

RASCAL 4.3 Inputs for Site Boundary Dose Projections

The Radiological Assessment System for Consequence Analysis (RASCAL), developed for the U.S. Nuclear Regulatory Commission, is designed to be used in the independent assessment of dose projections during response to radiological emergencies.

RASCAL Version 4.3 uses different tools to model reactor accidents, spent fuel accidents, and fuel cycle facility accidents as described in RASCAL 4: Description of Models and Methods and RASCAL 4.3 Technical Supplement. The RASCAL Source Term to Dose (STDose) tool is a source term release path model that determines what nuclides and how much activity of each nuclide is available for release to the environment. STDose also determines how the activity gets from the source to the environment and how much activity is actually released as a function of time.

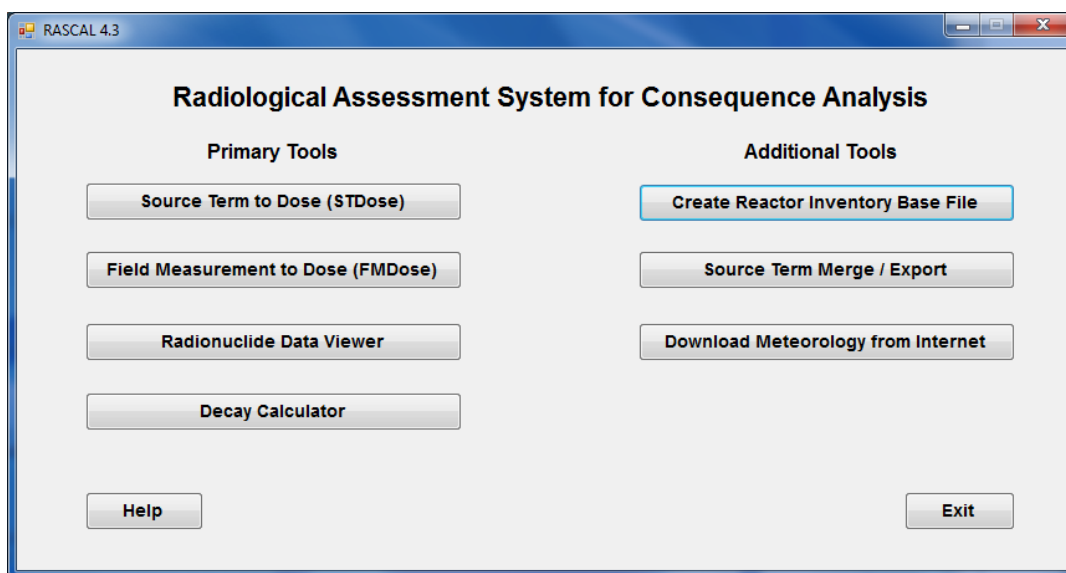
Defining and Running a Problem

The basic steps to setup a modeling run, calculate doses, and view results are as follows (the bold headings correspond to the STDose tool buttons):

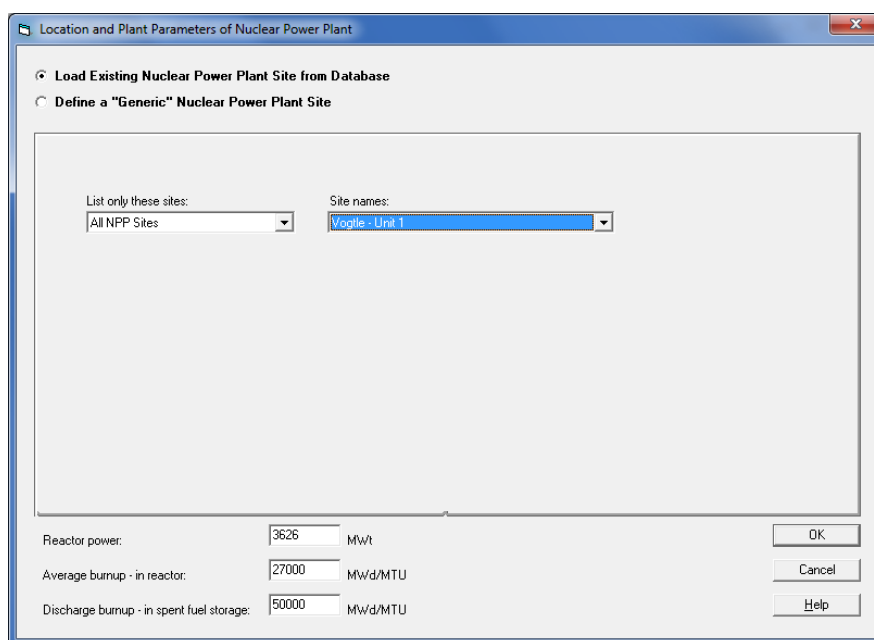
1. **Event Type** - Select the type of event to be modeled (See RASCAL User's Guide Section 2.1).
2. **Event Location** - Pick a location from the list of sites in the facility database (See RASCAL User's Guide Section 2.2.1).
3. **Source Term** - Select a source term type and define the source term characteristics (See RASCAL User's Guide Section 2.2.2).
4. **Release Pathways** - Select a release pathway type and define the release characteristics (See RASCAL User's Guide Section 2.2.3).
5. **Meteorology** - Select the meteorological data set to be used for the calculations. A number of test data sets have been provided in the Predefined Data area to be used for any location at any time (See RASCAL 4.3 User's Guide Section 2.6).
6. **Calculate Doses** - Calculations are started from this screen. Set the desired calculation distance, dose conversion factors, and end date and time for the simulation, and enter a case description (See RASCAL User's Guide Section 2.7).
7. **Detailed Results** - Results are viewable from the main screen tabs. Specifically, the maximum dose values and the computed source term summary are viewed by clicking the appropriate tab. More detailed source term details are available from the Details button (See RASCAL User's Guide Section 2.8).
8. **Save Case** - A modeling run can be saved as a single file (extension .std) for later recall (See RASCAL User's Guide Section 2.9).

For each run provided in the table in Enclosure 1, the permutations of source term, release start time, core damage end state, release pathway/characteristics, and meteorology were specified following the steps above as detailed in the following.

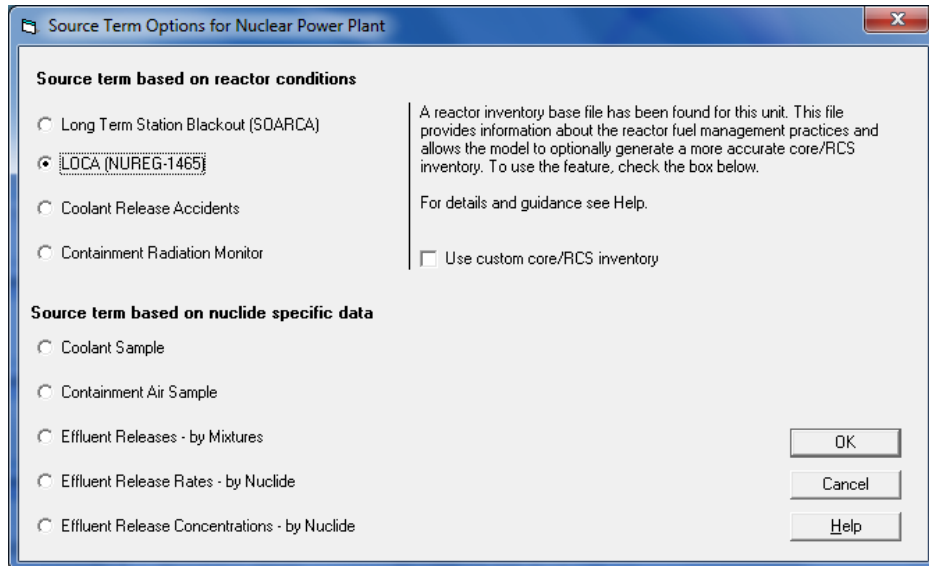
The **Source Term to Dose (STDose)** tool is selected to begin the case setup.



Event Type - After selection of the **Source Term to Dose (STDose)** tool, and the Nuclear Power Plant event type, default core inventories are provided for existing nuclear power plant sites. For all calculations, "Vogtle – Unit 1" was selected and the average burnup adjusted to 27,000 MWd/MTU as specified in Enclosure 1.



Source Term - RASCAL has four methods for estimating source terms that are defined accident sequences, including two core melt-accidents: *Long Term Station Blackout (SOARCA)* and *Loss of Cooling Accident (LOCA) (NUREG-1465)*. These source term models are described in RASCAL 4: Description of Models and Methods. The modeling runs were performed using either the SOARCA or LOCA (NUREG-1465) source terms as specified in Enclosure 1.



Source Term Options for Nuclear Power Plant

Source term based on reactor conditions

- ☐ Long Term Station Blackout (SOARCA)
- ☒ LOCA (NUREG-1465)
- ☐ Coolant Release Accidents
- ☐ Containment Radiation Monitor

A reactor inventory base file has been found for this unit. This file provides information about the reactor fuel management practices and allows the model to optionally generate a more accurate core/RCS inventory. To use the feature, check the box below.

For details and guidance see Help.

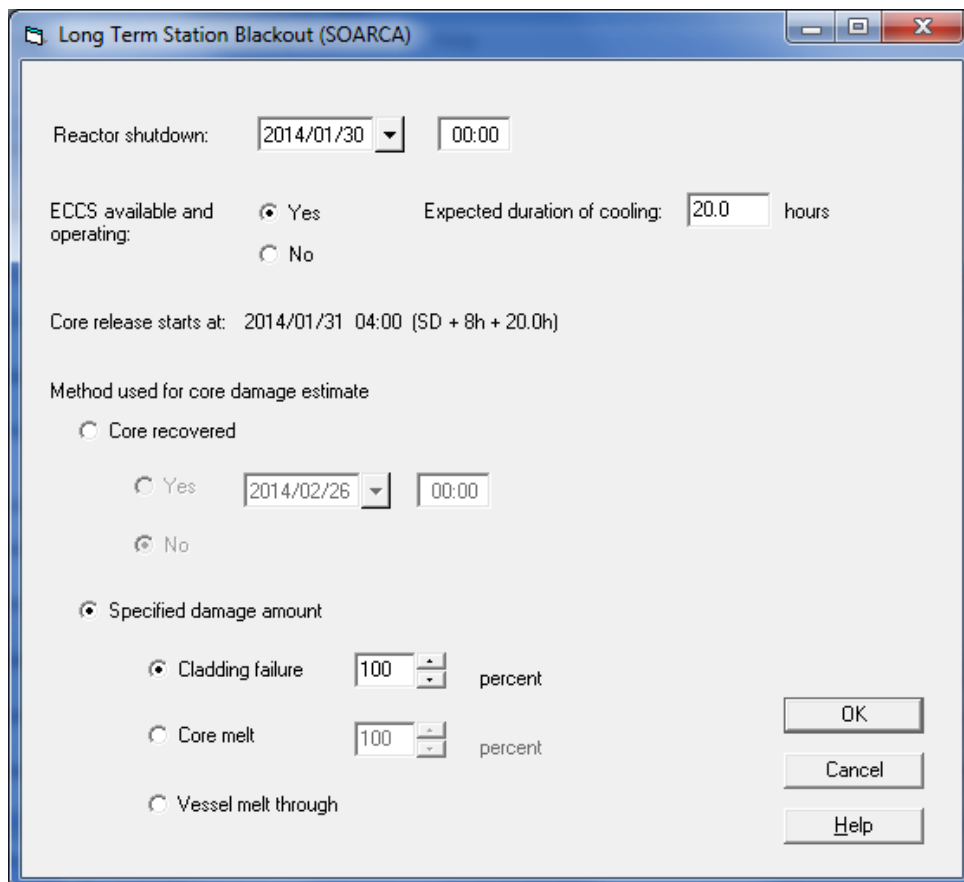
☐ Use custom core/RCS inventory

Source term based on nuclide specific data

- ☐ Coolant Sample
- ☐ Containment Air Sample
- ☐ Effluent Releases - by Mixtures
- ☐ Effluent Release Rates - by Nuclide
- ☐ Effluent Release Concentrations - by Nuclide

OK Cancel Help

Long Term Station Blackout - For the SOARCA modeling runs, RASCAL assumes a delay of at least 8 hours before the core is uncovered and a release begins. Additional delay time is specified by adjusting the amount of time core cooling is available. For SOARCA runs with 8 hours delay until core release, the expected duration of cooling was set to 0 hours (or ECCS available and operating set to “No”); and for runs with 28 hours delay, the expected duration of cooling was set to 20 hours.



Long Term Station Blackout (SOARCA)

Reactor shutdown: 2014/01/30 00:00

ECCS available and operating: ☒ Yes ☐ No Expected duration of cooling: 20.0 hours

Core release starts at: 2014/01/31 04:00 (SD + 8h + 20.0h)

Method used for core damage estimate

- ☐ Core recovered
 - ☐ Yes 2014/02/26 00:00
 - ☒ No
- ☒ Specified damage amount
 - ☒ Cladding failure 100 percent
 - ☐ Core melt 100 percent
 - ☐ Vessel melt through

OK Cancel Help

LOCA (NUREG-1465) - For LOCA modeling runs, the amount of fission products released from the core is estimated based on the amount of time the core remains uncovered. The delay time between shutdown and when the core is uncovered and the release starts can be specified by entering the time the respective events occur. As specified in Enclosure 1, the time between shutdown and the start of the release was set to either 4 or 24 hours.

LOCA (NUREG-1465)

Reactor shutdown: 2014/01/29 00:00

Core uncovered: 2014/01/29 04:00

Method used for core damage estimate

☐ Core recovered

☐ Yes 2014/02/26 00:00

☒ No

☒ Specified damage amount

☒ Cladding failure 100 percent

☐ Core melt 100 percent

☐ Vessel melt through 100 percent

OK

Cancel

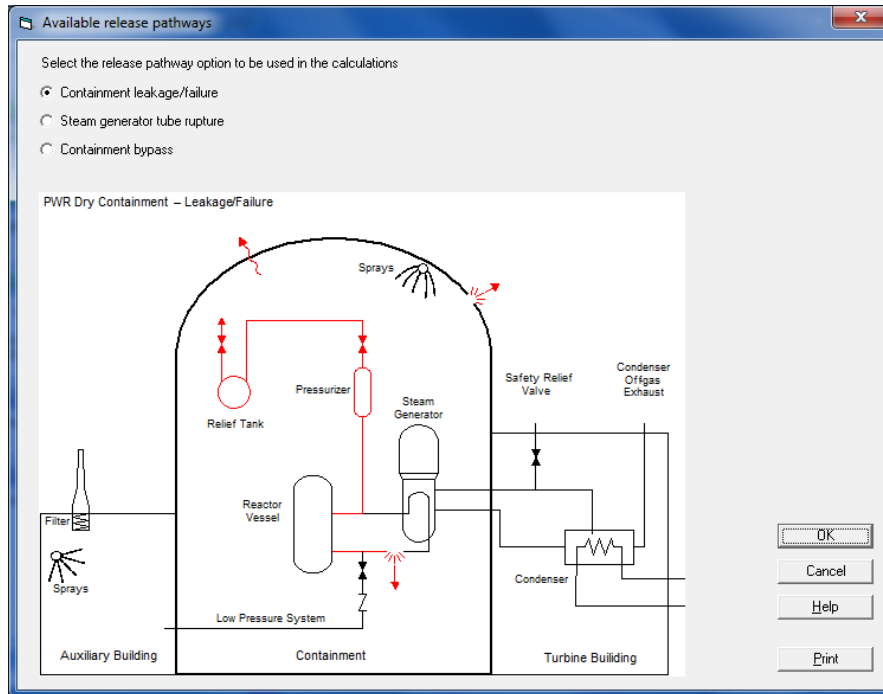
Help

For simplicity, the time of reactor shutdown was assumed to occur at midnight in all cases.

Core Damage State - For all runs the core damage end state was specified by selecting either 100% cladding failure, 100% core melt, or 100% vessel melt through.

Release Pathways - For both core-melt accident source terms the available release pathways are *Containment leakage/failure*, *Steam generator tube rupture*, and *Containment bypass*.

Containment Leakage - The following diagram is representative of the containment release pathway.



The options for controlling the amount of leakage and contributing factors include options for specifying leak rate, containment spray, and release height. The leak rates and use of sprays are adjustable over time by adding or removing event rows.

PWR - Dry Containment Leakage or Failure

Pathway description: <none> (optional; 60 character max)

Release height: 10.0 m

Release timings: Core release starts: 2013/12/05 12:00

Leak rate to atmosphere described by: ☒ Percent volume / time ☐ Containment pressure / hole size

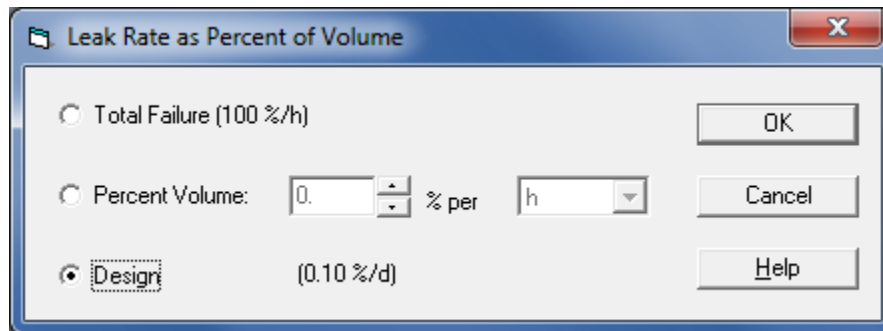
Date	Time	Event	Event setting
2013/12/05	12:00	Leak rate (% vol)	Design
2013/12/05	12:00	Sprays	Off

Buttons: Add Row, Remove Row, Sort Rows, Clear All, OK, Cancel, Help

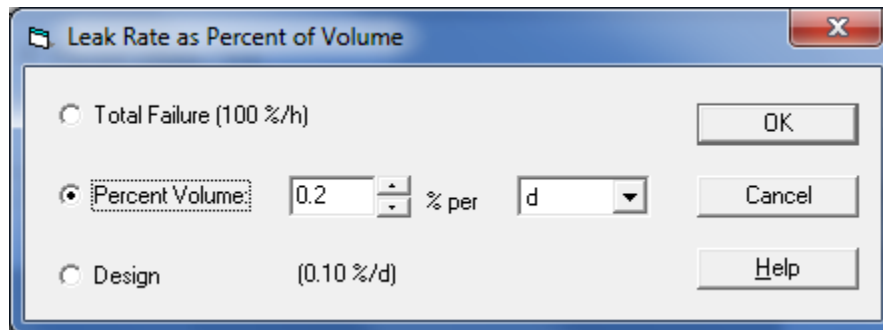
Leak Rate - There are two options for describing the leak. The first is to specify the containment leak rate as *percent volume/time*, and the other is to describe the leak by *containment pressure and hole size*.

For the modeling runs, containment leakage was specified to occur at the design leak rate for the duration of the release, or at the design leak rate until containment failure 48 hours after the start of the release. The containment failure was assumed to be a leak rate equivalent to a 1 inch hole at 125 psig containment pressure.

When the *percent volume/time* option is selected, RASCAL sets the leak rate to a default design leak rate of 0.1 %/d. However, per Enclosure 1 a design leak rate of 0.2 %/day is to be modeled which was manually entered in the *Percent Volume* option.

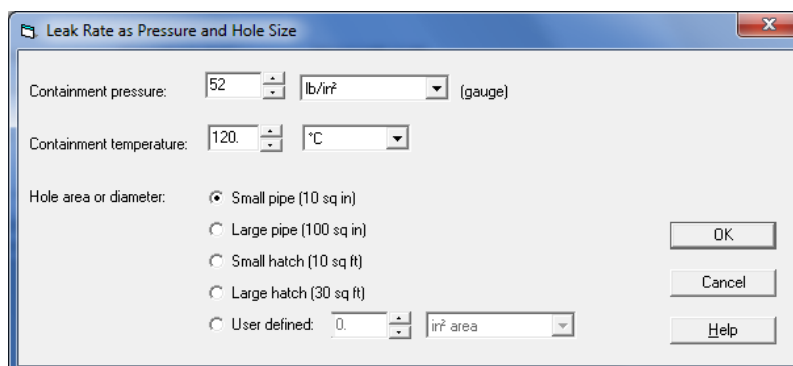


The screenshot shows a dialog box titled "Leak Rate as Percent of Volume". It contains three radio button options: "Total Failure (100 %/h)", "Percent Volume:", and "Design". The "Design" option is selected. To the right of "Design" is the text "(0.10 %/d)". The "Percent Volume:" option has a text input field with "0." and a dropdown menu set to "h". The "Total Failure" option has no input fields. There are three buttons on the right: "OK", "Cancel", and "Help".



The screenshot shows the same dialog box, but the "Percent Volume:" option is now selected. The text input field next to it now contains "0.2". The dropdown menu next to it is now set to "d". The "Design" option is now unselected. The other elements remain the same.

When the *containment pressure/hole size* option is selected, RASCAL calculates the leak rate based on the user inputs for containment pressure, temperature, and hole size. Although this method can be used to calculate the leak rate for the assumed containment failure, RASCAL only allows the user to describe the leak rate by one of the two methods (percent volume/time or containment pressure/hole size) in a particular run and the user cannot mix methods.



The screenshot shows a dialog box titled "Leak Rate as Pressure and Hole Size". It contains two input fields: "Containment pressure:" with a value of "52" and a unit dropdown set to "lb/in² (gauge)", and "Containment temperature:" with a value of "120" and a unit dropdown set to "°C". Below these are five radio button options for "Hole area or diameter": "Small pipe (10 sq in)", "Large pipe (100 sq in)", "Small hatch (10 sq ft)", "Large hatch (30 sq ft)", and "User defined:". The "Small pipe" option is selected. The "User defined:" option has a text input field with "0." and a unit dropdown set to "in² area". There are three buttons on the right: "OK", "Cancel", and "Help".

For the runs with design leakage followed by an assumed containment failure 48 hours after the start of release, the increased leak rate was accounted for by manually calculating the leak rate based on the assumed hole size and containment pressure following the method outlined in RASCAL 4: Description of Models and Methods, Section 1.5.2., and adding this value to the design leak rate of 0.2 %/day. First, the mass flow rate for time step k is computed from:

$$MFR(k) = C \left(\frac{\pi D}{4} \right) \sqrt{2\rho(P_1(k) - P_2)}$$

where $C = 0.63$, D is the hole diameter, ρ is the density of the containment atmosphere, $P_1(k)$ is the containment pressure at time step k , and P_2 is atmospheric pressure. Then, the leakage fraction from the containment during time step k is computed from:

$$LF(k) = \frac{MFR(k)t}{\rho V_c}$$

where t is the duration of time step k in seconds and V_c is the containment volume. RASCAL default time steps are 15 minutes and the default containment volume for Vogtle is $2.7 \times 10^6 \text{ ft}^3$. Simplified static values of containment pressure and containment temperature of 40C (with containment sprays operating) and 200C (without containment sprays) were used as specified in Enclosure 1. The computed leak rate for the assumed containment failure amounts to an additional 0.18 %/day. To change the leak rate once containment failure occurs, a row was added to describe the event (leak rate 0.38 %/d) and the time set to 48 hours after the start of release.

PWR - Dry Containment Leakage or Failure

Pathway description: (optional; 60 character max)

Release height:

Release timings: Core release starts: 2014/01/30 08:00

Leak rate to atmosphere described by: ☒ Percent volume / time ☐ Containment pressure / hole size

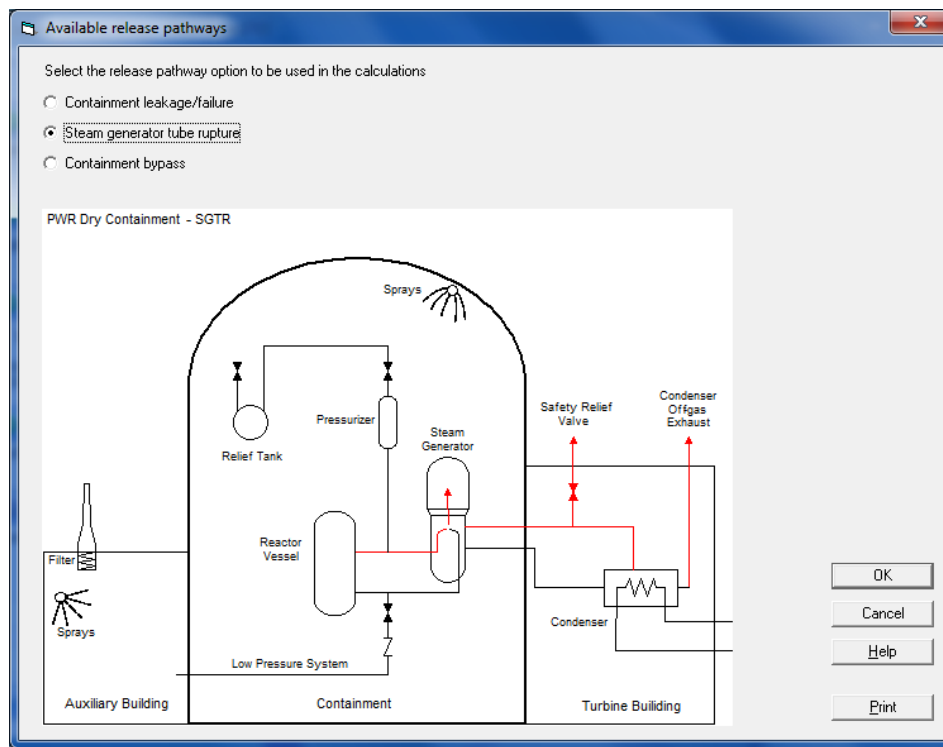
Date	Time	Event	Event setting
2014/01/30	08:00	Leak rate (% vol)	0.2 %/d
2014/01/30	08:00	Sprays	Off
2014/02/01	08:00	Leak rate (% vol)	0.38 %/d

Add Row Remove Row Sort Rows Clear All OK Cancel Help

Containment Spray - For each run, the sprays were set to either “On” or “Off” and remained so for the entire duration of the release. RASCAL 4: Description of Models and Methods describes the modeling of containment sprays.

Release Height - A release height of 10 m was used in all runs.

Steam Generator Tube Rupture - The SGTR release path has adjustable parameters for controlling the leak rate into tubes, location of rupture (above or below water line), steaming rate, and release point (safety relief valve or condenser exhaust).



As specified in Enclosure 1, for each of the runs with a SGTR release pathway, the leakage was assumed to be into 0.5 tubes, above the water level, at a steaming rate of 72,000 lbm/hr, and release through the safety relief valve. RASCAL assumes leakage into the steam generator from 1 failed tube to be equivalent to 500 gpm, so the leak rate was set to 250 gpm for the assumed 0.5 tube leakage.

Steam Generator Tube Rupture

Pathway description: (optional; 60 character max)

Release height: m

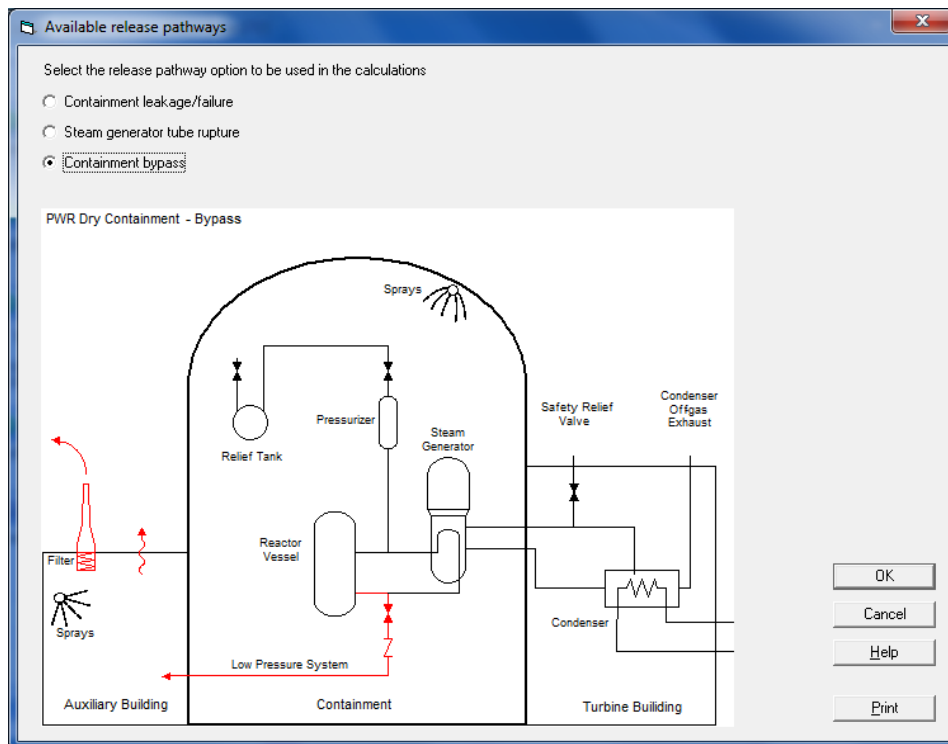
Release timings: Core release starts: 2014/01/30 00:00

Leak rate to atmosphere described by: Leak rate into SG and steaming rate

Date	Time	Event	Event setting
2014/01/30	00:00	Leak rate into SG	250 gal/min
2014/01/30	00:00	Rupture location	Above water level
2014/01/30	00:00	Steaming rate	72000 lb/h
2014/01/30	00:00	Release point	Safety relief valve

Buttons: Add Row, Remove Row, Sort Rows, Clear All, OK, Cancel, Help

Containment Bypass - The containment bypass release allows the user to control bypass flow rate and whether the release is filtered or not.



For the bypass runs, bypass flow rate was set to 1000 gal/min and filters either “On “ or “Off” as specified in Enclosure 1. Release height remained 10 m for all the runs.

Bypass of Containment

Pathway description: (optional; 60 character max)

Release height: m

Release timings: Core release starts: 2014/01/29 08:00

Leak rate to atmosphere described by: Bypass flow rate

Date	Time	Event	Event setting
2014/01/29	08:00	Bypass flow rate	1000 gal/min
2014/01/29	08:00	Filters	On

Buttons: Add Row, Remove Row, Sort Rows, Clear All, OK, Cancel, Help

Meteorology - RASCAL has a number of predefined weather conditions that include conditions for different seasons, time of day, and precipitation. The wind is assumed to be coming from the West in all predefined non site-specific weather datasets. Options exist to use actual observations and forecasts or Predefined Data for the site, but the following predefined weather conditions were selected for use in the modeling runs.

Meteorology	Stability Class	Wind Speed	Precipitation	Temperature	Relative Humidity
Summer - Afternoon - Calm	A	4 mph	No precip	85 F	40%
Summer - Afternoon - Windy	B	15 mph	No precip	85 F	40%
Winter - Rainy	D	10 mph	Rain	35 F	95%
Winter - Afternoon - Calm	C	4 mph	No precip	35 F	75%

Meteorology

Dataset Type

☐ Actual Observations and Forecasts

Create New

Edit Existing

Import

Delete

☒ Predefined Data (Non Site-specific)

☐ Predefined Data (Site Specific)

Available Datasets

Standard Meteorology

Summer - Afternoon - Calm

Summer - Afternoon - Rainy

Summer - Afternoon - Windy

Summer - Morning - Calm

Summer - Morning - Rainy

Summer - Morning - Windy

Summer - Night - Calm

Summer - Night - Rainy

Summer - Night - Windy

Winter - Afternoon - Calm

Winter - Afternoon - Windy

View Met Data

Description:

D stab 4 mph No precip 70 F 50% rh

Time period covered:

Dates will be adjusted to match release

OK Cancel Help

Weather conditions persist through the duration of the calculation unless the user specifies different meteorology, and the dose calculations are projected out to 96 hours from the start of release. For the Winter – Rain conditions it is unlikely these conditions would persist for 4 days straight, therefore, some practical assumptions were made. It was assumed the worst case precipitation would last for 24 hours from the start of release. The reasonableness of this assumption was validated by comparing the RASCAL modeling assumptions to the actual site weather conditions.

From the RASCAL 4.3 Workbook, for moderate rain, RASCAL assumes a precipitation rate of 0.04 in/hr to 0.2 in/hr, or approximately 1 to 4 inches/day. From Chapter 2.3 of the Vogtle Final Safety Analysis Report (FSAR), Table 2.3.2-1, the maximum 24 hour rainfall in the winter months is approximately 3.5 inches. Thus, 24 hours of moderate rain in the RASCAL model is a reasonable approximation of the worst case precipitation the site is likely to experience. The weather conditions persisting after the rain were specified as Winter – Afternoon – Calm. The other predefined weather conditions compare favorably to the climatological data tabulated in Chapter 2.3 of the FSAR.

Meteorological Processor - Data Entry

Enter data for: Vogtle

Retrieve Downloaded Data Change units or methods

Station ID	Type	Date	Time (24 h)	Wind Direct from (deg)	Speed (mph)	Stability Class	Precipitation	Air * Temp (deg F)	Air * Pressure (mb)	Dew Pt * (deg F)
VOGT										
LMFS1	Obs	2014/01/30	08:00	270	10.0	D	Rain	35		
KLKR	Obs	2014/01/31	08:00	270	4.0	C	No Precip	35		
KSSC	Obs	2014/02/01	00:00	270	4.0	C	No Precip	35		
WATS1	Obs	2014/02/02	00:00	270	4.0	C	No Precip	35		
KBNL	Obs	2014/02/03	00:00	270	4.0	C	No Precip	35		
KOGB	Obs	2014/02/04	00:00	270	4.0	C	No Precip	35		
KMNI										
KDYB										
KMKS										
KRBW										
KJZI										
KNBC										
41033										
KJYL										
KSVN										
KTBR										
KLHW										
KIFS										

*** Note:**
 For UF6 releases, air temperature, air pressure, and a measure of moisture are required.
 For all other releases, air pressure and moisture are not required. However, air temperature is required if the precipitation type is snow.

Calculate Doses - The dose calculations are being performed to provide site area boundary doses for comparison to the entry criteria for SAMGs. Since the meteorological conditions always assume the wind is coming from due West, an appropriate calculation distance is the distance from the release point to the Eastern site area boundary. From Chapter 2.3 of the Vogtle FSAR, Table 2.3.4-2, the assumed distance to the Eastern boundary ranges from approximately 0.7 to 1.15 miles (NE to SE direction). Therefore, dose projections at 1 mile are used to compare against entry conditions into the SAMGs.

Since dose projections are only needed at 1 mile, the *Distance of Calculation* was set to "Close-in only" which computes doses for distances of 0.1, 0.2, 0.3, 0.5, 0.7, 1.0, 1.5, and 2.0 miles for computational efficiency.

The end of calculations was set to 96 hours from the start of release, consistent with U.S. Environmental Protection Agency Protective Action Guides (EPA PAG) dose metrics.

RASCAL 4.3 includes two sets of inhalation dose conversion factors, i.e., dose conversion factors from the International Commission on Radiological Protection (ICRP) 26 (Federal Guidance Report (FGR) 11) and ICRP-60 (FGR-13). In general, the differences in CEDE dose conversion factors are small compared to the uncertainties in the source term and dispersion. However, for comparison to EPA PAG doses, the ICRP-60 inhalation dose conversion factors must be used and was selected for all runs. See RASCAL 4: Description of Models and Methods, Section 2.7 and the RASCAL 4.3 User's Guide for a more detailed discussion of these dose conversion factors.

Start the Calculations

Specify options and title for this set of calculations, then OK to begin calculations.

Distance of calculation:

- ☐ Close-in + out to 10 miles (16 km)
- ☐ Close-in + out to 25 miles (40 km)
- ☐ Close-in + out to 50 miles (80 km)
- ☐ Close-in + out to 100 miles (160 km)
- ☒ Close-in only

Using close-in distances in miles:

0.1, 0.2, 0.3, 0.5, 0.7, 1.0, 1.5, 2.0

☒ Defaults ☐ User defined

Start of release to atmosphere:

2014/01/30 08:00 (from release pathway definition)

End calculations at:

☒ Start of release to atmosphere plus: 96 hours

☐ User specified time: 2014/02/03 08:00

Inhalation dose factors to use in calculations:

☐ ICRP 26/30 ☒ ICRP 60/72

Case information:

Title: Run 1 (required - max 45 characters)

Case description: (optional - max 600 characters)

Analyst: ☒ Dose Analyst

Detailed Results - When the calculations are completed the Maximum Dose Values for the Close-In dose are displayed. The values of Total Effective Dose Equivalent (EDE) and Thyroid Committed Dose Equivalent (CDE) at 1 mile were used to determine entry into SAMGs with the results provided in the table in Enclosure 1.

Source Term to Dose - [Run 9.std]

File Settings Nuclide Data Viewer Site / Facility Data Viewer Help

Event Type

NPP Reactor

Event Location

Vogtle - Unit 1

Source Term

☐ Import

Long Term Station Blackout (SOARCA)

Release Path

PWR Dry

Meteorology

Predefined Conditions

Calculate Doses

Detailed Results

Save Case

Maximum Dose Values (rem) - Close-In

Dist from release	0.1	0.2	0.3	0.5	0.7	1.	1.5	2.
miles	0.1	0.2	0.3	0.5	0.7	1.	1.5	2.
(kilometers)	(0.16)	(0.32)	(0.48)	(0.8)	(1.13)	(1.61)	(2.41)	(3.22)
Total EDE	1.0E+03	4.0E+02	2.4E+02	1.2E+02	7.9E+01	4.8E+01	2.7E+01	1.7E+01
Thyroid CDE	3.2E+03	8.8E+02	4.1E+02	1.5E+02	8.2E+01	4.1E+01	1.9E+01	1.0E+01
Child Thyroid CDE	6.1E+03	1.7E+03	7.8E+02	2.9E+02	1.6E+02	7.9E+01	3.6E+01	2.0E+01
Inhalation CEDE	3.6E+02	9.5E+01	4.4E+01	1.6E+01	8.3E+00	4.0E+00	1.7E+00	8.7E-01
Cloudshine	1.0E+00	5.3E-01	3.3E-01	1.6E-01	1.1E-01	6.1E-02	3.0E-02	1.7E-02
4-day Groundshine	6.9E+02	3.1E+02	1.9E+02	1.0E+02	7.0E+01	4.4E+01	2.5E+01	1.6E+01
Inter Phase 1st Yr	7.3E+03	3.3E+03	2.1E+03	1.1E+03	7.6E+02	4.7E+02	2.7E+02	1.7E+02
Inter Phase 2nd Yr	4.1E+03	1.8E+03	1.2E+03	6.3E+02	4.2E+02	2.6E+02	1.5E+02	9.4E+01

Notes:

- Doses exceeding 2013 EPA Interim PAGs are underlined.
- Early-Phase PAGs: TEDE - 1 rem
- Thyroid CDE - adult thyroid dose from exposure to all radionuclides - as related to 1992 EPA PAGs (no interim PAG - not underlined)

Value displayed: ☒ Close-in dose ☐ Doses to miles ☐ Criticality shine dose

Display units: ☒ English ☐ Metric

Case Summary Source Term **Maximum Dose Values**

Save Case - All the modeling runs in Enclosure 1 were saved for recall and verification purposes.