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Incorporating Uncertainty in RADTRAN 6.0 Input Files

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ABSTRACT

This document provides a detailed discussion and guide for the use of the RADTRAN Uncertainty Analysis Module. As of this writing, the RADTRAN version in use is RADTRAN 6.0.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the contributions of Danielle Worthy, and Adam Boyd, in testing the RADTRAN Uncertainty Analysis Module. They would also like to acknowledge the management support of David Miller, as well as the management support of the Offices of Environmental Management and Civilian Radioactive Waste Management of the U. S. Department of Energy.

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1.0 Introduction

Uncertainty may be introduced into RADTRAN analyses by distributing input parameters. The MELCOR Uncertainty Engine (Gauntt and Erickson, 2004) has been adapted for use in RADTRAN to determine the parameter shape and minimum and maximum of the distribution, to sample on the distribution, and to create an appropriate RADTRAN batch file. Coupling input parameters is not possible in this initial application. It is recommended that the analyst be very familiar with RADTRAN and able to edit or create a RADTRAN input file using a text editor before implementing the RADTRAN Uncertainty Analysis Module.

Installation of the MELCOR Uncertainty Engine is required for incorporation of uncertainty into RADTRAN. The instructions and installation program are available from Ruth Weiner (rfweine@sandia.gov) or Matthew Dennis **(**mldenni@sandia.gov). Gauntt and Erickson (2004) provides installation instructions as well as a description and user guide for the uncertainty engine.

2.0 The MELCOR Uncertainty Engine

The RADTRAN Uncertainty Analysis Module and subsequent updates can be obtained by visiting https://radtran.sandia.gov/radcat/. Only registered RADTRAN/RADCAT users will be able to download the installer. After clicking on the "Download RADTRAN Uncertainty Analysis Module" link, you must input your username and password. After downloading the zip file, the uncertainty module installer (*RADTRAN6Uncertainty_Ver1*) can be extracted and installed on your system.

The MELCOR Uncertainty Engine will be installed to the desktop and start menu as *VBUncertainty.exe*, as well as the user guide and necessary "Distribution 6.0" file folder.

3.0 Generating an Input File for RADTRAN with the MELCOR Uncertainty Engine

Select an existing RADTRAN 6.0 file or create a new file. New files must be created as text files using a text editor instead of the RADCAT input file generator. A reference sheet is provided in Appendix A of the *RADCAT User Guide* (SAND2006-1965) as well as in Appendix B of this document. Save the text input with a **.unc* file extension in place of the normal **.rml* extension used in RADCAT or **.in5* (**.input* for RADTRAN 6.0) extension in RADTRAN. For example, the RADTRAN input file could appear as *test.unc*. Correspondingly, if you are using an existing RADTRAN input file, save a

copy (or rename the original) with the *.*unc* extension. This file designation allows the MELCOR Uncertainty Engine to recognize the file and read the input.

3.1 Populating the "Distribution 6.0" File Folder

The "Distribution" file folder installed to the desktop should be populated with the necessary RADTRAN files; however, this and proceeding sections explain how to create or replace the necessary information if needed. First, create and name a new file folder on the desktop or other preferred location. For the example presented here, the file folder is created on the desktop and named "Distribution 6.0." Open the folder and copy to it the RADTRAN executable, "rt6.exe" along with "RT6_Ingestion.BIN," "RT6_Defaults.INFILE," "RT6_Isotope.INFILE," and "RT6_Standard.INFILE." Then, pull down the "File" menu on the Standard tool bar, select "New", then select "Folder." Click on the newly created folder and rename it; in this example the new folder is named "rain." The previously mentioned RADTRAN files will require no further modification. Figure 1 shows what items should be included in the "Distribution 6.0" folder.

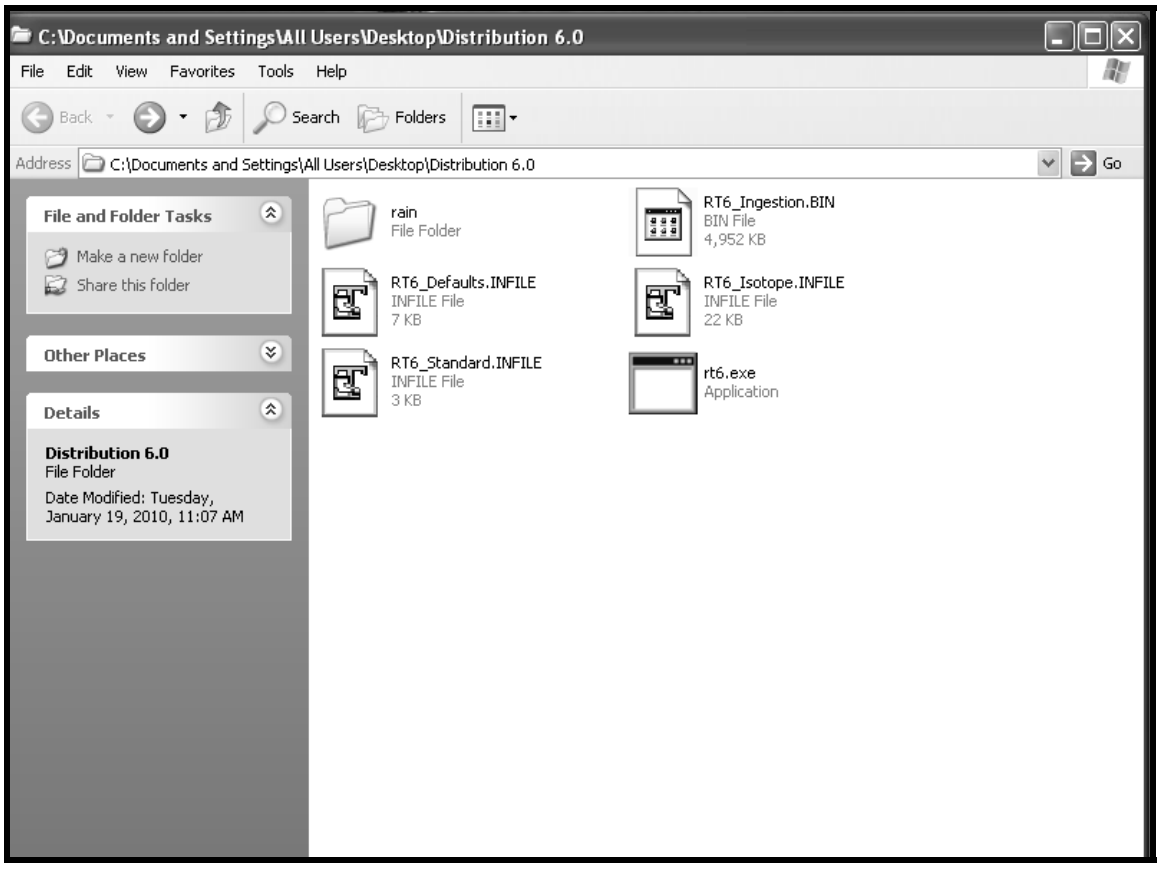

Figure 1. The "Distribution 6.0" File Folder Contents.

3.2 Creating the RADTRAN Uncertainty Analysis Module Input File

As previously stated, the input file with extension **.unc* must be created using a text editor. The following instructions will use an existing RADTRAN input file as an example; however, you will need to either use your own existing RADTRAN file or generate a new one. An example of a completed input code can be found in Appendix A of this document, and should be consulted when following these instructions.

Open the input file containing the standard RADTRAN input, named *test.unc* in the example case, with any text editor such as *WordPad*. Next, insert the following text string at the very beginning of your **.unc* file, before any remarks and before "RADTRAN 6" in the standard RADTRAN 6.0 input file (this would be before the TITLE command in versions 5.6 and earlier).

```
*eor* melgen
*r*i*f  gen_files\AP1000-3BE.gen
*r*i*f  Gen_Files\RN_Output.gen
*allowreplace
*
***Comments on mandatory definition section
* Variable definitions (%DEF%) are mandatory.
* Use one-word variable names. Spaces are allowed in the description.
* Other optional specifications:
*    Title string
*    Sample size between 5 and 500.
*    Base file and folder name, default 'Run'.
*    Initial distribution and inputs for a variable.
*
* The order of initial values required for each distribution type is:
*          %INIT%varname=BETA, p, q, xlow, xhigh
*          %INIT%varname=NORMAL1, mean, sd
*          %INIT%varname=NORMAL2, x05, x95
*          %INIT%varname=LOGNORMAL, mean, geo_sd
*          %INIT%varname=LOGUNIFORM, xlow, xhigh
*          %INIT%varname=TRIANGLE, xlow, xmidpt, xhigh
*          %INIT%varname=UNIFORM, xlow, xhigh
*
***Begin mandatory definition section
*%TITLE%RADTRAN_Distribution
*%DIRNAME%Case
*%DEF%PACKAGE=Package dose at 1 meter (mrem/hr)
*%DEF%VEHICLE=Vehicle dose at 1 meter (mrem/hr)
*%DEF%STOP=Stop time (hr)
*%DEF%PEOPLE=Number of people or people/km^2 at stop
*%DEF%SPEED=Vehicle speed (km/hr)
*%DEF%CURIE=Isotopic curie content (Ci)
*%DEF%WIND=Wind speed (m/s)
*%DEF%DEPOSITION=Deposition velocity (m/s)
*%DEF%EVACUATION=Evacuation time for groundshine (days)
*%SIZE%NSAMPLE=50
*%INIT%PACKAGE= NORMAL1,10,2
*%INIT%VEHICLE= NORMAL1,10,2
```

```
*%INIT%STOP=NORMAL1,10,2
*%INIT%PEOPLE=NORMAL1,10,2
*%INIT%SPEED=NORMAL1,10,2
*%INIT%CURIE=NORMAL1,10,2
*%INIT%WIND=NORMAL1,10,2
*%INIT%DEPOSITION=NORMAL1,10,2
*%INIT%EVACUATION=NORMAL1,10,2
***End mandatory definition section
```

You can copy the above text string into your **.unc* file which provides a default set of distributed RADTRAN input parameters. You can also define any additional variables that you would like to distribute in the "Begin mandatory definition section."

This example has defaulted the distributed variables to a normal distribution with the standard deviation equal to 2 and the mean equal to 10. The initial sample size is 50 as indicate by "`%SIZE%NSAMPLE=50`" above. These settings can be modified later with more appropriate defaults; however, the user can change the distribution parameters when the MELCOR Uncertainty Software is implemented.

Once the text string is inserted, the RADTRAN code following the string must be modified to allow for the distributed variables, as follows: Each defined variable (i.e. PACKAGE, VEHICLE, STOP, etc.) must be declared in the RADTRAN file in the same place where a numerical value would otherwise be entered. This is done by replacing the usual numerical value with **%#*VARIABLE_NAME*#%** where ***VARIABLE_NAME*** is replaced with the appropriate previously defined variable (i.e. %#PACKAGE#%, %#VEHICLE%#, %#STOP#%, etc.).

If more than one link, vehicle, package, or any variable is specified, and different distributions are desired for each, a separate variable declaration will need to be inserted; e.g., %#SPEED1#%, %#SPEED2#%, etc. for different vehicle speeds, %#CURIES1#%, %#CURIES2#%, etc for the curie content of each radionuclide, and so on. The variable name need not be %#SPEED1#%, %#SPEED2#%, etc, but could be %#SPEEDR#%, %#SPEEDS#%, etc. If the same declared variable name is used for each speed, for example, then the uncertainty engine will generate a number each iteration and place it in that particular variable slot.

4.0 Running the MELCOR Uncertainty Engine

Since you have now created a **.unc* input file containing all the necessary information for the RADTRAN Uncertainty Analysis Module, this file needs to be placed in the previously created *rain* file folder. Therefore, for our example, the *test.unc* file is placed in the *rain* folder. Proceed to START, then to PROGRAMS, then to RADTRAN Uncertainty Analysis and open the uncertainty program.

The software automatically opens the "open template file" window. From here, navigate to wherever the *rain* file folder is and open the *test.unc* text file, or whatever you have

named it. At this point, first determine how many sample points you would like to have, between 5 and 500, by using the arrow keys in the left-hand panel. Next, you **must** click on each variable. The type of distribution and parameters can be changed for each variable as you click on it. After all have been viewed, you can click on "write # case files". The selected number of case files, between 5 and 500, will be generated in the *rain* file folder. You will also have a file titled "CaseVarSamples.csv" in the *rain* file folder. This **.csv* file can be opened in Excel and provides you with a list of all the distributed input variables (speed, curie, etc.) for each RADTRAN sample run. Figure 2 shows an example of a populated *rain* file folder after running the uncertainty software for 50 case files.

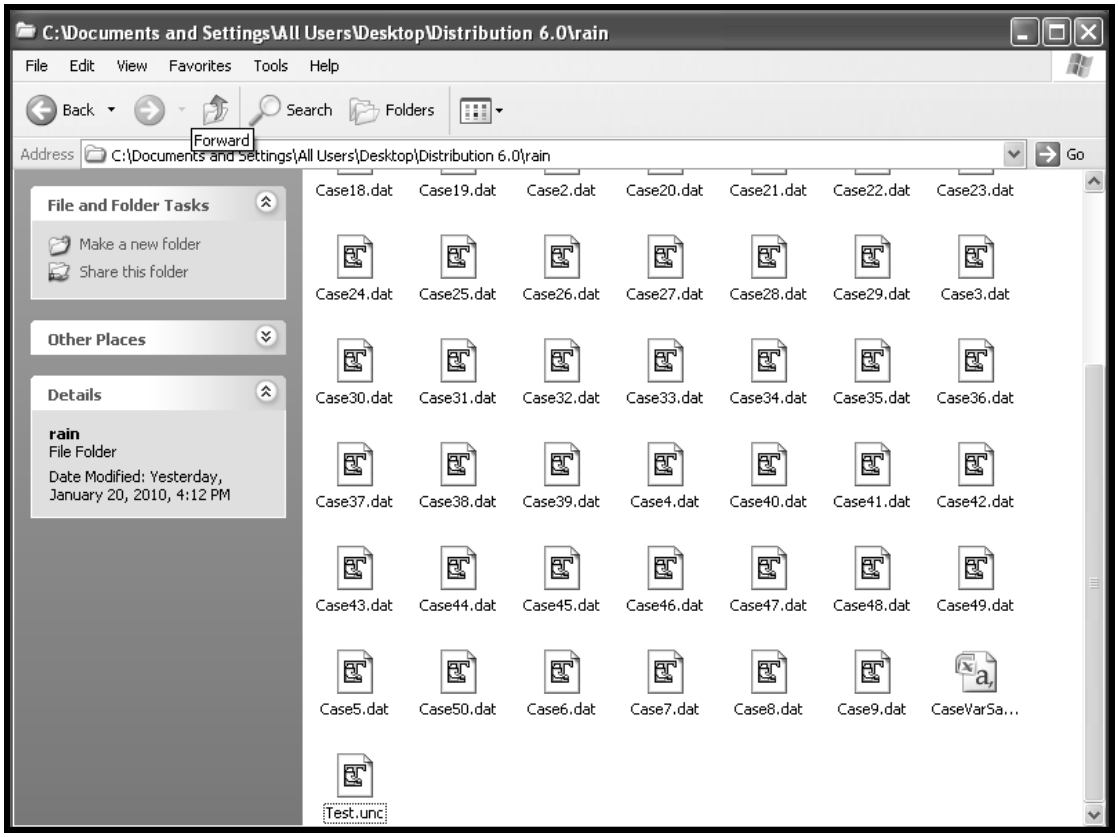

Figure 2. The Populated *rain* File Folder.

5.0 OPTIONAL: Creating the Batch File to Iterate RADTRAN Using Uncertainty Software Generated Cases

A batch file to iterate RADTRAN, entitled *test.bat*, is **already installed** in the "Distribution" file folder on the desktop. Double-clicking this batch file will run the RADTRAN Uncertainty Analysis Module. However, should the user wish to alter the batch file, this section provides instruction. The batch file is created by using an available text editor such as *WordPad* and renaming the file as "*.bat". The following command strings should be typed in the file:

```
type rain\headings.csv > all.txt
rt6 /b rain\case1.dat rain\out1.dat rain\out_monte1.csv type rain\out_monte1.csv >> all.txt
```

The *rain* in the previous text string can be changed based on the user, but it must match the named folder in the *"Distribution"* file folder created in Section 3.1. The second command line should be duplicated for n-cases, where n = the number of case files created using the uncertainty software, with the number changed in each line to correspond to 1, 2, 3… and so on. Below is an example of the text input in the sample *test.bat* file.

```
type rain\headings.csv > all.txt
rt6 /b rain\case1.dat rain\out1.dat rain\out_monte1.csv type rain\out_monte1.csv >> all.txt
rt6 /b rain\case2.dat rain\out2.dat rain\out_monte2.csv type rain\out_monte2.csv >> all.txt
rt6 /b rain\case3.dat rain\out3.dat rain\out_monte3.csv type rain\out_monte3.csv >> all.txt
rt6 /b rain\case4.dat rain\out4.dat rain\out_monte4.csv type rain\out_monte4.csv >> all.txt
rt6 /b rain\case5.dat rain\out5.dat rain\out_monte5.csv type rain\out_monte5.csv >> all.txt
rt6 /b rain\case6.dat rain\out6.dat rain\out_monte6.csv type rain\out_monte6.csv >> all.txt
rt6 /b rain\case7.dat rain\out7.dat rain\out_monte7.csv type rain\out_monte7.csv >> all.txt
rt6 /b rain\case8.dat rain\out8.dat rain\out_monte8.csv type rain\out_monte8.csv >> all.txt
rt6 /b rain\case9.dat rain\out9.dat rain\out_monte9.csv type rain\out_monte9.csv >> all.txt
rt6 /b rain\case10.dat rain\out10.dat rain\out_monte10.csv type rain\out_monte10.csv >> all.txt
…….. and so on for up to 500 cases
```

This *test.bat* file **must** be placed in the folder originally created on the desktop entitled "Distribution 6.0." Figure 3 shows the final "Distribution 6.0" folder contents.

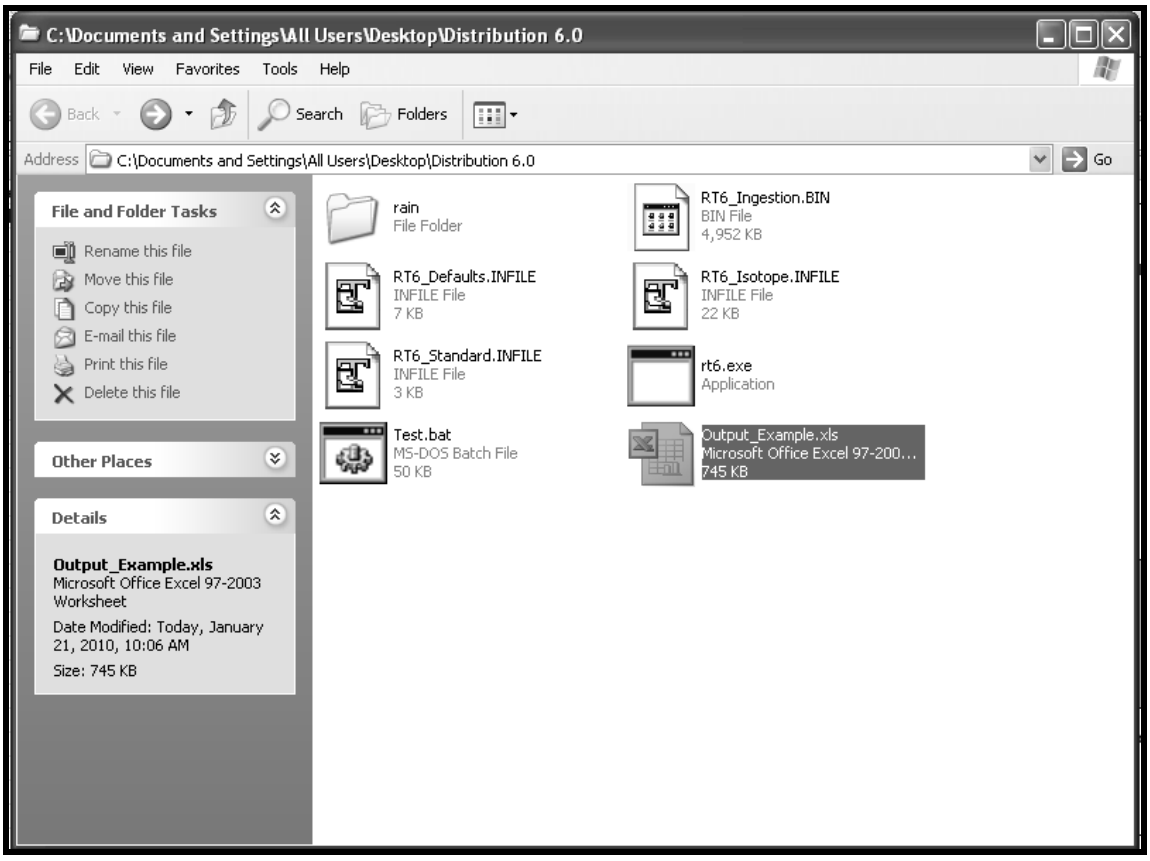

Figure 3. The "Distribution 6.0" Folder with All Necessary Files.

The final step is to double-click on the *test.bat* file and run the case files through RADTRAN. Please note, this will take appreciably longer to run than a standard RADTRAN/RADCAT file. The more iterations, the larger the sample points on the distribution, the longer it takes to run.

Once you create a batch file you can use it for another run provided the folder and file names you use are the same.

> HELPFUL HINT: If you create a batch file for more runs than you wish to make, the program will scroll through the unused runs. It may be convenient just to create a batch file for 500 runs and use that each time you analyze distributed variables.

6.0 Location and Type of Outputs

After the batch file is run, the outputs are placed in the *rain* folder. Opening the folder shows a corresponding number of *out#.dat* files and *out_monte#.csv* files. For instance, if there were 50 case files, there will be 50 RADTRAN output files and 50 Excel spreadsheets.

Each *out#.dat* file corresponds to a standard RADTRAN output file. From this file, the distributed outputs were selected and listed in the corresponding Excel spreadsheet which are collected and converted into a summary text file called *all.txt* and is located in the "Distribution" folder. The 15 numbers that are present correspond to the following list:

1. Crew In-Transit Population Exposure
2. Off-Link In-Transit Population Exposure
3. On-Link In-Transit Population Exposure
4. Maximum Individual In-Transit Dose
5. Stop Exposure
6. Handling Exposure

<u>Expected Values of Population Risk</u>

7. Total Groundshine
8. Total Inhalation
9. Total Resuspension
10. Total Cloudshine
11. Total Population Risk

<u>Societal Ingestion Risk</u>

12. Red Marrow
13. Thyroid
14. Effective

15. Undefined for Future Use

When the uncertainty software is installed, a file entitled *Output_Example.xls* is included in the "Distribution 6.0" folder. Open *all.txt*, select "Edit" from the toolbar, choose "Select All" (ctrl+A), and finally copy all. Navigate back to the "Distribution 6.0" folder and open the *Output_Example.xls* spreadsheet. The copied values from *all.txt* can be pasted into cell A3, converted from text to columns, and the remaining spreadsheet tabs will be populated with probability distribution functions and cumulative distribution functions for the 15 RADTRAN outputs listed above. Currently, the previously mentioned distributed outputs are hard-wired into the RADTRAN Uncertainty Analysis Module for automatic selection and cannot be altered by the user.

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Appendix A

Sample RADTRAN 6.0 Uncertainty Analysis

Module Input Deck

```
*eor* melgen
*r*i*f  gen_files\AP1000-3BE.gen
*r*i*f  Gen_Files\RN_Output.gen
*allowreplace
*
***Comments on mandatory definition section
* Variable definitions (%DEF%) are mandatory.
* Use one-word variable names. Spaces are allowed in the description.
* Other optional specifications:
*    Title string
*    Sample size between 5 and 500.
*    Base file and folder name, default 'Run'.
*    Initial distribution and inputs for a variable.
*
* The order of initial values required for each distribution type is:
*          %INIT%varname=BETA, p, q, xlow, xhigh
*          %INIT%varname=NORMAL1, mean, sd
*          %INIT%varname=NORMAL2, x05, x95
*          %INIT%varname=LOGNORMAL, mean, geo_sd
*          %INIT%varname=LOGUNIFORM, xlow, xhigh
*          %INIT%varname=TRIANGLE, xlow, xmidpt, xhigh
*          %INIT%varname=UNIFORM, xlow, xhigh
*
***Begin mandatory definition section
*%TITLE%RADTRAN_Distribution
*%DIRNAME%Case
*%DEF%STOP1=Rural stop time (hr)
*%DEF%STOP2=Suburban stop time (hr)
*%DEF%STOP3=Urban stop time (hr)
*%DEF%CURIE1=Co60 curie content (Ci)
*%DEF%CURIE2=Ni63 curie content (Ci)
*%DEF%CURIE3=Sr90 and Y90 curie content (Ci)
*%DEF%CURIE4=Tc99 curie content (Ci)
*%DEF%CURIE5=I129 curie content (Ci)
*%DEF%CURIE6=Cs134 curie content (Ci)
*%DEF%CURIE7=Cs137 curie content (Ci)
*%DEF%CURIE8=U234 curie content (Ci)
*%DEF%CURIE9=U235 curie content (Ci)
*%DEF%CURIE10=U238 curie content (Ci)
*%DEF%CURIE11=Np237 curie content (Ci)
*%DEF%CURIE12=Pu238 curie content (Ci)
*%DEF%CURIE13=Pu239 curie Content (Ci)
*%DEF%CURIE14=Pu240 curie Content (Ci)
*%DEF%CURIE15=Am241 curie Content (Ci)
*%DEF%CURIE16=Am243 curie Content (Ci)
*%DEF%CURIE17=Cm243 curie Content (Ci)
*%DEF%CURIE18=Cm244 curie Content (Ci)
```

```
*%DEF%DEP1=Particulate deposition velocity (m/s)
*%DEF%DEP2=Cesium deposition velocity (m/s)
*%DEF%DEP3=Ruthenium deposition velocity (m/s)
*%DEF%DEP4=CRUD Deposition velocity (m/s)
*%DEF%EVACUATION=Evacuation time (days)
*%DEF%ACCRATE=Accident Rate (accidents/km)
*
*%SIZE%NSAMPLE=50
*%INIT%STOP1=BETA,2,4.5,0,1
*%INIT%STOP2=BETA,2,4.5,0,1
*%INIT%STOP3=BETA,2,4.5,0,1
*%INIT%CURIE1=BETA,20,8.2,6600,170448
*%INIT%CURIE2=BETA,16,9.5,0,16680
*%INIT%CURIE3=BETA,20,9,629520,2420904
*%INIT%CURIE4=BETA,20,9,81.6,508.8
*%INIT%CURIE5=BETA,18,11,0,1.44
*%INIT%CURIE6=BETA,14.5,12,0,1807704
*%INIT%CURIE7=BETA,27.5,13,130200,3840000
*%INIT%CURIE8=BETA,1,6,0,6.48
*%INIT%CURIE9=BETA,25,15,22.8,24
*%INIT%CURIE10=BETA,100,100,16.08,16.8
*%INIT%CURIE11=BETA,25,16.8,0,24
*%INIT%CURIE12=BETA,9.5,12,0,241128
*%INIT%CURIE13=BETA,26,11,4368,11472
*%INIT%CURIE14=BETA,25,14,0,22320
*%INIT%CURIE15=BETA,22,4.5,0,37248
*%INIT%CURIE16=BETA,8.2,11,0,1704
*%INIT%CURIE17=BETA,8.5,11,0,1776
*%INIT%CURIE18=BETA,4,8,0,331440
*%INIT%DEP1=BETA,4.1,8.9,0,0.008505
*%INIT%DEP2=BETA,4.1,8.9,0,0.008505
*%INIT%DEP3=BETA,4.1,8.9,0,0.008505
*%INIT%DEP4=BETA,4.1,8.9,0,0.008505
*%INIT%EVACUATION=BETA,2,6,0,24
*%INIT%ACCRATE=BETA,2,6,0,0.0000008
***end mandatory definition section

**********************************************************************
RADTRAN 6
&& PWR Spent Fuel Assembly, 3-year Cooled, 24 Assemblies
&& Use National Weather Average
&& INTERDICT set to 4.00E+10
&& Yucca Mtn FEIS Severity and Release Fracs for S-Pb-S PWR Rail Cask
TITLE PWR SNF Rail Shipment
INPUT STANDARD
FORM UNIT
DIMEN 6 10 18
PARM 0 3 4 0
SEVERITY
   NPOP=1
     NMODE=2
       0.99991 3.87E-05 4.91E-05 5.77E-07 1.10E-07 8.52E-10
   NPOP=2
     NMODE=2
       0.99991 3.87E-05 4.91E-05 5.77E-07 1.10E-07 8.52E-10
   NPOP=3
     NMODE=2
```

```
        0.99991 3.87E-05 4.91E-05 5.77E-07 1.10E-07 8.52E-10


RELEASE
   GROUP=PARTS
      RFRAC
       0.00E+00  1.37E-07  2.52E-07  1.32E-05  1.37E-05  1.43E-05
      AERSOL
       1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
      RESP
       1.00E-01  1.00E-01  1.00E-01  1.00E-01  1.00E-01  1.00E-01
      DEPVEL   %#DEP1#%

   GROUP=CESIUM
      RFRAC
       0.00E+00  5.87E-09  1.68E-05  8.71E-06  3.60E-05  5.71E-05
      AERSOL
       1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
      RESP
       1.00E+00  1.00E-01  1.00E-01  1.00E-01  1.00E-01  1.00E-01
      DEPVEL   %#DEP2#%

   GROUP=RUTH
      RFRAC
       0.00E+00  1.34E-07  2.52E-07  1.32E-05  1.37E-05  4.63E-05
      AERSOL
       1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
      RESP
       1.00E-01  1.00E-01  1.00E-01  1.00E-01  1.00E-01  1.00E-01
      DEPVEL   %#DEP3#%

   GROUP=CRUD
      RFRAC
       0.00E+00  1.37E-03  9.44E-03  4.42E-03  5.36E-03  1.59E-02
      AERSOL
       1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
      RESP
       1.00E-01  1.00E-01  1.00E-01  1.00E-01  1.00E-01  1.00E-01
      DEPVEL   %#DEP4#%

   GROUP=GAS
      RFRAC
       0.00E+00  1.96E-01  8.39E-01  8.00E-01  8.35E-01  8.47E-01
      AERSOL
       1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
      RESP
       1.00E-01  1.00E-01  1.00E-01  1.00E-01  1.00E-01  1.00E-01
      DEPVEL   0.0000

PACKAGE SFUEL  14.0 1.000 0.000  5.20

        CO60        %#CURIE1#%  CRUD
        NI63        %#CURIE2#%  PARTS
        SR90        %#CURIE3#%  PARTS
         Y90        %#CURIE3#%  PARTS
        TC99        %#CURIE4#%  PARTS
        I129        %#CURIE5#%  GAS
```

```
        CS134       %#CURIE6#%  CESIUM
        CS137       %#CURIE7#%  CESIUM
        U234        %#CURIE8#%  PARTS
        U235        %#CURIE9#%  PARTS
        U238        %#CURIE10#% PARTS
        NP237       %#CURIE11#% PARTS
        PU238       %#CURIE12#% PARTS
        PU239       %#CURIE13#% PARTS
        PU240       %#CURIE14#% PARTS
        AM241       %#CURIE15#% PARTS
        AM243       %#CURIE16#% PARTS
        CM243       %#CURIE17#% PARTS
        CM244       %#CURIE18#% PARTS
        EU154       2.021E+05   PARTS
        PM147       6.192E+05   PARTS
        CM242       9.024E+03   PARTS
        AM242M      3.192E+02   PARTS
        CE144       9.288E+05   PARTS
        RU106       1.063E+06   RUTH
        PU241       1.565E+06   PARTS
        KR85        1.409E+05   GAS
        END


VEHICLE  -2 Rail  14.0  1.00  0.00  5.20   1.00
                       2.00  0.74  1.00   2.00
          SFUEL        1.00

 FLAGS
    IACC     2
    ITRAIN   2
    IUOPT    2
    REGCHECK 0

 MODSTD
    DDRWEF     1.80E-03
    FMINCL     2.00E+00
    DISTOFF RAIL 3.00E+01 3.00E+01 8.00E+02
    DISTON
      RAIL     3.00E+00
   BDF         5.00E-02
   BRATE       3.30E-04
   CULVL       2.00E-01
   EVACUATION  %#EVACUATION#%
   GECON       1.00E-04
   INTERDICT   4.00E+10
   LCFCON      5.00E-04  4.00E-04
   SURVEY      1.00E+01
   UBF         5.20E-01
   USWF        1.00E-01
   CAMPAIGN    8.33E-02
   MITDDIST    3.00E+01
   MITDVEL     2.40E+01
   RPD         6.00E+00
   RR          1.00E+00
   RU          1.80E-02
   RS          8.70E-01
```

```
   SMALLPKG    5.00E-01
   RPCTHYROID
      I129   5.77E+06
EOF

LINK Rural    Rail 3401.9 88.5 3.0    7.9 1.0 %#ACCRATE#% 1.00 R 1 0.50
LINK Suburbn  Rail  669.2 56.3 3.0  402.0 5.0 %#ACCRATE#% 1.00 S 1 0.00
LINK Urban    Rail  172.9 40.2 3.0 2380.2 5.0 %#ACCRATE#% 1.00 U 1 0.00

STOP Public_Rural      Rail     7.9  30.0   800.0  1.00  %#STOP1#%
STOP Public_Suburbn    Rail   402.0  30.0   800.0  1.00  %#STOP2#%
STOP Public_Urban      Rail  2380.2  30.0   800.0  1.00  %#STOP3#%

EOF
EOI
```

Appendix B

Creating a RADTRAN Input File With a Text Editor

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B.1 Input Keywords

Throughout this document historical units (rem, curie, etc) are used, because that is how RADTRAN is programmed. RADTRAN input must use historical units (curies, rem, etc.); RADTRAN output can be either historical or SI units, depending on the analyst's choice. If you need to convert from the source data:

1 curie (Ci) = 3.7 x 10^{10} becquerel (Bq)
1 rad = 0.01 gray (Gy)
1 rem = 0.01 sievert (Sv)

A RADTRAN input file can be created as an ordinary text file, using Microsoft™ WordPad or Notepad. Text entry in RADTRAN is in free format and is keyword-based. The keyword-based system allows most of the data to be entered with any number of intervening spaces or carriage returns. Keywords and data can appear anywhere in an 80-character line. The file should be named *filename*.unc, if it is to be used in the uncertainty program; *filename*.dat if it is to be imported into RADCAT.

A RADTRAN input file is an ASCII text file that consists of keywords, numbers, and alphanumeric labels of ten characters or less which are separated by one or more of the following delimiters: a blank space, comma, equal sign, or right and left parentheses. Keywords, numbers, or labels may appear anywhere in the 80-character line, but may not be split and continued on the next line. They must not contain embedded blanks, commas, equal signs, or parentheses. A master list is shown in Table B-1.

Figure B-1 shows a sample RADTRAN input file.

```
&& EDITIED JULY 14, 2005 12:02
TITLE LOSS OF SHIELDING
INPUT STANDARD
FORM UNIT
 DIMEN 6 4 18
 PARM  3 3 1
 SEVERITY
    NPOP=1
      NMODE=1
        1.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    NPOP=2
      NMODE=1
        1.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    NPOP=3
      NMODE=1
        1.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
 RELEASE
    GROUP=GRP1_B
       RFRAC
        1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
       AERSOL
        1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
       RESP
        1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
       DEPVEL 0.010000
    GROUP=CO
       RFRAC
        0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
       AERSOL
        0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
       RESP
         0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
       DEPVEL 0.000000
 PSPROB
    0.00E+00  0.00E+00  0.00E+00  1.00E+00  0.00E+00  0.00E+00
 LOS_SHIELD
      NPOP=1
        ACIDNT_PRB 1.71E-06  4.63E-07  3.21E-08  2.53E-10  2.20E-05
        FRAC_LOST  0.052     0.158     0.264     0.368     0.033
      NPOP=2
        ACIDNT_PRB 1.71E-06  4.63E-07  3.21E-08  2.53E-10  2.20E-05
        FRAC_LOST  0.052     0.158     0.264     0.368     0.033
      NPOP=3
        ACIDNT_PRB 1.71E-06  4.63E-07  3.21E-08  2.53E-10  2.20E-05
        FRAC_LOST  0.052     0.158     0.264     0.368     0.033
 DEFINE CS-137
        1.10E+04  3.00E-04  2.86E-05  9.12E-08  3.19E+04  0.00E+00
        0.00E+00  0.00E+00
        NONE
 PACKAGE  PKG_1  4.590E+00 1.000 0.000  4.25
            CO60        4.000E+06 CO
            CS-137      1.000E+01 GRP1_B
          END
 VEHICLE  -1 VEH1  4.592E+00 1.00  0.00  0.25  1.00
                             1.00  1.00  0.00  0.25
                   PKG_1  1.00
 MODSTD
    CULVL 1.000E+10
 FLAGS
    IUOPT 2
EOF
  LINK TRACK3     VEH1   15.99   88.0   2.0  11.30  352.0 2.74E-07 1.20 R 1 0.50
  STOP STOP1      VEH1    1.00   1.00   2.0   1.00   1.00
  LOS_STOP LOSC   VEH1    2.00   3.00  10.0   1.00   2.00
EOF
EOI
```

Figure B-1: Sample RADTRAN Input File.

Table B-1: Master List of RADTRAN 5.6 and RADTRAN 6 Keywords.

FIRST LEVEL	SECOND LEVEL	THIRD LEVEL	DESCRIPTION
RADTRAN 6 **(RADTRAN 6 ONLY)**	----	----	Keyword prior to TITLE
TITLE	----	----	User-defined alphanumeric title
INPUT	STANDARD	----	User elects whether to use standard input values or not
DIMEN	----	----	Enter three (3) values: NSEV, the number of severity categories, NRADIAL (=10) and NISOPLETH, the number of isopleths
PARM	---	----	Sets four (4) flags
FORM	UNIT or NONUNIT	----	Output format: dose (UNIT) or health effects (NONUNIT)
SEVERITY	NPOP	NMODE	Enter probabilities for NSEV severity categories for NPOP =1 (rural), 2 (suburban), and 3 (urban) . NMODE=1 (highway), 2 (rail), 3 (water)
RELEASE	GROUP	RFRAC	Release fraction for each physical/chemical group
	---	AERSOL	Fraction of release that is aerosol, for each physical/chemical group
	---	RESP	Fraction of aerosol that is respirable for each physical/chemical group
	---	DEPVEL	Deposition velocity for each physical/chemical group
	CLINE	----	Centerline downwind distance (m)
	AREADA	----	Isopleth area (m^2) for n areas
	DFLEV	----	Time-integrated concentrations (dilution factors for n areas (Ci-sec/m^2)
	PSPROB	----	Pasquill probabilities (6 values)
	ISOPLETHP	----	Populations of NISOPLETH isopleths; see DIMEN)
RISKIND			User-defined atmospheric dispersion model: enter release height, heat release, cask length, cask radius, wind speed, anemometer height, ambient temperature, atmospheric mixing height, rainfall rate, flag for dispersion model, numeric 1-6 for stability category, R or U for release location
LOS_SHIELD; **(RADTRAN 6 ONLY)**	NPOP		NPOP=1,2,3 as for SEVERITY
	ACIDNT_PROB		Conditional probability (severity fraction) of each type of loss-of-lead-shielding accident
	FRAC_LOST		Fraction of lead gamma shield lost

FIRST LEVEL	SECOND LEVEL	THIRD LEVEL	DESCRIPTION
DEFINE	----	----	Radionuclide name followed by 10 values (half-life, dose conversion factors)
TRANSFER	GAMMA NEUTRON	----	Coefficients for gamma radiation Coefficients for neutron radiation
PACKAGE	[END]	-----	Enter package name, dose rate at 1 m., gamma fraction, neutron fraction, critical dimension for each package type followed by radionuclide contents followed by END
VEHICLE	----	----	Enter vehicle name, dose rate at 1 m., gamma fraction, neutron fraction, critical dimension, distance to crew, number of shipments, number of crew, crew view, crew shielding factor for each vehicle type followed by the package(s) on the vehicle
MODSTD	SMALLPKG	----	Size of smallest package for nondispersal analysis
	UBF	----	Urban Building Fraction
	USWF	----	Urban Sidewalk Fraction
	EVACUATION	----	Evacuation time (days)
	SURVEY	----	Survey interval (days)
	INTERDICT	----	Interdiction threshold
	DISTOFF	FREEWAY	Enter perpendicular distance to shoulder, distance to nearest resident, distance to furthest resident
	----	SECONDARY	Enter perpendicular distance to shoulder, distance to nearest resident, distance to furthest resident
	----	STREET	Enter perpendicular distance to sidewalk, distance to nearest resident, distance to furthest resident
	----	RAIL	Enter perpendicular distance to shoulder, distance to nearest resident, distance to furthest resident
	----	WATER	Enter perpendicular distance to shoulder, distance to nearest resident, distance to furthest resident
	DISTON	FREEWAY	Minimum perpendicular distance to vehicle traveling opposite direction (m)
	----	SECONDARY	Minimum perpendicular distance to vehicle traveling opposite direction (m)
	----	STREET	Minimum perpendicular distance
	----	RAIL	Minimum perpendicular distance (m)
	----	WATER	Minimum perpendicular distance to vehicle Traveling opposite direction (m)

FIRST LEVEL	SECOND LEVEL	THIRD LEVEL	DESCRIPTION
	MITDDIST	----	Distance for Maximum In-Transit Dose (m)
	MITDVEL	----	Speed for Maximum In-Transit Dose (m/s)
	CAMPAIGN	----	Campaign duration (years)
	DDRWEF	----	Distance-dependent rail worker exposure factor (inspections/km)
	BDF	----	Building Dose Factor: fraction of outside air inside buildings
	CULVL	----	Clean-up Level (uCi/m^2)
	BRATE	----	Breathing Rate (m^3/s)
	FMINCL	----	Minimum number of rail classifications
	RPD	----	Ratio of Pedestrian Density to resident density
	RR	----	Rural shielding factor
	RS	----	Suburban shielding factor
	RU	----	Urban shielding factor
	RPCTHYROID	----	1-yr dose to thyroid via inhalation (rem per curie)
	LCFCON	----	Latent cancer fatalities per rem
	GECON	----	Genetic effects per rem
FLAGS	ITRAIN	---	1=General freight; 2=Dedicated Rail
	IUOPT	----	Shielding Options
	IACC	----	1=nondispersal; 2=dispersal
	REGCHECK		1=regulatory checks performed 2=regulatory checks not performed
EOF			"End of File" special keyword
LINK			Enter link name, vehicle name, link length (km), vehicle speed (km/hr), population density/km^2, persons/vehicle, vehicles/hr, accidents/km, R/S/U, road type (1, 2 , 3),farm fraction for each link
STOP			Enter stop name, vehicle name, persons or persons/km^2, minimum distance (m), maximum distance (m), shielding factor, exposure time (hr) for each stop
HANDLING			Enter handling name, vehicle name, number of handlers, distance (m), exposure time (hr) for each handling
LOS_STOP **(RADTRAN 6 ONLY)**			Enter LOS stop name vehicle name, persons or persons/km^2, minimum distance (m), maximum distance (m), shielding factor, exposure time (hr) for each LOS stop
EOF			"End of File" special keyword
EOI			"End of Input" special keyword terminates input

First-level keywords must be entered before any associated second- and third-level keywords. The entries for RELEASE (first level keyword) and GROUP (second level keyword) in Figure B-1 are examples of this. A first-level keyword is not always followed by a second- or third-level keyword. As the DIMEN keyword in the Master List illustrates, data may directly follow a first-level keyword, separated by spaces or other delimiters. The "or" separating two keywords in the Master List indicates that the user may enter one of the keywords, but not both, in a single analysis. The Description column of the Master List briefly describes the type of data to be entered after each keyword and gives the units that must be used. Arrays are described below.

Integer data can be entered as real numbers. Real variables can be entered as integers, in which case they will be converted internally. Entry format can be either exponential (e.g., 9.99E+01) or decimal (e.g., 99.9). A special delimiter character, the asterisk [*], may be entered in numeric-array fields to designate a repeat character. For example, to repeat the number 10.1 six times, enter 6*10.1. The asterisk must not be used in the data for DIMEN or PARM or in any alphanumeric-label. Two ampersands (&&) followed by a delimiter (usually a space) causes all subsequent information on that line to be entered as a comment line. Special keywords that are never followed by data are also noted in the Master List. They are EOF (End of File), EOI (End of Input), and END (marks end of data entry for keyword PACKAGE).

In order to further understand the Master List show in Table B-1, a generic input deck has been created below with a key to show how the input keywords are used.

Key:
[Brackets] indicate an optional statement
{Braces} indicate a required value
ALL CAPS indicates a keyword that must be entered

RADTRAN 6 **{required for 6.0 files, not 5.x}**
TITLE **{alphanumeric title}**
INPUT **{STANDARD (Default values) or ZERO}**
[OUTPUT] **{BQ_SV for SI Units}**
FORM **{UNIT for population dose or NONUNIT for health effects}**
DIMEN **{# of severity categories} {# of nondispersal accident radii} {# of dispersal areas}**
PARM **{0 no plotting/1 plotting} {1 incident free/2 accident/3 both} {1/2/3 level of output} {0 User-supplied time-integrated concentration isopleths and areas/1 Pasquill stability fractions/2 User-Defined metrological conditions}**
SEVERITY
NPOP = **{1 rural}**
NMODE = **{transport mode (see Mode Chart in Table B-2)}**
{Severity Fraction 1} {Severity Fraction 2} {Severity Fraction 3...}
NPOP = **{2 suburban}**
NMODE = **{transport mode (see Mode Chart in Table B-2)}**
{Severity Fraction 1} {Severity Fraction 2} {Severity Fraction 3...}
NPOP = **{3 urban}**
NMODE = **{transport mode (see Mode Chart in Table B-2)}**
{Severity Fraction 1} {Severity Fraction 2} {Severity Fraction 3...}

RELEASE

GROUP=**{group name}**

RFRAC

{Release Fraction 1} {Release Fraction 2} {Release Fraction 3...}

AERSOL

{Aerosol Fraction 1} {Aerosol Fraction 2} {Aerosol Fraction 3...}

RESP

{Respirable Fraction 1} {Respirable Fraction 2} {Respirable Fraction 3...}

DEPVEL

Deposition Velocity of Group (m/s)

[GROUP=...]

[ISOPLETHP]

{Population density of isopleth 1} {Population density of isopleth 2...}

[AREADA]

{Area of Isopleth 1 (m^2)} {Area of Isopleth 2...}

[DFLEV]

{Dilution Factor for Isopleth 1} {Dilution Factor for Isopleth 2...}

[CLINE]

{Center-Line Distance for Isopleth 1 (m)} {Center-Line Distance for Isopleth 2...}

[PSPROB]

{Pasquill Category A Fraction} {Pasquill Category B Fraction...}

[RISKIND] **(See Definitions for Input to the User-Defined Dispersion Model in Section B.7)**

&& USE_RADTRAN, REL_HT, HEAT_REL, SRC_WDTH, SRC_HT

0 10.0 100000 3.45 2.87

&& WS, ANEM_HT, AMB_T, HT_MIX, RAIN_RT

4.0 10.0 298.0 5000 0.0

&& (Pasquill-1, Briggs-2), Stability (A=1 through F=6)

1 4

&& (Rural-1, Urban/Suburban-2)

2

[LOS_SHIELD] **RADTRAN 6 ONLY**

NPOP = **{1 rural}**

ACIDNT_PRB

{Accident Probability 1} {Accident Probability 2 ...}

FRAC_LOST

{Fraction of Shielding Lost 1} {Fraction of Shielding Lost 2 ...}

NPOP = **{2 suburban}**

ACIDNT_PRB

{Accident Probability 1} {Accident Probability 2 ...}

FRAC_LOST

{Fraction of Shielding Lost 1} {Fraction of Shielding Lost 2 ...}

NPOP = **{3 urban}**

ACIDNT_PRB

{Accident Probability 1} {Accident Probability 2 ...}

FRAC_LOST

{Fraction of Shielding Lost 1} {Fraction of Shielding Lost 2 ...}

[DEFINE] **{Radionuclide Name}**
{Half-life (days)} {Photon Energy (MeV/disintegration)} {Cloudshine dose factor (rem-m^3/Ci-second)} {Groundshine dose factor (rem-m^3/μCi-day)} {50-yr committed effective dose equivalent for inhalation (rem/Ci inhaled)} {50-yr committed effective gonad dose for inhalation (rem/Ci inhaled)} {1-yr lung dose for inhalation (rem/Ci inhaled)} {1-yr marrow dose for inhalation (rem/Ci inhaled)} {Name for COMIDA Ingestion Data (or NONE)}
[DEFINE] **{Radionuclide Name...}**

PACKAGE **{alphanumeric identifier} {dose rate at 1m (mrem/hr)} {gamma fraction} {neutron fraction} {package dimension (m)}**
{Radionuclide Name} {Package Inventory (Ci)} {Group Name}
[**{Radionuclide Name} {Package Inventory (Ci)} {Group Name...}**]
END

VEHICLE **{minus sign if shipment is exclusive} {transportation mode number (see mode chart)} {identifier} {dose rate at one meter from vehicle (mrem/hr)} {gamma fraction} {neutron fraction} {vehicle length (m)} {number of shipments} {number of crew members} {distance of crew from package (m)} {crew shielding factor} {crew view dimension (m)}**
{package identifier} {number of packages per shipment}
[**{package identifier} {number of packages per shipment...}**]

[FLAGS]
{see Flag Chart in Table B-3}
[MODSTD]
{see MODSTD Standard Values List in Table B-4}
EOF

LINK **{link identifier} {vehicle name} {segment length (km)} {velocity (kph)} {vehicle occupancy} {population density (persons/km^2)} {vehicle density} {accident rate (acc/km)} {fatalities per accident} {R rural/S suburban/U urban} {1 interstate/2 non-interstate/3 city streets (highway) or rail or barge} {farm fraction}**
[LINK] **{link identifier...}**

STOP **{stop identifier} {vehicle name} {population density (annular) or number of persons (radial)} {minimum annular radius} {maximum annular radius (or same as minimum for radial)} {shielding fraction} {stop time (hr)}**
[STOP] **{stop identifier...}**

LOSS OF SHIELDING STOP RADTRAN 6 ONLY
[LOS_STOP] **{los_stop identifier} {vehicle name} {population density (annular) or number of persons (radial)} {minimum annular radius} {maximum annular radius (or same as minimum for radial)} {shielding fraction} {stop time (hr)}**

HANDLING **{handling identifier} {vehicle name} {number of handlers} {average handler distance} {handling time per package (hr)}**
[HANDLING] **{handling identifier...}**
EOF
EOI

Table B-2: Mode Chart

Mode	Mode Number	Conveyance Types Associated with Mode
HIGHWAY	1	Any truck; usually a tractor-trailer(also called a "semi" or a combination truck)
RAILWAY	2	One or more railcars in a single train
WATERWAY	3	Any vessel; usually barge

The five first-level keywords that must be entered are: TITLE, INPUT, FORM, DIMEN, and PARM. Each of these keywords is discussed below.

TITLE: The first input line must begin with the keyword TITLE followed by at least one space and then the title you wish to give your file. The actual letter count of a user-assigned title may not exceed 74 alphanumeric characters in length.

INPUT: The second line of the input file must begin with the keyword INPUT followed by the keyword default, which will bring up default values for a number of RADTRAN parameters. The user may overwrite these default values by entering specific values for each parameter he or she wishes to overwrite under keywords MODSTD and FLAGS, which are described later in this section.

DIMEN: There are three ordered numeric fields each separated by a delimiter that must follow DIMEN. They specify the dimensions of the following arrays:

- NSEV: The number of accident-severity categories that will be used in the analysis (maximum = 30); This number must correspond to the number of severity categories under SEVERITY.
- NRADIAL:
  - In RADTRAN 5.6 this number is radial distances used in an obsolete nondispersal accident analysis; enter 10 here.
  - In RADTRAN 6, the parameter value entered here is the number of loss-of-shielding accident severity categories (default = 10). This number must correspond to the number of severity categories under LOS_SHIELD.
- NISOPLETH: The number of downwind dose and deposition areas to be used in dispersal accident analysis (maximum = 30). This number must correspond to the number of isopleth areas actually used.

FORM: The third line of the input file must begin with the keyword FORM followed by at least one space and either UNIT or NONUNIT (second-level keywords).

PARM: With PARM, the user selects settings for four flags in RADTRAN 5.6, and three flags in RADTRAN 6. These flags control certain code functions. The flags, in order of entry, are:

1. The plot flag for placing data in output files for probability-consequence plots; the default value is yes (1); to not produce those files, set flag to zero (RADTRAN 5.6 only).
2. The selection flag with which the user selects incident-free analysis (1), accident analysis (2), or both (3); the default value is both (3);
3. The output flag for choosing the level of output; the default value is the full output (3). If set to 1, a short summary is printed; 2, 3, and 4 yield successively more detailed output. **Level 4 is not used in RADTRAN 6.0.**
4. The Weather flag: To select time-integrated concentration isopleths and areas based on National Weather data, set to (0); To select Pasquill stability categories, set to (1); To select User-Defined dispersion parameters set to (2); the default value is zero.

Flags under Keyword FLAGS: In addition to the flags already discussed under keyword PARM, four flags are set under the keyword FLAGS and one additional flag is associated with the keyword VEHICLE. Table B-3 lists the keywords.

Table B-3: FLAGS Chart

Flag Name	Flag Description	STANDARD (Default) Value
IACC	Setting this flag to 2 directs the code to work through all exposure pathways associated with atmospheric dispersal of package contents during an accident. The alternative value of IACC = 1 denotes non-dispersal and is no longer used in RADTRAN	2
ITRAIN	This flag, used only for rail mode, denotes whether shipment is by general freight (ITRAIN = 1) or by dedicated rail (ITRAIN = 2).	1
IUOPT	This flag is used to select a building shielding option. For the STANDARD value, persons in rural buildings are not shielded (100% exposure), persons in suburban dwellings are 87% exposed, and persons in urban dwellings are 18% exposed. Setting the IUOPT flag to 1 is equivalent to full shielding (everyone indoors is fully shielded and receives no dose). Setting the IUOPT flag to 3 is equivalent to no shielding (being indoors provides no protection and is the same as being outdoors).	2
REGCHECK	Setting this flag to 1 causes a series of regulatory checks to be performed. If any circumstances are identified that violate the regulatory requirements, then the appropriate parameter values are reset to the regulatory maximum and the calculation continues. The analyst may set REGCHECK = 0, which bypasses the regulatory-check subroutine.	1

Exclusive-Use Flag: Exclusive use is denoted by placing a negative sign in front of the mode designator in the VEHICLE array. In the absence of a negative sign, the shipment is considered non-exclusive-use for regulatory check purposes.

After TITLE, INPUT, FORM, DIMEN (and sometimes PARM) have been entered, most other keywords may follow in any order with two exceptions:

- A package must be described before it can be associated with a vehicle;
- A vehicle must be described before it can be associated with a LINK; and

- A nonstandard radionuclide (i.e., one described under keyword DEFINE) must be described before the assigned radionuclide can be associated with a material or a package.

The hierarchical relationship between the keywords also must be observed. After a keyword is entered, data are entered (the data are described briefly in Table B-1).

The keyword EOF must appear before values entered with LINK, STOP, and HANDLING are entered but after all other data have been entered. The keyword EOI must be entered on the last line of the input file.

B.2 Package-Specific Parameters

Values for the following five parameters are entered for each package on the line after the keyword PACKAGE .

1. Alphanumeric identifier, up to ten characters in length (e.g., SPENT_FUEL)
2. Package dose rate 1 m from surface of package (mrem/hr)
3. Fraction of dose rate that is gamma radiation
4. Fraction of dose rate that is neutron radiation
5. Characteristic Package Dimension (m)

A list of the radionuclides in a package must appear below the PACKAGE line for each package. Data for each radionuclide must be entered on a separate line. Three pieces of information, each separated by a space must appear on each radionuclide line. They are:

1. Radionuclide name in format, e.g., CO60, AM241M, or U234
2. Amount of activity for each radionuclide in the package (Ci)
3. Identifier for physical-chemical group to which the radionuclide is assigned (e.g., VOLATILE)

The radionuclide list must be terminated by the keyword END as shown in Figure B-2.

```
PACKAGE   SPENT_FUEL   1.368E+01   1.00   0.00   5.20
      CO60       9.220E+01   CRUD
      KR85       6.100E+03   GAS
      SR90       5.960E+04   ACT_OTHERS
      RU106      1.620E+04   RUTHENIUM
      CS134      2.740E+04   VOLATILE
      CS137      8.760E+04   VOLATILE
      CE144      1.220E+04   CE_EU
      EU154      7.000E+03   CE_EU
      PU238      2.960E+03   ACT_OTHERS
      PU239      4.100E+02   ACT_OTHERS
      PU240      4.680E+02   ACT_OTHERS
      PU241      1.260E+05   ACT_OTHERS
      AM241      1.290E+03   ACT_OTHERS
      AM243      1.990E+01   ACT_OTHERS
      CM244      1.790E+03   ACT_OTHERS
      END
```

Figure B-2: Keyword PACKAGE with Radionuclides.

B.3 Vehicle-Specific Parameters

The following parameters are entered for each vehicle on the line following the keyword VEHICLE:

1. Mode number (1 = truck; 2 = rail; 3 = other) modified by the Exclusive-Use Flag (a negative sign) if necessary
2. Alphanumeric vehicle identifier, up to 10 characters in length, with no spaces
3. Dose rate at one meter from the surface of the vehicle (mrem/hr)
4. Fraction of dose rate that is gamma radiation
5. Fraction of dose rate that is neutron radiation
6. Characteristic vehicle dimension (m)
7. Number of shipments to be carried out in the specified vehicle type
8. Number of crew members
9. Average distance (m) of crew members from the geometric center(s) of one or more radioactive-material package(s)
10. Crew Shielding Factor.
11. Crew View Package Dimension (m), largest dimension of the surface facing the crew (e.g., the diameter of a cylindrical package mounted on its side)

The VEHICLE line must be followed by any package identifiers (alphanumeric identifiers that the user creates under keyword PACKAGE). Each package type is listed on a separate line; the package identifier is followed by at least one space and a numeral

indicating the number of packages of that type being carried in the vehicle. In the example in Figure B-3, four packages of type PHARM_1 and five packages of type PHARM_2 are being carried by non-exclusive-use highway mode in a vehicle identified as VAN. The vehicle (VAN) has a maximum dose rate of 1.9 mrem/h (measured at 1 meter from the side of the van). The fraction of dose rate is 95% gamma radiation and 5% neutron radiation. The remaining values tell us that:

- The van is 3.5 m in length;
- One (1) shipment is being analyzed;
- There are two (2) crew member (driver),
- Who averages a distance of 2.1 m from the packages,
- Who is unshielded (i.e., the cab has a shielding factor of 1.00),
- And who is exposed, in this case, to a close-packed array of packages with an overall characteristic dimension of 1.5 m.

```
VEHICLE  1  VAN  1.9  0.95  0.05  3.5  1  2  2.1  1.00  1.5
                PHARM_1   4
                PHARM_2   5
```

Figure B-3: Keyword VEHICLE with Packages.

B.4 Route-Specific Parameters

Following the keyword LINK, the following parameters are entered for each route-segment. Each route-segment and its associated parameters must be on a separate line. The parameters are:

1. Alphanumeric Segment Identifier (user-defined)
2. Vehicle Identifier (previously defined; a new vehicle identifier cannot be entered here)
3. Segment length (km)
4. Velocity (kilometers per hour)
5. Occupancy of vehicles sharing the route with the shipment(s) (persons/vehicle)
6. Population density (persons/km^2) of area bordering route segment
7. Density of vehicles (vehicles/hour) sharing the route with the shipment(s)
8. Accident rate (accidents/vehicle-km)
9. Route segment character (R=rural, S=suburban, U=urban)
10. Route segment type (1=interstate; 2 = non-interstate; 3 = any other mode)
11. Fraction of land under cultivation (for rural route segments only).

Following the keyword STOP, the following parameters are entered. Each stop must be described on a separate line. The stop parameter array is:

1. Alphanumeric Stop identifier, up to 10 characters (user defined)
2. Vehicle Identifier (previously defined)
3. Option 1: Population Density (persons/km^2), or Option 2: Number of Persons
4. Minimum Radius of Annular Area
5. Maximum Radius of Annular Area (set equal to minimum for Option 2)
6. Shielding Fraction
7. Stop Time (hr).

Following the keyword HANDLING, the following parameters are entered. Each handling must be described on a separate line. The handling parameter array is:

1. Alphanumeric Handling identifier, up to 10 characters (user-defined);
2. Vehicle identifier (previously defined);
3. Number of handlers;
4. Average source-to-handler distance (m);
5. Handling time per package (hr/package).

B.5 Radionuclide Data

Values of ten radionuclide-specific parameters listed below are available for 148 commonly encountered radionuclides in an internal database in RADTRAN. When these radionuclides are entered in the format shown in Figure B-2, appropriate parameter values are electronically read into RADTRAN from the internal radionuclide library (see the *RADCAT User Guide* (SAND2006-1965) Appendix B). If the user wishes to enter radionuclides not in the internal library or to use different dose conversion factors, the radionuclide name should be entered in a different format following the keyword DEFINE and the following parameters should be entered and indented on the next line, as shown in Figure B-4.

1. Half-life (days)
2. Photon energy (MeV/disintegration)
3. Cloudshine dose factor (rem-m^3/Ci-sec)
4. Groundshine dose factor (rem-m^2/μCi-day)
5. 50-yr committed effective dose equivalent for inhalation (rem/Ci inhaled)
6. 50-yr committed effective gonad dose for inhalation (rem/Ci inhaled)
7. 1-yr lung dose for inhalation (rem/Ci inhaled)
8. 1-yr marrow dose for inhalation (rem/Ci inhaled)

The added radionuclide must also be added to the list under PACKAGE (see Figure B-1).

```
DEFINE AC-227
       7.95E+03  1.65E-04  2.15E-05  5.02E-05
       1.29E+09  0.00E+00  0.00E+00  0.00E+00
```

Figure B-4: Illustration of a DEFINE Statement

B.6 MODSTD Data

Default values are available for a large number of input variables, and are part of the STANDARD data set that is automatically called up by RADTRAN when the first level keyword INPUT is followed by a space and then the second level keyword STANDARD is entered. The STANDARD set of default values is printed out near the top of the RADTRAN output. If the user wishes to substitute a different value for the default value, a user-defined value should be listed with the appropriate second-level keyword under the first-level keyword MODSTD as shown in Figure B-5, below. Table B-4 shows the MODSTD array and gives the associated second-level keywords with a brief description of the default value.

```
MODSTD
   BDF    1.00E+00
   UBF    1.00E+00
   USWF   0.00E+00
   FMINCL 1.00E+00
   RR     1.00E+00
   RS     1.00E+00
   RU     1.00E+00
   CULVL  1.00E+04
```

Figure B-5: Illustration of MODSTD User-Defined Parameters.

Table B-4: MODSTD Standard (Default) Values List

MODSTD Name	Description	STANDARD (Default) Value
ADJACENT	See DISTON	
BDF	The Building Dose Factor describes the entrainment of aerosol particles in ventilation systems (i.e., the fraction of particles of an external aerosol that remain in aerosol form after passing through a ventilation system). The BDF is used to modify inhalation doses to persons in urban structures. The standard (default) value of 0.05 represents a conservative average across a series of building types, including residential, office, and industrial structures (Engelmann, 1990). This value is about five times higher than the value for high-rise buildings with air-conditioning systems used by Finley et al., (1980) for New York City, which has been used in RADTRAN in the past.	0.05
BRATE	This factor represents breathing rate and is used for calculation of inhalation doses. The breathing rate (BRATE = 3.30E-04 m^3/sec) of the Reference Man (70-kg adult male at light work) derived from Shleien, et al 1996; Table 12.6) has been used as the standard (default) value. The value in the cited table has been converted from liters per hour to m^3/sec.	3.30E-04
CAMPAIGN	This keyword specifies the duration of the shipping campaign in years. The value calculated with CAMPAIGN is the total number of off-link persons exposed. This result may be used to perform external calculations of annual off-link dose. Annual dose values may be compared with total dose in multi-year shipping campaigns and are useful for assessing regulatory compliance with standards based on annual doses. The standard (default) value is 0.0833 years. This is an average month in an average year, or $1/12^{th}$ of a year.	0.0833
CULVL	This factor describes Clean-Up Level, which is the required level to which contaminated surfaces must be cleaned up. The standard (default) value is the EPA guideline of 0.2 $\mu Ci/m^2$ (EPA, 1977). This value applies to the sum of deposited activity over all radionuclides of a multi-radionuclide material. Analysts who can justify use of more realistic values are urged to do so.	0.2

MOD STD Name	Description	STANDARD (Default) Value
DDRWEF	This keyword applies to rail mode only and specifies the Distance Dependent Rail Worker Exposure Factor. This factor is used to calculate the component of rail-worker dose that depends on distance traveled (e.g., exposure related to engine changes, crew shift-changes, etc., while en route). The standard (default) value of 0.0018 inspections/km is taken from Ostmeyer (1986).	0.0018
DISTOFF	This keyword specifies a set of three distances, in meters, used in off-link dose calculations for highway, rail, and barge modes. The three distances are: (1) the minimum perpendicular distance over which the off-link dose calculation will be integrated; (2) the minimum pedestrian-walkway width, for instances in which dose to pedestrians beside the link is calculated (see RPD for discussion of pedestrian density); and (3) the maximum perpendicular distance over which the off-link dose calculation will be integrated. DISTOFF must be followed one or more keywords that specify values for various link types. The standard (default) values, which are supplied for each link type, are from NUREG-0170 (NRC, 1977). The link types and values for each are:	
	FREEWAY Any limited-access divided highway. [30, 30, 800]	30, 30, 800
	SECONDARY Any non-limited-access highway that is not a city street (27, 30, 800)	27, 30, 800
	STREET Any city street. [5, 8, 800]	5,8,800
	RAIL Any rail right-of-way in the U.S. [30, 30, 800]	30, 30, 800
	WATER Any vessel. [200,200,800]	200, 200, 1000
	Note: The values are the same for FREEWAY and RAIL. Setting the first two values equal to each other is equivalent to a sidewalk width of zero and means there are no sidewalks or similar close-in areas where unshielded persons (pedestrians, bicyclists, etc.) may reasonably be expected to be found. For STREET, the sidewalk is modeled as being 3 m wide (Finley et al. 1980). The values for WATER conservatively model a narrow navigable waterway (e.g., Houston Ship Channel) and are taken from NUREG-0170 (NRC, 1977). The WATER values are the variables most likely to require modification by the analyst since other bodies of water that might be modeled have ship-to-shore distances that greatly exceed 200 m and even 800 m.	

MODSTD Name	Description	STANDARD (Default) Value
DISTON	This keyword specifies a perpendicular distance (i.e., a distance measured along a line at right angles to the line of travel of the RAM shipment) between the RAM shipment and other traffic lanes, in meters. For three link types, DISTON represents the *average* perpendicular distance between the shipment *centerline* and the *centerline* of oncoming traffic lanes(s). In the passing-vehicle case, DISTON represents the distance between the shipment *centerline* and the *centerline* of adjacent passing vehicles (HIGHWAY mode only). DISTON must be followed by a second keyword that specifies the link type. The standard (default) values in parentheses in the following list are taken from Madsen et al. (1986, p. 36-37).	
	FREEWAY Any limited-access, divided highway [15.0 m];	15
	SECONDARY Any non-limited access highway [3 m];STREET Any city street [3 m];	3 for secondary roads 3 for city streets
	RAIL Any rail right-of-way [3 m].	3
	An additional parameter for highway mode only is ADJACENT It represents the minimum perpendicular distance between shipment centerline and centerline of adjacent passing vehicles [4 m].	4
	Note: The FREEWAY value is based on the Madsen et al. (1986) model of a minimal Interstate configuration of 4 lanes with an average lane width of 5 m, and the most typical traffic configuration. The latter refers to the RAM shipment being in the outside lane, oncoming traffic in the corresponding outside lane, and passing vehicles in the inner lanes. The SECONDARY and STREET values are smaller because these roadways are modeled as being only 2 lanes wide with an average lane width of 3 m. The RAIL value is based on the minimum clearance between passing trains on double rail segments. The ADJACENT value represents the median value for all Interstate and secondary-road lane widths.	

MODSTD Name	Description	STANDARD (Default) Value
EVACUATION	This parameter specifies evacuation time in days following a dispersal accident, where this includes time to respond to the accident and carry out a course of action. The standard (default) value is 24 h (1 day). Mills et al. (1995) analyzed 66 verified hazmat accidents in which evacuations were carried out and found that the mean evacuation time was approximately 1 hour. Even when response time is added, a 24-hour (1-day) value for this variable is conservative. This parameter defined the time of exposure to groundshine and to resuspended material.	1.0
FMINCL	This keyword is applied to rail mode only and specifies the minimum number of railcar classifications or inspections per one-way trip. The standard (default) value is 2 since there are always at least two inspections per one-way trip - one at the beginning and one at the end of each trip (Wooden, 1986).	2
FREEWAY	See DISTOFF and DISTON	
GECON	This parameter specifies the Genetic Effects Conversion Factor. The standard (default) value is 1.0E-04 genetic effects/rem. This value is consistent with the recommendations of BEIR V (NRC/NAS, 1990) and ICRP 60 (ICRP, 1991). Estimates based on the only genetic effects (untoward pregnancy outcome and F_1 mortality) to have been documented in the atomic-bomb survivors have extremely high statistical and model uncertainties. Animal data, which is more reliable, consistently yield lower estimates. As noted in BEIR V, the recommended value is "probably …too high rather than too low" (NRC/NAS, 1990, p. 77).	1.00E-04
INTERDICT	This parameter specifies the threshold value for interdiction of contaminated land. The standard (default) value is 40, i.e., a value 40 times greater than CULVL, and it was taken from NUREG-0170 (NRC, 1977).	40
LCFCON	This parameter specifies the Latent Cancer Fatality (LCF) Conversion Factors; units are LCFs per rem. The standard (default) values are 5.0E-04 LCF/rem for the general public and 4.0E-04 LCF/rem for workers. They have been adjusted for low-dose and low-dose-rate decrease in effects with a DDRRF (Dose and Dose Rate Reduction Factor) of 2. These values are consistent with the recommendations of BEIR VII (NRC/NAS,2005) and ICRP 60 (ICRP, 1991). The dose-response relationship is assumed to be linear with no threshold in order to agree with current regulations. However, the majority of available data indicate that the actual dose-response relationship at very low doses is likely to be considerably less and, as noted in BEIR VII, is not incompatible with zero (NRC/NAS, 2005). Thus, cancer risk estimates obtained from RADTRAN 5 will be generally conservative.	5.0E-04 for the public 4.04E-04 for workers

MODSTD Name	Description	STANDARD (Default) Value
NE	This parameter is the neutron emission factor; it may be used to model neutron emissions following a loss-of-shielding accident. For commonly encountered radionuclides that spontaneously emit neutrons (curium-242, curium-244, and californium-242), the NE values are already available in the radionuclide library. All other radionuclides have no assigned NE factor. The NE keyword is applied only when the analyst wishes to assign a new value to an existing radionuclide or to a new material. The analyst must enter NE followed by the radionuclide name in standard format (or exactly as entered under keyword DEFINE) and the emission factor value in neutrons/s-Ci. The analyst must repeat the process (i.e., type NE followed by radionuclide name and NE factor value) for each radionuclide desired.	
MITDDIST	This parameter is used to calculate the maximum individual "in-transit" dose to a member of the public; it represents the minimum perpendicular distance, in meters, from the shipment centerline to an individual standing beside the road or railroad while a shipment passes. The standard (default) value is 30.0 m (NRC, 1977).	30
MITDVEL	This parameter is used to calculate the maximum individual "in-transit" dose; it represents the minimum velocity, in km/hr, of a shipment. The standard (default) value is 24.0 km/hr (15 mph) (NRC, 1977).	24
RAIL	See DISTOFF and DISTON	
RPD	This parameter is the Ratio of Pedestrian Density. It is used to calculate the density of unshielded persons on sidewalks and elsewhere in urban areas when the IUOPT Flag is not equal to 3 by indexing it to the population density of the surrounding area. RPD is also used in the calculation of accident consequences. The standard (default) is 6.0, which is based on empirical data from New York City (Finley, 1980). It means that the pedestrian density is six times the residential population density. This figure is likely to be conservative for most other urban areas, but similar data are seldom collected in other cities.	6.0
RPCTHYROID	This parameter is used to specify 1-year CEDE (rem per curie) to the thyroid from inhalation of radionuclides of iodine for estimation of early-mortality risk. Radioiodine mainly travels to and irradiates a single organ, the thyroid. In previous releases of RADTRAN, however, the 50-year CEDE was used to approximate the 1-year dose. One-year committed doses to the thyroid have been calculated directly for RADTRAN 5. This new parameter was not included in the internal radionuclide database, since it would have meant adding a new column containing zeros for all radionuclides but the radioiodines. The information has been included under the RPCTHYROID keyword instead. The standard (default) values are 1.27E+06 for iodine-131, 5.77E+06 for iodine-129, and 9.25E+05 for iodine-125.	1.27E+06 for I-131 5.77E+06 for I-129 9.25E+05 for I-125

MODSTD Name	Description	STANDARD (Default) Value
RR	This parameter specifies the Rural Shielding Factor. The standard (default) value is 1.0 (i.e., no shielding). Although even wood-frame construction provides some shielding, the Rural Shielding Factor is set to 1.0 to conservatively account for the fact that rural economies involve a relatively large fraction of outdoor employment (farming, ranching, etc.). RR is used in incident-free dose and in dose-risk calculation for non-dispersal accidents.	1.0
RS	This parameter specifies the Suburban Shielding Factor. The standard (default) value is 0.87, which represents a residential structure of wood-frame construction (Taylor and Daniel, 1982, p.12). RS is used in incident-free dose and in dose-risk calculations for non-dispersal accidents.	0.87
RU	This parameter specifies the Urban Shielding Factor. The standard (default) value is 0.018, which represents an urban commercial building constructed of concrete block (Taylor and Daniel, 1982, p.12). RU is used in incident-free dose and in dose-risk calculations for non-dispersal accidents.	0.018
SECONDARY	See DISTOFF and DISTON	
SMALLPKG	This parameter specifies the first Package Size Threshold. This parameter is used to determine the handling method that will be used for a package, which, in turn, is used in the calculation of handler dose. If a package is designated as “small” then an empirical algorithm for handling dose is used; if package dimensions exceed the threshold then another method is used. The standard (default) value for SMALLPKG is 0.5 m (Javitz, 1985). Although it is highly unlikely that this value will need to be altered, the analyst has the option to do so.	0.5
STREET	See DISTOFF and DISTON	
SURVEY	This parameter is used to specify the time (in days) required to survey contaminated land following a dispersal accident. The amount of deposited material removed by radioactive decay is calculated beginning with time of initial deposition. The longer a deposited material remains on the ground, the more is removed by decay and spread by forces such as wind and rain. The actual elapsed time between accident occurrence and completion of a survey is impossible to determine in advance, but is likely to be prolonged because of governmental and regulatory complexities. The standard (default) value is set to an unrealistically brief, but radiologically conservative, 10 days (NRC, 1977).	10

MODSTD Name	Description	STANDARD (Default) Value
UBF	This parameter is the Urban Building Fraction; it describes the fraction of the population that is indoors. This value plus USWF must equal one. (UBF + USWF = 1)	0.90
USWF	This parameter is the Urban Sidewalk Fraction; it specifies the fraction of the population that is outdoors. This value plus UBF must equal one. (UBF + USWF = 1)	0.10

B.7 Inputs to the User-Defined Dispersion Model

The User-Defined option allows modeling of hot and elevated releases, rainout, and the application of user-defined wind speeds. Note that the user can only use this option for one specific type of cask, release location, and wind stability class.

1. **Use RADTRAN** – This input is one (1) or zero (0). Selecting one will use the old RADTRAN distances and should only be used for release heights of less than three meters. Selecting zero is the preferred method for all release heights.

2. **Release Height (m)** – This parameter allows the user to specify the release height for an atmospheric dispersion. "Effective release height" is generally the elevation at which the plume begins to move downwind.

3. **Heat Release (calories/sec)** – This parameter allows the user to incorporate the amount of thermally-induced buoyancy and momentum that will affect the effective release height.

4. **Cask Length (m)** – This cask length should be the same as the largest cask dimension.

5. **Cask Radius (m)** – This cask radius should be the same as the largest cask radius that is not the largest cask dimension.

6. **Wind Speed at Anemometer (m/sec)** – This parameter will allow the user to specify the wind speed at an anemometer reading site.

7. **Anemometer Height (m)** – This parameter will allow the user to correlate the anemometer wind speed with the wind speed at the effective release height, usually 10 meters.

8. **Ambient Temperature (degrees Kelvin, K)** – This parameter adjusts the plume rise accordingly to adiabatic and potential temperature lapse rates.
   293 ^{o}K = 20 ^{o}C = 68 ^{o}F; 273 ^{o}K = 0 ^{o}C = 32 ^{o}F

9. **Atmospheric Mixing Height (m)** – This parameter will allow the user to define the height at which the plume will mix within other atmospheric conditions. If there is no temperature inversion, the mixing height is usually a kilometer (1000 meters) or more.

10. **Rainfall Rate** – This parameter will allow the user to incorporate wet deposition by rain or snowfall into the dispersion model. It is recommended that this parameter be used for light and medium rainfall (a few millimeters per hour) since this model does not incorporate the surface runoff or washout which is

experienced with heavy rainfall. The Solar and Meteorological Surface Observation Network has the following definitions for rainfall rates:

- Light Drizzle: Up to 0.25 mm/hr
- Medium Drizzle: 0.25 to 0.51 mm/hr
- Heavy Drizzle: Greater than 0.51 mm/hr

- Light Rainfall: Up to 2.5 mm/hr
- Medium Rainfall: 2.5 to 7.6 mm/hr
- Heavy Rainfall: Greater than 7.6 mm/hr

The following website can provide hourly rain data from the National Oceanic and Atmospheric Administration (NOAA) Forecast System Laboratory:

http://precip.fsl.noaa.gov/hourly_precip.html

11. **Dispersion Model** – This parameter will allow the user to choose between the Pasquill dispersion model, or the Briggs dispersion model. The former is suitable for ground-level releases and the latter is better for elevated releases.

12. **Stability Category** – This parameter will allow the user to determine which Pasquill stability class (A-F) will be used.

13. **Release Location** – This parameter allows the user to designate whether the release will be in a rural or suburban/urban location. Since this option provides different dispersion results, it should be used for Links that are either suburban/urban or rural only. If a combination of Links that are urban, suburban, and rural needs to be investigated, it is suggested that two different RADTRAN runs be conducted so as to reflect the dispersion models properly.

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