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Reference: (a) License No. DPR-3 (Docket No. 50-29)

Subject: RESRAD-BUILD Calculation for License Termination Plan (LTP)

This letter provides a copy of a calculation in support of the LTP for the Yankee Nuclear Power Station (YNPS). A hardcopy of the calculation is enclosed as well as an electronic copy of the input files via CD. The specific calculation provided is as follows:

(1) YA-CALC-00-003-03, "RESRAD-BUILD v3.21 Sensitivity Analysis for Building Occupancy"

This calculation is provided for your review. If you have any questions, please contact us.

Sincerely,

YANKEE ATOMIC ELECTRIC COMPANY

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NMSS01

CALCULATION TITLE PAGE

RESRAD-BUILD v3.21 Sensitivity Analysis for Building Occupancy
Title

YA-CALC-00-003-03
Calculation Number

Executive Summary:

Nuclide-specific sensitivity analyses are performed using the Building Occupancy Scenario to assess the sensitivity of the dose from building surface contamination to key input parameters. This analysis is performed using the probabilistic modules in RESRAD-BUILD Version 3.21 computer code. Parameters are identified as sensitive if the Partial Rank Correlation Coefficient (PRCC) is equal to or greater than 0.10.

Approvals	(Print & Sign Name)	
Preparer: Cynthia Harrington	Cynthia C Harrington	Date: 11/15/03
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Reviewer: Joe Bisson	J. Bisson	Date: 11/19/03
Approver (Cognizant Manager):		Date:

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A. PURPOSE:

The purpose of this calculation is to determine which parameters in the building occupancy scenario have the greatest effect on dose (and to identify them as "sensitive"). The determination of the sensitive parameters is

accomplished through the use of the probabilistic modules in RESRAD-BUILD V 3.21. A flow charted process is used to identify parameters as behavioral, metabolic or physical. Metabolic and behavioral parameters are assigned site-specific values or values from NUREG/CR- 5512 vol.3, -6697 or -6755. Physical parameters are assigned site-specific values or are treated stochastically and assigned a distribution from NUREG/CR-6697or 6755. The distribution statistics for stochastic parameters are used as the input to the probabilistic module of RESRAD-BUILD. The Partial Rank Correlation Coefficient (PRCC) is used as the measure of the dose sensitivity to variations in the input parameter.

B. SUMMARY OF RESULTS:

A summary of results of the sensitivity analysis for the nuclides in Table 1 is presented below. Parameters are listed in order of rank if the corresponding PRCC is greater or equal to 0.1.

Table 1 - Sensitive Parameters Based on RESRAD-BUILD Sensitivity Analysis

Nuclide	Rank 1 parameter	Rank 2 parameter	Rank 3 parameter	Rank 4 parameter	Rank 5 parameter	Rank 6 parameter	Rank 7 parameter
H-3	Time source removal (1)*	Time source removal (2)	Time source removal (4)	Time source removal (5)	Time source removal (3)	Resuspension Rate	Deposition Velocity
C-14	Time source removal (1)	Time source removal (4)	Time source removal (3)	Time source removal (5)	Time source removal (2)		
Fe-55	Time source removal (3)	Time source removal (1)	Time source removal (4)	Time source removal (5)	Resuspension Rate	Deposition Velocity	Time source removal (2)
Co-60	Time source removal (1)	Time source removal (5)	Resuspension Rate	Time source removal (2)	Deposition Velocity	Time source removal (4)	
Ni-63	Time source removal (1)	Time source removal (3)	Time source removal (5)	Time source removal (2)	Time source removal (4)	Resuspension Rate	
Sr-90	Time source removal (1)	Time source removal (4)	Time source removal (2)	Time source removal (5)	Time source removal (3)	Resuspension Rate	Deposition Velocity
Nb-94	Resuspension Rate	Deposition Velocity	Time source removal (1)				
Tc-99	Time source removal (1)	Time source removal (4)	Time source removal (2)	Time source removal (3)	Time source removal (5)		
Ag-108m	Time source removal (1)	Resuspension Rate	Deposition Velocity	Time source removal (4)	Time source removal (5)		
Sb-125	Time source removal (1)	Time source removal (4)	Time source removal (3)	Deposition Velocity	Resuspension Rate	Time source removal (2)	Time source removal (5)
Cs-134	Time source removal (1)	Time source removal (4)	Time source removal (2)	Time source removal (5)	Time source removal (3)	Deposition Velocity	Resuspension Rate
Cs-137	Time source removal (1)	Time source removal (5)	Time sour removal (3)	Time source removal (4)	Time source removal (2)	Resuspension Rate	Deposition Velocity
Eu-152	Time source removal (1)	Time source removal (5)					
Eu-154	Time source removal (1)	Resuspension Rate	Deposition Velocity	Time source removal (2)			
Eu-155	Time source removal (4)	Time source removal (5)	Time source removal (3)	Time source removal (2)	Time source removal (1)		
Pu-238	Time source removal (1)	Time source removal (4)	Time source removal (3)	Time source removal (5)	Time source removal (2)	Resuspension Rate	
Pu-239	Time source removal (1)	Time source removal (4)	Time source removal (3)	Time source removal (5)	Time source removal (2)		
Pu-241	Resuspension	Deposition	Time source	Time source	Time source		

Nuclide	Rank 1 parameter	Rank 2 parameter	Rank 3 parameter	Rank 4 parameter	Rank 5 parameter	Rank 6 parameter	Rank 7 parameter
	Rate	Velocity	removal (2)	removal (1)	removal (4)		
Am-241	Time source removal (1)	Time source removal (4)	Time source removal (3)	Time source removal (5)	Time source removal (2)		
Cm-243	Time source removal (1)	Time source removal (4)	Time source removal (3)	Time source removal (5)	Time source removal (2)	Resuspension Rate	Deposition Velocity

*Time Source Removal (#) indicates source number as designated in Table 2.1

C. REFERENCES:

1. NUREG/CR-5512, "Residual Radioactive From Contamination"
   - Volume 1: "Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent," October 1992 (PNL-7994).
   - Volume 2: "User's Manual DandD Version 2.1," April 2001 (SAND2001-0822P).
   - Volume 3: "Parameter Analysis, Draft Report for Comment," October 1999 (SAND99-2148).

2. NUREG/CR-6697,"Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes," November 2000, (ANL/EAD/TM-98).

3. NUREG/CR-6755, "Technical Basis for Calculating Radiation Doses for the Building Occupancy Scenario Using the Probabilistic RESRAD-BUILD 3.0 Code," February. 2002 (ANL/EAD/TM/02-1)

4. NUREG-1727, "NMSS Decommissioning Standard Review Plan," September 2000.
5. NUREG/CR-6676, "Probabilistic Dose Analysis Using Parameter Distributions Developed for RESRAD and RESRAD-BUILD Codes," May 2000 (ANL/EAD/TM-89).

6. NUREG/CR-6692, "Probabilistic Modules for the RESRAD and RESRAD-BUILD Computer Codes," November 2000, (ANL/EAD/TM-91).

7. Federal Guidance Report (FGR) 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion," EPA, 1988.

8. Federal Guidance Report (FGR) 12, "External Exposure to Radionuclides In Air, Water, And Soil," 1993, EPA

9. YA-REPT-00-001-03, "Radionuclide Selection for DCGL Determination," October 2003.

D. ASSUMPTIONS

1. Radionuclide List

A probabilistic run of the RESRAD-BUILD code was performed for the radionuclides listed in Table 2. This list of radionuclides was developed by consideration of historical site data, waste stream analysis and source terms in NUREG guidance to encompass the significant radionuclides that may present a significant dose impact (Ref 9).

Table 2
YNPS Radionuclide List

H-3	Tc-99	Eu-155
C-14	Ag-108m	Pu-238
Fe-55	Sb-125	Pu-239
Co-60	Cs-134	Pu-241
Ni-63	Cs-137	Am-241
Sr-90	Eu-152	Cm-243
Nb-94	Eu-154	

2. Conceptual Model Underlying the Dose Model

The conceptual model was developed based on site demolition plans and the characteristics of rooms/partial rooms expected to remain at the time of license termination. The model is comprised of a room, with dimensions representing an average wall to remain at the site. The four walls and floor of this room are assumed to be contaminated uniformly and to equal levels. This is considered to be a conservative assumption as normally the amount of contamination on room walls is less than that on the floor and decreases as the distance from the floor increases. No contaminated ceilings are included in the model, as partial rooms/rooms remaining at the time of license termination will either have no ceiling or will be covered with a ceiling constructed of new uncontaminated building materials. Attachment 1 provides the details for the determination of the room dimensions.

3. Dose Model: Building Occupancy Scenario

The building occupancy scenario defined in NUREG/CR-5512, Volumes 1, 2, and 3 and NUREG-1727 will be used to determine Building Surface Derived Concentration Guideline Levels, DCGL. This scenario is chosen because the basic premise of the building occupancy model for buildings decontaminated to an unrestricted release level is that this model will yield DCGL values that meet all the requirements for 10CFR20.1402.

The decommissioning of the Yankee Rowe site involves the demolition of many of the structures within the Radiation Control Area (RCA). The surfaces of all structures and rooms remaining will be surveyed for residual radioactivity. The threshold for the amount of residual radioactivity that can remain on a building surface at the time of license termination is based on a maximum annual dose of 25 mrem to members of the critical group. This scenario assumes that the critical group consists of light industrial workers working in the building following license termination.

Prior to use, the operability of the RESRAD-BUILD Version 3.21 code was verified in accordance with site procedures. The code, as used in this analysis, considers five exposure pathways to occupants of a building from residual radioactivity:

- External exposure directly from sources
- External exposure to deposited material
- External exposure due to air submersion
- Inhalation of airborne radioactive particulates
- Inadvertent ingestion of radioactive material directly from the sources

E. METHOD/BODY OF CALCULATION

Numerous input parameters are required by RESRAD-BUILD to calculate the dose to a building worker from various exposure pathways. Using the probabilistic modules in RESRAD-BUILD, a sensitivity analysis allows the identification of parameters with the greatest potential to effect the dose. The guidance published in NUREG/CR 6676, – 6697, - 6692 and 6755 has been used to develop an approach for selecting parameter values. This process is described below.

1. Parameter Selection Process

The conceptual and dose models discussed above are quantified by a set of input parameters in the RESRAD-BUILD code. Incorporated within RESRAD-BUILD v3.21 are probabilistic modules that allow the evaluation of dose as a function of parameter distributions. The process for classifying and selecting input parameter values was developed in accordance with the guidelines presented in NUREG/CR-6755, -6676, -6692 and -6697. NUREG/CR-6755 provides the technical basis for calculating doses for the Building Occupancy scenario using the probabilistic RESRAD- BUILD code and also provides input parameter information that has been updated since the publication of NUREG/CR 6697. A schematic flow diagram of the parameter selection process is provided in Figure 1. Each step of the selection process is discussed below.

Classification (Type)

The parameters were classified as behavioral, metabolic or physical consistent with NUREG/CR-6697. Behavioral parameters depend on the behavior of the receptor and the scenario definition. Metabolic parameters represent the metabolic characteristics of the receptor and are independent of the scenario definition. Physical parameters are the parameters that would not change if a different group of receptors were considered.

Prioritization

The NUREG/CR-6697 approach to prioritizing parameters was applied in this calculation. The priority of a particular parameter is based upon:

- The relevance of the parameter in dose calculations,
- The variability of the dose as a result of changes in the parameter value,
- The parameter type and
- The availability of parameter-specific data.

Priority 1 parameters are considered to be high priority; Priority 2 parameters are considered to be medium priority; and Priority 3 parameters are considered to be low priority.

Treatment

Input parameters are treated as either "deterministic," assigned a single value, or "stochastic", assigned a probability distribution. The treatment depends on parameter type, priority, availability of site-specific data and the relevance of the parameter in dose calculations.

- Behavioral and metabolic parameters were treated as deterministic and were assigned values from NUREG/CR-5512, Volume 3, NUREG/CR-6697, NUREG/CR 6755 (if updated), or the RESRAD default library.
- Parameters for which site-specific data is available were treated as deterministic.
- The remaining physical parameters, for which no site-specific data is available, were assigned values based on priority. Priority 1 and 2 parameters were treated as stochastic and were assigned probability distributions from NUREG/CR-6697or 6755, or a deterministic value from NUREG/CR-5512 vol.3, 6697or 6755. The priority 3 physical parameters were treated as deterministic and were assigned values from NUREG/CR-5512, Volume 3, NUREG/CR-6697, NUREG/CR-6755, or the RESRAD default library.

2. Parameter Value Assignment

Behavioral and Metabolic Parameters

Scenario-defined parameters are assigned values recommended in NUREG/CG-5512 vol. 3 for the building occupancy scenario and include:

Exposure duration: 365.25 days

Indoor fraction: 0.267

Time Fraction: 1

Breathing rate: 33.6 m^3/day

Receptor location: Center of room at a height of 1m

Direct ingestion rate: 1.34E-06 hr^{-1}

Calculated from NUREG/CR 5512 ingestion rate = 1.1E-04 m^2/hr divided by the total source area available to be inadvertently but directly ingested = 82.03 m^2.

Dose conversion factors: FGR11 and FGR12 values are used

Behavioral parameters not included in the NUREG/CR-5512 vol. 3 building occupancy scenario but used in the RESRAD-BUILD model include:

Air exchange rate for room: 1.52 hr^{-1} (updated in NUREG/CR-6755)

Indirect ingestion rate: 0 to shut off the pathway.

Only direct ingestion is modeled to be consistent with the building occupancy direct ingestion pathway utilized in the NRC's D&D computer code.

Air fraction: 0.07 for solids; 1.0 for H-3 (NUREG/CR-6697)

Physical Parameters

Site and scenario information is used to determine physical parameter values when it is available. For physical parameters identified as a Priority 1 or 2 (high and medium priority) a parameter distribution from NUREG/CR-6696, - 6755 or a deterministic value from NUREG/CR-5512 vol.3, -6696, - 6755 is used. For physical parameters identified as Priority 3 (low priority) a value is assigned from NUREG/CR-5512 vol.3, -6696, or -6755.

A three dimensional model is selected in RESRAD-BUILD to represent a typical room to remain at the YNPS site. A ceiling is not modeled since all structures remaining following demolition and license termination will be covered with new uncontaminated material. The average room is defined by the dimensions of 4.44 m wide by 4.44 m long and 3.51 m high. Attachment 1 provides information on the rooms/partial rooms to remain on the YNPS site. Each wall and floor surface is assumed to have uniform contamination over the entire surface.

Site and scenario defined parameters include:

Room area: 4.4 4m x 4.44 m = 19.71m^2

Room height: 3.51m

Location of sources: Center of four walls and floor (See Attachment 1, Section 2, Table 1.3- Receptor and Center of Source Locations)

Area of sources: Floor = 19.71 m^2

4 Walls = 15.58 m^2 each

Number of sources: 5

Type of source: Area

Direction of source: See Attachment 1, Section 2, Table 1.3- Receptor and Center of Source Locations

Receptor location: See Attachment 1, Section 2, Table 1.3- Receptor and Center of Source Locations

Removable fraction: 0.1 (NUREG/CR-5512 building occupancy scenario and NUREG-1727, Table C7.1)

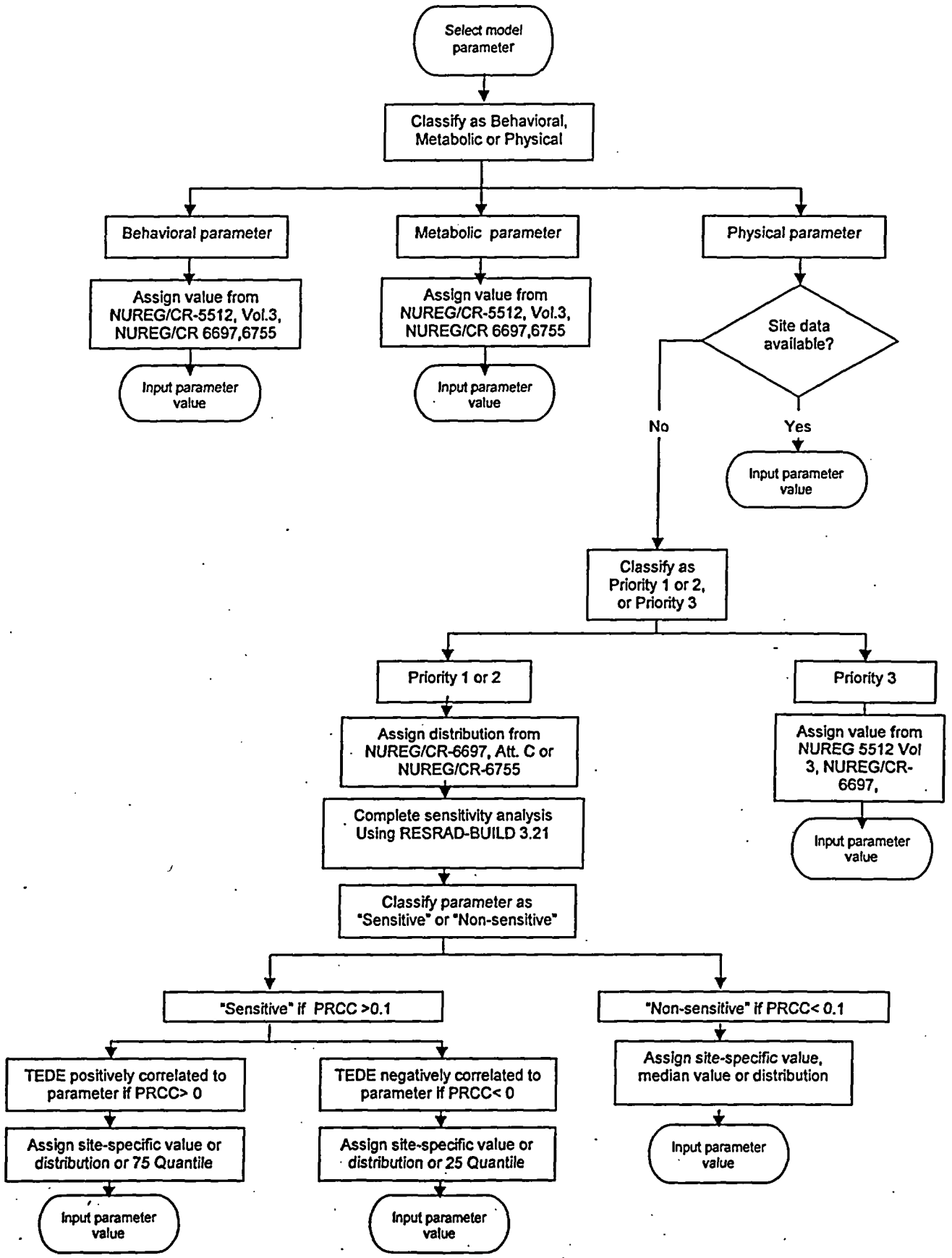
Physical parameters assigned a statistical distribution include:

Deposition velocity:	NUREG/CR-6755
Resuspension rate:	NUREG/CR-6755
Time for source removal:	NUREG/CR-6755

An Input correlation of 0.9 is established between the deposition velocity and the resuspension rate based on the guidance in NUREG/CR-6676, Section 8.2. Because the sources are constructed of the same material and subject to the same environment, an input correlation of 0.9 is established for the time for source removal between sources.

Attachment 2, Table 2.1 provides a listing of all the input parameters and the results of the parameter classification and selection process. All assigned values or distributions and the basis of each is also provided in Table 2.1.

Figure 1
Parameter Selection Process



3. RESRAD- BUILD Sensitivity Analyses Runs

The sensitivity runs were performed using the RESRAD- BUILD V3.21 code. The data in Attachment 2, Table 2.1 were used as parameter inputs to the Build code and, where appropriate, the probability distribution statistical parameters were entered into the probabilistic modules of the Build code. The code was run individually for all the radionuclides listed in Table 2 at a concentration of 1 pCi/m^2. The time of the maximum dose for all nuclides except Pu-241 is defined at an evaluation time of T = 1year. For Pu-241 the maximum dose occurs at T = 9 years.

Uncertainty Report

The RESRAD- BUILD Uncertainty Report provides regression and correlation coefficients for the average dose at the user defined evaluation time. The PRCC correlation coefficient has been used to identify sensitive parameters with the limit set at 0.1. Parameter values are further identified as being positively or negatively correlated to dose by assessing whether the PRCC value is greater than zero or less than zero.

NUREG/CR-6692 and -6697 guidance recommends the use of the PRCC or SRRC for cases where a non-linear relationship and widely disparate scales exists between the inputs and outputs. The NUREG/CR guidance further recommends the use of the PRCC if the strong correlations exist between input parameters.

Table 3 identifies, for each radionuclide, the sensitive parameters in order of rank, the coefficient of determination and the values of the PRCC.

Table 3 - Sensitivity Analysis Results Based on the Partial Rank Correlation Coefficient

Radionuclide	R-Square	Rank 1 parameter (PRCC Value)	Rank 2 parameter (PRCC Value)	Rank 3 parameter (PRCC Value)	Rank 4 parameter (PRCC Value)	Rank 5 parameter (PRCC Value)	Rank 6 parameter (PRCC Value)	Rank 7 parameter (PRCC Value)
H-3	1.00	RFO(1) -0.85	RFO(2) -0.78	RFO(4) -0.78	RFO(5) -0.76	RFO(3) -0.76	DKSUS 0.35	UD -0.31
C-14	1.00	RFO(1) 0.89	RFO(4) 0.85	RFO(3) 0.84	RFO(5) 0.82	RFO(2) 0.82		
Fe-55	0.92	RFO(3) 0.28	RFO(1) 0.28	RFO(4) 0.27	RFO(5) 0.23	DKSUS 0.23	UD -0.21	RFO(2) 0.15
Co-60	0.87	RFO(1) 0.45	RFO(5) 0.16	DKSUS -0.14	RFO(2) 0.13	UD 0.13	RFO(4) 0.10	
Ni-63	0.99	RFO(1) - 0.64	RFO(3) -0.58	RFO(5) -0.58	RFO(2) -0.58	RFO(4) -0.58	DKSUS 0.12	
Sr-90	0.99	RFO(1) - 0.71	RFO(4) -0.59	RFO(2) -0.56	RFO(5) -0.56	RFO(3) -0.52	DKSUS 0.37	UD -0.30
Nb-94	0.29	DKSUS -0.38	UD 0.25	RFO(1) 0.24				
Tc-99	0.95	RFO(1) 0.40	RFO(4) 0.34	RFO(2) 0.29	RFO(3) 0.27	RFO(5) 0.26		
Ag-108m	0.81	RFO(1) 0.50	DKSUS -0.49	UD 0.41	RFO(4) 0.13	RFO(5) -0.10		
Sb-125	0.96	RFO(1) 0.65	RFO(4) 0.38	RFO(3) 0.32	UD 0.26	DKSUS -0.25	RFO(2) 0.20	RFO(5) 0.16
Cs-134	0.89	RFO(1) 0.37	RFO(4) 0.20	RFO(2) 0.16	RFO(5) 0.15	RFO(3) 0.14	UD 0.12	DKSUS -0.11
Cs-137	0.99	RFO(1) 0.81	RFO(5) 0.59	RFO(3) 0.59	RFO(4) 0.57	RFO(2) 0.54	DKSUS -0.48	UD 0.43
Eu-152	0.57	RFO(1) 0.24	RFO(5) 0.11					
Eu-154	0.76	RFO(1) 0.42	DKSUS -0.20	UD 0.17	RFO(2) 0.13			
Eu-155	0.96	RFO(4) -0.48	RFO(5) -0.46	RFO(3) -0.44	RFO(2) -0.43	RFO(1) 0.19		
Pu-238	1.00	RFO(1) -0.91	RFO(4) -0.87	RFO(3) -0.86	RFO(5) -0.85	RFO(2) -0.85	DKSUS 0.11	
Pu-239	1.00	RFO(1) -0.91	RFO(4) -0.87	RFO(3) -0.86	RFO(5) -0.85	RFO(2) -0.85		
Pu-241	0.66	DKSUS 0.60	UD -0.54	RFO(2) -0.14	RFO(1) -0.13	RFO(4) -0.13		
Am-241	1.00	RFO(1) -0.91	RFO(4) -0.87	RFO(3) -0.86	RFO(5) -0.85	RFO(2) -0.85		
Cm-243	1.00	RFO(1) -0.91	RFO(4) -0.86	RFO(3) -0.85	RFO(5) -0.85	RFO(2) -0.84	DKSUS 0.22	UD -0.17

Parameter Definition:

DKSUS: Resuspension Rate

UD: Deposition Velocity

RFO(#): Time for Source Removal (source number)

Source: (1) Floor (2) West Wall (3) North Wall (4) East Wall (5) South Wall

ATTACHMENT 1

Supporting Documentation for Site-Specific Parameter Values

Table of Contents

1. Room Dimension

An inventory of the rooms and partial rooms that would remain on site following Phase I of the DEMCO demolition project (Ref. 1.1) was used as the starting point in determining room dimensions. Wall dimensions were determined from Site Drawings showing the building locations, building elevations and dimensions. Ceilings are not included in the model, as partial rooms/rooms remaining at the time of license termination will either have no ceiling or will be covered with a ceiling constructed of new uncontaminated building materials.

The average wall dimension was calculated using an Excel Spreadsheet and considers all the remaining walls. A total of twenty-six walls were used tc determine the scenario room length and width. The 40.5 meter long Primary Auxiliary Building (PAB) South Wall was excluded from the average wall distance calculation. This wall, which extends the entire length of the PAB was excluded because it is unlikely it would be used as one side of a single room built in the future. This data and the calculated wall length and height are shown in Table 1.1 - Remaining Room / Wall Dimensions. The portion of the room to remain is highlighted.

The average wall dimension (meters) from Table 1.1 was used to calculate the scenario room-floor surface area (meters^2) as follows:

Room area = (4.44) x (4.44) = 19.71 meters^2

The wall surface area in square meters was calculated as follows from the average wall length and height in meters from Table 1.1:

Wall area = (4.44) x (3.51) = 15.58 meters^2

The room and wall surface areas and the wall height are used as input to the RESRAD-BUILD code to define the five source terms.

All wall dimensions were obtained from plant drawings as referenced in Table 1.2 - Remaining Structures and Drawing Reference.

Reference:

1.1 Attachment E to the "Contract for the Performance of Demolition and Disposal and Related Services, By and Between DEMCO, Inc. and Yankee Atomic Electric Company, " dated February 28, 2003.

Table 1.1
Remaining Room / Wall Dimensions

Building	Room/Cubicle/Wall	Width (Ft/in)		Inches	Meters	Length (Ft /in)		Inches	Meters	Height (Ft/in)		Inches	Meters
PAB	TK-30 (PAB Basement) Room	12	6	150	3.81E+00	15	6	186	4.72E+00	18	6	222	5.64E+00
PAB	TK-27 (PAB Basement) Room	10	2	122	3.10E+00	15	6	186	4.72E+00	18	6	222	5.64E+00
PAB	South Wall (G-Line)					133*		1596	4.05E+01	13	0	156	3.96E+00
PAB	East Wall (2-Line to Fa)					17	0	204	5.18E+00	13	0	156	3.96E+00
I-X PIT	Southernmost Wall					33	0	396	1.01E+01	14	8	176	4.47E+00
I-X PIT	Easternmost Wall (Total Length)					31	10	382	9.70E+00	14	8	176	4.47E+00
SFP	Spent Fuel Pool (Room)	16	6	198	5.03E+00	33	8	404	1.03E+01	14	8	176	4.47E+00
New Fuel Vault	New Fuel Storage (South Wall)					15	0	180	4.57E+00	13	6	162	4.11E+00
Safe Shutdown	Pipe Chase (Cubicle)	4	0	48	1.22E+00	4	0	48	1.22E+00	8	0	96	2.44E+00
Waste Vault	Waste Transfer Pit (Cubicle)	9	0	108	2.74E+00	14	0	168	4.27E+00	9	10	118	3.00E+00
Elevator Pit	Elevator Pit (Cubicle)	7	10	94	2.39E+00	9	0	108	2.74E+00	6	6	78	1.98E+00
Waste Disposal	Pipe Chase Cubicle	5	0	60	1.52E+00	11	10	142	3.61E+00	10	1	121	3.07E+00
Waste Disposal	Distillate Heat ExchangerCubicle	9	0	108	2.74E+00	16	0	192	4.88E+00	7	0	84	2.13E+00
Waste Disposal	Evaporator Cubicle	10	6	126	3.20E+00	16	0	192	4.88E+00	7	0	84	2.13E+00
Waste Disposal	Drumming Pit Cubicle	10	4	124	3.15E+00	27	0	324	8.23E+00	7	0	84	2.13E+00
PAB	PAB Back Stairwell Pit (Cubicle)	11	4	136	3.45E+00	13	0	156	3.96E+00	8	2	98	2.49E+00

* PAB South Wall excluded from average wall length calculation

Total Wall Sum = 1.15E+02
Average Wall Distance, meters: 4.44E+00

Total Wall Height Sum = 5.61E+01
Average Wall Height, meters: 3.51E+00

Table 1.2

Remaining Structures and Drawing Reference

Building	Room/Wall/Pit	Room/Wall Width	Drawing Reference	Wall Length	Drawing Reference	Wall Height (Note 1)	Drawing Reference
PAB	Drain Collecting Tank Room (TK-30)	12' 6"	PAB 9699-FC-40D	15' 6"	PAB 9699-RC-40A	1022' 8"-1004' 2"=18' 6"	PAB 9699-FM-57A
PAB	Gravity Drain Tank Room (TK-27)	10' 2"	PAB 9699-FC-40D	15' 6"	PAB 9699-RC-40A	1022' 8"-1004' 2"=18' 6"	PAB 9699-FM-57A
PAB	South Wall (G-Line)			133' 0"	PAB 9699-FR-16A	1035' 8" - 1022' 8' =13' 0"	PAB 9699-FM-57A
PAB	East Wall (2-Line to Fa)			17' 0"	PAB 9699-FR-16A	1035' 8" - 1022' 8' =13' 0"	PAB 9699-FM-57A
I-X PIT	Southernmost Wall			33' 0"	I-X Pit 9699-FM-35B	1035' 8" - 1021' 0" =14' 8"	I-X Pit 9699-FM-35B
I-X PIT	Easternmost Wall F to E			25' 6"	PAB 9699-FM-57A	1035' 8" - 1021' 0" =14' 8"	I-X Pit 9699-FM-35B
I-X PIT	Easternmost Wall E to Wall End			6'4"	I-X Pit 9699-FM-35B		
I-X PIT	Easternmost Wall (Total Length)			31' 10"			
SFP	Spent Fuel Pool	16' 6"	Fuel Pit 9699-FM-21A	33' 8"	Fuel Pit 9699-FM-21A	1022' 8" - 1008' 0" =14' 8"	Fuel Pit 9699-FC-45B
New Fuel Vault	New Fuel Storage (South Wall)			15' 0"	PAB 9699-FM-57A	1035' 0" - 1021' 6" =13' 6"	Fuel Pit 9699-FM-21A
Safe Shutdown	Pipe Chase (555)	4' 0"	CES Rev.1 85005-F-1001	4' 0"	CES Rev.1 85005-F-1001	1034' 0" - 1026' 0" = 8' 0"	CES Rev.1 85005-F-1001
Waste Vault	Waste Transfer Pump Pit (underground)	9' 0"	9699-FC-50C	14' 0"	9699-FC-50C	1020' 6" - 1010' 8" =9' 10"	9699-FC-50C
Elevator Pit	Elevator Pit	7' 10"	PAB 9699-FC-43A	9' 0"	PAB 9699-FC-43A	1022' 8' - 1016' 2" =6' 6"	PAB 9699-FC-43A
Waste Disposal	Pipe Chase Cubicle	5' 0"	Waste Disp.9699-FA-17A	11' 10"	Waste Disp.9699-FA-17A	1035' 8" - 1025' 7" = 10' 1"	Waste Disp.9699-FA-17A
Waste Disposal	Distillate Heat Exchanger Cubicle	9' 0"	Waste Disp.9699-FA-17A	16' 0"	Waste Disp.9699-FA-17A	1035' 8" - 1028' 8" = 7' 0"	Waste Disp.9699-FA-17A
Waste Disposal	Evaporator Cubicle	10' 6"	Waste Disp.9699-FA-17A	16' 0'	Waste Disp.9699-FA-17A	1035' 8" - 1028' 8" = 7' 0"	Waste Disp.9699-FA-17A
Waste Disposal	Drumming Pit Cubicle	10' 4"	Waste Disp.9699-FA-17A	27' 0"	Waste Disp.9699-FA-17A	1035' 8" - 1028' 8" = 7' 0"	Waste Disp.9699-FA-17A
PAB	Back of PAB Stairwell Pit Cubicle	11' 4"	PAB 9699 RC-40B	13' 0"	PAB 9699 RC-40B	1035' 8" - 1027' 6' = 8' 2"	PAB 9699-FM-57B

Note 1: Top/ceiling height elevation is from DEMCO work scope Ref. 1.1

2. Source Configuration

NUREG/CR-6755, Section 4.1, describes three principal assumptions inherent in the Building Occupancy scenario: a fixed room area, uniform surface contamination, and the receptor location at the center of the floor at a height of 1 m. The configuration of the receptor and sources is illustrated in Figure 1.1. The RESRAD- BUILD input parameters, receptor location and center of source coordinates, are provided in Table 1.3

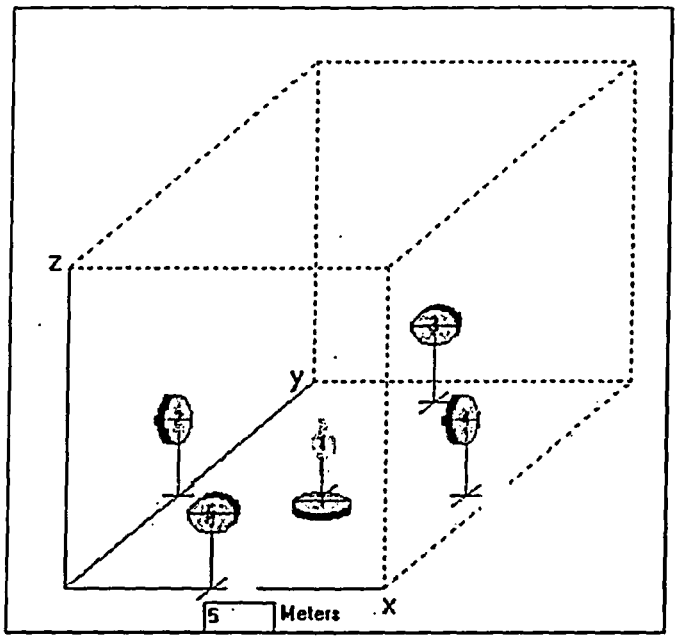


Figure 1.1. Configuration of Source and Receptor Locations for RESRAD-BUILD Model

Table 1.3
Receptor and Center of Source Locations, meters

			Axis		
Source #	Source Description	Wall Length	X	Y	Z
1	Floor		2.22	2.22	0
2	West Wall	4.44	0	2.22	1.76
3	North Wall	4.44	2.22	4.44	1.76
4	East Wall	4.44	4.44	2.22	1.76
5	South Wall	4.44	2.22	0	1.76
	Receptor Location		2.22	2.22	1
	Wall Height	3.51			

3. Direct Ingestion Rate

The source specific input parameter, Direct Ingestion Rate, is described in RESRAD-BUILD as the direct ingestion rate of the source by any receptor in the room. Each receptor will ingest the source at a rate determined by the ingestion rate and the amount of contamination in the source at that time. Direct ingestion is possible only if the receptor and the source are in the same room and has units of 1/hr for surface area sources.

NUREG 5512, volume 3 defines the average ingestion rate of 1.1E-4 m^2/hr as representative for the average individual in an industrial setting. The Direct Ingestion Rate for use in the Building Occupancy Scenario is calculated based on the total room source area as follows:

Direct Ingestion Rate = (1.1E-04 m^2/hr) / (Source Area)

= (1.1E-04 m^2/hr) / (82.03 m^2) = 1.34E-06 hr^{-1}

The direct ingestion defined in this manner used in conjunction with an indirect ingestion rate set to zero, adequately models the Building Occupancy Ingestion pathway.

Attachment 2

RESRAD-BUILD v3.21
Input Parameters to Sensitivity Analysis
Building Occupancy

Table 2.1 Input Parameters for Building Occupancy Sensitivity Runs

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/[d] Distribution	Basis	Distribution's Statistical Parameters				
						1	2	3	4	Median
Exposure Duration (days)	B	3	D	365.25	NUREG/CR-5512, Vol.3, 5.2.1	NR	NR	NR	NR	NR
Indoor Fraction	B	2		0.267	NUREG/CR-5512, Vol. 3, 5.2.2	NR	NR	NR	NR	NR
Evaluation Time (year)	P	3	D	0	t=0 corresponds maximum dose over the first year	NR	NR	NR	NR	NR
Number of Rooms	P	3	D	1	NUREG/CR-5512	NR	NR	NR	NR	NR
Deposition Velocity (m/sec)	P	2	S	Loguniform	NUREG/CR-6755, 3.3	2.70E-06	2.70E-03	-	-	-
Resuspension Rate (sec^{-1})	P	1	S	Loguniform	NUREG/CR-6755, 3.1	2.5E-11	1.35E-5	-	-	-
Air exchange rate for room (1/ h)	B	2	D	1.52	NUREG/CR-6697, Att.C, 7.4 and NUREG/CR-6755, 3.2	NR	NR	NR	NR	NR
Room area (m^2)	P	2	D	19.71	Site-specific model	NR	NR	NR	NR	NR
Room height (m)	P	2	D	3.51	Site-specific model	NR	NR	NR	NR	NR
Time fraction	B	3	D	1	NUREG/CR-5512	NR	NR	NR	NR	NR
Breathing rate (m^3/day)	B	2	D	33.6	NUREG/CR-5512 Vol. 3 5.3	NR	NR	NR	NR	NR
Indirect ingestion rate (m^2/hr)	B	2	D	0	NUREG/CR-5512 Vol. 3 5.2.3 Indirect ingestion is not modeled	NR	NR	NR	NR	NR
Receptor location: x,y,z (m)	B	3	D	2.22, 2.22, 1	NUREG/CR-5512	NR	NR	NR	NR	NR
Shielding thickness (cm)	P	2	D	0	Site-specific model- No Shielding assumed	NR	NR	NR	NR	NR
Shielding density (g/cc)	P	1	D	0	Site-specific model - No shielding assumed	NR	NR	NR	NR	NR
Shielding material	P	3	D	None	Site-specific model - No shielding assumed	NR	NR	NR	NR	NR
Number of sources	P	3	D	5	Site-specific model, Att. 1	NR	NR	NR	NR	NR
External dose conversion factor ((mrem/yr)/(dpm/m^2))	M	3	D	RESRAD-BUILD default	FGR 12	NR	NR	NR	NR	NR
Air submersion dose conversion factor ((mrem/yr)/(pCi/m^3))	M	3	D	RESRAD-BUILD default	FGR 12	NR	NR	NR	NR	NR
Inhalation dose conversion factor (mrem/pCi/g)	M	3	D	RESRAD-BUILD default	FGR 11	NR	NR	NR	NR	NR
Ingestion dose conversion factor (mrem/pCi/g)	M	3	D	RESRAD-BUILD default	FGR 11	NR	NR	NR	NR	NR

Table 2.1 Input Parameters for Building Occupancy Sensitivity Runs

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/[d] Distribution	Basis	Distribution's Statistical Parameters				
						1	2	3	4	Median
Source 1. Floor										
Type	P	3	D	Area	NUREG/CR-5512	NR	NR	NR	NR	NR
Direction	P	3	D	Z	NUREG/CR-5512	NR	NR	NR	NR	NR
Location of center of source: x,y,z (m)	P	3	D	2.22, 2.22, 0	Site-specific model, Att. 1	NR	NR	NR	NR	NR
Area (m2)	P	2	D	19.71	Site-specific model, Att 1	NR	NR	NR	NR	NR
Air fraction for H-3	B	2	D	1	NUREG/CR-6697, Att. C, 8.6	NR	NR	NR	NR	NR
Air fraction (for all nuclides except H-3)	B	2	D	0.07	NUREG/CR-6697, Att. C, 8.6	NR	NR	NR	NR	NR
Direct ingestion (hr-1)	B	2	D	1.34E-6	NUREG/CR-5512, Vol. 3, 5.2.3 1.1E-04m^2/h / 82.03 m^2	NR	NR	NR	NR	NR
Removable fraction	P	1	D	0.1	NUREG-1727 Table C 7.1 / NUREG/CR-6755, 3.5	NR	NR	NR	NR	NR
Time for source removal (days)	P	2	S	Triangular	NUREG/CR-6755, 3.6	1000	100000	10000	-	-
Radionuclide concentration (pCi/m^2)	P	2	D	1	Allows for proportional DCGL calculation	NR	NR	NR	NR	NR
Source 2. West Wall										
Type	P	3	D	Area	NUREG/CR-5512	NR	NR	NR	NR	NR
Direction	P	3	D	X	NUREG/CR-5512	NR	NR	NR	NR	NR
Location of center of source: x,y,z (m)	P	3	D	0, 2.22, 1.76	Site-specific model, Att 1	NR	NR	NR	NR	NR
Area (m2)	P	2	D	15.58	Site-specific model, Att 1	NR	NR	NR	NR	NR
Air fraction for H-3	B	2	D	1	NUREG/CR-6697 Att C, 8.6	NR	NR	NR	NR	NR
Air fraction (for all nuclides except H-	B	2	D	0.07	NUREG/CR-6697 Att C, 8.6	NR	NR	NR	NR	NR
Direct ingestion (hr-1)	B	2	D	1.34E-6	NUREG/CR-5512 Vol 3, 5.2.3 1.1E-04m^2/h / 82.03m^2	NR	NR	NR	NR	NR
Removable fraction	P	1	D	0.1	NUREG-1727 Table C 7.1 / NUREG/CR-6755, 3.5	NR	NR	NR	NR	NR
Time for source removal (days)	P	2	S	Triangular	NUREG/CR-6755, 3.6/ NUREG/CR- 6697	1000	100000	10000	-	-
Radionuclide concentration (pCi/m^2)	P	2	D	1	Allows for proportional DCGL calculation	NR	NR	NR	NR	NR
Source 3. North Wall										
Type	P	3	D	Area	NUREG/CR-5512	NR	NR	NR	NR	NR
Direction	P	3	D	Y	NUREG/CR-5512	NR	NR	NR	NR	NR

Table 2.1 Input Parameters for Building Occupancy Sensitivity Runs

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/[d] Distribution	Basis	Distribution's Statistical Parameters				
						1	2	3	4	Median
Location of center of source: x,y,z (m)	P	3	D	2.22, 4.44, 1.76	Site-specific model, Att 1	NR	NR	NR	NR	NR
Area (m2)	P	2	D	15.58	Site-specific model, Att 1	NR	NR	NR	NR	NR
Air fraction for H-3	B	2	D	1	NUREG/CR-6697 Att C, 8.6	NR	NR	NR	NR	NR
Air fraction (for all nuclides except H-3)	B	2	D	0.07	NUREG/CR-6697 Att C, 8.6	NR	NR	NR	NR	NR
Direct ingestion (hr-1)	B	2	D	1.34E-6	NUREG/CR-5512 Vol 3,5.2.3 1.1E-04m^2/h / 82.03m^2	NR	NR	NR	NR	NR
Removable fraction	P	1	D	0.1	NUREG-1727 Table C 7.1 / NUREG/CR-6755, 3.5	NR	NR	NR	NR	NR
Time for source removal (days)	P	2	S	Triangular	NUREG/CR-6755, 3.6/ NUREG/CR- 6697	1000	100000	10000	-	-
Radionuclide concentration (pCi/m^2)	P	2	D	1	Allows for proportional DCGL calculation	NR	NR	NR	NR	NR
Source 4. East Wall										
Type	P	3	D	Area	NUREG/CR-5512	NR	NR	NR	NR	NR
Direction	P	3	D	X	NUREG/CR-5512	NR	NR	NR	NR	NR
Location of center of source: x,y,z (m)	P	3	D	4.44, 2.22, 1.76	Site-specific model, Att 1	NR	NR	NR	NR	NR
Area (m2)	P	2	D	15.58	Site-specific model, Att 1	NR	NR	NR	NR	NR
Air fraction for H-3	B	2	D	1	NUREG/CR-6697, Att C, 8.6	NR	NR	NR	NR	NR
Air fraction (for all nuclides except H-3)	B	2	D	0.07	NUREG/CR-6697, Att C, 8.6	NR	NR	NR	NR	NR
Direct ingestion (hr-1)	B	2	D	1.34E-6	NUREG/CR-5512, 5.2.3 1.1E-04m^2/h / 82.03m^2	NR	NR	NR	NR	NR
Removable fraction	P	1	D	0.1	NUREG-1727 Table C 7.1 / NUREG/CR-6755, 3.5	NR	NR	NR	NR	NR
Time for source removal (days)	P	2	S	Triangular	NUREG/CR-6755, 3.6/ NUREG/CR- 6697	1000	100000	10000	-	-
Radionuclide concentration (pCi/m^2)	P	2	D	1	Allows for proportional DCGL calculation	NR	NR	NR	NR	NR
Source 5. South Wall										
Type	P	3	D	Area	NUREG/CR-5512	NR	NR	NR	NR	NR
Direction	P	3	D	Y	NUREG/CR-5512	NR	NR	NR	NR	NR
Location of center of source: x,y,z (m)	P	3	D	2.22, 0, 1.76	Site-specific model, Att 1	NR	NR	NR	NR	NR

Table 2.1 Input Parameters for Building Occupancy Sensitivity Runs

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/[d] Distribution	Basis	Distribution's Statistical Parameters				
						1	2	3	4	Median
Area (m2)	P	2	D	15.58	Site-specific model, Att 1	NR	NR	NR	NR	NR
Air fraction for H-3	B	2	D	1	NUREG/CR-6697 Att C, 8.6	NR	NR	NR	NR	NR
Air fraction (for all nuclides except H-3)	B	2	D	0.07	NUREG/CR-6697 Att C, 8.6	NR	NR	NR	NR	NR
Direct ingestion (hr-1)	B	2	D	1.34E-6	NUREG/CR-5512, 5.2.3 1.1E-04m^2/h / 82.03m^2	NR	NR	NR	NR	NR
Removable fraction	P	1	D	0.1	NUREG-1727 Table C 7.1 / NUREG/CR-6755, 3.5	NR	NR	NR	NR	NR
Time for source removal (days)	P	2	S	Triangular	NUREG/CR-6755. 3.6/ NUREG/CR- 6697	1000	100000	10000	-	-
Radionuclide concentration (pCi/m^2)	P	2	D	1	Allows for proportional DCGL calculation	NR	NR	NR	NR	NR

NOTES

[a] P = physical, B = behavioral, M = Metabolic (NUREG/CR-6697 Att B, Table 4.3)

[b] 1 = high priority parameter, 2 = medium priority parameter, 3 = low priority parameter (NUREG/CR-6697 Att B, Table 4.3)

[c] D = deterministic, S = stochastic (Figure 1)

[d] Statistical Parameters

Loguniform 1 = minimum, 2 = maximum
Triangular 1 = minimum, 2 = maximum, 3 = most likely
NR - None Required

Input Correlations: Resuspension Rate and Deposition Velocity = 0.9
Time to Source Removal = 0.9 (correlation set between sources)

Run Specifications: Random Seed = 1000
Number of Observations = 300
Number of Repetitions = 1
Dose Integrations = 5

Attachment 3

RESRAD-BUILD v3.21
Determination of Evaluation Time
Building Occupancy

Table 3.1
Result of Probabilistic Runs to Determine the Time Maximum Dose Occurs

Nuclide	Average Dose for 300 total obs. (100/3)					
	Evaluation Times					
	t=0	t=10	t=30	t=100	t=200	max
H-3	**8.09E-09**	3.84E-09	8.47E-10	4.33E-12	9.10E-16	8.09E-09
C-14	**2.69E-07**	2.23E-07	1.51E-07	3.91E-08	2.44E-08	2.69E-07
Mn-54	**7.94E-06**	2.36E-09	2.09E-16	4.64E-41	0.00E+00	7.94E-06
Fe-55	**6.89E-08**	4.40E-09	1.76E-11	7.16E-20	2.89E-32	6.89E-08
Co-60	**3.32E-05**	8.65E-06	5.91E-07	5.43E-11	1.02E-16	3.32E-05
Ni-63	**7.42E-08**	5.75E-08	3.37E-08	5.29E-09	1.47E-10	7.42E-08
Sr-90	**1.96E-05**	1.29E-05	5.42E-06	2.71E-07	1.99E-09	1.96E-05
Nb-94	**2.21E-05**	2.16E-05	2.07E-05	1.94E-05	1.89E-05	2.21E-05
Tc-99	**1.89E-07**	1.58E-07	1.07E-07	2.85E-08	2.52E-09	1.89E-07
Ru-106	**4.67E-06**	4.34E-09	3.81E-15	3.17E-36	0.00E+00	4.67E-06
Ag108m	**2.30E-05**	2.13E-05	1.84E-05	1.18E-05	6.67E-06	2.30E-05
Sb-125	**5.84E-06**	4.65E-07	2.98E-09	6.82E-17	9.01E-28	5.84E-06
Cs-134	**2.58E-05**	8.37E-07	8.97E-10	4.39E-20	1.02E-34	2.58E-05
Cs-137	**1.39E-05**	1.01E-05	5.40E-06	7.77E-07	6.75E-08	1.39E-05
Eu-152	**1.58E-05**	9.17E-06	3.11E-06	7.63E-08	4.11E-10	1.58E-05
Eu-154	**1.70E-05**	7.54E-06	1.49E-06	5.57E-09	2.06E-12	1.70E-05
Eu-155	**9.97E-07**	2.35E-07	1.33E-08	6.56E-13	5.33E-19	9.97E-07
Pu-238	**4.35E-04**	3.37E-04	1.95E-04	2.93E-05	8.18E-06	4.35E-04
Pu-239	**4.83E-04**	4.04E-04	2.74E-04	7.14E-05	4.36E-06	4.83E-04
Pu-241*	9.50E-06	**1.02E-05**	8.25E-06	2.17E-06	1.25E-07	1.02E-05
Am-241	**4.96E-04**	4.10E-04	2.69E-04	6.31E-05	3.63E-05	4.96E-04
Cm-243	**3.40E-04**	2.24E-04	9.36E-05	4.63E-06	4.09E-08	3.40E-04

* Additional Pu-241 runs at T= 4,6,8,10,12 years show 1.02E-05 at T=8 and T=10 years. T=9 year midpoint used as the time maximum dose occurs.

Attachment 4

CD Table of Contents for RESRAD-BUILD Input/Output Files

The enclosed CD contains the electronic image files containing the Building Occupancy Scenario DCGL and Dose Verification output pages from the RESRAD- BUILD V3.21 resbmc.rpt and resradb.rpt reports. The files below are provided for use in verifying inputs and probabilistic output.

CD Name: YA-CALC-00-003-03

File: Deterministic Input.pdf
Probabilistic Input_Output.pdf