 on the (7003) line], a request for CEDE automatically gives all organs.

Optional Inhalation Dose Calculation Control Line (7003)

This line is present only if IMOD (word 2) on the (7000) line is 1.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
1		7003	User-supplied inhalation parameters.
2	AMAD		Activity median aerodynamic diameter (μm). If zero, defaults to 1. AMAD must be $\geq 0.1 \mu\text{m}$.
3	ICCI		Clearance class indicator:
		1	Default to program-generated classes for oxides and hydroxides.
		2	User input of classes on (703X) lines. Unchanged classes default to those for oxides and hydroxides.
		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.

Optional Ingestion Dose Calculation Control Line (7004)

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

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
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. Requires ATIME below to be entered. 2 = User-supplied ingestion parameters on (705X) lines. Requires ATIME below to be entered.

Variable

<u>Word</u>	<u>Name</u>	<u>Entry</u>	<u>Description</u>
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 ($0 \leq \text{THD} < 60$.) 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].

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.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
1		Integer	703X (X = 1, 2, ..., etc.).
2	NN	Integer	Atomic number for element.
3	ICI(NN)	Integer	1 = Class D 2 = Class W 3 = Class Y
.	.	.	
.	.	.	
.	.	.	
2N	NN	Integer	
2N+1	ICI(NN)	Integer	

Enter as many pairs of entries on this or following lines as desired.

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).

<u>Word</u>	<u>Variable Name</u>	<u>Description</u>	<u>Default Value</u>	<u>Variable Name</u>
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_i

Ingestion Constants Line 2 (7052).

<u>Word</u>	<u>Variable Name</u>	<u>Description</u>	<u>Default Value</u>	<u>Variable Name</u>
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).

<u>Word</u>	<u>Variable Name</u>	<u>Description</u>	<u>Default Value</u>	<u>Variable Name</u>
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).

<u>Word</u>	<u>Variable Name</u>	<u>Description</u>	<u>Default Value</u>	<u>Variable Name</u>
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

Optional Acute Ingestion Constants Line 4 (7055).

You can omit this line; however, when it is not entered, all acute ingestion constants are set equal to 1.

<u>Word</u>	<u>Variable Name</u>	<u>Description</u>	<u>Default Value</u>	<u>Variable Name</u>
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.

Optional Element Selection Lines (7081+)

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

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
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.

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.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
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}).

Dose Calculation End Line (7999)

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

<u>Word</u>	<u>Entry</u>
1	7999

8000 Series—Fifty-Mile Radius Dose Calculation

Use the *Fifty-Mile Dose Selection Line (8000)* to initiate committed population doses within a fifty-mile radius of a nuclear facility calculation.

Fifty-Mile Dose Selection Line (8000)

<u>Word</u>	<u>Entry</u>
1	8000

Radionuclide Selection Control (8001)

<u>Word</u>	Variable <u>Name</u>	<u>Entry</u>	<u>Description</u>
1		8001	
2	INN	0	Doses are calculated from radionuclide inventory currently in memory from previous 1000 Series calculation or 2000 Series entry. Existing inventory can not contain more than 100 radionuclides with inventories greater than 0.
		1	<i>Nuclide Selection Lines</i> will immediately follow this line.

Nuclide Selection Lines

These lines are present only if INN on the (8001) line is equal to 1.

<u>Word</u>	Variable <u>Name</u>	<u>Entry</u>	<u>Description</u>
1	NUCL	Integer	Radionuclide identification number (see 4000 Series, <i>Radionuclide Data Change Line</i>). 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. The maximum number of radionuclides that can be entered in a fifty-mile dose calculation is 100. An (8011) line must follow last radionuclide identification entered.

Model Control Line (8011)

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
1		8011	
2	ICCI	Integer	Inhalation clearance class indicator: 1 Default to program-generated classes for oxides and hydroxides. 2 User input of classes on (703X) lines. Unchanged classes default to those for oxides and hydroxides. 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.
3	IDU	Integer	Dose unit: 1 rem 2 Sv
4	ING	Integer	Input control for ingestion calculations: 0 Chronic ingestion dose with program default parameters. 1 Ingestion dose controlled with user supplied parameters on the (8014) line.
5	IBSF	Integer	Input control for building shielding/exposure factors: 0 Program-supplied standard parameters. 1 User-supplied factors on the (8013) line.
6	BREATH		Average breathing rate (m ³ /s). If zero, defaults to 2.66E-4 for 24-hour average breathing rate.
7	TB		Values for the term “TB” depend on 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.

Variable

<u>Word</u>	<u>Name</u>	<u>Entry</u>	<u>Description</u>
			Ingestion from chronic release: For chronic releases, TB is the years of chronic long-term buildup of activity in the soil. TB should be equal to plant mid-point of operating life (y). If zero, defaults to 15 years.
8	TBG		Ground surface: 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 that an exposure period of <1 year has been chosen. If zero, defaults to 1 year.

Organ Control Line (8012)

Fifty-mile dose calculations can be made for up to a maximum of four organs at a time. Calculations for additional organs can be made by repeating the 8000 Series lines.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
1		8012	
2	IO(1)	Integer	1st organ number
3	IO(2)	Integer	2nd organ number
4	IO(3)	Integer	3rd organ number
5	IO(4)	Integer	4th organ number

Organ numbers and names (taken from the internal list) that are valid for the fifty-mile dose calculation are:

<u>Entry</u>	<u>Organ</u>	<u>Entry</u>	<u>Organ</u>
1	LUNGS	13	SPLEEN
2	S WALL	14	PANCREAS
3	SI WALL	15	MUSCLE
4	ULI WALL	16	SKIN
5	LLI WALL	17	BRAIN
6	TESTES	18	THYMUS
7	BREAST	19	BL WALL
8	BSURFACE	20	ADRENALS
9	R MARROW	21	ESUPHAGUS
10	THYROID	22	OVARIES
11	KIDNEYS	23	UTERUS
12	LIVER		

Building Shielding/Exposure Factors Line (8013)

This line is present only if IBSF, word 5 on the (8011) line, is equal to 1.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
1		8013	User input for building shielding/exposure factors. This line is present only when word 5 on the (8011) line is equal to 1.
2	BSF		Building shielding factor for external dose calculations. If zero, defaults to 0.70.
3	ASF		Occupancy factor for air immersion calculations. If zero, defaults to 1.

Optional Ingestion Dose Control Line (8014)

This line is present only if ING (word 4) on the (8011) line is 1.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
1		8014	
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. Requires ATIME below to be entered. 2 = User-supplied ingestion parameters on (705X) lines. Requires ATIME below to be entered.
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, while a time period of < 60 days signifies an acute release.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
			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. day. Otherwise must not be <0.04167.
5	THD		Harvest duration time period 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].

Exponential Leakage Time Line (8020)

You can omit the (8020) and (802X) lines to give a default linear over 1 second.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
1		8020	
2	TINHA		Decay time for exponential decay function. If zero, defaults to the time necessary to give 100% [see (5201+) lines].

Exponential Leakage Constants Lines (8021+)

If the (8020) line was omitted (giving default values), these lines also should be omitted.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
1		Integer	8021 (X = 1, 2, ...,etc.).
2	K1(1)		Linear constant in 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.

Clearance Class by Element Lines (8041+)

These lines are present only if ICCI (word 2) on (8011) line is equal to 1. 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.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
1		Integer	804X (X = 1, 2, ..., etc.).
2	IPOOL(5)	Integer	Atomic number for element.
3	NN	Integer	1 = Class D 2 = Class W 3 = Class Y
.	.	.	
.	.	.	
.	.	.	
2N	NN	Integer	
2N+1	ICC (N)	Integer	

Enter as many pairs of entries on this or following lines as desired.

External Population and Dispersion File Control Line (8050)

This line is present only when the data for the fifty-mile radius population, χ/Q_s , and site boundary data [(8051) through (8110) lines] are read from an external file. Use the first line of the external file for descriptive information. The second line in the external file must be a (8051) line. The data in the external file are as described on the subsequent lines, and the next line expected following the (8050) line must be the *Deposition Velocity Input Line* (8120).

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>
1		8050
2	EXTFILE	External filename. The name entered must be a valid DOS file name with no extension.

Fifty-Mile Radius Population Lines (8051+)

You must enter 16 lines for the 16 compass sectors. Sector 1 begins with north, and the remaining sectors progress clockwise.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
1		Integer	8050+X (X = 1 to 16). Sector X population for:
2	P(X,1)		0-10 miles
3	P(X,2)		10-20 miles
4	P(X,3)		20-30 miles
5	P(X,4)		30-40 miles
6	P(X,5)		40-50 miles

Fifty-Mile Radius χ/Q Lines (8071+)

Enter the diffusion dispersion coefficients (s/m^3) on these lines for the 16 compass sectors.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
1		Integer	8070+X (X = 1 to 16). Sector χ/Q for:
2	CQ(X,1)		0-10 miles
3	CQ(X,2)		10-20 miles
4	CQ(X,3)		20-30 miles
5	CQ(X,4)		30-40 miles
6	CQ(X,5)		40-50 miles

Sector Average Wind Velocity Lines (8091+)

Enter the average wind velocities for the 16 compass sectors.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
1		Integer	809X (X = 1, 2, ..., etc.).
2	VEL(1)		Average wind velocity (m/s) for sector 1 (N).
3	VEL(2)		Average wind velocity (m/s) for sector 2 (NNE).
.	.		
.	.		
N	VEL(16)		Average wind velocity (m/s) for sector 16 (NNW).

Enter additional values on this and following lines until average wind velocities for each of the 16 sectors have been entered. All wind velocities must be greater than zero.

Site-Boundary Meteorological Data Line (8110)

Enter meteorological data for the maximum exposed individual located at the site boundary.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
1		8110	
2	NSEC	Integer	Sector number for the maximum exposed individual.
3	CQSB		χ/Q for the maximum exposed individual (s/m^3).
4	SBD		Distance to the maximum exposed individual (m).
5	WIND		Average wind velocity toward the maximum exposed individual (m/s).

Deposition Velocity Input Line (8120)

Enter deposition velocities.

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
1		8120	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

Ingestion Dose Constant Lines (8201+)

These lines are present only if ITYPE (word 3) of the (8014) line is 2. Enter 5 lines. They are identical to the lines entered in *Optional Ingestion Dose Constants Lines (7051+)* except for word 1, which must be 8201, 8202, 8203, 8204, and 8205, respectively.

Fifty-Mile Radius Dose Calculation End Line (8999)

Use this line to end the input for the calculations initiated by the (8000) line.

<u>Word</u>	<u>Entry</u>
1	8999

9000 Series—Cloud Gamma Dose Calculation

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

<u>Word</u>	<u>Variable Name</u>	<u>Entry</u>	<u>Description</u>
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-6 RUNS

RSAC-6 is provided with nine examples that are useful in helping you learn how to run RSAC-6. Initially, the examples must be run using WinRP 2.0. Many of the steps in the examples have been added solely to demonstrate the capabilities of RSAC-6.

Example 1: Simulated Reactor Operation

This example demonstrates a fission product inventory calculation for a reactor that operates at a power level of 50 MW for a period of 50 days (4.32E6 seconds). At the end of the reactor operation, the inventory is fractionated to retain 1% solids, 25% halogens, 100% noble gases, 1% cesium, and 1% ruthenium. A printout of the inventory has been requested for decay times of 30., 90 and 120. days. The inventory printout has been limited to only those radionuclides with activities greater than zero at or following the first decay time of 30. days.

Example 1 Fission product inventory - Rsac

File Edit View Run Examples Tools Help

Add Series Fifty-Mile Radius Reports Critdos

1000 Fission Product Inventory Calculation

2000 Direct Radionuclide Input

5000 Meteorological Data Input

7000 Internal/External Dose Calculation

9000 Cloud Gamma Dose Calculation

Title: Fission product inventory from simulated reactor

Series	Title
1000	Requests a fission product inventory calculation
6000	Requests fission product inventory decay and printout

INEEL
Idaho National Engineering and Environmental Laboratory

Last Modified: 7/1/2005 9:24:09 AM

File Name: C:\Program Files\INEEL\WinRp\Examples\Example 1 Fission product inventory.rsac

WinRp Windows RSAC Plus

and

RSAC
Radiological Safety Analysis Computer Program

```

Radiological Safety Analysis Computer Program (RSAC 6.2)
Windows RSAC Plus (WinRp 2.0.0)
Name: Brad Schrader      Company: INEEL
Serial: H4JY6-52RR0-E    Run Date: 07/01/2005    Run Time: 09:24:56
File: Example 1 Fission product inventory.rsac

```

```

          RSAC-6 INPUT      20050701      09:24
0          1          2          3          4          5          6          7
123456789012345678901234567890123456789012345678901234567890123456789

```

```

* Fission product inventory from simulated reactor operation
# Requests a fission product inventory calculation
1000
1001,0,5.E7,4320000. * 5.E7 watts of power for 4.32E6 seconds
#
1004,-1,0.01,0.25,1.,0.01,0.01 * Fractionating inventory by group
#                               1% solids, 25% halogens, 100% noble gases
#                               1% Cs and 1% Ru
#
1999
# Requests fission product inventory decay and printout
6000,0,2,0,0 * Limiting listing to only those radionuclides with positive
#             vaules at or folowing the first requested decay time
#
6101,4,30.,90.,120. * Decay times of 30., 90., and 120. days
#               Zero time is automatically given
#

```

```

6200,1,0 * Requests inventory summation by group (solids, halogens, nobel
#         gases, cesium, and rutheinum). No summation by element is
#         requested.
#

```

```

6999
10000

```

```

***FISSION PRODUCT CALCULATION

```

```

      THE REACTOR HAS OPERATED AT  5.000E+07 WATTS FOR    4.320E+06 SECONDS
      BURNUP =  2.500E+03 MWd

```

```

FRACTIONATION BY ELEMENT GROUP
  SOLIDS = 1.000E-02  HALOGENS = 2.500E-01  NOBLE GASES = 1.000E+00
  CESIUM = 1.000E-02  RUTHENIUM = 1.000E-02

```

Example Runs

TOTAL RADIONUCLIDE REMAINING = 1.722E+18 D/s OR 4.655E+07 Ci

***DECAY CALCULATION

*** DECAY CALCULATION -- curie DECAY TIMES IN DAY

SUPPRESSING NUCLIDES WITH ZERO INVENTORY AT AND FOLLOWING 3.00E+01 DAY

NUCLIDE	HALF LIFE	3.00E+01	9.00E+01	1.20E+02
-----	-----	-----	-----	-----
10030 H- 3	1.23E+01 yr	3.44E+01	3.41E+01	3.39E+01
60140 C- 14	5.73E+03 yr	8.81E-08	8.81E-08	8.81E-08
300720 Zn- 72	4.65E+01 h	6.23E-06	2.97E-15	0.00E+00
310720 Ga- 72	1.41E+01 h	8.94E-06	4.26E-15	0.00E+00
320780 Ge- 78	8.80E+01 h	2.89E-01	3.43E-06	1.18E-08
330760 As- 76	1.08E+00 day	4.10E-12	0.00E+00	0.00E+00
330770 As- 77	3.88E+01 h	1.25E-04	7.53E-16	0.00E+00
330780 As- 78	9.07E+01 min	2.94E-01	3.49E-06	1.20E-08
340790 Se- 79	1.13E+06 yr	1.82E-05	1.82E-05	1.82E-05
350820 Br- 82	3.53E+01 h	1.24E-05	0.00E+00	0.00E+00
360850 Kr- 85	1.08E+01 yr	9.66E+02	9.56E+02	9.51E+02
360851 Kr- 85m	4.48E+01 h	7.55E+00	1.59E-09	2.31E-14
370870 Rb- 87	4.75E+10 yr	8.91E-10	8.91E-10	8.91E-10
380871 Sr- 87m	2.80E+00 h	5.94E+01	2.19E-04	4.22E-07
380890 Sr- 89	5.05E+01 day	6.53E+03	2.87E+03	1.90E+03
380900 Sr- 90	2.88E+01 yr	7.68E+01	7.65E+01	7.63E+01
390870 Y- 87	7.98E+01 h	5.73E+01	2.12E-04	4.08E-07
390900 Y- 90	6.41E+01 h	7.68E+01	7.65E+01	7.63E+01
390910 Y- 91	5.85E+01 day	7.59E+03	3.73E+03	2.61E+03
400930 Zr- 93	1.53E+06 yr	1.67E-03	1.67E-03	1.67E-03
400950 Zr- 95	6.40E+01 day	7.98E+03	4.17E+03	3.01E+03
400970 Zr- 97	1.69E+01 h	3.70E-09	0.00E+00	0.00E+00
410931 Nb- 93m	1.61E+01 yr	1.20E-05	2.37E-05	2.95E-05
410940 Nb- 94	2.03E+04 yr	1.67E-08	1.67E-08	1.67E-08
410950 Nb- 95	3.50E+01 day	6.60E+03	5.84E+03	4.79E+03
410951 Nb- 95m	8.66E+01 h	5.34E-01	5.27E-06	1.66E-08
410960 Nb- 96	2.34E+01 h	2.00E-09	0.00E+00	0.00E+00
410970 Nb- 97	7.21E+01 min	3.98E-09	0.00E+00	0.00E+00
410971 Nb- 97m	5.27E+01 s	3.50E-09	0.00E+00	0.00E+00
420990 Mo- 99	6.59E+01 h	1.28E+01	3.43E-06	1.77E-09
430990 Tc- 99	2.11E+05 yr	1.13E-02	1.13E-02	1.13E-02
430991 Tc- 99m	6.01E+00 h	1.25E+01	3.34E-06	1.73E-09
441030 Ru-103	3.93E+01 day	4.46E+03	1.55E+03	9.10E+02
441060 Ru-106	3.74E+02 day	1.43E+02	1.28E+02	1.21E+02
451031 Rh-103m	5.61E+01 min	4.02E+03	1.39E+03	8.20E+02
451050 Rh-105	3.54E+01 h	3.44E-03	1.84E-15	0.00E+00
451060 Rh-106	2.98E+01 s	1.43E+02	1.28E+02	1.21E+02
461070 Pd-107	6.50E+06 yr	1.13E-05	1.13E-05	1.13E-05
461090 Pd-109	1.37E+01 h	3.13E-14	0.00E+00	0.00E+00
461120 Pd-112	2.10E+01 h	3.81E-09	0.00E+00	0.00E+00
471100 Ag-110	2.46E+01 s	1.67E-02	1.41E-02	1.30E-02
471101 Ag-110m	2.50E+02 day	1.69E-02	1.43E-02	1.32E-02
471110 Ag-111	7.45E+00 day	6.57E+00	2.47E-02	1.52E-03
471120 Ag-112	3.13E+00 h	4.48E-09	0.00E+00	0.00E+00
481150 Cd-115	5.35E+01 h	5.28E-03	4.11E-11	3.63E-15
481151 Cd-115m	4.46E+01 day	2.03E+00	7.98E-01	5.01E-01
491151 In-115m	4.49E+00 h	5.76E-03	4.49E-11	3.96E-15
491170 In-117	4.32E+01 min	6.46E-03	1.20E-06	1.64E-08
491171 In-117m	1.16E+02 h	7.14E-01	1.33E-04	1.81E-06
501171 Sn-117m	1.36E+01 day	4.11E-06	1.93E-07	4.19E-08
501191 Sn-119m	2.93E+02 day	1.13E-01	9.78E-02	9.11E-02
501210 Sn-121	2.71E+01 h	7.53E-07	0.00E+00	0.00E+00
501211 Sn-121m	5.50E+01 yr	6.19E-05	6.18E-05	6.17E-05
501230 Sn-123	1.29E+02 day	4.70E+00	3.40E+00	2.90E+00
501250 Sn-125	9.64E+00 day	7.24E+00	9.68E-02	1.12E-02
501260 Sn-126	1.00E+05 yr	2.89E-04	2.89E-04	2.89E-04
511250 Sb-125	2.76E+00 yr	5.46E+00	5.31E+00	5.20E+00
511260 Sb-126	1.25E+01 day	7.59E-01	2.70E-02	5.12E-03
511261 Sb-126m	1.91E+01 min	2.89E-04	2.89E-04	2.89E-04
511270 Sb-127	3.85E+00 day	2.98E+00	6.07E-05	2.74E-07
521251 Te-125m	5.74E+01 day	5.68E-01	9.17E-01	1.01E+00
521270 Te-127	9.35E+00 h	2.81E+01	1.73E+01	1.43E+01
521271 Te-127m	1.09E+02 day	2.58E+01	1.76E+01	1.45E+01

*** DECAY CALCULATION -- curie DECAY TIMES IN DAY

SUPPRESSING NUCLIDES WITH ZERO INVENTORY AT AND FOLLOWING 3.00E+01 DAY

NUCLIDE	HALF LIFE	3.00E+01	9.00E+01	1.20E+02
521290 Te-129	6.96E+01 min	9.45E+01	2.74E+01	1.48E+01
521291 Te-129m	3.36E+01 day	1.45E+02	4.21E+01	2.27E+01
521310 Te-131	2.50E+01 min	2.02E-05	0.00E+00	0.00E+00
521311 Te-131m	3.00E+01 h	8.96E-05	0.00E+00	0.00E+00
521320 Te-132	3.20E+00 day	2.66E+01	6.14E-05	9.32E-08
531290 I-129	1.57E+07 yr	4.07E-04	4.08E-04	4.08E-04
531310 I-131	8.02E+00 day	2.18E+04	1.22E+02	9.15E+00
531320 I-132	2.30E+00 h	2.75E+01	6.33E-05	9.61E-08
531330 I-133	2.08E+01 h	2.45E-05	0.00E+00	0.00E+00
541291 Xe-129m	8.88E+00 day	7.73E-04	7.14E-06	6.87E-07
541311 Xe-131m	1.18E+01 day	2.56E+03	8.83E+01	1.55E+01
541330 Xe-133	5.24E+00 day	5.18E+04	1.86E+01	3.52E-01
541331 Xe-133m	2.19E+00 day	6.52E+00	3.69E-08	2.77E-12
541350 Xe-135	9.14E+00 h	5.81E-14	5.81E-14	5.81E-14
551340 Cs-134	2.06E+00 yr	4.32E+00	4.09E+00	3.98E+00
551350 Cs-135	2.30E+06 yr	9.17E-03	9.17E-03	9.17E-03
551360 Cs-136	1.32E+01 day	5.91E+00	2.50E-01	5.16E-02
551370 Cs-137	3.01E+01 yr	8.12E+01	8.09E+01	8.07E+01
561371 Ba-137m	2.55E+00 min	7.68E+01	7.65E+01	7.64E+01
561400 Ba-140	1.28E+01 day	4.70E+03	1.80E+02	3.53E+01
571400 La-140	1.68E+00 day	5.42E+03	2.08E+02	4.06E+01
581410 Ce-141	3.25E+01 day	8.40E+03	2.34E+03	1.23E+03
581430 Ce-143	3.30E+01 h	6.74E-03	5.07E-16	0.00E+00
581440 Ce-144	2.85E+02 day	2.36E+03	2.04E+03	1.90E+03
591430 Pr-143	1.36E+01 day	5.39E+03	2.51E+02	5.43E+01
591440 Pr-144	1.73E+01 min	2.36E+03	2.04E+03	1.90E+03
591441 Pr-144m	7.20E+00 min	3.38E+01	2.92E+01	2.71E+01
601470 Nd-147	1.10E+01 day	1.35E+03	3.05E+01	4.59E+00
611470 Pm-147	2.62E+00 yr	3.64E+02	3.63E+02	3.56E+02
611480 Pm-148	5.37E+00 day	1.36E+00	1.05E-01	6.33E-02
611481 Pm-148m	4.13E+01 day	5.94E+00	2.17E+00	1.31E+00
611490 Pm-149	5.31E+01 h	4.36E-01	2.97E-09	2.45E-13
611510 Pm-151	2.84E+01 h	4.06E-05	0.00E+00	0.00E+00
621470 Sm-147	1.06E+11 yr	2.54E-10	6.49E-10	8.42E-10
621510 Sm-151	9.00E+01 yr	1.82E+00	1.82E+00	1.82E+00
621530 Sm-153	4.63E+01 h	2.09E-02	8.93E-12	1.83E-16
631520 Eu-152	1.35E+01 yr	2.03E-03	2.01E-03	2.00E-03
631540 Eu-154	8.59E+00 yr	4.15E-01	4.10E-01	4.07E-01
631550 Eu-155	4.76E+00 yr	2.89E+00	2.82E+00	2.79E+00
631560 Eu-156	1.52E+01 day	7.15E+01	4.62E+00	1.18E+00
631570 Eu-157	1.52E+01 h	1.75E-13	0.00E+00	0.00E+00
641530 Gd-153	2.42E+02 day	3.93E-05	3.31E-05	3.03E-05
641590 Gd-159	1.85E+01 h	1.12E-11	0.00E+00	0.00E+00

TOTAL NUCLIDE INVENTORY 1.46E+05 2.89E+04 2.12E+04

TOTAL FPI BY GROUP -- curie

day	SOLIDS	HALOGENS	NOBLE GASES	CESIUM	RUTHENIUM
3.000E+01	6.41E+04	2.19E+04	5.53E+04	9.14E+01	4.60E+03
9.000E+01	2.60E+04	1.22E+02	1.10E+03	8.52E+01	1.67E+03
1.200E+02	1.91E+04	9.15E+00	1.00E+03	8.48E+01	1.03E+03

EXECUTION time = 2.00E-02 SECONDS

Example 2: Calculation of Inhalation Dose

The radionuclide inventory for this example has been entered directly using the 2000 Series option. The inventory consists of 2. Ci of Sr-90 and Y-90. The short-lived daughters of radionuclides should be entered along with their parents unless sufficient decay time has been provided to allow the short-lived daughters to buildup to equilibrium. RSAC-6 will automatically decay and ingrow progeny during the downwind transport time. However, in this example, the transport time to the downwind receptor is insufficient to allow the Y-90 buildup into equilibrium.

The release is assumed to occur at ground level with an average wind velocity of 4.5 m/s. A mixing layer depth of 1,000 m has been entered. No credit for plume depletion has been taken. This option may only be requested when the program is requested to calculate the meteorological diffusion. However, in this example standard deviations of the plume are entered directly to demonstrate how to use the option. Building wake correction has been requested for a building 40 m wide and 10 m high. While deposition velocities have been entered, they do not have an effect on the calculation.

The release has been decay corrected for a linear release occurring over a period of 15 minutes. While decay correction has little affect on the results from this example, it can significantly affect the subsequent dose calculations when short-lived radionuclides are present.

Two downwind distances have been specified for the subsequent dose calculations. WinRp 2.0 will not allow downwind distances of less than 10 meters to be entered when the program calculates the downwind diffusion. However, when standard deviations of the plume are entered directly by the user as in this example, any downwind distance may be selected if RSAC-6 is run directly from an ASCII input file. When this is done, the burden of certifying the validity of the meteorological diffusion is placed on the user.

In this example, doses from the inhalation pathway are requested for only selected organs. In addition, dose calculations are requested for only Sr and Y, which speeds up the calculation time. A standard high breathing rate of $3.33\text{E-}04 \text{ m}^3/\text{s}$ is used and doses are calculated using rem units. Doses are also calculated using the default RSAC-6 lung clearance classes that have been selected to give the maximum element doses. A respirable fraction of 0.25 has been used in the example.

Example 2 Calculation of inhalation dose - Rsac

File Edit View Run Examples Tools Help

Add Series Fifty-Mile Radius Reports Critdos

[1000 Fission Product Inventory Calculation](#)

[2000 Direct Radionuclide Input](#)

[5000 Meteorological Data Input](#)

[7000 Internal/External Dose Calculation](#)

[9000 Cloud Gamma Dose Calculation](#)

Title: Calculation of Inhalation Dose

Series	Title
2000	Entering radionuclides directly
5000	Requests of input of meteorological data
7000	Requesting inhalation dose calculation

INEEL
Idaho National Engineering and Environmental Laboratory

Last Modified: 4/28/2005 8:10:42 AM

File Name: C:\Program Files\INEEL\WinRp\Examples\Example 2 Calculation of inhalation dose.rsac

WinRp Windows RSAC Plus

and

RSAC
Radiological Safety Analysis Computer Program

RSAC Run Results - Example 2 Calculation of inhalation dose out0003.txt

Example 2 Calculation of inhalation dose

Input

- Direct radionuclide input
- Meteorological data
- Inhalation dose equivalent calculation

Graph & Plots

CEDE Chi/Q Airborne Concentration

TEDE Isopleth Ground Surface Concentration

Print... Close

Radiological Safety Analysis Computer Program (RSAC 6.2)
 Windows RSAC Plus (WinRp 2.0.0)
 Name: Brad Schrader Company: INEEL
 Serial: H4JY6-52RR0-E Run Date: 07/01/2005 Run Time: 09:33:36
 File: Example 2 Calculation of inhalation dose.rsac

```

RSAC-6 INPUT      20050701      09:33
0      1      2      3      4      5      6      7
123456789012345678901234567890123456789012345678901234567890123456789
789

* Calculation of Inhalation Dose
# Entering radionuclides directly
2000,0
# 0.5 Ci Sr-90
# 0.5 Ci Y-90
Sr-90,0.5
Y-90,0.5
2999
# Requests of input of meteorological data
5000,0
5001,4.5,0.,1000.,1.099E3,0.,0 * 4.5 m/s average wind velocity
# Ground level release
# 1000 m mixing layer depth
# 1099. g/cubic m air density
# No plume depletion by wet deposition
# No plume depletion by dry deposition

```

Radiological Safety Analysis Computer Program (RSAC 6.2)
 Windows RSAC Plus (WinRp 2.0.0)
 Name: Brad Schrader Company: INEEL
 Serial: H4JY6-52RR0-ERun Date: 07/01/2005 Run Time: 09:33:36
 File: Example 2 Calculation of inhalation dose.rsac

```

RSAC-6 INPUT      20050701      09:33
0      1      2      3      4      5      6      7
123456789012345678901234567890123456789012345678901234567890123456789

* Calculation of Inhalation Dose
# Entering radionuclides directly
2000,0
# 0.5 Ci Sr-90
# 0.5 Ci Y-90
Sr-90,0.5
Y-90,0.5
2999
# Requests of input of meteorological data
5000,0
5001,4.5,0.,1000.,1.099E3,0.,0 * 4.5 m/s average wind velocity
# Ground level release
# 1000 m mixing layer depth
# 1099. g/cubic m air density
# No plume depletion by wet deposition
# No plume depletion by dry deposition

5002,0.001,0.01,0.,0.001,0.001 * Entering deposition velocities
# 0.001 m/s for solids, Cs and Ru
# 0.01 for halogens
# 0.0 for nobel gases

5101,100.,150. * Requesting doses for 2 downwind distances, 100. and 150.
# meters

5201,0.001111,0. * Decay correct for a linear release over 15 minutes

5400,1,60.,10.6,0 * Using option for user input of plume standard deviations
# Requesting correction for building wake 60. meter wide
# by 10.6 meters high

5401,15.,8.,20.,11. * Standard deviations inserted in pairs of 2

```

Example Runs

```
#          100 meter distance, sigy = 15. m, sigz = 8. m
#          150 meter distance, sigy = 20. m, sigz = 11. m
#
5999
# Requesting inhalation dose calculation
7000,0,2,1,1,2 * Using program default parameters
#
#          Requesting dose printout for each radionuclide and organ
#          with crosswind doses for each organ
#
#          Doses in rem, for selected elements and organs
#
7001,3.33E-4,0.,0,0,0.25 * Hight breathing rate of 3.33E-4 cubic m/s
#          Defaulting to program calculated decay function
#          time which gives a 100% release of the inventory
#
#          Requesting a resirable fraction of 0.25.
#
7002,1,4,5,24 * Calculating dose for Lungs, Upper Large Intestine Wall,
#          Lower Large Intestine Wall, and CEDE
#
7081,38,39 * Calculating dose for Sr and Y only
#
7999
10000

***DIRECT RADIONUCLIDE INPUT

      ANY PREVIOUS INVENTORY HAS BEEN ZEROED

      NUCLIDE          HALF LIFE          CURIES

380900  Sr 90      2.878E+01  yr      5.000E-01
390900   Y 90      6.410E+01  h       5.000E-01

*** METEOROLOGICAL DATA

      MEAN WIND SPEED = 4.500E+00 (m/s)   STACK HEIGHT = 0.000E+00 (m)
      MIXING LAYER HEIGHT = 1.000E+03 (m)   AIR DENSITY = 1.099E+03 (g/cu m)
      WET DEPOSITION SCAVENGING COEFFICIENT = 0.000E+00 (1/S)

      NO CORRECTION IS BEING MADE FOR PLUME DEPLETION BY FALLOUT

      DEFAULT 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)
      1.111E-03           0.000E+00

      BUILDING WIDTH = 6.000E+01 (m)   BUILDING HEIGHT = 1.060E+01 (m)

      ENHANCED DEPOSITION PARAMETERS
      PARTICLE DIAMETER = 0.000E+00 (m)   PARTICLE DENSITY = 0.000E+00 (g/cm3)
      DOWNWIND DISTANCE   STACK          SIGY          SIGZ          CHI/Q
                        HEIGHT (m)        (m)            (m)            (s/cu m)
      1.000E+02           0.000E+00      2.209E+01      9.346E+00      3.426E-04
      DOWNWIND DISTANCE   STACK          SIGY          SIGZ          CHI/Q
                        HEIGHT (m)        (m)            (m)            (s/cu m)
      1.500E+02           0.000E+00      3.126E+01      1.300E+01      1.741E-04

*** INHALATION DOSE EQUIVALENT CALCULATION

      USING DOSE CONVERSION FACTORS FROM FEDERAL GUIDANCE REPORT 11

      RESPIRABLE FRACTION = 2.500E-01
      BREATHING RATE = 3.330E-04 (cu m/s)
      RELEASE TIME FOR EXPONENTIAL DECAY FUNCTION = 9.001E+02 (s)
      INTERNAL EXPOSURE TIME PERIOD = 5.000E+01 (yr)
      PARTICLE SIZE = 1.0 MICRON AMAD
      LUNG DEPOSITION FRACTIONS: N-P = 0.300 T-B = 0.080 P = 0.250
      DEFAULT ELEMENT LUNG CLEARANCE CLASSES SELECTED TO GIVE MAXIMUM DOSE
      DOWNWIND DISTANCE = 1.000E+02 (m)   PLUME TRAVEL TIME = 2.222E+01 (s)
                                           CHI/Q = 3.426E-04 (s/cu m)
```

LUNGS	INHALATION	ISOTOPE	NUCLIDE	CDE(rem)	WCDE (rem)
		Sr - 90	380900	1.51E-01	1.81E-02
		TOTAL Sr (ATOMIC NO 38)		1.51E-01	1.81E-02
		Y - 90	390900	4.91E-04	5.89E-05
		TOTAL Y (ATOMIC NO 39)		4.91E-04	5.89E-05
	TOTAL LUNGS	INHALATION =		1.51E-01	1.82E-02

ULI WALL INHALATION	ISOTOPE	NUCLIDE	CDE(rem)	WCDE (rem)
	Sr - 90	380900	3.20E-04	1.92E-05
	TOTAL Sr (ATOMIC NO 38)		3.20E-04	1.92E-05
	Y - 90	390900	2.79E-04	1.67E-05
	TOTAL Y (ATOMIC NO 39)		2.79E-04	1.67E-05
	TOTAL ULI WALL INHALATION =		5.99E-04	3.60E-05

LLI WALL INHALATION	ISOTOPE	NUCLIDE	CDE(rem)	WCDE (rem)
	Sr - 90	380900	1.09E-03	6.52E-05
	TOTAL Sr (ATOMIC NO 38)		1.09E-03	6.52E-05
	Y - 90	390900	6.65E-04	3.99E-05
	TOTAL Y (ATOMIC NO 39)		6.65E-04	3.99E-05
	TOTAL LLI WALL INHALATION =		1.75E-03	1.05E-04

DOWNWIND DISTANCE = 1.000E+02 CEDE INHALATION DOSE EQUIVALENT

CEDE	INHALATION	ISOTOPE	NUCLIDE	CEDE(rem)
		Sr - 90	380900	1.85E-02
		TOTAL Sr (ATOMIC NO 38)		1.85E-02
		Y - 90	390900	1.20E-04
		TOTAL Y (ATOMIC NO 39)		1.20E-04
	TOTAL CEDE	INHALATION =		1.86E-02

DOWNWIND DISTANCE = 1.500E+02 (m) PLUME TRAVEL TIME = 3.333E+01 (s)
 CHI/Q = 1.741E-04 (s/cu m)

LUNGS	INHALATION	ISOTOPE	NUCLIDE	CDE(rem)	WCDE (rem)
		Sr - 90	380900	7.67E-02	9.20E-03
		TOTAL Sr (ATOMIC NO 38)		7.67E-02	9.20E-03
		Y - 90	390900	2.50E-04	3.00E-05
		TOTAL Y (ATOMIC NO 39)		2.50E-04	3.00E-05
	TOTAL LUNGS	INHALATION =		7.69E-02	9.23E-03

ULI WALL INHALATION	ISOTOPE	NUCLIDE	CDE(rem)	WCDE (rem)
	Sr - 90	380900	1.63E-04	9.77E-06
	TOTAL Sr (ATOMIC NO 38)		1.63E-04	9.77E-06

Example Runs

```

          Y - 90      390900      1.42E-04      8.51E-06
          TOTAL Y (ATOMIC NO 39)      1.42E-04      8.51E-06
          TOTAL ULI WALL INHALATION =      3.05E-04      1.83E-05
          LLI WALL INHALATION      ISOTOPE      NUCLIDE      CDE(rem)      WCDE (rem)
          Sr - 90      380900      5.52E-04      3.31E-05
          TOTAL Sr (ATOMIC NO 38)      5.52E-04      3.31E-05
          Y - 90      390900      3.38E-04      2.03E-05

DOWNWIND DISTANCE = 1.500E+02      LLI WALL INHALATION DOSE EQUIVALENT
          LLI WALL INHALATION      ISOTOPE      NUCLIDE      CEDE(rem)

          TOTAL Y (ATOMIC NO 39)      3.38E-04      2.03E-05
          TOTAL LLI WALL INHALATION =      8.90E-04      5.34E-05
          CEDE      INHALATION      ISOTOPE      NUCLIDE      CEDE(rem)
          Sr - 90      380900      9.41E-03
          TOTAL Sr (ATOMIC NO 38)      9.41E-03
          Y - 90      390900      6.11E-05
          TOTAL Y (ATOMIC NO 39)      6.11E-05
          TOTAL CEDE      INHALATION =      9.47E-03

&&      INHALATION COMMITTED DOSE EQUIVALENTS ORDERED BY ORGAN (rem)

          DOWNWIND DISTANCES (m)
          ORGAN      NO.      1.00E+02      1.50E+02
          -----
          LUNGS      1      1.51E-01      7.69E-02
          ULI WALL      4      5.99E-04      3.05E-04
          LLI WALL      5      1.75E-03      8.90E-04

&&      INHALATION COMMITTED DOSE EQUIVALENCES ORDERED BYDOSE (rem)

          DOWNWIND DISTANCES (m)
          ORGAN      NO.      1.00E+02      1.50E+02
          -----
          LUNGS      1      1.51E-01      7.69E-02
          ULI WALL      4      5.99E-04      3.05E-04
          LLI WALL      5      1.75E-03      8.90E-04

&&      INHALATION WEIGHTED COMMITTED DOSE EQUIVALENTS (rem)

          DOWNWIND DISTANCES (m)
          ORGAN      NO.      1.00E+02      1.50E+02
          -----
          LUNGS      1      1.82E-02      9.23E-03
          ULI WALL      4      3.60E-05      1.83E-05
          LLI WALL      5      1.05E-04      5.34E-05
          CEDE      24      1.86E-02      9.47E-03

EXECUTION time = 2.00E-02 SECONDS

```

Example 3: Ingestion Dose Calculation from an Acute Release

This example uses the 2000 Series option to directly input the radionuclide inventory. The inventory is then decayed for a period of 20 years. Decay of the inventory for subsequent dose calculations must be done using the 1000 Series input. The release is assumed to occur at ground level with a 4 m/s average wind velocity.

Because no additional decay of the radionuclide inventory is desired during holdup before release, a linear release over a period of 1 second has been requested. In this example, χ/Q values are entered directly. When χ/Q values of standard deviations are entered directly, no plume depletion correction can be requested. However, in contrast to Example 2, deposition velocities must be entered to determine the amount of activity deposited on the ground and plant surfaces.

Ingestion doses have been requested for all organs and only selected elements. In this example, doses are calculated using the unit of Sv. The acute release is assumed to occur over a period of 1 day followed by a 7 day harvest period. The option for user supplied ingestion parameters has been requested to demonstrate how the standard default parameters can be changed.

Example 3 Ingest dose calc from acute release - Rsac

File Edit View Run Examples Tools Help

Add Series Fifty-Mile Radius Reports Critdos

[1000 Fission Product Inventory Calculation](#)

[2000 Direct Radionuclide Input](#)

[5000 Meteorological Data Input](#)

[7000 Internal/External Dose Calculation](#)

[9000 Cloud Gamma Dose Calculation](#)

Title: Ingestion dose calculation from an acute release

Series	Title
2000	Direct input of Pu and Am
1000	Decaying inventory for 20 years prior to calculating doses
5000	Input of meteorological data
7000	Requesting ingestion dose calculation with user supplied param...

WinRp Windows RSAC Plus

and

RSAC
Radiological Safety Analysis Computer Program

INEEL
Idaho National Engineering and Environmental Laboratory

Last Modified: 4/6/2005 9:52:32 AM

File Name: C:\Program Files\INEEL\WinRp\Examples\Example 3 Ingest dose calc from acute release.rsac

Example Runs

RSAC Run Results - Example 3 Ingest dose calc from acute release out0002.txt

Example 3 Ingest dose calc from acute release

Input

- Direct radionuclide input
- Fission product calculation
- Meteorological data
- Ingestion dose equivalent calculation

Graph & Plots

CEDE	Chi/Q	Airborne Concentration
TEDE	Isopleth	Ground Surface Concentration

Print... Close

Radiological Safety Analysis Computer Program (RSAC 6.2)
 Windows RSAC Plus (WinRp 2.0.0)
 Name: Brad Schrader Company: INEEL
 Serial: H4JY6-52RR0-E Run Date: 07/01/2005 Run Time: 09:37:44
 File: Example 3 Ingest dose calc from acute release.rsac

RSAC-6 INPUT 20050701 09:37

0 1 2 3 4 5 6 7

123456789012345678901234567890123456789012345678901234567890123456789

* Ingestion dose calculation from an acute release
 # Direct input of Pu and Am
 2000,0
 # 0.72 Ci of Pu-238
 # 0.18 Ci of Pu-239
 # 0.045 of Ci Am-241
 Am-241,0.045
 Pu-238,0.72
 Pu-239,0.18
 2999
 # Decaying inventory for 20 years prior to calculating doses
 1000
 1001,1,0.,0. * Retaining previously entered inventory
 #
 1003,631152000.,0.,0. * Decaying 20 yrs = 6.3115E+8 s
 #

Radiological Safety Analysis Computer Program (RSAC 6.2)
 Windows RSAC Plus (WinRp 2.0.0)
 Name: Brad Schrader Company: INEEL
 Serial: H4JY6-52RR0-ERun Date: 07/01/2005 Run Time: 09:37:44
 File: Example 3 Ingest dose calc from acute release.rsac

```
* Ingestion dose calculation from an acute release
# Direct input of Pu and Am
2000,0
# 0.72 Ci of Pu-238
# 0.18 Ci of Pu-239
# 0.045 of Ci Am-241
Am-241,0.045
Pu-238,0.72
Pu-239,0.18
2999
# Decaying inventory for 20 years prior to calculating doses
1000
1001,1,0.,0. * Retaining previously entered inventory
#
1003,631152000.,0.,0. * Decaying 20 yrs = 6.3115E+8 s
#
#
# This sets the reactor operating power to zero and
# operating the reactor for zero time.
#
# This prevents the addition of any activity other
# than the Pu and Am originally entered. Any decay
# of the inventory prior to calculating a downwind
# dose must be done in the 1000 Series.
#
1999
# Input of meteorological data
5000,0
5001,4.,0.,2000.,1.099E3,0.,0 * 4 m/s average wind velocity
# Ground level release
# 2000 m mixing layer depth
# 1099. g/cubic m air density
# No plume depletion by wet deposition
# No plume depletion by dry deposition
#
5002,0.001,0.01,0.,0.001,0.001 * Entering deposition velocities
# 0.001 m/s for solids, Cs and Ru
```



```
#
# 0.01 m/s for halogens
# 0.0 m/s for noble gases
#
5101,1000.,5000. * Requesting doses for 2 downwind distances 1000. and
# 5000. meters
#
5201,1.,0. * No decay correction of inventory is desired during release
# period. This is accomplished by simulating a puff release
# over a period of 1 second.
#
5400,3,0.,0.,0 * Using option to input Chi/Q values directly
# Building wake option cannot be used with direct Chi/Q
# input option
#
5421,2.1E-6,3.2E-7 * Entering Chi/Q values matched to the 2 downwind
# distances
#
5999
# Requesting ingestion dose calculation with user supplied parameters
7000,3,-2,2,1,1 * Printout of only dose summaries
# Requesting doses in Sv
# Requesting doses for only selected elements
# Calculating doses for all organs
#
7001,0,0.,15.,0 * Defaulting to program calculated values
#
7004,1,2,1.,7. * Requesting a printout of ingestion transfer parameters
#
# Requesting to input ingestion parameters
#
# Calculating ingestion dose for an acute release period
# occurring over 1 day
#
# Requesting a harvest duration time period of 7 days
# following the acute release
#
7051,520.,64.,110.,310.,0.5,0.75 * Changed the fraction of stored
# vegetables from the default of 0.76 to
# 0.5
#
# Changed the fraction of fresh vegetables
# from the default or 1.0 to 0.75
#
7052,0.57,0.2,1.,0.0021,60.,30.,1. * Retained default values
#
7053,225.,60.,1.,16.,2.,20. * Retained default values
#
7054,0.4,0.43,90.,2.,0.28,4.9 * Retained default values
#
7055,0.5,0.33,0.5,0.33 * Retained default values
#
7081,95,94 * Requesting doses for Pu and Am
#
7999
10000
```

***DIRECT RADIONUCLIDE INPUT

ANY PREVIOUS INVENTORY HAS BEEN ZEROED

NUCLIDE	HALF LIFE	CURIES
952410 Am241	4.322E+02 yr	4.500E-02
942380 Pu238	8.770E+01 yr	7.200E-01
942390 Pu239	2.411E+04 yr	1.800E-01

***FISSION PRODUCT CALCULATION

RADIONUCLIDE INVENTORY HAS BEEN DECAYED FOR 6.312E+08 SECONDS

TOTAL RADIONUCLIDE REMAINING = 3.101E+10 D/s OR 8.382E-01 Ci

*** METEOROLOGICAL DATA

Example Runs

MEAN WIND SPEED = 4.000E+00 (m/s) STACK HEIGHT = 0.000E+00 (m)
MIXING LAYER HEIGHT = 2.000E+03 (m) AIR DENSITY = 1.099E+03 (g/cu m)
WET DEPOSITION SCAVENGING COEFFICIENT = 0.000E+00 (1/s)

NO CORRECTION IS BEING MADE FOR PLUME DEPLETION BY FALLOUT

DEFAULT 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

CHI/Q VALUES INPUT DIRECTLY

DOWNWIND DISTANCE	CHI/Q
1.000E+03	2.100E-06
5.000E+03	3.200E-07

*** INGESTION DOSE EQUIVALENT CALCULATION

USING DOSE CONVERSION FACTORS FROM FEDERAL GUIDANCE REPORT 11

RELEASE TIME FOR EXPONENTIAL DECAY FUNCTION = 1.000E+00 (s)
INTERNAL EXPOSURE TIME PERIOD = 5.000E+01 (yr)

INGESTION CALCULATIONS MADE USING USER SUPPLIED 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)
5.00E-01	FRACTION OF STORED VEGETABLES FROM GARDEN
7.50E-01	FRACTION OF FRESH VEGETABLES FROM GARDEN
:	Ingestion dose calculation from an acute release
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)

ACUTE RELEASE OVER 1.000E+00 (d)
HARVEST DURATION TIME OF 7.000E+00 (d) AFTER ACUTE RELEASE
CONSUMPTION OF CROPS GROWN ON CONTAMINATED SOIL FOR 1.500E+01 (Y)

FRACTIONS OF ANNUAL VEGETABLES AND FORAGE CONTAMINATED BY ACUTE RELEASE

5.0E-01	STORED VEGETABLES
3.3E-01	FRESH VEGETABLES
5.0E-01	STORED FEED
3.3E-01	PASTURE FEED

INGESTION TRANSFER CONSTANTS

ELEMENT		BV1 FORAGE/ SOIL (dry)	BV2 VEG/SOIL (wet)	FM MILK (d/L)	FF MEAT (d/kg)	TRANS- LOCATION
H	1	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00
He	2	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00

Li	3	2.5E-02	1.7E-03	2.0E-02	1.0E-02	1.0E+00
Be	4	1.0E-02	6.4E-04	9.0E-07	1.0E-03	1.0E+00
B	5	4.0E+00	8.6E-01	1.5E-03	8.0E-04	1.0E+00
C	6	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00
N	7	3.0E+01	1.3E+01	2.5E-02	7.5E-02	1.0E+00
O	8	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00
F	9	6.0E-02	2.6E-03	1.0E-03	1.5E-01	1.0E+00
Ne	10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00
Na	11	7.5E-02	2.4E-02	3.5E-02	5.5E-02	1.0E+00
Mg	12	1.0E+00	2.4E-01	4.0E-03	5.0E-03	1.0E+00
Al	13	4.0E-03	2.8E-04	2.0E-04	1.5E-03	1.0E+00
Si	14	3.5E-01	3.0E-02	2.0E-05	4.0E-05	1.0E+00
P	15	3.5E+00	1.5E+00	1.5E-02	5.5E-02	1.0E+00
S	16	1.5E+00	6.4E-01	1.5E-02	1.0E-01	1.0E+00
Cl	17	7.0E+01	3.0E+01	1.5E-02	8.0E-02	1.0E+00
Ar	18	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00
K	19	1.0E+00	2.4E-01	7.0E-03	2.0E-02	1.0E+00
Ca	20	3.5E+00	1.5E-01	1.0E-02	7.0E-04	1.0E+00
ELEMENT		BV1 FORAGE/ SOIL (dry)	BV2 VEG/SOIL (wet)	FM MILK (d/L)	FF MEAT (d/kg)	TRANS- LOCATION
Sc	21	6.0E-03	4.3E-04	5.0E-06	1.5E-02	1.0E+00
Ti	22	5.5E-03	1.3E-03	1.0E-02	3.0E-02	1.0E+00
V	23	5.5E-03	1.3E-03	2.0E-05	2.5E-03	1.0E+00
Cr	24	7.5E-03	1.9E-03	1.5E-03	5.5E-03	1.0E+00
Mn	25	2.5E-01	2.1E-02	3.5E-04	4.0E-04	1.0E+00
Fe	26	4.0E-03	4.3E-04	2.5E-04	2.0E-02	1.0E+00
Co	27	2.0E-02	3.0E-03	2.0E-03	2.0E-02	1.0E+00
Ni	28	6.0E-02	2.6E-02	1.0E-03	6.0E-03	1.0E+00
Cu	29	4.0E-01	1.1E-01	1.5E-03	1.0E-02	1.0E+00
Zn	30	1.5E+00	3.9E-01	1.0E-02	1.0E-01	1.0E+00
Ga	31	4.0E-03	1.7E-04	5.0E-05	5.0E-04	1.0E+00
Ge	32	4.0E-01	3.4E-02	7.0E-02	7.0E-01	1.0E+00
As	33	4.0E-02	2.6E-03	6.0E-05	2.0E-03	1.0E+00
Se	34	2.5E-02	1.1E-02	4.0E-03	1.5E-02	1.0E+00
Br	35	1.5E+00	6.4E-01	2.0E-02	2.5E-02	1.0E+00
Kr	36	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00
Rb	37	1.5E-01	3.0E-02	1.0E-02	1.5E-02	1.0E+00
Sr	38	2.5E+00	1.1E-01	1.5E-03	3.0E-04	1.5E-01
Y	39	1.5E-02	2.6E-03	2.0E-05	3.0E-04	1.0E+00
Zr	40	2.0E-03	2.1E-04	3.0E-05	5.5E-03	1.0E+00
Nb	41	2.0E-02	2.1E-03	2.0E-02	2.5E-01	1.0E+00
Mo	42	2.5E-01	2.6E-02	1.5E-03	6.0E-03	1.0E+00
Tc	43	9.5E+00	6.4E-01	1.0E-02	8.5E-03	1.0E+00
Ru	44	7.5E-02	8.6E-03	6.0E-07	2.0E-03	5.0E-02
Rh	45	1.5E-01	1.7E-02	1.0E-02	2.0E-03	1.0E+00
Pd	46	1.5E-01	1.7E-02	1.0E-02	4.0E-03	1.0E+00
Ag	47	4.0E-01	4.3E-02	2.0E-02	3.0E-03	1.0E+00
Cd	48	5.5E-01	6.4E-02	1.0E-03	5.5E-04	1.0E+00
In	49	4.0E-03	1.7E-04	1.0E-04	8.0E-03	1.0E+00
Sn	50	3.0E-02	2.6E-03	1.0E-03	8.0E-02	1.0E+00
Sb	51	2.0E-01	1.3E-02	1.0E-04	1.0E-03	1.0E+00
Te	52	2.5E-02	1.7E-03	2.0E-04	1.5E-02	1.0E+00
I	53	1.5E-01	2.1E-02	1.0E-02	7.0E-03	1.0E-01
Xe	54	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00
Cs	55	8.0E-02	1.3E-02	7.0E-03	2.0E-02	5.0E-01
Ba	56	1.5E-01	6.4E-03	3.5E-04	1.5E-04	1.0E+00
La	57	1.0E-02	1.7E-03	2.0E-05	3.0E-04	1.0E+00
Ce	58	1.0E-02	1.7E-03	2.0E-05	7.5E-04	3.0E-01
Pr	59	1.0E-02	1.7E-03	2.0E-05	3.0E-04	1.0E+00
Nd	60	1.0E-02	1.7E-03	2.0E-05	3.0E-04	1.0E+00
Pm	61	1.0E-02	1.7E-03	2.0E-05	5.0E-03	1.0E+00
Sm	62	1.0E-02	1.7E-03	2.0E-05	5.0E-03	1.0E+00
Eu	63	1.0E-02	1.7E-03	2.0E-05	5.0E-03	1.0E+00
Gd	64	1.0E-02	1.7E-03	2.0E-05	3.5E-03	1.0E+00
Tb	65	1.0E-02	1.7E-03	2.0E-05	4.5E-03	1.0E+00
Dy	66	1.0E-02	1.7E-03	2.0E-05	5.5E-03	1.0E+00
Ho	67	1.0E-02	1.7E-03	2.0E-05	4.5E-03	1.0E+00
Er	68	1.0E-02	1.7E-03	2.0E-05	4.0E-03	1.0E+00

: Ingestion dose calculation from an acute release

Example Runs

ELEMENT		BV1 FORAGE/ SOIL (dry)	BV2 VEG/SOIL (wet)	FM MILK (d/L)	FF MEAT (d/kg)	TRANS- LOCATION
Tm	69	1.0E-02	1.7E-03	2.0E-05	4.5E-03	1.0E+00
Yb	70	1.0E-02	1.7E-03	2.0E-05	4.0E-03	1.0E+00
Lu	71	1.0E-02	1.7E-03	2.0E-05	4.5E-03	1.0E+00
Hf	72	3.5E-03	3.6E-04	5.0E-06	1.0E-03	1.0E+00
Ta	73	1.0E-02	1.1E-03	3.0E-06	6.0E-04	1.0E+00
W	74	4.5E-02	4.3E-03	3.0E-04	4.5E-02	1.0E+00
Re	75	1.5E+00	1.5E-01	1.5E-03	8.0E-03	1.0E+00
Os	76	1.5E-02	1.5E-03	5.0E-03	4.0E-01	1.0E+00
Ir	77	5.5E-02	6.4E-03	2.0E-06	1.5E-03	1.0E+00
Pt	78	9.5E-02	1.1E-02	5.0E-03	4.0E-03	1.0E+00
Au	79	4.0E-01	4.3E-02	5.5E-06	8.0E-03	1.0E+00
Hg	80	9.0E-01	8.6E-02	4.5E-04	2.5E-01	1.0E+00
Tl	81	4.0E-03	1.7E-04	2.0E-03	4.0E-02	1.0E+00
Pb	82	4.5E-02	3.9E-03	2.5E-04	3.0E-04	1.0E+00
Bi	83	3.5E-02	2.1E-03	5.0E-04	4.0E-04	1.0E+00
Po	84	2.5E-03	1.7E-04	3.5E-04	9.5E-05	1.0E+00
At	85	1.0E+00	6.4E-02	1.0E-02	1.0E-02	1.0E+00
Rn	86	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00
Fr	87	3.0E-02	3.4E-03	2.0E-02	2.5E-03	1.0E+00
Ra	88	1.5E-02	6.4E-04	4.5E-04	2.5E-04	1.0E+00
Ac	89	3.5E-03	1.5E-04	2.0E-05	2.5E-05	1.0E+00
Th	90	8.5E-04	3.6E-05	5.0E-06	6.0E-06	1.0E+00
Pa	91	2.5E-03	1.1E-04	5.0E-06	1.0E-05	1.0E+00
U	92	8.5E-03	1.7E-03	6.0E-04	2.0E-04	1.0E+00
Np	93	1.0E-01	4.3E-03	5.0E-06	5.5E-05	1.0E+00
Pu	94	4.5E-04	1.9E-05	1.0E-07	5.0E-07	1.0E-02
Am	95	5.5E-03	1.1E-04	4.0E-07	3.5E-06	3.0E-01
Cm	96	8.5E-04	6.4E-06	2.0E-05	3.5E-06	3.0E-01
Bk	97	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cf	98	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Es	99	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Fm	100	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

DOWNWIND DISTANCE = 1.000E+03 (m) PLUME TRAVEL TIME = 2.500E+02 (s)
CHI/Q = 2.100E-06 (s/cu m)

DOWNWIND DISTANCE = 5.000E+03 (m) PLUME TRAVEL TIME = 1.250E+03 (s)
CHI/Q = 3.200E-07 (s/cu m)

&& INGESTION COMMITTED DOSE EQUIVALENTS ORDERED BY ORGAN (Sv)

		DOWNWIND DISTANCES (m)	
ORGAN	NO.	1.00E+03	5.00E+03
-----		----	-----
LUNGS	1	1.27E-09	1.93E-10
S WALL	2	1.34E-07	2.04E-08
SI WALL	3	3.33E-07	5.07E-08
ULI WALL	4	1.92E-06	2.93E-07
LLI WALL	5	5.88E-06	8.97E-07
TESTES	6	2.56E-05	3.90E-06
BREASTS	7	1.14E-09	1.74E-10
BONE SUR	8	1.73E-03	2.63E-04
R MARROW	9	1.39E-04	2.11E-05
THYROID	10	9.08E-10	1.38E-10
KIDNEYS	11	1.35E-09	2.05E-10
LIVER	12	3.15E-04	4.80E-05
SPLEEN	13	1.01E-09	1.54E-10
PANCREAS	14	1.39E-09	2.12E-10
MUSCLE	15	1.14E-09	1.74E-10
SKIN	16	9.66E-10	1.47E-10
BRAIN	17	1.08E-09	1.65E-10
THYMUS	18	9.16E-10	1.40E-10
BL WALL	19	1.06E-09	1.62E-10
ADRENALS	20	1.49E-09	2.27E-10
ESOPHAGU	21	9.16E-10	1.40E-10
OVARIES	22	2.56E-05	3.90E-06
UTERUS	23	1.18E-09	1.79E-10

RADIOLOGICAL SAFETY ANALYSIS COMPUTER PROGRAM (RSAC-6)

(RSAC-6, REV 6.2, 03/11/02) SERIAL 1 DATE 20050720 TIME 09:37 PAGE 6
 : Ingestion dose calculation from an acute release

&& INGESTION COMMITTED DOSE EQUIVALENCES ORDERED BYDOSE (Sv)

ORGAN	NO.	DOWNWIND DISTANCES (m)	
		1.00E+03	5.00E+03
BONE SUR	8	1.73E-03	2.63E-04
LIVER	12	3.15E-04	4.80E-05
R MARROW	9	1.39E-04	2.11E-05
TESTES	6	2.56E-05	3.90E-06
OVARIES	22	2.56E-05	3.90E-06
LLI WALL	5	5.88E-06	8.97E-07
ULI WALL	4	1.92E-06	2.93E-07
SI WALL	3	3.33E-07	5.07E-08
S WALL	2	1.34E-07	2.04E-08
ADRENALS	20	1.49E-09	2.27E-10
PANCREAS	14	1.39E-09	2.12E-10
KIDNEYS	11	1.35E-09	2.05E-10
LUNGS	1	1.27E-09	1.93E-10
UTERUS	23	1.18E-09	1.79E-10
BREASTS	7	1.14E-09	1.74E-10
MUSCLE	15	1.14E-09	1.74E-10
BRAIN	17	1.08E-09	1.65E-10
BL WALL	19	1.06E-09	1.62E-10
SPLEEN	13	1.01E-09	1.54E-10
SKIN	16	9.66E-10	1.47E-10
THYMUS	18	9.16E-10	1.40E-10
ESOPHAGU	21	9.16E-10	1.40E-10
THYROID	10	9.08E-10	1.38E-10

&& INGESTION WEIGHTED COMMITTED DOSE EQUIVALENTS (Sv)

ORGAN	NO.	DOWNWIND DISTANCES (m)	
		1.00E+03	5.00E+03
LUNGS	1	1.52E-10	2.32E-11
S WALL	2	8.04E-09	1.23E-09
SI WALL	3	2.00E-08	3.04E-09
ULI WALL	4	1.15E-07	1.76E-08
LLI WALL	5	3.53E-07	5.38E-08
TESTES	6	6.40E-06	9.75E-07
BREASTS	7	1.72E-10	2.61E-11
BONE SUR	8	5.18E-05	7.89E-06
R MARROW	9	1.66E-05	2.53E-06
THYROID	10	2.72E-11	4.15E-12
KIDNEYS	11	8.08E-11	1.23E-11
LIVER	12	1.89E-05	2.88E-06
SPLEEN	13	6.08E-11	9.27E-12
PANCREAS	14	8.34E-11	1.27E-11
MUSCLE	15	6.86E-11	1.05E-11
SKIN	16	9.66E-12	1.47E-12
BRAIN	17	6.48E-11	9.88E-12
THYMUS	18	5.50E-11	8.38E-12
BL WALL	19	6.38E-11	9.72E-12
ADRENALS	20	8.95E-11	1.36E-11
ESOPHAGU	21	5.50E-11	8.38E-12
OVARIES	22	6.40E-06	9.75E-07
UTERUS	23	7.05E-11	1.07E-11
CEDE	24	9.42E-05	1.44E-05

EXECUTION time = 5.00E-02 SECONDS

Example 4: Ground Surface Dose Calculation

An inventory of only Co-60 is entered directly using the 2000 Series option. The 1000 Series option is used to demonstrate how the inventory can be fractionated at any time. In this case, the option to fractionate the entire inventory by a factor of 0.5 has been selected.

The release is assumed to occur at ground level during a Class C meteorological condition with a 2,000-m mixing layer depth. Diffusion is made using Hilsmeier-Gifford diffusion parameters.

In this example, the air density is changed to the standard sea level value. Ground surface doses are calculated in rem for all organs and the element Co only. A building shielding factor of 1. has been used to indicate that no reduction of the dose by buildings is desired. In addition, it is assumed that doses are being calculated for a controlled area where workers are normally present only 40/168 hours a week. Thus an occupancy factor of 0.2381 has been entered.

Example 4 Ground surface dose calculation - Rsac

File Edit View Run Examples Tools Help

Add Series Fifty-Mile Radius Reports Critdos

[1000 Fission Product Inventory Calculation](#)

[2000 Direct Radionuclide Input](#)

[5000 Meteorological Data Input](#)

[7000 Internal/External Dose Calculation](#)

[9000 Cloud Gamma Dose Calculation](#)

Title: Ground surface dose calculation

Series	Title
2000	Direct input of Co-60
1000	Using 1000 Series to fractionate inventory
5000	Input of meteorological data
7000	Requesting ground surface dose calculation

INEEL
Idaho National Engineering and Environmental Laboratory

Last Modified: 7/1/2005 9:40:48 AM

File Name: C:\Program Files\INEEL\WinRp\Examples\Example 4 Ground surface dose calculation.rsac

WinRp Windows RSAC Plus
and
RSAC
Radiological Safety Analysis Computer Program

Radiological Safety Analysis Computer Program (RSAC 6.2)

Windows RSAC Plus (WinRp 2.0.0)

Name: Brad Schrader Company: INEEL

Serial: H4JY6-52RR0-ERun Date: 07/01/2005 Run Time: 10:14:09

File: Example 4 Ground surface dose calculation.rsac

```
* Ground surface dose calculation
# Direct input of Co-60
2000,0
# Entered 75 Ci of Co-60
Co-60,75.
2999
# Using 1000 Series to fractionate inventory
1000
1001,1,0.,0. * Retaining existing inventory
#
1004,0,0.5 * Fractionating the inventory by a factor of 0.5
#
1999
# Input of meteorological data
5000,0
5001,6.,0.,2000.,1.240E3,0.,0 * 6 m/s average wind velocity
# Ground level release
# 2000. m mixing layer depth
# 1240. g/cubic m air density
#
5002,0.001,0.01,0.,0.001,0.001 * Defaulting to program standard deposition
# velocities
#
5101,3.5E3 * Calculating dose for 1 downwind distance
#
5201,1.,0. * Releasing as a puff
#
5400,2,0.,0.,0 * Requesting program to calculate sigmas
#
5410,1,3,0 * Hilsmeier-Gifford diffusion
# Class C
#
# Cannot request plume rise for ground level release
#
5999
# Requesting ground surface dose calculation
7000,4,-2,1,1,1 * Printing only summary doses
# Calculating doses in rem
# Requesting doses for only selected elements
# Requesting doses for all organs
#
7001,0,0.,1.,1.,0.2381 * Defaulting to program standard values except:
# The building shielding factor which has been
# changed to a factor of 1. indicating no reduction
# of the dose by buildings
#

0 1 2 3 4 5 6 7
123456789012345678901234567890123456789012345678901234567890123456789

#
# Receptor is assumed to be in a controlled work
# area and is present only 40/168 hours per week.
# An occupancy factor of 0.2381 has been entered.
#
7081,27 * Requesting dose calculation for only cobalt
#
7999
10000

0 1 2 3 4 5 6 7
123456789012345678901234567890123456789012345678901234567890123456789
```

***DIRECT RADIONUCLIDE INPUT

ANY PREVIOUS INVENTORY HAS BEEN ZEROED

Example Runs

```

      NUCLIDE          HALF LIFE          CURIES
270600  Co 60         5.271E+00  yr      7.500E+01

***FISSION PRODUCT CALCULATION

      FRACTION OF RADIONUCLIDE INVENTORY RELEASED = 5.000E-01

      TOTAL RADIONUCLIDE REMAINING = 1.388E+12  D/s OR 3.750E+01 Ci

*** METEOROLOGICAL DATA

      MEAN WIND SPEED = 6.000E+00 (m/s)    STACK HEIGHT = 0.000E+00 (m)
      MIXING LAYER HEIGHT = 2.000E+03 (m)    AIR DENSITY = 1.240E+03 (g/cu m)
      WET DEPOSITION SCAVENGING COEFFICIENT = 0.000E+00 (1/S)

      NO CORRECTION IS BEING MADE FOR PLUME DEPLETION BY FALLOUT

      DEFAULT 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

      PASQUILL CLASS C METEOROLOGY,  H-G    SIGMA VALUES

      NO BUILDING WAKE CORRECTION MADE

      ENHANCED DEPOSITION PARAMETERS
      PARTICLE DIAMETER = 0.000E+00 (m)    PARTICLE DENSITY = 0.000E+00 (g/cm3)
      DOWNWIND DISTANCE    STACK          SIGY          SIGZ          CHI/Q
                           HEIGHT (m)      (m)            (m)            (s/cu m)
      3.500E+03            0.000E+00    3.546E+02    1.979E+02    7.560E-07

*** GROUND SURFACE DEPOSITION DOSE EQUIVALENT CALCULATION

      USING DOSE RATE CONVERSION FACTORS FROM FEDERAL GUIDANCE REPORT 12

      OCCUPANCY FACTOR = 2.381E-01
      TIME RECEPTOR IS EXPOSED TO CONTAMINATED SOIL = 1.000E+00 (yr)
      BUILDING SHIELDING FACTOR = 1.000E+00
      RELEASE TIME FOR EXPONENTIAL DECAY FUNCTION = 1.000E+00 SECONDS

      DOWNWIND DISTANCE = 3.500E+03 (m)    PLUME TRAVEL TIME = 5.833E+02 (s)
                                           CHI/Q = 7.560E-07 (s/cu m)

&& GROUND SURFACE  DOSE EQUIVALENTS ORDERED BY ORGAN (rem)

      DOWNWIND DISTANCES (m)
      ORGAN  NO.  3.50E+03
      -----
      Lungs   1   1.62E-03
      S Wall  2   1.56E-03
      SI Wall 3   1.55E-03
      ULI Wall 4   1.56E-03
      LLI Wall 5   1.61E-03
      Testes  6   1.75E-03
      Breast  7   1.67E-03
      BSurface 8   2.22E-03
      R Marrow 9   1.67E-03
      Thyroid 10  1.61E-03
      Kidney  11  1.59E-03
      Liver   12  1.57E-03
      Spleen  13  1.57E-03
      Pancreas 14  1.46E-03
      Muscle  15  1.47E-03
      Skin    16  1.97E-03
      Brain   17  1.54E-03
      Thymus  18  1.50E-03
      U Bladd 19  1.59E-03
      Adrenal 20  1.75E-03
      Esophagu 21 1.42E-03
      Ovaries 22  1.46E-03
```


Uterus 23 1.52E-03

&& GROUND SURFACE DOSE EQUIVALENCES ORDERED BY DOSE (rem)

ORGAN	NO.	DOWNWIND DISTANCES (m)
-----	----	-----
BSurface	8	2.22E-03
Skin	16	1.97E-03
Testes	6	1.75E-03
Adrenal	20	1.75E-03
Breast	7	1.67E-03
R Marrow	9	1.67E-03
Lungs	1	1.62E-03
LLI Wall	5	1.61E-03
Thyroid	10	1.61E-03
Kidney	11	1.59E-03
U Bladd	19	1.59E-03
Liver	12	1.57E-03
Spleen	13	1.57E-03
S Wall	2	1.56E-03
ULI Wall	4	1.56E-03
SI Wall	3	1.55E-03
Brain	17	1.54E-03
Uterus	23	1.52E-03
Thymus	18	1.50E-03
Muscle	15	1.47E-03
Pancreas	14	1.46E-03
Ovaries	22	1.46E-03
Esophagu	21	1.42E-03

&& GROUND SURFACE WEIGHTED DOSE EQUIVALENTS (rem)

ORGAN	NO.	DOWNWIND DISTANCES (m)
-----	----	-----
Lungs	1	1.95E-04
S Wall	2	9.35E-05
SI Wall	3	9.31E-05
ULI Wall	4	9.35E-05
LLI Wall	5	9.65E-05
Testes	6	4.38E-04
Breast	7	2.51E-04
BSurface	8	6.67E-05
R Marrow	9	2.00E-04
Thyroid	10	4.82E-05
Kidney	11	9.52E-05
Liver	12	9.39E-05
Spleen	13	9.39E-05
Pancreas	14	8.75E-05
Muscle	15	8.79E-05
Skin	16	1.97E-05
Brain	17	9.26E-05
Thymus	18	9.01E-05
U Bladd	19	9.52E-05
Adrenal	20	1.05E-04
Esophagu	21	8.49E-05
Ovaries	22	3.65E-04
Uterus	23	9.13E-05
EXT EDE	24	1.68E-03

EXECUTION time = 2.00E-02 SECONDS

Example 5: Air Immersion Dose Calculation

This example assumes the release of only Xe-133. The release is assumed to be from a 50-m stack during Class D meteorology (Markee diffusion parameters) with a 10 m/s average wind velocity. A mixing layer depth of 2,500 m has been chosen. The release is assumed to occur exponentially as a function of time with a release half-time of 2 days. Plume rise above the top of the stack was calculated for a jet plume being released from a 1.22- internal stack diameter discharging with a 20 m/s efflux speed.

Air immersion doses were calculated for all organs with the dose expressed in rem. The decay time for the exponential release function was set to 2 hours (2.88E4 seconds) to give the air immersion dose that would be received during the first 2 hours following the onset of the release. To alert the user, RSAC-6 prints a warning when less than 100% of the inventory has been released. In this case, the release was purposely adjusted to give less than a 100% release.

When using the air immersion model, be sure that the plume size is large compared to the mean free path of the gamma rays and that it has diffused to the ground level. The easiest way to confirm this is to make a calculation using the finite-plume cloud gamma model (Series 9000) to see if the EDE converges. In this case, it is a good exercise for the user to verify that the results for the two models converge only to a factor of 3, indicating that the air immersion model is not appropriate in this case and that a cloud gamma calculation using a finite plume should be used.

Example 5 Air immersion dose calculation - Rsac

File Edit View Run Examples Tools Help

Add Series Fifty-Mile Radius Reports Critdos

[1000 Fission Product Inventory Calculation](#)

[2000 Direct Radionuclide Input](#)

[5000 Meteorological Data Input](#)

[7000 Internal/External Dose Calculation](#)

[9000 Cloud Gamma Dose Calculation](#)

Title: Air immersion dose calculation

Series	Title
2000	Direct input of Xe-133 only
5000	Input of meteorological data
7000	Requesting air immersion dose calculation

INEEL
Idaho National Engineering and Environmental Laboratory

Last Modified: 7/1/2005 10:16:49 AM

File Name: C:\Program Files\INEEL\WinRp\Examples\Example 5 Air immersion dose calculation.rsac

WinRp Windows RSAC Plus

and

RSAC
Radiological Safety Analysis Computer Program

Example Runs

```
#           defaulting to 0
#
#           20 m/s efflux speed of gases
#
5999
# Requesting air immersion dose calculation
7000,5,-2,1,1,1 * Air immersion dose calculation is a valid calculation
#               because the plume is large compared to the mean free path
#               of the photons
#
#               Printing only summary doses
#               Calculating doses in rem
#               Requesting doses for only selected elements
#               Requesting doses for all organs
#
7001,0,7.2E3,0,0 * Breathing rate not used - defaulting to program
#               calculated value
#
#               Exposing the receptor for only 2 h (7.2E3 s) This does
#               not release all of the inventory. The program prints a
#               warning when less than 100% of the inventory is released
#               to be sure that is really what is desired. This would
#               represent evacuation of the downwind location after 2
#               hours or the release was terminated after 2 hours.
#
7081,54 * Requesting dose calculation for only xenon. A request could have
#       been made for all elements; however, it would only take more
#       computer time to get the same result.
#
7999
10000

***DIRECT RADIONUCLIDE INPUT

      ANY PREVIOUS INVENTORY HAS BEEN ZEROED

      NUCLIDE           HALF LIFE           CURIES

541330 Xe133      5.243E+00 d      1.000E+06

*** METEOROLOGICAL DATA

      MEAN WIND SPEED = 1.000E+01 (m/s)   STACK HEIGHT = 5.000E+01 (m)
      MIXING LAYER HEIGHT = 2.500E+03 (m)   AIR DENSITY = 1.099E+03 (g/cu m)
      WET DEPOSITION SCAVENGING COEFFICIENT = 0.000E+00 (1/S)

      NO CORRECTION IS BEING MADE FOR PLUME DEPLETION BY FALLOUT

      DEFAULT DRY DEPOSITION VELOCITIES (m/s)
      SOLIDS = 0.000E+00   HALOGENS = 0.000E+00   NOBLE GASES = 0.000E+00
      CESIUM = 0.000E+00   RUTHENIUM = 0.000E+00
      THERE IS 1 SET OF LEAKAGE CONSTANTS (K1,K2)
      5.687E-05           5.687E-05

      PASQUILL CLASS D METEOROLOGY, MARKEE SIGMA VALUES

      PLUME RISE CALCULATED USING JET CONDITIONS
      STACK DIAMETER = 1.220E+00 (m)
      EFFLUENT VELOCITY = 2.000E+01 (m/s)
      RESTORING ACCELERATION = 0.000E+00 (1/sq s)

      ENHANCED DEPOSITION PARAMETERS
      PARTICLE DIAMETER = 0.000E+00 (m)   PARTICLE DENSITY = 0.000E+00 (g/cm3)
      DOWNWIND DISTANCE   STACK           SIGY           SIGZ           CHI/Q
                        HEIGHT (m)         (m)             (m)           (s/cu m)
      1.000E+04           5.732E+01   3.841E+02   2.998E+02   2.714E-07
      DOWNWIND DISTANCE   STACK           SIGY           SIGZ           CHI/Q
                        HEIGHT (m)         (m)             (m)           (s/cu m)
      3.000E+04           5.732E+01   8.322E+02   7.506E+02   5.081E-08

*** AIR IMMERSION DOSE EQUIVALENT CALCULATION

      USING DOSE RATE CONVERSION FACTORS FROM FEDERAL GUIDANCE REPORT 12
```

RELEASE TIME FOR EXPONENTIAL DECAY FUNCTION = 7.200E+03 SECONDS
 WARNING, EXPONENTIAL LEAKAGE CONSTANTS AND EXPONENTIAL DECAY TIME ARE NOT
 MATCHED, 3.36E+01 PERCENT OF INVENTORY RELEASED

DOWNWIND DISTANCE = 1.000E+04 (m) PLUME TRAVEL TIME = 1.000E+03 (s)
 CHI/Q = 2.714E-07 (s/cu m)

DOWNWIND DISTANCE = 3.000E+04 (m) PLUME TRAVEL TIME = 3.000E+03 (s)
 CHI/Q = 5.081E-08 (s/cu m)

&& AIR IMMERSION DOSE EQUIVALENTS ORDERED BY ORGAN (rem)

ORGAN	NO.	DOWNWIND DISTANCES (m)	
		1.00E+04	3.00E+04
Lungs	1	4.83E-04	9.02E-05
S Wall	2	4.03E-04	7.51E-05
SI Wall	3	3.10E-04	5.79E-05
ULI Wall	4	3.39E-04	6.33E-05
LLI Wall	5	3.14E-04	5.85E-05
Testes	6	5.89E-04	1.10E-04
Breast	7	7.17E-04	1.34E-04
BSurface	8	1.88E-03	3.50E-04
R Marrow	9	3.92E-04	7.31E-05
Thyroid	10	5.53E-04	1.03E-04
Kidney	11	4.35E-04	8.13E-05
Liver	12	4.10E-04	7.65E-05
Spleen	13	4.06E-04	7.58E-05
Pancreas	14	3.38E-04	6.31E-05
Muscle	15	2.96E-04	5.53E-05
Skin	16	1.82E-03	3.39E-04
Brain	17	4.54E-04	8.47E-05
Thymus	18	4.65E-04	8.67E-05
U Bladd	19	3.81E-04	7.10E-05
Adrenal	20	5.09E-04	9.49E-05
Esophagu	21	2.93E-04	5.48E-05
Ovaries	22	2.83E-04	5.29E-05
Uterus	23	2.98E-04	5.55E-05

&& AIR IMMERSION DOSE EQUIVALENCES ORDERED BY DOSE (rem)

ORGAN	NO.	DOWNWIND DISTANCES (m)	
		1.00E+04	3.00E+04
BSurface	8	1.88E-03	3.50E-04
Skin	16	1.82E-03	3.39E-04
Breast	7	7.17E-04	1.34E-04
Testes	6	5.89E-04	1.10E-04
Thyroid	10	5.53E-04	1.03E-04
Adrenal	20	5.09E-04	9.49E-05
Lungs	1	4.83E-04	9.02E-05
Thymus	18	4.65E-04	8.67E-05
Brain	17	4.54E-04	8.47E-05
Kidney	11	4.35E-04	8.13E-05
Liver	12	4.10E-04	7.65E-05
Spleen	13	4.06E-04	7.58E-05
S Wall	2	4.03E-04	7.51E-05
R Marrow	9	3.92E-04	7.31E-05
U Bladd	19	3.81E-04	7.10E-05
ULI Wall	4	3.39E-04	6.33E-05
Pancreas	14	3.38E-04	6.31E-05
LLI Wall	5	3.14E-04	5.85E-05
SI Wall	3	3.10E-04	5.79E-05
Uterus	23	2.98E-04	5.55E-05
Muscle	15	2.96E-04	5.53E-05
Esophagu	21	2.93E-04	5.48E-05
Ovaries	22	2.83E-04	5.29E-05

&& AIR IMMERSION WEIGHTED DOSE EQUIVALENTS (rem)

ORGAN	NO.	DOWNWIND DISTANCES (m)	
		1.00E+04	3.00E+04

Example Runs

Lungs	1	5.80E-05	1.08E-05
S Wall	2	2.42E-05	4.51E-06
SI Wall	3	1.86E-05	3.48E-06
ULI Wall	4	2.04E-05	3.80E-06
LLI Wall	5	1.88E-05	3.51E-06
Testes	6	1.47E-04	2.75E-05
Breast	7	1.08E-04	2.01E-05
BSurface	8	5.63E-05	1.05E-05
R Marrow	9	4.70E-05	8.77E-06
Thyroid	10	1.66E-05	3.09E-06
Kidney	11	2.61E-05	4.88E-06
Liver	12	2.46E-05	4.59E-06
Spleen	13	2.44E-05	4.55E-06
Pancreas	14	2.03E-05	3.79E-06
Muscle	15	1.78E-05	3.32E-06
Skin	16	1.82E-05	3.39E-06
Brain	17	2.72E-05	5.08E-06
Thymus	18	2.79E-05	5.20E-06
U Bladd	19	2.28E-05	4.26E-06
Adrenal	20	3.05E-05	5.70E-06
Esophagu	21	1.76E-05	3.29E-06
Ovaries	22	7.08E-05	1.32E-05
Uterus	23	1.79E-05	3.33E-06
EXT EDE	24	5.71E-04	1.07E-04

EXECUTION time = 1.00E-02 SECONDS

Example 6: Fifty-Mile Radius Dose Calculation for a Chronic Release

The radionuclide inventory for this fifty-mile radius dose calculation is entered directly through the 2000 Series lines. Doses from inhalation are calculated using a 24-hour average breathing rate of $2.66\text{E-}4\text{ m}^3/\text{s}$ and the RSAC-6 default lung clearance classes selected to give maximum element doses. Committed doses are calculated for the ingestion pathway assuming that crops are grown on the contaminated soil for a period of 15 years using RSAC-6 default ingestion parameters. Doses from the ground surface pathway assume that the receptor is exposed for a period of 1 year following initiation of the release.

The inventory entered using the 2000 Series lines is assumed to be the activity that is actually released during the chronic release period. As such, care must be exercised not to inadvertently decay correct the inventory again during the holdup period before release. This was done by omitting the (8020) and (8021) lines, thereby, defaulting to only 1-second holdup time for the exponential decay function. This essentially gives no additional decay before release.

Population and dispersion coefficients are read from an external file called "popcq". This external file was prepared by using WinRp 2.0, and the input data was saved as an external file.

Example Runs

```
Radiological Safety Analysis Computer Program (RSAC 6.2)
Windows RSAC Plus (WinRp 2.0.0)
Name: Brad Schrader      Company: INEEL
Serial: H4JY6-52RR0-E   Run Date: 07/01/2005      Run Time: 10:20:12
File: Example 6 Fifty mile radius for chronic release.rsac
```

```
* Fifty-mile radius dose calculation for a chronic release
# Entering radionuclides directly
2000,0
H-3,0.021
Sr-89,3.1E-5
Sr-90,3.5
Y-90,3.5
Rh-106m,0.35
Ru-106,0.35
I-129,2.5E-6
Cs-134,2.1
Ba-137m,3.5
Cs-137,3.7
Ce-144,2.8
Pr-144m,2.8
Pm-147,2.2
Eu-154,0.21
Th-228,5.3E-7
Pu-238,1.2E-3
Pu-239,1.8E-5
Am-241,4.E-6
2999
# Requesting a 50 mile population dose calculation
8000
8001,0 * The option chosen requests dose calculations for all radionuclides
# that were entered in the 2000 Series input. When the user wants
# to be selective in which radionuclides, use the "Radionuclides
# will be selected below" option and then select the desired
# radionuclides.
#
8011,3,1,0,0,2.66E-4,15.,1. * Using program default lung clearance classes
# which are selected to give the maximum
# element dose
#
# Doses in rem with ingestion dose controlled
# by user provided parameters on Line 8014
#
```



```

#                               Using 24 hour average breathing rate
#
#                               Requesting calculation of dose from
#                               consumption of crops grown on the
#                               contaminated soil for a period of 15 years
#
#                               Requesting ground surface dose calculation
#                               time of 1 year following the initiation of
#                               release
#
#
8012,1,8,10,24  * A maximum of 4 organs can be specified during a run.
#               Requesting dose to the Lungs, Bone Surface, Thyroid, and
#               CEDE.
#
8020,0.
# Entering the population and dispersion coefficients
8051,0.,30.,3.,19.,12.
8052,0.,0.,80.,440.,750.
8053,0.,0.,350.,780.,940.
8054,0.,0.,190.,530.,1.5E4
8055,0.,30.,100.,850.,4.3E4
8056,0.,0.,100.,5.8E3,7.1E3
8057,0.,7.,250.,1.6E3,4.4E4
8058,0.,0.,46.,610.,4.9E3
8059,0.,0.,0.,100.,8.4E3
8060,0.,0.,0.,0.,130.
8061,0.,0.,0.,0.,0.
8062,0.,6.,9.,130.,210.
8063,0.,1.4E3,180.,120.,27.
8064,3.,110.,310.,66.,560.
8065,3.,24.,99.,140.,150.
8066,0.,96.,99.,56.,78.
8071,2.E-8,6.E-9,2.E-9,2.E-9,1.E-9
8072,2.E-8,1.E-8,8.E-9,3.E-9,2.E-9
8073,3.E-8,2.E-8,1.E-8,7.E-9,7.E-9
8074,3.E-8,2.E-8,1.E-8,1.E-8,2.E-9
8075,3.E-8,1.E-8,6.E-9,3.E-9,1.E-9
8076,7.E-8,2.E-8,6.E-9,1.E-9,9.E-10
8077,7.E-8,2.E-8,8.E-9,3.E-9,2.E-9
8078,4.E-8,2.E-8,6.E-9,3.E-9,1.E-9
8079,3.E-8,2.E-8,6.E-9,3.E-9,1.E-9
8080,3.E-8,2.E-8,1.E-8,3.E-9,1.E-9
8081,2.E-8,6.E-9,1.E-9,5.E-10,2.E-10
8082,1.E-8,2.E-9,6.E-10,3.E-10,1.E-10
8083,1.E-8,2.E-9,6.E-10,3.E-10,1.E-10
8084,1.E-8,2.E-9,8.E-10,5.E-10,2.E-10
8085,1.E-8,3.E-9,1.E-9,3.E-10,2.E-10
8086,2.E-8,6.E-9,3.E-9,1.E-9,1.E-10
8091,4.5,4.5,4.5,4.5
8092,4.5,4.5,4.5,4.5
8093,4.5,4.5,4.5,4.5
8094,4.5,4.5,4.5,4.5
8110,3,4.E-8,1.4E4,4.5  * Site Boundary data
#
8120,0.001,0.01,0.,0.001,0.001  * Using the program default deposition
#                               velocities
#
8999
10000

      : Fifty-mile radius dose calculation for a chronic release

***DIRECT RADIONUCLIDE INPUT

      ANY PREVIOUS INVENTORY HAS BEEN ZEROED

      NUCLIDE          HALF LIFE          CURIES

      10030   H   3      1.233E+01   yr      2.100E-02
      380890  Sr  89      5.053E+01   d       3.100E-05
      380900  Sr  90      2.878E+01   yr      3.500E+00
      390900  Y   90      6.410E+01   h       3.500E+00
      451061  Rh106m     1.310E+02   m       3.500E-01
      441060  Ru106      3.736E+02   d       3.500E-01

```

Example Runs

531290	I129	1.570E+07	yr	2.500E-06
551340	Cs134	2.065E+00	yr	2.100E+00
561371	Ba137m	2.552E+00	m	3.500E+00
551370	Cs137	3.007E+01	yr	3.700E+00
581440	Ce144	2.849E+02	d	2.800E+00
591441	Pr144m	7.200E+00	m	2.800E+00
611470	Pm147	2.623E+00	yr	2.200E+00
631540	Eu154	8.593E+00	yr	2.100E-01
902280	Th228	1.912E+00	yr	5.300E-07
942380	Pu238	8.770E+01	yr	1.200E-03
942390	Pu239	2.411E+04	yr	1.800E-05
952410	Am241	4.322E+02	yr	4.000E-06

***FIFTY MILE ANNUAL DOSE CALCULATIONS

EXTERNAL DOSE-RATE CONVERSION FACTORS FROM FEDERAL GUIDANCE REPORT #12

INTERNAL DOSE CONVERSION FACTORS FROM FEDERAL GUIDANCE REPORT #11

BREATHING RATE = 2.6600E-04 cu m/s

DEFAULT ELEMENT LUNG CLEARANCE CLASSES SELECTED TO GIVE MAXIMUM DOSE

BUILDING SHIELDING/EXPOSURE FACTORS

7.000E-01 DEPOSITION

1.000E+00 AIR IMMERSION

RELEASE TIME FOR EXPONENTIAL DECAY FUNCTION = 1.0000E+00 (s)

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)

INTERNAL EXPOSURE INTEGRATION PERIOD = 50 yr

GROUND SURFACE EXPOSURE PERIOD = 1.000E+00 yr

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

			BEFORE DECAY	
NUCLIDE			INVENTORY (Ci)	LUNG CLASS
1	10030	H- 3	2.100E-02	HTO
2	380890	Sr- 89	3.100E-05	Y
3	380900	Sr- 90	3.500E+00	Y
4	390900	Y- 90	3.500E+00	Y
5	441060	Ru-106	3.500E-01	Y
6	451061	Rh-106m	3.500E-01	Y

7	531290	I-129	2.500E-06	D
8	551340	Cs-134	2.100E+00	D
9	551370	Cs-137	3.700E+00	D
10	561371	Ba-137m	3.500E+00	D
11	581440	Ce-144	2.800E+00	Y
12	591441	Pr-144m	2.800E+00	Y
13	611470	Pm-147	2.200E+00	Y
14	631540	Eu-154	2.100E-01	W
15	902280	Th-228	5.300E-07	W
16	942380	Pu-238	1.200E-03	W
17	942390	Pu-239	1.800E-05	W
18	952410	Am-241	4.000E-06	W

50 MILE POPULATION VALUES

SECTOR	DISTANCE (MILES)					SECTOR TOTAL
	0-10	10-20	20-30	30-40	40-50	
1 N	0.0E+00	3.0E+01	3.0E+00	1.9E+01	1.2E+01	6.4E+01
2 NNE	0.0E+00	0.0E+00	8.0E+01	4.4E+02	7.5E+02	1.3E+03
3 NE	0.0E+00	0.0E+00	3.5E+02	7.8E+02	9.4E+02	2.1E+03
4 ENE	0.0E+00	0.0E+00	1.9E+02	5.3E+02	1.5E+04	1.6E+04
5 E	0.0E+00	3.0E+01	1.0E+02	8.5E+02	4.3E+04	4.4E+04
6 ESE	0.0E+00	0.0E+00	1.0E+02	5.8E+03	7.1E+03	1.3E+04
7 SE	0.0E+00	7.0E+00	2.5E+02	1.6E+03	4.4E+04	4.6E+04
8 SSE	0.0E+00	0.0E+00	4.6E+01	6.1E+02	4.9E+03	5.6E+03
9 S	0.0E+00	0.0E+00	0.0E+00	1.0E+02	8.4E+03	8.5E+03
10 SSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E+02	1.3E+02
11 SW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
12 WSW	0.0E+00	6.0E+00	9.0E+00	1.3E+02	2.1E+02	3.6E+02
13 W	0.0E+00	1.4E+03	1.8E+02	1.2E+02	2.7E+01	1.7E+03
14 WNW	3.0E+00	1.1E+02	3.1E+02	6.6E+01	5.6E+02	1.0E+03
15 NW	3.0E+00	2.4E+01	9.9E+01	1.4E+02	1.5E+02	4.2E+02
16 NNW	0.0E+00	9.6E+01	9.9E+01	5.6E+01	7.8E+01	3.3E+02

50 MILE RADIUS TOTAL 1.4E+05

50 MILE CHI/Q (s/cu m)

SECTOR	DISTANCE (MILES)				
	0-10	10-20	20-30	30-40	40-50
1 N	2.0E-08	6.0E-09	2.0E-09	2.0E-09	1.0E-09
2 NNE	2.0E-08	1.0E-08	8.0E-09	3.0E-09	2.0E-09
3 NE	3.0E-08	2.0E-08	1.0E-08	7.0E-09	7.0E-09
4 ENE	3.0E-08	2.0E-08	1.0E-08	1.0E-08	2.0E-09
5 E	3.0E-08	1.0E-08	6.0E-09	3.0E-09	1.0E-09
6 ESE	7.0E-08	2.0E-08	6.0E-09	1.0E-09	9.0E-10
7 SE	7.0E-08	2.0E-08	8.0E-09	3.0E-09	2.0E-09
8 SSE	4.0E-08	2.0E-08	6.0E-09	3.0E-09	1.0E-09
9 S	3.0E-08	2.0E-08	6.0E-09	3.0E-09	1.0E-09
10 SSW	3.0E-08	2.0E-08	1.0E-08	3.0E-09	1.0E-09
11 SW	2.0E-08	6.0E-09	1.0E-09	5.0E-10	2.0E-10
12 WSW	1.0E-08	2.0E-09	6.0E-10	3.0E-10	1.0E-10
13 W	1.0E-08	2.0E-09	6.0E-10	3.0E-10	1.0E-10
14 WNW	1.0E-08	2.0E-09	8.0E-10	5.0E-10	2.0E-10
15 NW	1.0E-08	3.0E-09	1.0E-09	3.0E-10	2.0E-10
16 NNW	2.0E-08	6.0E-09	3.0E-09	1.0E-09	1.0E-10

50 MILE CHI/Q * POPULATION VALUES (person-s/cu m)

SECTOR	DISTANCE (MILES)					SECTOR TOTAL
	0-10	10-20	20-30	30-40	40-50	
1 N	0.0E+00	1.8E-07	6.0E-09	3.8E-08	1.2E-08	2.4E-07
2 NNE	0.0E+00	0.0E+00	6.4E-07	1.3E-06	1.5E-06	3.5E-06
3 NE	0.0E+00	0.0E+00	3.5E-06	5.5E-06	6.6E-06	1.6E-05

Example Runs

4	ENE	0.0E+00	0.0E+00	1.9E-06	5.3E-06	3.0E-05	3.7E-05
5	E	0.0E+00	3.0E-07	6.0E-07	2.6E-06	4.3E-05	4.6E-05
6	ESE	0.0E+00	0.0E+00	6.0E-07	5.8E-06	6.4E-06	1.3E-05
7	SE	0.0E+00	1.4E-07	2.0E-06	4.8E-06	8.8E-05	9.5E-05
8	SSE	0.0E+00	0.0E+00	2.8E-07	1.8E-06	4.9E-06	7.0E-06
9	S	0.0E+00	0.0E+00	0.0E+00	3.0E-07	8.4E-06	8.7E-06
10	SSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E-07	1.3E-07
11	SW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
12	WSW	0.0E+00	1.2E-08	5.4E-09	3.9E-08	2.1E-08	7.7E-08
13	W	0.0E+00	2.8E-06	1.1E-07	3.6E-08	2.7E-09	2.9E-06
14	WNW	3.0E-08	2.2E-07	2.5E-07	3.3E-08	1.1E-07	6.4E-07
15	NW	3.0E-08	7.2E-08	9.9E-08	4.2E-08	3.0E-08	2.7E-07
16	NNW	0.0E+00	5.8E-07	3.0E-07	5.6E-08	7.8E-09	9.4E-07

50 MILE RADIUS TOTAL 2.3E-04

AVERAGE WIND VELOCITY FOR EACH SECTOR

SECTOR	(m/s)
1 N	4.5E+00
2 NNE	4.5E+00
3 NE	4.5E+00
4 ENE	4.5E+00
5 E	4.5E+00
6 ESE	4.5E+00
7 SE	4.5E+00
8 SSE	4.5E+00
9 S	4.5E+00
10 SSW	4.5E+00
11 SW	4.5E+00
12 WSW	4.5E+00
13 W	4.5E+00
14 WNW	4.5E+00
15 NW	4.5E+00
16 NNW	4.5E+00

LOCATION OF MAXIMUM EXPOSED INDIVIDUAL:

SECTOR = 3 NE
 DISTANCE = 1.4E+04 m
 CHI/Q = 4.0E-08 s/cu m
 AVERAGE WIND VELOCITY = 4.5E+00 m/s

INTERNAL DOSES (rem) FOR THE MAXIMUM EXPOSED INDIVIDUAL FROM INHALATION

NUCLIDE	ORGAN			
	LUNGS	BONE SUR	THYROID	CEDE
H- 3	2.1E-11	2.1E-11	2.1E-11	2.1E-11
Sr- 89	1.0E-10	1.9E-13	9.7E-15	1.4E-11
Sr- 90	3.9E-04	9.8E-06	3.7E-08	4.8E-05
Y- 90	1.3E-06	2.1E-09	7.1E-11	3.1E-07
Ru-106	1.4E-05	2.2E-08	2.4E-08	1.8E-06
Rh-106m	2.6E-09	6.7E-11	7.0E-11	5.1E-10
I-129	3.1E-14	1.4E-14	1.5E-10	4.6E-12
Cs-134	9.8E-07	9.1E-07	9.2E-07	1.0E-06
Cs-137	1.3E-06	1.2E-06	1.2E-06	1.3E-06
Ba-137m	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ce-144	8.7E-05	5.2E-07	3.2E-08	1.1E-05
Pr-144m	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pm-147	6.7E-06	1.7E-06	1.7E-12	9.2E-07
Eu-154	6.5E-07	4.3E-06	5.9E-08	6.4E-07
Th-228	2.0E-09	2.9E-08	2.8E-11	1.4E-09
Pu-238	8.7E-07	9.0E-05	4.5E-11	5.0E-06
Pu-239	1.2E-08	1.5E-06	6.4E-13	8.2E-08
Am-241	2.9E-09	3.4E-07	2.5E-13	1.9E-08
TOTALS	5.1E-04	1.1E-04	2.2E-06	7.1E-05

EXTERNAL DOSES (rem) FOR THE MAXIMUM EXPOSED INDIVIDUAL FROM AIR IMMERSION

NUCLIDE	ORGAN			
	Lungs	BSurface	Thyroid	EXT EDE
H- 3	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sr- 89	3.5E-16	9.6E-16	3.8E-16	3.8E-16
Sr- 90	3.6E-12	1.3E-11	4.1E-12	4.2E-12
Y- 90	9.9E-11	2.5E-10	1.0E-10	1.1E-10
Ru-106	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Rh-106m	6.0E-09	9.5E-09	6.1E-09	6.1E-09
I-129	8.6E-17	4.4E-16	1.5E-16	1.5E-16
Cs-134	2.5E-08	4.0E-08	2.5E-08	2.5E-08
Cs-137	4.0E-12	1.4E-11	4.5E-12	4.6E-12
Ba-137m	1.6E-08	2.6E-08	1.6E-08	1.6E-08
Ce-144	3.4E-10	1.1E-09	3.7E-10	3.8E-10
Pr-144m	1.9E-12	7.7E-12	2.6E-12	2.6E-12
Pm-147	1.9E-13	7.7E-13	2.4E-13	2.4E-13
Eu-154	2.0E-09	3.2E-09	2.1E-09	2.1E-09
Th-228	7.1E-18	2.2E-17	7.5E-18	7.8E-18
Pu-238	2.0E-16	1.8E-15	7.7E-16	9.4E-16
Pu-239	7.6E-18	2.7E-17	1.1E-17	1.2E-17
Am-241	4.3E-16	1.8E-15	5.0E-16	5.2E-16
TOTALS	4.9E-08	8.0E-08	5.0E-08	5.0E-08

EXTERNAL DOSES (rem) FOR THE MAXIMUM EXPOSED INDIVIDUAL FROM GROUND SURFACE

NUCLIDE	ORGAN			
	Lungs	BSurface	Thyroid	EXT EDE
H- 3	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sr- 89	4.3E-14	1.2E-13	4.6E-14	4.9E-14
Sr- 90	2.7E-09	1.0E-08	3.0E-09	3.5E-09
Y- 90	5.8E-08	1.4E-07	6.1E-08	6.5E-08
Ru-106	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Rh-106m	9.1E-10	1.3E-09	9.3E-10	9.5E-10
I-129	1.3E-12	7.0E-12	2.0E-12	2.3E-12
Cs-134	9.2E-06	1.3E-05	9.6E-06	9.6E-06
Cs-137	2.9E-09	1.1E-08	3.2E-09	3.7E-09
Ba-137m	6.9E-06	1.0E-05	7.2E-06	7.2E-06
Ce-144	1.2E-07	3.7E-07	1.2E-07	1.3E-07
Pr-144m	8.7E-10	4.1E-09	1.1E-09	1.2E-09
Pm-147	1.5E-10	7.0E-10	1.9E-10	2.3E-10
Eu-154	8.1E-07	1.2E-06	8.2E-07	8.5E-07
Th-228	2.8E-15	8.9E-15	3.0E-15	3.7E-15
Pu-238	3.3E-13	5.2E-12	1.4E-12	3.5E-12
Pu-239	5.0E-15	3.7E-14	1.1E-14	2.3E-14
Am-241	2.8E-13	1.3E-12	3.1E-13	3.9E-13
TOTALS	1.7E-05	2.5E-05	1.8E-05	1.8E-05

INTERNAL DOSES (rem) FOR THE MAXIMUM EXPOSED INDIVIDUAL FROM INGESTION

NUCLIDE	ORGAN			
	LUNGS	BONE SUR	THYROID	CEDE
H- 3	6.0E-11	6.0E-11	6.0E-11	6.0E-11
Sr- 89	7.0E-13	1.4E-11	7.0E-13	7.3E-12
Sr- 90	4.1E-06	1.1E-03	4.1E-06	1.0E-04
Y- 90	1.6E-11	4.6E-10	1.6E-11	3.7E-06
Ru-106	5.0E-08	5.1E-08	5.0E-08	2.6E-07
Rh-106m	7.4E-19	7.6E-19	1.1E-19	1.0E-17
I-129	8.1E-12	1.1E-11	1.2E-07	3.7E-09
Cs-134	3.8E-05	3.8E-05	3.8E-05	4.3E-05
Cs-137	5.6E-05	5.5E-05	5.5E-05	5.9E-05

Example Runs

Ba-137m	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ce-144	2.5E-09	4.9E-08	2.0E-09	2.2E-06
Pr-144m	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pm-147	1.9E-13	2.5E-07	3.0E-14	2.7E-07
Eu-154	2.1E-08	4.3E-07	5.5E-09	2.5E-07
Th-228	4.0E-13	4.1E-10	4.0E-13	1.9E-11
Pu-238	5.3E-13	9.9E-07	5.0E-13	5.4E-08
Pu-239	7.3E-15	1.6E-08	7.0E-15	9.0E-10
Am-241	1.9E-14	1.0E-08	7.4E-15	5.5E-10
TOTALS	9.8E-05	1.2E-03	9.7E-05	2.1E-04

TOTAL EXPOSURES FOR THE MAXIMUM EXPOSED INDIVIDUAL (rem)

NUCLIDE	ORGAN			
	LUNGS	BONE SUR	THYROID	CEDE
H- 3	8.1E-11	8.1E-11	8.1E-11	8.1E-11
Sr- 89	1.0E-10	1.4E-11	7.6E-13	2.1E-11
Sr- 90	4.0E-04	1.1E-03	4.1E-06	1.5E-04
Y- 90	1.3E-06	1.5E-07	6.2E-08	4.0E-06
Ru-106	1.4E-05	7.3E-08	7.4E-08	2.0E-06
Rh-106m	9.5E-09	1.1E-08	7.1E-09	7.6E-09
I-129	9.5E-12	1.8E-11	1.2E-07	3.7E-09
Cs-134	4.8E-05	5.2E-05	4.8E-05	5.3E-05
Cs-137	5.7E-05	5.6E-05	5.6E-05	6.0E-05
Ba-137m	6.9E-06	1.0E-05	7.2E-06	7.2E-06
Ce-144	8.7E-05	9.4E-07	1.6E-07	1.3E-05
Pr-144m	8.7E-10	4.1E-09	1.1E-09	1.2E-09
Pm-147	6.7E-06	2.0E-06	1.9E-10	1.2E-06
Eu-154	1.5E-06	6.0E-06	8.9E-07	1.7E-06
Th-228	2.0E-09	2.9E-08	2.8E-11	1.4E-09
Pu-238	8.7E-07	9.1E-05	4.7E-11	5.1E-06
Pu-239	1.2E-08	1.5E-06	6.6E-13	8.3E-08
Am-241	2.9E-09	3.5E-07	5.7E-13	1.9E-08
TOTALS	6.2E-04	1.4E-03	1.2E-04	3.0E-04

TOTAL EXPOSURE FOR EACH RADIONUCLIDE IS THE SUMMATION OF THE DOSE
RESULTING FROM INHALATION, AIR IMMERSION, GROUND SURFACE AND INGESTION

INTERNAL 50-MILE DOSES (person-rem) FROM INHALATION

NUCLIDE	ORGAN			
	LUNGS	BONE SUR	THYROID	CEDE
H- 3	1.2E-07	1.2E-07	1.2E-07	1.2E-07
Sr- 89	5.9E-07	1.1E-09	5.6E-11	7.9E-08
Sr- 90	2.3E+00	5.6E-02	2.1E-04	2.8E-01
Y- 90	7.4E-03	1.2E-05	4.1E-07	1.8E-03
Ru-106	8.3E-02	1.3E-04	1.4E-04	1.0E-02
Rh-106m	6.3E-06	1.6E-07	1.7E-07	1.2E-06
I-129	1.8E-10	7.9E-11	8.9E-07	2.7E-08
Cs-134	5.6E-03	5.3E-03	5.3E-03	6.0E-03
Cs-137	7.4E-03	6.7E-03	6.7E-03	7.3E-03
Ba-137m	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ce-144	5.0E-01	3.0E-03	1.9E-04	6.4E-02
Pr-144m	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pm-147	3.9E-02	1.0E-02	9.9E-09	5.3E-03
Eu-154	3.8E-03	2.5E-02	3.4E-04	3.7E-03
Th-228	1.1E-05	1.7E-04	1.6E-07	8.1E-06
Pu-238	5.0E-03	5.2E-01	2.6E-07	2.9E-02
Pu-239	7.1E-05	8.6E-03	3.7E-09	4.8E-04
Am-241	1.7E-05	2.0E-03	1.5E-09	1.1E-04
TOTALS	2.9E+00	6.4E-01	1.3E-02	4.1E-01

EXTERNAL 50-MILE DOSES (person-rem) FROM AIR IMMERSION

NUCLIDE	ORGAN			
	Lungs	BSurface	Thyroid	EXT EDE
H- 3	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sr- 89	2.0E-12	5.6E-12	2.2E-12	2.2E-12
Sr- 90	2.1E-08	7.4E-08	2.4E-08	2.4E-08
Y- 90	5.7E-07	1.4E-06	6.1E-07	6.2E-07
Ru-106	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Rh-106m	1.4E-05	2.3E-05	1.5E-05	1.5E-05
I-129	5.0E-13	2.5E-12	8.9E-13	8.8E-13
Cs-134	1.4E-04	2.3E-04	1.5E-04	1.5E-04
Cs-137	2.3E-08	7.8E-08	2.6E-08	2.7E-08
Ba-137m	9.1E-05	1.5E-04	9.3E-05	9.3E-05
Ce-144	2.0E-06	6.5E-06	2.2E-06	2.2E-06
Pr-144m	7.6E-09	3.1E-08	1.1E-08	1.1E-08
Pm-147	1.1E-09	4.4E-09	1.4E-09	1.4E-09
Eu-154	1.2E-05	1.8E-05	1.2E-05	1.2E-05
Th-228	4.1E-14	1.3E-13	4.4E-14	4.5E-14
Pu-238	1.2E-12	1.0E-11	4.5E-12	5.4E-12
Pu-239	4.4E-14	1.6E-13	6.5E-14	7.1E-14
Am-241	2.5E-12	1.1E-11	2.9E-12	3.0E-12
TOTALS	2.6E-04	4.3E-04	2.7E-04	2.7E-04

EXTERNAL 50-MILE DOSES (person-rem) FROM GROUND SURFACE

NUCLIDE	ORGAN			
	Lungs	BSurface	Thyroid	EXT EDE
H- 3	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sr- 89	2.5E-10	6.8E-10	2.6E-10	2.8E-10
Sr- 90	1.5E-05	5.9E-05	1.8E-05	2.0E-05
Y- 90	3.4E-04	8.3E-04	3.6E-04	3.8E-04
Ru-106	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Rh-106m	2.2E-06	3.2E-06	2.2E-06	2.3E-06
I-129	7.6E-09	4.0E-08	1.2E-08	1.3E-08
Cs-134	5.3E-02	7.7E-02	5.5E-02	5.5E-02
Cs-137	1.7E-05	6.1E-05	1.9E-05	2.1E-05
Ba-137m	4.0E-02	5.9E-02	4.2E-02	4.1E-02
Ce-144	6.8E-04	2.1E-03	7.2E-04	7.7E-04
Pr-144m	3.5E-06	1.6E-05	4.5E-06	4.9E-06
Pm-147	8.7E-07	4.0E-06	1.1E-06	1.3E-06
Eu-154	4.7E-03	7.0E-03	4.7E-03	4.9E-03
Th-228	1.6E-11	5.2E-11	1.7E-11	2.1E-11
Pu-238	1.9E-09	3.0E-08	8.3E-09	2.0E-08
Pu-239	2.9E-11	2.1E-10	6.6E-11	1.4E-10
Am-241	1.6E-09	7.6E-09	1.8E-09	2.2E-09
TOTALS	9.9E-02	1.5E-01	1.0E-01	1.0E-01

INTERNAL 50-MILE DOSES (person-rem) FROM INGESTION

NUCLIDE	ORGAN			
	LUNGS	BONE SUR	THYROID	CEDE
H- 3	3.5E-07	3.5E-07	3.5E-07	3.5E-07
Sr- 89	4.0E-09	8.1E-08	4.0E-09	4.2E-08
Sr- 90	2.4E-02	6.6E+00	2.4E-02	6.0E-01
Y- 90	9.2E-08	2.7E-06	9.2E-08	2.1E-02
Ru-106	2.9E-04	2.9E-04	2.9E-04	1.5E-03
Rh-106m	1.8E-15	1.8E-15	2.7E-16	2.5E-14
I-129	4.7E-08	6.2E-08	7.1E-04	2.1E-05
Cs-134	2.2E-01	2.2E-01	2.2E-01	2.5E-01
Cs-137	3.2E-01	3.2E-01	3.2E-01	3.4E-01
Ba-137m	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Example Runs

Ce-144	1.4E-05	2.8E-04	1.1E-05	1.3E-02
Pr-144m	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pm-147	1.1E-09	1.5E-03	1.8E-10	1.6E-03
Eu-154	1.2E-04	2.5E-03	3.2E-05	1.4E-03
Th-228	2.3E-09	2.4E-06	2.3E-09	1.1E-07
Pu-238	3.1E-09	5.7E-03	2.9E-09	3.1E-04
Pu-239	4.2E-11	9.5E-05	4.1E-11	5.2E-06
Am-241	1.1E-10	5.9E-05	4.3E-11	3.2E-06
TOTALS	5.6E-01	7.1E+00	5.6E-01	1.2E+00

TOTAL RADIONUCLIDE EXPOSURE WITHIN 50-MILE RADIUS (person-rem)

NUCLIDE	ORGAN			
	LUNGS	BONE SUR	THYROID	CEDE
H- 3	4.7E-07	4.7E-07	4.7E-07	4.7E-07
Sr- 89	5.9E-07	8.3E-08	4.4E-09	1.2E-07
Sr- 90	2.3E+00	6.6E+00	2.4E-02	8.8E-01
Y- 90	7.8E-03	8.4E-04	3.6E-04	2.3E-02
Ru-106	8.3E-02	4.2E-04	4.3E-04	1.2E-02
Rh-106m	2.3E-05	2.6E-05	1.7E-05	1.8E-05
I-129	5.5E-08	1.0E-07	7.1E-04	2.1E-05
Cs-134	2.8E-01	3.0E-01	2.8E-01	3.1E-01
Cs-137	3.3E-01	3.3E-01	3.3E-01	3.5E-01
Ba-137m	4.0E-02	5.9E-02	4.2E-02	4.2E-02
Ce-144	5.0E-01	5.4E-03	9.2E-04	7.8E-02
Pr-144m	3.5E-06	1.6E-05	4.5E-06	4.9E-06
Pm-147	3.9E-02	1.2E-02	1.1E-06	6.9E-03
Eu-154	8.6E-03	3.4E-02	5.1E-03	1.0E-02
Th-228	1.1E-05	1.7E-04	1.6E-07	8.3E-06
Pu-238	5.0E-03	5.2E-01	2.7E-07	2.9E-02
Pu-239	7.1E-05	8.7E-03	3.8E-09	4.8E-04
Am-241	1.7E-05	2.0E-03	3.3E-09	1.1E-04
TOTALS	3.6E+00	7.9E+00	6.8E-01	1.7E+00

TOTAL EXPOSURE FOR EACH RADIONUCLIDE IS THE SUMMATION OF THE DOSE
RESULTING FROM INHALATION, AIR IMMERSION, GROUND SURFACE AND INGESTION

TOTAL SECTOR EXPOSURES (person-rem) WITHIN 50-MILE RADIUS FOR THE LUNGS

SECTOR	DISTANCE (MILES)					SECTOR TOTAL
	0-10	10-20	20-30	30-40	40-50	
1 N	0.0E+00	2.8E-03	9.3E-05	5.9E-04	1.9E-04	3.7E-03
2 NNE	0.0E+00	0.0E+00	1.0E-02	2.1E-02	2.3E-02	5.4E-02
3 NE	0.0E+00	0.0E+00	5.4E-02	8.5E-02	1.0E-01	2.4E-01
4 ENE	0.0E+00	0.0E+00	3.0E-02	8.2E-02	4.7E-01	5.8E-01
5 E	0.0E+00	4.7E-03	9.3E-03	4.0E-02	6.7E-01	7.2E-01
6 ESE	0.0E+00	0.0E+00	9.3E-03	9.0E-02	9.9E-02	2.0E-01
7 SE	0.0E+00	2.2E-03	3.1E-02	7.5E-02	1.4E+00	1.5E+00
8 SSE	0.0E+00	0.0E+00	4.3E-03	2.8E-02	7.6E-02	1.1E-01
9 S	0.0E+00	0.0E+00	0.0E+00	4.7E-03	1.3E-01	1.4E-01
10 SSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.0E-03	2.0E-03
11 SW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
12 WSW	0.0E+00	1.9E-04	8.4E-05	6.1E-04	3.3E-04	1.2E-03
13 W	0.0E+00	4.4E-02	1.7E-03	5.6E-04	4.2E-05	4.6E-02
14 WNW	4.7E-04	3.4E-03	3.9E-03	5.1E-04	1.7E-03	1.0E-02
15 NW	4.7E-04	1.1E-03	1.5E-03	6.5E-04	4.7E-04	4.2E-03
16 NNW	0.0E+00	9.0E-03	4.6E-03	8.7E-04	1.2E-04	1.5E-02

50 MILE RADIUS TOTAL 3.6E+00

TOTAL SECTOR EXPOSURES (person-rem) WITHIN 50-MILE RADIUS FOR THE BONE SUR

SECTOR	DISTANCE (MILES)					SECTOR TOTAL
	0-10	10-20	20-30	30-40	40-50	
1 N	0.0E+00	6.2E-03	2.1E-04	1.3E-03	4.1E-04	8.1E-03
2 NNE	0.0E+00	0.0E+00	2.2E-02	4.5E-02	5.1E-02	1.2E-01
3 NE	0.0E+00	0.0E+00	1.2E-01	1.9E-01	2.3E-01	5.3E-01
4 ENE	0.0E+00	0.0E+00	6.5E-02	1.8E-01	1.0E+00	1.3E+00
5 E	0.0E+00	1.0E-02	2.1E-02	8.7E-02	1.5E+00	1.6E+00
6 ESE	0.0E+00	0.0E+00	2.1E-02	2.0E-01	2.2E-01	4.4E-01
7 SE	0.0E+00	4.8E-03	6.8E-02	1.6E-01	3.0E+00	3.2E+00
8 SSE	0.0E+00	0.0E+00	9.4E-03	6.3E-02	1.7E-01	2.4E-01
9 S	0.0E+00	0.0E+00	0.0E+00	1.0E-02	2.9E-01	3.0E-01
10 SSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.4E-03	4.4E-03
11 SW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
12 WSW	0.0E+00	4.1E-04	1.8E-04	1.3E-03	7.2E-04	2.6E-03
13 W	0.0E+00	9.6E-02	3.7E-03	1.2E-03	9.2E-05	1.0E-01
14 WNW	1.0E-03	7.5E-03	8.5E-03	1.1E-03	3.8E-03	2.2E-02
15 NW	1.0E-03	2.5E-03	3.4E-03	1.4E-03	1.0E-03	9.3E-03
16 NNW	0.0E+00	2.0E-02	1.0E-02	1.9E-03	2.7E-04	3.2E-02

50 MILE RADIUS TOTAL 7.9E+00

TOTAL SECTOR EXPOSURES (person-rem) WITHIN 50-MILE RADIUS FOR THE THYROID

SECTOR	DISTANCE (MILES)					SECTOR TOTAL
	0-10	10-20	20-30	30-40	40-50	
1 N	0.0E+00	5.3E-04	1.8E-05	1.1E-04	3.5E-05	6.9E-04
2 NNE	0.0E+00	0.0E+00	1.9E-03	3.9E-03	4.4E-03	1.0E-02
3 NE	0.0E+00	0.0E+00	1.0E-02	1.6E-02	1.9E-02	4.6E-02
4 ENE	0.0E+00	0.0E+00	5.6E-03	1.6E-02	8.8E-02	1.1E-01
5 E	0.0E+00	8.8E-04	1.8E-03	7.5E-03	1.3E-01	1.4E-01
6 ESE	0.0E+00	0.0E+00	1.8E-03	1.7E-02	1.9E-02	3.8E-02
7 SE	0.0E+00	4.1E-04	5.9E-03	1.4E-02	2.6E-01	2.8E-01
8 SSE	0.0E+00	0.0E+00	8.1E-04	5.4E-03	1.4E-02	2.1E-02
9 S	0.0E+00	0.0E+00	0.0E+00	8.8E-04	2.5E-02	2.6E-02
10 SSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E-04	3.8E-04
11 SW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
12 WSW	0.0E+00	3.5E-05	1.6E-05	1.1E-04	6.2E-05	2.3E-04
13 W	0.0E+00	8.2E-03	3.2E-04	1.1E-04	7.9E-06	8.6E-03
14 WNW	8.8E-05	6.5E-04	7.3E-04	9.7E-05	3.3E-04	1.9E-03
15 NW	8.8E-05	2.1E-04	2.9E-04	1.2E-04	8.8E-05	8.0E-04
16 NNW	0.0E+00	1.7E-03	8.7E-04	1.6E-04	2.3E-05	2.7E-03

50 MILE RADIUS TOTAL 6.8E-01

Example Runs

TOTAL SECTOR EXPOSURES (person-rem) WITHIN 50-MILE RADIUS FOR THE CEDE

SECTOR	DISTANCE (MILES)					SECTOR TOTAL
	0-10	10-20	20-30	30-40	40-50	
1 N	0.0E+00	1.4E-03	4.5E-05	2.9E-04	9.0E-05	1.8E-03
2 NNE	0.0E+00	0.0E+00	4.8E-03	9.9E-03	1.1E-02	2.6E-02
3 NE	0.0E+00	0.0E+00	2.6E-02	4.1E-02	5.0E-02	1.2E-01
4 ENE	0.0E+00	0.0E+00	1.4E-02	4.0E-02	2.3E-01	2.8E-01
5 E	0.0E+00	2.3E-03	4.5E-03	1.9E-02	3.2E-01	3.5E-01
6 ESE	0.0E+00	0.0E+00	4.5E-03	4.4E-02	4.8E-02	9.6E-02
7 SE	0.0E+00	1.1E-03	1.5E-02	3.6E-02	6.6E-01	7.2E-01
8 SSE	0.0E+00	0.0E+00	2.1E-03	1.4E-02	3.7E-02	5.3E-02
9 S	0.0E+00	0.0E+00	0.0E+00	2.3E-03	6.3E-02	6.6E-02
10 SSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.8E-04	9.8E-04
11 SW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
12 WSW	0.0E+00	9.0E-05	4.1E-05	2.9E-04	1.6E-04	5.8E-04
13 W	0.0E+00	2.1E-02	8.1E-04	2.7E-04	2.0E-05	2.2E-02
14 WNW	2.3E-04	1.7E-03	1.9E-03	2.5E-04	8.4E-04	4.8E-03
15 NW	2.3E-04	5.4E-04	7.5E-04	3.2E-04	2.3E-04	2.1E-03
16 NNW	0.0E+00	4.3E-03	2.2E-03	4.2E-04	5.9E-05	7.1E-03

50 MILE RADIUS TOTAL 1.7E+00

EXECUTION time = 5.00E-02 SECONDS

Example 7: Comparison of Cloud Gamma Dose Models

This example demonstrates cloud gamma dose calculations using the finite plume model. This example cautions users on the use of the air immersion model when the plume size is not large compared to the mean free path of the gamma rays.

The example consists of the release of Cs-137 and its daughter Ba-137m at ground level during Class F meteorology (Hilsmeier-Gifford diffusion). Four downwind distances ranging from 1.E2 to 1.E5 m have been chosen to show the magnitude of error in the use of the air immersion model when improperly used. At the 1.E2-m distance, the air immersion model over estimates the dose by approximately a factor of 50. Even at the 1.E5 meter distance, the air immersion model still overestimates the dose by a factor of 1.4. During stable meteorology, plumes never diffuse to sufficient size to allow use of the commonly used air immersion model. The finite plume model should always be used to test results for convergence before using the air immersion or semi-infinite models.

Example 7 Comparison on cloud gamma dose models - Rsac

File Edit View Run Examples Tools Help

Add Series Fifty-Mile Radius Reports Critdos

[1000 Fission Product Inventory Calculation](#)

[2000 Direct Radionuclide Input](#)

[5000 Meteorological Data Input](#)

[7000 Internal/External Dose Calculation](#)

[9000 Cloud Gamma Dose Calculation](#)

Title: Comparison of cloud gamma dose models

Series	Title
2000	Entering inventory for CS-137 and Ba-137m
5000	Input of meteorological data
9000	Comparing cloud gamma dose models
7000	Calculating cloud gamma doses using the air immersion model

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Last Modified: 7/1/2005 10:25:32 AM

File Name: C:\Program Files\INEEL\WinRp\Examples\Example 7 Comparison on cloud gamma dose models.rsac

WinRp Windows RSAC Plus

and

RSAC
Radiological Safety Analysis Computer Program

Example Runs

RSAC Run Results - Example 7 Comparison on cloud gamma dose models out0001.txt

Graph & Plots
 CEDE Chi/Q Airborne Concentration
 TEDE Isopleth Ground Surface Concentration

Print... Close

Radiological Safety Analysis Computer Program (RSAC 6.2)
 Windows RSAC Plus (WinRp 2.0.0)
 Name: Brad Schrader Company: INEEL
 Serial: H4JY6-52RR0-E Run Date: 07/01/2005 Run Time: 10:25:59
 File: Example 7 Comparison on cloud gamma dose models.rsac

RSAC-6 INPUT 20050701 10:25

0 1 2 3 4 5 6 7
 123456789012345678901234567890123456789012345678901234567890123456789

* Comparison of cloud gamma dose models
 # Entering inventory for CS-137 and Ba-137m
 2000,0
 # RSAC-6 will automatically build in progeny when the inventory is decayed
 # sufficiently long prior to release or when the transport time is adequate.
 # However, in this case, the transport time is not adequate to build in the
 # Ba-137m, the source of the photons. When in doubt, enter the correct amount
 # of the progeny.
 Ba-137m,94.6
 Cs-137,100.
 2999
 # Input of meteorological data
 5000,0
 5001,0.5,0.,400.,1.099E3,0.,0 * 0.5 m/s average wind velocity
 # Ground level release
 # 400. m mixing layer depth
 # 1099. g/cubic m air density
 #

```

Radiological Safety Analysis Computer Program (RSAC 6.2)
Windows RSAC Plus (WinRp 2.0.0)
Name: Brad Schrader      Company: INEEL
Serial: H4JY6-52RR0-E    Run Date: 07/01/2005      Run Time: 10:25:59
File: Example 7 Comparison on cloud gamma dose models.rsac
* Comparison of cloud gamma dose models
# Entering inventory for CS-137 and Ba-137m
2000,0
# RSAC-6 will automatically build in progeny when the inventory is decayed
# sufficiently long prior to release or when the transport time is adequate.
# However, in this case, the transport time is not adequate to build in the
# Ba-137m, the source of the photons. When in doubt, enter the correct amount
# of the progeny.
Ba-137m,94.6
Cs-137,100.
2999
# Input of meteorological data
5000,0
5001,0.5,0.,400.,1.099E3,0.,0 * 0.5 m/s average wind velocity
# Ground level release
# 400. m mixing layer depth
# 1099. g/cubic m air density
#
5101,1.E2,1.E3,1.E4,1.E5 * 4 downwind distances have been entered to show
# how the models converge when the plume size
# becomes larger. Even at 1.E5 m the models have
# yet to really converge well. Plumes released
# during Class F or G Classes are simply too small
# to get good results from either the air
# immersion or the semi-infinite models. When
# plumes are adequately large, the doses
# calculated between the models should converge to
# better than a factor of 1.2. In this sample
# problem, the doses only agree to a factor of 1.6.
#
5201,1.,0. * Releasing as a puff
#
5400,2,0.,0.,0 * Requesting the program to calculate sigmas
#
5410,1,6,0 * Hilsmeier-Gifford diffusion
# Class F
#
5999
# Comparing cloud gamma dose models
  
```

```

9000,0,0.  * Calculating cloud gamma doses using the finite plume model and
#           the semi-infinite model
#
9000,1,0.
# Calculating cloud gamma doses using the air immersion model
7000,5,-2,1,1,2
7001,0,0.,0,0  * Defaulting to program values
#
7002,24  * Requesting only CEDE so that the models can be compared.
#
7081,56,55  * Calculating doses for only Cs and Ba
#
7999
10000

```

***DIRECT RADIONUCLIDE INPUT

ANY PREVIOUS INVENTORY HAS BEEN ZEROED

NUCLIDE	HALF LIFE	CURIES
561371 Ba137m	2.552E+00 m	9.460E+01
551370 Cs137	3.007E+01 yr	1.000E+02

*** METEOROLOGICAL DATA

MEAN WIND SPEED = 5.000E-01 (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)

NO CORRECTION IS BEING MADE FOR PLUME DEPLETION BY FALLOUT

DEFAULT DRY DEPOSITION VELOCITIES (m/s)
 SOLIDS = 0.000E+00 HALOGENS = 0.000E+00 NOBLE GASES = 0.000E+00
 CESIUM = 0.000E+00 RUTHENIUM = 0.000E+00
 THERE IS 1 SET OF LEAKAGE CONSTANTS (K1,K2)
 1.000E+00 0.000E+00

PASQUILL CLASS F METEOROLOGY, H-G SIGMA VALUES

NO BUILDING WAKE CORRECTION MADE

ENHANCED DEPOSITION PARAMETERS

PARTICLE DIAMETER = 0.000E+00 (m)	PARTICLE DENSITY = 0.000E+00 (g/cm3)
DOWNWIND DISTANCE STACK SIGY SIGZ CHI/Q	
HEIGHT (m) (m) (m) (s/cu m)	
1.000E+02 0.000E+00 4.011E+00 2.372E+00 6.691E-02	
DOWNWIND DISTANCE STACK SIGY SIGZ CHI/Q	
HEIGHT (m) (m) (m) (s/cu m)	
1.000E+03 0.000E+00 3.531E+01 1.290E+01 1.398E-03	
DOWNWIND DISTANCE STACK SIGY SIGZ CHI/Q	
HEIGHT (m) (m) (m) (s/cu m)	
1.000E+04 0.000E+00 2.876E+02 4.818E+01 4.594E-05	
DOWNWIND DISTANCE STACK SIGY SIGZ CHI/Q	
HEIGHT (m) (m) (m) (s/cu m)	
1.000E+05 0.000E+00 1.952E+03 9.108E+01 3.581E-06	

***GAMMA DOSE CALCULATION WITH EXPOSURE TIME = 1.0000E+00 (s)

CALCULATIONS MADE USING THE FINITE MODEL

EXTERNAL EDE

DOWNWIND DISTANCE = 1.000E+02 (m)	DOSE = 1.57E-02 (rem)
DOWNWIND DISTANCE = 1.000E+03 (m)	DOSE = 1.76E-03 (rem)
DOWNWIND DISTANCE = 1.000E+04 (m)	DOSE = 2.26E-04 (rem)
DOWNWIND DISTANCE = 1.000E+05 (m)	DOSE = 2.67E-05 (rem)

***GAMMA DOSE CALCULATION WITH EXPOSURE TIME = 1.0000E+00 (s)

CALCULATIONS MADE USING THE SEMI-INFINITE MODEL

EXTERNAL EDE

Example Runs

```
DOWNWIND DISTANCE = 1.000E+02 (m)      DOSE = 6.94E-01 (rem)
DOWNWIND DISTANCE = 1.000E+03 (m)      DOSE = 1.45E-02 (rem)
DOWNWIND DISTANCE = 1.000E+04 (m)      DOSE = 4.77E-04 (rem)
DOWNWIND DISTANCE = 1.000E+05 (m)      DOSE = 3.72E-05 (rem)

*** AIR IMMERSION DOSE EQUIVALENT CALCULATION

      USING DOSE RATE CONVERSION FACTORS FROM FEDERAL GUIDANCE REPORT 12

RELEASE TIME FOR EXPONENTIAL DECAY FUNCTION = 1.000E+00 SECONDS

DOWNWIND DISTANCE = 1.000E+02 (m)      PLUME TRAVEL TIME = 2.000E+02 (s)
                                      CHI/Q = 6.691E-02 (s/cu m)

DOWNWIND DISTANCE = 1.000E+03 (m)      PLUME TRAVEL TIME = 2.000E+03 (s)
                                      CHI/Q = 1.398E-03 (s/cu m)

DOWNWIND DISTANCE = 1.000E+04 (m)      PLUME TRAVEL TIME = 2.000E+04 (s)
                                      CHI/Q = 4.594E-05 (s/cu m)

DOWNWIND DISTANCE = 1.000E+05 (m)      PLUME TRAVEL TIME = 2.000E+05 (s)
                                      CHI/Q = 3.581E-06 (s/cu m)

&& AIR IMMERSION DOSE EQUIVALENTS ORDERED BY ORGAN (rem)

      DOWNWIND DISTANCES (m)
      ORGAN  NO.  1.00E+02  1.00E+03  1.00E+04  1.00E+05
      -----
NO DOSE CALCULATED (NO FGR#12 DRCF FOR REQUESTED RADIONUCLIDES)

&& AIR IMMERSION DOSE EQUIVALENCES ORDERED BY DOSE (rem)

      DOWNWIND DISTANCES (m)
      ORGAN  NO.  1.00E+02  1.00E+03  1.00E+04  1.00E+05
      -----
NO DOSE CALCULATED (NO FGR#12 DRCF FOR REQUESTED RADIONUCLIDES)

&& AIR IMMERSION WEIGHTED DOSE EQUIVALENTS (rem)

      DOWNWIND DISTANCES (m)
      ORGAN  NO.  1.00E+02  1.00E+03  1.00E+04  1.00E+05
      -----
EXT EDE    24   7.37E-01  1.54E-02  5.06E-04  3.94E-05

EXECUTION time = 3.00E-02 SECONDS
```

Example 8: Hypothetical Criticality Accident

This example demonstrates how to model a complex scenario following a hypothetical criticality accident in a single RSAC-6 run. The initial radionuclide inventory is established by running the reactor at 250 MW for a period of 30 days. The reactor is assumed to be shut down for a period of 3 years before a criticality accident involving only 10% of the reactor inventory.

Because RSAC-6 does not calculate actinides, the 2000 Series option is used to show how actinide inventories can be added to the calculated fission product inventory.

The 1000 Series is used to calculate the additional fission product inventory produced immediately following a $3.E18$ fissions criticality occurring over a period of 0.001 second

One of the concerns from a criticality accident is the amount of iodines released. The direct fission yield of most of the iodines is small compared to the chain yield. Thus, it is necessary to calculate the ingrowth of iodines for a period of time following the criticality accident until either off-gas ventilation systems can be isolated or the energy present has dissipated sufficiently to reduce continued release of iodines to the off-gas system. The amount of iodines that would continue to be released during a 40-minute period subsequent to the criticality excursion are calculated using the option that allows releases from an operating reactor to be calculated. While a reactor is not really being operated, the modeling can be used by assuming a reactor that operates at a very low power level during the 40-minute period. An insignificant operating power level of $1.E-6$ W is used to incrementally release the iodines that buildup during the 40-minute period.

At this stage of the accident, further refinement of the source term can be made by fractionating the inventory by individual element. To demonstrate this option, element fractionations are based on the release fractions presented in Table 6-10 of DOE-HDBK-3010 (DOE 1994).

The inventory is now released to the off-gas system. It is decayed for 50 seconds until the first HEPA filter is reached. At that time the solids are reduced by a factor of $1.E-3$, which gives a decontamination factor of 1,000 for the HEPA filter. After emerging from the first HEPA filter, the inventory is decayed for 2.5 minutes until the final two HEPA filters are reached. A decontamination factor of 500 is taken for each of these two HEPA filters yielding a net reduction in the solids by a factor of $4.E-6$.

At this stage of the accident analysis, the activity is discharged to a 76-m stack. For worst case meteorology, the release is assumed to occur during Class F (Markee diffusion) with a 2 m/s average wind velocity. It is further assumed that the release occurs at about daylight and that the plume fumigates when the downwind receptor location is reached. Plume rise from the stack is calculated for a jet plume and a 2.44-m stack internal diameter and a 10.16 m/s efflux speed.

The doses from inhalation are calculated for all organs; however, only dose summaries have been requested. Lung clearance classes have been defaulted to the maximum element doses. The respirable fraction has been set to 1.

Ground surface dose calculations have been made for a period of 1 year subsequent to the release. The receptors are assumed to be in a controlled onsite location occupied for 40/168 hours per week for an occupancy factor of 0.2381.

The final request is for a summary dose of the EDE by pathway. A warning is printed that no ingestion dose calculations were made. Ingestion dose calculations are not applicable because the calculation was done for a controlled onsite location.

Example Runs

Example 8 Hypothetical criticality accident - Rsac

File Edit View Run Examples Tools Help

Add Series Fifty-Mile Radius Reports Critdos

1000 Fission Product Inventory Calculation

2000 Direct Radionuclide Input

5000 Meteorological Data Input

7000 Internal/External Dose Calculation

9000 Cloud Gamma Dose Calculation

Title: Hypothetical criticality accident

Series	Title
1000	Build the initial fission product inventory for the fissionable material
2000	Add actinides directly to the previously calculated fission produc...
1000	Add fission product inventory from the criticality accident
1000	1000 Series re-entered to decay and fractionate the inventory
5000	Input of meteorological parameters
7000	Requesting an inhalation dose calculation
7000	Requesting ground surface dose calculation for all organs
9000	Requesting calculation of the cloud gamma dose
3000	Dose summary by pathway

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Last Modified: 6/23/2005 8:47:42 AM

File Name: C:\Program Files\INEEL\WinRp\Examples\Example 8 Hypothetical criticality accident.rsac

WinRp Windows RSAC Plus

and

RSAC
Radiological Safety Analysis Computer Program

RSAC Run Results - Example 8 Hypothetical criticality accident out0018.txt

Example 8 Hypothetical criticality accident

Graph & Plots
CEDE Chi/Q Airborne Concentration
TEDE Isopleth Ground Surface Concentration

Print... Close

Radiological Safety Analysis Computer Program (RSAC 6.2)
Windows RSAC Plus (WinRp 2.0.0)
Name: Brad Schrader Company: INEEL
Serial: H4JY6-S2RR0-E Run Date: 07/01/2005 Run Time: 10:28:36
File: Example 8 Hypothetical criticality accident.rsac

RSAC-6 INPUT 20050701 10:28

123456789012345678901234567890123456789012345678901234567890123456789

* Hypothetical criticality accident
Build the initial fission product inventory for the fissionable material
1000
1001,0,2.5E8,2592000. * Reactor operates at 250 MW power for 30 days

1003,94672800.,0.,0. * Decay the inventory after shutdown of the reactor
for a period of 3 years

1004,0,0.1 * Accident involves 10% of the original reactor inventory

1999
Add actinides directly to the previously calculated fission product inventory
2000,-1 * The RSAC-6 fission product calculation model does not calculate
actinides. Actinides and activation products calculated using
other means such as using the ORIGEN2 code can be added to the
RSAC-6 calculated inventory.

.28 Ci of Pu-238

Radiological Safety Analysis Computer Program (RSAC 6.2)

Windows RSAC Plus (WinRp 2.0.0)

Name: Brad Schrader Company: INEEL

Serial: H4JY6-52RR0-ERun Date: 07/01/2005 Run Time: 10:28:36

File: Example 8 Hypothetical criticality accident.rsac

```

* Hypothetical criticality accident
# Build the initial fission product inventory for the fissionable material
1000
1001,0,2.5E8,2592000.  * Reactor operates at 250 MW power for 30 days
#
1003,94672800.,0.,0.  * Decay the inventory after shutdown of the reactor
#                          for a period of 3 years
#
1004,0,0.1  * Accident involves 10% of the original reactor inventory
#
1999
# Add actinides directly to the previously calculated fission product inventory
2000,-1  * The RSAC-6 fission product calculation model does not calculate
#          actinides. Actinides and activation products calculated using
#          other means such as using the ORIGEN2 code can be added to the
#          RSAC-6 calculated inventory.
#
# .28 Ci of Pu-238
# 1.4 Ci of Pu-239
Pu-238,0.28
Pu-239,1.4
2999
# Add fission product inventory from the criticality accident
1000
1001,1,0.,0.  * Retaining previous inventory
#
1003,0.,9.901E10,0.001  * 3E18 Fissions in 0.001 second
#                          3.E18 (fis) / 3.03E10 (w perfis) / .001 (s) =
#                          9.901E+10 W
#
1200,1,1  * Even though the criticality is assumed to last only 0.001
#          second, not all of the activity is immediately released from a
#          process. It is not uncommon for the halogens to continue to
#          evolve from the process for a period of time. In this sample
#          problem, this continued evolution of the halogens is assumed to
#          last for an additional 40 minutes.
#
#          Using the incremental release option, a fraction all of the
#          noble gases and a fraction of the solids are assumed to promptly
#          be released to the off gas system. The activity for the
#          released noble gases and solids is moved to a hold buffer from
#          which they can be decayed and fractionated in a subsequent
#          program step. All of the halogens are temporarily retained with
#          the original activity to be released in a subsequent step of the
#          program.
#
#          The last entry on the 1200 line being equal to 1 signifies that
#          the activity leaked from original inventory is being retained
#          for further calculations.
#          -----
#
#          The 1201 line indicates how much activity is to be released
#          following the criticality excursion from the "main" buffer to
#          the "hold" buffer (see pages 4-6 and 4-7 of the manual)
#
#          Releasing .001% solids, Ru and Cs to the "hold" buffer. At this
#          stage of the calculation, it is desired to only move a small
#          amount of the solids for future fractionations which will not
#          significantly affect the amount of solids remaining in the
#          "main" buffer. The solids activity remaining in the "main"
#          buffer will be used to ingrow halogens in a subsequent step.
#
#          Releasing 100% noble gases
#
#          At this stage of the calculation, no halogens are released to
#          the "hold" buffer
#
#

```

Example Runs

```
#          Release rates are calculated by dividing the total release
#          fraction by the operating time.
#
#          Fraction   Time   Rate
#          Solids      .00001 / .001 = .01
#          Halogens    0.      / .001 = 0.
#          Noble Gases 1.      / .001 = 1.E3
#
1201,0.01,0.,1.E3,0.01,0.01
1003,0.,1.E-6,2400. * This step operates the fissioning at a very low level
#                   over the subsequent 40 minute period. This
#                   contributes very little to the fission product
#                   inventory but yet allows the halogens to continue to
#                   build up from their precursors.
#
1200,80,1 * Releasing all of the halogens that ingrow from their parent
#          solid fission products in the "main" buffer to the "hold"
#          buffer over a subsequent 40 minute period. This is done
#          incrementally using 80 time steps over the following 40
#          minutes, or 30 seconds per time step. The halogen activity is
#          being added to the "hold" buffer which already contains the
#          inventory for a small fraction of the solids and 100% of the
#          noble gases. Upon completion of this setp of of the
#          claculation, the activity in the "hold" buffer is being
#          selected to be used for subsequent calculations.
#
#          Releasing 100% of the halogens that ingrow during each of the
#          80 30 second incremental release periods from their precursors.
#          RSAC-6 will not release more than 100% of the remaining
#          inventory even though too large of a release rate is requested.
#
#          We now have the halogens that ingrow over a 40 minute period
#          added to the noble gases and the small fraction of the solids
#          fraction that were originally released to the hold buffer in a
#          previous step.
#
1201,0.,1.,0.,0.,0.
1999
# 1000 Series re-entered to decay and fractionate the inventory
1000
1001,1,0.,0. * Retaining the previous inventory
#
1004,-1,1.E5,1.,1.,1.E5,1.E5 * The solids, Cs and Ru are now being restored
#                               to their original amounts prior to
#                               fractionating the release by individual
#                               elements. The inventory contains 0.001% of
#                               the solids or a fraction of 1.E-5. The
#                               solids, Cs and Ru are therefore being
#                               multiplied by 1.E+5 to restore their
#                               original amounts. The halogens and noble
#                               gases are already at the correct amounts, so
#                               they are multiplied by 1.
#
1004,1,1. * A request has now been made to frationate the inventory by
#          element. Any elements not included in the subsequent element
#          fractionation are multiplied by 1.
#
# Element fractionations are based on the release fractions presented in Table
# 6-10 of DOE-HDBK-3010 for heated spent fuel
#
1101,89,6.E-4,47,0.0004,13,6.E-4,95,6.E-4
1102,18,0.5,33,0.0004,85,0.05,79,0.002
1103,56,0.03,4,0.03,83,0.0004,97,6.E-4
1104,35,0.05,6,6.E-4,20,0.0004,48,0.0004
1105,58,0.0004,98,6.E-4,17,0.05,27,0.03
1106,24,0.03,55,0.2,66,6.E-4,68,6.E-4
1107,63,6.E-4,9,0.05,26,0.03,87,0.2
1108,64,6.E-4,1,0.5,72,0.0004,80,0.0004
1109,67,6.E-4,53,0.05,49,0.0004,77,0.002
1110,19,0.2,36,0.5,57,6.E-4,71,6.E-4
1111,12,0.03,25,0.03,42,0.03,11,0.2
1112,41,0.03,60,6.E-4,28,0.002,93,0.0004
1113,76,0.002,15,6.E-4,91,0.0004,46,0.0004
1114,61,6.E-4,84,0.07,59,6.E-4,94,0.0004
```

```

1115,88,0.03,37,0.2,45,0.002,86,0.5
1116,44,0.002,16,0.07,51,0.0004,21,6.E-4
1117,34,0.07,14,6.E-4,62,6.E-4,50,0.0004
1118,38,0.03,65,6.E-4,43,0.03,52,0.07
1119,90,0.0004,22,0.0004,81,0.0004,69,6.E-4
1120,92,0.0004,23,0.03,54,0.5,39,6.E-4
1121,70,6.E-4,30,0.0004,40,0.0004
1003,50.,0.,0. * Decaying the entire inventory for 50 seconds until the
# first HEPA filter is reached
#
1004,-1,1.E-3,1.,1.,1.E-3,1.E-3 * The decontamination factor for the first
# HEPA filter is 99.9% for solids, or a
# fraction of 1.E-3
#
1003,150.,0.,0. * Decay the inventory for 2.5 minutes for transport time to
# reach the final 2 HEPA filters
#
1004,-1,4.E-6,1.,1.,4.E-6,4.E-6 * The acceptable decontamination factor for
# successive HEPA filters is 99.8% each.
# For 2 additional filters this amounts to
# a fraction for solids of 4.E-6.
#
1999
# Input of meteorological parameters
5000,0
5001,2.,76.,380.,1.099E3,0.,1 * 2. m/s average wind velocity
# 76. m stack height
# 380. m mixing layer depth
# Depletion of the plume by dry deposition
#
5002,0.001,0.01,0.,0.001,0.001 * Using standard deposition velocities
#
5101,3.E3 * Calculating doses for 1 downwind distance
#
5201,1.,0. * No further decay correction is desired prior to the release
# from the stack to the atmosphere.
#
5400,2,0.,0.,0 * Requesting the program to calculate sigmas
#
5410,2,7,1 * Markee diffusion
# Class F fumigation
# Requesting jet plume rise
#
5411,2.44,0.,10.16,0. * 2.44 m stack internal diameter
# 10.16 m/s efflux speed
#
5999
# Requesting an inhalation dose calculation
7000,0,-2,1,0,1 * Printing out only dose summaries for all elements
# Requesting doses for all organs
#
7001,3.33E-4,0.,0,0,1. * Defaulting to program calculated release time
# Respirable fraction is set to 1.
#
7999
# Requesting ground surface dose calculation for all organs
7000,4,-2,1,0,1
7001,0,3.33E-4,1.,0.,0.2381 * Defaulting to a 1 year exposure period
# following the release. This would simulate
# continued downwind activities with no cleanup
# action.
#
7999
# Requesting calculation of the cloud gamma dose
9000,0,0. * Use the finite plume model
#
# Dose summary by pathway
3000,2 * A request is being made for a dose summary by pathway. A warning
# is printed at the bottom of the dose summary stating that the dose
# summary does not include ingestion dose calculations. When the
# receptor is in a controlled area, there would be no dose from
# ingestion.
#
10000

```

Example Runs

***FISSION PRODUCT CALCULATION

THE REACTOR HAS OPERATED AT 2.500E+08 WATTS FOR 2.592E+06 SECONDS
BURNUP = 7.500E+03 MWd

RADIONUCLIDE INVENTORY HAS BEEN DECAYED FOR 9.467E+07 SECONDS

FRACTION OF RADIONUCLIDE INVENTORY RELEASED = 1.000E-01

TOTAL RADIONUCLIDE REMAINING = 1.010E+15 D/s OR 2.730E+04 Ci

***DIRECT RADIONUCLIDE INPUT

PREVIOUS INVENTORY INCREASED BY THE FOLLOWING VALUES

NUCLIDE	HALF LIFE	CURIES
942380 Pu238	8.770E+01 yr	2.800E-01
942390 Pu239	2.411E+04 yr	1.400E+00

***FISSION PRODUCT CALCULATION

RADIONUCLIDE INVENTORY HAS BEEN DECAYED FOR 0.000E+00 SECONDS

THE OPTION HAS BEEN CHOSEN TO RELEASE ACTIVITY DURING REACTOR OPERATION
CALCULATING WITH 1 REACTOR OPERATING STEP OF 1.000E-03 s

RELEASE RATE (fraction/s)
SOLID 1.000E-02
HALOGEN 0.000E+00
NOBLE GAS 1.000E+03
CESIUM 1.000E-02
RUTHENIUM 1.000E-02

THE REACTOR HAS OPERATED AT 9.901E+10 WATTS FOR 1.000E-03 SECONDS
BURNUP = 1.146E-03 MWd

RADIONUCLIDE INVENTORY HAS BEEN DECAYED FOR 0.000E+00 SECONDS

PARAMETERS FOR THE RELEASE OF ACTIVITY DURING REACTOR OPERATION HAVE
BEEN CHANGED

CALCULATING WITH 80 REACTOR OPERATING STEPS OF 3.000E+01 s EACH

RELEASE RATE (fraction/s)
SOLID 0.000E+00
HALOGEN 1.000E+00
NOBLE GAS 0.000E+00
CESIUM 0.000E+00
RUTHENIUM 0.000E+00

THE REACTOR HAS OPERATED AT 1.000E-06 WATTS FOR 2.400E+03 SECONDS
BURNUP = 1.146E-03 MWd

RETAINING FISSION PRODUCT INVENTORY RELEASED DURING REACTOR OPERATION

TOTAL RADIONUCLIDE REMAINING = 9.670E+16 D/s OR 2.614E+06 Ci

***FISSION PRODUCT CALCULATION

FRACTIONATION BY ELEMENT GROUP

SOLIDS = 1.000E+05 HALOGENS = 1.000E+00 NOBLE GASES = 1.000E+00
CESIUM = 1.000E+05 RUTHENIUM = 1.000E+05

WARNING, A RELEASE FRACTION OF GREATER THAN 1.0 HAS BEEN REQUESTED

FRACTIONATION (ELEMENT, VALUE)

Ac 6.000E-04	Ag 4.000E-04	Al 6.000E-04	Am 6.000E-04
Ar 5.000E-01	As 4.000E-04	At 5.000E-02	Au 2.000E-03
Ba 3.000E-02	Be 3.000E-02	Bi 4.000E-04	Bk 6.000E-04
Br 5.000E-02	C 6.000E-04	Ca 4.000E-04	Cd 4.000E-04
Ce 4.000E-04	Cf 6.000E-04	Cl 5.000E-02	Co 3.000E-02
Cr 3.000E-02	Cs 2.000E-01	Dy 6.000E-04	Er 6.000E-04
Eu 6.000E-04	F 5.000E-02	Fe 3.000E-02	Fr 2.000E-01
Gd 6.000E-04	H 5.000E-01	Hf 4.000E-04	Hg 4.000E-04
Ho 6.000E-04	I 5.000E-02	In 4.000E-04	Ir 2.000E-03
K 2.000E-01	Kr 5.000E-01	La 6.000E-04	Lu 6.000E-04
Mg 3.000E-02	Mn 3.000E-02	Mo 3.000E-02	Na 2.000E-01

Nb	3.000E-02	Nd	6.000E-04	Ni	2.000E-03	Np	4.000E-04
Os	2.000E-03	P	6.000E-04	Pa	4.000E-04	Pd	4.000E-04
Pm	6.000E-04	Po	7.000E-02	Pr	6.000E-04	Pu	4.000E-04
Ra	3.000E-02	Rb	2.000E-01	Rh	2.000E-03	Rn	5.000E-01
Ru	2.000E-03	S	7.000E-02	Sb	4.000E-04	Sc	6.000E-04
Se	7.000E-02	Si	6.000E-04	Sm	6.000E-04	Sn	4.000E-04
Sr	3.000E-02	Tb	6.000E-04	Tc	3.000E-02	Te	7.000E-02
Th	4.000E-04	Ti	4.000E-04	Tl	4.000E-04	Tm	6.000E-04
U	4.000E-04	V	3.000E-02	Xe	5.000E-01	Y	6.000E-04
Yb	6.000E-04	Zn	4.000E-04	Zr	4.000E-04		

FRACTIONATION FOR THE REST OF THE RADIONUCLIDE INVENTORY = 1.000E+00

RADIONUCLIDE INVENTORY HAS BEEN DECAYED FOR 5.000E+01 SECONDS

FRACTIONATION BY ELEMENT GROUP

SOLIDS = 1.000E-03	HALOGENS = 1.000E+00	NOBLE GASES = 1.000E+00
CESIUM = 1.000E-03	RUTHENIUM = 1.000E-03	

RADIONUCLIDE INVENTORY HAS BEEN DECAYED FOR 1.500E+02 SECONDS

FRACTIONATION BY ELEMENT GROUP

SOLIDS = 4.000E-06	HALOGENS = 1.000E+00	NOBLE GASES = 1.000E+00
CESIUM = 4.000E-06	RUTHENIUM = 4.000E-06	

TOTAL RADIONUCLIDE REMAINING = 2.919E+14 D/s OR 7.889E+03 Ci

*** METEOROLOGICAL DATA

MEAN WIND SPEED = 2.000E+00 (m/s)	STACK HEIGHT = 7.600E+01 (m)
MIXING LAYER HEIGHT = 3.800E+02 (m)	AIR DENSITY = 1.099E+03 (g/cu m)
WET DEPOSITION SCAVENGING COEFFICIENT = 0.000E+00 (1/S)	

PLUME DEPLETION BY FALLOUT STANDARD DEPOSITION IS INCLUDED

DEFAULT 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
-----------	-----------

PASQUILL CLASS F FUMIGATION METEOROLOGY WITH MARKEE SIGY(S)

PLUME RISE CALCULATED USING JET CONDITIONS

STACK DIAMETER = 2.440E+00 (m)
EFFLUENT VELOCITY = 1.016E+01 (m/s)
RESTORING ACCELERATION = 1.750E-03 (1/sq s)

ENHANCED DEPOSITION PARAMETERS

PARTICLE DIAMETER = 0.000E+00 (m) PARTICLE DENSITY = 0.000E+00 (g/cm3)

DOWNWIND DISTANCE	STACK HEIGHT (m)	SIGY (m)	SIGZ (m)	CHI/Q (s/cu m)
3.000E+03	1.449E+02	4.380E+02	2.627E+02	1.198E-06

*** FRACTION OF PLUME REMAINING AIRBORNE FOLLOWING DEPLETION BY DEPOSITION

WARNING TERRAIN AMPLIFICATION FACTOR HAS BEEN APPLIED

TO THE DEPOSITION VELOCITIES. THIS WILL CHANGE THE SURFACE CONCENTRATION

THE TAF IS SET = 0.00E+00

DOWNWIND DISTANCE	SOLIDS	HALOGENS	CESIUM	RUTHENIUM
3.000E+03	9.992E-01	9.919E-01	9.992E-01	9.992E-01

*** ENHANCED DRY DEPOSITION VELOCITIES FOR DEPLETION LAYER (m/s)

SOLIDS = 1.000E-03	HALOGENS = 1.000E-02	NOBLE GASES = 0.000E+00
CESIUM = 1.000E-03	RUTHENIUM = 1.000E-03	

*** INHALATION DOSE EQUIVALENT CALCULATION

USING DOSE CONVERSION FACTORS FROM FEDERAL GUIDANCE REPORT 11

Example Runs

```
RESPIRABLE FRACTION = 1.000E+00
BREATHING RATE = 3.330E-04 (cu m/s)
RELEASE TIME FOR EXPONENTIAL DECAY FUNCTION = 1.000E+00 (s)
INTERNAL EXPOSURE TIME PERIOD = 5.000E+01 (yr)

PARTICLE SIZE = 1.0 MICRON AMAD
LUNG DEPOSITION FRACTIONS: N-P = 0.300 T-B = 0.080 P = 0.250

DEFAULT ELEMENT LUNG CLEARANCE CLASSES SELECTED TO GIVE MAXIMUM DOSE

DOWNWIND DISTANCE = 3.000E+03 (m) PLUME TRAVEL TIME = 1.500E+03 (s)
CHI/Q = 1.198E-06 (s/cu m)
```

&& INHALATION COMMITTED DOSE EQUIVALENTS ORDERED BY ORGAN (rem)

ORGAN	NO.	DOWNWIND DISTANCES (m)
-----	---	-----
LUNGS	1	1.19E-04
S WALL	2	4.74E-05
SI WALL	3	3.53E-06
ULI WALL	4	3.85E-06
LLI WALL	5	3.92E-06
TESTES	6	2.22E-06
BREASTS	7	3.17E-06
BONE SUR	8	3.06E-06
R MARROW	9	3.20E-06
THYROID	10	3.98E-04
KIDNEYS	11	3.24E-06
LIVER	12	3.96E-06
SPLEEN	13	4.56E-06
PANCREAS	14	5.72E-06
MUSCLE	15	3.17E-06
SKIN	16	2.41E-06
BRAIN	17	5.51E-07
THYMUS	18	5.18E-06
BL WALL	19	2.41E-06
ADRENALS	20	4.17E-06
ESOPHAGU	21	5.18E-06
OVARIES	22	2.54E-06
UTERUS	23	2.61E-06

&& INHALATION COMMITTED DOSE EQUIVALENCES ORDERED BYDOSE (rem)

ORGAN	NO.	DOWNWIND DISTANCES (m)
-----	---	-----
THYROID	10	3.98E-04
LUNGS	1	1.19E-04
S WALL	2	4.74E-05
PANCREAS	14	5.72E-06
THYMUS	18	5.18E-06
ESOPHAGU	21	5.18E-06
SPLEEN	13	4.56E-06
ADRENALS	20	4.17E-06
LIVER	12	3.96E-06
LLI WALL	5	3.92E-06
ULI WALL	4	3.85E-06
SI WALL	3	3.53E-06
KIDNEYS	11	3.24E-06
R MARROW	9	3.20E-06
BREASTS	7	3.17E-06
MUSCLE	15	3.17E-06
BONE SUR	8	3.06E-06
UTERUS	23	2.61E-06
OVARIES	22	2.54E-06
SKIN	16	2.41E-06
BL WALL	19	2.41E-06
TESTES	6	2.22E-06
BRAIN	17	5.51E-07

&& INHALATION WEIGHTED COMMITTED DOSE EQUIVALENTS (rem)

DOWNWIND DISTANCES (m)

ORGAN	NO.	3.00E+03
-----	---	-----
LUNGS	1	1.43E-05
S WALL	2	2.85E-06
SI WALL	3	2.12E-07
ULI WALL	4	2.31E-07
LLI WALL	5	2.35E-07
TESTES	6	5.56E-07
BREASTS	7	4.75E-07
BONE SUR	8	9.19E-08
R MARROW	9	3.84E-07
THYROID	10	1.19E-05
KIDNEYS	11	1.94E-07
LIVER	12	2.38E-07
SPLEEN	13	2.74E-07
PANCREAS	14	3.43E-07
MUSCLE	15	1.90E-07
SKIN	16	2.41E-08
BRAIN	17	3.30E-08
THYMUS	18	3.11E-07
BL WALL	19	1.45E-07
ADRENALS	20	2.50E-07
ESOPHAGU	21	3.11E-07
OVARIES	22	6.34E-07
UTERUS	23	1.56E-07
CEDE	24	3.20E-05

*** GROUND SURFACE DEPOSITION DOSE EQUIVALENT CALCULATION

USING DOSE RATE CONVERSION FACTORS FROM FEDERAL GUIDANCE REPORT 12
 OCCUPANCY FACTOR = 2.381E-01
 TIME RECEPTOR IS EXPOSED TO CONTAMINATED SOIL = 1.000E+00 (yr)
 BUILDING SHIELDING FACTOR = 7.000E-01
 RELEASE TIME FOR EXPONENTIAL DECAY FUNCTION = 3.330E-04 SECONDS
 WARNING, EXPONENTIAL LEAKAGE CONSTANTS AND EXPONENTIAL DECAY TIME ARE NOT
 MATCHED, 3.33E-02 PERCENT OF INVENTORY RELEASED

DOWNWIND DISTANCE = 3.000E+03 (m) PLUME TRAVEL TIME = 1.500E+03 (s)
 CHI/Q = 1.198E-06 (s/cu m)

&& GROUND SURFACE DOSE EQUIVALENTS ORDERED BY ORGAN (rem)

ORGAN	NO.	DOWNWIND DISTANCES (m)
-----	---	-----
Lungs	1	3.96E-09
S Wall	2	3.78E-09
SI Wall	3	3.74E-09
ULI Wall	4	3.77E-09
LLI Wall	5	3.87E-09
Testes	6	4.28E-09
Breast	7	4.09E-09
BSurface	8	5.56E-09
R Marrow	9	4.06E-09
Thyroid	10	3.95E-09
Kidney	11	3.83E-09
Liver	12	3.80E-09
Spleen	13	3.80E-09
Pancreas	14	3.53E-09
Muscle	15	3.54E-09
Skin	16	2.43E-08
Brain	17	3.75E-09
Thymus	18	3.72E-09
U Bladd	19	3.88E-09
Adrenal	20	4.26E-09
Esophagu	21	3.44E-09
Ovaries	22	3.66E-09
Uterus	23	3.69E-09

&& GROUND SURFACE DOSE EQUIVALENCES ORDERED BY DOSE (rem)

ORGAN	NO.	DOWNWIND DISTANCES (m)
-----	---	-----
Skin	16	2.43E-08
BSurface	8	5.56E-09
Testes	6	4.28E-09
Adrenal	20	4.26E-09

Example Runs

Breast	7	4.09E-09
R Marrow	9	4.06E-09
Lungs	1	3.96E-09
Thyroid	10	3.95E-09
U Bladd	19	3.88E-09
LLI Wall	5	3.87E-09
Kidney	11	3.83E-09
Spleen	13	3.80E-09
Liver	12	3.80E-09
S Wall	2	3.78E-09
ULI Wall	4	3.77E-09
Brain	17	3.75E-09
SI Wall	3	3.74E-09
Thymus	18	3.72E-09
Uterus	23	3.69E-09
Ovaries	22	3.66E-09
Muscle	15	3.54E-09
Pancreas	14	3.53E-09
Esophagu	21	3.44E-09

&& GROUND SURFACE WEIGHTED DOSE EQUIVALENTS (rem)
DOWNWIND DISTANCES (m)

ORGAN	NO.	3.00E+03
-----	---	-----
Lungs	1	4.75E-10
S Wall	2	2.27E-10
SI Wall	3	2.24E-10
ULI Wall	4	2.26E-10
LLI Wall	5	2.32E-10
Testes	6	1.07E-09
Breast	7	6.14E-10
BSurface	8	1.67E-10
R Marrow	9	4.87E-10
Thyroid	10	1.19E-10
Kidney	11	2.30E-10
Liver	12	2.28E-10
Spleen	13	2.28E-10
Pancreas	14	2.12E-10
Muscle	15	2.13E-10
Skin	16	2.43E-10
Brain	17	2.25E-10
Thymus	18	2.23E-10
U Bladd	19	2.33E-10
Adrenal	20	2.56E-10
Esophagu	21	2.06E-10
Ovaries	22	9.15E-10
Uterus	23	2.22E-10
EXT EDE	24	4.11E-09

***GAMMA DOSE CALCULATION WITH EXPOSURE TIME = 1.0000E+00 (s)
CALCULATIONS MADE USING THE FINITE MODEL
EXTERNAL EDE

DOWNWIND DISTANCE = 3.000E+03 (m) DOSE = 4.95E-04 (rem)

*** PATHWAY CONTRIBUTION TO THE EDE (rem), DOWNWIND DISTANCE = 3.00E+03 (m)

NUCLIDE	INHALATION	INGESTION	GROUND SUR	AIR IMMERS	TOTAL
-----	-----	-----	-----	-----	-----
SUBTOTALS	3.20E-05	-	4.11E-09	-	3.20E-05
			FINITE MODEL CLOUD GAMMA		4.95E-04
				TOTAL	5.27E-04

WARNINGS

NO INGESTION DOSE CALCULATIONS WERE MADE

EXECUTION time = 7.90E-01 SECONDS

Example 9: Dose Calculations with Changing Meteorological Conditions

This example demonstrates how to sum the doses from a release that occurs during a changing meteorological condition. The release is assumed to occur over a period of 8 hours with the first hour during a Class F fumigation condition and the remaining 7 hours during a Class C condition.

In this example, the radionuclide inventory is read from an external file called "ex9src". After reading the inventory, the 1000 Series option is used to fractionate the inventory by a factor of 1/8 for that released during the first hour. After completing dose calculations for the inhalation pathway from the first hour of release, the 1000 Series option is again used to first decay the original inventory for a period of 1 hour. The inventory is then multiplied by a factor of 7 to give the inventory that is released during the final 7 hours of the release. The 5000 Series for meteorological data is reentered to change to Class C meteorology. The only data that cannot be changed are the downwind distance.

After completing dose calculations for the inhalation pathway for the last 7 hours of the release, the 3000 Series summary option is used to request dose summaries by pathway and radionuclide. Because only doses from the inhalation dose pathway were calculated, a warning is printed indicating that doses were not calculated for the other pathways.

Example 9 Dose calc with changing meteorological conditions - Rsac

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Add Series Fifty-Mile Radius Reports Critdos

[1000 Fission Product Inventory Calculation](#)

[2000 Direct Radionuclide Input](#)

[5000 Meteorological Data Input](#)

[7000 Internal/External Dose Calculation](#)

[9000 Cloud Gamma Dose Calculation](#)

Title: Dose calculations with changing meteorological

Series	Title
2000	Reading fission product inventory from external file
1000	Fractionate radionuclide inventory for initial hour of release
5000	Enter meteorological data for first hour of release
7000	Calculating inhalation dose summary
1000	Fractionating the fission product inventory for the last 7 hours of ...
5000	Entering meteorological data for the final 7 hours of release
7000	Inhalation dose for the last 7 hours of release
3000	Requesting dose summaries by pathway and radionuclide

WinRp Windows RSAC Plus

and

RSAC
Radiological Safety Analysis Computer Program

INEEL
Idaho National Engineering and Environmental Laboratory

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File Name: C:\Program Files\INEEL\WinRp\Examples\Example 9 Dose calc with changing meteorological conditions.rsac

File: Example 9 Dose calc with changing meterological conditions.rsac

5999

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# Calculating inhalation dose summary
7000,0,-2,1,0,1 * Calculating for all elements and organs for the first
#                   hour of release
#
7001,3.33E-4,0.,0,0,0. * Defaulting to program calculated values with
#                   respirable fraction set to 0
#
7999
# Fractionating the fission product inventory for the last 7 hours of release
1000
1001,1,0.,0. * Retaining the previous inventory
#
1004,0,7. * Multiplying the previous inventory for a 1 hour release by 7.
#           to give the amount released during the next 7 hours of release
#
1003,3600.,0.,0. * Decaying the original inventory for a period of 1 hour
#
1999
# Entering meteorological data for the final 7 hours of release
5000,0
5001,5.,70.,2000.,1.099E3,0.,0 * Only changes are for a 5 m/s wind velocity
#                               and a 2000. m mixing layer depth
#
5002,0.001,0.01,0.,0.001,0.001
5101,2.E4
5201,3.978E-5,0. * Changed linear constant for 7 hour release
#
5400,2,0.,0.,0
5410,2,3,1 * Changed to Class C
#
5411,2.,0.,8.5,0.
5999
# Inhalation dose for the last 7 hours of release
7000,0,-2,1,0,1
7001,3.33E-4,0.,0,0,0.
7999
# Requesting dose summaries by pathway and radionuclide
3000,3
10000

```

***DIRECT RADIONUCLIDE INPUT

ANY PREVIOUS INVENTORY HAS BEEN ZEROED

NUCLIDE	HALF LIFE	CURIES
380890 Sr 89	5.053E+01 d	7.340E-04
380900 Sr 90	2.878E+01 yr	1.770E-03
390900 Y 90	6.410E+01 h	1.770E-03
390910 Y 91	5.851E+01 d	1.740E-03
410940 Nb 94	2.030E+04 yr	4.000E-13
400950 Zr 95	6.402E+01 d	2.680E-03
410950 Nb 95	3.497E+01 d	5.800E-03
441060 Ru106	3.736E+02 d	1.620E-03
451060 Rh106	2.980E+01 s	1.620E-03
511250 Sb125	2.758E+00 yr	9.990E-05
551370 Cs137	3.007E+01 yr	1.890E-03
561371 Ba137m	2.552E+00 m	1.790E-03
581440 Ce144	2.849E+02 d	2.110E-02
591440 Pr144	1.728E+01 m	2.110E-02
611470 Pm147	2.623E+00 yr	5.870E-03

***FISSION PRODUCT CALCULATION

FRACTION OF RADIONUCLIDE INVENTORY RELEASED = 1.250E-01

TOTAL RADIONUCLIDE REMAINING = 3.218E+08 D/s OR 8.698E-03 Ci

*** METEOROLOGICAL DATA

MEAN WIND SPEED = 2.000E+00 (m/s) STACK HEIGHT = 7.000E+01 (m)
MIXING LAYER HEIGHT = 3.800E+02 (m) AIR DENSITY = 1.099E+03 (g/cu m)
WET DEPOSITION SCAVENGING COEFFICIENT = 0.000E+00 (1/S)

Example Runs

NO CORRECTION IS BEING MADE FOR PLUME DEPLETION BY FALLOUT
DEFAULT 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)
2.778E-04 0.000E+00
PASQUILL CLASS F FUMIGATION METEOROLOGY WITH MARKEE SIGY(S)

PLUME RISE CALCULATED USING JET CONDITIONS
STACK DIAMETER = 2.000E+00 (m)
EFFLUENT VELOCITY = 8.500E+00 (m/s)
RESTORING ACCELERATION = 1.750E-03 (1/sq s)
ENHANCED DEPOSITION PARAMETERS
PARTICLE DIAMETER = 0.000E+00 (m) PARTICLE DENSITY = 0.000E+00 (g/cm3)
DOWNWIND DISTANCE STACK SIGY SIGZ CHI/Q
 HEIGHT (m) (m) (m) (s/cu m)
2.000E+04 1.270E+02 1.917E+03 2.731E+02 2.738E-07

*** INHALATION DOSE EQUIVALENT CALCULATION

USING DOSE CONVERSION FACTORS FROM FEDERAL GUIDANCE REPORT 11

RESPIRABLE FRACTION = 1.000E+00
BREATHING RATE = 3.330E-04 (cu m/s)
RELEASE TIME FOR EXPONENTIAL DECAY FUNCTION = 3.600E+03 (s)
INTERNAL EXPOSURE TIME PERIOD = 5.000E+01 (yr)
PARTICLE SIZE = 1.0 MICRON AMAD
LUNG DEPOSITION FRACTIONS: N-P = 0.300 T-B = 0.080 P = 0.250
DEFAULT ELEMENT LUNG CLEARANCE CLASSES SELECTED TO GIVE MAXIMUM DOSE
DOWNWIND DISTANCE = 2.000E+04 (m) PLUME TRAVEL TIME = 1.000E+04 (s)
CHI/Q = 2.738E-07 (s/cu m)

&& INHALATION COMMITTED DOSE EQUIVALENTS ORDERED BY ORGAN (rem)

ORGAN	NO.	DOWNWIND DISTANCES (m)
-----	---	-----
LUNGS	1	1.02E-06
S WALL	2	2.36E-09
SI WALL	3	3.47E-09
ULI WALL	4	1.39E-08
LLI WALL	5	3.89E-08
TESTES	6	1.12E-09
BREASTS	7	1.39E-09
BONE SUR	8	2.70E-08
R MARROW	9	7.80E-09
THYROID	10	1.28E-09
KIDNEYS	11	1.39E-09
LIVER	12	2.56E-08
SPLEEN	13	2.03E-08
PANCREAS	14	1.67E-09
MUSCLE	15	1.39E-09
SKIN	16	1.09E-09
BRAIN	17	8.22E-11
THYMUS	18	1.85E-09
BL WALL	19	1.15E-09
ADRENALS	20	1.84E-09
ESOPHAGU	21	1.85E-09
OVARIES	22	1.29E-09
UTERUS	23	1.23E-09

&& INHALATION COMMITTED DOSE EQUIVALENCES ORDERED BYDOSE (rem)

ORGAN	NO.	DOWNWIND DISTANCES (m)
-----	---	-----
LUNGS	1	1.02E-06
LLI WALL	5	3.89E-08
BONE SUR	8	2.70E-08
LIVER	12	2.56E-08
SPLEEN	13	2.03E-08
ULI WALL	4	1.39E-08
R MARROW	9	7.80E-09
SI WALL	3	3.47E-09

S WALL	2	2.36E-09
THYMUS	18	1.85E-09
ESOPHAGU	21	1.85E-09
ADRENALS	20	1.84E-09
PANCREAS	14	1.67E-09
KIDNEYS	11	1.39E-09
BREASTS	7	1.39E-09
MUSCLE	15	1.39E-09
OVARIES	22	1.29E-09
THYROID	10	1.28E-09
UTERUS	23	1.23E-09
BL WALL	19	1.15E-09
TESTES	6	1.12E-09
SKIN	16	1.09E-09
BRAIN	17	8.22E-11

&& INHALATION WEIGHTED COMMITTED DOSE EQUIVALENTS (rem)

ORGAN	NO.	DOWNWIND DISTANCES (m)
-----	----	-----
LUNGS	1	1.23E-07
S WALL	2	1.41E-10
SI WALL	3	2.08E-10
ULI WALL	4	8.34E-10
LLI WALL	5	2.33E-09
TESTES	6	2.80E-10
BREASTS	7	2.09E-10
BONE SUR	8	8.10E-10
R MARROW	9	9.35E-10
THYROID	10	3.84E-11
KIDNEYS	11	8.37E-11
LIVER	12	1.53E-09
SPLEEN	13	1.22E-09
PANCREAS	14	1.00E-10
MUSCLE	15	8.36E-11
SKIN	16	1.09E-11
BRAIN	17	4.93E-12
THYMUS	18	1.11E-10
BL WALL	19	6.93E-11
ADRENALS	20	1.11E-10
ESOPHAGU	21	1.11E-10
OVARIES	22	3.22E-10
UTERUS	23	7.40E-11
CEDE	24	1.31E-07

***FISSION PRODUCT CALCULATION

FRACTION OF RADIONUCLIDE INVENTORY RELEASED = 7.000E+00

RADIONUCLIDE INVENTORY HAS BEEN DECAYED FOR 3.600E+03 SECONDS

TOTAL RADIONUCLIDE REMAINING = 2.262E+09 D/s OR 6.112E-02 Ci

*** METEOROLOGICAL DATA

MEAN WIND SPEED = 5.000E+00 (m/s) STACK HEIGHT = 7.000E+01 (m)
MIXING LAYER HEIGHT = 2.000E+03 (m) AIR DENSITY = 1.099E+03 (g/cu m)
WET DEPOSITION SCAVENGING COEFFICIENT = 0.000E+00 (1/S)

NO CORRECTION IS BEING MADE FOR PLUME DEPLETION BY FALLOUT

DEFAULT 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)
3.978E-05 0.000E+00

PASQUILL CLASS C METEOROLOGY, MARKEE SIGMA VALUES

PLUME RISE CALCULATED USING JET CONDITIONS
STACK DIAMETER = 2.000E+00 (m)
EFFLUENT VELOCITY = 8.500E+00 (m/s)
RESTORING ACCELERATION = 0.000E+00 (1/sq s)

ENHANCED DEPOSITION PARAMETERS				
PARTICLE DIAMETER = 0.000E+00 (m)		PARTICLE DENSITY = 0.000E+00 (g/cm3)		
DOWNWIND DISTANCE	STACK	SIGY	SIGZ	CHI/Q
	HEIGHT (m)	(m)	(m)	(s/cu m)
2.000E+04	8.020E+01	2.050E+03	1.596E+03	1.946E-08

*** INHALATION DOSE EQUIVALENT CALCULATION

USING DOSE CONVERSION FACTORS FROM FEDERAL GUIDANCE REPORT 11

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RESPIRABLE FRACTION = 1.000E+00
BREATHING RATE = 3.330E-04 (cu m/s)
RELEASE TIME FOR EXPONENTIAL DECAY FUNCTION = 2.514E+04 (s)
INTERNAL EXPOSURE TIME PERIOD = 5.000E+01 (yr)

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PARTICLE SIZE = 1.0 MICRON AMAD
LUNG DEPOSITION FRACTIONS: N-P = 0.300 T-B = 0.080 P = 0.250

DEFAULT ELEMENT LUNG CLEARANCE CLASSES SELECTED TO GIVE MAXIMUM DOSE

DOWNWIND DISTANCE = 2.000E+04 (m) PLUME TRAVEL TIME = 4.000E+03 (s)
CHI/Q = 1.946E-08 (s/cu m)

&& INHALATION COMMITTED DOSE EQUIVALENTS ORDERED BY ORGAN (rem)

ORGAN	NO.	DOWNWIND DISTANCES (m)
-----	----	-----
LUNGS	1	5.08E-07
S WALL	2	1.17E-09
SI WALL	3	1.73E-09
ULI WALL	4	6.91E-09
LLI WALL	5	1.93E-08
TESTES	6	5.57E-10
BREASTS	7	6.93E-10
BONE SUR	8	1.34E-08
R MARROW	9	3.88E-09
THYROID	10	6.37E-10
KIDNEYS	11	6.94E-10
LIVER	12	1.27E-08
SPLEEN	13	1.01E-08
PANCREAS	14	8.29E-10
MUSCLE	15	6.93E-10
SKIN	16	5.43E-10
BRAIN	17	4.09E-11
THYMUS	18	9.21E-10
BL WALL	19	5.74E-10
ADRENALS	20	9.16E-10
ESOPHAGU	21	9.21E-10
OVARIES	22	6.41E-10
UTERUS	23	6.13E-10

[illegible]

ORGAN	NO.	DOWNWIND DISTANCES (m)
-----	----	-----
LUNGS	1	5.08E-07
LLI WALL	5	1.93E-08
BONE SUR	8	1.34E-08
LIVER	12	1.27E-08
SPLEEN	13	1.01E-08
ULI WALL	4	6.91E-09
R MARROW	9	3.88E-09
SI WALL	3	1.73E-09
S WALL	2	1.17E-09
THYMUS	18	9.21E-10
ESOPHAGU	21	9.21E-10
ADRENALS	20	9.16E-10
PANCREAS	14	8.29E-10
KIDNEYS	11	6.94E-10
BREASTS	7	6.93E-10

MUSCLE	15	6.93E-10
OVARIES	22	6.41E-10
THYROID	10	6.37E-10
UTERUS	23	6.13E-10
BL WALL	19	5.74E-10
TESTES	6	5.57E-10
SKIN	16	5.43E-10
BRAIN	17	4.09E-11

&& INHALATION WEIGHTED COMMITTED DOSE EQUIVALENTS (rem)

ORGAN	NO.	DOWNWIND DISTANCES (m)
		2.00E+04
LUNGS	1	6.09E-08
S WALL	2	7.04E-11
SI WALL	3	1.04E-10
ULI WALL	4	4.15E-10
LLI WALL	5	1.16E-09
TESTES	6	1.39E-10
BREASTS	7	1.04E-10
BONE SUR	8	4.03E-10
R MARROW	9	4.65E-10
THYROID	10	1.91E-11
KIDNEYS	11	4.16E-11
LIVER	12	7.63E-10
SPLEEN	13	6.06E-10
PANCREAS	14	4.97E-11
MUSCLE	15	4.16E-11
SKIN	16	5.43E-12
BRAIN	17	2.45E-12
THYMUS	18	5.52E-11
BL WALL	19	3.45E-11
ADRENALS	20	5.50E-11
ESOPHAGU	21	5.52E-11
OVARIES	22	1.60E-10
UTERUS	23	3.68E-11
CEDE	24	6.50E-08

*** PATHWAY CONTRIBUTION TO THE EDE (rem), DOWNWIND DISTANCE = 2.00E+04 (m)

NUCLIDE	INHALATION	INGESTION	GROUND SUR	AIR IMMERS	TOTAL
380890 Sr- 89	5.18E-10	-	-	-	5.18E-10
380900 Sr- 90	3.92E-08	-	-	-	3.92E-08
390900 Y- 90	2.55E-10	-	-	-	2.55E-10
390910 Y- 91	1.45E-09	-	-	-	1.45E-09
410940 Nb- 94	2.83E-18	-	-	-	2.83E-18
400950 Zr- 95	1.08E-09	-	-	-	1.08E-09
410950 Nb- 95	5.74E-10	-	-	-	5.74E-10
441060 Ru-106	1.32E-08	-	-	-	1.32E-08
511250 Sb-125	2.08E-11	-	-	-	2.08E-11
521251 Te-125m	5.87E-15	-	-	-	5.87E-15
551370 Cs-137	1.03E-09	-	-	-	1.03E-09
581440 Ce-144	1.35E-07	-	-	-	1.35E-07
591440 Pr-144	1.56E-11	-	-	-	1.56E-11
611470 Pm-147	3.93E-09	-	-	-	3.93E-09
621470 Sm-147	2.08E-20	-	-	-	2.08E-20

*** PATHWAY CONTRIBUTION TO THE EDE (rem), DOWNWIND DISTANCE = 2.00E+04 (m)

NUCLIDE	INHALATION	INGESTION	GROUND SUR	AIR IMMERS	TOTAL
TOTALS	1.96E-07	-	-	-	1.96E-07

WARNINGS

NO INGESTION DOSE CALCULATIONS WERE MADE
 NO GROUND SURFACE DOSE CALCULATIONS WERE MADE
 NO AIR IMMERSION OR CLOUD GAMMA DOSE CALCULATIONS WERE MADE

EXECUTION time = 1.80E-01 SECONDS

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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:

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

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

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

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 ($\text{n/cm}^2\text{-s}$)

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

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 nth radionuclide from the mth radionuclide precursor is

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

By summing all the precursors of a particular nuclide, the general solution for the total number of atoms for the kth radionuclide of the decay chain is obtained:

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

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

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

Therefore, the buildup equation can be written as

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

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

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

where

$N_k(t)$ = the total number of atoms for the k^{th} radionuclide of the decay chain

$$E_k (e^{-\lambda_i t}) = \sum_{m=1}^k Q_m \left[\prod_{i=m}^{k-1} (\lambda_i) \right] \sum_{i=m}^k \left[\frac{e^{-\lambda_i t}}{\prod_{\substack{j=m \\ j \neq i}}^k (\lambda_j - \lambda_i)} \right] \quad (\text{A-10})$$

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-6.2 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-6.2 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; Clawson et al. 1989) as follows:

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

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 Engineering Laboratory (Clawson et al. 1989) and are presented in Table A-1.

RSAC-6.2 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 Engineering Laboratory.

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, Yanskey et al. 1966).

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

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) using the following equations:

$$\Sigma_y = (\sigma_y^2 + \Delta \sigma_{y1}^2 + \Delta \sigma_{y2}^2)^{1/2} \quad (\text{A-13})$$

$$\Sigma_z = (\sigma_z^2 + \Delta \sigma_{z1}^2 + \Delta \sigma_{z2}^2)^{1/2} \quad (\text{A-14})$$

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:

$$\sigma_{y1}^2 = 9.13 \times 10^5 \left[1 - \left(1 + \frac{x}{1000 * u} \right) \exp\left(-\frac{x}{1000 * u}\right) \right] \quad (\text{A-15})$$

$$\sigma_{z1}^2 = 6.67 \times 10^2 \left[1 - \left(1 + \frac{x}{100 * u} \right) \exp\left(-\frac{x}{100 * u}\right) \right] \quad (\text{A-16})$$

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 these 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:

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

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

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:

$$\Sigma_{y_{\max}} = \frac{2 \pi x}{\sqrt{12}} \quad (\text{A-19})$$

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, Turner 1970, Yanskey et al. 1966). 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), 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

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

where

z = vertical distance from the plume centerline (m)

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-6.2 are made using a deposition velocity as defined by Chamberlain (1953) as

$$V_d = -\frac{F}{\chi} \quad (\text{A-21})$$

where

$$\begin{aligned} V_d &= \text{dry deposition velocity (m/s)} \\ F &= \text{deposition flux (Ci/m}^2\text{s)} \\ \chi &= \text{airborne concentration (Ci/m}^3\text{)}. \end{aligned}$$

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

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

where

$$\begin{aligned} \omega &= \text{surface contamination (Ci/m}^2\text{)} \\ V_d &= \text{deposition velocity (m/s)} \\ t &= \text{time that the ground is exposed to the plume (s)}. \end{aligned}$$

Dry deposition velocities are a function of particle size and chemical species. Values recommended for use in RSAC-6.2 are published by Sehmel (1980).

Wet deposition in RSAC-6.2 is based on the modeling summarized by Hanna et al. (1982). The modeling assumes the plume concentration (C) decreases exponentially with time:

$$C(t) = C(0) \exp [-\Lambda t] \quad (\text{A-23})$$

where

$$\begin{aligned} \Lambda &= \text{scavenging coefficient (s}^{-1}\text{)} \\ t &= \text{time since precipitation began (s)}. \end{aligned}$$

A-2.3 Plume Depletion

RSAC-6.2 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) model. The Chamberlain model expressed in Pasquill notation is:

$$F_{\text{dry}}^C = \exp \left\{ \sqrt{\frac{2}{\pi}} \frac{V_d}{u} \int_0^x \frac{1}{\sigma_z} \exp \left[-\frac{1}{2} \left(\frac{h^2}{\sigma_z^2} \right) \right] dx \right\} \quad (\text{A-24})$$

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 INEEL (Markee 1967). The modified Chamberlain equation is as follows:

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

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

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

The total plume depletion is:

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

A-2.4 Leakage Rate Function

RSAC-6.2 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:

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

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 ($1 \leq n \leq 10$)
$K1_j$	=	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-6.2 rather than using RSAC-6.2 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-6.2, 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-6.2 leakage function is presented in Section 4.1, *Leakage Decay Constants Lines (5201+)*.

A-2.5 Plume Rise

Plume rise in RSAC-6.2 is calculated for either jet or buoyant plumes using the methodology developed by Briggs (1969). For jet plumes in neutral, windy, or lapse conditions, the jet centerline plume rise is given by

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

where

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

D = internal stack diameter (m)

ω_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

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

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

When stable meteorological conditions exist, plume rise is calculated using

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

where

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

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

RSAC-6.2 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

$$\Delta h = \frac{1.6}{u} F^{\frac{1}{3}} x^{\frac{2}{3}} \quad (\text{A-33})$$

where

$$F = 3.7 \times 10^{-5} Q_H$$

$$Q_H = \text{stack gasses heat emission (cal/s).}$$

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

$$x_e = \text{downwind distance (ft)}$$

$$x_e^* = 0.52 F_e^{\frac{2}{5}} h_e^{\frac{3}{5}} \quad (\text{A-34})$$

$$F_e = 4.3 \times 10^{-3} Q_H$$

$$h_e = \text{elevation of the point of release above the ground plane (ft)}$$

$$\Delta h = 0.3048 \Delta h_e \text{ (m).}$$

Beyond this distance, plume rise is calculated using

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

where

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

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

A-3 DOSE CALCULATIONS

A-3.1 Inhalation Dose

RSAC-6.2 calculates inhalation doses using the ICRP 30 (1979) 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) weighting factor to calculate what is called the weighted committed dose equivalent (WCDE) in RSAC-6.2. 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-6.2 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:

$$\frac{\text{DCF}_{(\text{New})}}{\text{DCF}_{(1\ \mu\text{m})}} = f_{\text{NP}} \frac{D_{\text{NP}(\text{New})}}{D_{\text{NP}(1\ \mu\text{m})}} + f_{\text{TB}} \frac{D_{\text{TB}(\text{New})}}{D_{\text{TB}(1\ \mu\text{m})}} + f_{\text{P}} \frac{D_{\text{P}(\text{New})}}{D_{\text{P}(1\ \mu\text{m})}} \quad (\text{A-36})$$

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-6.2 default classes are presented in Appendix D.

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

Region	Compartment	Class ^a					
		D		W		Y	
		T day	F	T day	F	T day	F
NP (D _{NP} = 0.30)	a	0.01	0.5	0.01	0.1	0.01	0.01
	b	0.01	0.5	0.40	0.9	0.40	0.99
TB (D _{TB} = 0.08)	c	0.01	0.95	0.01	0.5	0.01	0.01
	d	0.2	0.05	0.2	0.4	0.2	0.99
P (D _P = 0.25)	e	0.5	0.8	50	0.15	500	0.05
	f	NA ^b	NA	1.0	0.4	1.0	0.4
	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). 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

$$D_{ij} = DFI_{ij} [U^v f_g C_i^v + U^m C_i^m + U^F C_i^F + U^L f_l C_i^L] \quad (A-37)$$

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-6.2 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

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

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-6.2 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-6.2 element-dependent parameters used to calculate concentrations in crops.

		Root uptake factors		Transfer coefficients		Translocation factor
Element		Forage B_{iv1}	Produce B_{iv2}	Milk F_m	Meat F_f	
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-6.2 element-dependent parameters used to calculate concentrations in crops.

		Root uptake factors		Transfer coefficients		Translocation factor F _T
Element		Forage B _{iv1}	Produce B _{iv2}	Milk F _m	Meat F _f	
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-6.2 element-dependent parameters used to calculate concentrations in crops.

		Root uptake factors		Transfer coefficients		Translocation factor F_T
Element		Forage B_{iv1}	Produce B_{iv2}	Milk F_m	Meat F_f	
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-6.2 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).

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). 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

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

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

$$C_i^m = F_m C_i^{fd} Q_F e^{-\lambda_i t_f} \quad (A-40)$$

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

$$C_i^F = F_f C_i^{fd} Q_F \exp(-\lambda_i t_c) \quad (A-41)$$

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

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

where

C_T^V	=	concentration of tritium in vegetation (pCi/kg)
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$$3.169 \times 10^7 = \frac{(1.0 \times 10^{12} \text{ pCi/Ci}) (1.0 \times 10^3 \text{ g/kg})}{3.156 \times 10^7 \text{ s/yr}} \quad (A-43)$$

Q_T = annual release of tritium (Ci/yr)

$\frac{\chi}{Q}$ = atmospheric diffusion relative to the initial point of release (s/m³)

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/m³).

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

$$C_{14}^v = 3.169 \times 10^7 Q_{14} \frac{\chi}{Q} \left[\frac{0.11}{0.16} \right] \quad (\text{A-44})$$

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/m³).

A-3.2.2 Acute Release

The ingestion equations presented in Regulatory Guide 1.109 (NRC 1977a) 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-6.2. 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/m²) collected during the acute release period for radionuclide i can be calculated using the following equation:

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

where

- A_D = activity on vegetation collected during the acute release period
 d_i = deposition rate of radionuclide i (pCi/m²-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

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

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

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

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

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

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/m²).

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

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

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

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

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:

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

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

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

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

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

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

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

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

$$C_{is}^v = d_i B_{iv} \frac{[1 - e^{-\lambda_i t_b}]}{P \lambda_i} \quad (A-55)$$

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/m² 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_i). The equation for the concentration of activity in vegetation from the soil uptake pathway from an acute release is then

$$C_{is}^v = d_i B_{iv} \beta_i \frac{[1 - e^{-\lambda_i t_a}]}{P \lambda_i} \quad (A-56)$$

where β_i is defined as

$$\beta_i = F_a + \sum_{j=2}^{N_{tb}} e^{-\lambda_i j} \quad (A-57)$$

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

$$C_i^v = [C_{id}^v + c_{iF}^v + C_{is}^v] e^{-\lambda_i t_h} \quad (\text{A-58})$$

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

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

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-6.2 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

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

where

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

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

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

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

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). 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-6.2 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

$$D_i^G = \text{DRCF}_i \frac{\chi}{Q} V_d F_{bs} \int_0^{t_b} A_i dt \quad (\text{A-62})$$

where

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

DRCF_i = dose rate conversion factor ($\text{rem}\cdot\text{m}^2/\text{dis}$)

$\frac{\chi}{Q}$ = 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:

$$A_i = N_{i0} \lambda_i e^{-\lambda_i t} \quad (\text{A-63})$$

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

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

This integrates to

$$D_i^G = DRCF_i \frac{\lambda_i}{Q} V_d F_{bs} [N_{i0} - N_{i1}] \quad (\text{A-65})$$

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:

$$N_{i1} = N_{i0} e^{-\lambda_i t_b} \quad (\text{A-66})$$

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

$$D_i^G = DRCF_i \frac{\lambda_i}{Q} V_d F_{bs} \sum_{j=1}^i [N_{j0} - N_{j1}] \quad (\text{A-67})$$

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

$$D_i^G = DRCF_i \frac{\chi}{Q} V_d F_{bs} N_{i0} [1 - e^{-\lambda_i t_b}] \quad (\text{A-68})$$

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-6.2 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-6.2 contains an option to calculate air immersion doses using Federal Guidance Report No. 12 (Eckerman 1993) 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

$$D_i^A = A_i \frac{\chi}{Q} DRCF_i \quad (\text{A-69})$$

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 ($\text{rem}\cdot\text{m}^3/\text{Ci}\cdot\text{s}$).

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). 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:

$$D_k = \sum_{j=1}^n K l_j f_k \lambda_k \int_0^{\infty} k(x) E_k [GEXP_j(x)] \left[\int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \frac{\chi}{Q}(x, y, z) G_i(r) dz dy \right] dx \quad (A-70)$$

where

- D_k = the air entrance dose from the k^{th} radionuclide
- n = number of exponential leakage approximations
- $K l_j$ = 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:

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

where

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

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

where

- x = 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).

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

where

- r = distance from a source to the receptor
- v = 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-6.2 have been developed from those published by Berger et al. (1968). 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-6.2 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 Stegun 1964). 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-6.2 integrates the activity in the plume using gamma rays distributed the nine energy groups presented in Table A-9. The RSAC-6.2 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). 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) is

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

where

DG_i^S = cloud gamma dose from radionuclide I

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

Ψ = concentration time integral (Ci-s/m³).

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-6.2 Nuclear Data Library

Appendix B

RSAC-6.2 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.

$$(\text{atomic number} \times 10,000) + (\text{mass number} \times 10) + (0 \text{ for ground state or } 1 \text{ for metastable state}).$$

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 (Chu 1999). Decay schemes primarily were derived from a computer data file prepared by D. C. Kocher (RSIC 1981). When the Kocher file did not contain data for the desired radionuclide or it was found to be outdated, data were obtained from either ICRP 38 (ICRP 1983) or derived from the ORIGEN2 (RSIC 1991) library for enriched U-235 in a pressurized water reactor. Fission yields and cross sections were derived from the data in the ORIGEN2 file. 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-6.2; 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-6.2 only uses them to correct fission product inventories calculated by RSAC-6.2 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 systematics (Croff et al. 1979). 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-6.2 to suppress printing these radionuclides.

Radionuclide			Half-life	Yield	FRACT	IDATR	NGROUP	ISTART	XSECT
10030	H	3	1.233E+01 yr	1.100E-02	1.000E+00	-1	3	0	5.518E-07
40070	Be	7	5.329E+01 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
40100	Be	10	1.510E+06 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
60110	C	11	2.039E+01 min	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
60140	C	14	5.730E+03 yr	1.300E-06	1.000E+00	-1	1	0	9.197E-08
90180	F	18	1.098E+02 min	0.000E+00	1.000E+00	-1	2	0	-1.000E+00
110220	Na	22	2.602E+00 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
110240	Na	24	1.496E+01 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
120280	Mg	28	2.091E+01 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
130260	Al	26	7.400E+05 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
140310	Si	31	1.573E+02 min	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
150320	P	32	1.426E+01 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
150330	P	33	2.534E+01 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
160350	S	35	8.751E+01 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
170360	Cl	36	3.010E+05 yr	0.000E+00	1.000E+00	-1	2	0	-1.000E+00
180370	Ar	37	3.504E+01 d	0.000E+00	1.000E+00	-1	3	0	-1.000E+00
170380	Cl	38	3.724E+01 min	0.000E+00	1.000E+00	-1	2	0	-1.000E+00
170390	Cl	39	5.560E+01 min	0.000E+00	1.000E+00	0	2	0	-1.000E+00
180390	Ar	39	2.690E+02 yr	0.000E+00	1.000E+00	-1	3	0	-1.000E+00
180410	Ar	41	1.093E+02 min	0.000E+00	1.000E+00	-1	3	0	-1.000E+00
190400	K	40	1.277E+09 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
200410	Ca	41	1.030E+05 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
190420	K	42	1.236E+01 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
190430	K	43	2.230E+01 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
220440	Ti	44	6.300E+01 yr	0.000E+00	1.000E+00	1	1	0	-1.000E+00
210441	Sc	44m	5.860E+01 hr	0.000E+00	9.863E-01	0	1	1	-1.000E+00
210440	Sc	44	3.927E+00 hr	0.000E+00	1.000E+00	-1	1	2	-1.000E+00
200450	Ca	45	1.626E+02 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
220450	Ti	45	1.848E+02 min	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
200470	Ca	47	4.536E+00 d	0.000E+00	1.000E+00	0	1	0	-1.000E+00
210470	Sc	47	3.349E+00 d	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
210460	Sc	46	8.379E+01 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
210480	Sc	48	4.367E+01 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
230480	V	48	1.597E+01 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
200490	Ca	49	8.718E+00 min	0.000E+00	1.000E+00	0	1	0	-1.000E+00
210490	Sc	49	5.720E+01 min	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
240490	Cr	49	4.230E+01 min	0.000E+00	1.000E+00	0	1	0	-1.000E+00
230490	V	49	3.300E+02 d	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
220510	Ti	51	5.760E+00 min	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
240510	Cr	51	2.770E+01 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
260520	Fe	52	8.275E+00 hr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
250521	Mn	52m	2.110E+01 min	0.000E+00	1.750E-02	0	1	1	-1.000E+00
250520	Mn	52	5.591E+00 d	0.000E+00	1.000E+00	-1	1	2	-1.000E+00
250530	Mn	53	3.740E+06 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
250540	Mn	54	3.123E+02 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
260550	Fe	55	2.730E+00 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
250560	Mn	56	2.579E+00 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
280560	Ni	56	6.077E+00 d	0.000E+00	1.000E+00	0	1	0	-1.000E+00
270560	Co	56	7.727E+01 d	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
280570	Ni	57	3.560E+01 hr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
270570	Co	57	2.718E+02 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
270581	Co	58m	9.150E+00 hr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
270580	Co	58	7.082E+01 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
260590	Fe	59	4.450E+01 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
280590	Ni	59	7.600E+04 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
260600	Fe	60	1.500E+06 yr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
270601	Co	60m	1.047E+01 min	0.000E+00	9.975E-01	0	1	1	-1.000E+00
270600	Co	60	5.271E+00 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
270610	Co	61	1.650E+00 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
270621	Co	62m	1.391E+01 min	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
300620	Zn	62	9.186E+00 hr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
280630	Ni	63	1.001E+02 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
300630	Zn	63	3.847E+01 min	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
280650	Ni	65	2.517E+00 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
290640	Cu	64	1.270E+01 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
300650	Zn	65	2.443E+02 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
310660	Ga	66	9.490E+00 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00

Radionuclide		Half-life	Yield	FRACT	IDATR	NGROUP	ISTART	XSECT
290670	Cu 67	6.183E+01 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
310670	Ga 67	3.261E+00 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
320680	Ge 68	2.708E+02 d	0.000E+00	1.000E+00	0	1	0	-1.000E+00
310680	Ga 68	6.763E+01 min	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
300691	Zn 69m	1.376E+01 hr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
300690	Zn 69	5.640E+01 min	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
320690	Ge 69	3.905E+01 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
310700	Ga 70	2.114E+01 min	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
300711	Zn 71m	3.960E+00 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
320710	Ge 71	1.143E+01 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
330720	As 72	2.600E+01 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
270720	Co 72	1.227E-01 s	8.870E-07	1.000E+00	0	1	0	-3.000E-01
280720	Ni 72	2.100E+00 s	2.850E-05	1.000E+00	0	1	1	-3.000E-01
290720	Cu 72	6.600E+00 s	3.360E-05	1.000E+00	0	1	2	-3.000E-01
300720	Zn 72	4.650E+01 hr	6.760E-06	1.000E+00	0	1	3	0.000E+00
310720	Ga 72	1.410E+01 hr	4.220E-08	1.000E+00	-1	1	4	0.000E+00
270730	Co 73	1.155E-01 s	9.070E-08	1.000E+00	0	1	0	-3.000E-01
280730	Ni 73	9.000E-01 s	1.490E-05	1.000E+00	0	1	1	-3.000E-01
290730	Cu 73	3.900E+00 s	9.860E-05	1.000E+00	0	1	2	-3.000E-01
300730	Zn 73	2.350E+01 s	1.280E-04	1.000E+00	0	1	3	-3.000E-01
310730	Ga 73	4.860E+00 hr	6.880E-06	1.000E+00	-1	1	4	0.000E+00
340730	Se 73	7.150E+00 hr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
330730	As 73	8.030E+01 d	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
270740	Co 74	1.075E-01 s	7.320E-08	1.000E+00	0	1	0	-3.000E-01
280740	Ni 74	1.100E+00 s	2.420E-05	1.000E+00	0	1	1	-3.000E-01
290740	Cu 74	1.594E+00 s	2.310E-04	1.000E+00	0	1	2	-3.000E-01
300740	Zn 74	9.560E+01 s	3.620E-04	1.000E+00	0	1	3	-3.000E-01
310740	Ga 74	8.120E+00 min	2.190E-05	1.000E+00	-1	1	4	0.000E+00
330740	As 74	1.777E+01 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
270750	Co 75	8.016E-02 s	9.620E-09	1.000E+00	0	1	0	-3.000E-01
280750	Ni 75	1.796E-01 s	9.940E-06	1.000E+00	0	1	1	-3.000E-01
290750	Cu 75	1.224E+00 s	2.710E-04	1.000E+00	0	1	2	-3.000E-01
300750	Zn 75	1.020E+01 s	1.090E-03	1.000E+00	0	1	3	-3.000E-01
310750	Ga 75	1.260E+02 min	1.790E-04	9.600E-01	1	1	4	-3.000E-01
320751	Ge 75m	4.770E+01 s	2.060E-06	1.000E+00	0	1	1	-3.000E-01
320750	Ge 75	8.278E+01 min	2.060E-06	1.000E+00	-1	1	2	4.139E-01
340750	Se 75	1.198E+02 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
280760	Ni 76	2.683E-01 s	3.260E-06	1.000E+00	0	1	0	-3.000E-01
290760	Cu 76	6.410E-01 s	2.700E-04	1.000E+00	0	1	1	-3.000E-01
300760	Zn 76	5.700E+00 s	2.950E-03	1.000E+00	0	1	2	-3.000E-01
310760	Ga 76	3.260E+01 s	1.280E-03	1.000E+00	-1	1	3	0.000E+00
330760	As 76	1.078E+00 d	2.230E-07	1.000E+00	-1	1	1	0.000E+00
280770	Ni 77	1.030E-01 s	4.510E-07	1.000E+00	0	1	0	-3.000E-01
290770	Cu 77	4.690E-01 s	1.170E-04	1.000E+00	0	1	1	-3.000E-01
300770	Zn 77	2.080E+00 s	3.620E-03	1.000E+00	0	1	2	-3.000E-01
310770	Ga 77	1.320E+01 s	5.320E-03	1.200E-01	1	1	3	-3.000E-01
320771	Ge 77m	5.290E+01 s	4.780E-04	7.900E-01	1	1	1	0.000E+00
320770	Ge 77	1.130E+01 hr	6.890E-04	1.000E+00	0	1	2	0.000E+00
330770	As 77	3.883E+01 hr	1.270E-05	1.000E+00	-1	1	3	0.000E+00
350770	Br 77	5.704E+01 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
280780	Ni 78	1.376E-01 s	5.060E-08	1.000E+00	0	1	0	-3.000E-01
290780	Cu 78	3.420E-01 s	4.450E-05	1.000E+00	0	1	1	-3.000E-01
300780	Zn 78	1.470E+00 s	4.250E-03	1.000E+00	0	1	2	-3.000E-01
310780	Ga 78	5.090E+00 s	1.420E-02	1.000E+00	0	1	3	-3.000E-01
320780	Ge 78	8.800E+01 hr	2.000E-03	1.000E+00	0	1	4	0.000E+00
330780	As 78	9.070E+01 min	2.180E-04	1.000E+00	-1	1	5	0.000E+00
290790	Cu 79	1.880E-01 s	5.180E-06	1.000E+00	0	1	0	-3.000E-01
300790	Zn 79	9.950E-01 s	1.650E-03	1.000E+00	0	1	1	-3.000E-01
310790	Ga 79	2.847E+00 s	1.520E-02	1.000E+00	0	1	2	-3.000E-01
320790	Ge 79	1.898E+01 s	2.660E-02	1.000E+00	0	1	3	-3.000E-01
330790	As 79	9.010E+00 min	9.410E-03	1.000E+00	0	1	4	0.000E+00
340791	Se 79m	3.920E+00 min	8.050E-06	1.000E+00	0	1	5	0.000E+00
340790	Se 79	1.130E+06 yr	8.030E-06	1.000E+00	-1	1	6	3.630E-01
360790	Kr 79	3.504E+01 hr	0.000E+00	1.000E+00	-1	3	0	-1.000E+00
290800	Cu 80	9.110E-02 s	7.030E-07	1.000E+00	0	1	0	-3.000E-01
300800	Zn 80	5.450E-01 s	7.550E-04	1.000E+00	0	1	1	-3.000E-01

Radionuclide		Half-life	Yield	FRACT	IDATR	NGROUP	ISTART	XSECT
310800	Ga 80	1.697E+00 s	2.130E-02	1.000E+00	0	1	2	-3.000E-01
320800	Ge 80	2.950E+01 s	8.880E-02	1.000E+00	0	1	3	-3.000E-01
330800	As 80	1.520E+01 s	1.490E-02	1.000E+00	-1	1	4	0.000E+00
350801	Br 80m	4.420E+00 hr	0.000E+00	1.000E+00	0	2	0	-1.000E+00
350800	Br 80	1.768E+01 min	0.000E+00	1.000E+00	-1	2	1	-1.000E+00
290810	Cu 81	7.447E-02 s	3.670E-08	1.000E+00	0	1	0	-3.000E-01
300810	Zn 81	2.900E-01 s	1.320E-04	1.000E+00	0	1	1	-3.000E-01
310810	Ga 81	1.217E+00 s	1.160E-02	1.000E+00	0	1	2	-3.000E-01
320810	Ge 81	7.600E+00 s	1.330E-01	1.000E+00	0	1	3	-3.000E-01
330810	As 81	3.330E+01 s	5.980E-02	1.000E+00	1	1	4	0.000E+00
340811	Se 81m	5.728E+01 min	6.850E-03	1.000E+00	0	1	5	0.000E+00
340810	Se 81	1.845E+01 min	2.190E-03	1.000E+00	-1	1	6	0.000E+00
370810	Rb 81	4.576E+00 hr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
360810	Kr 81	2.290E+05 yr	0.000E+00	1.000E+00	-1	3	1	-1.000E+00
350821	Br 82m	6.130E+00 min	8.000E-05	9.760E-01	0	2	4	0.000E+00
350820	Br 82	3.530E+01 hr	5.920E-05	1.000E+00	-1	2	5	0.000E+00
380820	Sr 82	2.555E+01 d	0.000E+00	9.997E-01	0	1	0	-1.000E+00
370820	Rb 82	1.273E+00 min	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
300830	Zn 83	8.386E-02 s	1.020E-06	1.000E+00	0	1	0	-3.000E-01
310830	Ga 83	3.100E-01 s	9.540E-04	1.000E+00	0	1	1	-3.000E-01
320830	Ge 83	1.850E+00 s	9.740E-02	1.000E+00	0	1	2	-3.000E-01
330830	As 83	1.340E+01 s	3.220E-01	3.600E-01	1	1	3	-3.000E-01
340831	Se 83m	7.010E+01 s	6.400E-02	1.000E+00	1	1	4	0.000E+00
340830	Se 83	2.230E+01 min	4.830E-02	1.000E+00	0	1	5	0.000E+00
350830	Br 83	2.400E+00 hr	3.710E-03	1.000E+00	1	2	2	0.000E+00
370830	Rb 83	8.620E+01 d	0.000E+00	7.620E-01	0	1	0	-1.000E+00
360831	Kr 83m	1.830E+00 hr	3.990E-06	1.000E+00	-1	3	4	0.000E+00
310840	Ga 84	8.500E-02 s	5.490E-05	1.000E+00	0	1	0	-3.000E-01
320840	Ge 84	9.660E-01 s	1.910E-02	1.000E+00	0	1	1	-3.000E-01
330840	As 84	4.020E+00 s	3.000E-01	1.000E+00	0	1	2	-3.000E-01
340840	Se 84	3.100E+00 min	6.621E-01	1.000E+00	1	1	3	0.000E+00
350841	Br 84m	6.000E+00 min	1.900E-02	1.000E+00	-1	2	4	0.000E+00
350840	Br 84	3.180E+01 min	1.800E-02	1.000E+00	-1	2	5	0.000E+00
370840	Rb 84	3.277E+01 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
320850	Ge 85	5.350E-01 s	6.440E-03	1.000E+00	0	1	0	-3.000E-01
330850	As 85	2.021E+00 s	2.010E-01	8.000E-01	0	1	1	-3.000E-01
340850	Se 85	3.170E+01 s	4.600E-01	1.000E+00	1	1	2	-3.000E-01
340851	Se 85m	1.900E+01 s	4.600E-01	1.000E+00	0	1	3	-3.000E-01
350850	Br 85	2.900E+00 min	1.690E-01	1.000E+00	0	2	4	0.000E+00
360851	Kr 85m	4.480E+01 hr	1.370E-02	2.110E-01	0	3	5	0.000E+00
360850	Kr 85	1.076E+01 yr	2.280E-03	1.000E+00	-1	3	6	1.840E-01
380851	Sr 85m	6.763E+01 min	0.000E+00	8.790E-01	0	1	0	-1.000E+00
380850	Sr 85	6.484E+01 d	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
320860	Ge 86	2.590E-01 s	1.140E-03	1.000E+00	0	1	0	-3.000E-01
330860	As 86	9.450E-01 s	1.130E-01	1.000E+00	0	1	1	-3.000E-01
340860	Se 86	1.530E+01 s	1.190E+00	5.000E-01	1	1	2	-3.000E-01
350861	Br 86m	4.500E+00 s	3.020E-01	1.000E+00	-1	2	3	-3.000E-01
350860	Br 86	5.510E+01 s	2.920E-01	1.000E+00	-1	2	4	0.000E+00
370860	Rb 86	1.863E+01 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
400860	Zr 86	1.650E+01 hr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
390860	Y 86	1.474E+01 hr	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
320870	Ge 87	1.255E-01 s	1.830E-04	1.000E+00	0	1	0	-3.000E-01
330870	As 87	4.800E-01 s	6.440E-02	1.000E+00	0	1	1	-3.000E-01
340870	Se 87	5.290E+00 s	9.340E-01	1.000E+00	0	1	2	-3.000E-01
350870	Br 87	5.560E+01 min	1.190E+00	1.000E+00	0	2	3	0.000E+00
360870	Kr 87	7.630E+01 min	3.420E-01	1.000E+00	0	3	4	5.518E+01
390870	Y 87	7.980E+01 hr	0.000E+00	9.990E-01	0	1	0	-1.000E+00
380871	Sr 87m	2.803E+00 hr	0.000E+00	3.000E-03	0	1	1	-1.000E+00
370870	Rb 87	4.750E+10 yr	1.000E-01	1.000E+00	-1	1	7	7.690E-02
320880	Ge 88	1.427E-01 s	2.080E-06	1.000E+00	0	1	0	-3.000E-01
330880	As 88	1.300E-01 s	2.630E-03	1.000E+00	0	1	1	-3.000E-01
340880	Se 88	1.530E+00 s	3.550E-01	1.000E+00	0	1	2	-3.000E-01
350880	Br 88	1.634E+01 s	2.140E+00	1.000E+00	0	2	3	0.000E+00
360880	Kr 88	2.840E+00 hr	1.090E+00	1.000E+00	0	3	4	0.000E+00
370880	Rb 88	1.778E+01 min	3.200E-02	1.000E+00	-1	1	5	9.197E-02
400880	Zr 88	8.340E+01 d	0.000E+00	1.000E+00	0	1	0	-1.000E+00
390880	Y 88	1.067E+02 d	0.000E+00	1.000E+00	-1	1	1	-1.000E+00

Radionuclide		Half-life	Yield	FRACT	IDATR	NGROUP	ISTART	XSECT
330890	As 89	1.294E-01 s	2.070E-04	1.000E+00	0	1	0	-3.000E-01
340890	Se 89	4.100E-01 s	9.270E-02	1.000E+00	0	1	1	-3.000E-01
350890	Br 89	4.348E+00 s	1.800E+00	1.000E+00	0	2	2	-3.000E-01
360890	Kr 89	3.150E+00 min	2.740E+00	1.000E+00	0	3	3	0.000E+00
370890	Rb 89	1.515E+01 min	1.700E-01	1.000E+00	0	1	4	0.000E+00
380890	Sr 89	5.053E+01 d	2.580E-03	1.000E+00	-1	1	5	5.264E-02
400890	Zr 89	7.841E+01 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
340900	Se 90	5.545E-01 s	3.220E-02	1.000E+00	0	1	0	-3.000E-01
350900	Br 90	1.910E+00 s	1.240E+00	8.800E-01	0	2	1	-3.000E-01
360900	Kr 90	3.232E+01 s	3.450E+00	8.810E-01	1	3	2	0.000E+00
370901	Rb 90m	2.580E+02 s	4.280E-01	9.770E-01	1	1	3	0.000E+00
370900	Rb 90	1.580E+02 s	6.760E-01	1.000E+00	0	1	4	0.000E+00
380900	Sr 90	2.878E+01 yr	2.820E-02	1.000E+00	3	1	5	8.739E-02
390901	Y 90m	3.190E+00 hr	1.250E-05	1.000E+00	0	1	8	0.000E+00
390900	Y 90	6.410E+01 hr	2.300E-04	1.000E+00	-1	1	9	5.920E-01
340910	Se 91	1.845E-01 s	3.220E-03	1.000E+00	0	1	0	-3.000E-01
350910	Br 91	5.410E-01 s	3.910E-01	1.000E+00	0	2	1	-3.000E-01
360910	Kr 91	8.570E+00 s	3.020E+00	1.000E+00	0	3	2	0.000E+00
370910	Rb 91	5.840E+01 s	2.230E+00	1.000E+00	0	1	3	0.000E+00
380910	Sr 91	9.630E+00 hr	2.290E-01	4.260E-01	1	1	4	0.000E+00
390911	Y 91m	4.971E+01 min	2.720E-04	1.000E+00	0	1	5	0.000E+00
390910	Y 91	5.851E+01 d	6.240E-04	1.000E+00	-1	1	6	1.651E-01
340920	Se 92	2.478E-01 s	4.770E-05	1.000E+00	0	1	0	-3.000E-01
350920	Br 92	3.430E-01 s	1.890E-02	1.000E+00	0	2	1	-3.000E-01
360920	Kr 92	1.840E+00 s	1.470E+00	1.000E+00	0	3	2	0.000E+00
370920	Rb 92	4.492E+00 s	3.260E+00	1.000E+00	0	1	3	0.000E+00
380920	Sr 92	2.710E+00 hr	1.180E+00	1.000E+00	0	1	4	0.000E+00
390920	Y 92	3.540E+00 hr	9.810E-03	1.000E+00	-1	1	5	0.000E+00
350930	Br 93	1.020E-01 s	4.710E-03	1.000E+00	0	2	0	-3.000E-01
360930	Kr 93	1.286E+00 s	5.000E-01	1.000E+00	0	3	1	0.000E+00
370930	Rb 93	5.840E+00 s	3.030E+00	1.000E+00	0	1	2	0.000E+00
380930	Sr 93	7.423E+00 min	2.700E+00	1.000E+00	0	1	3	0.000E+00
390930	Y 93	1.018E+01 hr	9.810E-02	1.000E+00	0	1	4	0.000E+00
400930	Zr 93	1.530E+06 yr	2.500E-01	1.000E+00	2	1	5	1.029E+00
410931	Nb 93m	1.613E+01 yr	9.370E-09	1.000E+00	-1	1	8	0.000E+00
420931	Mo 93m	6.850E+00 hr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
420930	Mo 93	4.000E+03 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
350940	Br 94	7.000E-02 s	3.270E-04	1.000E+00	0	2	0	-3.000E-01
360940	Kr 94	2.000E-01 s	2.270E-01	1.000E+00	0	3	1	-3.000E-01
370940	Rb 94	2.702E+00 s	1.520E+00	1.000E+00	0	1	2	-3.000E-01
380940	Sr 94	7.530E+01 s	4.250E+00	1.000E+00	0	1	3	0.000E+00
390940	Y 94	1.870E+01 min	3.520E-01	1.000E+00	-1	1	4	0.000E+00
410941	Nb 94m	6.263E+00 min	4.380E-07	9.952E-01	0	1	0	0.000E+00
410940	Nb 94	2.030E+04 yr	4.350E-07	1.000E+00	-1	1	1	-1.000E+00
350950	Br 95	1.166E-01 s	7.330E-06	1.000E+00	0	2	0	-3.000E-01
360950	Kr 95	7.800E-01 s	1.020E-02	1.000E+00	0	3	1	0.000E+00
370950	Rb 95	3.775E-01 s	8.960E-01	1.000E+00	0	1	2	0.000E+00
380950	Sr 95	2.390E+01 s	4.570E+00	1.000E+00	0	1	3	-3.000E-01
390950	Y 95	1.030E+01 min	9.480E-01	1.000E+00	0	1	4	0.000E+00
400950	Zr 95	6.402E+01 d	2.950E-02	1.000E+00	2	1	5	2.325E-01
410951	Nb 95m	8.660E+01 hr	1.290E-04	9.450E-01	0	1	7	0.000E+00
410950	Nb 95	3.497E+01 d	4.000E-05	1.000E+00	-1	1	8	8.508E-01
410960	Nb 96	2.335E+01 hr	6.100E-04	1.000E+00	-1	1	3	0.000E+00
430961	Tc 96m	5.150E+01 min	0.000E+00	9.800E-01	0	1	0	-1.000E+00
430960	Tc 96	4.280E+00 d	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
360970	Kr 97	1.485E-01 s	4.060E-05	1.000E+00	0	3	0	-3.000E-01
370970	Rb 97	1.699E-01 s	3.640E-02	1.000E+00	0	1	1	-3.000E-01
380970	Sr 97	4.260E-01 s	1.900E+00	1.000E+00	0	1	2	0.000E+00
390970	Y 97	3.750E+00 s	3.120E+00	1.000E+00	0	1	3	0.000E+00
400970	Zr 97	1.691E+01 hr	8.740E-01	5.300E-02	1	1	4	0.000E+00
410971	Nb 97m	5.270E+01 s	6.860E-03	1.000E+00	0	1	5	0.000E+00
410970	Nb 97	7.210E+01 min	1.680E-02	1.000E+00	-1	1	6	0.000E+00
430971	Tc 97m	9.010E+01 d	0.000E+00	1.000E+00	1	1	0	-1.000E+00
440970	Ru 97	2.900E+00 d	0.000E+00	9.992E-01	0	1	0	-1.000E+00
430970	Tc 97	2.600E+06 yr	0.000E+00	1.000E+00	-1	1	2	-1.000E+00
360980	Kr 98	2.243E-01 s	4.240E-06	1.000E+00	0	3	0	-3.000E-01

Radionuclide	Half-life	Yield	FRACT	IDATR	NGROUP	ISTART	XSECT
370980 Rb 98	1.140E-01 s	5.260E-03	1.000E+00	0	1	1	-3.000E-01
380980 Sr 98	6.530E-01 s	6.980E-01	1.000E+00	0	1	2	-3.000E-01
390980 Y 98	5.480E-01 s	2.920E+00	1.000E+00	0	1	3	-3.000E-01
400980 Zr 98	3.070E+01 s	2.100E+00	1.000E+00	1	1	4	-3.000E-01
410981 Nb 98m	5.130E+01 min	2.720E-02	1.000E+00	-1	1	0	0.000E+00
410980 Nb 98	2.860E+00 s	4.480E-02	1.000E+00	-1	1	5	0.000E+00
430980 Tc 98	4.200E+06 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
370990 Rb 99	5.030E-02 s	4.060E-04	1.000E+00	0	1	0	-3.000E-01
380990 Sr 99	2.690E-01 s	1.540E-01	1.000E+00	0	1	1	-3.000E-01
390990 Y 99	1.470E+00 s	1.860E+00	1.000E+00	0	1	2	-3.000E-01
400990 Zr 99	2.100E+00 s	3.770E+00	1.000E+00	0	1	3	0.000E+00
410990 Nb 99	1.500E+01 s	1.370E-01	1.000E+00	1	1	4	0.000E+00
410991 Nb 99m	2.600E+00 min	1.490E-01	1.000E+00	0	1	0	0.000E+00
420990 Mo 99	6.594E+01 hr	2.870E-03	1.140E-01	1	1	6	1.013E+00
430991 Tc 99m	6.010E+00 hr	3.340E-07	1.000E+00	0	1	7	0.000E+00
430990 Tc 99	2.111E+05 yr	7.500E-02	1.000E+00	-1	1	9	9.136E+00
371000 Rb100	5.100E-02 s	1.700E-05	1.000E+00	0	1	0	-3.000E-01
381000 Sr100	2.020E-01 s	2.380E-02	1.000E+00	0	1	1	-3.000E-01
391000 Y100	7.350E-01 s	8.570E-01	1.000E+00	0	1	2	-3.000E-01
401000 Zr100	7.100E+00 s	4.450E+00	5.000E-01	1	1	3	-3.000E-01
411001 Nb100m	2.990E+00 s	4.690E-01	1.000E+00	-1	1	4	-3.000E-01
411000 Nb100	1.500E+00 s	4.690E-01	1.000E+00	-1	1	5	-3.000E-01
381010 Sr101	1.180E-01 s	2.960E-03	1.000E+00	0	1	0	-3.000E-01
391010 Y101	4.480E-01 s	2.690E-01	1.000E+00	0	1	1	-3.000E-01
401010 Zr101	2.100E+00 s	3.200E+00	1.000E+00	0	1	2	-3.000E-01
411010 Nb101	7.100E+00 s	1.500E+00	1.000E+00	0	1	3	0.000E+00
421010 Mo101	1.461E+01 min	1.120E-01	1.000E+00	0	1	4	0.000E+00
431010 Tc101	1.422E+01 min	2.340E-04	1.000E+00	-1	1	5	0.000E+00
451011 Rh101m	4.340E+00 d	0.000E+00	7.200E-02	0	1	0	-1.000E+00
451010 Rh101	3.300E+00 yr	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
381020 Sr102	6.900E-02 s	1.970E-04	1.000E+00	0	1	0	-3.000E-01
391020 Y102	3.600E-01 s	5.370E-02	1.000E+00	0	1	1	-3.000E-01
401020 Zr102	2.900E+00 min	1.730E+00	1.000E+00	0	1	2	-3.000E-01
411020 Nb102	1.300E+00 s	2.040E+00	1.000E+00	0	1	3	-3.000E-01
421020 Mo102	1.130E+01 min	4.140E-01	1.000E+00	1	1	4	-3.000E-01
431021 Tc102m	4.350E+00 min	1.290E-03	5.000E-01	0	1	5	0.000E+00
431020 Tc102	5.280E+00 s	1.290E-03	1.000E+00	-1	1	6	0.000E+00
451021 Rh102m	2.900E+00 yr	0.000E+00	5.000E-02	0	1	0	-1.000E+00
451020 Rh102	2.070E+02 d	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
461030 Pd103	1.699E+01 d	0.000E+00	1.000E+00	1	1	0	-1.000E+00
381030 Sr103	1.386E-01 s	4.800E-06	1.000E+00	0	1	0	-3.000E-01
391030 Y103	2.300E-01 s	5.340E-03	1.000E+00	0	1	1	-3.000E-01
401030 Zr103	1.300E+00 s	5.260E-01	1.000E+00	0	1	2	-3.000E-01
411030 Nb103	1.500E+00 s	1.680E+00	1.000E+00	0	1	3	-3.000E-01
421030 Mo103	6.750E+01 s	9.230E-01	1.000E+00	0	1	4	-3.000E-01
431030 Tc103	5.420E+01 s	1.800E-02	1.000E+00	0	1	5	-3.000E-01
441030 Ru103	3.926E+01 d	4.000E-05	9.006E-01	0	5	6	2.666E+00
451031 Rh103m	5.612E+01 min	1.050E-09	1.000E+00	-1	1	7	0.000E+00
471060 Ag106	2.396E+01 min	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
471061 Ag106m	8.280E+00 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
381040 Sr104	1.925E-01 s	8.230E-08	1.000E+00	0	1	0	-3.000E-01
391040 Y104	1.442E-01 s	2.540E-04	1.000E+00	0	1	1	-3.000E-01
401040 Zr104	1.200E+00 s	8.010E-02	1.000E+00	0	1	2	-3.000E-01
411040 Nb104	4.800E+00 s	7.320E-01	1.000E+00	0	1	3	-3.000E-01
421040 Mo104	6.000E+01 s	1.020E+00	1.000E+00	0	1	4	-3.000E-01
431040 Tc104	1.830E+01 min	5.750E-02	1.000E+00	-1	1	5	0.000E+00
391050 Y105	1.736E-01 s	2.250E-05	1.000E+00	0	1	0	-3.000E-01
401050 Zr105	6.000E-01 s	1.030E-02	1.000E+00	0	1	1	-3.000E-01
411050 Nb105	2.950E+00 s	2.030E-01	1.000E+00	0	1	2	-3.000E-01
421050 Mo105	3.560E+01 s	7.210E-01	1.000E+00	0	1	3	-3.000E-01
431050 Tc105	7.600E+00 min	9.690E-02	1.000E+00	0	1	4	-3.000E-01
441050 Ru105	4.440E+00 hr	2.340E-03	7.550E-01	1	5	5	2.908E-01
451051 Rh105m	4.500E+01 s	7.300E-07	8.000E-01	0	1	6	0.000E+00
451050 Rh105	3.536E+01 hr	5.200E-03	1.000E+00	-1	1	7	2.800E-01
401060 Zr106	9.800E-01 s	2.480E-03	1.000E+00	0	1	0	-3.000E-01
411060 Nb106	1.020E+00 s	7.000E-02	1.000E+00	0	1	1	-3.000E-01
421060 Mo106	8.400E+00 s	2.940E-01	1.000E+00	0	1	2	-3.000E-01

Radionuclide		Half-life	Yield	FRACT	IDATR	NGROUP	ISTART	XSECT
431060	Tc106	3.560E+01 s	4.980E-02	1.000E+00	0	1	3	-3.000E-01
441060	Ru106	3.736E+02 d	1.200E-03	1.000E+00	3	5	4	7.708E-01
451061	Rh106m	1.310E+02 min	3.400E-03	1.000E+00	-1	1	7	0.000E+00
451060	Rh106	2.980E+01 s	8.300E-03	7.519E-01	-1	1	8	0.000E+00
391070	Y107	1.046E-01 s	3.740E-08	1.000E+00	0	1	0	-3.000E-01
401070	Zr107	2.485E-01 s	1.190E-04	1.000E+00	0	1	1	-3.000E-01
411070	Nb107	3.300E-01 s	1.140E-02	1.000E+00	0	1	2	-3.000E-01
421070	Mo107	3.500E+00 s	1.240E-01	1.000E+00	0	1	3	-3.000E-01
431070	Tc107	2.120E+01 s	5.380E-02	1.000E+00	0	1	4	-3.000E-01
451070	Rh107	2.170E+01 min	7.240E-06	1.000E+00	2	1	5	0.000E+00
461071	Pd107m	2.130E+01 s	7.640E-10	1.000E+00	0	1	7	0.000E+00
461070	Pd107	6.500E+06 yr	7.403E-10	1.000E+00	-1	1	8	2.816E+00
401080	Zr108	4.075E-01 s	2.640E-06	1.000E+00	0	1	0	-3.000E-01
411080	Nb108	1.900E-01 s	8.490E-04	1.000E+00	0	1	1	-3.000E-01
421080	Mo108	1.090E+00 s	3.270E-02	1.000E+00	0	1	2	-3.000E-01
431080	Tc108	5.170E+00 s	4.640E-02	1.000E+00	0	1	3	-3.000E-01
441080	Ru108	4.550E+00 min	1.150E-02	1.000E+00	2	5	4	0.000E+00
451081	Rh108m	1.680E+01 s	4.580E-05	1.000E+00	-1	1	5	0.000E+00
451080	Rh108	6.000E+00 min	4.580E-05	1.000E+00	-1	1	6	0.000E+00
471081	Ag108m	4.180E+02 yr	0.000E+00	8.900E-02	0	1	0	-1.000E+00
471080	Ag108	2.370E+00 min	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
401090	Zr109	1.387E-01 s	1.750E-08	1.000E+00	0	1	0	-3.000E-01
411090	Nb109	1.900E-01 s	2.620E-05	1.000E+00	0	1	1	-3.000E-01
421090	Mo109	5.300E-01 s	4.050E-03	1.000E+00	0	1	2	-3.000E-01
431090	Tc109	8.700E-01 s	2.100E-02	1.000E+00	0	1	3	-3.000E-01
441090	Ru109	3.450E+01 s	1.890E-02	5.000E-01	1	5	4	-3.000E-01
451091	Rh109m	5.000E+01 s	3.170E-04	1.000E+00	0	1	5	-3.000E-01
451090	Rh109	8.000E+01 s	3.170E-04	5.000E-01	2	1	6	-3.000E-01
461091	Pd109m	4.696E+00 min	1.300E-06	1.000E+00	1	1	7	0.000E+00
461090	Pd109	1.370E+01 hr	1.300E-06	9.995E-01	0	1	9	0.000E+00
471091	Ag109m	3.960E+01 s	1.330E-10	1.000E+00	-1	1	10	0.000E+00
481090	Cd109	4.626E+02 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
471101	Ag110m	2.498E+02 d	4.000E-09	1.330E-02	1	1	2	0.000E+00
471100	Ag110	2.460E+01 s	3.700E-09	1.000E+00	-1	1	3	0.000E+00
411110	Nb111	1.562E-01 s	1.410E-08	1.000E+00	0	1	1	-3.000E-01
421110	Mo111	3.000E-01 s	3.770E-05	1.000E+00	0	1	2	-3.000E-01
431110	Tc111	3.000E-01 s	2.490E-03	1.000E+00	0	1	3	-3.000E-01
441110	Ru111	2.120E+00 min	1.800E-02	1.000E+00	0	5	4	-3.000E-01
451110	Rh111	1.100E+01 s	5.560E-03	9.960E-01	1	1	5	-3.000E-01
461111	Pd111m	5.500E+00 hr	1.250E-04	3.200E-01	1	1	6	-3.000E-01
461110	Pd111	2.340E+01 min	1.260E-04	1.000E+00	0	1	7	0.000E+00
471111	Ag111m	6.480E+01 s	1.620E-07	1.000E+00	0	1	8	0.000E+00
471110	Ag111	7.450E+00 d	1.580E-07	1.000E+00	-1	1	9	3.461E+00
481111	Cd111m	4.854E+01 min	2.500E-11	1.000E+00	-1	1	2	0.000E+00
491110	In111	2.805E+00 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
421120	Mo112	6.890E-01 s	4.155E-06	1.000E+00	0	1	0	-3.000E-01
431120	Tc112	2.800E-01 s	5.350E-04	1.000E+00	0	1	1	-3.000E-01
441120	Ru112	1.750E+00 s	9.880E-03	1.000E+00	0	5	2	-3.000E-01
451120	Rh112	2.100E+00 s	7.530E-03	1.000E+00	0	1	3	-3.000E-01
461120	Pd112	2.103E+01 hr	8.990E-04	1.000E+00	0	1	4	0.000E+00
471120	Ag112	3.130E+00 hr	1.700E-04	1.000E+00	-1	1	5	0.000E+00
481131	Cd113m	1.410E+01 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
481130	Cd113	9.300E+15 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
501100	Sn110	4.110E+00 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
501130	Sn113	1.151E+02 d	0.000E+00	1.000E+00	0	1	0	-1.000E+00
491131	In113m	1.658E+00 hr	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
421130	Mo113	1.970E-01 s	2.702E-07	1.000E+00	0	1	0	-3.000E-01
431130	Tc113	1.300E-01 s	1.130E-04	1.000E+00	0	1	1	-3.000E-01
441130	Ru113	8.000E-01 s	5.500E-03	1.000E+00	0	5	2	-3.000E-01
451130	Rh113	2.800E+00 s	9.750E-03	1.000E+00	0	1	3	-3.000E-01
461130	Pd113	9.300E+01 s	3.020E-03	9.000E-01	1	1	4	-3.000E-01
471131	Ag113m	6.870E+01 s	1.520E-05	1.000E+00	-1	1	5	-3.000E-01
471130	Ag113	5.370E+00 hr	1.520E-05	1.300E-01	-1	1	6	-3.000E-01
421140	Mo114	3.215E-01 s	1.728E-08	1.000E+00	0	1	0	-3.000E-01
431140	Tc114	1.734E-01 s	1.630E-05	1.000E+00	0	1	1	-3.000E-01
441140	Ru114	5.300E-01 s	2.040E-03	1.000E+00	0	5	2	-3.000E-01

Radionuclide		Half-life	Yield	FRACT	IDATR	NGROUP	ISTART	XSECT
451140	Rh114	1.850E+00 s	8.640E-03	1.000E+00	0	1	3	-3.000E-01
461140	Pd114	2.420E+00 min	6.390E-03	1.000E+00	0	1	4	-3.000E-01
471140	Ag114	4.600E+00 s	1.670E-04	1.000E+00	-1	1	5	0.000E+00
491141	In114m	4.951E+01 d	0.000E+00	9.570E-01	0	1	0	-1.000E+00
491140	In114	7.190E+01 s	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
461150	Pd115	2.500E+01 s	1.512E-02	7.300E-01	0	1	0	-3.000E-01
471150	Ag115	2.000E+01 min	4.670E-04	1.000E-04	0	1	1	0.000E+00
481151	Cd115m	4.460E+01 d	1.460E-03	1.000E+00	-1	1	2	8.225E+00
491150	In115	4.410E+14 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
491161	In116m	5.429E+01 min	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
481150	Cd115	5.346E+01 hr	1.460E-02	1.000E+00	0	1	0	0.000E+00
491151	In115m	4.486E+00 hr	4.055E-05	9.630E-01	-1	1	1	0.000E+00
471170	Ag117	7.280E+01 s	8.219E-03	1.000E+00	0	1	0	-3.000E-01
481170	Cd117	2.490E+00 hr	2.555E-03	9.000E-01	2	1	1	0.000E+00
481171	Cd117m	3.360E+00 hr	4.550E-03	4.800E-01	0	1	2	0.000E+00
491171	In117m	1.162E+02 hr	1.000E-02	9.000E-03	0	1	3	9.196E-01
491170	In117	4.320E+01 min	6.330E-10	1.000E+00	-1	1	4	9.196E-01
501171	Sn117m	1.360E+01 d	0.000E+00	1.000E+00	-1	1	2	0.000E+00
511170	Sb117	2.800E+00 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
441180	Ru118	6.160E-01 s	8.436E-07	1.000E+00	0	5	1	-3.000E-01
451180	Rh118	2.953E-01 s	2.320E-04	1.000E+00	0	1	2	-3.000E-01
461180	Pd118	1.900E+00 s	6.380E-03	5.000E-01	1	1	3	-3.000E-01
471181	Ag118m	2.000E+00 s	3.580E-03	5.900E-01	1	1	4	-3.000E-01
471180	Ag118	3.760E+00 s	6.570E-03	1.000E+00	0	1	5	-3.000E-01
481180	Cd118	5.030E+01 min	1.380E-03	1.000E+00	1	1	6	-3.000E-01
491181	In118m	4.450E+00 min	4.150E-06	1.000E+00	-1	1	7	0.000E+00
491180	In118	5.000E+00 s	4.150E-06	1.000E+00	-1	1	8	0.000E+00
451190	Rh119	4.478E-01 s	4.170E-05	1.000E+00	0	1	0	-3.000E-01
461190	Pd119	9.200E-01 s	3.390E-03	1.000E+00	0	1	1	-3.000E-01
471190	Ag119	2.100E+00 s	9.260E-03	5.000E-01	2	1	2	-3.000E-01
481190	Cd119	2.690E+00 min	2.230E-03	1.000E+00	0	1	3	-3.000E-01
491191	In119m	1.800E+01 min	4.000E-03	1.000E+00	-1	1	4	-3.000E-01
481191	Cd119m	2.200E+00 min	2.230E-03	1.000E+00	-1	1	5	0.000E+00
501191	Sn119m	2.931E+02 d	2.650E-04	1.000E+00	-1	1	0	0.000E+00
441200	Ru120	2.932E-01 s	3.070E-09	1.000E+00	0	5	0	-3.000E-01
451200	Rh120	1.624E-01 s	5.482E-06	1.000E+00	0	1	1	-3.000E-01
461200	Pd120	5.000E-01 s	1.140E-03	1.000E+00	0	1	2	-3.000E-01
471200	Ag120	1.230E+00 s	7.650E-03	1.000E+00	0	1	3	-3.000E-01
481200	Cd120	5.080E+01 s	8.710E-03	5.000E-01	1	1	4	-3.000E-01
491201	In120m	4.620E+01 s	1.850E-04	1.000E+00	-1	1	5	1.476E-03
491200	In120	3.080E+00 s	1.850E-04	1.000E+00	-1	1	6	1.476E-03
511203	Sb120b	5.760E+00 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
451210	Rh121	2.210E-01 s	5.344E-07	1.000E+00	0	1	0	-3.000E-01
461210	Pd121	6.222E-01 s	2.920E-04	1.000E+00	0	1	1	-3.000E-01
471210	Ag121	7.800E-01 s	4.800E-03	1.000E+00	0	1	2	-3.000E-01
481210	Cd121	1.350E+01 s	1.210E-02	8.200E-01	1	1	3	-3.000E-01
491211	In121m	3.880E+00 min	9.580E-04	1.000E+00	2	1	4	-3.000E-01
491210	In121	2.310E+01 s	6.280E-04	1.000E+00	1	1	5	-3.000E-01
501211	Sn121m	5.500E+01 yr	8.780E-06	1.000E+00	-1	1	6	0.000E+00
501210	Sn121	2.706E+01 hr	8.750E-06	1.000E+00	-1	1	7	0.000E+00
521211	Te121m	1.540E+02 d	0.000E+00	8.860E-01	0	1	0	-1.000E+00
521210	Te121	1.678E+01 d	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
511220	Sb122	2.724E+00 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
541220	Xe122	2.010E+01 hr	0.000E+00	1.000E+00	0	3	0	-1.000E+00
531220	I122	3.630E+00 min	0.000E+00	1.000E+00	-1	2	1	-1.000E+00
451230	Rh123	1.335E-01 s	5.115E-09	1.000E+00	0	1	0	-3.000E-01
461230	Pd123	3.100E-01 s	1.540E-05	1.000E+00	0	1	1	-3.000E-01
471230	Ag123	3.090E-01 s	1.280E-03	1.000E+00	0	1	2	-3.000E-01
481230	Cd123	2.100E+00 s	1.390E-02	7.700E-01	2	1	3	-3.000E-01
491231	In123m	4.780E+01 s	3.130E-03	3.800E-01	2	1	4	-3.000E-01
501230	Sn123	1.292E+02 d	1.620E-03	1.000E+00	-1	1	5	0.000E+00
491230	In123	5.980E+00 s	3.210E-03	1.000E+00	0	1	6	0.000E+00
501231	Sn123m	4.006E+01 min	2.940E-04	1.000E+00	-1	1	7	0.000E+00
541230	Xe123	2.080E+00 hr	0.000E+00	1.000E+00	0	3	0	-1.000E+00
531230	I123	1.327E+01 hr	0.000E+00	9.999E-01	1	2	1	-1.000E+00
521231	Te123m	1.197E+02 d	0.000E+00	1.000E+00	1	1	2	-1.000E+00
521230	Te123	1.000E+13 yr	0.000E+00	1.000E+00	-1	1	3	-1.000E+00

Radionuclide		Half-life	Yield	FRACT	IDATR	NGROUP	ISTART	XSECT
511240	Sb124	6.020E+01 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
531240	I124	4.176E+00 d	0.000E+00	1.000E+00	-1	2	0	-1.000E+00
461240	Pd124	5.600E-01 s	3.030E-06	1.000E+00	0	1	0	-3.000E-01
471240	Ag124	1.720E-01 s	5.850E-04	1.000E+00	0	1	1	-3.000E-01
481240	Cd124	1.250E+00 s	1.410E-02	1.000E+00	0	1	2	-3.000E-01
491240	In124	3.110E+00 s	1.350E-02	1.000E+00	-1	1	3	-3.000E-01
471250	Ag125	1.660E-01 s	1.390E-04	1.000E+00	0	1	0	-3.000E-01
481250	Cd125	6.500E-01 s	7.780E-03	7.000E-01	1	1	1	-3.000E-01
491251	In125m	1.220E+01 s	7.960E-03	1.000E+00	1	1	2	-3.000E-01
491250	In125	2.360E+00 s	1.350E-02	3.000E-01	1	1	3	-3.000E-01
501251	Sn125m	9.520E+00 min	5.000E-03	1.000E+00	1	1	4	0.000E+00
501250	Sn125	9.640E+00 d	1.000E-02	1.000E+00	0	1	5	5.443E-01
511250	Sb125	2.758E+00 yr	1.200E-04	2.310E-01	0	1	6	7.621E-01
521251	Te125m	5.740E+01 d	1.380E-07	1.000E+00	-1	1	7	0.000E+00
541250	Xe125	1.690E+01 hr	0.000E+00	1.000E+00	0	3	0	-1.000E+00
531250	I125	5.941E+01 d	0.000E+00	1.000E+00	-1	2	1	-1.000E+00
461260	Pd126	2.870E-01 s	3.780E-08	1.000E+00	0	1	0	-3.000E-01
471260	Ag126	1.070E-01 s	5.320E-05	1.000E+00	0	1	1	-3.000E-01
481260	Cd126	5.060E-01 s	8.160E-03	1.000E+00	0	1	2	-3.000E-01
491260	In126	1.600E+00 s	4.120E-02	1.000E+00	0	1	3	-3.000E-01
501260	Sn126	1.000E+05 yr	2.500E-02	1.000E+00	1	1	4	4.442E-02
511261	Sb126m	1.915E+01 min	5.020E-04	1.400E-01	0	1	6	0.000E+00
511260	Sb126	1.246E+01 d	9.740E-04	1.000E+00	-1	1	7	1.871E+00
531260	I126	1.311E+01 d	0.000E+00	1.000E+00	-1	2	0	-1.000E+00
481270	Cd127	3.700E-01 s	4.100E-03	5.000E-01	1	1	0	-3.000E-01
491270	In127	1.090E+00 s	2.490E-02	1.000E+00	1	1	1	-3.000E-01
491271	In127m	3.670E+00 s	2.500E-02	1.000E+00	0	1	2	-3.000E-01
501270	Sn127	2.100E+00 hr	4.720E-02	1.000E+00	1	1	4	0.000E+00
501271	Sn127m	4.130E+00 min	5.040E-02	1.000E+00	0	1	3	0.000E+00
511270	Sb127	3.850E+00 d	7.460E-03	8.310E-01	1	1	5	0.000E+00
521271	Te127m	1.090E+02 d	9.800E-05	9.817E-01	0	1	6	2.053E+00
521270	Te127	9.350E+00 hr	4.000E-03	1.000E+00	-1	1	7	0.000E+00
541270	Xe127	3.640E+01 d	0.000E+00	1.000E+00	-1	3	0	-1.000E+00
471280	Ag128	1.024E-01 s	1.380E-06	1.000E+00	0	1	0	-3.000E-01
481280	Cd128	3.400E-01 s	1.820E-03	1.000E+00	0	1	1	-3.000E-01
491280	In128	8.400E-01 s	6.200E-02	1.000E+00	0	1	2	-3.000E-01
501280	Sn128	5.907E+01 min	3.060E-01	1.000E+00	0	1	3	0.000E+00
511281	Sb128m	1.040E+01 min	1.210E-02	1.000E+00	-1	1	4	0.000E+00
511280	Sb128	9.010E+00 hr	1.600E-02	1.000E+00	-1	1	5	0.000E+00
531280	I128	2.499E+01 min	0.000E+00	1.000E+00	-1	2	0	-1.000E+00
481290	Cd129	2.700E-01 s	3.060E-04	1.000E+00	0	1	0	-3.000E-01
491290	In129	6.100E-01 s	3.940E-02	5.000E-01	1	1	1	-3.000E-01
501291	Sn129m	6.900E+00 min	3.300E-01	1.000E+00	1	1	2	-3.000E-01
501290	Sn129	2.230E+00 min	2.030E-01	1.000E+00	0	1	3	-3.000E-01
511290	Sb129	4.400E+00 hr	1.140E-01	8.693E-01	1	1	4	0.000E+00
521291	Te129m	3.360E+01 d	1.200E-02	6.500E-01	0	1	5	2.900E-01
521290	Te129	6.960E+01 min	1.480E-02	1.000E+00	0	1	6	0.000E+00
531290	I129	1.570E+07 yr	2.500E-02	1.000E+00	-1	2	7	5.272E+00
541291	Xe129m	8.880E+00 d	5.821E-09	1.000E+00	-1	3	1	0.000E+00
551290	Cs129	3.206E+01 hr	0.000E+00	1.000E+00	-1	4	0	-1.000E+00
481300	Cd130	2.000E-01 s	8.100E-04	1.000E+00	0	1	0	-3.000E-01
491300	In130	3.200E-01 s	7.340E-02	1.000E+00	0	1	1	-3.000E-01
501300	Sn130	3.720E+00 min	8.720E-01	1.000E+00	0	1	2	0.000E+00
511301	Sb130m	6.300E+00 min	3.020E-01	1.000E+00	-1	1	3	0.000E+00
511300	Sb130	3.950E+01 min	2.180E-01	1.000E+00	-1	1	0	0.000E+00
531301	I130m	9.000E+00 min	1.050E-04	8.300E-01	0	2	4	0.000E+00
531300	I130	1.236E+01 hr	1.970E-04	1.000E+00	-1	2	5	0.000E+00
481310	Cd131	1.193E-01 s	7.700E-05	1.000E+00	0	1	0	-3.000E-01
491310	In131	2.820E-01 s	2.440E-02	1.000E+00	0	1	1	-3.000E-01
501310	Sn131	5.600E+01 s	9.590E-01	1.000E+00	0	1	2	-3.000E-01
511310	Sb131	2.303E+01 min	1.590E+00	9.320E-01	1	1	3	0.000E+00
521311	Te131m	3.000E+01 hr	1.900E-01	7.780E-01	1	1	4	0.000E+00
521310	Te131	2.500E+01 min	1.190E-01	1.000E+00	0	1	5	0.000E+00
531310	I131	8.021E+00 d	4.150E-03	1.086E-02	0	2	6	3.229E-01
541311	Xe131m	1.184E+01 d	1.040E-06	1.000E+00	-1	3	7	0.000E+00
561310	Ba131	1.150E+01 d	0.000E+00	1.000E+00	0	1	0	-1.000E+00

Radionuclide		Half-life	Yield	FRACT	IDATR	NGROUP	ISTART	XSECT
551310	Cs131	9.689E+00 d	0.000E+00	1.000E+00	-1	4	1	-1.000E+00
481320	Cd132	1.448E-01 s	6.140E-06	1.000E+00	0	1	0	-3.000E-01
491320	In132	2.010E-01 s	6.620E-03	1.000E+00	0	1	1	-3.000E-01
501320	Sn132	3.970E+01 s	5.860E-01	1.000E+00	1	1	2	0.000E+00
511321	Sb132m	4.100E+00 min	1.070E+00	1.000E+00	1	1	3	0.000E+00
511320	Sb132	2.790E+00 min	1.080E+00	1.000E+00	0	1	4	0.000E+00
521320	Te132	3.204E+00 d	1.540E+00	1.000E+00	0	1	5	4.890E-04
531320	I132	2.295E+00 hr	2.060E-02	1.000E+00	-1	2	6	0.000E+00
551320	Cs132	6.479E+00 d	0.000E+00	1.000E+00	-1	4	0	-1.000E+00
491330	In133	1.800E-01 s	3.950E-04	1.000E+00	0	1	0	-3.000E-01
501330	Sn133	1.450E+00 s	1.690E-01	1.000E+00	0	1	1	-3.000E-01
511330	Sb133	2.500E+00 min	2.080E+00	9.780E-01	1	1	2	0.000E+00
521331	Te133m	5.540E+01 min	2.880E+00	1.300E-01	0	1	3	0.000E+00
521330	Te133	1.250E+01 min	3.520E+00	1.000E+00	1	2	4	0.000E+00
531331	I133m	9.000E+00 s	1.290E-01	1.000E+00	0	2	5	0.000E+00
531330	I133	2.080E+01 hr	0.000E+00	9.712E-01	1	2	6	0.000E+00
541331	Xe133m	2.190E+00 d	2.670E-03	1.000E+00	0	3	7	0.000E+00
541330	Xe133	5.243E+00 d	8.790E-04	1.000E+00	-1	3	8	2.440E+01
561331	Ba133m	3.890E+01 hr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
561330	Ba133	1.051E+01 yr	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
491340	In134	1.380E-01 s	6.960E-06	1.000E+00	0	1	0	-3.000E-01
501340	Sn134	1.120E+00 s	1.190E-02	1.000E+00	1	1	1	-3.000E-01
511341	Sb134m	1.023E+01 s	2.580E-01	1.000E+00	1	1	2	-3.000E-01
511340	Sb134	7.800E-01 s	2.580E-01	1.000E+00	0	1	3	0.000E+00
521340	Te134	4.180E+01 min	6.180E+00	1.000E+00	1	1	4	9.197E-03
531341	I134m	3.600E+00 min	4.520E-01	9.800E-01	0	2	5	0.000E+00
531340	I134	5.250E+01 min	4.570E-01	1.000E+00	-1	2	6	0.000E+00
541341	Xe134m	2.900E-01 s	2.380E-02	1.000E+00	-1	3	0	-3.000E-01
551341	Cs134m	2.903E+00 hr	5.300E-05	1.000E+00	3	4	2	0.000E+00
551340	Cs134	2.065E+00 yr	1.380E-05	1.000E+00	-1	4	6	2.298E+01
501350	Sn135	2.910E-01 s	1.240E-03	1.000E+00	0	1	0	-3.000E-01
511350	Sb135	1.710E+00 s	1.960E-01	1.000E+00	0	1	1	-3.000E-01
521350	Te135	1.900E+01 s	3.110E+00	1.000E+00	0	1	2	0.000E+00
531350	I135	6.570E+00 hr	2.980E+00	8.350E-01	1	2	3	2.119E-03
541351	Xe135m	1.529E+01 min	1.518E-01	1.000E+00	1	3	4	0.000E+00
541350	Xe135	9.140E+00 hr	9.780E-02	1.000E+00	4	3	6	2.090E+05
551351	Cs135m	5.300E+01 min	6.250E-04	1.000E+00	1	4	9	0.000E+00
551350	Cs135	2.300E+06 yr	9.010E-04	1.000E+00	-1	4	11	2.391E+00
561351	Ba135m	2.870E+01 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
501360	Sn136	4.131E-01 s	5.430E-05	1.000E+00	0	1	0	-3.000E-01
511360	Sb136	8.200E-01 s	2.990E-02	1.000E+00	0	1	1	-3.000E-01
521360	Te136	1.750E+01 s	1.850E+00	1.000E+00	1	1	2	-3.000E-01
531361	I136m	4.690E+01 s	1.950E+00	1.000E+00	-1	2	0	-3.000E-01
531360	I136	8.340E+01 s	1.190E+00	1.000E+00	-1	2	3	0.000E+00
551360	Cs136	1.316E+01 d	7.510E-03	1.000E+00	-1	4	2	0.000E+00
511370	Sb137	2.837E-01 s	2.130E-03	1.000E+00	0	1	0	-3.000E-01
521370	Te137	2.490E+00 s	4.200E-01	1.000E+00	0	1	1	-3.000E-01
531370	I137	2.450E+01 s	2.840E+00	1.000E+00	0	2	2	-3.000E-01
541370	Xe137	3.818E+00 min	2.870E+00	1.000E+00	0	3	3	0.000E+00
551370	Cs137	3.007E+01 yr	1.250E-01	9.460E-01	0	4	4	2.559E-02
561371	Ba137m	2.552E+00 min	2.580E-04	1.000E+00	-1	1	5	0.000E+00
571370	La137	6.000E+04 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
511380	Sb138	1.304E-01 s	1.320E-04	1.000E+00	0	1	0	-3.000E-01
521380	Te138	1.400E+00 s	8.720E-02	1.000E+00	0	1	1	-3.000E-01
531380	I138	6.490E+00 s	1.570E+00	1.000E+00	0	2	2	0.000E+00
541380	Xe138	1.408E+01 min	4.560E+00	1.000E+00	1	3	3	0.000E+00
551381	Cs138m	2.910E+00 min	2.480E-01	7.500E-01	0	4	0	0.000E+00
551380	Cs138	3.341E+01 min	3.010E-01	1.000E+00	-1	4	5	0.000E+00
571380	La138	1.050E+11 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
511390	Sb139	1.720E-01 s	5.870E-06	1.000E+00	0	1	0	-3.000E-01
521390	Te139	4.237E-01 s	1.300E-02	1.000E+00	0	1	1	-3.000E-01
531390	I139	2.290E+00 s	7.230E-01	1.000E+00	0	2	2	0.000E+00
541390	Xe139	3.968E+01 s	4.350E+00	1.000E+00	0	3	3	0.000E+00
551390	Cs139	9.270E+00 min	1.310E+00	1.000E+00	0	4	4	0.000E+00
561390	Ba139	8.306E+01 min	6.710E-02	1.000E+00	-1	1	5	5.518E-01
581390	Ce139	1.376E+02 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
521400	Te140	7.520E-01 s	1.210E-03	1.000E+00	0	1	0	-3.000E-01

Radionuclide		Half-life	Yield	FRACT	IDATR	NGROUP	ISTART	XSECT
531400	I140	8.600E-01 s	2.150E-01	1.000E+00	0	2	0	-3.000E-01
541400	Xe140	1.360E+01 s	3.400E+00	1.000E+00	0	3	0	0.000E+00
551400	Cs140	6.370E+01 s	2.230E+00	1.000E+00	0	4	1	0.000E+00
561400	Ba140	1.275E+01 d	4.290E-01	1.000E+00	0	1	2	5.285E-01
571400	La140	1.678E+00 d	6.040E-03	1.000E+00	-1	1	3	2.210E+00
521410	Te141	2.358E-01 s	4.190E-05	1.000E+00	0	1	0	-3.000E-01
531410	I141	4.300E-01 s	3.080E-02	1.000E+00	0	2	1	-3.000E-01
541410	Xe141	1.730E+00 s	1.150E+00	1.000E+00	0	3	2	0.000E+00
551410	Cs141	2.494E+01 s	3.240E+00	1.000E+00	0	4	3	1.518E-03
561410	Ba141	1.827E+01 min	1.460E+00	1.000E+00	0	1	4	0.000E+00
571410	La141	3.920E+00 hr	1.940E-02	1.000E+00	0	1	5	0.000E+00
581410	Ce141	3.250E+01 d	2.430E-05	1.000E+00	-1	1	6	2.971E+00
601410	Nd141	2.490E+00 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
521420	Te142	4.912E-01 s	8.030E-07	1.000E+00	0	1	0	-3.000E-01
531420	I142	1.960E-01 s	2.230E-03	1.000E+00	0	2	1	-3.000E-01
541420	Xe142	1.220E+00 s	3.800E-01	1.000E+00	0	3	2	-3.000E-01
551420	Cs142	1.700E+00 s	2.460E+00	1.000E+00	0	4	3	-3.000E-01
561420	Ba142	1.060E+01 min	2.930E+00	1.000E+00	0	1	4	0.000E+00
571420	La142	9.110E+01 min	1.000E-01	1.000E+00	-1	1	5	0.000E+00
581420	Ce142	5.000E+16 yr	0.000E+00	1.000E+00	-1	1	5	-1.000E+00
591420	Pr142	1.912E+01 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
531430	I143	3.280E-01 s	9.080E-05	1.000E+00	0	2	0	-3.000E-01
541430	Xe143	3.000E-01 s	5.200E-02	1.000E+00	0	3	1	-3.000E-01
551430	Cs143	1.780E+00 s	1.470E+00	1.000E+00	0	4	2	-3.000E-01
561430	Ba143	1.433E+01 s	3.780E+00	1.000E+00	0	1	3	-3.000E-01
571430	La143	1.420E+01 min	6.010E-01	1.000E+00	0	1	4	0.000E+00
581430	Ce143	3.304E+01 hr	2.850E-02	1.000E+00	0	1	5	1.755E+00
591430	Pr143	1.357E+01 d	2.950E-06	1.000E+00	-1	1	6	1.214E+01
611430	Pm143	2.650E+02 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
531440	I144	1.327E-01 s	3.420E-06	1.000E+00	0	2	0	-3.000E-01
541440	Xe144	1.150E+00 s	6.570E-03	1.000E+00	0	3	1	-3.000E-01
551440	Cs144	1.010E+00 s	3.110E-01	1.000E+00	0	4	2	0.000E+00
561440	Ba144	1.150E+01 s	3.930E+00	1.000E+00	0	1	3	0.000E+00
571440	La144	4.080E+01 s	1.110E+00	1.000E+00	0	1	4	0.000E+00
581440	Ce144	2.849E+02 d	6.090E-02	9.857E-01	1	1	5	1.491E+01
591441	Pr144m	7.200E+00 min	6.678E-05	9.994E-01	0	1	6	0.000E+00
591440	Pr144	1.728E+01 min	8.250E-05	1.000E+00	-1	1	7	0.000E+00
601440	Nd144	2.290E+15 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
611440	Pm144	3.630E+02 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
541450	Xe145	9.000E-01 s	1.480E-04	1.000E+00	0	3	0	-3.000E-01
551450	Cs145	5.940E-01 s	7.180E-02	1.000E+00	0	4	1	-3.000E-01
561450	Ba145	4.310E+00 s	1.920E+00	1.000E+00	0	1	2	-3.000E-01
571450	La145	2.480E+01 s	1.690E+00	1.000E+00	0	1	3	-3.000E-01
581450	Ce145	3.010E+00 min	2.300E-01	1.000E+00	0	1	4	0.000E+00
591450	Pr145	5.984E+00 hr	9.320E-04	1.000E+00	-1	1	5	0.000E+00
611450	Pm145	1.770E+01 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
541460	Xe146	9.372E-01 s	1.380E-05	1.000E+00	0	3	0	-3.000E-01
551460	Cs146	3.430E-01 s	8.100E-03	1.000E+00	0	4	1	-3.000E-01
561460	Ba146	2.220E+00 s	6.680E-01	1.000E+00	0	1	2	-3.000E-01
571460	La146	6.270E+00 s	1.620E+00	1.000E+00	0	1	3	-3.000E-01
581460	Ce146	1.352E+01 min	6.730E-01	1.000E+00	0	1	4	0.000E+00
591460	Pr146	2.415E+01 min	8.540E-03	1.000E+00	-1	1	5	0.000E+00
611460	Pm146	5.530E+00 yr	0.000E+00	3.590E-01	0	1	0	-1.000E+00
621460	Sm146	1.030E+08 yr	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
541470	Xe147	2.638E-01 s	2.393E-07	1.000E+00	0	1	0	-3.000E-01
551470	Cs147	2.250E-01 s	5.900E-04	1.000E+00	0	4	1	-3.000E-01
561470	Ba147	8.930E-01 s	1.300E-01	1.000E+00	0	1	2	-3.000E-01
571470	La147	4.015E+00 s	9.370E-01	1.000E+00	0	1	3	-3.000E-01
581470	Ce147	5.640E+01 s	1.160E+00	1.000E+00	0	1	4	-3.000E-01
591470	Pr147	1.340E+01 min	5.380E-02	1.000E+00	0	1	5	0.000E+00
601470	Nd147	1.098E+01 d	2.960E-04	1.000E+00	2	1	6	2.006E+01
611470	Pm147	2.623E+00 yr	0.000E+00	1.000E+00	1	1	9	6.192E+02
621470	Sm147	1.060E+11 yr	1.010E-06	1.000E+00	-1	1	11	0.000E+00
551480	Cs148	1.580E-01 s	1.810E-05	1.000E+00	0	4	0	-3.000E-01
561480	Ba148	6.070E-01 s	1.520E-02	1.000E+00	0	1	1	-3.000E-01
571480	La148	1.050E+00 s	3.420E-01	1.000E+00	0	1	2	-3.000E-01

Radionuclide	Half-life	Yield	FRACT	IDATR	NGROUP	ISTART	XSECT
581480	Ce148	5.600E+01 s	1.170E+00	1.000E+00	0	1	-3.000E-01
591480	Pr148	2.270E+00 min	1.610E-01	1.000E+00	-1	1	0.000E+00
611481	Pm148m	4.129E+01 d	7.420E-07	4.200E-02	1	1	0.000E+00
611480	Pm148	5.370E+00 d	5.100E-06	1.000E+00	-1	1	0.000E+00
621480	Sm148	7.000E+15 yr	0.000E+00	1.000E+00	-1	1	-1.000E+00
641480	Gd148	7.460E+01 yr	0.000E+00	1.000E+00	-1	1	-1.000E+00
641490	Gd149	9.280E+00 d	0.000E+00	1.000E+00	0	1	-1.000E+00
631480	Eu148	5.450E+01 d	0.000E+00	1.000E+00	-1	1	-1.000E+00
561490	Ba149	3.440E-01 s	9.270E-04	1.000E+00	0	1	-3.000E-01
571490	La149	1.050E+00 s	7.020E-02	1.000E+00	0	1	-3.000E-01
581490	Ce149	5.300E+00 s	7.100E-01	1.000E+00	0	1	-3.000E-01
591490	Pr149	2.260E+00 min	2.890E-01	1.000E+00	0	1	0.000E+00
601490	Nd149	1.728E+00 hr	1.810E-02	1.000E+00	1	1	0.000E+00
611490	Pm149	5.308E+01 hr	3.120E-05	1.000E+00	-1	1	1.324E+02
621490	Sm149	2.000E+15 yr	0.000E+00	1.000E+00	-1	1	-1.000E+00
611500	Pm150	2.680E+00 hr	2.820E-07	1.000E+00	-1	1	0.000E+00
631500	Eu150	3.690E+01 yr	0.000E+00	1.000E+00	-1	1	-1.000E+00
631503	Eu150b	1.280E+01 d	0.000E+00	1.000E+00	-1	1	-1.000E+00
571510	La151	9.536E-01 s	8.950E-04	1.000E+00	0	1	-3.000E-01
581510	Ce151	1.020E+00 s	7.580E-02	1.000E+00	0	1	-3.000E-01
591510	Pr151	1.890E+01 s	2.240E-01	1.000E+00	0	1	-3.000E-01
601510	Nd151	1.244E+01 min	1.190E-01	1.000E+00	0	1	0.000E+00
611510	Pm151	2.840E+01 hr	1.770E-03	1.000E+00	0	1	1.031E+02
621510	Sm151	9.000E+01 yr	3.800E-06	1.000E+00	-1	1	7.260E+02
561520	Ba152	7.548E-01 s	1.960E-08	1.000E+00	0	1	-3.000E-01
571520	La152	3.094E-01 s	4.980E-05	1.000E+00	0	1	-3.000E-01
581520	Ce152	1.400E+00 s	1.360E-02	1.000E+00	0	1	-3.000E-01
591520	Pr152	3.630E+00 s	1.080E-01	1.000E+00	0	1	-3.000E-01
601520	Nd152	1.140E+01 min	1.450E-01	1.000E+00	1	1	-3.000E-01
611521	Pm152m	7.520E+00 min	3.670E-03	1.000E+00	0	1	-3.000E-01
611520	Pm152	4.120E+00 min	3.670E-03	1.000E+00	-1	1	0.000E+00
631520	Eu152	1.354E+01 yr	0.000E+00	1.000E+00	-1	1	1.914E+02
631521	Eu152m	9.312E+00 hr	0.000E+00	7.200E-01	0	1	-1.000E+00
641520	Gd152	1.080E+14 yr	0.000E+00	1.000E+00	-1	1	-1.000E+00
571530	La153	4.370E-01 s	1.460E-06	1.000E+00	0	1	-3.000E-01
581530	Ce153	1.725E+00 s	1.310E-03	1.000E+00	0	1	-3.000E-01
591530	Pr153	4.300E+00 min	3.130E-02	1.000E+00	0	1	-3.000E-01
601530	Nd153	2.890E+01 min	1.170E-01	1.000E+00	0	1	-3.000E-01
611530	Pm153	5.400E+00 min	1.650E-02	1.000E+00	1	1	0.000E+00
621530	Sm153	4.627E+01 hr	3.340E-04	1.000E+00	-1	1	8.977E+01
641530	Gd153	2.416E+02 d	9.700E-12	1.000E+00	-1	1	0.000E+00
571540	La154	1.753E-01 s	3.135E-08	1.000E+00	0	1	-3.000E-01
581540	Ce154	3.590E-01 s	8.090E-05	1.000E+00	0	1	-3.000E-01
591540	Pr154	2.300E+00 s	5.530E-03	1.000E+00	0	1	-3.000E-01
601540	Nd154	2.590E+01 s	5.100E-02	1.000E+00	1	1	-3.000E-01
611541	Pm154m	2.680E+00 min	9.400E-03	1.000E-01	0	1	-3.000E-01
611540	Pm154	1.730E+00 min	9.400E-03	1.000E+00	-1	1	0.000E+00
631540	Eu154	8.593E+00 yr	1.730E-06	1.000E+00	-1	1	1.286E+02
581550	Ce155	7.125E-01 s	3.310E-06	1.000E+00	0	1	-3.000E-01
591550	Pr155	1.890E+00 s	6.840E-04	1.000E+00	0	1	-3.000E-01
601550	Nd155	8.900E+00 s	1.720E-02	1.000E+00	0	1	-3.000E-01
611550	Pm155	4.150E+01 s	1.570E-02	1.000E+00	0	1	-3.000E-01
621550	Sm155	2.230E+01 min	2.590E-03	1.000E+00	1	1	0.000E+00
631550	Eu155	4.761E+00 yr	2.000E-08	1.000E+00	-1	1	3.655E+02
581560	Ce156	1.162E+00 s	9.134E-08	1.000E+00	0	1	-3.000E-01
591560	Pr156	5.104E-01 s	5.080E-05	1.000E+00	0	1	-3.000E-01
601560	Nd156	5.470E+00 s	3.500E-03	1.000E+00	0	1	-3.000E-01
611560	Pm156	2.670E+01 s	8.040E-03	1.000E+00	1	1	-3.000E-01
621560	Sm156	9.400E+00 hr	3.340E-03	1.000E-03	0	1	0.000E+00
631560	Eu156	1.519E+01 d	4.540E-05	1.000E+00	-1	1	7.378E+02
581570	Ce157	3.618E-01 s	2.450E-09	1.000E+00	0	1	-3.000E-01
591570	Pr157	6.780E-01 s	3.100E-06	1.000E+00	0	1	-3.000E-01
601570	Nd157	4.150E+00 s	5.940E-04	1.000E+00	0	1	-3.000E-01
611570	Pm157	1.056E+01 s	3.470E-03	1.000E+00	0	1	-3.000E-01
621570	Sm157	4.820E+02 s	3.530E-03	1.000E-03	0	1	-3.000E-01
631570	Eu157	1.518E+01 hr	8.121E-03	1.000E+00	-1	1	4.609E+02
661570	Dy157	8.140E+00 hr	0.000E+00	1.000E+00	0	1	-1.000E+00

Radionuclide		Half-life	Yield	FRACT	IDATR	NGROUP	ISTART	XSECT
651570	Tb157	7.100E+01 yr	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
591580	Pr158	2.630E-01 s	1.280E-07	1.000E+00	0	1	0	-3.000E-01
601580	Nd158	7.890E+00 s	6.660E-05	1.000E+00	0	1	1	-3.000E-01
611580	Pm158	4.800E+00 s	1.040E-03	1.000E+00	0	1	2	-3.000E-01
621580	Sm158	5.300E+00 min	2.580E-03	1.000E+00	0	1	3	-3.000E-01
631580	Eu158	4.590E+01 min	2.580E-04	1.000E+00	-1	1	4	0.000E+00
631580	Tb158	1.800E+02 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
591590	Pr159	3.140E-01 s	2.104E-09	1.000E+00	0	1	0	-3.000E-01
601590	Nd159	1.410E+00 s	3.080E-06	1.000E+00	0	1	1	-3.000E-01
611590	Pm159	4.230E+00 s	1.430E-04	1.000E+00	0	1	2	-3.000E-01
621590	Sm159	1.137E+01 s	9.040E-04	1.000E+00	0	1	3	-3.000E-01
631590	Eu159	1.810E+01 min	2.620E-04	1.000E+00	1	1	4	0.000E+00
641590	Gd159	1.848E+01 hr	1.220E-05	1.000E+00	-1	1	6	0.000E+00
661590	Dy159	1.444E+02 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
651600	Tb160	7.230E+01 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
651610	Tb161	6.880E+00 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
671641	Ho164m	3.750E+01 min	0.000E+00	1.000E+00	0	1	0	-1.000E+00
671640	Ho164	2.900E+01 min	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
661650	Dy165	2.334E+00 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
661660	Dy166	8.160E+01 hr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
671660	Ho166	2.683E+01 hr	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
671661	Ho166m	1.200E+03 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
681690	Er169	9.400E+00 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
701690	Yb169	3.203E+01 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
691700	Tm170	1.286E+02 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
681710	Er171	7.516E+00 hr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
691710	Tm171	1.920E+00 yr	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
711741	Lu174m	1.420E+02 d	0.000E+00	9.930E-01	0	1	0	-1.000E+00
711740	Lu174	3.310E+00 yr	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
701750	Yb175	4.185E+00 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
721750	Hf175	7.000E+01 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
711761	Lu176m	3.635E+00 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
711760	Lu176	3.780E+10 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
711771	Lu177m	1.604E+02 d	0.000E+00	2.200E-01	0	1	0	-1.000E+00
711770	Lu177	6.734E+00 d	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
721771	Hf177m	5.140E+01 min	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
711780	Lu178	2.840E+01 min	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
711781	Lu178m	2.310E+01 min	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
721781	Hf178m	3.100E+01 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
721791	Hf179m	2.505E+01 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
741790	W179	3.705E+01 min	0.000E+00	1.000E+00	0	1	0	-1.000E+00
731790	Ta179	1.820E+00 yr	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
731801	Ta180m	1.200E+15 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
721810	Hf181	4.239E+01 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
741810	W181	1.212E+02 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
721820	Hf182	9.000E+06 yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
731821	Ta182m	1.584E+01 min	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
731820	Ta182	1.144E+02 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
751823	Re182b	6.400E+01 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
751822	Re182a	1.270E+01 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
721830	Hf183	1.067E+00 hr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
731830	Ta183	5.100E+00 d	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
731840	Ta184	8.700E+00 hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
751841	Re184m	1.690E+02 d	0.000E+00	7.470E-01	0	1	0	-1.000E+00
751840	Re184	3.800E+01 d	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
731850	Ta185	4.940E+01 min	0.000E+00	1.000E+00	0	1	0	-1.000E+00
741850	W185	7.510E+01 d	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
761850	Os185	9.360E+01 d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
731860	Ta186	1.050E+01 min	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
751861	Re186m	2.000E+05 yr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
751860	Re186	9.064E+01 hr	0.000E+00	9.220E-01	-1	1	1	-1.000E+00
741870	W187	2.372E+01 hr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
751870	Re187	4.350E+10 yr	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
741880	W188	6.940E+01 d	0.000E+00	1.000E+00	1	1	0	-1.000E+00
751881	Re188m	1.860E+01 min	0.000E+00	1.000E+00	0	1	0	-1.000E+00
751880	Re188	1.698E+01 hr	0.000E+00	1.000E+00	-1	1	2	-1.000E+00

Radionuclide		Half-life		Yield	FRACT	IDATR	NGROUP	ISTART	XSECT
751890	Re189	2.430E+01	hr	0.000E+00	2.410E-01	0	1	0	-1.000E+00
761891	Os189m	5.800E+00	hr	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
761901	Os190m	9.900E+00	min	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
771904	Ir190n	3.250E+00	hr	0.000E+00	5.000E-02	0	1	0	-1.000E+00
771901	Ir190m	1.200E+00	hr	0.000E+00	1.000E+00	0	1	1	-1.000E+00
771900	Ir190	1.178E+01	d	0.000E+00	1.000E+00	-1	1	2	-1.000E+00
761911	Os191m	1.310E+01	hr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
761910	Os191	1.540E+01	d	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
781910	Pt191	2.802E+00	d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
771921	Ir192m	2.410E+02	yr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
771920	Ir192	7.383E+01	d	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
761930	Os193	3.050E+01	hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
781931	Pt193m	4.330E+00	d	0.000E+00	1.000E+00	0	1	0	-1.000E+00
781930	Pt193	5.000E+01	yr	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
761940	Os194	6.000E+00	yr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
771940	Ir194	1.928E+01	hr	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
771941	Ir194m	1.710E+02	d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
801940	Hg194	4.440E+02	yr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
791940	Au194	3.802E+01	hr	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
781951	Pt195m	4.020E+00	d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
791951	Au195m	3.050E+01	s	0.000E+00	1.000E+00	0	1	0	-1.000E+00
791950	Au195	1.861E+02	d	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
781971	Pt197m	9.541E+01	min	0.000E+00	9.670E-01	0	1	0	-1.000E+00
781970	Pt197	1.989E+01	hr	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
801971	Hg197m	2.380E+01	hr	0.000E+00	9.300E-01	0	1	0	-1.000E+00
801970	Hg197	6.414E+01	hr	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
791981	Au198m	2.270E+00	d	0.000E+00	1.000E+00	0	1	0	-1.000E+00
791980	Au198	2.695E+00	d	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
791990	Au199	3.139E+00	d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
801991	Hg199m	4.260E+01	min	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
812000	Tl200	2.610E+01	hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
812010	Tl201	7.291E+01	hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
822020	Pb202	5.250E+04	yr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
812020	Tl202	1.223E+01	d	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
802030	Hg203	4.661E+01	d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
822030	Pb203	5.187E+01	hr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
812040	Tl204	3.780E+00	yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
822050	Pb205	1.530E+07	yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
832101	Bi210m	3.040E+06	yr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
812060	Tl206	4.199E+00	min	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
832060	Bi206	6.243E+00	d	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
832080	Bi208	3.680E+05	yr	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
942450	Pu245	1.050E+01	hr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
952450	Am245	2.050E+00	hr	0.000E+00	1.000E+00	7	1	1	-1.000E+00
962410	Cm241	3.280E+01	d	0.000E+00	1.000E+00	0	1	0	-1.000E+00
942370	Pu237	4.520E+01	d	0.000E+00	1.000E+00	9	1	0	-1.000E+00
982530	Cf253	1.781E+01	d	0.000E+00	3.100E-03	1	1	0	-1.000E+00
992530	Es253	2.047E+01	d	0.000E+00	1.000E+00	1	1	1	-1.000E+00
962490	Cm249	6.415E+01	min	0.000E+00	1.000E+00	0	1	2	-1.000E+00
972490	Bk249	3.200E+02	d	0.000E+00	1.000E+00	0	1	3	-1.000E+00
982490	Cf249	3.510E+02	yr	0.000E+00	1.000E+00	0	1	4	-1.000E+00
962450	Cm245	8.500E+03	yr	0.000E+00	1.000E+00	0	1	5	-1.000E+00
942410	Pu241	1.435E+01	yr	0.000E+00	1.000E+00	0	1	6	-1.000E+00
952410	Am241	4.322E+02	yr	0.000E+00	1.000E+00	1	1	7	-1.000E+00
922370	U237	6.750E+00	d	0.000E+00	1.000E+00	0	1	8	-1.000E+00
932370	Np237	2.144E+06	yr	0.000E+00	1.000E+00	0	1	9	-1.000E+00
912330	Pa233	2.697E+01	d	0.000E+00	1.000E+00	0	1	10	-1.000E+00
922330	U233	1.592E+05	yr	0.000E+00	1.000E+00	0	1	11	-1.000E+00
902290	Th229	7.340E+03	yr	0.000E+00	1.000E+00	0	1	12	-1.000E+00
882250	Ra225	1.490E+01	d	0.000E+00	1.000E+00	0	1	13	-1.000E+00
892250	Ac225	1.000E+01	d	0.000E+00	1.000E+00	0	1	14	-1.000E+00
872210	Fr221	4.900E+00	min	0.000E+00	1.000E+00	0	1	15	-1.000E+00
852170	At217	3.230E-02	s	0.000E+00	1.000E+00	0	1	16	-1.000E+00
832130	Bi213	4.559E+01	min	0.000E+00	2.160E-02	1	1	17	-1.000E+00
842130	Po213	4.200E-06	s	0.000E+00	1.000E+00	1	1	18	-1.000E+00
812090	Tl209	2.200E+00	min	0.000E+00	1.000E+00	0	1	19	-1.000E+00
822090	Pb209	3.253E+00	hr	0.000E+00	1.000E+00	-1	1	20	-1.000E+00

Radionuclide		Half-life	Yield	FRACT	IDATR	NGROUP	ISTART	XSECT
982520	Cf252	2.645E+00 yr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
962480	Cm248	3.400E+05 yr	0.000E+00	1.000E+00	0	1	1	-1.000E+00
942440	Pu244	8.080E+07 yr	0.000E+00	1.000E+00	0	1	2	-1.000E+00
922400	U240	1.410E+01 hr	0.000E+00	1.000E+00	0	1	3	-1.000E+00
932401	Np240m	7.220E+00 min	0.000E+00	9.989E-01	8	1	4	-1.000E+00
932400	Np240	6.190E+01 min	0.000E+00	1.000E+00	9	1	5	-1.000E+00
912320	Pa232	1.310E+00 d	0.000E+00	1.000E+00	2	1	0	-1.000E+00
932363	Np236b	2.250E+01 hr	0.000E+00	5.200E-01	6	1	0	-1.000E+00
942360	Pu236	2.858E+00 yr	0.000E+00	1.000E+00	0	1	2	-1.000E+00
922320	U232	6.890E+01 yr	0.000E+00	1.000E+00	8	1	3	-1.000E+00
952440	Am244	1.010E+01 hr	0.000E+00	1.000E+00	1	1	0	-1.000E+00
982480	Cf248	3.335E+02 d	0.000E+00	1.000E+00	0	1	1	-1.000E+00
962440	Cm244	1.810E+01 yr	0.000E+00	1.000E+00	0	1	2	-1.000E+00
942400	Pu240	6.563E+03 yr	0.000E+00	1.000E+00	1	1	13	-1.000E+00
932362	Np236a	1.540E+05 yr	0.000E+00	9.110E-01	0	1	0	-1.000E+00
922360	U236	2.342E+07 yr	0.000E+00	1.000E+00	0	1	14	-1.000E+00
902320	Th232	1.405E+10 yr	0.000E+00	1.000E+00	0	1	15	-1.000E+00
882280	Ra228	5.750E+00 yr	0.000E+00	1.000E+00	0	1	16	-1.000E+00
892280	Ac228	6.150E+00 hr	0.000E+00	1.000E+00	0	1	17	-1.000E+00
902280	Th228	1.912E+00 yr	0.000E+00	1.000E+00	0	1	19	-1.000E+00
882240	Ra224	3.660E+00 d	0.000E+00	1.000E+00	0	1	20	-1.000E+00
862200	Rn220	5.560E+01 s	0.000E+00	1.000E+00	0	3	21	-1.000E+00
842160	Po216	1.450E-01 s	0.000E+00	1.000E+00	0	1	22	-1.000E+00
822120	Pb212	1.064E+01 hr	0.000E+00	1.000E+00	0	1	23	-1.000E+00
832120	Bi212	6.055E+01 min	0.000E+00	3.593E-01	0	1	24	-1.000E+00
812080	Tl208	3.053E+00 min	0.000E+00	1.000E+00	-1	1	25	-1.000E+00
842120	Po212	2.990E-07 s	0.000E+00	1.000E+00	-1	1	0	-1.000E+00
952421	Am242m	1.410E+02 yr	0.000E+00	9.952E-01	0	1	0	-1.000E+00
952420	Am242	1.602E+01 hr	0.000E+00	1.730E-01	11	1	1	-1.000E+00
962420	Cm242	1.628E+02 d	0.000E+00	1.000E+00	12	1	2	-1.000E+00
992540	Es254	2.757E+02 d	0.000E+00	1.000E+00	4	1	0	-1.000E+00
992541	Es254m	3.930E+01 hr	0.000E+00	1.000E+00	0	1	0	-1.000E+00
1002540	Fm254	3.240E+00 hr	0.000E+00	1.000E+00	3	1	1	-1.000E+00
982540	Cf254	6.050E+01 d	0.000E+00	3.100E-03	0	1	0	-1.000E+00
962500	Cm250	9.000E+03 yr	0.000E+00	2.500E-01	2	1	1	-1.000E+00
972500	Bk250	3.217E+00 hr	0.000E+00	1.000E+00	0	1	5	-1.000E+00
982500	Cf250	1.308E+01 yr	0.000E+00	1.000E+00	2	1	6	-1.000E+00
942460	Pu246	1.084E+01 d	0.000E+00	1.000E+00	0	1	7	-1.000E+00
952460	Am246	3.900E+01 min	0.000E+00	1.000E+00	0	1	8	-1.000E+00
962460	Cm246	4.730E+03 yr	0.000E+00	9.997E-01	0	1	9	-1.000E+00
942420	Pu242	3.733E+05 yr	0.000E+00	1.000E+00	2	1	10	-1.000E+00
932380	Np238	2.117E+00 d	0.000E+00	1.000E+00	0	1	0	-1.000E+00
942380	Pu238	8.770E+01 yr	0.000E+00	1.000E+00	4	1	12	-1.000E+00
922380	U238	4.470E+09 yr	0.000E+00	1.000E+00	0	1	13	-1.000E+00
902340	Th234	2.410E+01 d	0.000E+00	9.980E-01	1	1	14	-1.000E+00
912340	Pa234	6.700E+00 hr	0.000E+00	1.000E+00	1	1	15	-1.000E+00
912341	Pa234m	1.170E+00 min	0.000E+00	9.987E-01	0	1	16	-1.000E+00
922340	U234	2.455E+05 yr	0.000E+00	1.000E+00	3	1	17	-1.000E+00
912300	Pa230	1.740E+01 d	0.000E+00	9.500E-02	0	1	18	-1.000E+00
922300	U230	2.080E+01 d	0.000E+00	1.000E+00	0	1	19	-1.000E+00
902260	Th226	3.057E+01 min	0.000E+00	1.000E+00	1	1	20	-1.000E+00
902300	Th230	7.538E+04 yr	0.000E+00	1.000E+00	0	1	21	-1.000E+00
882260	Ra226	1.600E+03 yr	0.000E+00	1.000E+00	0	1	22	-1.000E+00
862220	Rn222	3.823E+00 d	0.000E+00	1.000E+00	1	3	23	-1.000E+00
882220	Ra222	3.800E+01 s	0.000E+00	1.000E+00	4	1	24	-1.000E+00
842180	Po218	3.100E+00 min	0.000E+00	1.000E+00	0	1	25	-1.000E+00
822140	Pb214	2.680E+01 min	0.000E+00	1.000E+00	0	1	26	-1.000E+00
832140	Bi214	1.990E+01 min	0.000E+00	9.998E-01	1	1	27	-1.000E+00
862180	Rn218	3.500E-02 s	0.000E+00	1.000E+00	0	1	28	-1.000E+00
842140	Po214	1.643E-04 s	0.000E+00	1.000E+00	1	1	29	-1.000E+00
812100	Tl210	1.300E+00 min	0.000E+00	1.000E+00	0	1	30	-1.000E+00
822100	Pb210	2.230E+01 yr	0.000E+00	1.000E+00	0	1	31	-1.000E+00
832100	Bi210	5.013E+00 d	0.000E+00	1.000E+00	0	1	32	-1.000E+00
842100	Po210	1.384E+02 d	0.000E+00	1.000E+00	-1	1	33	-1.000E+00
992550	Es255	3.980E+01 d	0.000E+00	1.000E+00	0	1	0	-1.000E+00
1002550	Fm255	2.007E+01 hr	0.000E+00	1.000E+00	0	1	1	-1.000E+00

Radionuclide		Half-life	Yield	FRACT	IDATR	NGROUP	ISTART	XSECT
982510	Cf251	8.980E+02 yr	0.000E+00	1.000E+00	0	1	2	-1.000E+00
962470	Cm247	1.560E+07 yr	0.000E+00	1.000E+00	0	1	3	-1.000E+00
942430	Pu243	4.956E+00 hr	0.000E+00	1.000E+00	0	1	4	-1.000E+00
952430	Am243	7.370E+03 yr	0.000E+00	1.000E+00	1	1	5	-1.000E+00
922390	U239	2.354E+01 min	0.000E+00	1.000E+00	0	1	0	-1.000E+00
932390	Np239	2.356E+00 d	0.000E+00	1.000E+00	1	1	1	-1.000E+00
962430	Cm243	2.910E+01 yr	0.000E+00	9.980E-01	0	1	2	-1.000E+00
942390	Pu239	2.411E+04 yr	0.000E+00	1.000E+00	1	1	9	-1.000E+00
932350	Np235	3.961E+02 d	0.000E+00	9.999E-01	0	1	0	-1.000E+00
922350	U235	7.038E+08 yr	0.000E+00	1.000E+00	0	1	11	-1.000E+00
902310	Th231	2.552E+01 hr	0.000E+00	1.000E+00	1	1	12	-1.000E+00
922310	U231	4.200E+00 d	0.000E+00	1.000E+00	0	1	13	-1.000E+00
912310	Pa231	3.276E+04 yr	0.000E+00	1.000E+00	0	1	14	-1.000E+00
892270	Ac227	2.177E+01 yr	0.000E+00	9.862E-01	1	1	15	-1.000E+00
872230	Fr223	2.180E+00 min	0.000E+00	9.999E-01	1	1	16	-1.000E+00
902270	Th227	1.872E+01 d	0.000E+00	1.000E+00	0	1	17	-1.000E+00
882230	Ra223	1.144E+01 d	0.000E+00	1.000E+00	0	1	18	-1.000E+00
862190	Rn219	3.960E+00 s	0.000E+00	1.000E+00	0	3	19	-1.000E+00
842150	Po215	1.781E-03 s	0.000E+00	1.000E+00	0	1	20	-1.000E+00
822110	Pb211	3.610E+01 min	0.000E+00	1.000E+00	0	1	21	-1.000E+00
832110	Bi211	2.140E+00 min	0.000E+00	9.973E-01	3	1	22	-1.000E+00
852110	At211	7.214E+00 hr	0.000E+00	5.830E-01	1	2	0	-1.000E+00
832070	Bi207	3.155E+01 yr	0.000E+00	1.000E+00	-1	1	1	-1.000E+00
842110	Po211	5.160E-01 s	0.000E+00	1.000E+00	0	1	3	-1.000E+00
812070	Tl207	4.770E+00 min	0.000E+00	1.000E+00	-1	1	25	-1.000E+00

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	<i>A</i>	$\Delta T/\Delta z \leq -1.9$
Moderately unstable	<i>B</i>	$-1.9 < \Delta T/\Delta z \leq -1.7$
Slightly unstable	<i>C</i>	$-1.7 < \Delta T/\Delta z \leq -1.5$
Neutral	<i>D</i>	$-1.5 < \Delta T/\Delta z \leq -0.5$
Slightly stable	<i>E</i>	$-0.5 < \Delta T/\Delta z \leq 1.5$
Moderately stable	<i>F</i>	$1.5 < \Delta T/\Delta z \leq 4.0$
Extremely stable	<i>G</i>	$4.0 < \Delta T/\Delta z$

BY STANDARD DEVIATION OF HORIZONTAL WIND DIRECTION

Stability classification	Pasquill categories	σ_θ^a (deg)
Extremely unstable	<i>A</i>	$\sigma_\theta \geq 22.5$
Moderately unstable	<i>B</i>	$22.5 > \sigma_\theta \geq 17.5$
Slightly unstable	<i>C</i>	$17.5 > \sigma_\theta \geq 12.5$
Neutral	<i>D</i>	$12.5 > \sigma_\theta \geq 7.5$
Slightly stable	<i>E</i>	$7.5 > \sigma_\theta \geq 3.8$
Moderately stable	<i>F</i>	$3.8 > \sigma_\theta \geq 2.1$
Extremely stable	<i>G</i>	$2.1 > \sigma_\theta$

^aDetermined for a 15-min to 1-h period for horizontal diffusion.

Appendix D

Lung Clearance Classes

Appendix D

Lung Clearance Classes^a for Oxides or Hydroxides

Z	Element	Allowable Clearance Classes			Z	Element	Allowable Clearance Classes		
1	H ^b	H ₂	<u>HTO</u>		41	Nb		W	<u>Y</u>
4	Be			<u>Y</u>	42	Mo	D		<u>Y</u>
6	C ^b	CO	<u>ORG</u>	CO ₂	43	Tc	D	<u>W</u>	
9	F	<u>D</u>	W	Y	44	Ru	D	W	<u>Y</u>
11	Na	<u>D</u>			45	Rh	D	W	<u>Y</u>
12	Mg	D	<u>W</u>		46	Pd	D	W	<u>Y</u>
13	Al	D	<u>W</u>		47	Ag	D	W	<u>Y</u>
14	Si	D	<u>W</u>	Y	48	Cd	D	W	<u>Y</u>
15	P	D	<u>W</u>		49	In	D	<u>W</u>	
16	S	D	<u>W</u>	V ^c	50	Sn	D	<u>W</u>	
17	Cl	<u>D</u>	W	Y	51	Sb	D	<u>W</u>	
19	K	<u>D</u>			52	Te	D	<u>W</u>	
20	Ca		<u>W</u>		53	I	<u>D</u>		
21	Sc			<u>Y</u>	55	Cs	<u>D</u>		
22	Ti	D	<u>W</u>	Y	56	Ba	<u>D</u>		
23	V	D	<u>W</u>		57	La	D	<u>W</u>	
24	Cr	D	W	<u>Y</u>	58	Ce		W	<u>Y</u>
25	Mn	D	<u>W</u>		59	Pr		W	<u>Y</u>
26	Fe	D	<u>W</u>		60	Nd		W	<u>Y</u>
27	Co		W	<u>Y</u>	61	Pm		W	<u>Y</u>
28	Ni	D	<u>W</u>	V	62	Sm		<u>W</u>	
29	Cu	D	W	<u>Y</u>	63	Eu		<u>W</u>	
30	Zn			<u>Y</u>	64	Gd	D	<u>W</u>	
31	Ga	<u>D</u>			65	Tb		<u>W</u>	
32	Ge	D	<u>W</u>		66	Dy		<u>W</u>	
33	As		<u>W</u>		67	Ho		<u>W</u>	
34	Se	D	<u>W</u>		68	Er		<u>W</u>	
35	Br	<u>D</u>	W		69	Tm		<u>W</u>	
37	Rb	<u>D</u>			70	Yb		W	<u>Y</u>
38	Sr	<u>D</u>		Y	71	Lu		W	<u>Y</u>
39	Y		W	<u>Y</u>	72	Hf	D	<u>W</u>	
40	Zr	D	<u>W</u>	Y	73	Ta		W	<u>Y</u>

Lung Clearance Classes for Oxides or Hydroxides

Z	Element	Allowable Clearance Classes			Z	Element	Allowable Clearance Classes		
74	W	<u>D</u>			88	Ra	<u>W</u>		
75	Re	D	<u>W</u>		89	Ac	D	W	<u>Y</u>
76	Os	D	W	<u>Y</u>	90	Th		W	<u>Y</u>
77	Ir	D	W	<u>Y</u>	91	Pa		W	<u>Y</u>
78	Pt	<u>D</u>			92	U	D	W	<u>Y</u>
79	Au	D	W	<u>Y</u>	93	Np		<u>W</u>	
80	Hg	D	<u>W</u>	V	94	Pu		W	<u>Y</u>
81	Tl	<u>D</u>			95	Am		<u>W</u>	
82	Pb	<u>D</u>			96	Cm		<u>W</u>	
83	Bi	D	<u>W</u>		97	Bk		<u>W</u>	
84	Po	D	<u>W</u>		98	Cf		W	<u>Y</u>
85	At	D	<u>W</u>		99	Es		<u>W</u>	
87	Fr	<u>D</u>			100	Fm		<u>W</u>	

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.

Lung Clearance Classes for Maximum Element Dose

Z	Element	Allowable Clearance Classes			Z	Element	Allowable Clearance Classes		
1	H	H ₂	<u>HTO</u>		41	Nb		W	<u>Y</u>
4	Be				42	Mo	D		<u>Y</u>
6	C	CO	<u>ORG</u>	CO ₂	43	Tc	D	<u>W</u>	
9	F	<u>D</u>	W	Y	44	Ru	D	W	<u>Y</u>
11	Na	<u>D</u>			45	Rh	D	W	<u>Y</u>
12	Mg	D	<u>W</u>		46	Pd	D	W	<u>Y</u>
13	Al	<u>D</u>	W		47	Ag	D	W	<u>Y</u>
14	Si	D	W	<u>Y</u>	48	Cd	<u>D</u>	W	Y
15	P	D	<u>W</u>		49	In	<u>D</u>	W	
16	S	D	<u>W</u>	V ^c	50	Sn	D	<u>W</u>	
17	Cl	<u>D</u>	W	Y	51	Sb	<u>D</u>	W	
19	K	<u>D</u>			52	Te	D	<u>W</u>	
20	Ca		<u>W</u>		53	I	<u>D</u>		
21	Sc			<u>Y</u>	55	Cs	<u>D</u>		
22	Ti	D	W	<u>Y</u>	56	Ba	<u>D</u>		
23	V	D	<u>W</u>		57	La	D	<u>W</u>	
24	Cr	D	W	<u>Y</u>	58	Ce		W	<u>Y</u>
25	Mn	D	<u>W</u>		59	Pr		W	<u>Y</u>
26	Fe	<u>D</u>	W		60	Nd		W	<u>Y</u>
27	Co		W	<u>Y</u>	61	Pm		W	<u>Y</u>
28	Ni	D	<u>W</u>	V	62	Sm		<u>W</u>	
29	Cu	D	W	<u>Y</u>	63	Eu		<u>W</u>	
30	Zn			<u>Y</u>	64	Gd	<u>D</u>	W	
31	Ga	<u>D</u>			65	Tb		<u>W</u>	
32	Ge	<u>D</u>	W		66	Dy		<u>W</u>	
33	As		<u>W</u>		67	Ho		<u>W</u>	
34	Se	D	<u>W</u>		68	Er		<u>W</u>	
35	Br	<u>D</u>	W		69	Tm		<u>W</u>	
37	Rb	<u>D</u>			70	Yb		W	<u>Y</u>
38	Sr	D		<u>Y</u>	71	Lu		W	<u>Y</u>
39	Y		W	<u>Y</u>	72	Hf	<u>D</u>	W	
40	Zr	<u>D</u>	W	Y	73	Ta		W	<u>Y</u>

Lung Clearance Classes for Maximum Element Dose

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75	Re	D	<u>W</u>		89	Ac	<u>D</u>	W	Y
76	Os	D	W	<u>Y</u>	90	Th		<u>W</u>	Y
77	Ir	D	W	<u>Y</u>	91	Pa		W	<u>Y</u>
78	Pt	<u>D</u>			92	U	D	W	<u>Y</u>
79	Au	<u>D</u>	W	Y	93	Np		<u>W</u>	
80	Hg	D	<u>W</u>	V	94	Pu		<u>W</u>	Y
81	Tl	<u>D</u>			95	Am		<u>W</u>	
82	Pb	<u>D</u>			96	Cm		<u>W</u>	
83	Bi	D	<u>W</u>		97	Bk		<u>W</u>	
84	Po	<u>D</u>	W		98	Cf		W	<u>Y</u>
85	At	<u>D</u>	W		99	Es		<u>W</u>	
87	Fr	<u>D</u>			100	Fm		<u>W</u>	