



# **SNAP/RADTRAD 4.0 Workshop**

## **RADTRAD Exercises**

**October 19-21, 2016**



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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.

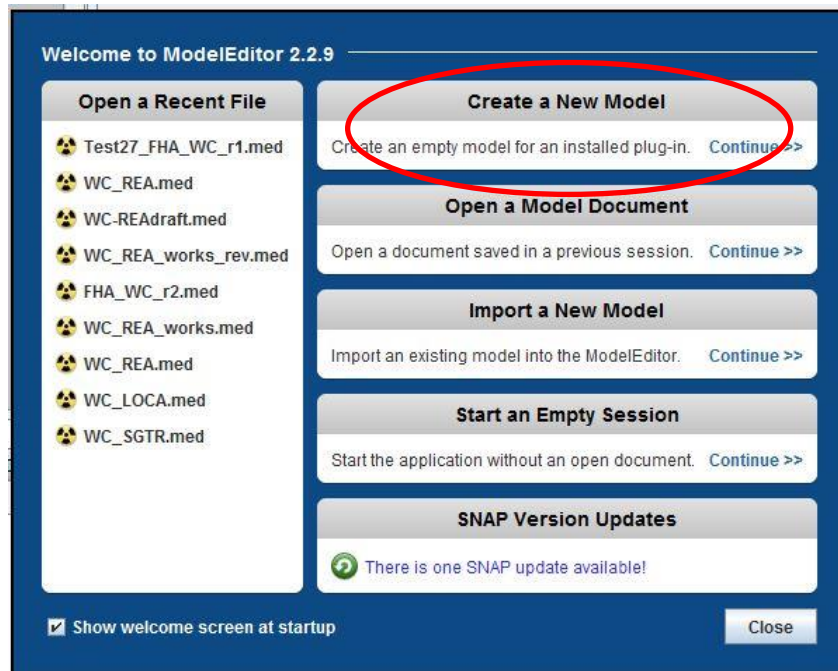
### Step 1 – Preliminary Setup (Open to Create a New Model)

1. Open the SNAP Model Editor to Create a New Model:
  - a) Start the SNAP Model Editor from the start button:

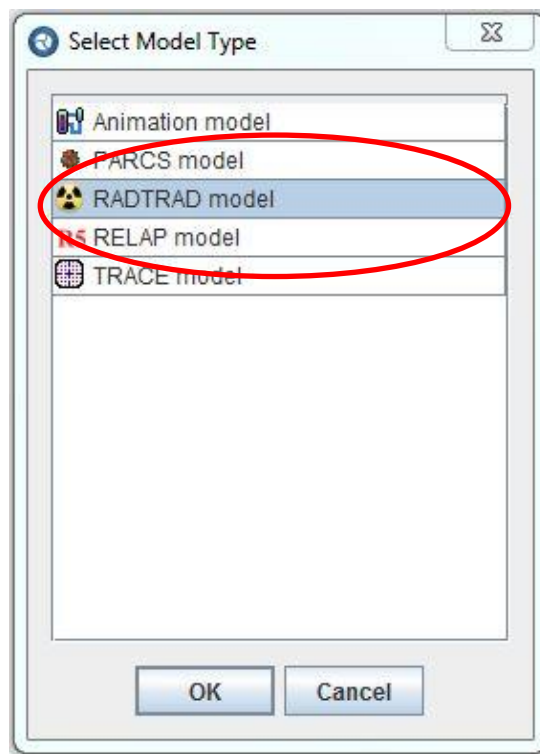


Model Editor

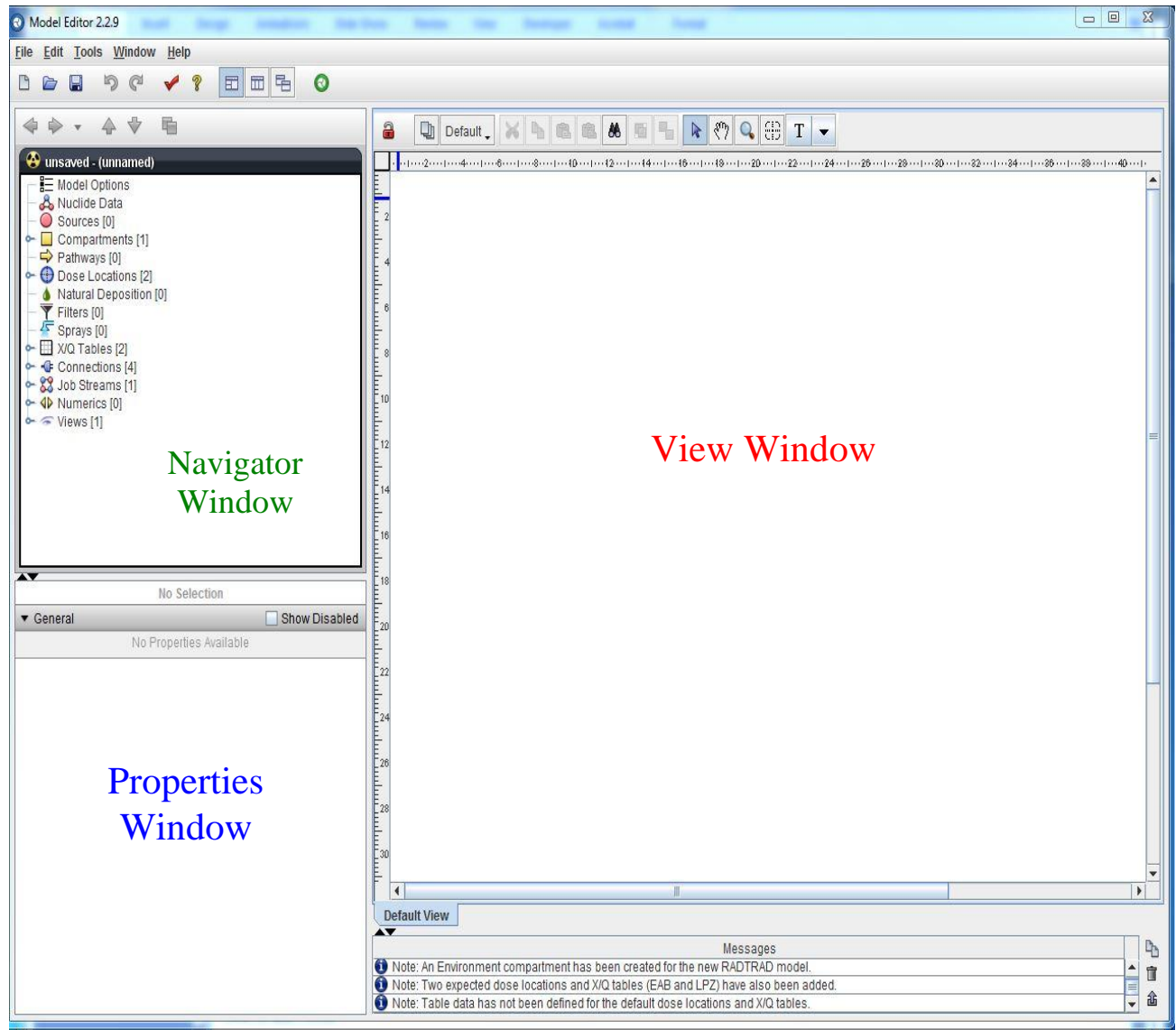
- b) Click on the “Create a New Model” option:



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



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



3. 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 below:

Attribute	Value
<b>I. General</b>	
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
<b>II. Sources</b>	See Table 1-2
<b>III. Activity Release Parameters</b>	
Containment Volume	2.5E6 ft <sup>3</sup>
Containment Leak Rate	0-24 hrs., 0.2 %/day >24 hrs., 0.1 %/day
<b>IV. Miscellaneous</b>	
Dose Conversion Factors	FGR 11 & 12
Time Step Algorithm	Default
EAB, LPZ Breathing Rate	3.5E-4 m <sup>3</sup> /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/m <sup>3</sup> 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 1-1. Common Input Values**

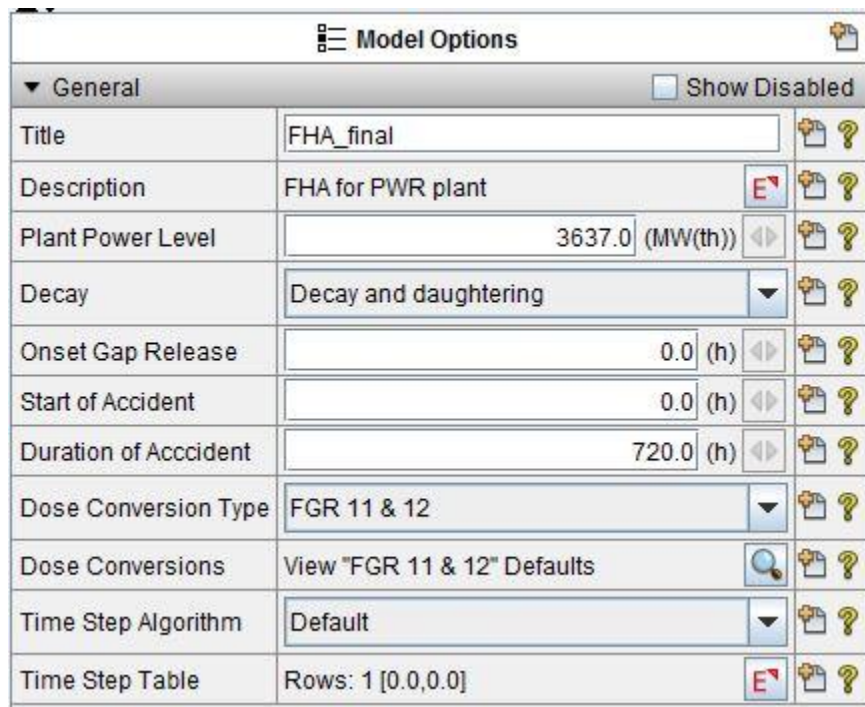
The additional assumptions used for the fuel handling accident (FHA) for the reference plant are listed in Table 1-2, Additional Assumptions Used for Fuel Handling Accident Analysis.



## 2. Detailed Steps

### a) Setting Model Options

- Click on “Model Options” in the Navigator Window, and a Properties Window similar to the following will appear:



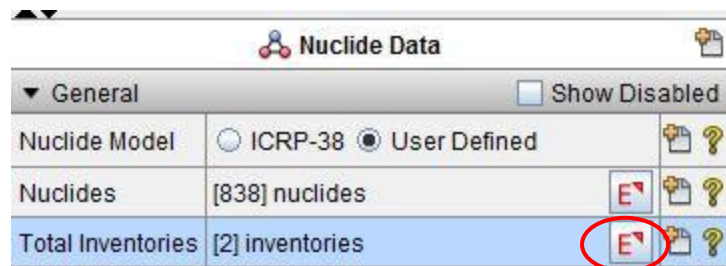
The screenshot shows the "Model Options" window with a "General" tab. It contains various input fields and dropdown menus for configuring the model. The "Title" is "FHA\_final", "Description" is "FHA for PWR plant", "Plant Power Level" is "3637.0 (MW(th))", "Decay" is "Decay and daughtering", "Onset Gap Release" is "0.0 (h)", "Start of Accident" is "0.0 (h)", "Duration of Accident" is "720.0 (h)", "Dose Conversion Type" is "FGR 11 & 12", "Dose Conversions" is "View 'FGR 11 & 12' Defaults", "Time Step Algorithm" is "Default", and "Time Step Table" is "Rows: 1 [0.0,0.0]".

Model Options	
▼ General <input type="checkbox"/> Show Disabled	
Title	FHA_final
Description	FHA for PWR plant
Plant Power Level	3637.0 (MW(th))
Decay	Decay and daughtering
Onset Gap Release	0.0 (h)
Start of Accident	0.0 (h)
Duration of Accident	720.0 (h)
Dose Conversion Type	FGR 11 & 12
Dose Conversions	View "FGR 11 & 12" Defaults
Time Step Algorithm	Default
Time Step Table	Rows: 1 [0.0,0.0]

- In the Properties Window set the **unknown** values for the model as shown above. The dropdown values should be set as indicated.


### b) Setting Nuclide Data

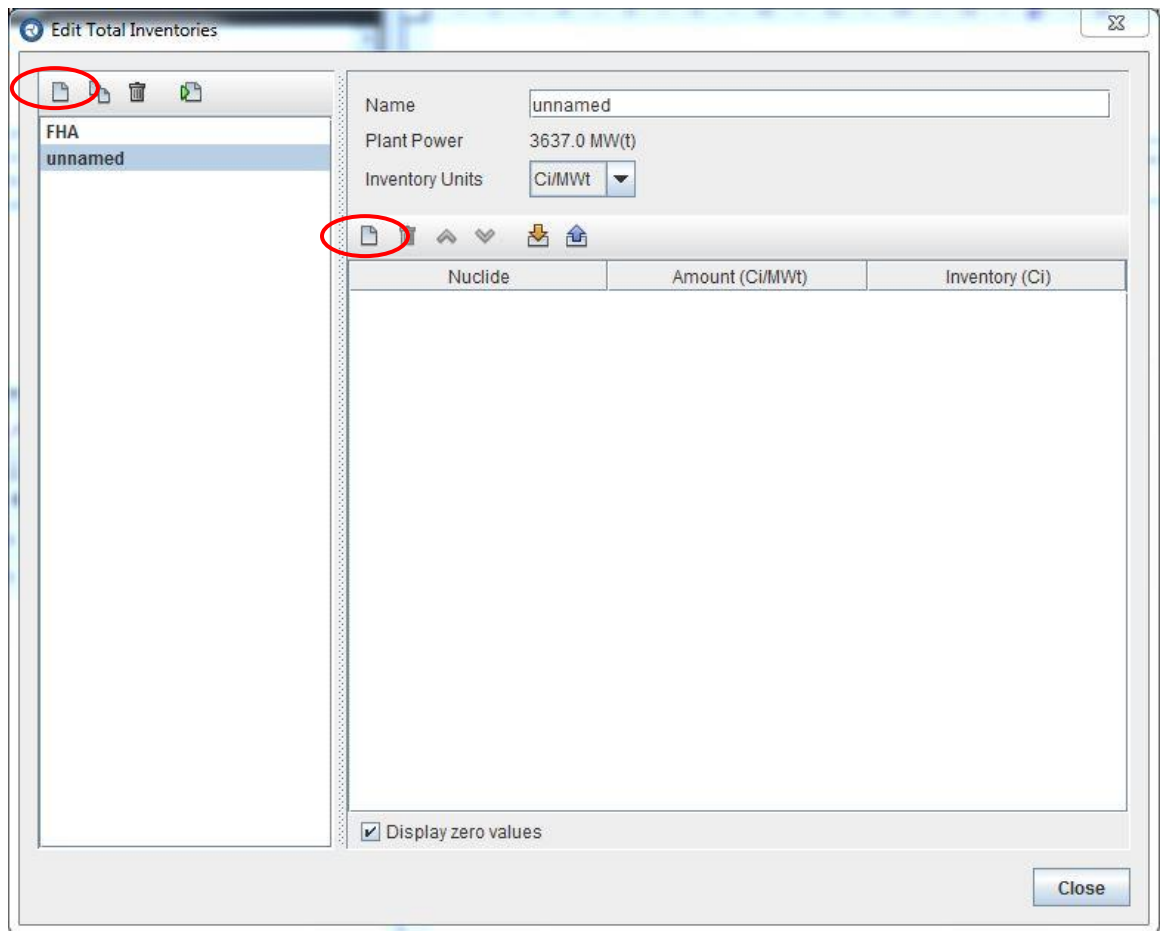
- Click on “Nuclide Data” in the Navigator Window, and the following Nuclide Data window appears:





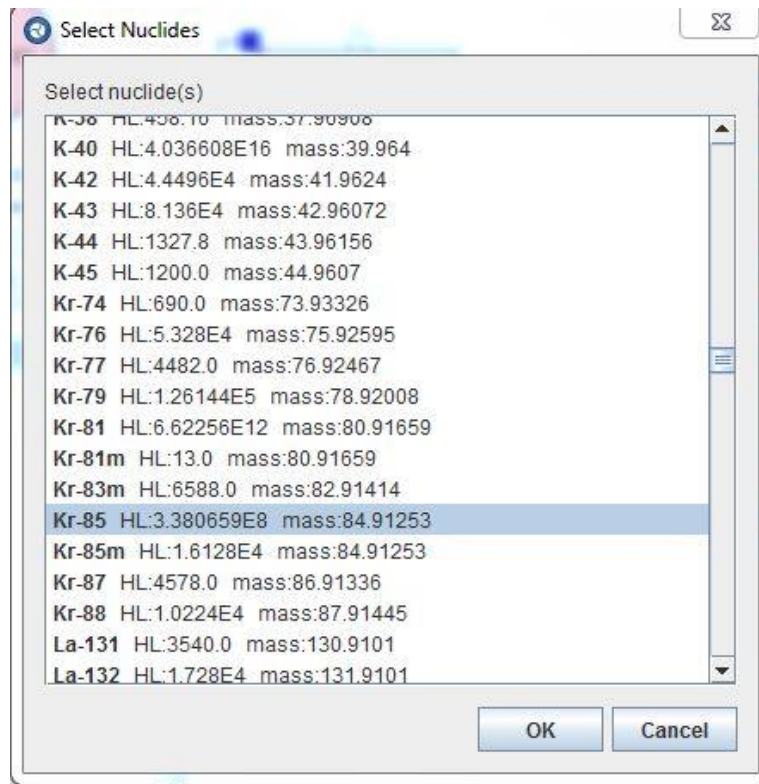
The screenshot shows the "Nuclide Data" window with a "General" tab. It contains input fields for "Nuclide Model", "Nuclides", and "Total Inventories". The "Nuclide Model" is set to "User Defined", "Nuclides" is "[838] nuclides", and "Total Inventories" is "[2] inventories". The "Total Inventories" field is highlighted with a red circle.

Nuclide Data	
▼ General <input type="checkbox"/> Show Disabled	
Nuclide Model	<input type="radio"/> ICRP-38 <input checked="" type="radio"/> User Defined
Nuclides	[838] nuclides
Total Inventories	[2] inventories

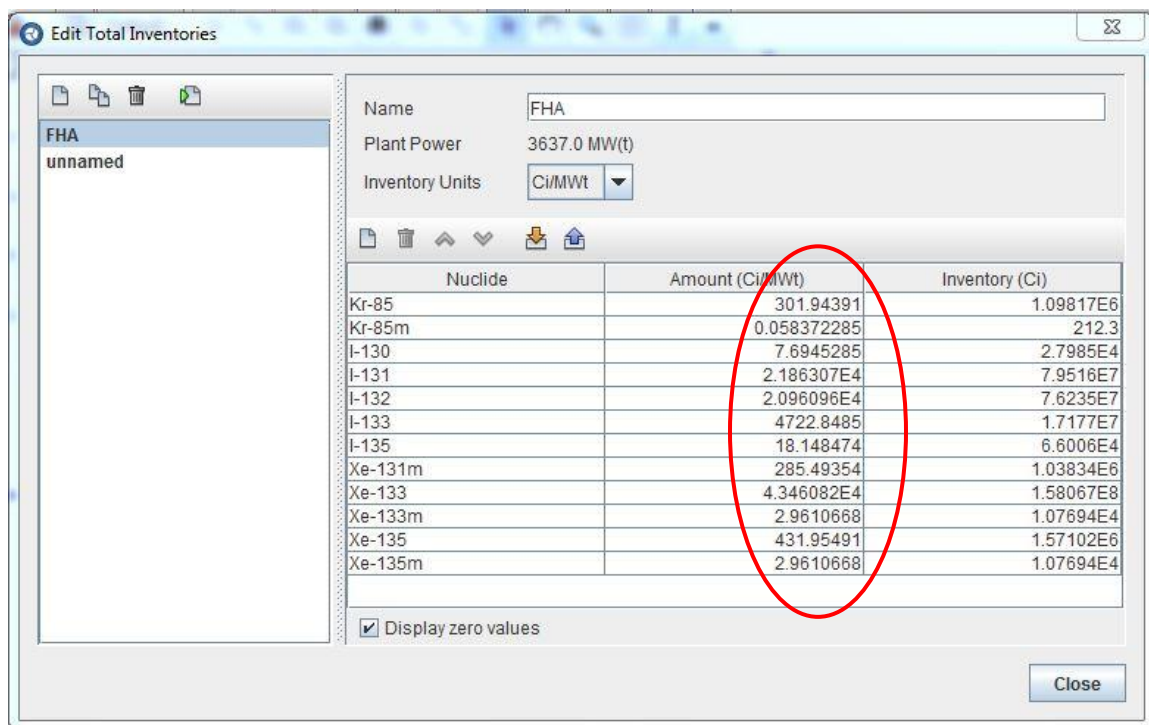
- Choose the  button next to Total Inventories, and an “Edit Total Inventories” Window similar to the following will appear:



- 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.



- Enter the nuclides shown in the screen shot below, then click “OK”:



- In the “Edit Total Inventories” Window, set the **unknown** amounts for the nuclides as shown above from Table 2-1. The inventories for each nuclide will be calculated by the code as they are entered.

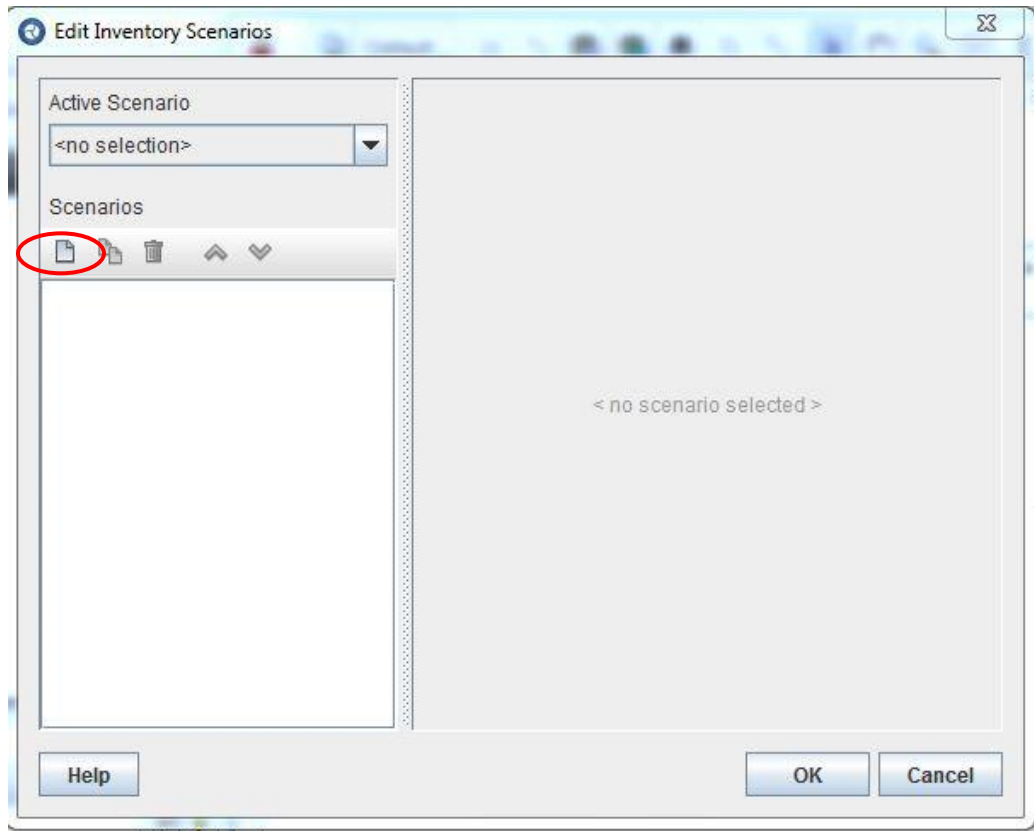
c) Setting up a Source

- 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.

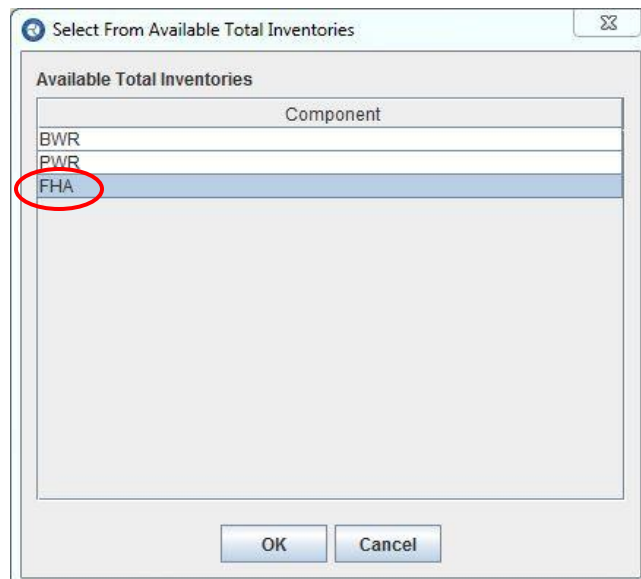
Source 1 (PWR source)		?
▼ General <input type="checkbox"/> Show Disabled		
Name	PWR source	?
Component Number	1	?
Description	<none>	E ?
Source Scenarios	[1] active: FHA	E ?
Source Term Fraction	1.0 (-) <>	?
Iodine Physical Form	User Defined	?
Aerosol Fraction	0.0 (-) <>	?
Elemental Fraction	0.7 (-) <>	?
Organic Fraction	0.3 (-) <>	?
Compartments	1 compartment connection	E ?

- Use 1.0 for the Source Term Fraction and Iodine 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.



- The following screen results after choosing FHA for Accident Type:

**Edit Inventory Scenarios**

Active Scenario: FHA

Scenarios: FHA

Scenario Name: FHA

Accident Parameters | Adjusted Inventory | Release Fractions and Timings | Source Term

Total Inventory: FHA

Accident Type: FHA

**Plant Parameters**

Number of rods or assemblies in core	193.0	(-)	?
Number of rods or assemblies damaged	1.2	(-)	?
Fraction of rods or assemblies damaged	0.006	(-)	?
Radial peaking factor	1.65	(-)	?
Pool Iodine DF	200.0	(-)	?
Decay period (hrs)	0.0	(-)	?

**Gap Fractions**

I-131	0.12	(-)	?
Kr-85	0.3	(-)	?
Other NG	0.1	(-)	?
Other Iodine	0.1	(-)	?
Alkali Metals	0.0	(-)	?

**Insert Gap Fraction Presets**

RG 1.25

RG 1.183

Help OK Cancel

- 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 Adjusting Inventory by clicking on the tab:

The screenshot shows the 'Edit Inventory Scenarios' dialog box with the 'Adjusted Inventory' tab selected. The 'Scenario Name' is 'FHA'. The 'Reference Power' is set to 1.0 MW(t) and 'Plant Power' is 3637.0 MW(t). A table displays nuclide inventory data.

Nuclide	Amount (Ci/MWt)	Inventory (Ci)
Kr-85	0.92929887	3379.86
Kr-85m	5.988452E-5	0.2178
I-130	3.946934E-5	0.14355
I-131	0.13457685	489.456
I-132	0.10751993	391.05
I-133	0.02422601	88.11
I-135	9.309321E-5	0.33858
Xe-131m	0.29288974	1065.24
Xe-133	44.586747	1.62162E5
Xe-133m	3.037778E-3	11.0484
Xe-135	0.44314545	1611.72
Xe-135m	3.037778E-3	11.0484

☒ Display zero values

- Under the Release Fractions and Timings tab, verify the values of 1.0 for Noble Gases, Halogens and Alkali Metals gap release fractions.

The screenshot shows the 'Edit Inventory Scenarios' dialog box with the 'Release Fractions and Timings' tab selected. The 'Scenario Name' is 'FHA'. The 'Use accident release fractions and timings' checkbox is checked. The 'Release Fractions' table shows values of 1.0 for Noble Gases, Halogens, and Alkali Metals in the 'Gap' column.

Group	Gap	Early	Ex-Vessel	Late
Noble Gases	1.0	0.0	0.0	0.0
Halogens	1.0	0.0	0.0	0.0
Alkali Metals	1.0	0.0	0.0	0.0
Tellurium	0.0	0.0	0.0	0.0
Alkaline Earth Met...	0.0	0.0	0.0	0.0
Noble Metals	0.0	0.0	0.0	0.0
Cerium	0.0	0.0	0.0	0.0
Lanthanides	0.0	0.0	0.0	0.0
Others	0.0	0.0	0.0	0.0
Non-radioactive A...	0.0	0.0	0.0	0.0

- 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.
- Deposition, filters and sprays are not being used in this problem.

Compartment 2 (Containment)		
▼ General <input type="checkbox"/> Show Disabled		
Name	Containment	
Component Number	2	
Description	<none>	
Type	Normal	
Output Detail Level	Full Edit at Time Steps	
Volume	2.5E6 (ft <sup>3</sup> )	
Deposition	<none>	
Filter	<none>	
Spray	<none>	

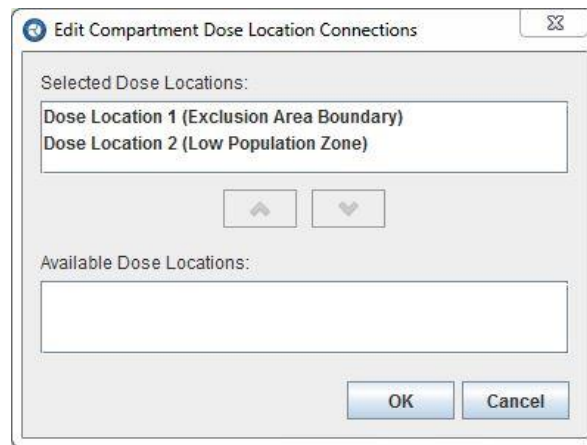
e) Environment Compartment

- 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:

Compartment 1 (Environment)		
▼ General <input type="checkbox"/> Show Disabled		
Name	Environment	
Component Number	1	
Description	<none>	
Type	Environment	
Output Detail Level	Full Edit at Time Steps	
Dose Locations	2 Dose Location connections	





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

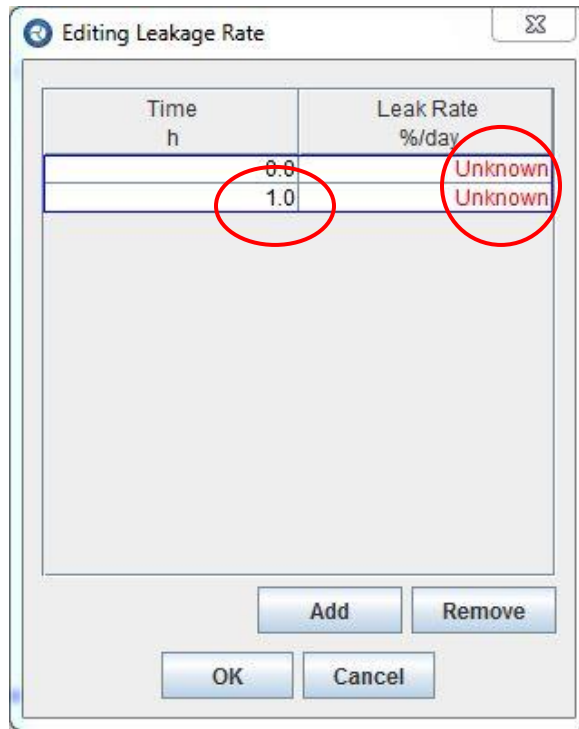


f) Setting up a Leak to the Environment

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

➡ Pathway 1 (Leak to Environment)		📁 ?
▼ General <span>Show Disabled</span>		
Name	Leak to Environment	📁 ?
Component Number	1	📁 ?
Description	<none>	 📁 ?
From Compartment	<input type="checkbox"/> Compartment 1 (Containment)	📁 ?
To Compartment	<input type="checkbox"/> Compartment 2 (Environment)	📁 ?
Pathway Type	Air Leakage	▼ 📁 ?
Printout detail level	Transport Each Time Step	▼ 📁 ?
Leakage Rate	Rows: 2 [0.0,1.0E12],[720.0,1.0E12]	 📁 ?

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



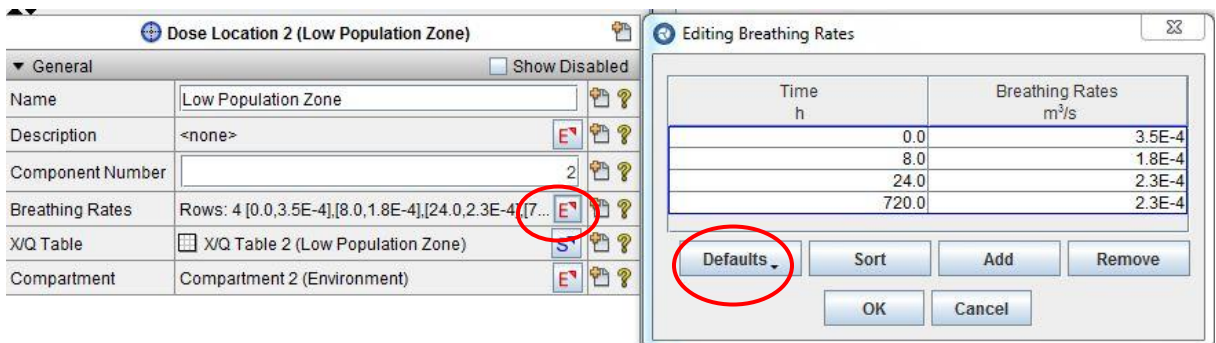
The dialog box titled "Editing Leakage Rate" contains a table with two columns: "Time h" and "Leak Rate %/day". The table has two rows. The first row has "0.0" in the Time column and "Unknown" in the Leak Rate column. The second row has "1.0" in the Time column and "Unknown" in the Leak Rate column. Both the "1.0" and the "Unknown" values are circled in red. Below the table are buttons for "Add", "Remove", "OK", and "Cancel".

Time h	Leak Rate %/day
0.0	Unknown
1.0	Unknown

- Now enter a leakage rate of  $1.0E12$  for both lines, and change the time to end at 720 hr.
- 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

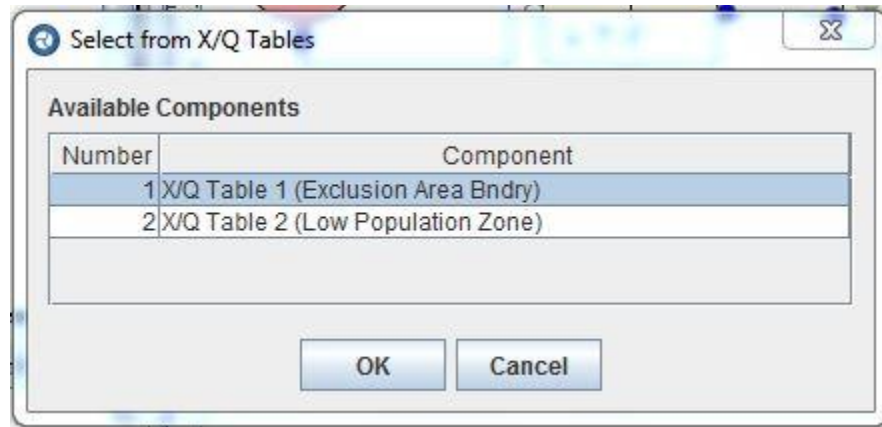
- Under “Dose Locations,” click on each dose location (EAB and LPZ) and verify the breathing rates that are automatically input.



The image shows two overlapping dialog boxes. The background dialog box is titled "Dose Location 2 (Low Population Zone)" and has a "General" tab. It contains fields for Name, Description, Component Number, Breathing Rates, X/Q Table, and Compartment. The Breathing Rates field shows a list of rows: "Rows: 4 [0.0,3.5E-4],[8.0,1.8E-4],[24.0,2.3E-4],[720.0,2.3E-4]". The foreground dialog box is titled "Editing Breathing Rates" and contains a table with two columns: "Time h" and "Breathing Rates m³/s". The table has four rows with values: (0.0, 3.5E-4), (8.0, 1.8E-4), (24.0, 2.3E-4), and (720.0, 2.3E-4). Below the table are buttons for "Defaults", "Sort", "Add", "Remove", "OK", and "Cancel". The "Defaults" button is circled in red.

Time h	Breathing Rates m³/s
0.0	3.5E-4
8.0	1.8E-4
24.0	2.3E-4
720.0	2.3E-4

- Click on the  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 input for the Exclusion Area Boundary and Low Population Zone.

**FHA\_simple.med - (FHA\_simple)**


- Model Options
- Nuclide Data
- Sources [1]
- Compartments [2]
- Pathways [1]
- Dose Locations [2]
- Natural Deposition [0]
- Filters [0]
- Sprays [0]
- X/Q Tables [2]
  - X/Q Table 1 (Exclusion Area Bndry)
  - X/Q Table 2 (Low Population Zone)
- Connections [7]
- Job Streams [1]
- Numerics [0]
- Views [1]

**unsaved - (unnamed)**

**X/Q Table 1 (Exclusion Area Bndry)**


▼ General ☐ Show Disabled

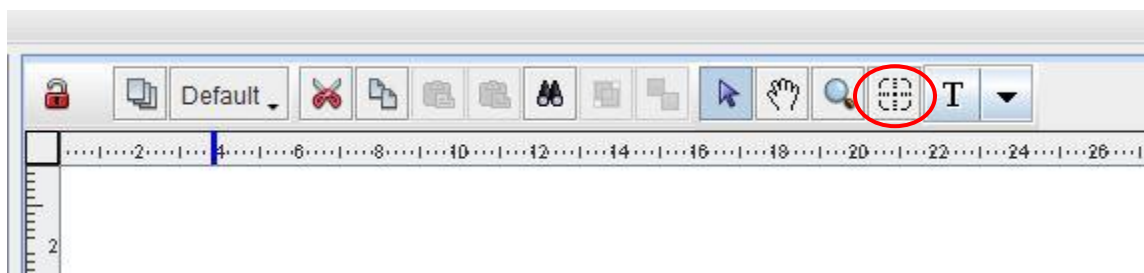
Name	Exclusion Area Bndry	
Component Number	1	
Description	<none>	
X/Q Table	Rows: 2 [0.0, 1.4E-4], [720.0, 1.4E-4]	

- Click the “X/Q Table” node for the EAB, click on the  and input the information from Table 1-1 for EAB. Repeat for the LPZ.

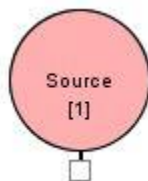
Time h	X/Q s/m <sup>3</sup>
0.0	1.4E-4
720.0	1.4E-4

Time h	X/Q s/m <sup>3</sup>
0.0	4.5E-5
2.0	2.39E-5
8.0	1.29E-5
24.0	5.49E-6
96.0	1.61E-6
720.0	1.61E-6

**Step 3** - “Connections” are added to the model via the connection tool () in the View Window.




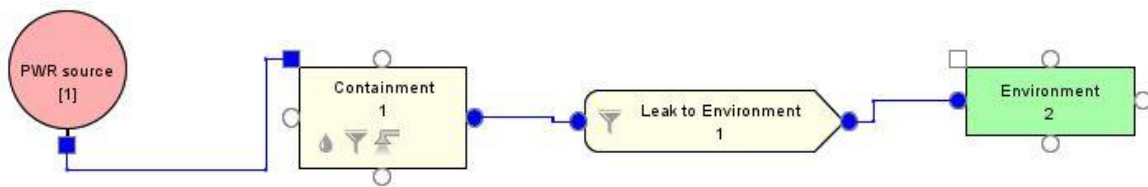
- Right-click in the Navigator Window on Source 1 and choose “Add to View.”
- An icon for the source will appear in the View Window.



- Repeat this procedure for the containment and environment compartments and the pathway from the containment to the environment.



- 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.



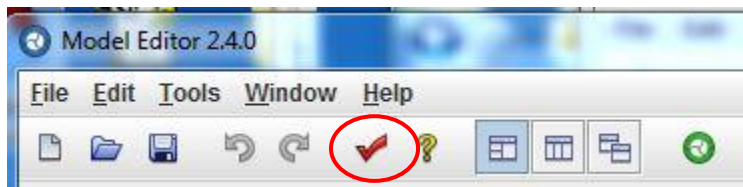
#### h) Setting the Job Stream

- In the Job Stream Properties Window, rename Simple\_Stream to PWR\_FHA (I used FHA\_simple).
- Indicate the Root Folder for your machine
- Indicate a Relative Location under the Root Folder for the output. I am using RADTRAD/FHA\_final
- The resulting window should look as follows:

▼ General		<input type="checkbox"/> Show Disabled
Name	PWR_FHA_simple	
Description	<none>	
Stream Type	Basic Job Stream	
File Groups	0 Groups	
Platform	Local	
Root Folder	Fall_2016_class_CD	
Relative Location	Exercises/FHA_simple/	
Log Level	Information	
View in Job Status	<input checked="" type="radio"/> Yes <input type="radio"/> No	
Linear Execution	<input type="radio"/> Yes <input checked="" type="radio"/> No	

#### 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:

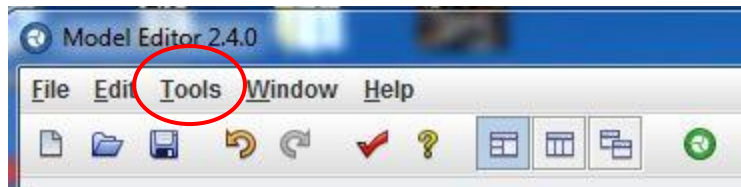
Open the SNAP Configuration Tool and start the SNAP server:

- Start the SNAP Configuration Tool under Tools\Configuration Tool. (  )
- 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).



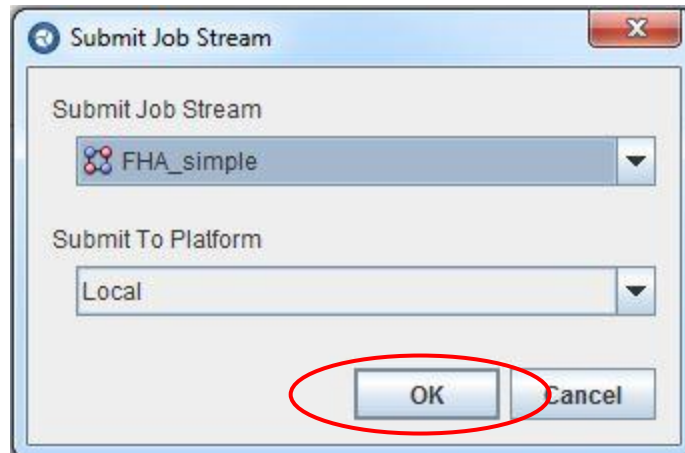
## Step 6 - Run the Simulation

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.

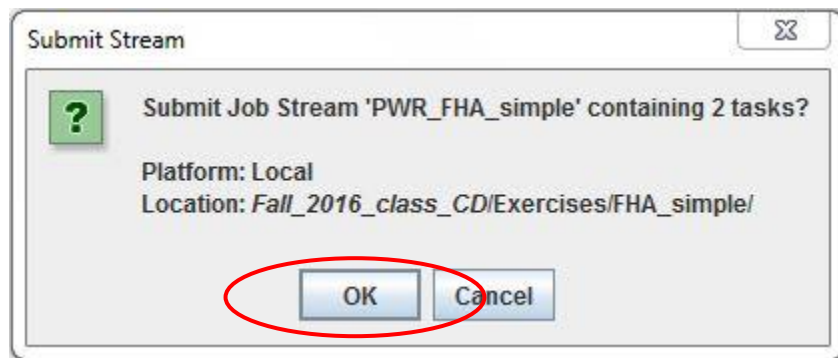


- A submit job stream window will appear. Click “OK.”




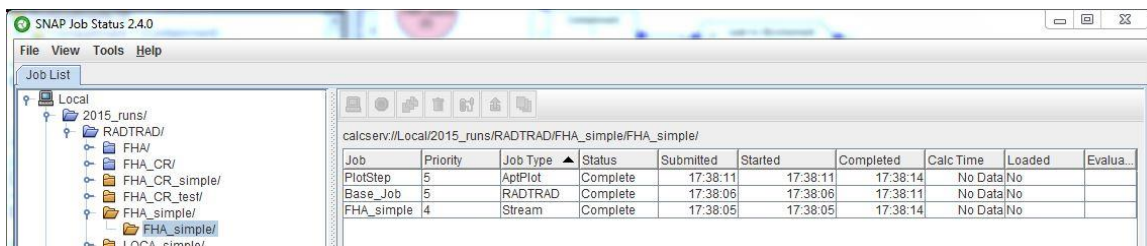


- A second job stream window will appear. Click “OK.”



## 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	26.667	0.97924

Final Doses (Low Population Zone)			
Time (hr)	Whole Body (rem)	Thyroid (rem)	TEDE (rem)
720.0	0.052428	8.5715	0.31475

## **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 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.

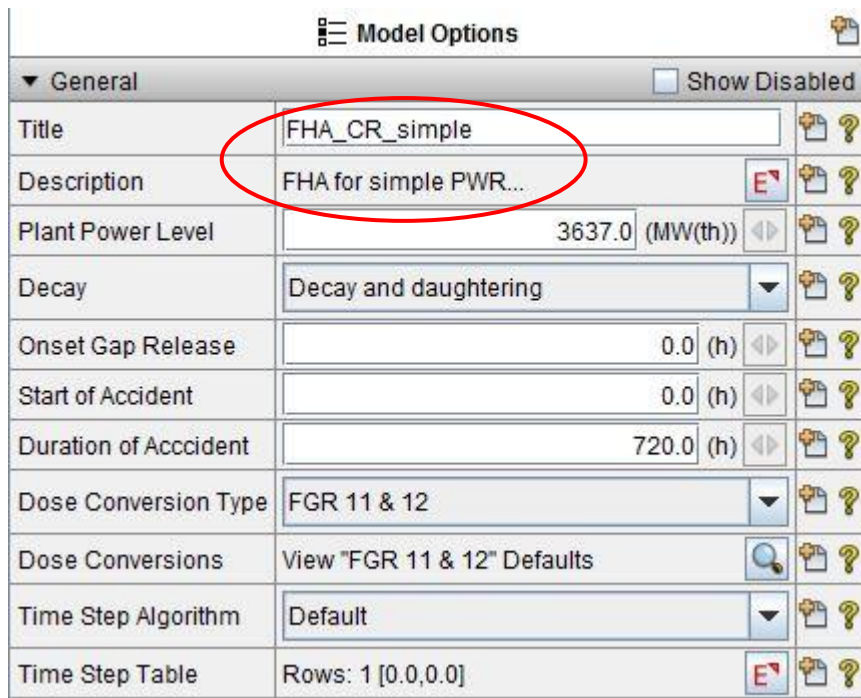
### **Input Values:**

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:

**Step 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.



The screenshot shows the 'Model Options' dialog box with the 'General' tab selected. The 'Title' field is set to 'FHA\_CR\_simple' and the 'Description' field is set to 'FHA for simple PWR...'. Both fields are circled in red. The 'Plant Power Level' is 3637.0 (MW(th)). The 'Decay' is set to 'Decay and daughtering'. The 'Onset Gap Release' is 0.0 (h). The 'Start of Accident' is 0.0 (h). The 'Duration of Accident' is 720.0 (h). The 'Dose Conversion Type' is 'FGR 11 & 12'. The 'Dose Conversions' are 'View "FGR 11 & 12" Defaults'. The 'Time Step Algorithm' is 'Default'. The 'Time Step Table' is 'Rows: 1 [0.0,0.0]'. The 'Show Disabled' checkbox is unchecked.

Model Options	
General	
Title	FHA_CR_simple
Description	FHA for simple PWR...
Plant Power Level	3637.0 (MW(th))
Decay	Decay and daughtering
Onset Gap Release	0.0 (h)
Start of Accident	0.0 (h)
Duration of Accident	720.0 (h)
Dose Conversion Type	FGR 11 & 12
Dose Conversions	View "FGR 11 & 12" Defaults
Time Step Algorithm	Default
Time Step Table	Rows: 1 [0.0,0.0]

- Job Streams\Name to 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.

▼ General		<input type="checkbox"/> Show Disabled
Name	FHA_CR_simple	
Description	<none>	
Stream Type	Basic Job Stream	
File Groups	0 Groups	
Platform	Local	
Root Folder	Fall_2016_class_CD	
Relative Location	Exercises/FHA_CR_simple/	
Log Level	Information	
View in Job Status	<input checked="" type="radio"/> Yes <input type="radio"/> No	
Linear Execution	<input type="radio"/> Yes <input checked="" type="radio"/> No	

## Step 2 - Additional Compartments

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

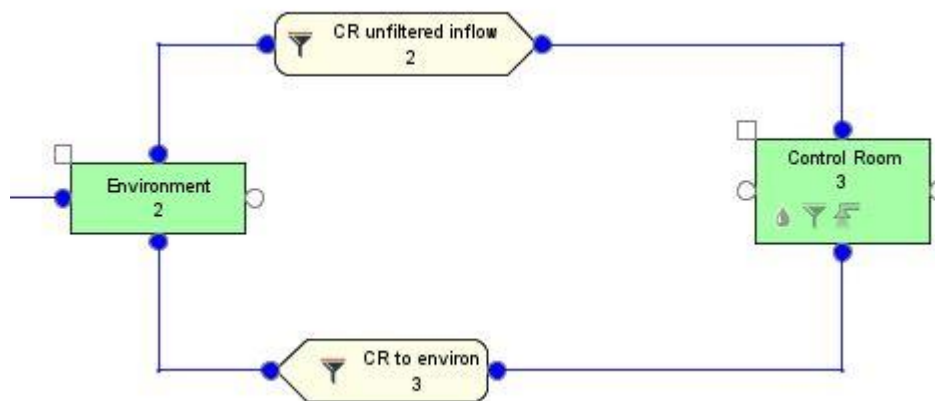
Compartment 3 (Control Room)		
▼ General		<input type="checkbox"/> Show Disabled
Name	Control Room	
Component Number	3	
Description	<none>	
Type	Control Room Dose	
Output Detail Level	Full Edit at Time Steps	
Volume	2831.6847 (m <sup>3</sup> )	
Deposition	<none>	
Filter	<none>	
Spray	<none>	
Dose Locations	1 Dose Location connection	

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

### Step 3 - Additional Pathways

1. 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:
  - a. an unfiltered pathway from the Environment to the Control Room named “CR unfiltered inflow,”
  - b. 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.



- c. 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.

➔ Pathway 2 (CR unfiltered inflow)		
▼ General <span>Show Disabled</span>		
Name	CR unfiltered inflow	📄 ?
Component Number	2	📄 ?
Description	<none>	E 📄 ?
From Compartment	Compartment 2 (Environment)	📄 ?
To Compartment	Compartment 3 (Control Room)	📄 ?
Pathway Type	Filtered Pathway	📄 ?
Printout detail level	None	📄 ?
Filter	Filter 1 (CR unfiltered inflow)	S 📄 ?

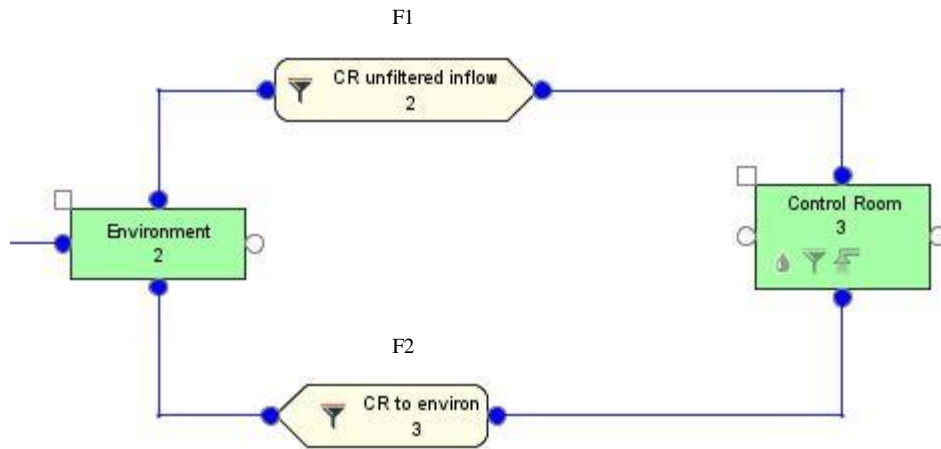
## Step 4 - Additional Filters

1. In the Navigation Window, right click on “Filter (0)” and select “New.” This will cause “Filter 1” to appear in the Properties Window. We will do this twice to add two filters:


🔍 Filter 1 (CR unfiltered inflow)		
▼ General <span>Show Disabled</span>		
Name	CR unfiltered inflow	📄 ?
Component Number	1	📄 ?
Description	<none>	E 📄 ?
Filter Table	Rows: 2 [0.0,2000.0,0.0,0.0,0.0],[720.0,2000.0,0....	E 📄 ?

2. The two filters represent:

F1. Unfiltered flow from the Environment to the Control Room,  
 F2. Control Room flow to the Environment.



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

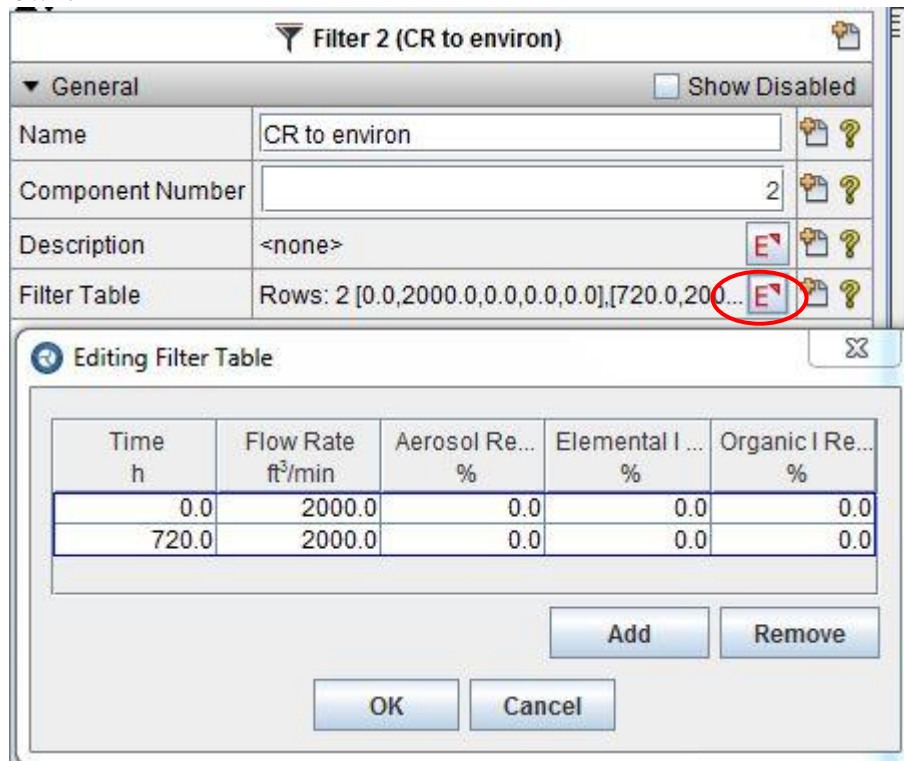
Note that you can annotate the model by using the Text Annotation tool. Click on the  icon, and then select Annotation->Text Annotation. A small text box will appear which can be filled in.

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 (ft <sup>3</sup> /min)	F2 (ft <sup>3</sup> /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:



**Filter 2 (CR to environ)**

▼ General ☐ Show Disabled

Name: CR to environ

Component Number: 2

Description: <none>

Filter Table: Rows: 2 [0.0,2000.0,0.0,0.0,0.0],[720.0,2000.0,0.0,0.0,0.0]

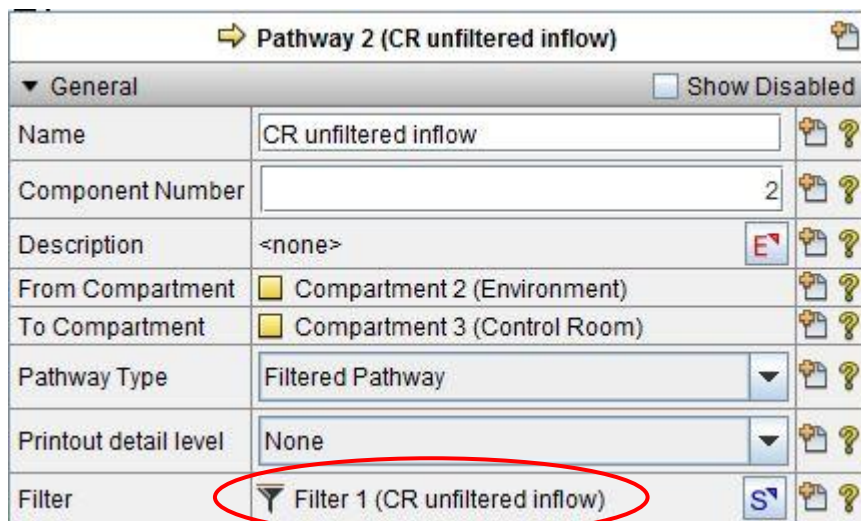
**Editing Filter Table**

Time h	Flow Rate ft³/min	Aerosol Re... %	Elemental I ... %	Organic I Re... %
0.0	2000.0	0.0	0.0	0.0
720.0	2000.0	0.0	0.0	0.0

Add Remove

OK Cancel

3. Create one filter table for each filter indicated in the above table. The filter name should correspond to the pathway name for clarity.
4. Once the filter tables have been created, ensure that the appropriate filter table has been referenced in the two pathway properties windows (reference step 4 above) as illustrated in the figure below.



**Pathway 2 (CR unfiltered inflow)**

▼ General ☐ Show Disabled

Name: CR unfiltered inflow

Component Number: 2

Description: <none>

From Compartment: ☒ Compartment 2 (Environment)

To Compartment: ☒ Compartment 3 (Control Room)

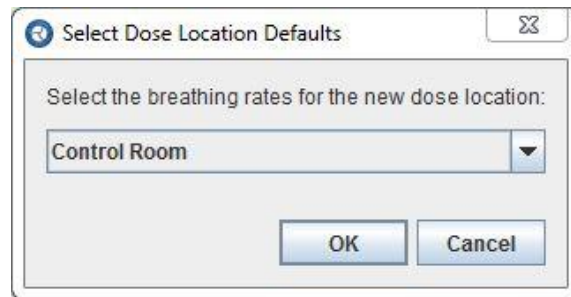
Pathway Type: Filtered Pathway

Printout detail level: None

Filter: **Filter 1 (CR unfiltered inflow)**

## Step 5 - Additional Dose Location

1. A third Dose Location will also need to be added for the Control Room. When a new dose location is requested, the following screen results requesting you to select a dose location so default values can be set:











2. When “Control Room” is selected, a Breathing Rate table is automatically entered.
3. 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.

Dose Location 3 (Control Room)		
▼ General <span>Show Disabled</span>		
Name	Control Room	📄 ?
Description	<none>	E 📄 ?
Component Number	3	📄 ?
Breathing Rates	Rows: 2 [0.0,3.5E-4],[720.0,3.5E-4]	E 📄 ?
X/Q Table	X/Q Table 3 (Control Room - containm...	S 📄 ?
Occupancy Factors	Rows: 4 [0.0,1.0],[24.0,0.6],[96.0,0.4],[720....	E 📄 ?
Compartment	Compartment 3 (Control Room)	E 📄 ?

4. 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:

**X/Q Table 3 (Control Room - containment leakage)**

▼ General ☐ Show Disabled

Name	Control Room - containment leakage	 
Component Number	3	 
Description	<none>	 
X/Q Table	Rows: 2 [0.0,6.12E-4],[720.0,6.12E-4]	 
















**Editing X/Q Table** ✖

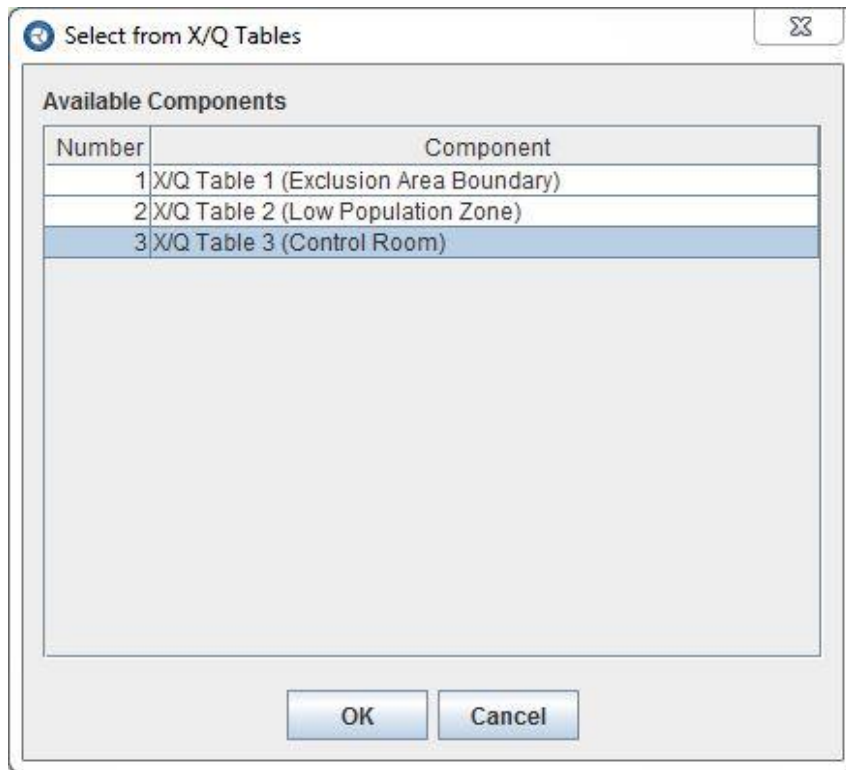
Time h	X/Q s/m <sup>3</sup>
0.0	6.12E-4
720.0	6.12E-4

5. 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.

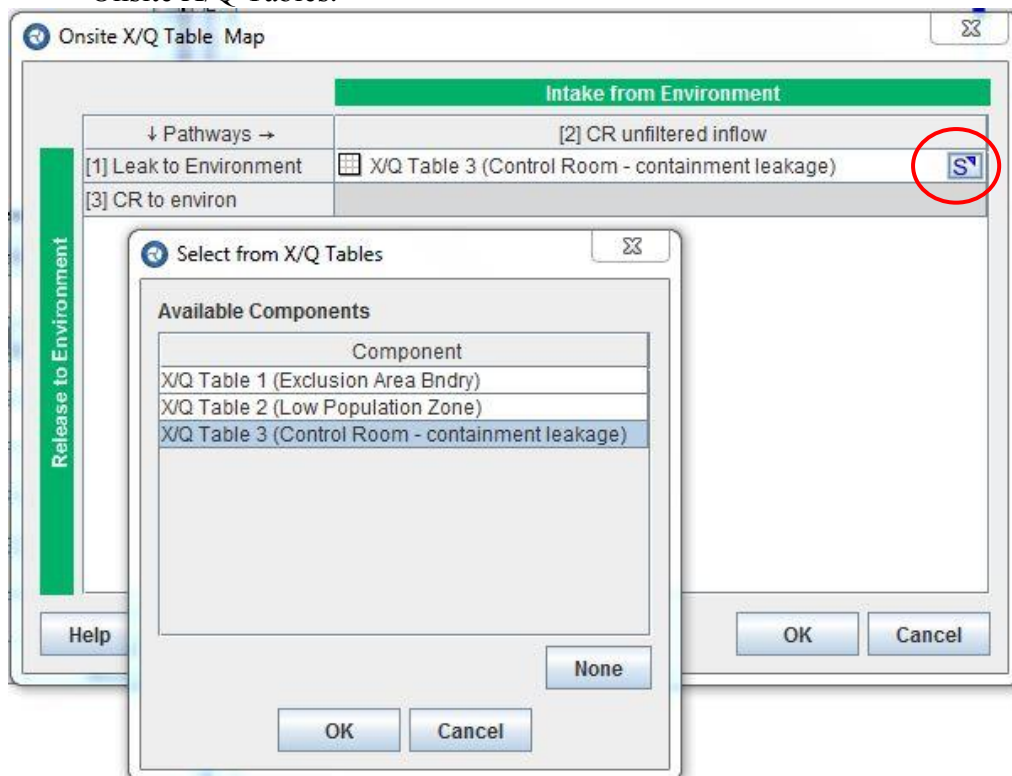
**Dose Location 3 (Control Room)**

▼ General ☐ Show Disabled

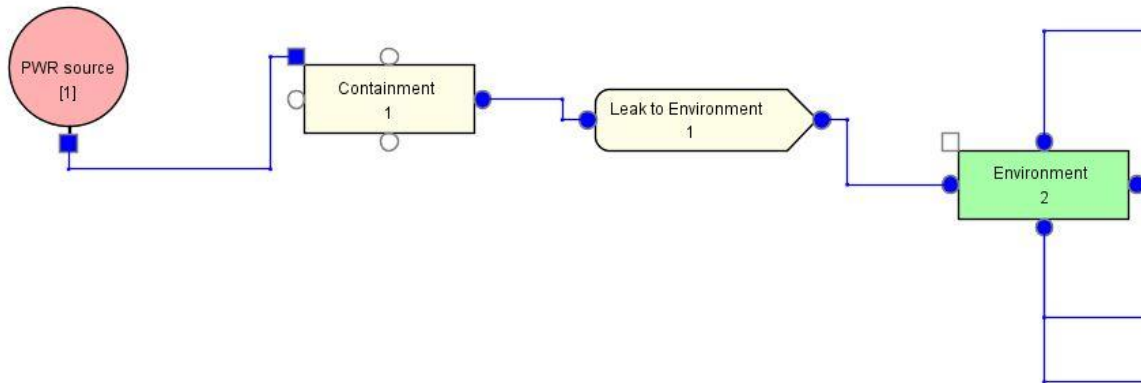
Name	Control Room	 
Description	<none>	 
Component Number	3	 
Breathing Rates	Rows: 2 [0.0,0.741608],[720.0,0.741608]	 
X/Q Table	 X/Q Table 3 (Control Room - containm...	 
Occupancy Factors	Rows: 4 [0.0,1.0],[24.0,0.6],[96.0,0.4],[720....	 
Compartment	Compartment 3 (Control Room)	 



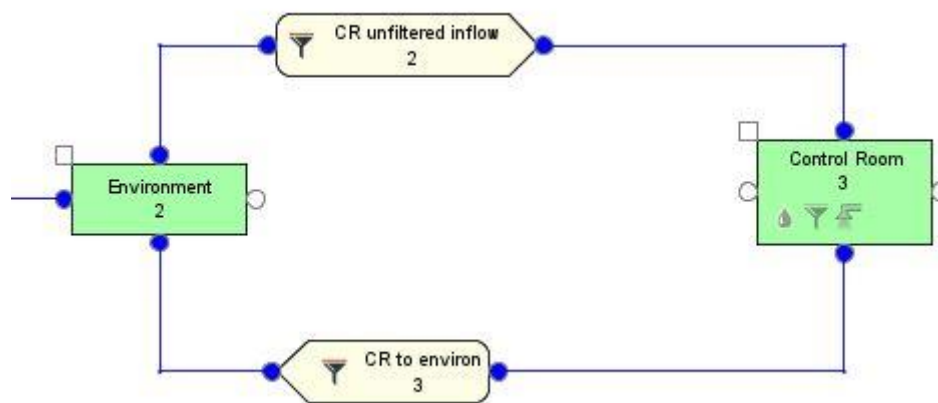
- Go back to the Environment compartment and enter the CR X/Q table to the "Onsite X/Q Tables."



7. Compare your model in the View Window with that shown.



Fuel Handling Accident (FHA) RADTRAD Model



RADTRAD Control Room Model

8. 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	26.667	0.97924

Final Doses (Low Population Zone)			
Time (hr)	Whole Body (rem)	Thyroid (rem)	TEDE (rem)
720.0	0.052428	8.5715	0.31475

Final Doses (Control Room)			
Time (hr)	Whole Body (rem)	Thyroid (rem)	TEDE (rem)
720.0	0.028921	116.07	3.5786

**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 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:**

**Step 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:

PWR_REA_simple		
▼ General		<input type="checkbox"/> Show Disabled
Name	PWR_REA_simple	[Add] [Help]
Description	PWR REA for a reference plant.	[Edit] [Add] [Help]
Stream Type	Basic Job Stream	[Edit] [Add] [Help]
File Groups	0 Groups	[Edit] [Add] [Help]
Platform	Local	[Add] [Help]
Root Folder	Fall_2016_class_CD	[Edit] [Add] [Help]
Relative Location	Exercises/REA_simple/	[Add] [Help]
Log Level	Information	[Add] [Help]
View in Job Status	<input checked="" type="radio"/> Yes <input type="radio"/> No	[Add] [Help]
Linear Execution	<input type="radio"/> Yes <input checked="" type="radio"/> No	[Add] [Help]

**Step 2 -** 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.

Edit Total Inventories

Name: AST\_Core\_Activity

Plant Power: 3637.0 MW(t)

Inventory Units: Ci/MWt

Nuclide	Amount (Ci/MWt)	Inventory (Ci)
Kr-85	302.44707	1.1E6
Kr-85m	7396.2057	2.69E7
Kr-87	1.457245E4	5.3E7
Kr-88	1.957657E4	7.119999E7
Rb-86	51.14105	1.86E5
I-130	544.40473	1.98E6
I-131	2.777014E4	1.01E8
I-132	4.096783E4	1.49E8
I-133	5.77399E4	2.1E8
I-134	6.488864E4	2.36E8
I-135	5.499038E4	2.0E8
Xe-131m	288.69948	1.05E6
Xe-133	5.526533E4	2.01E8
Xe-133m	1666.2084	6.06E6
Xe-135	1.116305E4	4.060001E7
Xe-135m	1.207039E4	4.390001E7
Xe-138	4.949134E4	1.8E8
Cs-134	4536.7061	1.65E7

☒ Display zero values

Close

- 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.
- Source1\Iodine Physical Form should be changed to “NUREG-1465”

**Source 1 (PWR\_REA\_Source)**

▼ General ☐ Show Disabled

Name	PWR_REA_Source	
Component Number	1	
Description	<none>	
Source Scenarios	[1] active: REA_source	
Source Term Fraction	1.0 (-)	
Iodine Physical Form	NUREG-1465	
Aerosol Fraction	0.95 (-)	
Elemental Fraction	0.0485 (-)	
Organic Fraction	1.5E-3 (-)	
Compartments	1 compartment connection	

- Select source scenarios and define a REA\_Source scenario. Change input as indicated in the following pop-up window:

**Edit Inventory Scenarios**

Active Scenario: REA\_source

Scenarios: REA\_source

Scenario Name: REA\_source

Accident Parameters

Total Inventory: AST\_Core\_Activity

Accident Type: REA-CRDA

**Accident Parameters**

Fraction of clad breached: 0.1 (-)

Fraction of breach > melt: 2.5E-3 (-)

Radial peaking factor: 1.65 (-)

**Release Fractions**

Gap Release

Noble Gas: 0.1 (-)

Iodines: 0.1 (-)

Alkali Metals: 0.12 (-)

Melt Release

Noble Gas: 1.0 (-)

Iodines: 0.5 (-)

Alkali Metals: 0.5 (-)

Help OK Cancel

- 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):

Scenario Name: REA\_source

Active Scenario: REA\_source

Scenarios: REA\_source

Release Fractions and Timings tab

☒ Use accident release fractions and timings

RFT File Header Lines

User-defined source release

Duration (h):

Release Durations (hrs)

Gap: 1.0E-4 Ex-Vessel: 0.0

Early: 0.0 Late: 0.0

Release Fractions

Group	Gap	Early	Ex-Vessel	Late
Noble Gases	1.0	0.0	0.0	0.0
Halogens	1.0	0.0	0.0	0.0
Alkali Metals	1.0	0.0	0.0	0.0
Tellurium	0.0	0.0	0.0	0.0
Alkaline Earth Met...	0.0	0.0	0.0	0.0
Noble Metals	0.0	0.0	0.0	0.0
Cerium	0.0	0.0	0.0	0.0
Lanthanides	0.0	0.0	0.0	0.0
Others	0.0	0.0	0.0	0.0
Non-radioactive A...	0.0	0.0	0.0	0.0

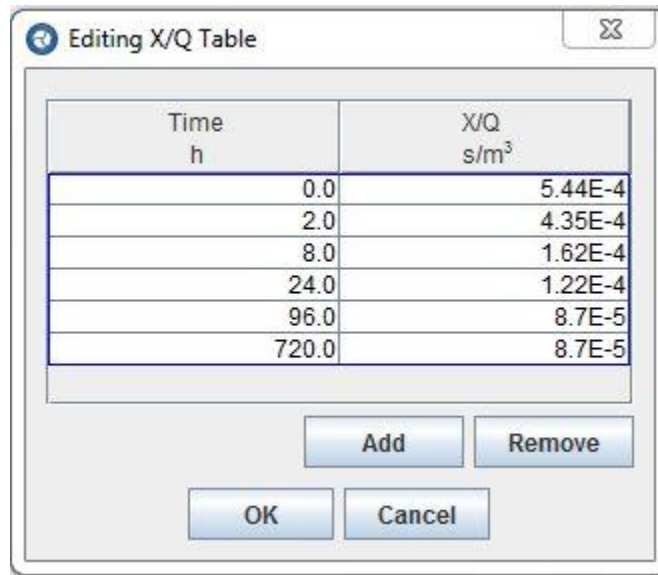
- Leak rate table for the pathway from Containment to Environment under Pathways should be changed to the information given in Table 3-2:

Editing Leakage Rate

Time h	Leak Rate %/day
0.0	0.2
24.0	0.1
720.0	0.1

Buttons: Sort, Add, Remove, OK, Cancel

- 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:



Time h	X/Q s/m <sup>3</sup>
0.0	5.44E-4
2.0	4.35E-4
8.0	1.62E-4
24.0	1.22E-4
96.0	8.7E-5
720.0	8.7E-5

**Step 3 -** 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):

- 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.”

**Pathway 4 (CR filtered inflow)**

▼ General ☐ Show Disabled

Name	CR filtered inflow	
Component Number		4
Description	<none>	
From Compartment	<input type="checkbox"/> Compartment 2 (Environment)	
To Compartment	<input type="checkbox"/> Compartment 3 (Control Room)	
Pathway Type	Filtered Pathway	
Printout detail level	None	
Filter	<input type="checkbox"/> Filter 4 (CR filtered inflow)	

Select from Filters

Available Components

Number	Component
1	Filter 1 (CR unfiltered inflow)
2	Filter 2 (CR to environ)
3	Filter 3 (CR recirc flow)
4	Filter 4 (CR filtered inflow)

None Create

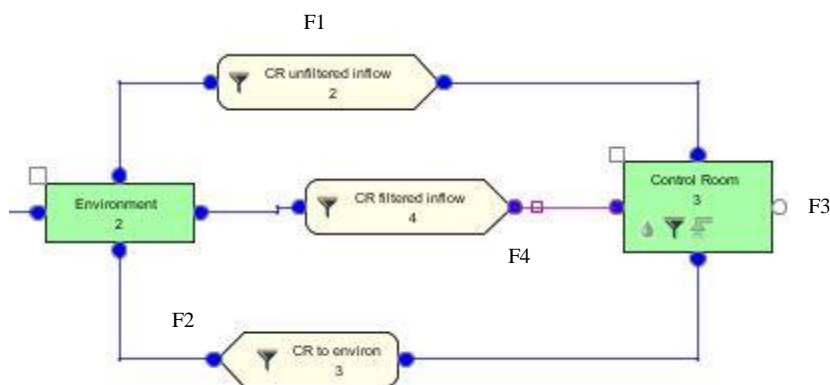
OK Cancel

b. 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:



c. 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.

d. 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

e. 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:

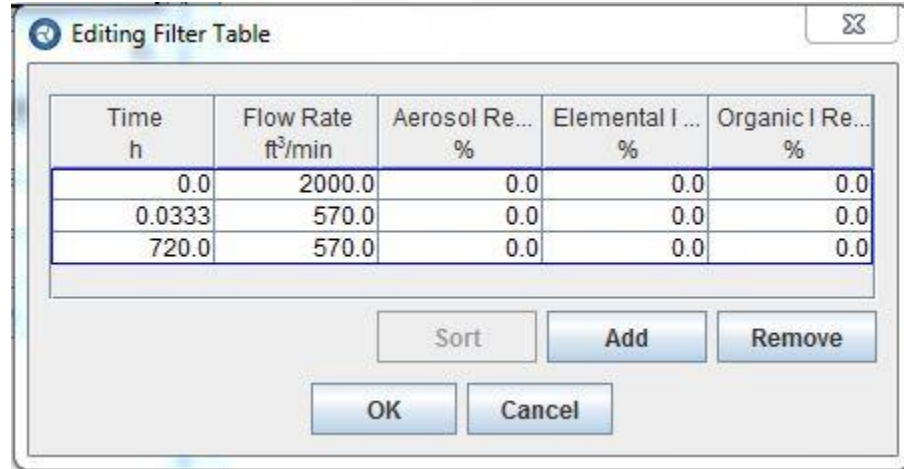
Filter 1 table, CR unfiltered inflow:

Time h	Flow Rate ft³/min	Aerosol Re... %	Elemental I ... %	Organic I Re... %
0.0	2000.0	0.0	0.0	0.0
0.0333	20.0	0.0	0.0	0.0
720.0	20.0	0.0	0.0	0.0

Buttons: Sort, Add, Remove, OK, Cancel



Filter 2 table, CR to environment:



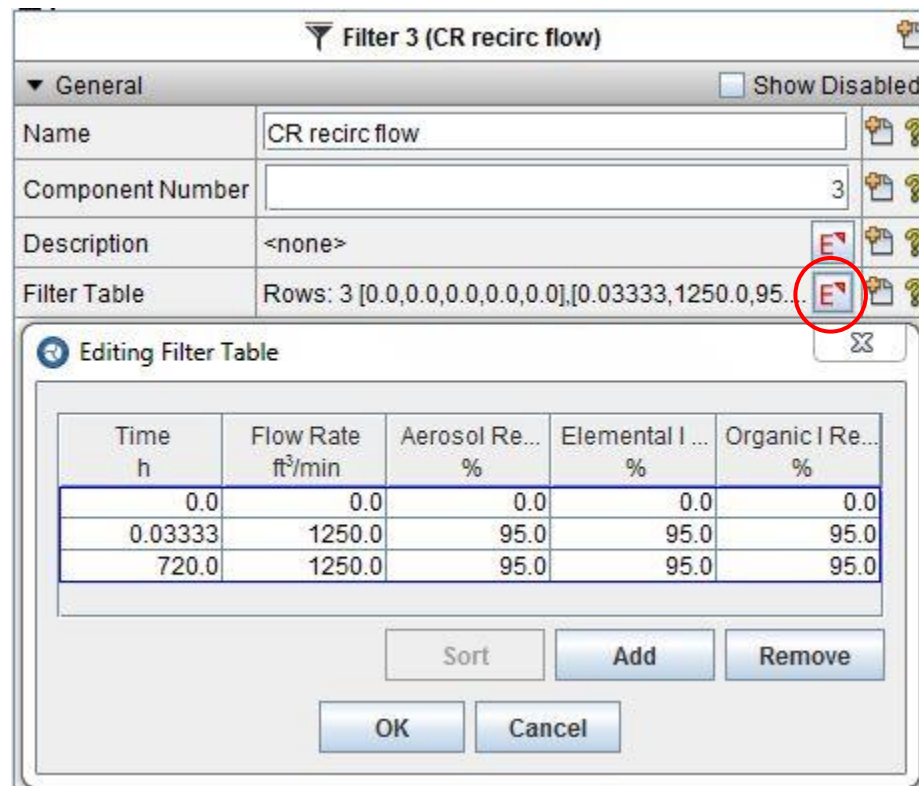
The dialog box titled "Editing Filter Table" contains a table with the following data:

Time h	Flow Rate ft <sup>3</sup> /min	Aerosol Re... %	Elemental I ... %	Organic I Re... %
0.0	2000.0	0.0	0.0	0.0
0.0333	570.0	0.0	0.0	0.0
720.0	570.0	0.0	0.0	0.0

Below the table are buttons for "Sort", "Add", "Remove", "OK", and "Cancel".

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

Filter 3 tables:



The dialog box titled "Filter 3 (CR recirc flow)" has a "General" tab. It contains the following fields:

- Name: CR recirc flow
- Component Number: 3
- Description: <none>
- Filter Table: Rows: 3 [0.0,0.0,0.0,0.0,0.0],[0.03333,1250.0,95.0],...

Below the fields is an "Editing Filter Table" dialog box with the following data:

Time h	Flow Rate ft <sup>3</sup> /min	Aerosol Re... %	Elemental I ... %	Organic I Re... %
0.0	0.0	0.0	0.0	0.0
0.03333	1250.0	95.0	95.0	95.0
720.0	1250.0	95.0	95.0	95.0

Buttons for "Sort", "Add", "Remove", "OK", and "Cancel" are at the bottom.

















Filter 4 table:

Time h	Flow Rate ft <sup>3</sup> /min	Aerosol Re... %	Elemental I ... %	Organic I Re... %
0.0	0.0	0.0	0.0	0.0
0.0333	550.0	95.0	95.0	95.0
720.0	550.0	95.0	95.0	95.0

Sort Add Remove

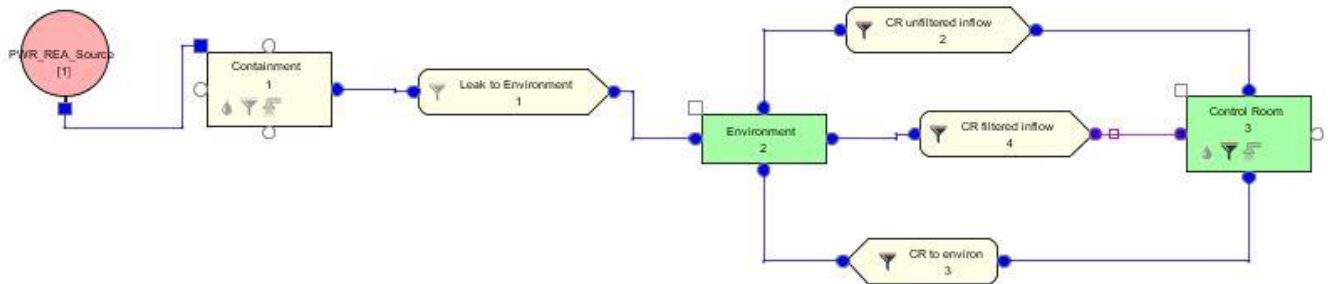
OK Cancel

**Step 4 -** Go back and indicate the appropriate recirculation filter in the Filter section of the Compartment input for the Control Room by clicking on the  next to “Filter” and choosing “Filter 3 (CR recirc flow)”.

Compartment 3 (Control Room)	
▼ General <span>Show Disabled</span>	
Name	Control Room 
Component Number	3 
Description	<none> 
Type	Control Room Dose 
Output Detail Level	Full Edit at Time Steps 
Volume	1.0E5 (ft <sup>3</sup> ) 
Deposition	 <none> 
Filter	 Filter 3 (CR recirc flow) 
Spray	 <none> 
Dose Locations	1 Dose Location connection 

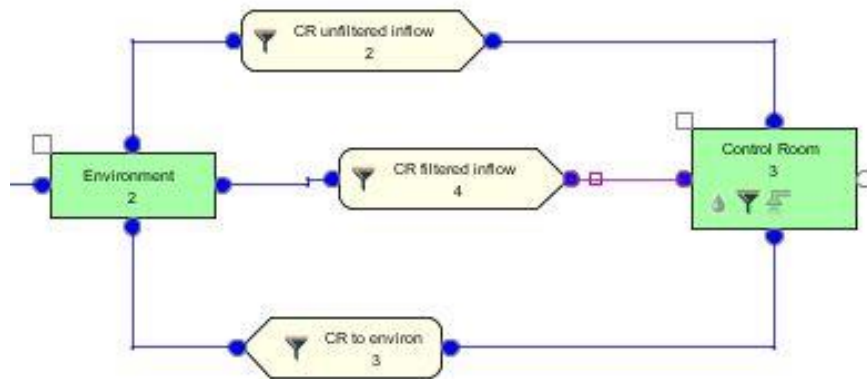
The last step is to go back to the Environment compartment and enter the CR X/Q table for the additional pathway (CR filtered flow) to the “Onsite X/Q Tables.”

**Step 5 -** 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	20.502	0.87583

## **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:**



**Step 1 -** Save the REA model as SGTR. Correspondingly, change the following:

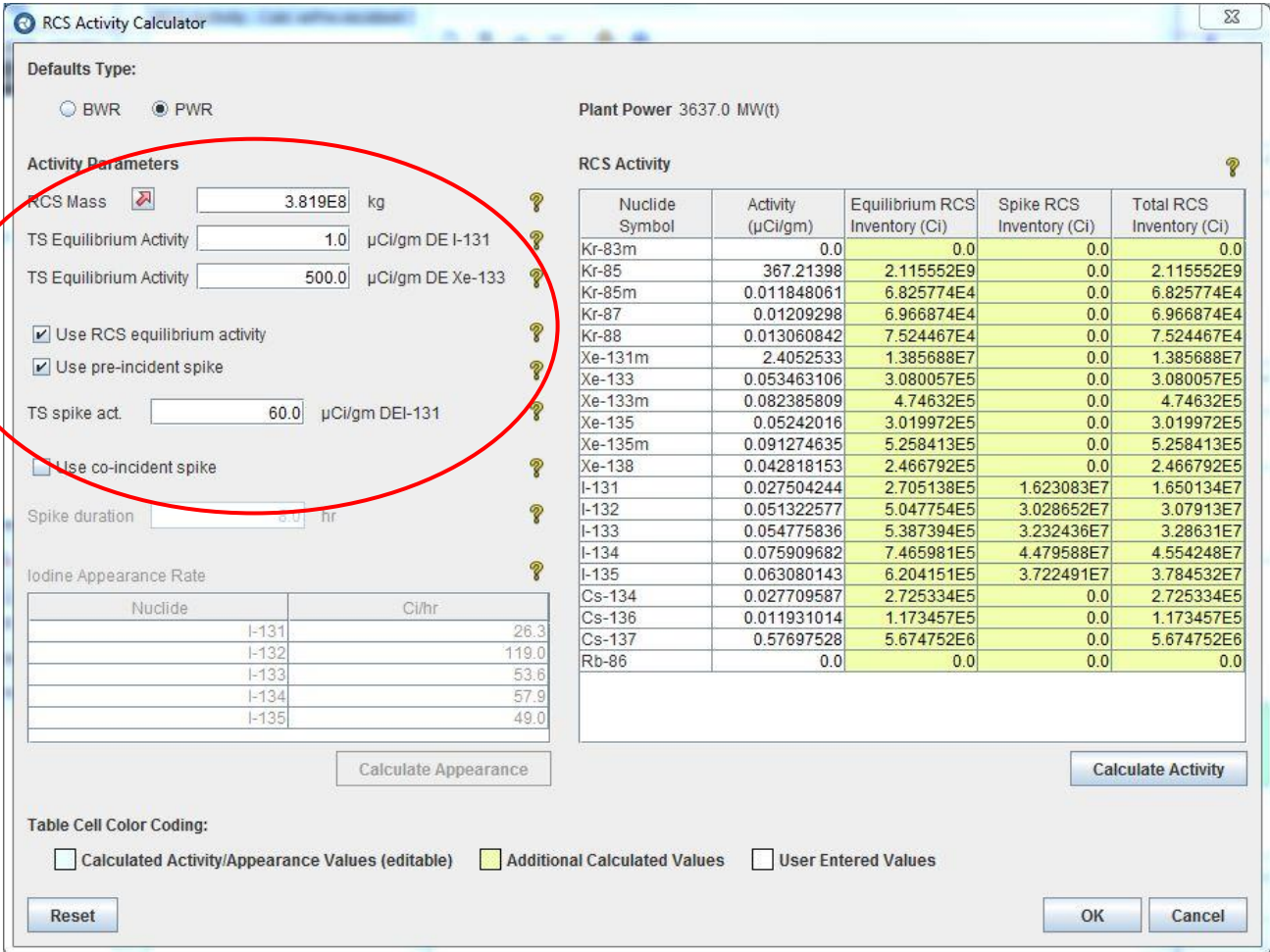
- Model Options\General\Title to SGTR
- Model Options\General\Description to SGTR for reference PWR plant
- Job Streams\Name to SGTR
- Job Streams\Description to SGTR for a reference PWR plant
- Change the relative location of the output under Job Streams so that you don't wipe out your previous results.

**Step 2 -** 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 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

**Step 3 -** 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.
3. Enter the data shown in the following RCS activity screenshot. Values are listed in Table 4-1.




**RCS Activity Calculator**

Defaults Type:  
☐ BWR ☒ PWR

Plant Power 3637.0 MW(t)

**Activity Parameters**

RCS Mass  3.819E8 kg

TS Equilibrium Activity 1.0 µCi/gm DE I-131

TS Equilibrium Activity 500.0 µCi/gm DE Xe-133

☒ Use RCS equilibrium activity

☒ Use pre-incident spike

TS spike act. 60.0 µCi/gm DEI-131

☐ Use co-incident spike

Spike duration 6.0 hr

**Iodine Appearance Rate**

Nuclide	Ci/hr
I-131	26.3
I-132	119.0
I-133	53.6
I-134	57.9
I-135	49.0

**RCS Activity**

Nuclide Symbol	Activity (µCi/gm)	Equilibrium RCS Inventory (Ci)	Spike RCS Inventory (Ci)	Total RCS Inventory (Ci)
Kr-83m	0.0	0.0	0.0	0.0
Kr-85	367.21398	2.115552E9	0.0	2.115552E9
Kr-85m	0.011848061	6.825774E4	0.0	6.825774E4
Kr-87	0.01209298	6.966874E4	0.0	6.966874E4
Kr-88	0.013060842	7.524467E4	0.0	7.524467E4
Xe-131m	2.4052533	1.385688E7	0.0	1.385688E7
Xe-133	0.053463106	3.080057E5	0.0	3.080057E5
Xe-133m	0.082385809	4.74632E5	0.0	4.74632E5
Xe-135	0.05242016	3.019972E5	0.0	3.019972E5
Xe-135m	0.091274635	5.258413E5	0.0	5.258413E5
Xe-138	0.042818153	2.466792E5	0.0	2.466792E5
I-131	0.027504244	2.705138E5	1.623083E7	1.650134E7
I-132	0.051322577	5.047754E5	3.028652E7	3.07913E7
I-133	0.054775836	5.387394E5	3.232436E7	3.28631E7
I-134	0.075909682	7.465981E5	4.479588E7	4.554248E7
I-135	0.063080143	6.204151E5	3.722491E7	3.784532E7
Cs-134	0.027709587	2.725334E5	0.0	2.725334E5
Cs-136	0.011931014	1.173457E5	0.0	1.173457E5
Cs-137	0.57697528	5.674752E6	0.0	5.674752E6
Rb-86	0.0	0.0	0.0	0.0

Calculate Appearance

Calculate Activity

Table Cell Color Coding:  
☐ Calculated Activity/Appearance Values (editable) ☒ Additional Calculated Values ☐ User Entered Values

Reset OK Cancel

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

**RCS Activity Inputs - PWR**

Letdown flow	<input type="text" value="6.6E4"/>	lbm/hr (FD)	?
Cation demin flow	<input type="text" value="0.0"/>	lbm/hr (FA)	?
Flow to BRS	<input type="text" value="0.0"/>	lbm/hr (FB)	?
NG release fraction	<input type="text" value="0.0"/>	lbm/hr (Y)	?

	Iodines	Cesiums
Cation Removal (NA)	<input type="text" value="0.0"/>	<input type="text" value="0.0"/>
Mixed bed removal (NB)	<input type="text" value="0.0"/>	<input type="text" value="0.0"/>

OK Cancel

- 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.

**Edit Total Inventories**

Name: RCS Activity with Pre-incident Spike

Plant Power: 3637.0 MWt

Inventory Units: Ci/MWt

Nuclide	Amount (Ci/MWt)	Inventory (Ci)
Kr-85	581.7056	2.115663E6
Kr-85m	0.018768575	68.261307
Kr-87	0.019156554	69.672386
Kr-88	0.020689748	75.248615
I-131	4.5373124	1.650221E4
I-132	8.4665684	3.079291E4
I-133	9.0362446	3.286482E4
I-134	12.522647	4.554487E4
I-135	10.406187	3.78473E4
Xe-131m	3.8101745	1.38576E4
Xe-133	0.084691189	308.02185
Xe-133m	0.13050779	474.65685
Xe-135	0.083039051	302.01303
Xe-135m	0.14458863	525.86884
Xe-138	0.06782846	246.69211
Cs-134	0.074937498	272.54768
Cs-136	0.0322661	117.35181
Cs-137	1.5603655	5675.0493

☐ Display zero values

Close

**Step 4 -** Create two sources, one for the failed SG and one for the 3 intact SGs.

- Using the calculated RCS activity, create two sources. You may want to delete the REA source to avoid confusion.
- For Accident Type, choose “Use Total Inventory” on the Accident Parameters tab. 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.
- Input a Source Term Fraction of 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.
- Input Release Fractions and Timings as shown below for the failed SG source.

Scenario Name: Failed SG

Accident Parameters | Adjusted Inventory | **Release Fractions and Timings** | Source Term

Import | Export

RFT File Header Lines

User-defined source release

Duration (h):

Release Durations (hrs)

Gap: 1.0E-4 Ex-Vessel: 0.0

Early: 0.0 Late: 0.0

Release Fractions

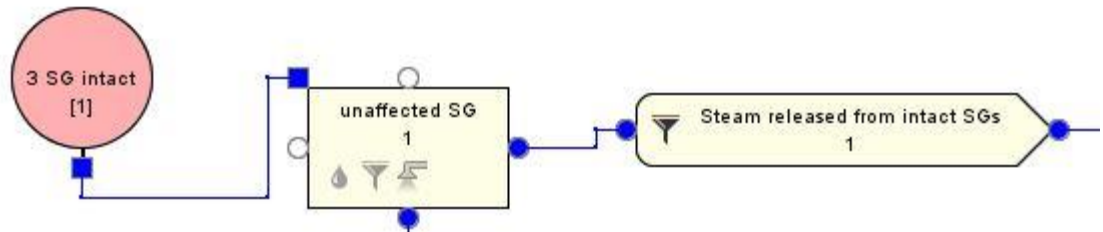
Group	Gap	Early	Ex-Vessel	Late
Noble Gases	1.0	0.0	0.0	0.0
Halogens	1.0	0.0	0.0	0.0
Alkali Metals	1.0	0.0	0.0	0.0
Tellurium	0.0	0.0	0.0	0.0
Alkaline Earth Metals	0.0	0.0	0.0	0.0
Noble Metals	0.0	0.0	0.0	0.0
Cerium	0.0	0.0	0.0	0.0
Lanthanides	0.0	0.0	0.0	0.0
Others	0.0	0.0	0.0	0.0
Non-radioactive Aero...	0.0	0.0	0.0	0.0

Help OK Cancel

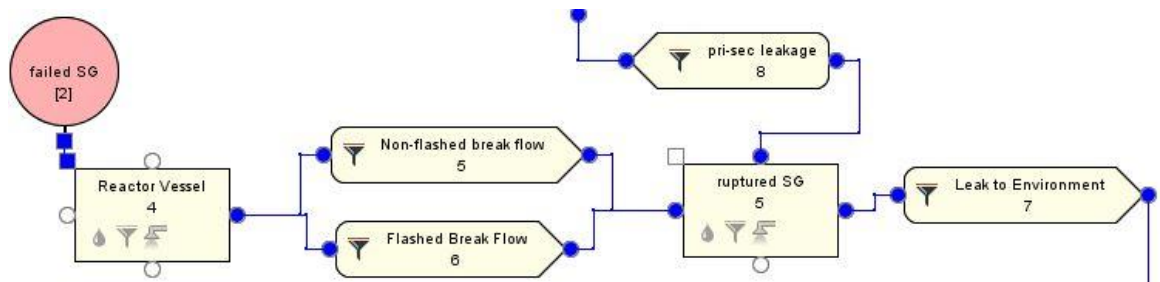
- Repeat the same steps for the 3 intact SGs. Use 0.1 for the release fractions.

**Step 5 -** Create two release pathways.

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.



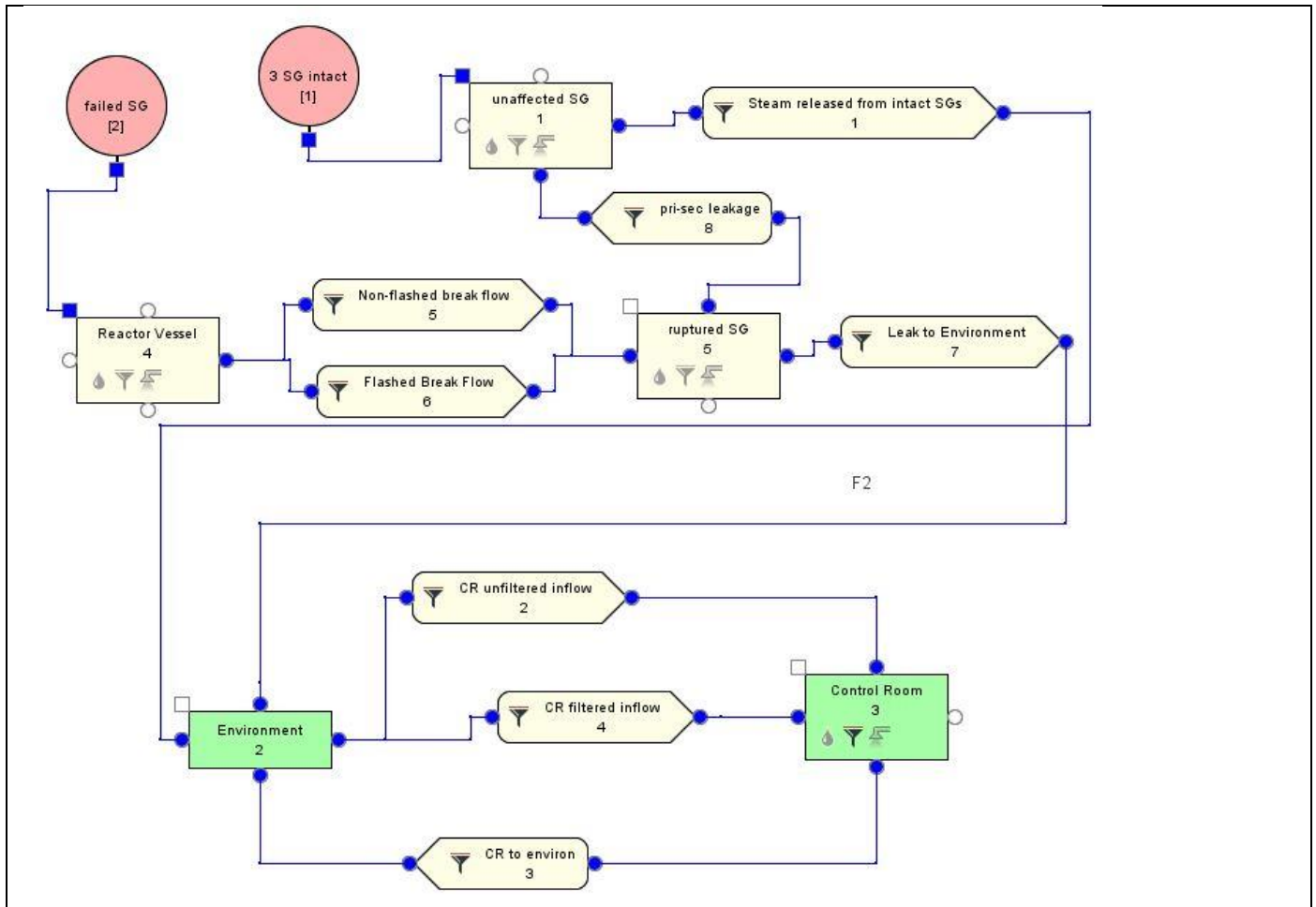
2. The second release pathway will be for the failed SG. There are various ways to accomplish this step. For example, you can edit the existing pathway data. Alternately, you can define new components. Your goal is to end with the noding given below.



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 then 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 the 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".

3. 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."





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.
- 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

Time	Flow Rate (lbm/min)	Aerosol Removal (%)	Elemental I (%)	Organic I (%)
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

The data presented in the above tables was calculated from Table 4-1. 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. Table 4-1 indicates a SG iodine water/steam partition coefficient of 100. 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.

## Results:

Worst Two-Hour Doses (Exclusion Area Boundary)			
Time (hr)	Whole Body (rem)	Thyroid (rem)	TEDE (rem)
0.0-2.0	0.3393	54.096	2.4530

Final Doses (Low Population Zone)			
Time (hr)	Whole Body (rem)	Thyroid (rem)	TEDE (rem)
720.0	0.11024	17.622	0.80053

Final Doses (Control Room)			
Time (hr)	Whole Body (rem)	Thyroid (rem)	TEDE (rem)
720.0	0.037246	28.888	1.1687

## **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 pathway includes a source, one compartment and one pathway, and the final pathway includes a source, two compartments, and three 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:

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 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

▼ General		<input type="checkbox"/> Show Disabled
Title	LOCA_simple	
Description	LOCA for a representative PWR	
Plant Power Level	3637.0 (MW(th))	
Decay	Decay, no daughtering	
Onset Gap Release	0.0 (h)	
Start of Accident	0.0 (h)	
Duration of Accident	720.0 (h)	
Dose Conversion Type	FGR 11 & 12	
Dose Conversions	View "FGR 11 & 12" Defaults	
Time Step Algorithm	Default	
Time Step Table	Rows: 1 [0.0,0.0]	

- 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.


LOCA_simple		Show Disabled	
Name	LOCA_simple		
Description	LOCA for a reference PWR plant with a si...		
Stream Type	Basic Job Stream		
File Groups	0 Groups		
Platform	Local		
Root Folder	Fall_2016_class_CD		
Relative Location	Exercises/LOCA_simple/		
Log Level	Information		
View in Job Status	<input checked="" type="radio"/> Yes <input type="radio"/> No		
Linear Execution	<input type="radio"/> Yes <input checked="" type="radio"/> No		

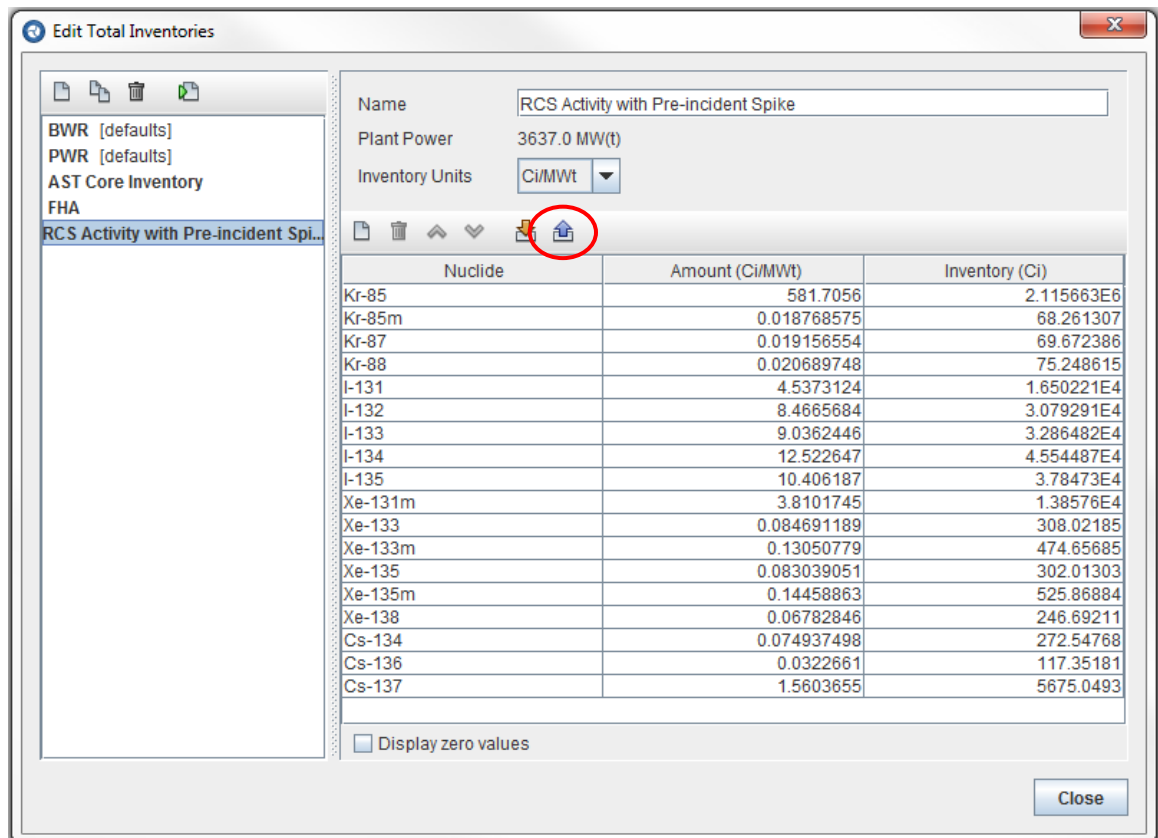
**Step 2** - Note that the following will be done to create the LOCA model:

- 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.

**Step 3** - 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.

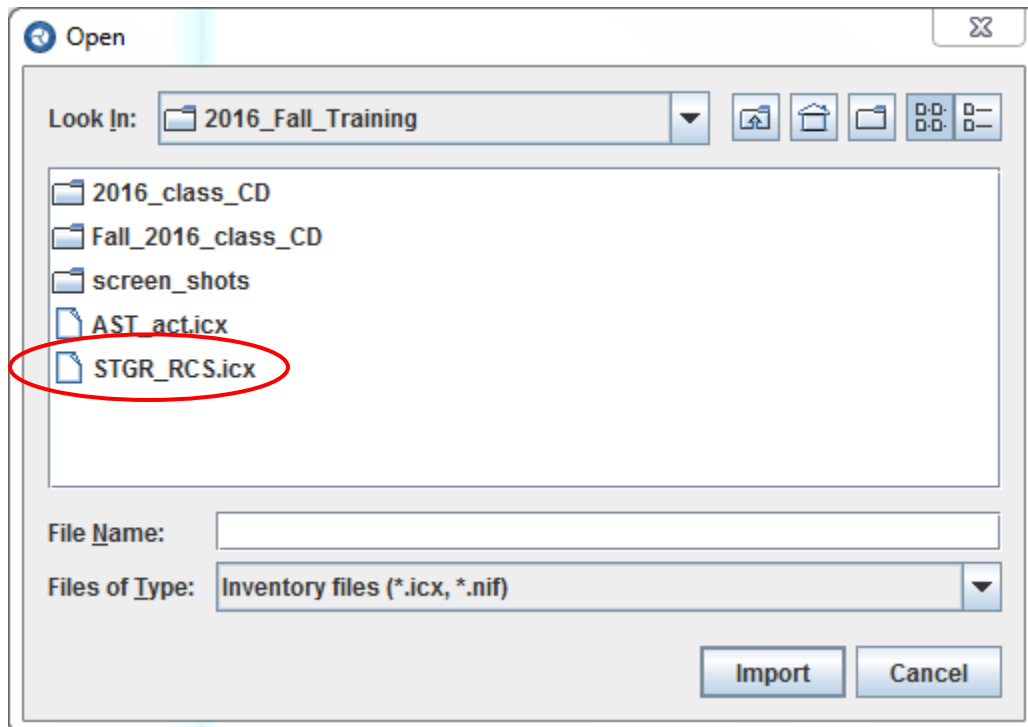
- Click on “Nuclide Data” in the Navigator Window, then click the  next to Total Inventories in the Properties Window to open an “Edit Total Inventories” screen.
- For our first inventory, we will use the Core Activity inventory that was input as part of the REA model. (Reference Step 2 of Exercise 3 for this inventory, called “Core\_Activity”.)
- For the second inventory we will use the RCS Activity inventory that was calculated in the SGTR exercise. In order to do this, we will export the inventory from the SGTR model, and import it into this model:
  - To export the SGTR inventory –
    - Open the SGTR model, if not already open.
    - Click on Nuclide Data, then Total Inventories to have the following screen appear. Choose the “RCS Activity with Pre-incident Spiking” inventory.



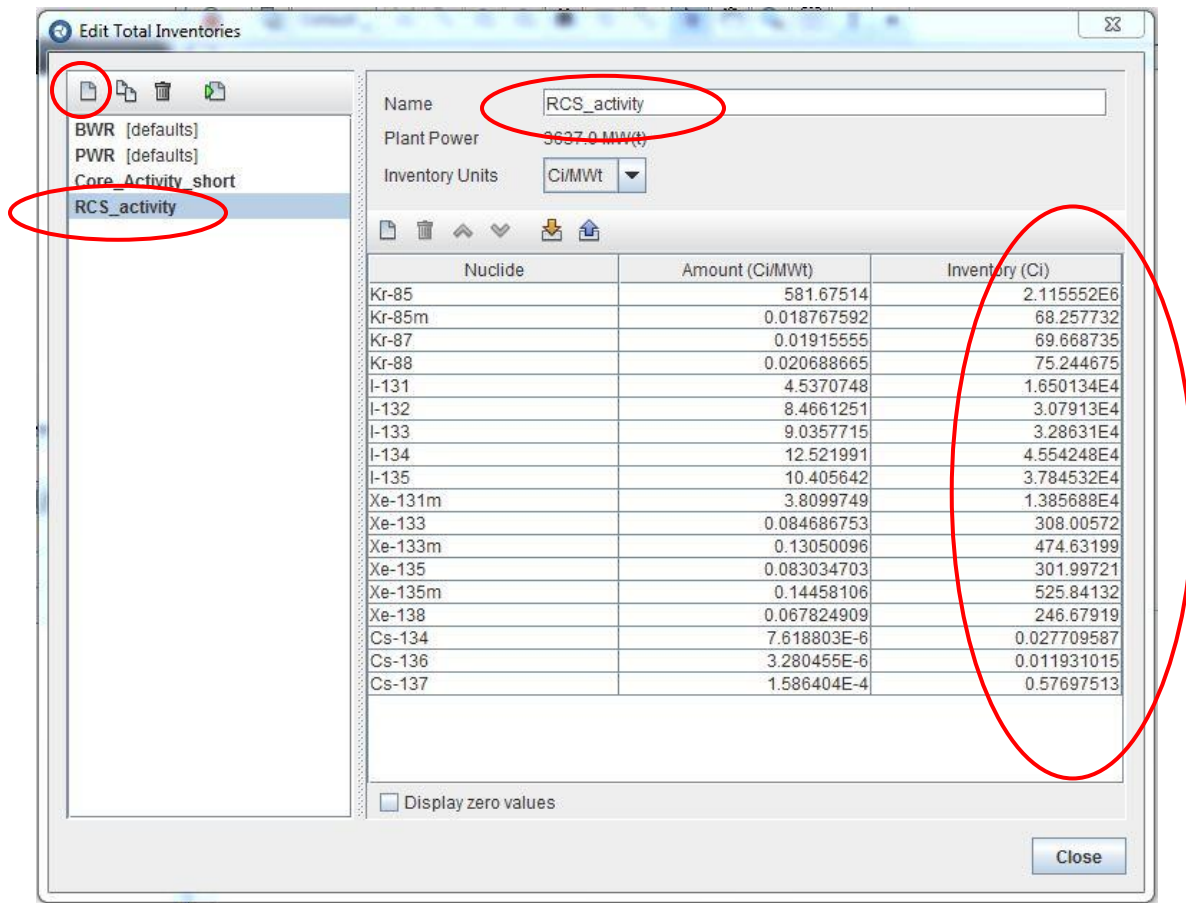
Nuclide	Amount (Ci/MWt)	Inventory (Ci)
Kr-85	581.7056	2.115663E6
Kr-85m	0.018768575	68.261307
Kr-87	0.019156554	69.672386
Kr-88	0.020689748	75.248615
I-131	4.5373124	1.650221E4
I-132	8.4665684	3.079291E4
I-133	9.0362446	3.286482E4
I-134	12.522647	4.554487E4
I-135	10.406187	3.78473E4
Xe-131m	3.8101745	1.38576E4
Xe-133	0.084691189	308.02185
Xe-133m	0.13050779	474.65685
Xe-135	0.083039051	302.01303
Xe-135m	0.14458863	525.86884
Xe-138	0.06782846	246.69211
Cs-134	0.074937498	272.54768
Cs-136	0.0322661	117.35181
Cs-137	1.5603655	5675.0493



3. 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 desktop.
  4. Close the “Edit Total Inventories” window for the SGTR exercise.
  5. Return to the LOCA\_simple exercise.
- ii. 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:



4. Choose the STRG\_RCE.icx file on the desktop and click “Import”.
5. Name the file “RCS\_activity”. The imported inventory should be as follows:



#### Step 4 - 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.

**Edit Inventory Scenarios**

Active Scenario: Containment Source

Scenarios: Containment Source

Scenario Name: Containment Source

Accident Parameters | **Adjusted Inventory** | Release Fractions and Timings | Source Term

Import | **Export**

RFT File Header Lines

LOCA release fractions

Duration (h):

Release Durations (hrs)

Gap: 0.49167 Ex-Vessel: 0.0

Early: 1.3 Late: 0.0

Release Fractions

Group	Gap	Early	Ex-Vessel	Late
Noble Gases	0.05	0.95	0.0	0.0
Halogens	0.05	0.35	0.0	0.0
Alkali Metals	0.05	0.25	0.0	0.0
Tellurium	0.0	0.05	0.0	0.0
Alkaline Earth Me...	0.0	0.02	0.0	0.0
Noble Metals	0.0	2.5E-3	0.0	0.0
Cerium	0.0	5.0E-4	0.0	0.0
Lanthanides	0.0	2.0E-4	0.0	0.0
Others	0.0	0.0	0.0	0.0
Non-radioactive ...	0.0	0.0	0.0	0.0

Help OK Cancel

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

**Source 1 (Containment Source)**

General Show Disabled

Name: Containment Source

Component Number: 1

Description: <none>

Source Scenarios: [1] active: Containment Source

Source Term Fraction: 1.0 (-)

Iodine Physical Form: User Defined

Aerosol Fraction: 0.95 (-)

Elemental Fraction: 0.0485 (-)

Organic Fraction: 1.5E-3 (-)

Compartments: 1 compartment connection

- 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.

Source 2 (sump Source 1)		
▼ General <input type="checkbox"/> Show Disabled		
Name	sump Source 1	
Component Number	2	
Description	<none>	
Source Scenarios	[1] active: Sump Source 1	
Source Term Fraction	0.1 (-)	
Iodine Physical Form	User Defined	
Aerosol Fraction	0.0 (-)	
Elemental Fraction	0.97 (-)	
Organic Fraction	0.03 (-)	
Compartments	1 compartment connection	

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

Source 3 (sump Source 2)		
▼ General <input type="checkbox"/> Show Disabled		
Name	sump Source 2	
Component Number	3	
Description	<none>	
Source Scenarios	[1] active: Sump Source 2	
Source Term Fraction	1.0 (-)	
Iodine Physical Form	User Defined	
Aerosol Fraction	0.0 (-)	
Elemental Fraction	0.97 (-)	
Organic Fraction	0.03 (-)	
Compartments	1 compartment connection	

- 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.

The screenshot shows the 'Source 4 (RCS Source)' window with the following fields and values:

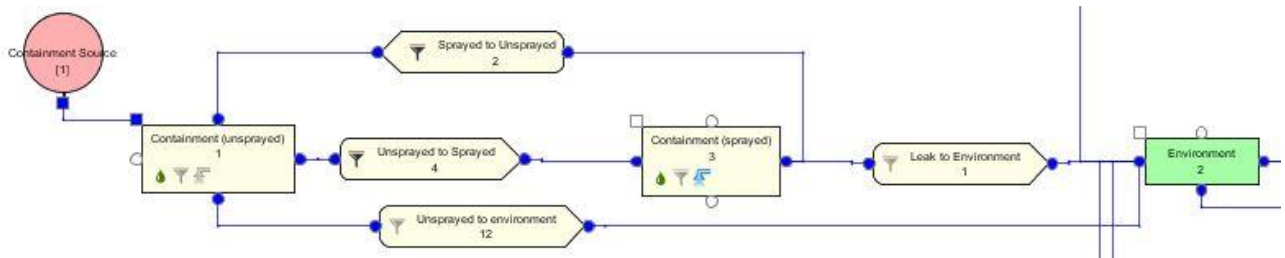
Source 4 (RCS Source)	
▼ General <span>Show Disabled</span>	
Name	RCS Source
Component Number	4
Description	<none>
Source Scenarios	[1] active: RCS Source
Source Term Fraction	1.0 (-)
Iodine Physical Form	User Defined
Aerosol Fraction	0.0 (-)
Elemental Fraction	0.97 (-)
Organic Fraction	0.03 (-)
Compartments	1 compartment connection

## 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, and two additional pathways leading from the sprayed and unsprayed portions of the containment 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.
- 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.
- a) 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 spray to the model by going to the containment (sprayed) component, clicking on  next to “Spray”, and choosing Spray 1 (Containment Spray).

**Spray 1 (Containment Spray)**

▼ General Show Disabled

Name	Containment Spray	
Component Number	1	
Description	<none>	
Aerosol Removal Model	User Defined Coefficient...	
Aerosol Removal Coefficients	Rows: 2 [0.03333,5.0],[5.0,0.0]	
Elemental Iodine Removal Model	User Defined Coefficient...	
Elemental Iodine Removal Coefficients	Rows: 2 [0.03333,10.0],[5.0,0.0]	
Organic Iodine Removal Model	None	
Aerosol DF Limit Enabled	<input type="radio"/> True <input checked="" type="radio"/> False	
Aerosol Lambda /10 DF Limit Enabled	<input checked="" type="radio"/> True <input type="radio"/> False	
Aerosol Lambda /10 DF Limit	50.0 (-)	
Elemental-I DF Limit Enabled	<input checked="" type="radio"/> True <input type="radio"/> False	
Elemental-I DF Limit	200.0 (-)	

**Editing Aerosol Removal Coefficients**

Time h	Removal Coefficient 1/hour
0.03333	5.0
5.0	0.0

Sort Add Remove

OK Cancel

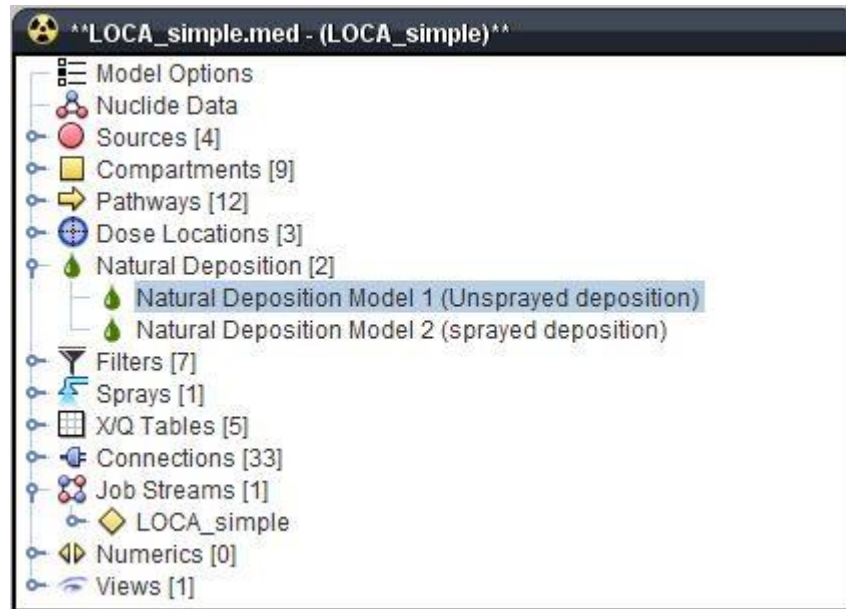
**Editing Elemental Iodine Removal Coefficients**

Time h	Removal Coefficient 1/hour
0.03333	10.0
5.0	0.0

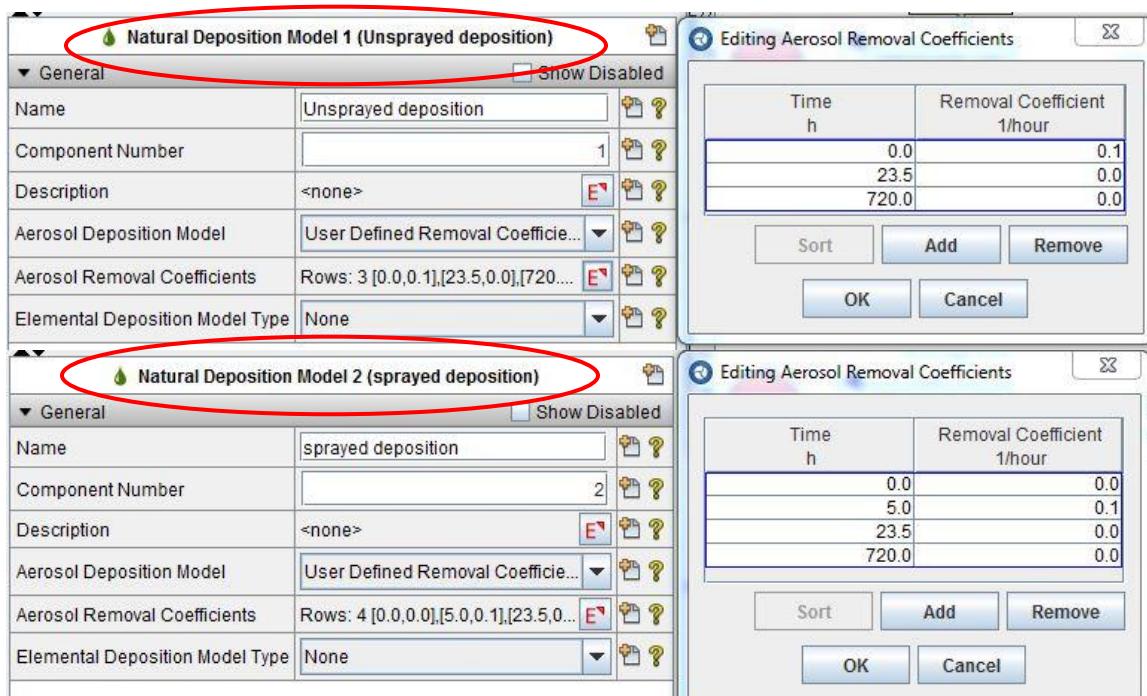
Sort Add Remove

OK Cancel


- b) 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.

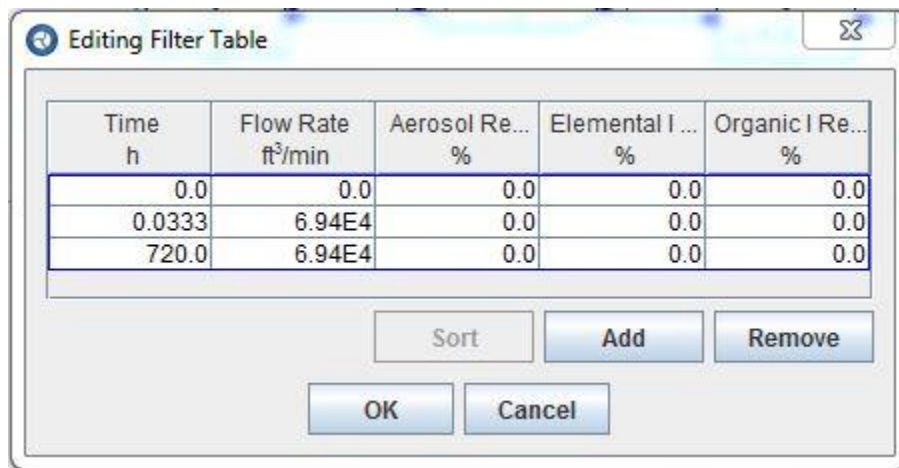





Be sure to add deposition to the model by going to both containment components, clicking on  next to “Deposition”, and choosing Natural Deposition Model 1 or 2 (Unsprayed or Sprayed deposition) as appropriate.

- c) 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 3, containment mixing table:



Time h	Flow Rate ft³/min	Aerosol Re... %	Elemental I ... %	Organic I Re... %
0.0	0.0	0.0	0.0	0.0
0.0333	6.94E4	0.0	0.0	0.0
720.0	6.94E4	0.0	0.0	0.0

Be sure to add this filter to the model by going to the pathways between the containment components, clicking on  next to “Filter”, and choosing Filter 5 (containment mixing).

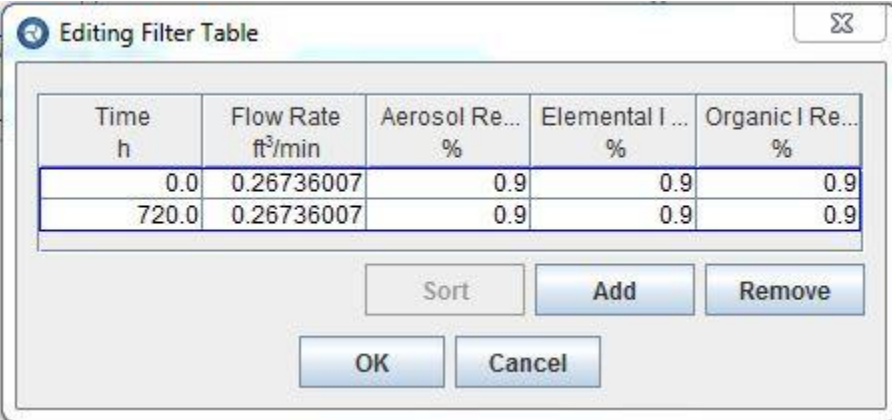
- d) The X/Q table for this pathway is the same one we already input for the REA case (Control-Room – containment leakage). We will connect this to the model at the end of this exercise.

**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.

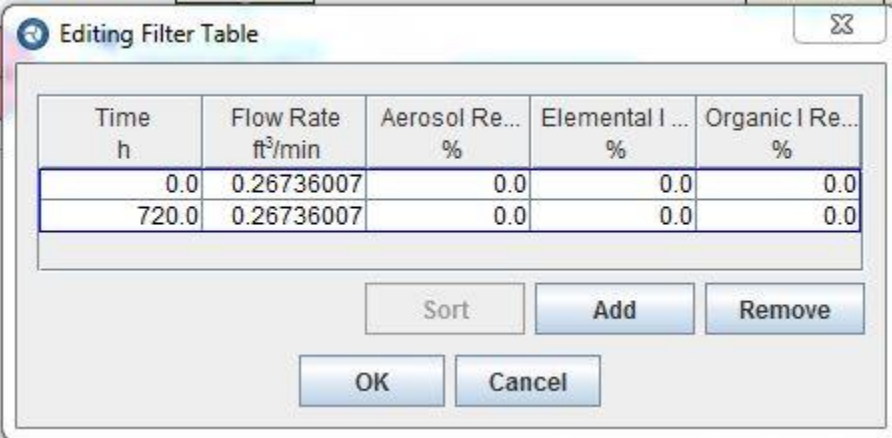
- Filtered pathways for from the sump to the aux. building and aux. building to the environment.
  - Inputs for these components are listed in Table 5-1. For details on adding compartments and pathways, see Exercise 1, Step 2, sections 2.d and 2.f.
  - When adding the X/Q table, note that the ECCS Leakage and Containment Purge pathways use the same table. So the table can be labeled accordingly as “Control Room – Cont. Purge & ECCS Leakage”.
- e) 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 1, aux vent table:



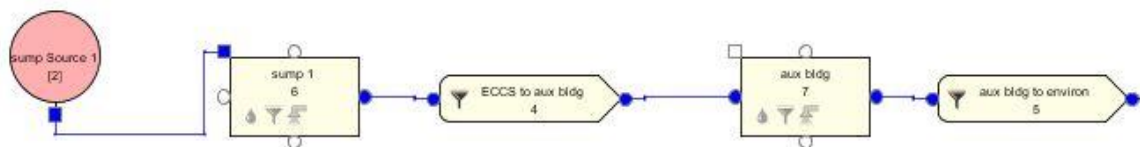
Time h	Flow Rate ft³/min	Aerosol Re... %	Elemental I ... %	Organic I Re... %
0.0	0.26736007	0.9	0.9	0.9
720.0	0.26736007	0.9	0.9	0.9

Filter 7, aux vent intake table:



Time h	Flow Rate ft³/min	Aerosol Re... %	Elemental I ... %	Organic I Re... %
0.0	0.26736007	0.0	0.0	0.0
720.0	0.26736007	0.0	0.0	0.0

- The resulting model should look as follows:

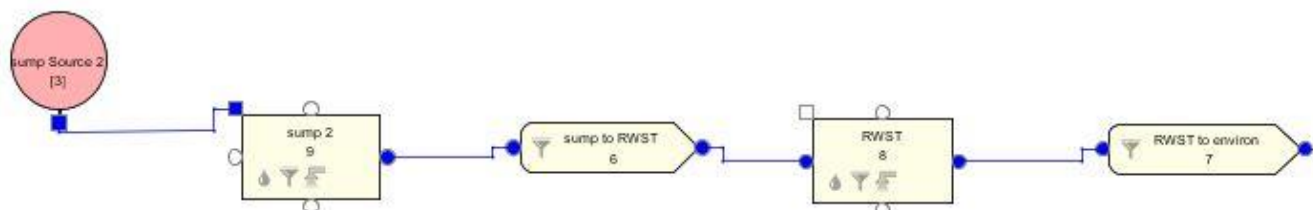


**3. Refueling Water Storage Tank Back-Leakage Pathway** – For this pathway, a portion of the ECCS recirculation is assumed to leak into the RWST. All iodine activity released from the fuel is assumed to be in the sump solution immediately. The release pathway model should include:

- 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	
Editing Leakage Rate		Editing Leakage Rate	
Time h	Leak Rate %/day	Time h	Leak Rate %/day
0.0	0.1189	0.0	1.189
720.0	0.1189	720.0	1.189
<div>Sort Add Remove</div> <div>OK Cancel</div>		<div>Sort Add Remove</div> <div>OK Cancel</div>	

- 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:



**4. 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:

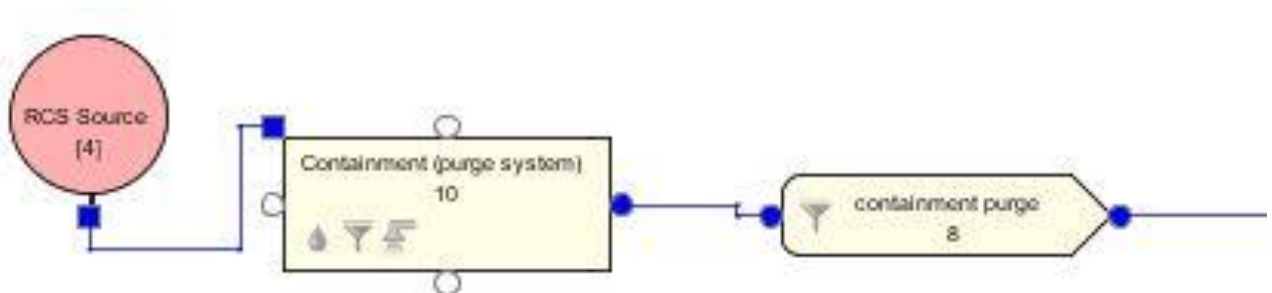
Editing Leakage Rate

Time h	Leak Rate %/day
0.0	269.57
2.77E-3	0.0
720.0	0.0

Sort Add Remove

OK Cancel

- 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.

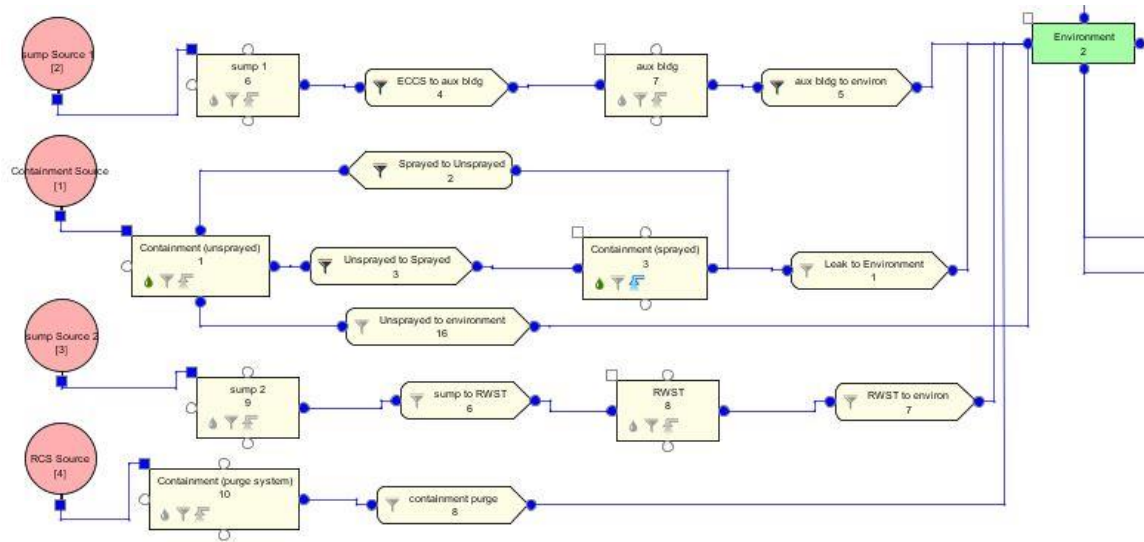
- f) Go back to the environment compartment and open the Onsite X/Q Table screen:

Compartment 1 (Environment)	
▼ General <span>Show Disabled</span>	
Name	Environment
Component Number	1
Description	<none>
Type	Environment
Output Detail Level	Full Edit at Time Steps
Dose Locations	2 Dose Location connections
Onsite X/Q Tables	5 X/Q Tables

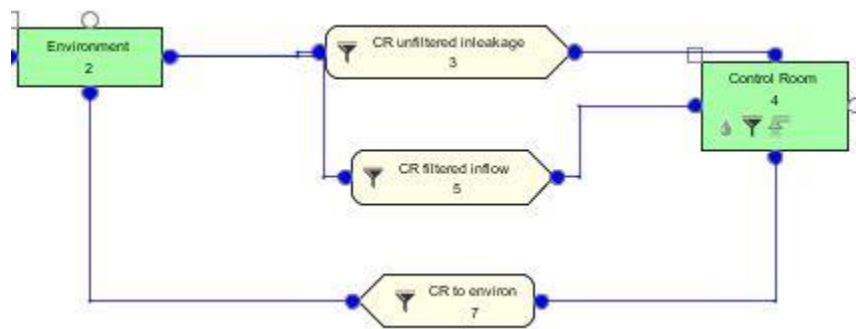
- g) Choose the appropriate X/Q table for the connection between the intake from Environment to the pathway to the Release to Environment as shown below:

↓ Pathways →	Intake from Environment	
	[3] CR unfiltered inflow	[7] CR filtered inflow
[1] Leak to Environment	X/Q Table 3 (Control Room - containment le...	X/Q Table 3 (Control Room - containment le...
[5] CR to environ		
[8] aux bldg to environ	X/Q Table 4 (Control Room - Mini-Purge & E...	X/Q Table 4 (Control Room - Mini-Purge & E...
[10] RWST to environ	X/Q Table 5 (Control Room - RWST Backle...	X/Q Table 5 (Control Room - RWST Backlea...
[11] containment purge	X/Q Table 4 (Control Room - Mini-Purge & E...	X/Q Table 4 (Control Room - Mini-Purge & E...
[12] Unsprayed to environment	X/Q Table 3 (Control Room - containment le...	X/Q Table 3 (Control Room - containment le...

**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 10 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	0.61304	75.742	3.2737

Final Doses (Low Population Zone)			
Time (hr)	Whole Body (rem)	Thyroid (rem)	TEDE (rem)
720.0	0.43022	58.049	2.8900

Final Doses (Control Room)			
Time (hr)	Whole Body (rem)	Thyroid (rem)	TEDE (rem)
720.0	0.13847	49.207	2.4792





**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	1.09817E6	301.94391
Kr-85m	2.69E7	212.3	0.058372285
I-130	1.98E6	2.7985E4	7.6945285
I-131	1.01E8	7.9516E7	2.186307E4
I-132	1.49E8	7.6235E7	2.096096E4
I-133	2.1E8	1.7177E7	4722.8485
Xe-131m	1.05E6	6.6006E4	18.148474
Xe-133	2.01E8	1.03834E6	285.49354
Xe-133m	6.06E6	1.58067E8	4.346082E4
Xe-135	4.060001E7	1.07694E4	2.9610668
Xe-135m	4.390001E7	1.57102E6	431.95491
Xe-138	1.8E8	1.07694E4	2.9610668
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**

<b>Control Room (CR) Model Input Parameters</b>	
Volume	1.0E5 ft <sup>3</sup> (2831.6847 m <sup>3</sup> )
Flow rate of Unfiltered Pathway to CR	2000 ft <sup>3</sup> /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 m <sup>3</sup> /sec for the entire run
<i>X/Q</i> Table – CR atmospheric dispersion factors (sec/m <sup>3</sup> )	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.
<b>Unfiltered Pathway Input Parameters – Normal Mode</b>	
Flow rate of Pathway to CR	2,000 ft <sup>3</sup> /min
Aerosol Removal Efficiency	0%
Elemental Iodine Removal Efficiency	0%
Organic Iodine Removal Efficiency	0%
<b>Emergency Mode Parameters</b>	
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 ft <sup>3</sup> /min
CR Filtered Inflow	550 ft <sup>3</sup> /min
CR Unfiltered Inflow	20 ft <sup>3</sup> /min

**Table 3-1. Core Activities for REA, STGR, and LOCA Analysis**

<b>Nuclide</b>	<b>Core Activity (REA, SGTR, LOCA) (Ci)</b>	<b>RCS Activity (SGTR, LOCA) (Ci)</b>
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**

<b>Attribute</b>	<b>Value</b>
<b>I. Sources</b>	
Core activity - REA	See Table 3-1
Source Term Fraction	1.0
<b>Iodine Physical Form</b>	
Aerosol Fraction	0.95
Elemental Fraction	0.0485
Organic Fraction	1.5E-3
<b>II. Accident Parameters Tab</b>	
Fraction of clad breached	0.1
Fraction of breach > melt	0.0025
<b>REA Release Fractions</b>	
NG	Gap 0.1; melt 1.0
Iodines	Gap 0.1; melt 0.5
Alkali Metals	Gap 0.12; melt 0.5
<b>III. Release Fractions and Timings Tab</b>	
NG, halogens, alkali metals	1.0
Gap release duration	1E-4 hrs
<b>IV. X/Q Tables</b>	
<b>Control room atmospheric dispersion factors (sec/m<sup>3</sup>)</b>	
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**

<b>Attribute</b>	<b>Value</b>
<b>RCS Activity Calculator Data</b>	
Reactor vessel mass (lbm)	8.42E5 lbm (3.8192E8 gm)
TS Equilibrium Activity	1.0 $\mu\text{Ci/gm}$ DE I-131 500 $\mu\text{Ci/gm}$ DE Xe-133
TS Spike Activity for Pre-incident Spike	60 $\mu\text{Ci/gm}$ 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
<b>Release Fractions</b>	
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
<b>Control room atmospheric dispersion factors (<math>\text{sec/m}^3</math>)</b>	
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
<b>Removal Efficiencies</b>	
Organic iodine removal efficiency (%)	99
Elemental iodine removal efficiency (%)	99
Aerosol iodine removal efficiency (%)	99
Primary to Secondary leakage rate	1 gpm (0.1337 lbm/hr)
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
<b>Compartment Data</b>	
Reactor Vessel mass (lbm)	3.99E5
Ruptured SG mass (lbm)	7.00E+4
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 (ft <sup>3</sup> )	4.05E5 (15% of total)	
Containment volume, sprayed (ft <sup>3</sup> )	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 regions to environment		
Leak to Environment	See Table 1-1 for containment leak rate	
Spray removal coefficients		
Organic iodine spray removal coefficient (hr <sup>-1</sup> )	None	
Elemental iodine spray removal coefficient calculations		
Spray removal coefficient (hr <sup>-1</sup> ) 0.0333 – 5 hr	10	
Elemental-I DF Limit Enabled	200	
Aerosol spray removal coefficient calculations		
Spray removal coefficient (hr <sup>-1</sup> ) 0.0333 – 5 hr	5	

Aerosol Lambda/10 DF Limit Enabled	50
Natural Deposition Model 1 (unsprayed region)	
Particulate sedimentation removal coefficient (hr <sup>-1</sup> )	0.1
Credited in unsprayed portion of containment	0 - 23.5 hr
Natural Deposition Model 2 (sprayed region)	
Particulate sedimentation removal coefficient (hr <sup>-1</sup> )	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/m <sup>3</sup> )	
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
<b>2.ECCS Leakage (sump source 1)</b>	
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 ft <sup>3</sup> )
Auxiliary building volume (ft <sup>3</sup> )	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 ft <sup>3</sup> /min)
Auxiliary building exhaust filter efficiency (all forms of iodine) (%)	90
Control room atmospheric dispersion factors (sec/m <sup>3</sup> )	
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
<b>3.RWST Back-Leakage (sump source 2)</b>	
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 ft <sup>3</sup> )
Sump volume (ft <sup>3</sup> )	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 activity becomes airborne	3.8 (0.1189 %/day)

Control room atmospheric dispersion factors (sec/m <sup>3</sup> )	
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
<b>4. Containment Purge (RCS Source)</b>	
Source Term Fraction	1.0
RCS activity released (%)	100
Iodine chemical form of releases (%)	
Elemental	97
Organic	3
Aerosol	0
RCS mass, maximum (lbm)	8.42E+05 (4.7323774E4 ft <sup>3</sup> )
Containment volume (ft <sup>3</sup> )	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/m <sup>3</sup> )	
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