****

**SNAP/RADTRAD 4.0 Workshop**

**RADTRAD Exercises**

**2018 UAE Users Group Meeting**

**March 25-29, 2018**

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# Exercise 1 – Instructions for Setting up a Simple RADTRAD Fuel Handling Accident (FHA) Model

**Purpose:**

The purpose of this exercise is to set up a simple Fuel Handling Accident model.

**Accident Description:**

A fuel assembly is assumed to be dropped and damaged during refueling, along with some of the fuel rods from a neighboring assembly. Analysis is performed with assumptions selected so the results are bounding for the accident occurring either inside containment or in the fuel building. No credit for containment isolation or filtration by the fuel pool ventilation system is taken.

**Description:**

* A source from a representative PWR plant will be used.
* This model will represent a containment with a source, an environment, and a single leak to the environment.
* This model is set up to investigate the resulting doses to the exclusion area boundary (EAB) and low population zone (LPZ) at the end to the accident.

**Detailed Steps:**

|  |
| --- |
| Overview of Steps |
| 1. Preliminary Setup (Open to Create a New Model) |
| 2. Set up a Simple RADTRAD Model |
| 3. Run SNAP 'Model Check' and Fix Any Errors |
| 4. Open the SNAP Configuration Tool and Start the SNAP Server |
| 5. Run the Simulation |
| 6. Check Results. Make Corrections if Necessary. |

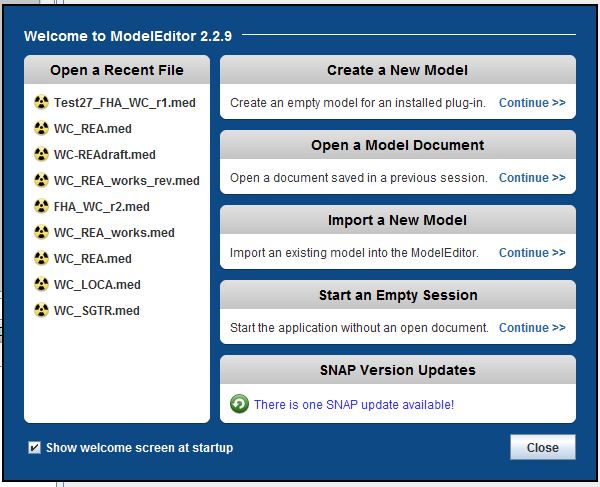
**Step 1** – Preliminary Setup (Open to Create a New Model)

1. Open the SNAP Model Editor to Create a New Model:

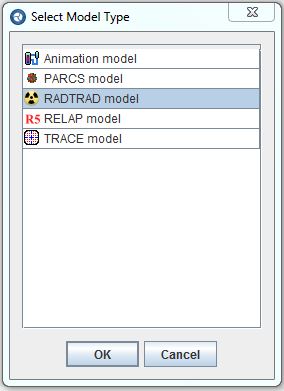
* 1. Start the SNAP Model Editor from the start button:

C:\Users\dianem\Desktop\Diane's work\RADTRAD4\RADTRAD_icon.JPG Model Editor Icon

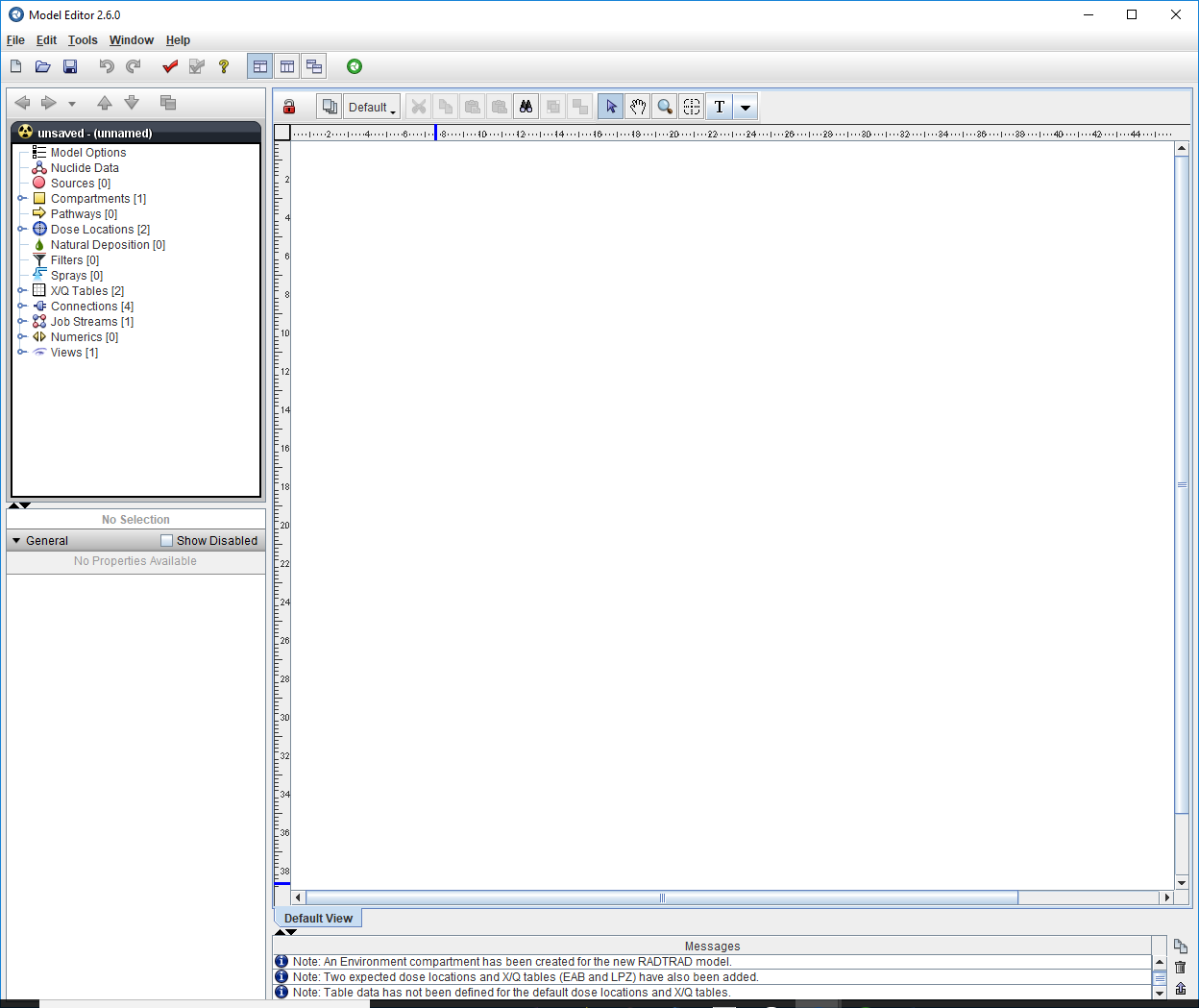
* 1. Click on the “Create a New Model” option:



and select the RADTRAD model type to start the Model Editor:



1. The following SNAP windows and model editor diagram should appear:



View Window

Properties Window

Navigator Window

1. Verify that the default used for model units is the British system.

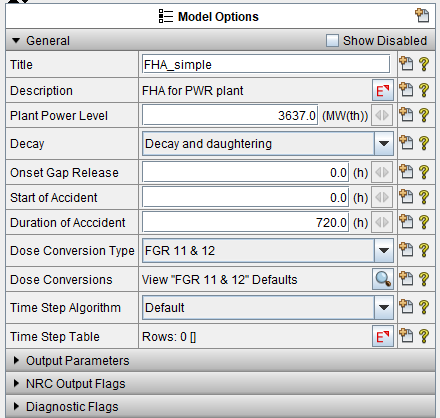
* To do this, once the model editor is open, right click on the black title bar, scroll down to “Engineering Units” and choose “British.”

**Step 2** – Set up the RADTRAD FHA Model

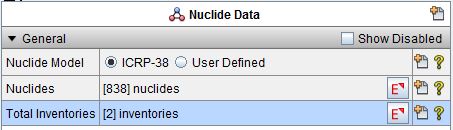
1. The common parameters used for accident analysis for the reference plant are listed in Table 1-1, Common Input Values (see tables at end of this document). The additional assumptions used for the fuel handling accident (FHA) for the reference plant are listed in Table 1-2, Additional Assumptions Used for Fuel Handling Accident Analysis.

2. Detailed Steps

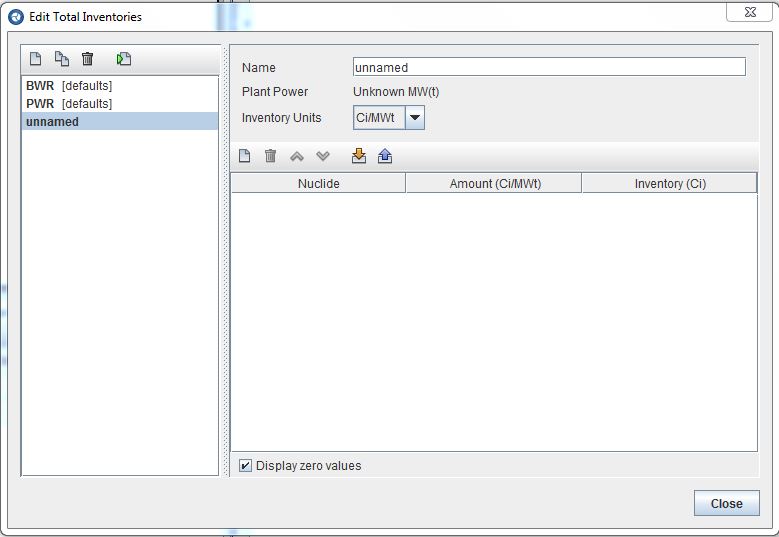
* 1. Setting Model Options
  + Click on “Model Options” in the Navigator Window, and a Properties Window similar to the following will appear:



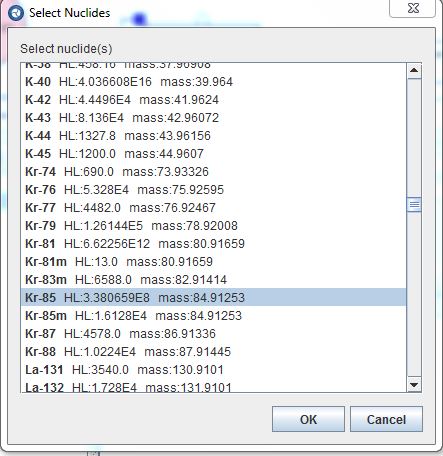
* + In the Properties Window set the unknown values for the model as shown above. The dropdown values should be set as indicated.
  1. Setting Nuclide Data
  + Click on “Nuclide Data” in the Navigator Window, and the following Nuclide Data window appears:



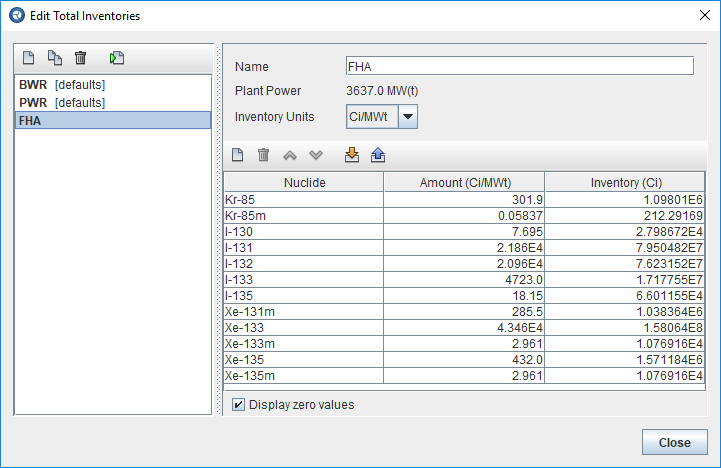
* + Choose the button next to Total Inventories, and an “Edit Total Inventories” Window similar to the following will appear:



* + Click on the “Create a new inventory” ( ) button, and a new inventory named “unnamed” will appear.
  + Click on the “Add a nuclide to the inventory” ( ) button, and the following screen will result. Choose multiple nuclides by pressing the CTRL key or Shift and click on your keyboard.

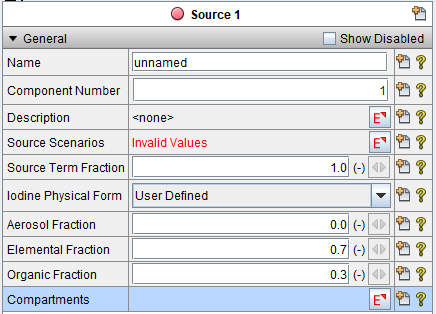


* + In the “Edit Total Inventories” Window, set the unknown amounts for the nuclides as shown (screenshot is on the following page). The inventories for each nuclide will be calculated by the code as they are entered. The values are also listed in Table 1-2. Note that a 76 hour decay period is applied to the inventory.

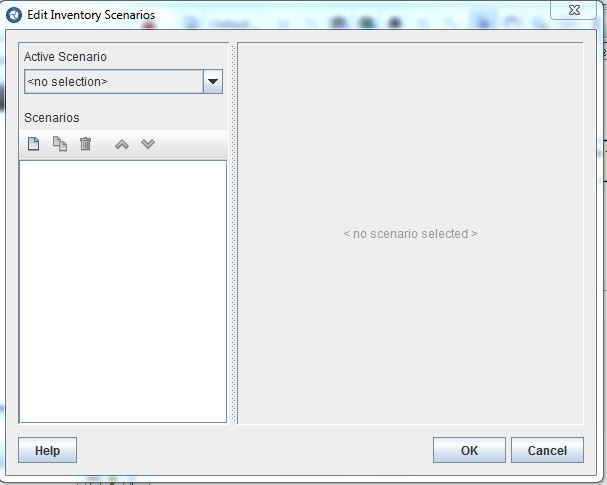


c) Setting up a Source

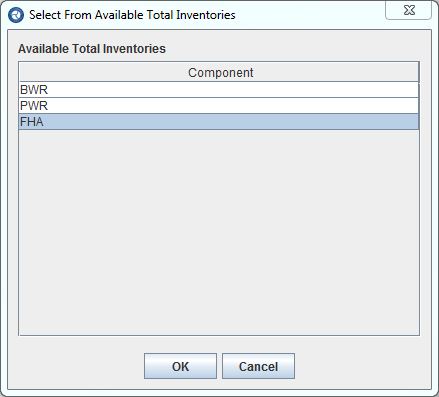
* + In the Navigator Window, right click on “Sources (0)” and select “New”. This will cause “Source 1” to appear under “Nuclide Definitions” in the window. In the Name text box, enter “FHA source.”



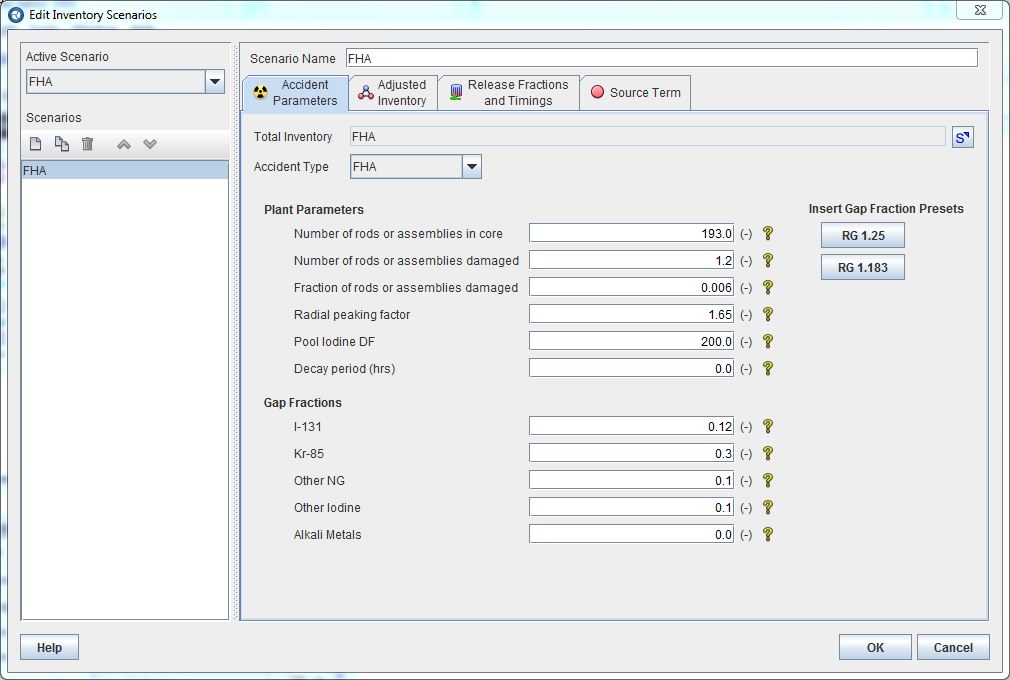
* Use 1.0 for the Source Term Fraction and Iodine chemical form fractions as indicated above.
* Click the  button next to Source Scenarios and the following screen results:



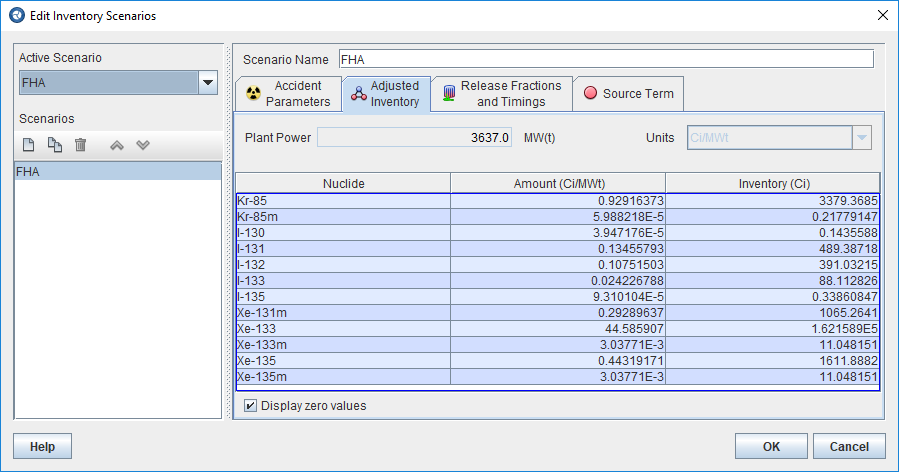
* Click the  button, and select the FHA total inventory we created above.



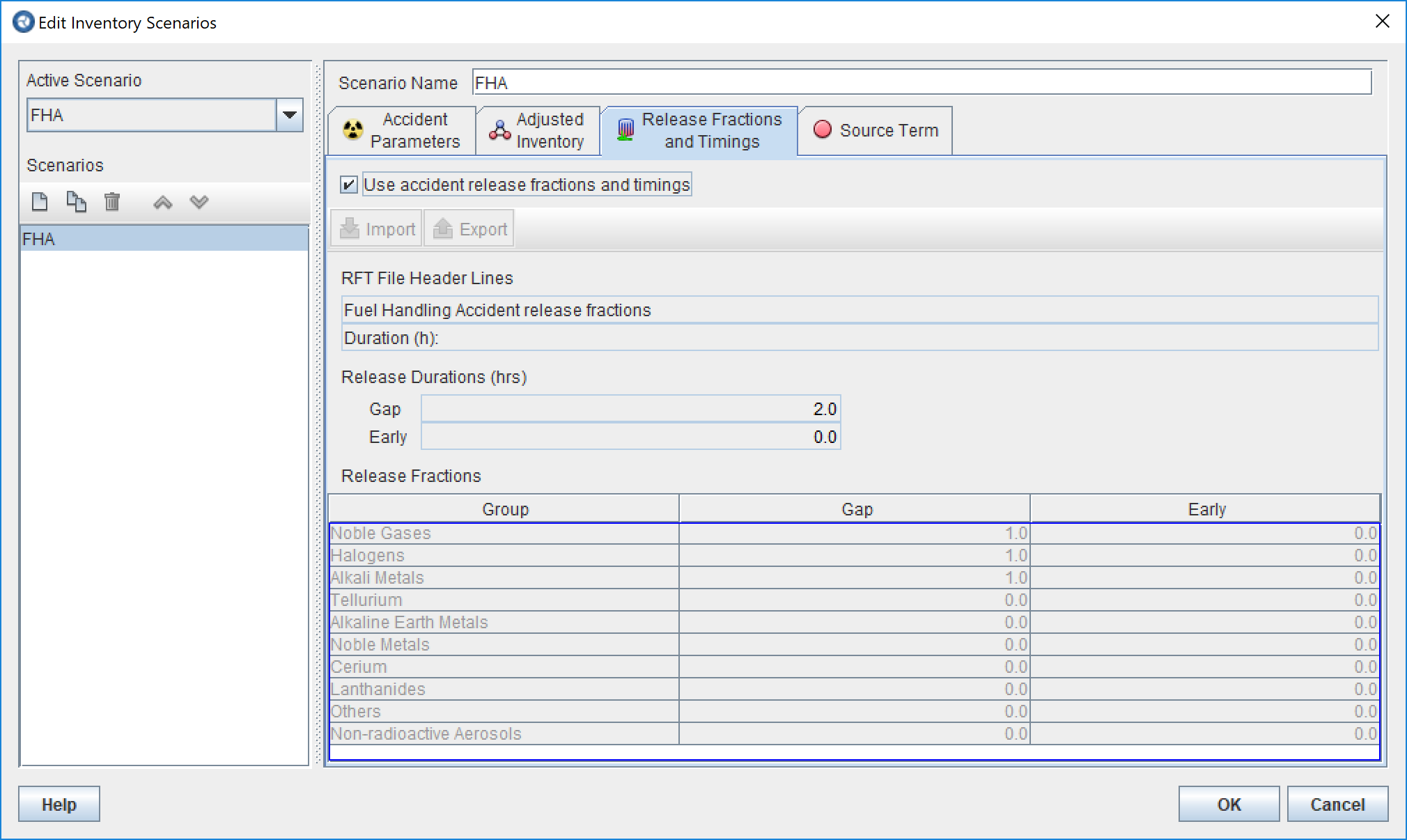
* Enter data as required into the Edit Inventory Scenario window as shown below. Note that decay is included in the source, so that the decay period listed here is set to 0.



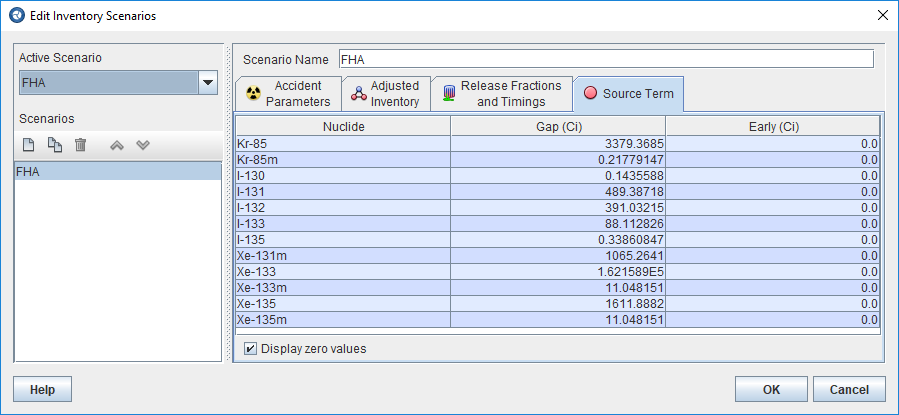
* On the Accident Parameters screen, input Plant Parameters and Gap Fractions as indicated above. The “Fraction of rods or assemblies damaged” will be calculated from the other information input.
* Title the Scenario Name “FHA.”
* Review the resulting Adjusted Inventory by clicking on the tab:



* Under the Release Fractions and Timings tab, verify the values of 1.0 for Noble Gases, Halogens and Alkali Metals gap release fractions. Also, confirm that the gap release time is 2 hours. We are using the SNAP/RADTRAD gap release model for this release.

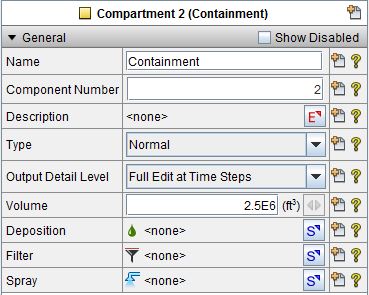


* Click on the Source Term tab and review inventories.



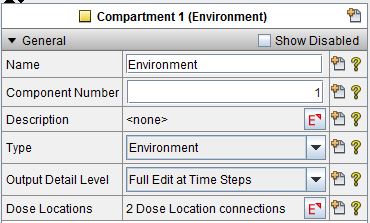
d) Setting up Containment Compartment

* Similarly for “Compartments,” create a new compartment and name it “Containment”. Under “Output Detail Level,” choose “Full Edit at Time Steps.
* Input information from Table 1-1 as before. Note that the Normal compartment type is used.
* Deposition, filters and sprays are not being used in this problem.

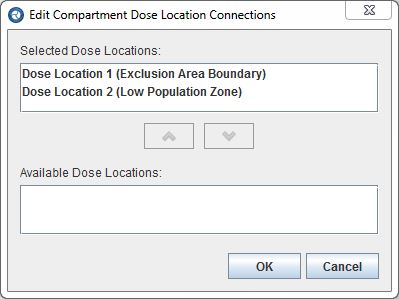


e) Environment Compartment

* The Environment compartment is created automatically. Under “Output Detail Level,” choose “Full Edit at Time Steps. The Environment Compartment Properties View should appear as follows:

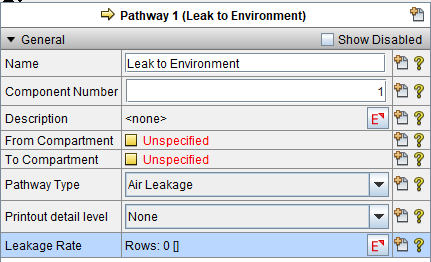


* Click on the  button next to Dose Locations, and verify the dose location connections:

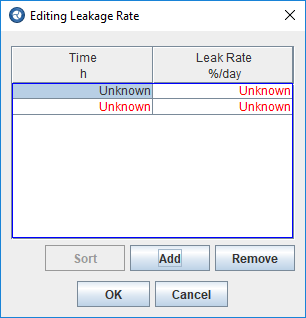


f) Setting up a Leak to the Environment

* Create a “New” Pathway. Title it “Leak to Environment.” Set the Pathway Type to “Air Leakage.”



* Enter the Leakage Rate by clicking  next to Leakage Rate. The following screen will appear blank. Choose “Add” twice to get the following:



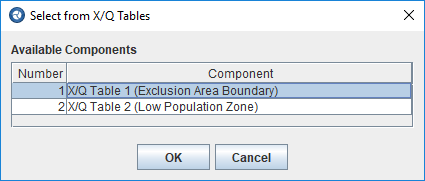
* Now enter time date of 0, 720 hours and a leakage rate of 1.0E12 for both times. This leakage rate value essentially bypasses the containment.
* The “From Compartment” and “To Compartment” sections will be automatically input when the components are connected in the view window in a later step.

g) Setting up Dose Locations

* Under “Dose Locations,” click on each dose location (EAB and LPZ) and verify the breathing rates that are automatically input. Note that you need to switch to SI Units.

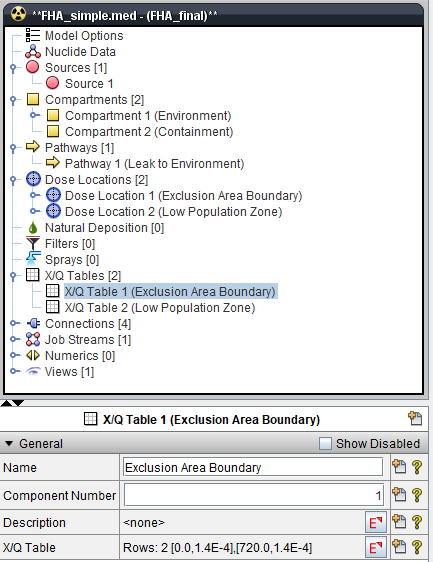
|  |  |
| --- | --- |
|  |  |

* Click on the C:\Users\dianem\Desktop\Diane's work\RADTRAD4\training\S.JPG next to “X/Q Table”, and the following screen results in order to choose the appropriate table for the dose location being input. The X/Q tables have been automatically chosen for the Environment.



h) Reviewing X/Q Tables

* Under “X/Q Tables,” note that there is a X/Q table automatically defined for the Exclusion Area Boundary and Low Population Zone. X/Q data needs to be entered.
* Click the “X/Q Table” node for the EAB, click on the  and input the information from Table 1-1 for EAB. The screenshot below shows the appearance of the Navigator and Properties Views after the X/Q data is entered.



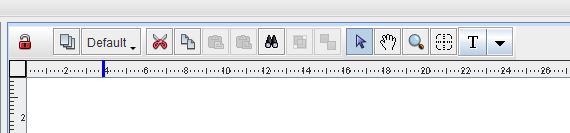
* Repeat for the LPZ (Data is listed in Table 1-1). Resulting screenshots are shown below.

|  |  |
| --- | --- |
|  |  |

1. Components now are added to the default view and connected.

Components can be added using the menus or dragged to the default view window.

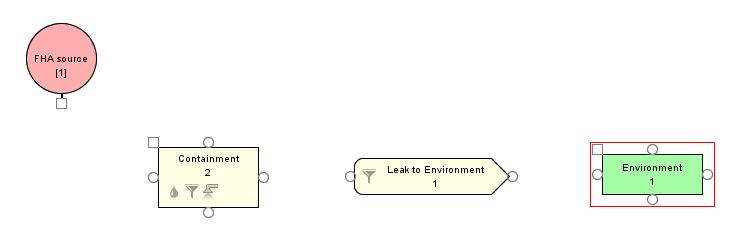
“Connections” are added to the model via the connection tool () in the View Window.



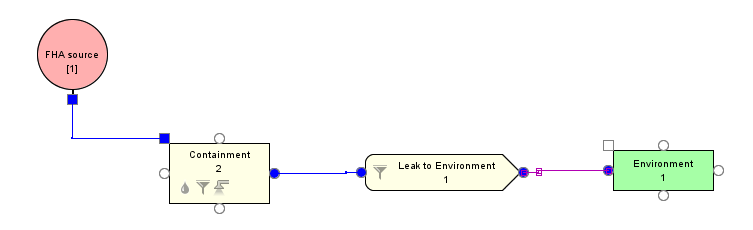
* Right-click in the Navigator Window on Source 1 and choose “Add to View.”
* An icon for the source will appear in the View Window.



* Repeat this procedure for the containment and environment compartments and the pathway from the containment to the environment. Either use the menus or drag and drop.

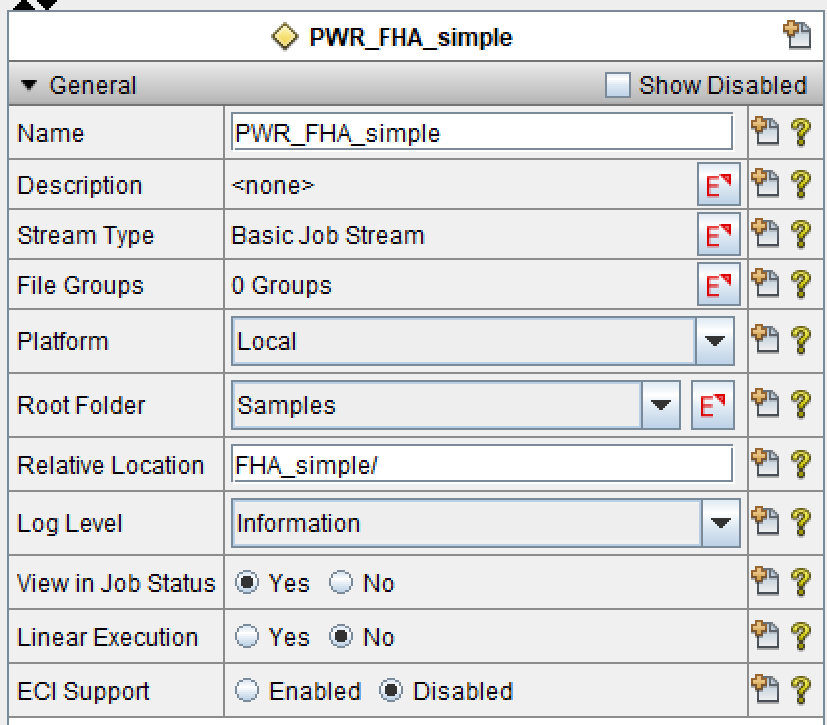


* Once the View Window contains the four components, select the ‘connection tool’ icon  from the toolbar. Now click on the connection points between the components as shown below.



h) Setting the Job Stream

* In the Job Stream Properties Window, rename Simple\_Stream to PWR\_FHA\_simple.
* Define the Root Folder for your machine
* Define a Relative Location under the Root Folder for the output. Note that this is computer-specific.
* An example screenshot of the PWR\_FHA\_simple job stream window is given below:

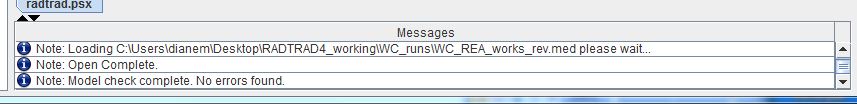


**Step 4** - Run SNAP 'Model Check' and Fix Any Errors

* At the top of the Model Editor screen, under “Tools,” select “Check Model.”



* If any errors occur, a window will open listing the deficiencies.
* If no errors occur, a note in the “Messages” area (bottom right of the Model Editor screen) which states “Note: Model check complete. No errors found.”

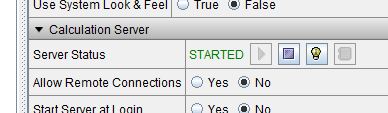


**Step 5** - Open the SNAP Configuration Tool and start the SNAP server

Prior to running the exercise, assure yourself that the SNAP configuration tool is running and open to a starting point as follows:

Open the SNAP Configuration Tool and start the SNAP server:

* 1. Start the SNAP Configuration Tool under Tools\Configuration Tool. (C:\Users\dianem\Desktop\Diane's work\RADTRAD4\training\config_tool.JPG)
  2. On the “Server Status” option click  to start the calculation server (if the server is not running), then close the SNAP Configuration Tool (click  on the window).

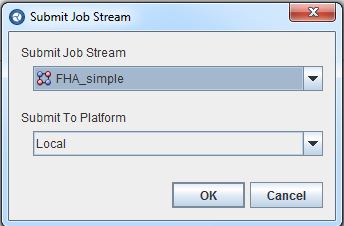


**Step 6** - Run the Simulation

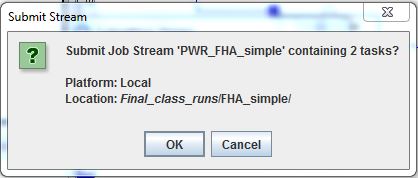
Once any errors have been corrected in the model, select “Tools” and “Submit Job…” from the toolbar at the top of the Model Editor screen.



* A submit job stream window will appear. Click “OK.”

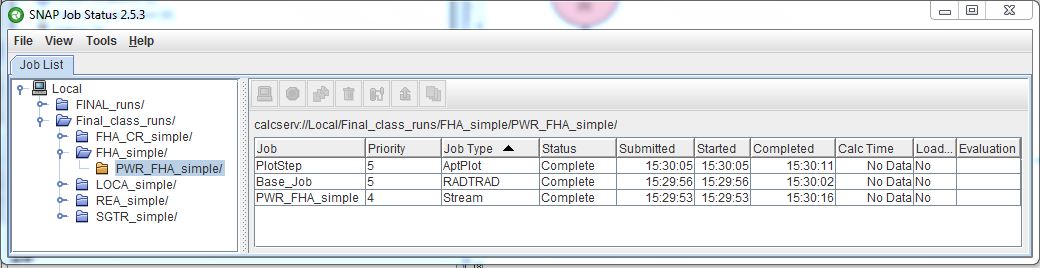


* A second job stream window will appear. Click “OK.”



**Step 7** - Check Results, Make Corrections if Necessary.

* When the job has been submitted, a SNAP Job Status window will appear. Once the job is completed, the output can be viewed by clicking on the  icon and selecting “Output File.”



* Verify that the dose results are reasonable. Make any necessary corrections, rerun the simulation and check results again.

**Results:**

|  |  |  |  |
| --- | --- | --- | --- |
| Worst Two-Hour Doses (Exclusion Area Boundary) | | | |
| Time (hr) | Whole Body (rem) | Thyroid (rem) | TEDE (rem) |
| 0.0-2.0 | 0.16311 | 26.663 | 0.97912 |

|  |  |  |  |
| --- | --- | --- | --- |
| Final Doses (Low Population Zone) | | | |
| Time (hr) | Whole Body (rem) | Thyroid (rem) | TEDE (rem) |
| 720.0 | 0.052428 | 8.5704 | 0.31472 |

# Exercise 2 – Adding a Control Room (FHA with Control Room)

**Purpose:**

The purpose of this exercise is to add a control room to the FHA model developed in Exercise 1.

**Description:**

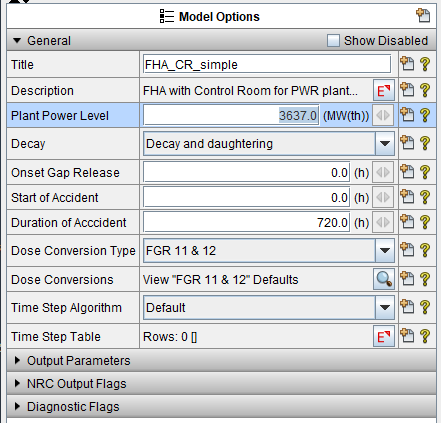
* This model will have three compartments (containment with a User Defined source, an environment and a simple control room), with
* a leak to the environment from the containment, and unfiltered pathways between the environment and control room.
* Decay with daughter production is included in the simulation.
* The FHA modeled does not credit the emergency mode of operation for the control room to meet the acceptable dose (from 10CFR50.67), so only the normal mode of operation is modeled in this model.
* This model is set up to investigate the resulting doses to the exclusion area boundary (EAB) and low population zone (LPZ) and Control Room at the end to the accident.

**Input Values:**

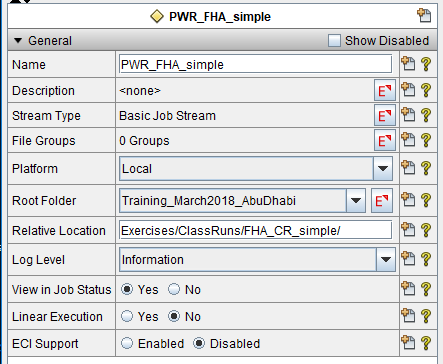
* + 1. From Exercise 1, Table 1-1 input values are used. Begin with the model resulting from Exercise 1.
    2. Additional input values for Exercise 2:
* Details for the control room parameters are included in Table 2-1. The data for the normal mode of operation is used in this model.
* The assumptions used for the fuel handling accident (FHA) for the reference plant are listed in Table 1-2. Control room X/Q inputs are included in Table 2-1 for the control room parameters.

**Detailed Steps:**

* + - 1. Save the FHA model as FHA\_CR\_simple. This will ensure that the previous model remains unchanged. Correspondingly, change the following:
* Model Options\General\Title to FHA\_CR\_simple
* Model Options\General\Description to FHA for simple PWR with a control room.

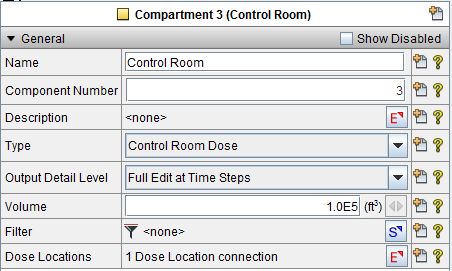


* Job Streams\Name to PWR\_FHA\_CR\_simple
* Consider changing the relative location of the output under Job Streams by appending the name of the Job Stream to the end of the relative location, i.e., Exercises\FHA\_CR\_simple. This creates a unique folder for the resulting output files.



1. **Additional Compartments**

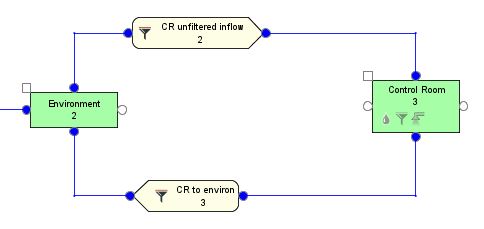
Add a control room as a third compartment, with the “Type” being “Control Room Dose.” Use values listed in Table 2-1. Add the Control Room component to the default view.



We will discuss the Dose Locations connection later. For now, leave as 0.

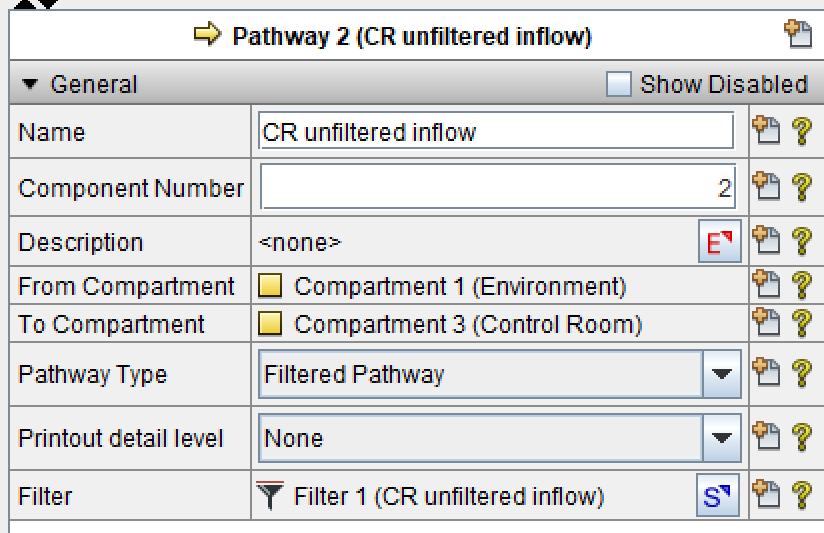
1. **Additional Pathways**
2. For our reference plant, only the normal mode of operation for the control room is modeled for this accident. So the following two pathways should be created and added to the default view:
3. an unfiltered pathway from the Environment to the Control Room named “CR unfiltered inflow,”
4. Unfiltered exhaust pathway for the Control Room to the Environment named “CR to environ.”

See Exercise 1, Step 2, section 2.f for details on setting up a new pathway.



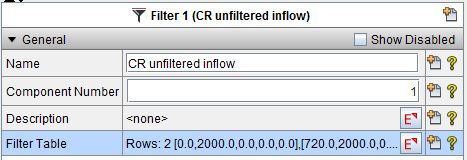
1. Note that to change the direction of a flow pathway in the View Window, right-click on the pathway icon of interest, select Drawn Orientation and select Left. Other orientations are also available. Note that the Selection Tool needs to be active.

2. We will model these new pathways as filtered pathways with 0% removal rates in order to have the ability to input the flow rates which are indicated in the input information. The filter table input requires flow rates and removal rates as a function of time. Therefore, change the Pathway Type to Filtered Pathway for both new pathways.



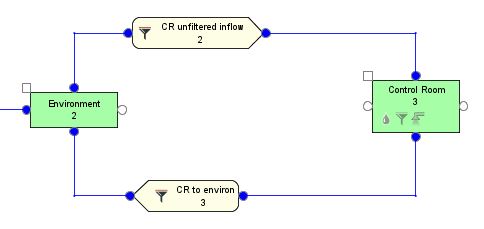
1. **Additional Filters**

1. In the Navigation Window, right click on “Filter (0)” and select “New.” This will cause “Filter 1” to appear in the Properties Window. Add a second filter in the same manner:



2. The two filters represent:

1. Unfiltered flow from the Environment to the Control Room,
2. Control Room flow to the Environment.



F2

F1

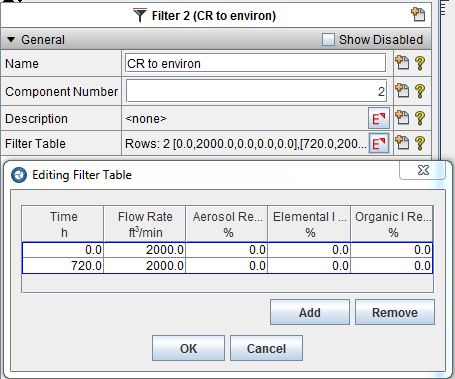
Filters should be named consistent with the flow pathway name to minimize the possibility of errors.

Note that you can annotate the model by using the Text Annotation tool. Click on the  icon, and then select Annotation->Text Annotation. A small text box will appear which can be filled in.

In order to determine the values for the filter tables, the information for normal ventilation flowrates from Table 2-1 was consolidated into the following:

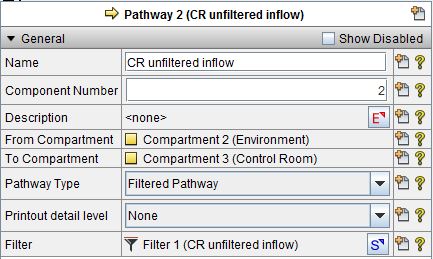
|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Time (hr) | F1  (ft3/min) | F2  (ft3/min) | Aerosol Removal % | Elem. I Removal % | Organic I Removal % |
| 0 | 2,000 | 2,000 | 0 | 0 | 0 |
| 720 | 2,000 | 2,000 | 0 | 0 | 0 |

The filter tables are accessed by clicking on the  next to Filter Table as shown in the following screenshot:

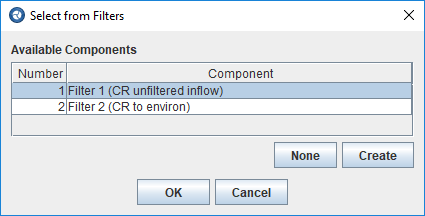


3. Create one filter table for each filter indicated in the above table. Enter the filter name using the pathway name for clarity.

* + 1. Once the filter tables have been created, ensure that the appropriate filter table has been referenced in the two pathway properties windows. This step is completed by clicking on the Select icon and selecting the appropriate filter as illustrated in the screenshots below.

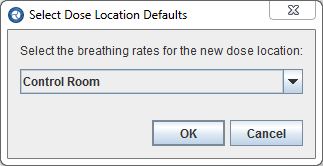


Select Icon

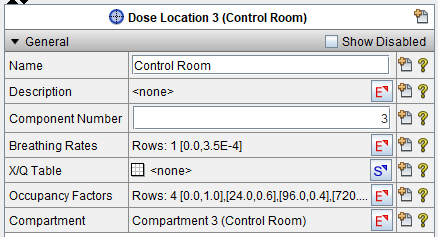


1. **Additional Dose Location**

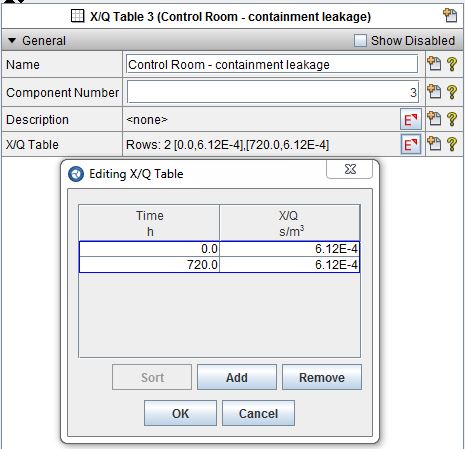
A third Dose Location will also need to be added for the Control Room. When a new dose location is selected, the following screen results requesting that you select a dose location so default values for occupancy factors and breathing rates can be set:



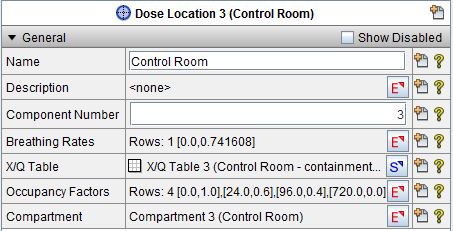
* + 1. When “Control Room” is selected, a Breathing Rate table is automatically specified.
    2. Name the Dose Location “Control Room,” and under “Compartment,” select “Compartment 3 (Control Room)” to connect the information for Dose Location 3 to the Control Room. Switch the units from British to SI so that the breathing rate is displayed in a more recognizable value.

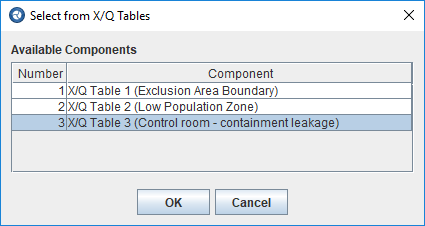


* + 1. Input a third X/Q table with the Control Room X/Q values found in Table 2-1. The resulting table should look as follows:

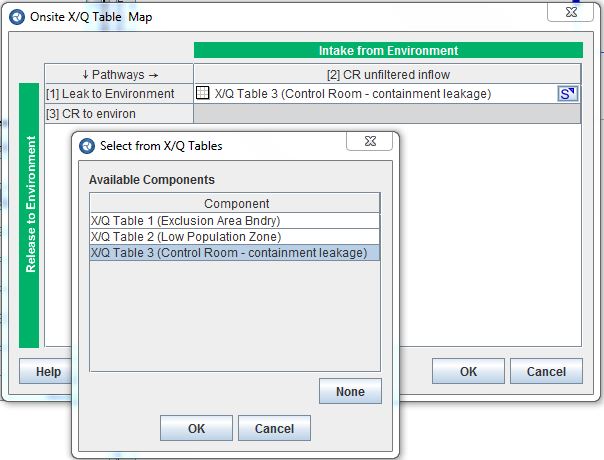


* + 1. Now go back to Dose Location 3 (Control Room), click on X\Q Table and select X\Q Table 3 (Control Room) to complete entering a new dose location.

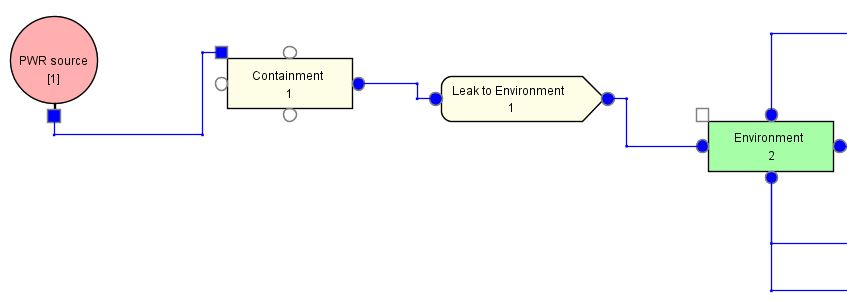




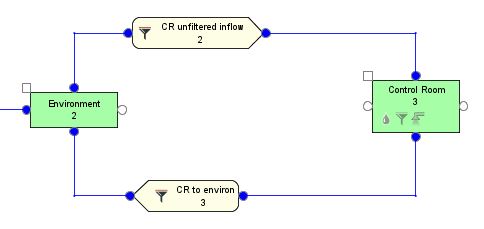
* + 1. Go back to the Environment compartment and enter the CR X/Q table to the “Onsite X/Q Tables.”



* + 1. Compare your model in the View Window with that shown.



Fuel Handling Accident (FHA) RADTRAD Model



RADTRAD Control Room Model

* + 1. Check the model, run the simulation and compare the results with those listed below.

**Results:**

|  |  |  |  |
| --- | --- | --- | --- |
| Worst Two-Hour Doses (Exclusion Area Boundary) | | | |
| Time (hr) | Whole Body (rem) | Thyroid (rem) | TEDE (rem) |
| 0.0-2.0 | 0.16311 | 26.663 | 0.97912 |

|  |  |  |  |
| --- | --- | --- | --- |
| Final Doses (Low Population Zone) | | | |
| Time (hr) | Whole Body (rem) | Thyroid (rem) | TEDE (rem) |
| 720.0 | 0.052428 | 8.5704 | 0.31472 |

|  |  |  |  |
| --- | --- | --- | --- |
| Final Doses (Control Room) | | | |
| Time (hr) | Whole Body (rem) | Thyroid (rem) | TEDE (rem) |
| 720.0 | 0.028920 | 116.05 | 3.5781 |

**Conclusion:**

The LPZ and EAB doses are the same as those in exercise 1, which does not contain a control room.

# Exercise 3 – Rod Ejection Accident

**Purpose:**

The purpose of this exercise is to simulate a rod ejection accident for a reference plant. We will begin with the model used for Exercise 2.

**Accident Description:**

It is assumed that a mechanical failure of the pressure housing of a control rod mechanism has occurred, resulting in the ejection of a rod cluster assembly and drive shaft. As a result, it is assumed there is some fuel cladding damage and a small amount of fuel melt. Due to the pressure differential between the primary and secondary systems, it is assumed that there is steam generator tube leakage, and radioactive reactor coolant passes from the primary into the secondary system. A portion of this is released to the outside atmosphere through the ARVs and/or the main steam safety valves. Finally, radioactive reactor coolant is discharged to the containment via the spill from the opening in the reactor vessel head. A portion of this radioactivity is released through containment leakage to the environment.

**Radiological Calculations:**

The analysis uses the analytical methods and assumptions outlined in RG 1.183, Appendix H. There are two pathways considered for radiological release, release from the containment to the atmosphere, and release via primary-to-secondary accident-induced SG tube leakage to the four SGs. Each release path is evaluated independently as if it were the only pathway available. These calculations will consider the first pathway only.

**Description:**

* This model will have three compartments (containment with a User Defined source, an environment and a control room), with
* a leak to the environment from the containment, and various filtered and unfiltered pathways to the environment and the control room.
* The REA modeled does credit the emergency mode of operation for the control room to meet the acceptable dose (from 10CFR50.67), so the emergency mode of operation is added to this model.
* Decay and daughter production is included in the simulation.
* This model is set up to investigate the resulting doses to the exclusion area boundary (EAB) and low population zone (LPZ) and Control Room at the end to the accident.

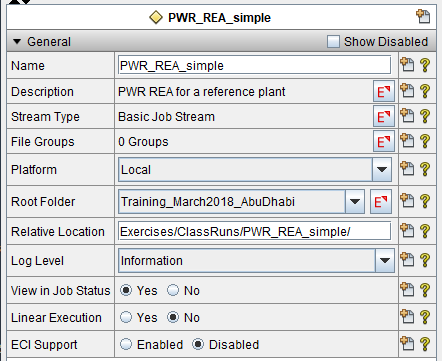
**Input Values:**

* + 1. From Exercise 1, Table 1-1 input values are used. Begin with the model resulting from Exercise 2.
    2. Additional input values for Exercise 3:
* The physical model for the Rod Ejection Accident (REA) is similar to that for the Fuel Handling Accident (FHA), with the addition of the emergency mode of operation for the control room added to the model.
* Numerically, this accident uses a different source and various other numerical inputs.
* The assumptions used for the Rod Ejection Accident (REA) for the reference plant are listed in Table 3-2.

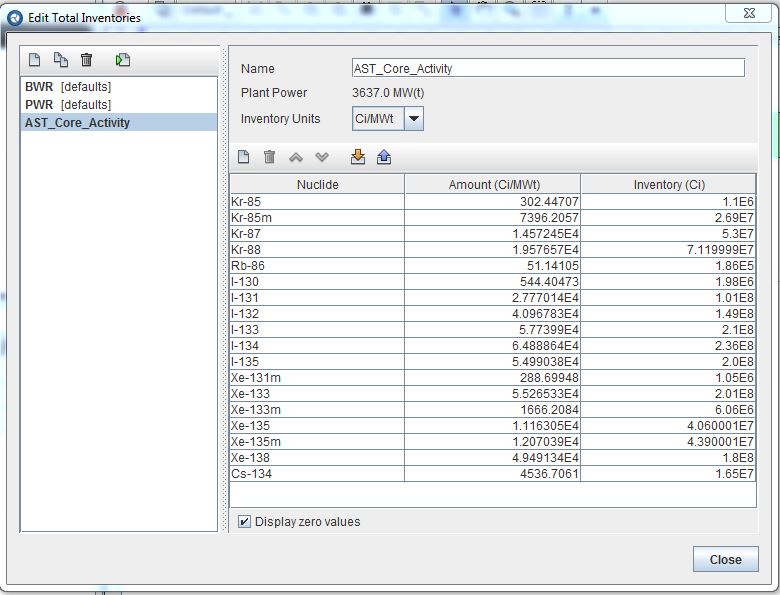
**Detailed Steps:**

* + - 1. Save the FHA model as REA. Correspondingly, change the following:
* Model Options\General\Title to PWR\_REA\_simple
* Model Options\General\Description to PWR REA simple for reference plant
* Job Streams\Name to PWR\_REA\_simple
* Job Streams\Description to PWR REA simple for a reference plant
* Consider changing the relative location of the output under Job Streams by appending the name of the Job Stream to the end of the relative location, i.e. RADTRAD\PWR\_REA\_simple. This creates a unique folder for the resulting output files.

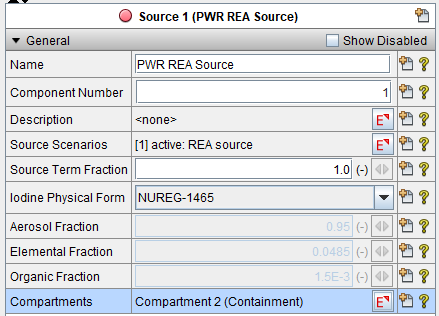
The resulting Job Stream Properties Window will look similar to the following:

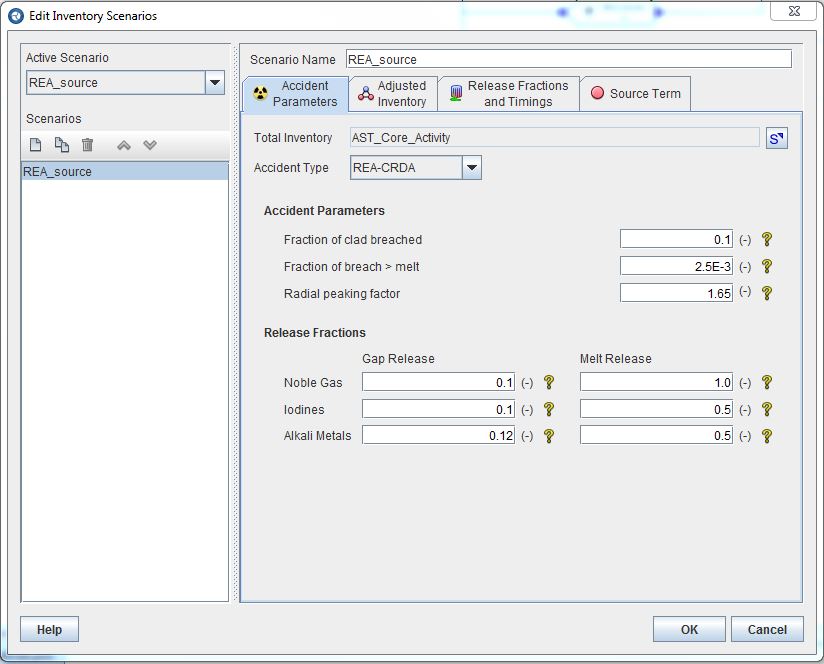


* + - 1. Using the model from Exercise 2 as a base, the following inputs need to be changed to those given in Table 3-2:
* Inventory under Nuclide Data – create a new inventory and title it “AST Core Activity”. Input data from the Core Activity column from Table 3-1. See Exercise 1, Step 2, item 2b for details on adding a new inventory.

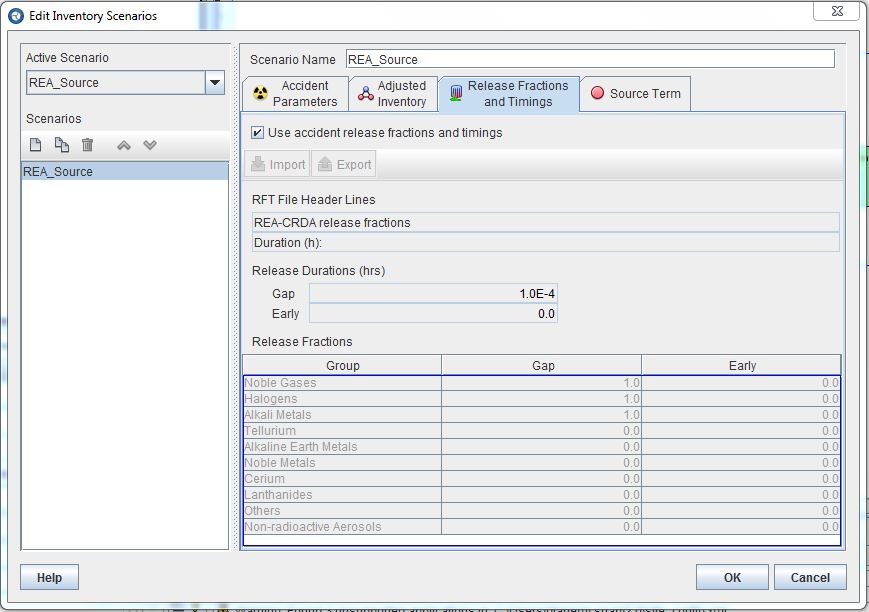


* Use SNAP editing features to list the nuclides in the same order as in Table 3‑1 to make it easier to add activity information.
* Select source scenarios and define a REA\_Source scenario. Change input as indicated in the following screenshots. Source1\Iodine Physical Form should be changed to “NUREG-1465”

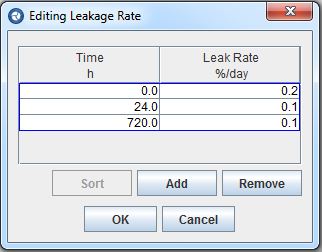




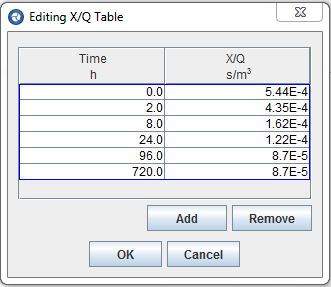
* Release Fractions and Timings tab under Sources\Edit Inventory Scenarios should indicate the following (if “use accident release fractions and timings” button is checked, the same inputs are generated as defaults):



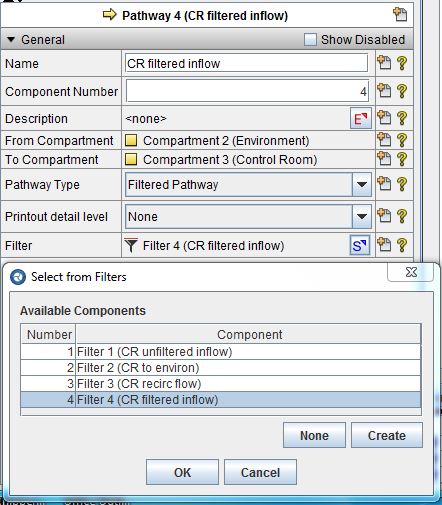
* Leak rate table for the pathway from Containment Leak to Environment under Pathways should be changed to the information given in Table 3-2:



* Control Room X/Q table – use the input listed in Table 3-2 in the X/Q Table 3 (Control Room-containment leakage) as follows:



1. Because the Fuel Handling Accident did not credit the control room switching to emergency mode operation, the following changes need to be made to add emergency mode operation to our model (reference steps 3 and 4 of Exercise 2 for more details on the addition of pathways and filters):
2. One additional pathway needs to be added to account for filtered flow which occurs during emergency mode: a filtered pathway from the Environment to the Control Room, named “CR filtered inflow.”



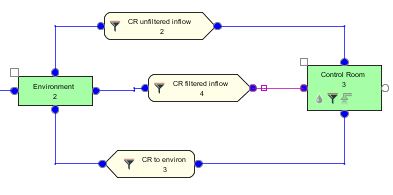
1. Two additional filters should be created to represent:

F3. Control Room recirculation flow

F4. filtered flow from Environment to Control Room

These are indicated on the drawing below:

F1



F2

F4

F3

1. Note that there are two types of emergency modes:
   1. Prior to operator action, and
   2. Following operator action.

The flowrate data for these two types differs only by the time they occur, so these two emergency mode types will be combined into one flow table.

1. The following flow tables under Filters need to be adjusted for emergency mode flows:

F1. CR unfiltered inflow table

F2. CR to environment table

F3. CR recirculation flow table

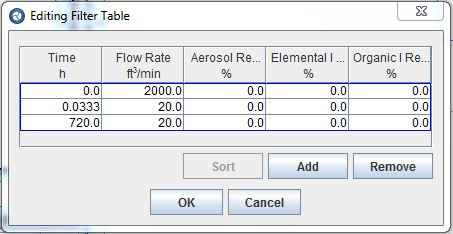
F4. CR filtered inflow table

1. In order to determine the values for the filter tables, the information from the reference plant was consolidated into the following table. The filter tables for the four filters will use flow rates and removal rates as indicated in Table 2-1, Control Room Data. Note that the 95% removal applies to all form of iodine.

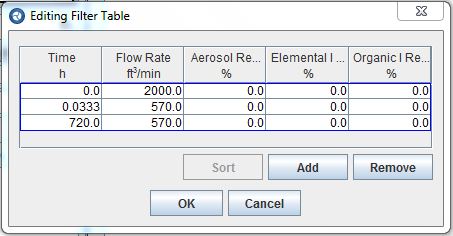
|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Time (hr) | Removal % | F1  cfm | F2  cfm | Removal % | F3  cfm | F4  cfm |
| 0-2 min | 0 | 2,000 | 2,000 | 0 | 1250 | 0 |
| 90 min-720 hr | 0 | 50 | 570 | 95 | 1250 | 550 |

* See Step 4 of the Detailed Steps in Exercise 2 for details on adding filter tables in SNAP. Here are the resulting filter tables for Filter 1 and Filter 2:

Filter 1 table, CR unfiltered inflow:

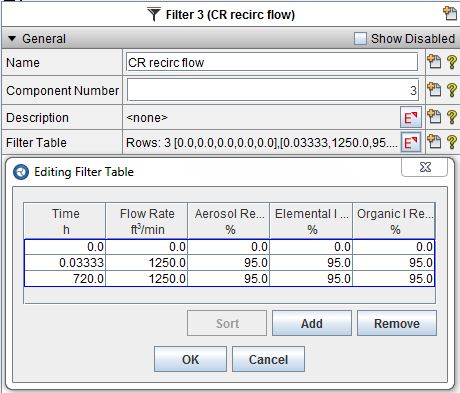


Filter 2 table, CR to environment:

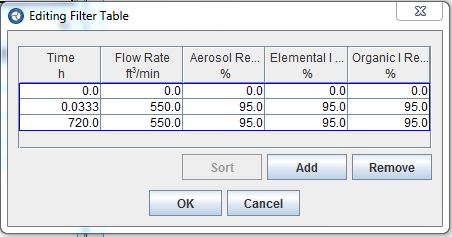


1. The filter tables for the filters will use flow rates and removal rates as indicated in Table 2-1.

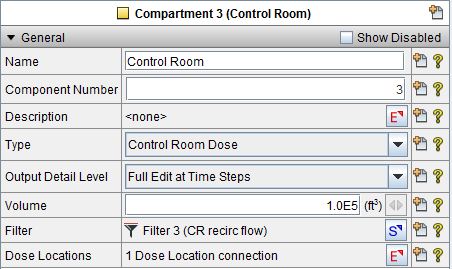
Filter 3 tables:



Filter 4 table:

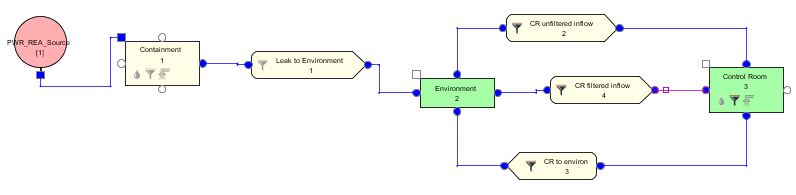


1. Go back and indicate the appropriate recirculation filter in the Filter section of the Compartment input for the Control Room by clicking on the C:\Users\dianem\Desktop\RADTRAD_2015_training\Exercise_3\ex3_s.JPG next to “Filter” and choosing “Filter 3 (CR recirc flow)”. Similarly, set the CR filtered inflow pathway filter to the corresponding filter in that flowpath.



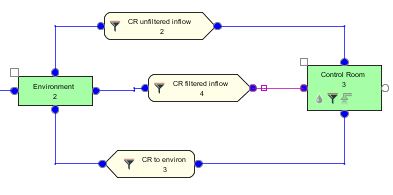
The last step is to go back to the Environment compartment and enter the CR X/Q table for the additional pathway (CR filtered flow) to the “Onsite X/Q Tables.”

1. Compare your model in the View Window with that shown below:



PWR Rod Ejection Accident (REA) RADTRAD Model

This run gives us a baseline control room model to use with our subsequent runs.



RADTRAD Control Room Model

1. Check the model, run the simulation and compare the results with those listed below.

**Results:**

|  |  |  |  |
| --- | --- | --- | --- |
| Worst Two-Hour Doses (Exclusion Area Boundary) | | | |
| Time (hr) | Whole Body (rem) | Thyroid (rem) | TEDE (rem) |
| 0.0-2.0 | 0.091106 | 20.840 | 0.86876 |

|  |  |  |  |
| --- | --- | --- | --- |
| Final Doses (Low Population Zone) | | | |
| Time (hr) | Whole Body (rem) | Thyroid (rem) | TEDE (rem) |
| 720.0 | 0.073207 | 34.435 | 1.4817 |

|  |  |  |  |
| --- | --- | --- | --- |
| Final Doses (Control Room) | | | |
| Time (hr) | Whole Body (rem) | Thyroid (rem) | TEDE (rem) |
| 720.0 | 0.0071214 | 20.503 | 0.87593 |

# Exercise 4 – Steam Generator Tube Rupture Accident

**Purpose:**

The purpose of this exercise is to simulate a steam generator tube rupture (SGTR) accident for a reference plant. We will begin with the model used for Exercise 3. This exercise will use the RCS activity calculator.

**Accident Description:**

For the SGTR accident, the complete severance of a single SG tube is assumed to occur. Due to the pressure differential between the primary and secondary systems, radioactive reactor coolant is discharged from the primary into the secondary system. A portion of this radioactivity is released to the outside atmosphere through the ARVs. Following the closure of the ruptured steam generator ARV block valve, there is additional radiological dose due to the leakage from the primary system into the intact steam generators and the initial concentration of radioactivity contained in the intact steam generators as steaming continues to provide plant cooldown.

A portion of the break flow that is transferred to the ruptured steam generator beginning at event initiation is assumed to be released directly to the environment through flashing. The entire 1 gpm primary-to-secondary accident-induced leakage allowed by the TS is assumed to be leaking into the intact steam generators with a density based on cooled liquid which otherwise is negligible compared to the flow through the ruptured tube. This leakage begins at event initiation and continues throughout the event.

**Radiological Calculations:**

The analysis assumes no fuel failure results from the accident, so pre-accident iodine spike and accident-initiated iodine spike scenarios are considered, consistent with RG 1.183. For the pre-accident spike case, it is assumed that a reactor transient has occurred prior to the SGTR and has raised the RCS iodine concentration to the TS limit for a transient. For the accident-initiated iodine spike case, the reactor trip associated with the SGTR creates an iodine spike that is assumed to increase the iodine release rate from the fuel to the RCS to a value corresponding to the maximum equilibrium RCS concentration. The iodine appearance rates are conservatively calculated assuming maximum letdown flow with perfect cleanup.

**Model Description:**

This model will have two release pathways leading to the environment, with the environment connecting to the control room model from the REA analysis. Decay is included in the simulation. This model is set up to investigate the resulting doses to the exclusion area boundary (EAB) and low population zone (LPZ) and Control Room at the end to the accident.

**Input Values:**

* + 1. From Exercise 1, Table 1-1 input values are used. Begin with the model resulting from Exercise 3.
    2. Additional input values for Exercise 4:
* The assumptions used for the steam generator tube rupture accident (SGTR) for the reference plant are listed in Table 4-1. Control room X/Q inputs are included here as well.
* The physical model of this accident requires two release pathways to the environment with an additional pathway leading between the two.
* Our control room model designed in the REA exercise will be used in this exercise as well.

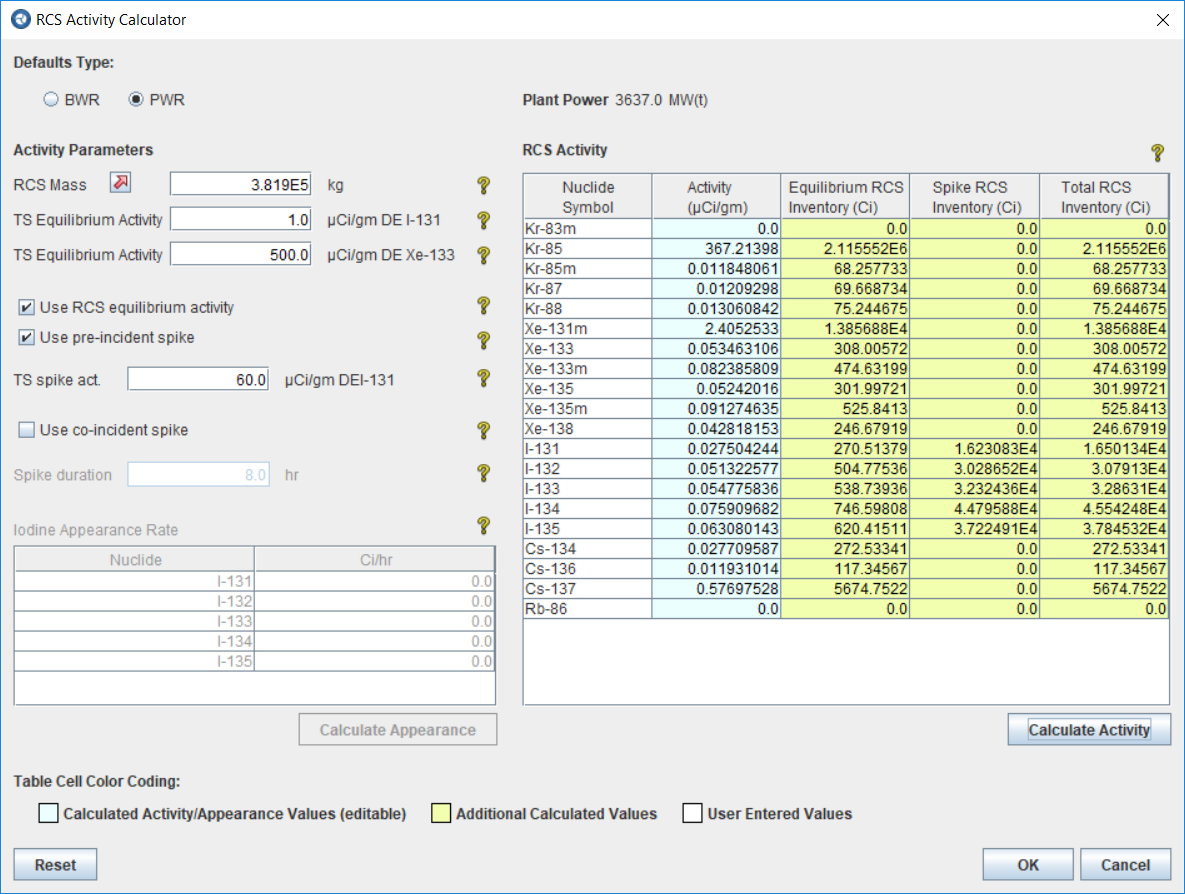
**Detailed Steps:**

* + - 1. Save the REA model as SGTR. Correspondingly, change the following:
* Model Options\General\Title to SGTR
* Model Options\General\Description to SGTR for reference PWR plant
* Job Streams\Name to SGTR
* Job Streams\Description to SGTR for a reference PWR plant
* Change the relative location of the output under Job Streams so that you don’t wipe out your previous results.

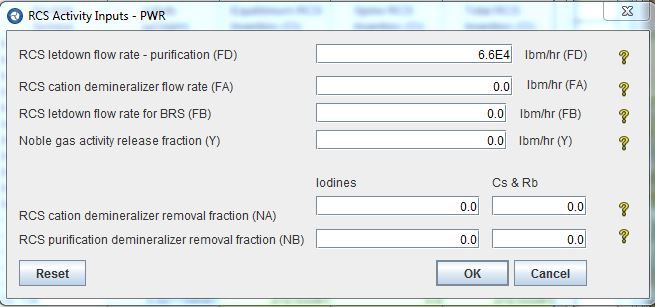
* + - 1. Using the model from Exercise 3 as a base, the following inputs need to be changed to those given in Table 4-1:
* Two sources will be created: one for the 3 intact SGs, and one for the ruptured SG which will include RCS inventory activity
* Source1\Iodine Physical Form should be changed to agree with those in Table 4-1
* Two release pathways are modeled: one for the three unaffected steam generators, and one containing the ruptured steam generator
* A pathway leading between the two release pathways

1. Calculate a reactor coolant system concentration using the RCS Activity Calculator as follows:
   1. Click on “Nuclide Data” in the Navigator Window, then click the  next to Total Inventories in the Properties Window to open an “Edit Total Inventories” screen.
   2. Click on the (  ) icon to activate the RCS Activity Calculator.

* 1. Enter the data shown in the following RCS activity screenshot. Values are listed in Table 4-1.



* 1. When the RCS Activity Inputs window appears after clicking on the Calculate Activity button, enter the data below.



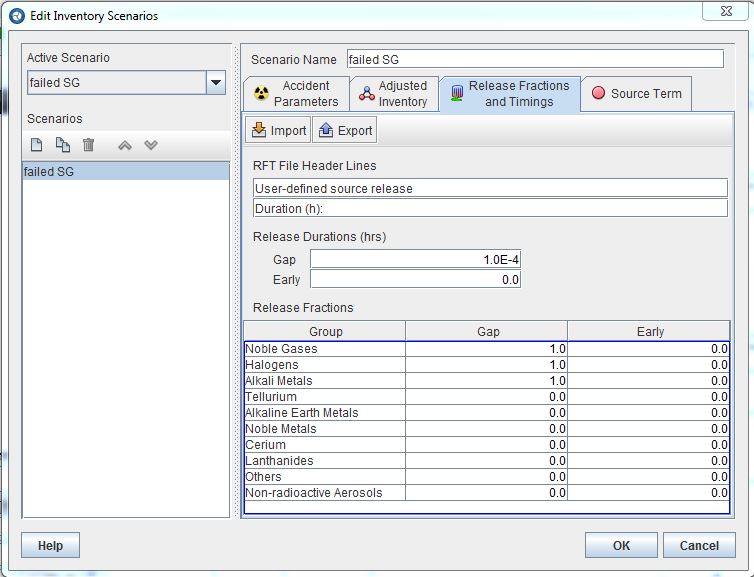
|  |
| --- |
|  |
| * 1. On the Edit Total Inventories screen, change the name “RCS Activity” to RCS Activity with Pre-incident Spike. The resulting window should appear as shown below. |

1. Create two source scenarios, one for the failed SG and one for the 3 intact

SGs.

* Using the calculated RCS activity, create two source scenarios. We will use the same RCS coolant source for both steam generators.

* Starting with the failed steam generator, choose “Use Total Inventory” on the Accident Parameters tab for the accident type. On the Release Fractions and Timing tab, use release fractions of 1.0 for the noble gases, halogens and alkali metals. Use 1.0E-4 for the gap release duration (See the next screenshot). Click on OK when you are satisfied that the input is complete.



* After completing and exiting the Edit Inventory Scenarios editor, set the Source Term Fraction to 1.0
* Input a User Defines Iodine Physical Form chemical form of releases of 97% elemental and 3% organic (See Table 4-1) for both sources.
* Repeat the same steps for the 3 intact SGs. Use 0.1 for the release fraction (assumed).

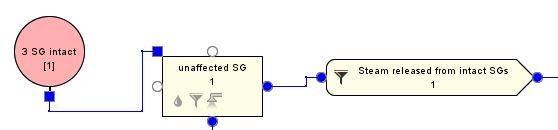
1. Create two release pathways. Flow rate and removal fractions are

tabulated at the end of this section. Note that cut and paste can be used. It

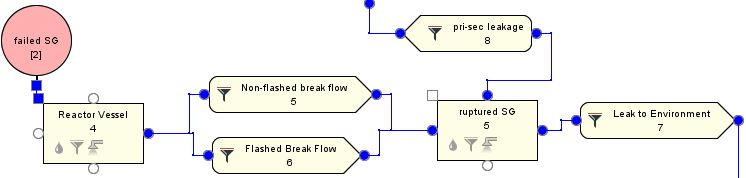
is probably easiest to input the component nodalization and then specify

the data. The control room model does not change in this problem.

* 1. The first release pathway consists of a single compartment representing the three unaffected SGs and a single pathway between these SGs and the environment. The existing components from the REA model can be used, with the input data changed to that from Table 4-1. The 3 SG (intact) source will be used in this release/flow pathway.



* 1. The second release pathway will be for the failed SG. There are various ways to accomplish this step. For example, you can edit the existing pathway data. Alternately, you can define new components. Your goal is to end with the noding given below.



Note that the connections from the environment going to the right do not change so you could start with a new model, develop the noding below and the cut and paste the control building and control room components into the new model. The cutting and pasting approach used is typical of Windows where you highlight what you want to cut (or copy), then right click and choose “copy.” Then click anywhere in the View Window, right click and choose “paste”. Not only are the components duplicated in the View Window, but there information contained in the Properties Window has been duplicated as well. Note that this method can also be used between models, however the numbering of the components will need to be adjusted. To do this, click on a component in the View Window, right click, and choose “Renumber”.

* 1. One last point. It is a good idea to name the various components as you assemble the model. Otherwise you will lose track of “what goes with what.”

|  |
| --- |
| C:\Users\dianem\Desktop\RADTRAD_2015_training\Exercise_4\ex4_model.JPG |

Data for the different nodes is given below:

* Unaffected SG compartment (normal) has a mass for all 3 sources of 5.85E5 lbm. Note that we are entering this value in the Volume box. However, as long as the flow path is input in lbm/min, we are preserving units and will be OK (f/V relationship).
* Steam released from Intact SGs – we will link a filter to this pathway so that you will need to define a filter with the following input. **Note that you can Copy and Paste within this table (right-click).**

| Time | Flow Rate  (lbm/min) | Aerosol  Removal (%) | Elemental I  (%) | Organic I  (%) |
| --- | --- | --- | --- | --- |
| 0.0 | 6.492115E5 | 99.0 | 99.0 | 99.0 |
| 0.01 | 3993.0 | 99.0 | 99.0 | 99.0 |
| 0.31 | 0.0 | 99.0 | 99.0 | 99.0 |
| 0.97 | 1.644897E4 | 99.0 | 99.0 | 99.0 |
| 1.07 | 5995.41 | 99.0 | 99.0 | 99.0 |
| 1.43 | 2482.87 | 99.0 | 99.0 | 99.0 |
| 2.09 | 2768.36 | 99.0 | 99.0 | 99.0 |
| 12.0 | 0.0 | 99.0 | 99.0 | 99.0 |

* Reactor Vessel – use a normal compartment and a mass of 3.99E5 lbm.
* Non-flashed break flow – will be a filtered pathway using the following data

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Time | Flow Rate  (lbm /min) | Aerosol  Removal (%) | Elemental I  (%) | Organic I  (%) |
| 0.0 | 2570.19 | 99.0 | 99.0 | 99.0 |
| 0.01 | 2464.57 | 99.0 | 99.0 | 99.0 |
| 0.31 | 2946.24 | 99.0 | 99.0 | 99.0 |
| 0.81 | 3299.12 | 99.0 | 99.0 | 99.0 |
| 0.97 | 3178.74 | 99.0 | 99.0 | 99.0 |
| 1.07 | 2820.0 | 99.0 | 99.0 | 99.0 |
| 1.43 | 1041.31 | 99.0 | 99.0 | 99.0 |
| 2.09 | 0.0 | 99.0 | 99.0 | 99.0 |

* Flashed Break Flow – will be a filtered pathway using the following data.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Time | Flow Rate  (lbm /min) | Aerosol  Removal (%) | Elemental I  (%) | Organic I  (%) |
| 0.0 | 506.42 | 0.0 | 0.0 | 0.0 |
| 0.01 | 165.82 | 0.0 | 0.0 | 0.0 |
| 0.31 | 447.74 | 0.0 | 0.0 | 0.0 |
| 0.81 | 263.56 | 0.0 | 0.0 | 0.0 |
| 0.97 | 105.72 | 0.0 | 0.0 | 0.0 |
| 1.07 | 0.0 | 0.0 | 0.0 | 0.0 |

* Ruptured Steam Generator – use a normal compartment and a mass of 7.0E4 lbm.
* Leak to environment – filtered pathway using the following data.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Time | Flow Rate  (lbm /min) | Aerosol  Removal (%) | Elemental I  (%) | Organic I  (%) |
| 0.0 | 2.170385E5 | 0.0 | 0.0 | 0.0 |
| 0.01 | 1569.67 | 0.0 | 0.0 | 0.0 |
| 0.31 | 4995.03 | 0.0 | 0.0 | 0.0 |
| 0.81 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2.09 | 4.26 | 0.0 | 0.0 | 0.0 |
| 12.0 | 0.0 | 0.0 | 0.0 | 0.0 |

* pri-sec leakage – connects the reactor vessel to the unaffected SGs. Filtered pathway is used with the following data. This data represents a reactor coolant leakage rate of 1 gpm.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Time | Flow Rate  (lbm /min)) | Aerosol  Removal (%) | Elemental I  (%) | Organic I  (%) |
| 0.0 | 0.1337 | 0.0 | 0.0 | 0.0 |
| 720.0 | 0.1337 | 0.0 | 0.0 | 0.0 |

Note that iodine removal coefficients of “0” are used in most cases. However, the removal coefficients for the non-flashed break flow and steam released from the intact SGs are determined from the partition factor for the SG. A SG iodine water/steam partition coefficient of 100 is assumed. Therefore, removal coefficients of 99% for Aerosol, Elemental and Organic I are used in the filter tables for these pathways.

Check the model, run the simulation and compare the results with those listed below. Also note the availability of dose fractions by radionuclide in the radtrad.out file.

**Results:**

|  |  |  |  |
| --- | --- | --- | --- |
| Worst Two-Hour Doses (Exclusion Area Boundary) | | | |
| Time (hr) | Whole Body (rem) | Thyroid (rem) | TEDE (rem) |
| 0.0-2.0 | 0.20903 | 31.651 | 1.4488 |

|  |  |  |  |
| --- | --- | --- | --- |
| Final Doses (Low Population Zone) | | | |
| Time (hr) | Whole Body (rem) | Thyroid (rem) | TEDE (rem) |
| 720.0 | 0.068846 | 10.313 | 0.47281 |

|  |  |  |  |
| --- | --- | --- | --- |
| Final Doses (Control Room) | | | |
| Time (hr) | Whole Body (rem) | Thyroid (rem) | TEDE (rem) |
| 720.0 | 0.026152 | 15.861 | 0.64741 |

# Exercise 5 – Loss of Coolant Accident

**Purpose:**

The purpose of this exercise is to simulate a loss of coolant accident (LOCA) accident for a reference PWR plant. We will begin with the model used for Exercise 3.

**Accident Description:**

For the LOCA accident, an abrupt failure of the main reactor coolant pipe is assumed to occur. Activity from the reactor coolant system (RCS) is released to containment and a portion of this activity is released to the environment via four pathways:

* + - * 1. The mini-purge system prior to containment isolation.
        2. It is assumed the emergency core cooling features fail to prevent the core from significant degradation. Activity from the core is released to the containment and then to the environment via containment leakage,
        3. Once recirculation of the ECCS is established, iodine activity in the sump solution may be released to the environment by means of leakage from ESF equipment outside containment in the auxiliary building, and
        4. by means of leakage from the ESF to the RWST with subsequent leaking or venting.

**Description:**

* This model will have four release pathways leading to an environment, with the environment connecting to our control room model. Two of the release pathways will include a source, two compartments and two pathways. One release pathway includes a source, one compartment and one pathway. The final pathway includes a source, two compartments, and four pathways.
* There will also be the control room to the environment model that was used for the REA analysis.
* Decay, natural deposition, and sprays are included in the simulation.
* This model is set up to investigate the resulting doses to the exclusion area boundary (EAB) and low population zone (LPZ) and Control Room at the end to the accident.

**Input Values:**

Table 1-1 input values are used. Begin with the model resulting from Exercise 3 (REA accident).

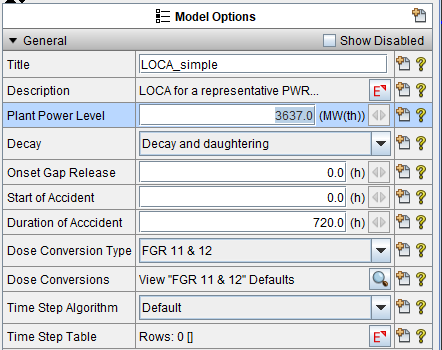
Additional input values for Exercise 5:

* The assumptions used for the loss of coolant accident (LOCA) for the reference plant are listed in Table 5-1. Control room X/Q inputs are included here as well.
* The physical model of this accident requires four release pathways to the environment.
* Our control room model designed in the REA exercise will be used in this exercise as well.
* We will use the RCS nuclide definitions calculated for the SGTR scenario.

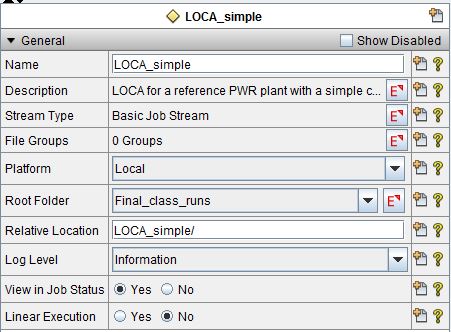
**Detailed Steps:**

**Step 1** - Save the REA model (from Exercise 3) as LOCA simple. Correspondingly, change the following:

* Model Options\General\Title to LOCA\_simple
* Model Options\General\Description to LOCA\_simple for representative PWR

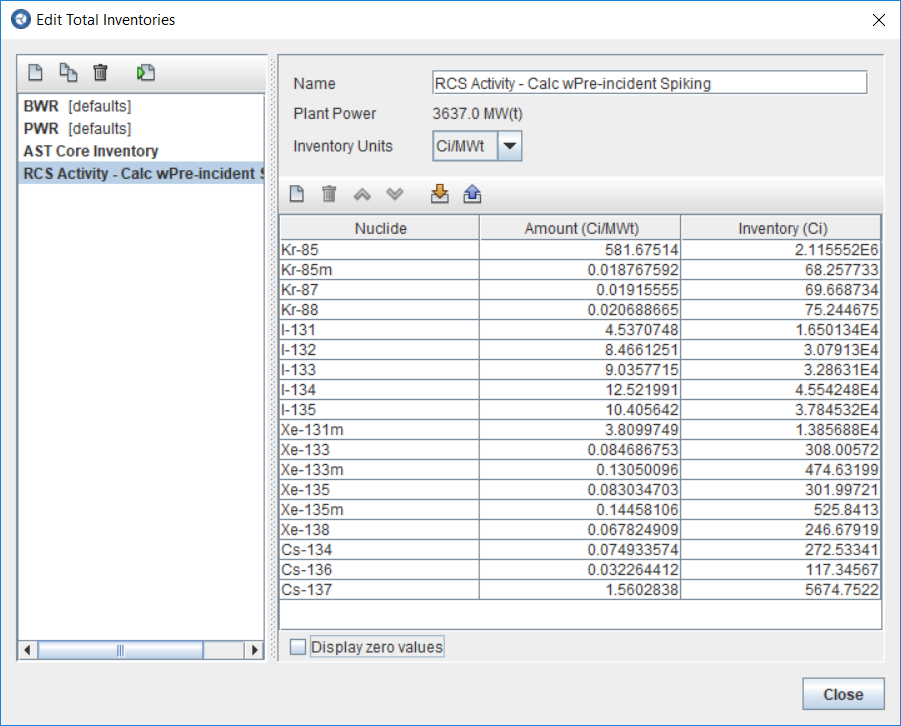


* Job Streams\Name to LOCA\_simple
* Job Streams\Description to LOCA for a reference PWR plant with a simple control room
* Consider changing the relative location of the output under Job Streams by appending the name of the Job Stream to the end of the relative location, i.e., RADTRAD\LOCA\_simple. This creates a unique folder for the resulting output files.

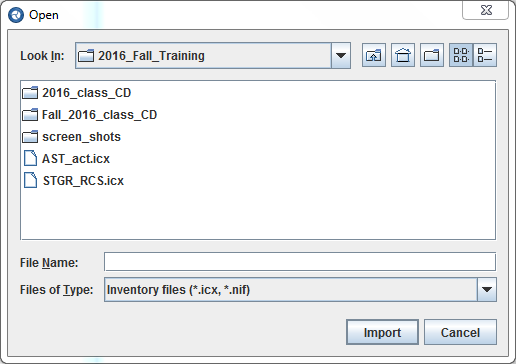


* + - 1. Note that the following will be done to create the LOCA model:
* Two sources will be used:
  + one containing core activity (already input as part of the REA), which will be used for the containment leakage, ECCS leakage, and RWST back-leakage flow pathways, and
  + one using the RCS activity for the containment purge (from the SGTR case).
* Source Release Fractions and Timings to be used for both sources are indicated in Table 5-1.
* Four flow pathways are modeled: one each for the containment leakage, ECCS leakage, RWST back-leakage generators, and containment purge.
* Source1\Iodine Physical Form for each flow pathway will be changed to agree with those in Table 5-1.
* X/Q tables for each flow pathway are given in Table 5-1.
* Inputs specific to each flow pathway are given in Table 5-1.

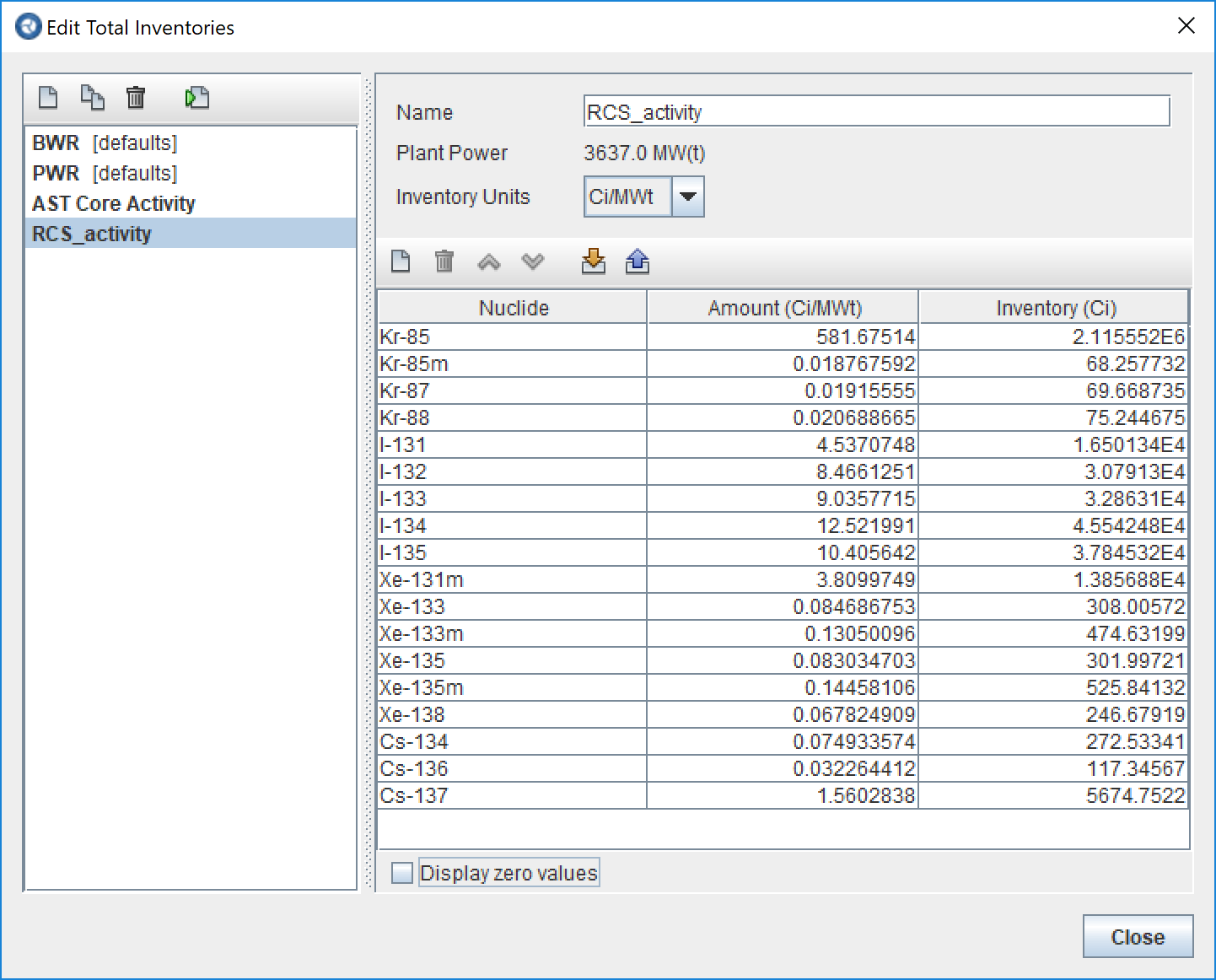
1. Collect two nuclide inventories. One is already in our present LOCA model as an existing inventory from the REA model. For the second inventory we will import an activity used in the SGTR exercise.
   1. Click on “Nuclide Data” in the Navigator Window, then click the  next to Total Inventories in the Properties Window to open an “Edit Total Inventories” screen.
   2. For our first inventory, we will use the Core Activity inventory that was input as part of the REA model. (Reference Step 2 of Exercise 3 for this inventory, called “REA\_Source”).
   3. For the second inventory we will use the RCS Activity inventory that was calculated in the SGTR exercise. In order to so this, we will export the inventory from the SGTR model, and import it into this model:
      1. To export the SGTR inventory –
         1. Open the SGTR model, if not already open.
         2. Click on Nuclide Data, then Total Inventories to have the following screen appear. Choose the “RCS Activity w Pre-incident Spike” inventory.



* + - 1. Click the “Export the current inventory nuclides” button. A window will pop up requesting a file name and location to save the file. Title it ”SGTR\_RCS” and save it to your working directory.
      2. Close the “Edit Total Inventories” window for the SGTR exercise.
      3. Return to the LOCA\_simple exercise.
    1. To import the SGTR\_RCS inventory to the LOCA exercise,
       1. Click on Nuclide Data, then Total Inventories to have the following screen appear:
       2. Click the “Create a new inventory” button, and “unnamed” will appear in the inventory list.
       3. Click the “Import an inventory” button, and a screen similar to the following will appear:

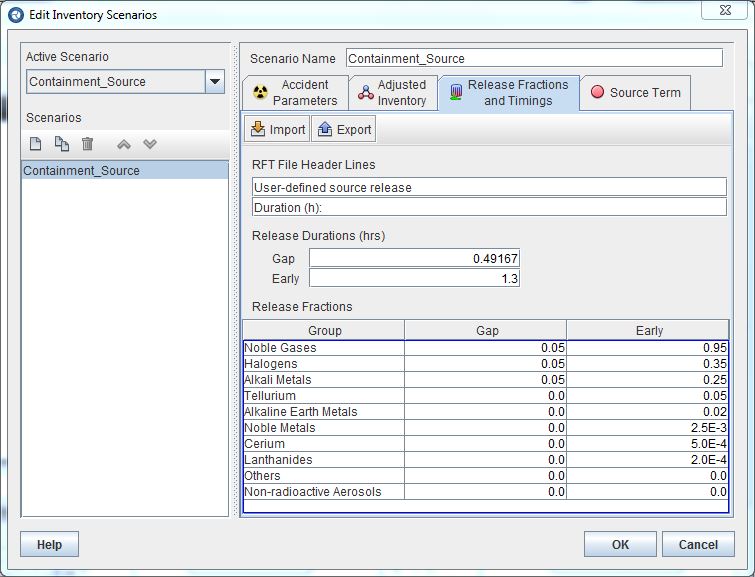


* + - 1. Choose the STRG\_RCE.icx file on the desktop and click “Import”.
      2. Name the file “RCS\_activity”. The imported inventory should be as follows:

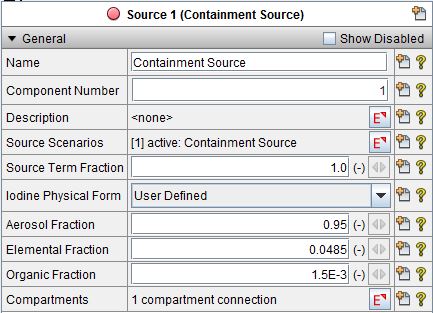


1. Create four sources.

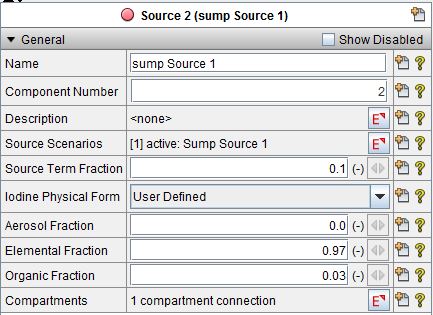
* Using the two nuclide inventories just entered, create four sources. See Exercise 1, Step 2, item 2c for details about entering source data.
  + The AST Core Activity nuclide data should be used to create a Containment Source, Sump Source 1 and Sump Source 2. We are currently using this to create a source called “PWR source”. Start with this to create your Containment Source.
  + The RCS Activity nuclide data should be used to create a RCS Source
* Note that one method for creating the four sources is to right click on the name of a particular source and “copy.” Then click on “Sources (),” right click and “paste.” Use this method to create the sump and containment sources.
* For Accident Type in all cases, choose “Use Total Inventory.”
* Release Fractions and Timings used for all sources are given in Table 5-1. For convenience, when these numbers have been input once, click “Export” and save the information to import in the next source Release Fractions and Timings tab. When inputting a file name to save the export, make sure you include the extension .srx. Use this method to create the RCS source.



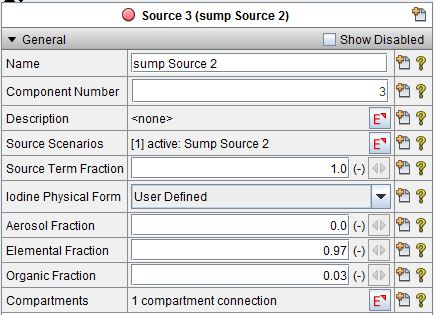
* The Iodine Physical Form Release Fractions to be used in each case are indicated in Table 5-1.



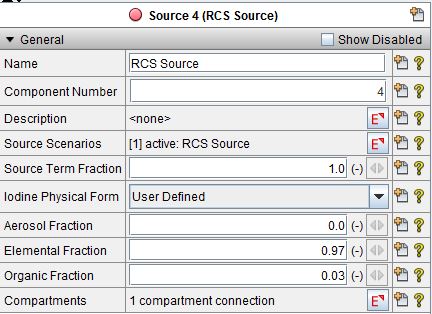
* Sump Source 1 uses a Source Term Fraction of 0.1 to account for an assumption that 10 % of the iodine activity in the ECCS leakage pathway becomes airborne and is available for release to the environment.



* Sump Source 2, Containment Source and RCS Source use a Source Term Fraction of 1.0.



* Make sure you enter the source Component Numbers along with the Name in the Properties Window. They should be numbered sequentially 1 to 4 or there will be an error message when the model check is done.



**Step 5** – Model four leakage pathways.

* + - Inputs for four release pathways need to be modeled with information given in Table 5-1.
    - Each of the four pathways leads to the environment. The environment then leads to the control room model set up earlier.
    - Let us consider each of the four release pathways:

1. **Containment Leakage Pathway** - This pathway models all activity released from the fuel to go into the unsprayed portion of containment before being mixed with the sprayed portion of the containment. The release pathway model should include:

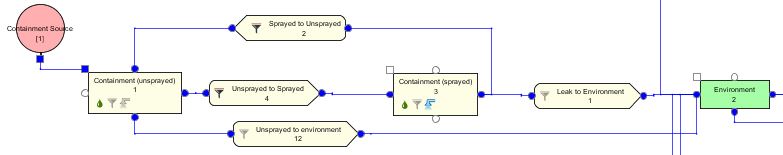
The core activity (containment) source.

Components for the sprayed and unsprayed portions of the containment.

Four pathways: two leading between the containment components (filtered pathways), and two additional pathways leading from the sprayed and unsprayed portions of the containment to the environment (air leakage pathways).

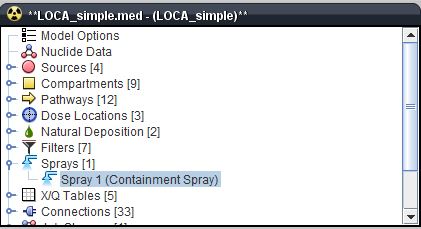
Inputs for these components are listed in Table 5-1. For details on adding compartments and pathways, see Exercise 1, Step 2, sections 2.d and 2.f.

The resulting model should look as follows:



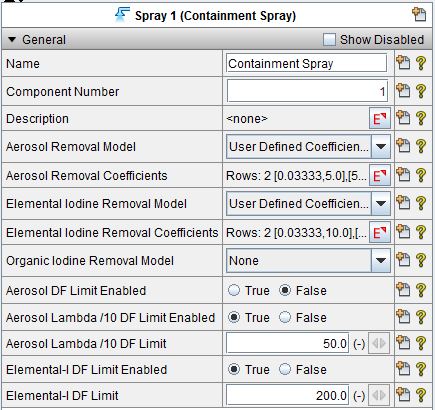
There is time-dependent removal of elemental iodine and particulates from the containment atmosphere by containment sprays and natural deposition. Therefore this pathway requires the use of the spray model and the natural deposition model.

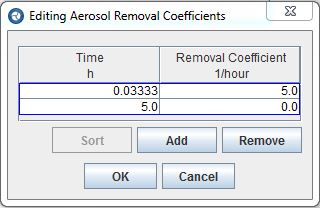
1. Spray model addition – to include a spray model for the sprayed portion of the containment, right click on the “Sprays” section of the Navigator Window and choose “new.”

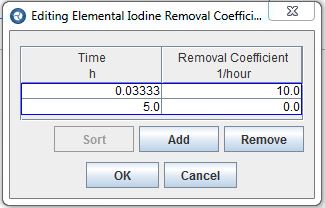


The following screen will result in the Properties Window. The screen can be populated with information from Table 5-1.

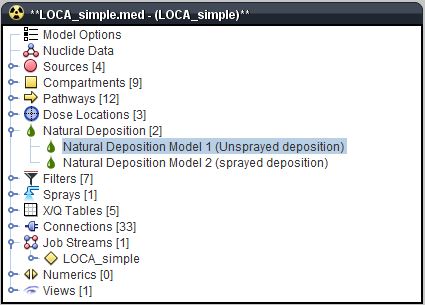
Be sure to add the spay to the model by going to the containment (sprayed) component, clicking on C:\Users\dianem\Desktop\select.JPG next to “Spray”, and choosing Spray 1 (Containment Spray).



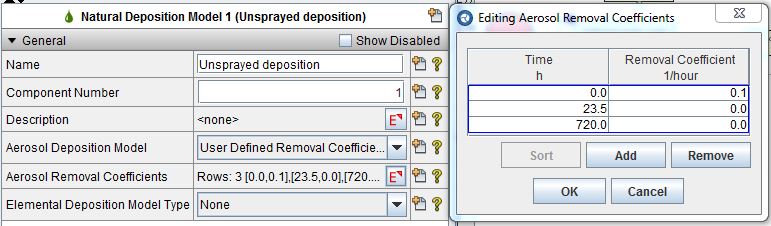


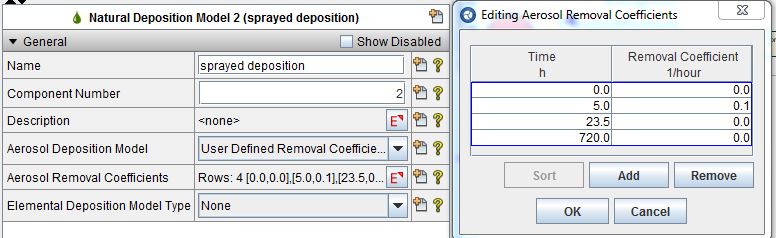


1. Natural Deposition model addition - to include an aerosol natural deposition model for the sprayed and unsprayed portions of the containment, right click on the “Natural Deposition” section of the Navigator Window and choose “new.”



The following screen will result in the Properties Window. The screen can be populated with information from Table 5-1. It will be necessary to create one model for the sprayed portion of the containment and another for the unsprayed portion due to timing differences.

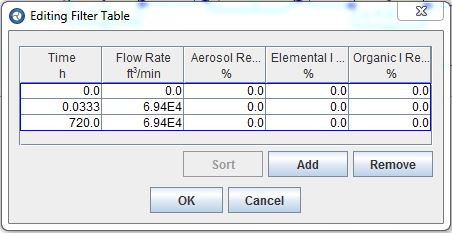




Be sure to add deposition to the model by going to both containment components, clicking on C:\Users\dianem\Desktop\select.JPG next to “Deposition”, and choosing Natural Deposition Model 1 or 2 (Unsprayed or Sprayed deposition) as appropriate.

1. One filter will be added in this pathway to model the circulation between the sprayed and unsprayed portions of the containment. See Step 4 of the Detailed Steps in Exercise 2 for details on adding filter tables in SNAP. Here is the resulting filter table the filter:

Filter 5, containment mixing table:



Be sure to add this filter to the model by going to the pathways between the containment components, clicking on C:\Users\dianem\Desktop\select.JPG next to “Filter”, and choosing Filter 5 (containment mixing).

1. The X/Q table for this pathway is the same one we already input for the REA case (Control-Room – containment leakage). We will connect this to the model at the end of this exercise.
2. **ECCS Leakage Pathway -** This pathway assumes all iodine activity released from the fuel is in the sump solution immediately. The only removal of activity from the sump is by radioactive decay or leakage to the auxiliary building. When ECCS recirculation is established following the LOCA, leakage is assumed to occur from ESF equipment in the aux. building. Recirculation is modeled to initiate at the start of the event and continues throughout the event. The release pathway model should include:

The core activity source called Sump Source 1.

Components for the sump and aux building.

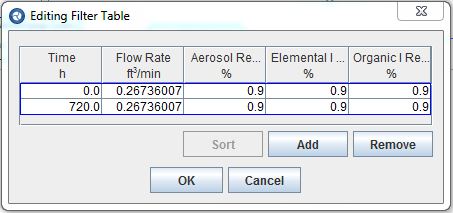
Filtered pathways for from the sump to the aux. building and aux. building to the environment.

Inputs for these components are listed in Table 5-1. For details on adding compartments and pathways, see Exercise 1, Step 2, sections 2.d and 2.f.

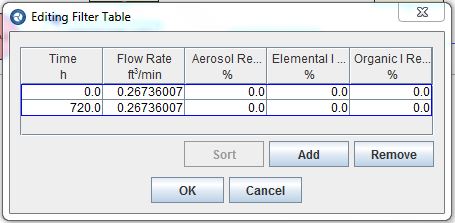
When adding the X/Q table, note that the ECCS Leakage and Containment Purge pathways use the same table. So the table can be labeled accordingly as “Control Room – Cont. Purge & ECCS Leakage”.

1. Two filters will be added in this pathway for the sump to the aux. building and the aux building to the environment to account for ECCS leakage to the aux. building and aux. building exhaust to the environment. See Step 4 of the Detailed Steps in Exercise 2 for details on adding filter tables in SNAP. Here are the resulting filter tables for the two filters:

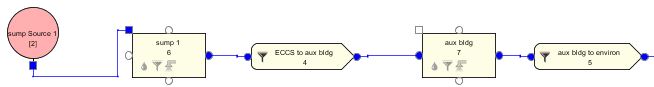
Filter 6, Aux Bldg vent to Environment table:



Filter 7, Sump 1 (ECCS) to Aux Bldg table:



The resulting model should look as follows:



* + - * 1. **Refueling Water Storage Tank Back-Leakage Pathway –** For this pathway, a portion of the ECCS recirculation is assumed to leak into the RWST. All iodine activity released from the fuel is assumed to be in the sump solution immediately. The release pathway model should include:

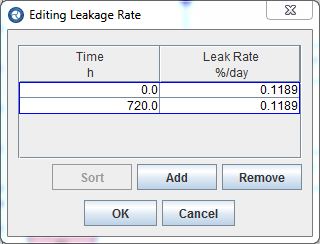
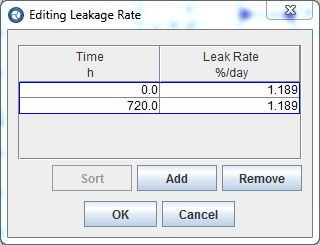
The core activity source called Sump Source 2.

Components for the sump and RWST.

Pathways for air leakage from the sump to the RWST and RWST to the environment.

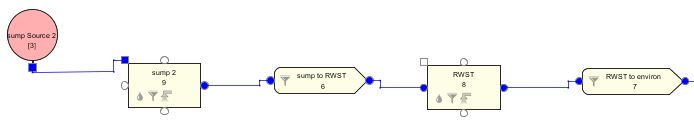
Leakage Rate tables for the 2 pathways are as follows:

RWST to environment sump 2 to RWST

Inputs for these components are listed in Table 5-1. Be sure to add a new X/Q table for this pathway.

The resulting model should look as follows:



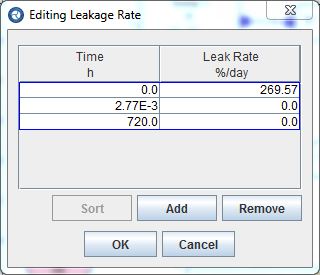
* + - * 1. **Containment Purge Release Pathway -** For this pathway, all of the initial primary coolant activity is instantly released from the RCS and is evenly distributed throughout the containment volume. This release pathway model should include:

The core activity source called RCS source.

Components for the containment.

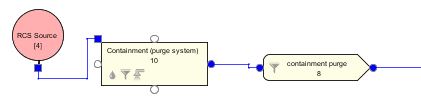
Pathway for the containment purge (air leakage) to the environment.

The air leakage rate table is as follows:



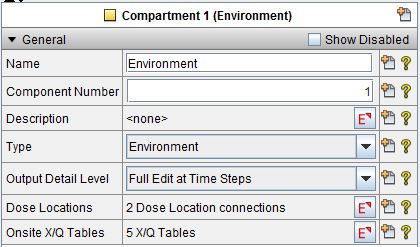
Inputs for these components are listed in Table 5-1. Note a X/Q table with the same values was entered for the ECCS leakage pathway.

The resulting model should look as follows:

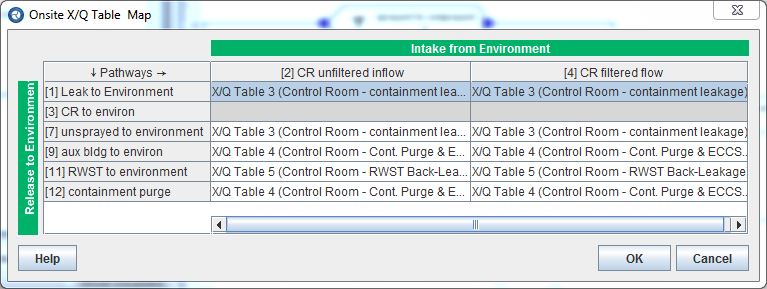


**Step 6 –** Once the release pathways are modeled, go back to the environment compartment and connect the appropriate X/Q tables to their associated pathways. This is done with the Onsite X/Q Table Map.

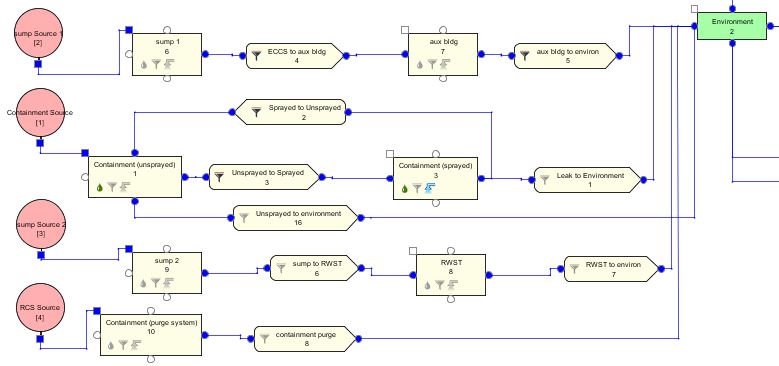
1. Go back to the environment compartment and open the Onsite X/Q Table screen:



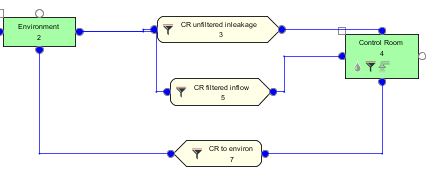
1. Choose the appropriate X/Q table for the connection between the intake from Environment to the pathway to the Release to Environment as shown below:

****

**Step 7** – Confirm that all the release pathways lead to environment and the environment leads to the previously modeled control building/control room model used for the REA model. Compare your model in the View Window with that shown.



Loss of Coolant Accident (LOCA) RADTRAD Model



Control Room RADTRAD Model

**Step 8** - **Check SNAP/RADTRAD Model, Fix Errors and Save Model**

Details may be found under Step 3 of Exercise 1.

**Step 9 – Run Exercise 5 Model Simulation**

Details may be found under Steps 4 and 5 of Exercise 1.

**Step 10 – View Results, Make Corrections**

Details may be found under Step 6 of Exercise 1.

**Results:**

|  |  |  |  |
| --- | --- | --- | --- |
| Worst Two-Hour Doses (Exclusion Area Boundary) | | | |
| Time (hr) | Whole Body (rem) | Thyroid (rem) | TEDE (rem) |
| 0.3-2.3 | 0.63627 | 75.824 | 3.300 |

|  |  |  |  |
| --- | --- | --- | --- |
| Final Doses (Low Population Zone) | | | |
| Time (hr) | Whole Body (rem) | Thyroid (rem) | TEDE (rem) |
| 720.0 | 0.48382 | 57.942 | 2.9412 |

|  |  |  |  |
| --- | --- | --- | --- |
| Final Doses (Control Room) | | | |
| Time (hr) | Whole Body (rem) | Thyroid (rem) | TEDE (rem) |
| 720.0 | 0.16183 | 50.767 | 2.566 |

Table 1-1. Common Input Values

|  |  |
| --- | --- |
| **Attribute** | **Value** |
| 1. **General** |  |
| Plant/Inventory Information Type | PWR |
| Plant Power Level | 3637.0 MWth |
| Decay | Decay and daughtering |
| Accident Duration | 720.0 hr |
| Start of Accident | 0 hr |
| Onset Gap Release | 0 hr |
| Pool Iodine DF | 200 |
| 1. **Sources** | See Table 1-2 |
| 1. **Activity Release Parameters** |  |
| Containment Volume | 2.5E6 ft3 |
| Containment Leak Rate | 0-24 hrs., 0.2 %/day  >24 hrs., 0.1 %/day |
| 1. **Miscellaneous** |  |
| Dose Conversion Factors | FGR 11 & 12 |
| Time Step Algorithm | Default |
| EAB, LPZ Breathing Rate | 3.5E-4 m3/sec until 8 hrs.  1.8E-4 from 8 to 24 hrs.  2.3E-4 from 24 to 720 hrs. |
| X/Q Table – EAB | 1.40E-4 sec/m3 from 0 to 720 hrs. |
| X/Q Table – LPZ | 4.50E-5 from 0 to 2 hrs.  2.39E-5 from 2 to 8 hrs.  1.29E-5 from 8 to 24 hrs.  5.49E-6 from 24 to 96 hrs.  1.61E-6 from 96 to 720 hrs. |

Table 1-2. Additional Assumptions Used for Fuel Handling Accident Analysis

|  |  |  |  |
| --- | --- | --- | --- |
| **Attribute** | | **Value** | |
| **I. Core Activity - FHA** | | | |
| **Nuclide** | **Core Activity (Ci)** | **Core Activity Corrected for 76 hour decay (Ci)** | **Amount (Ci/MWt)** |
| Kr-85 | 1.1E6 | 1.098E+06 | 3.019E+02 |
| Kr-85m | 2.69E7 | 2.123E+02 | 5.837E-02 |
| I-130 | 1.98E6 | 2.799E+04 | 7.695E+00 |
| I-131 | 1.01E8 | 7.952E+07 | 2.186E+04 |
| I-132 | 1.49E8 | 7.624E+07 | 2.096E+04 |
| I-133 | 2.1E8 | 1.718E+07 | 4.723E+03 |
| Xe-131m | 1.05E6 | 6.601E+04 | 1.815E+01 |
| Xe-133 | 2.01E8 | 1.038E+06 | 2.855E+02 |
| Xe-133m | 6.06E6 | 1.581E+08 | 4.346E+04 |
| Xe-135 | 4.06E7 | 1.077E+04 | 2.961E+00 |
| Xe-135m | 4.39E7 | 1.571E+06 | 4.320E+02 |
| Xe-138 | 1.8E8 | 1.077E+04 | 2.961E+00 |
| **Source Scenario Parameters** | | | |
| Total Inventory | | PWR | |
| Accident Type | | FHA | |
| Number of assemblies/rods in core | | 193 | |
| Number of fuel assemblies damaged | | 1.2 | |
| Peaking factor | | 1.65 | |
| Overall pool iodine DF | | 200 | |
| Decay period (hr) | | 76 | |
| Source Term Fraction | | 1.0 | |
| **Gap Fractions** (from RG 1.125) | | | |
| I-131 | | 0.12 | |
| Kr-85 | | 0.03 | |
| Other iodines and noble gases | | 0.10 | |
| Alkali Metals | | 0 | |
| Duration of release (hr) | | 2 | |
| Release Fractions: Noble Gases, Halogens, Alkali Metals | | 1.0 | |
| **II. Activity Release Parameters** (Pathway Data) | | | |
| Containment Leak Rate to Environment | | 1.0E12 %/day for duration of accident | |

Table 2-1. Assumptions Used for Control Room

|  |  |
| --- | --- |
| **Control Room (CR) Model Input Parameters** | |
| Volume | 1.0E5 ft3 (2831.6847 m3) |
| Flow rate of Unfiltered Pathway to CR | 2000 ft3/min |
| Occupancy Factors | 1.0 from 0 to 24 hrs.  0.6 from 24 to 96 hrs.  0.4 from 96 to 720 hrs.  0 after 720 hrs. |
| Breathing Rate | 3.5E-4 m3/sec for the entire run |
| *Χ/Q* Table – CR atmospheric dispersion factors (sec/m3) | 5.44E-4 from 0 to 2 hrs.  4.35E-4 from 2 to 8 hrs.  1.62E-4 from 8 to 24 hrs.  1.22E-4 from 24 to 96 hrs.  8.70E-5 from 96 to 720 hrs. |
| **Unfiltered Pathway Input Parameters – Normal Mode** | |
| Flow rate of Pathway to CR | 2,000 ft3/min |
| Aerosol Removal Efficiency | 0% |
| Elemental Iodine Removal Efficiency | 0% |
| Organic Iodine Removal Efficiency | 0% |
| **Emergency Mode Parameters** | |
| Operator Action/Delay time | 2 min. (0.0333 hr) |
| Aerosol Removal Efficiency (all filtered pathways) | 95% |
| Elemental Iodine Removal Efficiency (all filtered pathways) | 95% |
| Organic Iodine Removal Efficiency (all filtered pathways) | 95% |
| CR Recirculation Flow | 1250 ft3/min |
| CR Filtered Inflow | 550 ft3/min |
| CR Unfiltered Inflow | 20 ft3/min |
|  | |

Table 3-1. Radionuclide Activities for REA, STGR,

and LOCA Analysis

|  |  |  |
| --- | --- | --- |
| **Nuclide** | **Core Activity (REA, SGTR, LOCA) (Ci)** | **RCS Activity (SGTR, LOCA) (Ci)** |
| Kr-85 | 1.1E6 | 2.115552E6 |
| Kr-85m | 2.69E7 | 68.257733 |
| Kr-87 | 5.3E7 | 69.668734 |
| Kr-88 | 7.12E7 | 75.244675 |
| Rb-86 | 1.86E5 |  |
| I-130 | 1.98E6 |  |
| I-131 | 1.01E8 | 1.650134E4 |
| I-132 | 1.49E8 | 3.07913E4 |
| I-133 | 2.1E8 | 3.28631E4 |
| I-134 | 2.36E8 | 4.554248E4 |
| I-135 | 2.0E8 | 3.784532E4 |
| Xe-131m | 1.05E6 | 1.385688E4 |
| Xe-133 | 2.01E8 | 308.00572 |
| Xe-133m | 6.06E6 | 474.63199 |
| Xe-135 | 4.06E7 | 301.99721 |
| Xe-135m | 4.39E7 | 525.8413 |
| Xe-138 | 1.8E8 | 246.67919 |
| Cs-134 | 1.65E7 | 272.53341 |
| Cs-136 |  | 117.34567 |
| Cs-137 |  | 5674.7522 |

Table 3-2. Additional Assumptions Used for Rod Ejection Analysis

|  |  |
| --- | --- |
| **Attribute** | **Value** |
| **I. Sources** | |
| Core activity - REA | See Table 3-1 |
| Source Term Fraction | 1.0 |
| **Iodine Physical Form** | NUREG-1465 |
| Aerosol Fraction | 0.95 |
| Elemental Fraction | 0.0485 |
| Organic Fraction | 1.5E-3 |
| **II. Accident Parameters Tab** | |
| Fraction of clad breached | 0.1 |
| Fraction of breach > melt | 0.0025 |
| **REA Release Fractions** | |
| NG | Gap 0.1; melt 1.0 |
| Iodines | Gap 0.1; melt 0.5 |
| Alkali Metals | Gap 0.12; melt 0.5 |
| **III. Release Fractions and Timings Tab** | |
| NG, halogens, alkali metals | 1.0 |
| Gap release duration | 1E-4 hrs |
| **IV. X/Q Tables** | |
| **Control room atmospheric dispersion factors (sec/m3)** | |
| 0-2 hrs. | 5.44E-4 |
| 2-8 hrs | 4.35E-4 |
| 8-24 hrs. | 1.62E-4 |
| 24-96 hrs. | 1.22E-4 |
| 96-720 hrs. | 8.7E-5 |

Table 4-1. Additional Assumptions Used for SGTR Dose Analysis

|  |  |
| --- | --- |
| **Attribute** | **Value** |
| **RCS Activity Calculator Data** | |
| Reactor vessel mass (lbm) | 8.42E5 lbm (3.8192E5 kg) |
| TS Equilibrium Activity | 1.0 µCi/gm DE I-131  500 µCi/gm DE Xe-133 |
| TS Spike Activity for Pre-incident Spike | 60 µCi/gm DE I-131 |
| Letdown Flow | 66,000 lb/hr |
| Normal letdown flow rate (co-incident spike) | 132 gpm |
| RCS T/S leakage (co-incident spike) | 11 gpm |
| Mixed bed demin DF (co-incident spike) | 100 |
| Spike multiplier (co-incident spike) | 335 |
| **Release Fractions** | |
| Failed SG | 1.0 for NG, Halogens, Alkali Metals |
| Intact SG | 0.1 for NG, Halogens, Alkali Metals |
| Gap Release Duration (hrs) | 1.0E-4 |
| **Control room atmospheric dispersion factors (sec/m3)** | |
| 0-2 hrs. | 1.04E-3 |
| 2-8 hrs | 7.46E-4 |
| 8-24 hrs. | 3.03E-4 |
| 24-96 hrs. | 1.9E-4 |
| 96-720 hrs. | 1.39E-4 |
| **Removal Efficiencies** | |
| Organic iodine removal efficiency (%) | 99 |
| Elemental iodine removal efficiency (%) | 99 |
| Aerosol iodine removal efficiency (%) | 99 |
| Primary to Secondary leakage rate | 1 gpm (0.1337 ft3/min, 8.33 lbm/min) |
| Iodine chemical form of releases (%) | |
| Elemental | 97 |
| Organic | 3 |
| Aerosol | 0 |
| Source Term Fraction –both sources | 1.0 |
| SG iodine water/steam partition coefficient | 100 |
| **Compartment Data** | |
| Reactor Vessel mass (lbm) | 3.99E5 |
| Ruptured SG mass (lbm) | 7.00E4 |
| Unaffected SG mass (lbm) | 5.85E5 |
| Transient mass transfer data | See Tables in Step 5 of Exercise 4 |

Table 5-1. Additional Assumptions Used for Loss of Coolant Accident Analysis

|  |  |  |
| --- | --- | --- |
| **Attribute** | **Value** | |
| **Sources** | | |
| Core activity - containment leakage, ECCS leakage, and RWST back-leakage | See Table 3-1 | |
| RCS activity – containment purge | See Table 3-1 | |
| **Activity Release Parameters (all sources)** | | |
|  | Gap | Early |
| Noble Gases | 0.05 | 0.95 |
| Halogens | 0.05 | 0.35 |
| Alkali Metals | 0.05 | 0.25 |
| Tellurium | 0.0 | 0.05 |
| Alkaline Earth Metals | 0.0 | 0.02 |
| Noble Metals | 0.0 | 2.5E-3 |
| Cerium | 0.0 | 5.0E-4 |
| Lanthanides | 0.0 | 2.0E-4 |
| Others | 0.0 | 0.0 |
| Non-radioactive Aerosols | 0.0 | 0.0 |
| Release Durations | 0.49167 hr | 1.3 hr |
| **1. Containment Leakage (containment source)** | | |
| Source Term Fraction | 1.0 | |
| Iodine chemical form of releases (%) | | |
| Elemental | 4.85 | |
| Organic | 0.15 | |
| Aerosol | 95 | |
| Containment volume, unsprayed (ft3) | 4.05E5 (15% of total) | |
| Containment volume, sprayed (ft3) | 2.295E6 (85% of total) | |
| Filter Data | | |
| Mixing between sprayed and unsprayed containment volumes (cfm) – both directions (begins at 2 min)  0.0333 (2 min) – 720 hr | 6.94E+04 ft3/min | |
| Leakage Data –unsprayed and sprayed regions to environment | | |
| Leak to Environment | See Table 1-1 for containment leak rate | |
| Spray removal coefficients | | |
| Organic iodine spray removal coefficient (hr -1) | None | |
| Elemental iodine spray removal coefficient calculations | | |
| Spray removal coefficient (hr -1)  0.0333 – 5 hr | 10 | |
| Elemental-I DF Limit Enabled | 200 | |
| Aerosol spray removal coefficient calculations | | |
| Spray removal coefficient (hr -1)  0.0333 – 5 hr | 5 | |
| Aerosol Lambda/10 DF Limit Enabled | 50 | |
| Natural Deposition Model 1 (unsprayed region) | | |
| Particulate sedimentation removal coefficient (hr-1) | 0.1 | |
| Credited in unsprayed portion of containment | 0 - 23.5 hr | |
| Natural Deposition Model 2 (sprayed region) | | |
| Particulate sedimentation removal coefficient (hr-1) | 0.1 | |
| Credited in sprayed portion when sprays are not on until termination time (hr) | 5 - 23.5 hr | |
| Control room atmospheric dispersion factors (sec/m3) | | |
| 0-2 hrs. | 5.44E-04 | |
| 2-8 hrs | 4.35E-04 | |
| 8-24 hrs. | 1.62E-04 | |
| 24-96 hrs. | 1.22E-04 | |
| 96-720 hrs. | 8.70E-05 | |
| **2.ECCS Leakage (sump source 1)** | | |
| Source Term Fraction | 0.1 | |
| Iodine chemical form of releases (%) | | |
| Elemental | 97 | |
| Organic | 3 | |
| Aerosol | 0 | |
| Sump volume, maximum (gal) | 4.60+05 (6.149305E4 ft3) | |
| Auxiliary building volume (ft3) | 1.0E5 | |
| Time to initiate ECCS recirculation (min) | 0 | |
| ECCS leakage to auxiliary building(gpm) (unfiltered) and auxiliary building exhaust to environment | 2 (0.26736 ft3/min) | |
| Auxiliary building exhaust filter efficiency (all forms of iodine) (%) | 90 | |
| Control room atmospheric dispersion factors (sec/m3) | | |
| 0-2 hrs. | 6.12E-04 | |
| 2-8 hrs | 4.38E-04 | |
| 8-24 hrs. | 1.79E-04 | |
| 24-96 hrs. | 1.14E-04 | |
| 96-720 hrs. | 8.94E-05 | |
| **3.RWST Back-Leakage (sump source 2)** | | |
| Source Term Fraction | 1.0 | |
| Iodine chemical form of releases (%) | | |
| Elemental | 97 | |
| Organic | 3 | |
| Aerosol | 0 | |
| RWST initial gas volume, minimum (gal) | 3.54E+05 (4.7323774E4 ft3) | |
| Sump volume (ft3) | 3.441039E6 | |
| Time to initiate ECCS recirculation (min) (air leakage) | 0 | |
| ECCS leakage to RWST (gpm) | 3.8 (1.189 %/day) | |
| Release from RWST gas space (gpm)  (10% of ECCS leakage rate assumed) | 0.38 (0.1189 %/day) | |
| Control room atmospheric dispersion factors (sec/m3) | | |
| 0-2 hrs. | 6.80E-04 | |
| 2-8 hrs | 6.19E-04 | |
| 8-24 hrs. | 2.27E-04 | |
| 24-96 hrs. | 1.96E-04 | |
| 96-720 hrs. | 1.53E-04 | |
| **4. Containment Purge (RCS Source)** | | |
| Source Term Fraction | 1.0 | |
| RCS activity released (%) | 100 | |
| RCS Activity Release Time (hr) | 1.0E-4 | |
| Iodine chemical form of releases (%) | | |
| Elemental | 97 | |
| Organic | 3 | |
| Aerosol | 0 | |
| RCS mass, maximum (lbm) | 8.42E+05 (4.7323774E4 ft3) | |
| Compartment volume (ft3) | 2.5E+06 | |
| Maximum purge flow rate, unfiltered air leakage (cfm) | 4,680 (269.57 %/day) | |
| Duration of purge release (sec) | 10 (2.778E-3 hr) | |
| Control room atmospheric dispersion factors (sec/m3) | | |
| 0-2 hrs. | 6.12E-04 | |
| 2-8 hrs | 4.38E-04 | |
| 8-24 hrs. | 1.79E-04 | |
| 24-96 hrs. | 1.14E-04 | |
| 96-720 hrs. | 8.94E-05 | |