CALCULATION TITLE PAGE

CALCULATION NUMBER: PSAT 3019CF.QA.05

CALCULATION TITLE: Fuel Handling Accident Dose for Vermont Yankee

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REASON FOR REVISION: Nonconformance Rpt

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Purpose

The purpose of this calculation is to provide an analysis of the Fuel Handling Accident (FHA) for Vermont Yankee. This update provides (1) implementation of the Reference 1 (AST) source terms and (2) both offsite and control room doses.

Summary of Results

Table 1 – FHA Summary of Dose Results (TEDE in Rem/Applicable Reference 1 Limit)

Case	Control Room	EAB	LPZ
0% Ground-Level Release, 24-Hour Decay	0.15305/5	0.47194/6.3	< 0.47194/6.3
20% Ground-Level Release, 24-Hour Decay	3.14204/5	1.59761/6.3	< 1.59761/6.3
0% Ground-Level Release, 96-Hour Decay	0.10708/5	0.27413/6.3	< 0.27413/6.3
20% Ground-Level Release, 96-Hour Decay	2.19841/5	0.92799/6.3	< 0.92799/6.3

This table shows that all cases meet the applicable limits at all locations. Appendix B explains that in order to have acceptable control room doses without any containment credit (i.e., 100% ground level release), a miminum of 14 days' decay is needed.

Methodology

This dose analysis fully complies with NRC Regulatory Guide 1.183 (Reference 1). Following accident initiation (either at 24 or 96 hours after shutdown), the radionuclide inventory from the damaged fuel pins is assumed to leak out to the environment instantaneously (even though releases to the environment could be assumed to occur over a 2-hour period according to Reference 1).

Credit is taken for the plant stack in achieving an elevated release for at least a portion of the activity released from the damaged fuel. In one case, 100% of the activity is assumed to be released to the environment from the plant stack; in a second case, 20% of the activity is assumed to be released to the environment at ground level and 80% is assumed to be released to the environment from the plant stack. In no case is SGTS filtration credited. Due to these simplifying, conservative assumptions, a spreadsheet is used to calculate the control room, EAB, and LPZ doses.

The time duration that corresponds to the 20% release of activity to the environment at ground level (were a two-hour release to be considered as opposed to an instantaneous release) is different depending on release assumptions. If the activity release rate were assumed to be uniform, the 20% release would correspond to 0.2 x 120 minutes = 24 minutes out of the two hours. If the activity release were assumed to correspond to a constant fractional release rate and 99% of the release were assumed to occur over two hours, the 20% release would correspond to [ln(0.8)/ln(0.01)] x 120 minutes = 6 minutes out of the two hours. Either of these two assumptions would be consistent with Reference 1.

Releases account for:

- a 1.02 multiplier on licensed power,
- a radial peaking factor of 1.65,
- 5% gap activity (except 10% for Kr85 and 8% for I131),
- a pin failure fraction of 0.571% corresponding to 2.1 assemblies out of 368 assemblies,
- an overall iodine DF of 200 and an infinite DF for other radionuclides except for noble gas.

The TEDE values obtained from the revised analysis are compared with the 6.3 rem FHA TEDE limit for offsite doses and the 5 rem TEDE limit for the control room (Reference 1).

Assumptions

Assumption 1: The accident is assumed to occur either 24 hours or 96 hours after shutdown. Consequently, core inventories were calculated that correspond to each decay time.

Justification: Fuel handling would not begin before 24 hours after shutdown. 96 hours after shutdown is more typical.

Assumption 2: The release to the environment from the refueling floor occurs within two hours.

Justification: Reference 1

Assumption 3: The DF in the refueling pool does not exceed 200 for iodine. No DF is applied to noble gas, and the DF for other radionuclides is assumed to be infinite.

Justification: Reference 1

Assumption 4: Credit is taken for containment, collection, and elevated release of at least 80% of the activity escaping the fuel pool. No credit is needed (or taken) for SGTS filters.

Justification: As can be seen from the results summary, the ground level release is limited to 20% of the activity released from the fuel pool.

References

1. "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors", US NRC Regulatory Guide 1.183, Revision 0, July 2000
2. PSAT 3019CF.QA.03, "DESIGN DATA BASE FOR APPLICATION OF THE REVISED DBA SOURCE TERM TO VERMONT YANKEE", Revision 0
3. RADDECAY Version 3, Grove Engineering, Inc., 1990.
4. VY Calculation VYC-2260, "Bounding Core Inventories of Actinides and Fission Products for Design-Basis Applications at 1950 MWt" Revision 0
5. S. L. Humphries et al, "RADTRAD: A Simplified Model for Radionuclide Tansport and Removal and Dose Estimation", NUREG/CR-6604, Sandia National Laboratories, December 1997.

Design Inputs

Design Input Data (Reference 2 for all inputs, Item numbers given in brackets)

Power Level: 1950 MWt [8.1]
Core inventory at shutdown: see Item 1.1 of Reference 2
Total number of fuel assemblies in core: 368 assemblies [1.2]
Number of damaged assemblies: 2.1 [2.4]
Gap release fractions:

Radio-nuclide Group	Release Fraction from Gap to Coolant
Kr-85	10%
Other NG	5%
I-131	8%
Other Iodines	5%

[2.5]

Peaking factor: 1.65 [2.6]

Control Room Free Volume: 41,533.75 ft^3 [3.4]

X/Q values in sec/m^3:

EAB:	1.7E-3 (ground-level) 2.03E-4 (1st half-hour elevated), 1.54E-3 (2nd half-hour elevated), 9.17E-5 (remainder elevated)	[5.1]
LPZ:	*	
CR:	5.89E-3 (ground-level) 2.39E-4 (1st half-hour elevated), 1.05E-6 (2nd half-hour elevated), 8.7E-7 (remainder elevated)	[5.3]

*LPZ dose not necessary since release is limited to two hours and EAB is more limiting

Breathing Rate in m^3/s (from start of release): 3.5E-4 [5.4]

Iodine Species: 99.85% elemental, 0.15% organic** [2.7]
** Iodine chemical form not critical since control room filters are not used. Elemental iodine DF adjusted to obtain overall iodine of DF of 200 per Reference 1. No DF applied to organic iodine.

Calculation

Core inventories at one or four days after shutdown are calculated using the RADDECAY Code (Reference 3). The gap activity of noble gas and iodine (set at 99.85% elemental, 0.15% organic per References 1 and 2) is added from the core to the gap.

The starting point of the calculation was the t = 0 shutdown inventories (Ci/MWt) from Reference 2, Item 1.1. RADDECAY was then run starting with the t = 0 inventories for the noble gas and iodine isotopes. Given the activity (Ci or Ci/MWt) of an isotope at t = 0, RADDECAY calculates the curies or Ci/MWt at any subsequent time of that isotope and its daughters. To get the total curies of the isotope of interest one must add the curies resulting from its direct decay plus the curies resulting from decay in chains in which it is a daughter product.

For Kr83m, Kr85, Kr85m, I133 and I134, there were no shutdown activities listed for certain of their parent nuclides (Br83, Br85, Te133, Te133m, and Te134). These were obtained directly from Reference 4. In all cases, the activity contribution from these additional nuclides is negligible except for Br83 to Kr83m and Te134 to I134. While the parents contributed markedly to the activity for Kr83m and I134, the EAB and CR dose contribution for both of these nuclides is zero to five significant figures; therefore, the contributions have no significance for the dose.

The final activities are shown in Table 2.

Table 2 – Core Inventories (per MWt) for FHA

Nuclide	Shutdown	Adjusted	24 Hours	96 Hours
Br83	4.24E+03	*	*	*
Kr83m	4.24E+03	same	15.6	negligible
Br85	9.61E+03	*	*	*
Kr85m	9.71E+03	same	239	negligible
Kr85	5.05E+02	1.01E+03	1010	1009
Kr87	1.94E+04	same	0.038	negligible
Kr88	2.75E+04	same	72.3	negligible
Kr89	3.46E+04	same	negligible	negligible
Te131m	4.31E+03	*	*	*
I131	2.85E+04	4.56E+04	42105	32776
Xe131m	3.18E+02	same	327	338
Te132	3.97E+04	*	*	*
I132	4.05E+04	same	33065	17466
Te133m	2.30E+04	*	*	*
Te133	3.39E+04	*	*	*
I133	5.79E+04	same	26656	2420
Xe133m	1.76E+03	same	1594	766
Xe133	5.78E+04	same	55528	40184
Te134	5.31E+04	*	*	*
I134	6.43E+04	same	negligible	negligible
I135	5.39E+04	same	4351	2.3
Xe135m	1.14E+04	same	negligible	negligible
Xe135	2.33E+04	same	15285	106
Xe137	5.07E+04	same	negligible	negligible
Xe138	5.05E+04	same	negligible	negligible

* Considered as parent only

These activities are compared to those calculated as part of the check calculation in Appendix A (see Table A-1).

The offsite X/Qs are from Reference 2 as previously noted. A weighted-average X/Q is calculated depending on the percentage of activity released with the elevated release CR and EAB X/Q and the ground-level release CR and EAB X/Q. Cases for both zero and 20% ground release are considered. As noted under Methodology, if it is assumed that the normalized release to the environment is linear (i.e., 0.5 per hour for two hours), then the 20% ground-level X/Q means that the ground-level release lasted 0.4 hours or 24 minutes. If a constant fractional release rate is assumed such that 99% is released in two hours (2.3 per hour), then the 20% ground-level X/Q means that the ground level release lasted approximately 0.1 hour or 6 minutes.

So using the database (Reference 2) values as follows for the CR:

Stack (fumig):	2.39E-4
Stack (norm):	1.05E-6 (1/2 hour), 8.7E-7 (1 hour)
RB siding:	5.89E-3

the "zero" case would just use a weighted average 0.25 x 2.39E-4 + 0.25 x 1.05E-6 + 0.5 x 8.7E-7 = 6.04E-5, while the "20%" case would use a weighted average of 0.2 x 5.89E-3 + 0.25 x 2.39E-4 + 0.25 x 1.05E-6 + 0.3 x 8.7E-7 = 1.24E-3.

In like manner, for the EAB dose:

Stack (fumig):	2.03E-4
Stack (norm):	1.54E-4 (1/2 hour), 9.17E-5 (1 hour)
Ground-level:	1.7E-3

the "zero" case would just use a weighted average 0.25 x 2.03E-4 + 0.25 x 1.54E-4 + 0.5 x 9.17E-5 = 1.35E-4, while the "20%" case would use a weighted average of 0.2 x 1.7E-3 + 0.25 x 2.03E-4 + 0.25 x 1.54E-4 + 0.3 x 9.17E-5 = 4.57E-4.

The breathing rate of 3.5E-4 m^3/s is taken from Reference 2.

Note that no credit is taken for the SGTS filtration.

Results

An EXCEL spreadsheet calculation has been carried out to obtain the results for each of four cases (0% and 20% elevated release for 24 hours and 96 hours decay). The spreadsheet is constructed as follows:

Rows 1 and 2:	Title and headings for X/Q values (EAB and CR)
Row 3:	Reactor Power (MWt) accounting for uncertainties
Row 4:	Control Room free volume (ft^3)
Row 5:	Release fraction (fraction of total inventory released during the accident) RF = 0.05 x (no. of damaged assemblies/total no. of fuel assemblies in core) RF = 0.05 x 2.1 /368 = 2.85E-4
Row 6:	Radial power peaking factor
Column 1:	Radionuclides, with distinction between iodine chemical forms
Column 2:	Decayed core inventory (24 hours or 96 hours, as appropriate)
Column 3:	Whole Body DCF, equal to "Cloudshine Effective" from Ref. 5 after conversion to rem-m^3/Ci-sec
Column 4:	CEDE DCF, equal to "Inhaled Chronic Effective" from Ref. 5 after conversion to rem/Ci
Column 5:	TEDE DCF = (Whole Body DCF) + (CEDE DCF x Breathing Rate)
Column 6:	CR TEDE DCF = (Whole Body DCF x (CR Volume)$^{0.338}$/1173) + (CEDE DCF x Breathing Rate) This CR DCF differs from the TEDE DCF as it includes a finite volume correction for the Whole Body dose taken from Ref. 1. CR volume must be in ft^3.

Column 7: EAB TEDE = (Ci/MWt) x (Power Level) x (Release Fraction) x (Peaking Factor) x (Appropriate Nuclide Multiplier of 1.0 for noble gas, 0.0015 for organic iodine, or 0.9985 divided by DF = 285 for elemental iodine) x (EAB X/Q) x (TEDE DCF)

Column 8: CR TEDE = (Ci/MWt) x (Power Level) x (Release Fraction) x (Peaking Factor) x (Appropriate Nuclide Multiplier of 1.0 for noble gas, 0.0015 for organic iodine, or 0.9985 divided by DF = 285 for elemental iodine) x (CR X/Q) x (CR TEDE DCF)

The "appropriate nuclide multipilers" are 1.0 for the noble gases, 0.0015 for organic iodine, and (1.0 – 0.0015)/(refueling pool DF) for the elemental iodine. The refueling pool DF for elemenatal iodine is calculated as follows:

1. Assume an effective DF of 200.
2. The fraction of the iodine inventory released from the pool is 1/200 = 0.005. Of this, 0.0015 is for organics, so the elemental iodine release fraction is 0.0035.
3. DF = 1.0/0.0035 ≈285.

The spreadsheet results for 24 hour decay before the fuel handling accident are shown in Tables 3 and 4 for 0% ground level release and 20% ground level release, respectively. Corresponding results for 96 hours after shutdown appear in Tables 5 and 6. Contrrol room and EAB doses are explicitly calculated; and because the release occurs within two hours, the EAB doses are bounding for the LPZ.

Table 3. Doses after a Fuel Handling Accident (0% ground-level release, 24-hour decay).

VY FHA (24 hrs)		EAB	CR				
	X/Qs =	1.35E-04	6.04E-05	sec/m^3 (0% release at ground level)			
Power =	1950	MWt					
CR Vol =	41533.75	ft^3					
Rel Frac. =	2.85E-04						
Peaking =	1.65	WB	CEDE	TEDE	CR TEDE	EAB	CR
Nuclide	Ci/MW	DCF	DCF	DCF	DCF	TEDE	TEDE
Kr83m	1.56E+01	1.49E-05	0	1.5E-05	5E-07	0.00000	0.00000
Kr85m	2.39E+02	0.0277	0	0.0277	0.0009	0.00082	0.00001
Kr85	1.01E+03	4.40E-04	0	0.00044	1E-05	0.00006	0.00000
Kr87	3.80E-02	0.1524	0	0.1524	0.0047	0.00000	0.00000
Kr88	7.23E+01	0.3774	0	0.3774	0.0117	0.00338	0.00005
Kr89	0.00E+00	0.323	0	0.323	0.01	0.00000	0.00000
Xe131m	0.00E+00	0.00149	0	0.00149	5E-05	0.00000	0.00000
Xe133m	0.00E+00	0.00507	0	0.00507	0.0002	0.00000	0.00000
Xe133	5.30E+04	0.00577	0	0.00577	0.0002	0.03787	0.00053
Xe135m	0.00E+00	0.07548	0	0.07548	0.0023	0.00000	0.00000
Xe135	1.45E+04	0.04403	0	0.04403	0.0014	0.07903	0.00110
Xe137	0.00E+00	0.0303	0	0.0303	0.0009	0.00000	0.00000
Xe138	0.00E+00	0.199	0	0.199	0.0062	0.00000	0.00000
I131Org	4.21E+04	0.06734	32893	11.5799	11.515	0.09054	0.04028
I132Org	3.31E+04	0.4144	381.1	0.54779	0.1462	0.00336	0.00040
I133Org	2.67E+04	0.10878	5846	2.15488	2.0495	0.01067	0.00454
I134Org	0.00E+00	0.481	131.35	0.52697	0.0609	0.00000	0.00000
I135Org	4.35E+03	0.3069	1228.4	0.73684	0.4395	0.00060	0.00016
I131Elem	4.21E+04	0.06734	32893	11.5799	11.515	0.21147	0.09408
I132Elem	3.31E+04	0.4144	381.1	0.54779	0.1462	0.00786	0.00094
I133Elem	2.67E+04	0.10878	5846	2.15488	2.0495	0.02491	0.01060
I134Elem	0.00E+00	0.481	131.35	0.52697	0.0609	0.00000	0.00000
I135Elem	4.35E+03	0.3069	1228.4	0.73684	0.4395	0.00139	0.00037
					Total TEDE=	**0.47194**	**0.15305**

Table 4. Doses after a Fuel Handling Accident (20% ground level release, 24-hour decay).

VY FHA (24 hrs)		EAB	CR				
Ground Level X/Qs =		4.57E-04	1.24E-03	sec/m3 (20% release at ground level)			
Power =	1950	MW(t)					
CR Vol =	41533.75	ft3					
Rel Fract =	2.85E-04						
Peaking =	1.65	WB	CEDE	TEDE	CR TEDE	EAB	CR
Nuclide	Ci/MW	DCF	DCF	DCF	DCF	TEDE	TEDE
Kr83m	1.56E+01	1.49E-05	0	1.5E-05	5E-07	0.00000	0.00000
Kr85m	2.39E+02	0.0277	0	0.0277	0.0009	0.00277	0.00023
Kr85	1.01E+03	4.40E-04	0	0.00044	1E-05	0.00019	0.00002
Kr87	3.80E-02	0.1524	0	0.1524	0.0047	0.00000	0.00000
Kr88	7.23E+01	0.3774	0	0.3774	0.0117	0.01143	0.00096
Kr89	0.00E+00	0.323	0	0.323	0.01	0.00000	0.00000
Xe131m	0.00E+00	0.00149	0	0.00149	5E-05	0.00000	0.00000
Xe133m	0.00E+00	0.00507	0	0.00507	0.0002	0.00000	0.00000
Xe133	5.30E+04	0.00577	0	0.00577	0.0002	0.12820	0.01079
Xe135m	0.00E+00	0.07548	0	0.07548	0.0023	0.00000	0.00000
Xe135	1.45E+04	0.04403	0	0.04403	0.0014	0.26754	0.02252
Xe137	0.00E+00	0.0303	0	0.0303	0.0009	0.00000	0.00000
Xe138	0.00E+00	0.199	0	0.199	0.0062	0.00000	0.00000
I131Org	4.21E+04	0.06734	32893	11.5799	11.515	0.30648	0.82691
I132Org	3.31E+04	0.4144	381.1	0.54779	0.1462	0.01139	0.00825
I133Org	2.67E+04	0.10878	5846	2.15488	2.0495	0.03611	0.09318
I134Org	0.00E+00	0.481	131.35	0.52697	0.0609	0.00000	0.00000
I135Org	4.35E+03	0.3069	1228.4	0.73684	0.4395	0.00202	0.00326
I131Elem	4.21E+04	0.06734	32893	11.5799	11.515	0.71585	1.93140
I132Elem	3.31E+04	0.4144	381.1	0.54779	0.1462	0.02659	0.01926
I133Elem	2.67E+04	0.10878	5846	2.15488	2.0495	0.08433	0.21763
I134Elem	0.00E+00	0.481	131.35	0.52697	0.0609	0.00000	0.00000
I135Elem	4.35E+03	0.3069	1228.4	0.73684	0.4395	0.00471	0.00762
					Total TEDE	**1.59761**	**3.14204**

Table 5. Doses after a Fuel Handling Accident (0% ground level release, 96-hour decay).

VY FHA (96 hrs)		EAB	CR				
Ground Level X/Qs =		1.35E-04	6.04E-05	sec/m^3 (0% release at ground level)			
Power =	1950	MWt					
CR Vol =	41533.8	ft^3					
Rel Frac. =	2.85E-04						
Peaking =	1.65	WB	CEDE	TEDE	CR TEDE	EAB	CR
Nuclide	Ci/MW	DCF	DCF	DCF	DCF	TEDE	TEDE
Kr83m	0	1.49E-05	0	1.5E-05	5E-07	0.00000	0.00000
Kr85m	0	0.0277	0	0.0277	0.0009	0.00000	0.00000
Kr85	1009	4.40E-04	0	0.00044	1E-05	0.00005	0.00000
Kr87	0	0.1524	0	0.1524	0.0047	0.00000	0.00000
Kr88	0	0.3774	0	0.3774	0.0117	0.00000	0.00000
Kr89	0	0.323	0	0.323	0.01	0.00000	0.00000
Xe131m	338	0.00149	0	0.00149	5E-05	0.00006	0.00000
Xe133m	766	0.00507	0	0.00507	0.0002	0.00048	0.00001
Xe133	40184	0.00577	0	0.00577	0.0002	0.02871	0.00040
Xe135m	0	0.07548	0	0.07548	0.0023	0.00000	0.00000
Xe135	106	0.04403	0	0.04403	0.0014	0.00058	0.00001
Xe137	0	0.0303	0	0.0303	0.0009	0.00000	0.00000
Xe138	0	0.199	0	0.199	0.0062	0.00000	0.00000
I131Org	32776	0.06734	32893	11.5799	11.515	0.07048	0.03135
I132Org	17466	0.4144	381.1	0.54779	0.1462	0.00178	0.00021
I133Org	2420	0.10878	5846	2.15488	2.0495	0.00097	0.00041
I134Org	0	0.481	131.35	0.52697	0.0609	0.00000	0.00000
I135Org	2.3	0.3069	1228.4	0.73684	0.4395	0.00000	0.00000
I131Elem	32776	0.06734	32893	11.5799	11.515	0.16461	0.07323
I132Elem	17466	0.4144	381.1	0.54779	0.1462	0.00415	0.00050
I133Elem	2420	0.10878	5846	2.15488	2.0495	0.00226	0.00096
I134Elem	0	0.481	131.35	0.52697	0.0609	0.00000	0.00000
I135Elem	2.3	0.3069	1228.4	0.73684	0.4395	0.00000	0.00000
					Total TEDE=	**0.27413**	**0.10708**

Table 6. Doses after a Fuel Handling Accident (20% ground level release, 96-hour decay):

VY FHA (96 hrs)		EAB	CR				
Ground Level X/Qs =		4.57E-04	1.24E03	sec/m3 (20% release at ground level)			
Power =	1950	MW(t)					
CR Vol =	41533.8	ft3					
Rel Fract =	2.85E-04						
Peaking =	1.65	WB	CEDE	TEDE	CR	EAB	CR
Nuclide	Ci/MW	DCF	DCF	DCF	DCF	TEDE	TEDE
Kr83m	0	1.49E-05	0	1.5E-05	5E-07	0.00000	0.00000
Kr85m	0	0.0277	0	0.0277	0.0009	0.00000	0.00000
Kr85	1009	4.40E-04	0	0.00044	1E-05	0.00019	0.00002
Kr87	0	0.1524	0	0.1524	0.0047	0.00000	0.00000
Kr88	0	0.3774	0	0.3774	0.0117	0.00000	0.00000
Kr89	0	0.323	0	0.323	0.01	0.00000	0.00000
Xe131m	338	0.00149	0	0.00149	5E-05	0.00021	0.00002
Xe133m	766	0.00507	0	0.00507	0.0002	0.00163	0.00014
Xe133	40184	0.00577	0	0.00577	0.0002	0.09720	0.00818
Xe135m	0	0.07548	0	0.07548	0.0023	0.00000	0.00000
Xe135	106	0.04403	0	0.04403	0.0014	0.00196	0.00016
Xe137	0	0.0303	0	0.0303	0.0009	0.00000	0.00000
Xe138	0	0.199	0	0.199	0.0062	0.00000	0.00000
I131Org	32776	0.06734	32893	11.5799	11.515	0.23858	0.64369
I132Org	17466	0.4144	381.1	0.54779	0.1462	0.00601	0.00436
I133Org	2420	0.10878	5846	2.15488	2.0495	0.00328	0.00846
I134Org	0	0.481	131.35	0.52697	0.0609	0.00000	0.00000
I135Org	2.3	0.3069	1228.4	0.73684	0.4395	0.00000	0.00000
I131Elem	32776	0.06734	32893	11.5799	11.515	0.55723	1.50345
I132Elem	17466	0.4144	381.1	0.54779	0.1462	0.01405	0.01018
I133Elem	2420	0.10878	5846	2.15488	2.0495	0.00766	0.01976
I134Elem	0	0.481	131.35	0.52697	0.0609	0.00000	0.00000
I135Elem	2.3	0.3069	1228.4	0.73684	0.4395	0.00000	0.00000
					Total TEDE=	**0.92799**	**2.19841**

Reference 1 states that the control room dose limit is 5 rem TEDE and that the offsite dose limit for the FHA is 6.3 rem TEDE. The results from Tables 3 through 6 can be compared to these limits. Note that there is considerable margin for the control room doses and for the EAB and LPZ doses.

Conclusions

The FHA control room and offsite doses are well within their Reference 1 limits if the ground level release is limited. Even if 20% of the release is at ground level, the limits are not exceeded, with either 24 or 96 hours of decay prior to the start of the accident.

Appendix A - Check Calculation Using the STARDOSE Computer Code

This appendix provides a check calculation for the FHA analysis for VY using the STARDOSE computer code (Reference A-1). The analysis makes use of the same dose conversion factors (DCFs) as used in the dose calculation spreadsheets provided in the main body of the calculation.

The release is assumed to occur on the refueling floor, and the activity release to the environment is designed to be complete within two hours. For cases involving ground-level release, the assumption is made that a fractional release rate necessary to release 99% of the acitivity to the environment in two hours (i.e., 0.0384 per minute) occurs for six minutes at the start of the accident. Beyond that time (i.e., for the next 0.5 hours, for the next 0.5 hours after that, and finally for the last 0.9 hours), the elevated release X/Qs are used in decending order of magnitude for both the EAB dose and the CR dose. Fractional release rates are then varied to obtain a average absolute release rate of 0.5 per hour for the next hour (i.e., 0.0125 per minute for the first half of that one hour and then 0.02 per minute for the last half of that one hour) and finally to release the remaining 30% of the activity withing the last 0.9 hours (0.063 per minute). By so doing, 20% of the activity is released within the first six minutes (ground-level release), 25% within the next half-hour, another 25% within the half-hour after that, and then finally, 29% during the remaining 0.9 hours (leaving 1% not released). This is a conservative interpretation of the Reference A-2 requirement that the release be complete within two hours, and it is consistent with the X/Q averaging done in the main body of the calculation.

For cases not involving ground-level release, the intent is to release 25% within the first half-hour, 25% within the next half-hour, and 49% within the final one hour (leaving 1% not released). The corresponding fractional release rates are 0.0096 per minute, 0.01335 per minute, and 0.065 per minute, respectively.

The control room dose calculation is continued for a minimum of 22 hours after the end of the release. With a fresh air intake rate of 3700 cfm and a control room volume of 4.15E4 ft^3 (Reference A-3), the room turnover rate is 0.09 per minute which means nearly 120 volume changes in 22 hours. Continuing the dose calculation for 22 hours the end of the release ensures that the control room dose is fully accumulated.

STARDOSE Calculation

The model in STARDOSE consists of three control volumes. The first control volume is the gap (nominally 100 ft^3), the second is the reactor building (RB) refueling floor (also nominally 100 ft^3), and the third is the control room (4.15E4 ft^3 per Reference A-3). Note that the nominal 100 ft^3 volumes are used to conveniently calculate exchange rates.

The core power is assumed to be 1950 MWt as in the main body of the calculation. The gap activity of noble gas, iodine (set at 100% organic because the iodine form is not relevant without filters in the control room), and tellurium (as an iodine precursor) is added from the core to the gap over the first 0.01 hours of the analysis. It is added at 8.25 core inventories per hour so that the release is 8.25%. This 8.25% is to account for a "base" gap fraction of 5% (Reference A-2) and a peaking factor of 1.65 (Reference A-3). Note, however, that because the gap activities for Kr-85 and I-131 are respectively 10% and 8% per Reference A-2, the inventories of these two radionuclides in the attached STARDOSE LIBFILE1.TXT file were increased by a factor of 2 and 8/5, respectively, as compared to the activities given in Reference A-3.

Once the activity has been established in the gap, it is allowed to decay until 23.9833 or 95.9833 hours, as appropriate. It is then released to the RB at 0.571 cfm (0.571% per minute) for 0.0167 hours (one minute) so that the assumed 0.571% of the assemblies are represented as in the main body of the calculation. A filter efficiency of 0.995 is used to account for the water DF of 200 applied to the iodine. Since tellurium was also released to provide additional iodine during the decay period, a filter efficiency of 0.99999 is used to prevent its subsequent release to the RB (although a small amount would be present). No other particulates are assumed to be released in the STARDOSE model because (per Reference A-2), the scrubbing DF is assumed to be infinite for that activity.

All of this activity is in the RB by 24 hours or 96 hours, as appropriate. At 24/96 hours, the release to the environment is assumed to begin at the rates specifed above. Note that no credit for SGTS filtration is taken.

The X/Qs are from Reference A-3 but displaced by 24 or 96 hours, as appropriate. The breathing rate of 3.5E-4 m^3/sec is also taken from Reference A-3.

As for the control room, a fresh air intake rate of 3700 cfm (Reference A-3) and an occupancy factor of unity are used.

Four cases are run (as in the main body of the calculation): 0% and 20% ground-level release and 24- and 96-hour decay times.

The LIBFILE1.TXT file of Attachment A-1, common to all AST STARDOSE runs, contains the radionuclide input data. The core inventories listed in Column 5 are from Reference A-3 (with the Kr-85 and I-131 inventories increased by a factor of 2 and 8/5, as described above). The Dose Conversion Factors (Column 8 for whole body and Column 12 for CEDE) are the same as in the main body of the calculation. Decay constants (per second) come from Reference A-4.

Input files are provided as Attachments A-2 through A-5.

Output file excerpts are provided in the Results section below. The core inventory in the gap at the start of the gap release is shown in the following table for comparison to the values in the main body of the calculation. Note that the agreement is good except for Kr83m and, to a lesser extent, for Xe131m and Xe133m. This is because the daughter ingrowth formulation in STARDOSE is less sophisticated than for the RADDECAY code used in the main body of the calculation. However, the important daughter ingrowth contributions are properly represented in STARDOSE, and the three dose contributors just mentioned have very little impact on the overall dose calculation.

Table A-1
Gap Inventory Comparison
(Ci/MWt at Stated Time, No Peaking, Multipliers for Kr85 and I131 Included)

Nuclide	24 Hours*	24 Hours**	96 Hours*	96 Hours**
Kr83m	15.6	1	negligible	0
Kr85m	239	219	negligible	0
Kr85	1010	1007	1009	1007
Kr87	0.038	0.04	negligible	0
Kr88	72.3	72	negligible	0
Kr89	negligible	0	negligible	0
I131	42105	42207	32776	32883
Xe131m	327	300	338	252
I132	33065	32945	17466	17218
I133	26656	26107	2420	2393
Xe133m	1594	1299	766	527
Xe133	55528	55571	40184	40466
I134	negligible	0	negligible	0
I135	4351	4563	2.3	3
Xe135m	negligible	0	negligible	0
Xe135	15285	15540	106	116
Xe137	negligible	0	negligible	0
Xe138	negligible	0	negligible	0

*Main body of calculation
**STARDOSE

Results

Excerpt from STARDOSE output corresponding to Attachment 2 INPUT.DAT (0% ground-level release, 24-hour decay):

```
Control_Room

             thyroid     wbody       skin        CEDE
Total dose:  4.90E+000   1.92E-003   8.89E-002   1.51E-001
Noble gas    0.00E+000   1.75E-003   8.69E-002   0.00E+000
Org iodine   4.90E+000   1.63E-004   1.98E-003   1.51E-001

environment

            thyroid     wbody       skin        CEDE
EAB dose:   1.05E+001   1.31E-001   1.89E-001   3.24E-001

             thyrd_eab   wbody_eab   skin_eab    CEDE_eab
Noble gas    0.00E+000   1.20E-001   1.85E-001   0.00E+000
Org iodine   1.05E+001   1.08E-002   4.09E-003   3.24E-001
```

Excerpt from STARDOSE output corresponding to Attachment 3 INPUT.DAT (20% ground-level release, 24-hour decay):

Control_Room

	thyroid	wbody	skin	CEDE
Total dose:	1.03E+002	4.08E-002	1.89E+000	3.18E+000
Noble gas	0.00E+000	3.73E-002	1.84E+000	0.00E+000
Org iodine	1.03E+002	3.57E-003	4.27E-002	3.18E+000

environment

	thyroid	wbody	skin	CEDE
EAB dose:	3.70E+001	4.73E-001	6.77E-001	1.14E+000

	thyrd_eab	wbody_eab	skin_eab	CEDE_eab
Noble gas	0.00E+000	4.31E-001	6.61E-001	0.00E+000
Org iodine	3.70E+001	4.15E-002	1.54E-002	1.14E+000

Excerpt from STARDOSE output corresponding to Attachment 4 INPUT.DAT (0% ground-level release, 96-hour decay):

Control_Room

	thyroid	wbody	skin	CEDE
Total dose:	3.50E+000	4.91E-004	2.75E-002	1.07E-001
Noble gas	0.00E+000	4.16E-004	2.67E-002	0.00E+000
Org iodine	3.50E+000	7.52E-005	7.94E-004	1.07E-001

environment

	thyroid	wbody	skin	CEDE
EAB dose:	7.52E+000	3.38E-002	5.91E-002	2.30E-001

	thyrd_eab	wbody_eab	skin_eab	CEDE_eab
Noble gas	0.00E+000	2.88E-002	5.75E-002	0.00E+000
Org iodine	7.52E+000	4.94E-003	1.63E-003	2.30E-001

Excerpt from STARDOSE output corresponding to Attachment 5 INPUT.DAT (20% ground-level release, 96-hour decay):

Control_Room

	thyroid	wbody	skin	CEDE
Total dose:	7.36E+001	1.04E-002	5.80E-001	2.25E+000
Noble gas	0.00E+000	8.75E-003	5.63E-001	0.00E+000
Org iodine	7.36E+001	1.64E-003	1.73E-002	2.25E+000

environment

	thyroid	wbody	skin	CEDE
EAB dose:	2.64E+001	1.20E-001	2.08E-001	8.05E-001

	thyrd_eab	wbody_eab	skin_eab	CEDE_eab
Noble gas	0.00E+000	1.01E-001	2.02E-001	0.00E+000
Org iodine	2.64E+001	1.92E-002	6.22E-003	8.05E-001

Table A-2 summarizes offsite and control room dose results for all four cases:

Table A-2 – Doses for the FHA Analysis (in rem)

Case	24 hour or 96 hour decay?	0% or 20% ground-level release	EAB TEDE (Main Body)	EAB TEDE (STARDOSE)	CR TEDE (Main Body)	CR TEDE (STARDOSE)
A	24	0	0.472	0.455	0.153	0.153
B	24	20	1.598	1.613	3.14	3.22
C	96	0	0.274	0.264	0.108	0.108
D	96	20	0.928	0.925	2.20	2.26

Conclusions

The dose agreement for all cases is excellent. The STARDOSE runs confirm the results from the main body of the calculation.

Reference A-2 states that the control room dose limit is 5 rem TEDE and that the offsite dose limit for the FHA is 6.3 rem TEDE. The results from Table A-2 can be compared to these limits.

For the limiting case of only 24 hour's decay and 20% ground-level release, the FHA control room dose represents about 63% of the 5-rem limit. The EAB dose has almost a factor four margin.

References

A-1. "STARDOSE Model Report", Polestar Applied Technology, Inc., PSATCI09.03, January 1997

A-2. "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors", US NRC Regulatory Guide 1.183, Revision 0, July 2000

A-3. PSAT 3019CF.QA.03, "Design Data Base for Application of the Revised DBA Source Term to Vermont Yankee", Revision 0

A-4. NUREG/CR-5106 (Manual for TACT5 – Version SAIC 9/23/87), File MLWRICRP.30

```
n_isotopes  20    n_isotope_groups  11

Kr83m N_Gas NONE  NONE  4.24E+03    1.04E-04    0     1.49E-05    0     0     0     0     0     0     0
      0     0     0
Kr85m N_Gas NONE  NONE  9.71E+03    4.39E-05    0     0.0277      0     0     0.05  0     0.22  0     0
      0     0     0
Kr85  N_Gas NONE  NONE  1.01E+03    2.04E-09    0     4.40E-04    0     0     0.05  0     0.22  0     0
      0     0     0
Kr87  N_Gas NONE  NONE  1.94E+04    1.52E-04    0     0.1524      0     0     0.34  0     1.48  0     0
      0     0     0
Kr88  N_Gas NONE  NONE  2.75E+04    6.88E-05    0     0.3774      0     0     0.08  0     0.35  0     0
      0     0     0
Kr89  N_Gas NONE  NONE  3.46E+04    3.63E-03    0     0.323 0     0     0.35  0     1.52  0     0     0
      0     0
Xe131m      N_Gas NONE  NONE  3.18E+02    6.68E-07    0     0.00149     0     0     0.02  0     0.04  0
      0     0     0     0
Xe133m      N_Gas NONE  NONE  1.76E+03    3.49E-06    0     0.00507     0     0     0.03  0     0.13  0
      0     0     0     0
Xe133 N_Gas I133Org     NONE  5.78E+04    1.52E-06    0     0.00577     0     0     0.01  0     0.04  0
      0     0     0     0
Xe135m      N_Gas NONE  NONE  1.14E+04    7.40E-04    0     0.07548     0     0     0.02  0     0.09  0
      0     0     0     0
Xe135 N_Gas I135Org     NONE  2.33E+04    2.09E-05    0     0.04403     0     0     0.06  0     0.26  0
      0     0     0     0
Xe137 N_Gas NONE  NONE  5.07E+04    2.96E-03    0     0.0303      0     0     0.46  0     2     0     0
      0     0     0
Xe138 N_Gas NONE  NONE  5.05E+04    6.80E-04    0     0.199 0     0     0.15  0     0.65  0     0     0
      0     0
I131Org     Org_I Te131m      NONE  4.57E+04    9.96E-07    1080400     0.06734     0     0     0.03  32893
      0.13  0     0     0     0     0
I132Org     Org_I Te132 NONE  4.05E+04    8.27E-05    6438  0.4144      0     0     0.11  381.1 0.48  0
      0     0     0     0
I133Org     Org_I NONE  Xe133 5.79E+04    9.22E-06    179820      0.10878     0     0     0.09  5846  0.39
      0     0     0     0     0
I134Org     Org_I NONE  NONE  6.43E+04    2.23E-04    1065.6      0.481 0     0     0.14  131.35      0.61
      0     0     0     0     0
I135Org     Org_I NONE  Xe135 5.39E+04    2.86E-05    31302 0.3069      0     0     0.08  1228.4      0.35
      0     0     0     0     0
Te131m      TeGrp NONE  I131Org     4.31E+03    6.42E-06    0     0     0     0     0     0     0     0
      0     0     0     0
Te132 TeGrp NONE  I132Org     3.97E+04    2.51E-06    0     0     0     0     0     0     0     0     0
      0     0     0
```

```
edit_time
0.0 0.01 23.9833 24.0 48.0
end_edit_time

participating_isotopes
Kr83m    Kr85m    Kr85     Kr87     Kr88     Kr89
Xe131m   Xe133m   Xe133    Xe135m   Xe135    Xe137    Xe138
I131Org      I132Org      I133Org      I134Org      I135Org
Te131m       Te132
end_participating_isotopes

core
thermal_power                  1950
elemental_iodine_frac                0.0
organic_iodine_frac                  1.0
particulate_iodine_frac        0.0
release_frac
to_control_volume GAP
Time  N_Gas  I_Grp  CsGrp  TeGrp  BaGrp  NMtls  CeGrp  LaGrp  SrGrp
0.01  8.25   8.25   0      8.25   0      0      0      0      0
48    0      0      0      0      0      0      0      0      0
end_to_control_volume
end_release_frac
end_core

control_volume
obj_type                       OBJ_CV
name                           GAP
air_volume                     100
water_volume                         0
surface_area                         0
has_recirc_filter              false
end_control_volume

control_volume
obj_type                       OBJ_CV
name                           RB
air_volume                     100
water_volume                         0
surface_area                         0
has_recirc_filter              false
end_control_volume

control_volume
obj_type                       OBJ_CR
name                           Control_Room
air_volume                     4.15e+004
water_volume                   0
surface_area                   0
has_recirc_filter              false
breathing_rate
Time (hr)        Value (cms)
48              0.00035
end_breathing_rate
occupancy_factor
Time (hr)        Value (frac)
48               1
end_occupancy_factor
end_control_volume

junction
```

```
junction_type                       AIR_JUNCTION
downstream_location                 AIR_SPACE
upstream                      CORE
downstream                    GAP
has_filter                    false
flow_rate
Time  (hr)  Value (cfm)
48          1
end_flow_rate
end_junction

junction
junction_type                       AIR_JUNCTION
downstream_location                 AIR_SPACE
upstream                      GAP
downstream                    RB
has_filter                    true
flow_rate
Time  (hr)  Value (cfm)
23.9833           0
24          0.571
48          0
end_flow_rate
filter_efficiency
Time  NobleGas    ElemIodine  OrgIodine   PartIodine  Solubles    Insolubles
48    0           0           0.995       0           0           0.99999
end_filter_efficiency
frac_4_daughter_resusp
Time  NobleGas    ElemIodine  OrgIodine   PartIodine  Solubles    Insolubles
48     0                0           0           0           0           0
end_frac_4_daughter_resusp
reevolution_rate
Time  NobleGas    ElemIodine  OrgIodine   PartIodine  Solubles    Insolubles
48    0           0           0           0           0           0
end_reevolution_rate
end_junction

junction
junction_type                       AIR_JUNCTION
downstream_location                 AIR_SPACE
upstream                      RB
downstream                    environment
has_filter                    false
flow_rate
Time  (hr)  Value (cfm)
24          0
24.5        0.96
25          1.335
26          6.5
48          0
end_flow_rate
X_over_Q_4_site_boundary
Time  (hr)  Value (s/m*3)
24    0
24.5  2.03e-4
25    1.54e-4
26    9.17e-5
48    0.0
end_X_over_Q_4_site_boundary
X_over_Q_4_low_population_zone
Time  (hr)  Value (s/m*3)
```

```
48        0.0
end_X_over_Q_4_low_population_zone
X_over_Q_4_ctrl_room
Time  (hr)  Value (s/m*3)
24     0.0
24.5   2.39e-4
25     1.05e-6
26     8.70e-7
48        0.0
end_X_over_Q_4_ctrl_room
end_junction

junction
junction_type                          AIR_JUNCTION
downstream_location                    AIR_SPACE
upstream                               environment
downstream                             Control_Room
has_filter                             false
flow_rate
Time (hr)        Value (cfm)
48                 3700
end_flow_rate
end_junction

junction
junction_type                          AIR_JUNCTION
downstream_location                    AIR_SPACE
upstream                               Control_Room
downstream                             environment
has_filter                             false
flow_rate
Time (hr)        Value (cfm)
48                 3700
end_flow_rate
X_over_Q_4_ctrl_room
Time (hr)        Value (s/m*3)
48               0
end_X_over_Q_4_ctrl_room
X_over_Q_4_site_boundary
Time (hr)        Value (s/m*3)
48               0
end_X_over_Q_4_site_boundary
X_over_Q_4_low_population_zone
Time (hr)        Value (s/m*3)
48               0
end_X_over_Q_4_low_population_zone
end_junction

environment
breathing_rate_sb
Time (hr)        Value (cms)
24            0.0
26            0.00035
48               0.0
end_breathing_rate_sb
breathing_rate_lpz
Time (hr)        Value (cms)
48               0.0
end_breathing_rate_lpz
end_environment
```

```
edit_time
0.0 0.01 23.9833 24.0 48.0
end_edit_time

participating_isotopes
Kr83m   Kr85m   Kr85    Kr87    Kr88    Kr89
Xe131m  Xe133m  Xe133   Xe135m  Xe135   Xe137   Xe138
I131Org     I132Org     I133Org     I134Org     I135Org
Te131m      Te132
end_participating_isotopes

core
thermal_power                   1950
elemental_iodine_frac                  0.0
organic_iodine_frac                    1.0
particulate_iodine_frac         0.0
release_frac
to_control_volume GAP
Time  N_Gas I_Grp CsGrp TeGrp BaGrp NMtls CeGrp LaGrp SrGrp
0.01  8.25  8.25  0     8.25  0     0     0     0     0
48    0     0     0     0     0     0     0     0     0
end_to_control_volume
end_release_frac
end_core

control_volume
obj_type                        OBJ_CV
name                            GAP
air_volume                      100
water_volume                           0
surface_area                           0
has_recirc_filter               false
end_control_volume

control_volume
obj_type                        OBJ_CV
name                            RB
air_volume                      100
water_volume                           0
surface_area                           0
has_recirc_filter               false
end_control_volume

control_volume
obj_type                        OBJ_CR
name                            Control_Room
air_volume                      4.15e+004
water_volume                    0
surface_area                    0
has_recirc_filter               false
breathing_rate
Time (hr)        Value (cms)
48              0.00035
end_breathing_rate
occupancy_factor
Time (hr)        Value (frac)
48               1
end_occupancy_factor
end_control_volume

junction
```

```
junction_type                                   AIR_JUNCTION
downstream_location                             AIR_SPACE
upstream                                  CORE
downstream                                GAP
has_filter                                false
flow_rate
Time   (hr)   Value  (cfm)
48            1
end_flow_rate
end_junction

junction
junction_type                                   AIR_JUNCTION
downstream_location                             AIR_SPACE
upstream                                  GAP
downstream                                RB
has_filter                                true
flow_rate
Time   (hr)   Value  (cfm)
23.9833             0
24            0.571
48            0
end_flow_rate
filter_efficiency
Time  NobleGas    ElemIodine  OrgIodine    PartIodine   Solubles    Insolubles
48    0           0           0.995        0            0           0.99999
end_filter_efficiency
frac_4_daughter_resusp
Time  NobleGas    ElemIodine  OrgIodine    PartIodine   Solubles    Insolubles
48    0           0           0            0            0           0
end_frac_4_daughter_resusp
reevolution_rate
Time  NobleGas    ElemIodine  OrgIodine    PartIodine   Solubles    Insolubles
48    0           0           0            0            0           0
end_reevolution_rate
end_junction

junction
junction_type                                   AIR_JUNCTION
downstream_location                             AIR_SPACE
upstream                                  RB
downstream                                environment
has_filter                                false
flow_rate
Time   (hr)   Value  (cfm)
24            0
24.1          3.84
24.6          1.25
25.1          2
26            6.5
120           0
end_flow_rate
X_over_Q_4_site_boundary
Time   (hr)   Value  (s/m*3)
24     0
24.1   1.7e-3
24.6   2.03e-4
25.1   1.54e-4
26     9.17e-5
48     0.0
end_X_over_Q_4_site_boundary
```

```
X_over_Q_4_low_population_zone
Time  (hr)  Value (s/m*3)
48    0.0
end_X_over_Q_4_low_population_zone
X_over_Q_4_ctrl_room
Time  (hr)  Value (s/m*3)
24    0.0
24.1  5.89e-3
24.6  2.39e-4
25.1  1.05e-6
26    8.70e-7
48    0.0
end_X_over_Q_4_ctrl_room
end_junction

junction
junction_type                           AIR_JUNCTION
downstream_location                     AIR_SPACE
upstream                                environment
downstream                              Control_Room
has_filter                              false
flow_rate
Time (hr)        Value (cfm)
48                 3700
end_flow_rate
end_junction

junction
junction_type                           AIR_JUNCTION
downstream_location                     AIR_SPACE
upstream                                Control_Room
downstream                              environment
has_filter                              false
flow_rate
Time (hr)        Value (cfm)
48                 3700
end_flow_rate
X_over_Q_4_ctrl_room
Time (hr)         Value (s/m*3)
48              0
end_X_over_Q_4_ctrl_room
X_over_Q_4_site_boundary
Time (hr)         Value (s/m*3)
48              0
end_X_over_Q_4_site_boundary
X_over_Q_4_low_population_zone
Time (hr)         Value (s/m*3)
48              0
end_X_over_Q_4_low_population_zone
end_junction

environment
breathing_rate_sb
Time (hr)         Value (cms)
24           0.0
26           0.00035
48              0.0
end_breathing_rate_sb
breathing_rate_lpz
Time (hr)         Value (cms)
48              0.0
```

```
end_breathing_rate_lpz
end_environment
```

```
edit_time
0.0 0.01 95.9833 96.0 120.0
end_edit_time

participating_isotopes
Kr83m    Kr85m    Kr85     Kr87     Kr88     Kr89
Xe131m   Xe133m   Xe133    Xe135m   Xe135    Xe137    Xe138
I131Org       I132Org       I133Org       I134Org       I135Org
Te131m        Te132
end_participating_isotopes

core
thermal_power                     1950
elemental_iodine_frac                   0.0
organic_iodine_frac                     1.0
particulate_iodine_frac           0.0
release_frac
to_control_volume GAP
Time  N_Gas I_Grp CsGrp TeGrp BaGrp NMtls CeGrp LaGrp SrGrp
0.01  8.25  8.25  0     8.25  0     0     0     0     0
120   0     0     0     0     0     0     0     0     0
end_to_control_volume
end_release_frac
end_core

control_volume
obj_type                          OBJ_CV
name                              GAP
air_volume                        100
water_volume                            0
surface_area                            0
has_recirc_filter                 false
end_control_volume

control_volume
obj_type                          OBJ_CV
name                              RB
air_volume                        100
water_volume                            0
surface_area                            0
has_recirc_filter                 false
end_control_volume

control_volume
obj_type                          OBJ_CR
name                              Control_Room
air_volume                        4.15e+004
water_volume                      0
surface_area                      0
has_recirc_filter                 false
breathing_rate
Time (hr)        Value (cms)
120              0.00035
end_breathing_rate
occupancy_factor
Time (hr)        Value (frac)
120               1
end_occupancy_factor
end_control_volume

junction
```

```
junction_type                        AIR_JUNCTION
downstream_location                  AIR_SPACE
upstream                       CORE
downstream                     GAP
has_filter                     false
flow_rate
Time  (hr)  Value (cfm)
120         1
end_flow_rate
end_junction

junction
junction_type                        AIR_JUNCTION
downstream_location                  AIR_SPACE
upstream                       GAP
downstream                     RB
has_filter                     true
flow_rate
Time  (hr)  Value (cfm)
95.9833           0
96          0.571
120         0
end_flow_rate
filter_efficiency
Time  NobleGas   ElemIodine  OrgIodine   PartIodine  Solubles    Insolubles
120   0          0           0.995       0           0           0.99999
end_filter_efficiency
frac_4_daughter_resusp
Time  NobleGas   ElemIodine  OrgIodine   PartIodine  Solubles    Insolubles
120     0        0           0           0           0           0
end_frac_4_daughter_resusp
reevolution_rate
Time  NobleGas   ElemIodine  OrgIodine   PartIodine  Solubles    Insolubles
120   0          0           0           0           0           0
end_reevolution_rate
end_junction

junction
junction_type                        AIR_JUNCTION
downstream_location                  AIR_SPACE
upstream                       RB
downstream                     environment
has_filter                     false
flow_rate
Time  (hr)  Value (cfm)
96          0
96.5        0.96
97          1.335
98          6.5
120         0
end_flow_rate
X_over_Q_4_site_boundary
Time  (hr)  Value (s/m*3)
96    0
96.5  2.03e-4
97    1.54e-4
98    9.17e-5
120   0.0
end_X_over_Q_4_site_boundary
X_over_Q_4_low_population_zone
Time  (hr)  Value (s/m*3)
```

```
120     0.0
end_X_over_Q_4_low_population_zone
X_over_Q_4_ctrl_room
Time   (hr)  Value (s/m*3)
96     0.0
96.5   2.39e-4
97     1.05e-6
98     8.70e-7
120     0.0
end_X_over_Q_4_ctrl_room
end_junction

junction
junction_type                              AIR_JUNCTION
downstream_location                        AIR_SPACE
upstream                                   environment
downstream                                 Control_Room
has_filter                                 false
flow_rate
Time (hr)        Value (cfm)
120                3700
end_flow_rate
end_junction

junction
junction_type                              AIR_JUNCTION
downstream_location                        AIR_SPACE
upstream                                   Control_Room
downstream                                 environment
has_filter                                 false
flow_rate
Time (hr)        Value (cfm)
120                3700
end_flow_rate
X_over_Q_4_ctrl_room
Time (hr)        Value (s/m*3)
120              0
end_X_over_Q_4_ctrl_room
X_over_Q_4_site_boundary
Time (hr)        Value (s/m*3)
120              0
end_X_over_Q_4_site_boundary
X_over_Q_4_low_population_zone
Time (hr)        Value (s/m*3)
120              0
end_X_over_Q_4_low_population_zone
end_junction

environment
breathing_rate_sb
Time (hr)        Value (cms)
96           0.0
98           0.00035
120              0.0
end_breathing_rate_sb
breathing_rate_lpz
Time (hr)        Value (cms)
120              0.0
end_breathing_rate_lpz
end_environment
```

```
junction_type                        AIR_JUNCTION
downstream_location                  AIR_SPACE
upstream                       CORE
downstream                     GAP
has_filter                     false
flow_rate
Time  (hr)  Value (cfm)
120         1
end_flow_rate
end_junction

junction
junction_type                        AIR_JUNCTION
downstream_location                  AIR_SPACE
upstream                       GAP
downstream                     RB
has_filter                     true
flow_rate
Time  (hr)  Value (cfm)
95.9833           0
96          0.571
120         0
end_flow_rate
filter_efficiency
Time  NobleGas   ElemIodine  OrgIodine   PartIodine  Solubles    Insolubles
120   0          0           0.995       0           0           0.99999
end_filter_efficiency
frac_4_daughter_resusp
Time  NobleGas   ElemIodine  OrgIodine   PartIodine  Solubles    Insolubles
120    0         0           0           0           0           0
end_frac_4_daughter_resusp
reevolution_rate
Time  NobleGas   ElemIodine  OrgIodine   PartIodine  Solubles    Insolubles
120   0          0           0           0           0           0
end_reevolution_rate
end_junction

junction
junction_type                        AIR_JUNCTION
downstream_location                  AIR_SPACE
upstream                       RB
downstream                     environment
has_filter                     false
flow_rate
Time  (hr)  Value (cfm)
96          0
96.1        3.84
96.6        1.25
97.1        2
98          6.5
120         0
end_flow_rate
X_over_Q_4_site_boundary
Time  (hr)  Value (s/m*3)
96    0
96.1  1.7e-3
96.6  2.03e-4
97.1  1.54e-4
98    9.17e-5
120   0.0
end_X_over_Q_4_site_boundary
```

```
edit_time
0.0 0.01 95.9833 96.0 120.0
end_edit_time

participating_isotopes
Kr83m    Kr85m    Kr85     Kr87     Kr88     Kr89
Xe131m   Xe133m   Xe133    Xe135m   Xe135    Xe137    Xe138
I131Org      I132Org      I133Org      I134Org      I135Org
Te131m       Te132
end_participating_isotopes

core
thermal_power                  1950
elemental_iodine_frac                0.0
organic_iodine_frac                  1.0
particulate_iodine_frac        0.0
release_frac
to_control_volume GAP
Time  N_Gas  I_Grp  CsGrp  TeGrp  BaGrp  NMtls  CeGrp  LaGrp  SrGrp
0.01  8.25   8.25   0      8.25   0      0      0      0      0
120   0      0      0      0      0      0      0      0      0
end_to_control_volume
end_release_frac
end_core

control_volume
obj_type                       OBJ_CV
name                           GAP
air_volume                     100
water_volume                         0
surface_area                         0
has_recirc_filter              false
end_control_volume

control_volume
obj_type                       OBJ_CV
name                           RB
air_volume                     100
water_volume                         0
surface_area                         0
has_recirc_filter              false
end_control_volume

control_volume
obj_type                       OBJ_CR
name                           Control_Room
air_volume                     4.15e+004
water_volume                   0
surface_area                   0
has_recirc_filter              false
breathing_rate
Time (hr)       Value (cms)
120             0.00035
end_breathing_rate
occupancy_factor
Time (hr)       Value (frac)
120              1
end_occupancy_factor
end_control_volume

junction
```

```
junction_type                           AIR_JUNCTION
downstream_location                     AIR_SPACE
upstream                          CORE
downstream                        GAP
has_filter                        false
flow_rate
Time   (hr)  Value (cfm)
120          1
end_flow_rate
end_junction

junction
junction_type                           AIR_JUNCTION
downstream_location                     AIR_SPACE
upstream                          GAP
downstream                        RB
has_filter                        true
flow_rate
Time   (hr)  Value (cfm)
95.9833            0
96           0.571
120          0
end_flow_rate
filter_efficiency
Time  NobleGas    ElemIodine  OrgIodine   PartIodine  Solubles    Insolubles
120   0           0           0.995       0           0           0.99999
end_filter_efficiency
frac_4_daughter_resusp
Time  NobleGas    ElemIodine  OrgIodine   PartIodine  Solubles    Insolubles
120     0         0           0           0           0           0
end_frac_4_daughter_resusp
reevolution_rate
Time  NobleGas    ElemIodine  OrgIodine   PartIodine  Solubles    Insolubles
120   0           0           0           0           0           0
end_reevolution_rate
end_junction

junction
junction_type                           AIR_JUNCTION
downstream_location                     AIR_SPACE
upstream                          RB
downstream                        environment
has_filter                        false
flow_rate
Time   (hr)  Value (cfm)
96           0
96.5         0.96
97           1.335
98           6.5
120          0
end_flow_rate
X_over_Q_4_site_boundary
Time   (hr)  Value (s/m*3)
96     0
96.5   2.03e-4
97     1.54e-4
98     9.17e-5
120    0.0
end_X_over_Q_4_site_boundary
X_over_Q_4_low_population_zone
Time   (hr)  Value (s/m*3)
```

```
120     0.0
end_X_over_Q_4_low_population_zone
X_over_Q_4_ctrl_room
Time  (hr)  Value (s/m*3)
96    0.0
96.5  2.39e-4
97    1.05e-6
98    8.70e-7
120     0.0
end_X_over_Q_4_ctrl_room
end_junction

junction
junction_type                              AIR_JUNCTION
downstream_location                        AIR_SPACE
upstream                                   environment
downstream                                 Control_Room
has_filter                                 false
flow_rate
Time (hr)        Value (cfm)
120                3700
end_flow_rate
end_junction

junction
junction_type                              AIR_JUNCTION
downstream_location                        AIR_SPACE
upstream                                   Control_Room
downstream                                 environment
has_filter                                 false
flow_rate
Time (hr)        Value (cfm)
120                3700
end_flow_rate
X_over_Q_4_ctrl_room
Time (hr)        Value (s/m*3)
120              0
end_X_over_Q_4_ctrl_room
X_over_Q_4_site_boundary
Time (hr)        Value (s/m*3)
120              0
end_X_over_Q_4_site_boundary
X_over_Q_4_low_population_zone
Time (hr)        Value (s/m*3)
120              0
end_X_over_Q_4_low_population_zone
end_junction

environment
breathing_rate_sb
Time (hr)        Value (cms)
96          0.0
98          0.00035
120              0.0
end_breathing_rate_sb
breathing_rate_lpz
Time (hr)        Value (cms)
120              0.0
end_breathing_rate_lpz
end_environment
```

```
junction_type                          AIR_JUNCTION
downstream_location                    AIR_SPACE
upstream                         CORE
downstream                       GAP
has_filter                       false
flow_rate
Time   (hr)  Value (cfm)
120          1
end_flow_rate
end_junction

junction
junction_type                          AIR_JUNCTION
downstream_location                    AIR_SPACE
upstream                         GAP
downstream                       RB
has_filter                       true
flow_rate
Time   (hr)  Value (cfm)
95.9833            0
96           0.571
120          0
end_flow_rate
filter_efficiency
Time  NobleGas    ElemIodine   OrgIodine    PartIodine   Solubles     Insolubles
120   0           0            0.995        0            0            0.99999
end_filter_efficiency
frac_4_daughter_resusp
Time  NobleGas    ElemIodine   OrgIodine    PartIodine   Solubles     Insolubles
120     0         0            0            0            0            0
end_frac_4_daughter_resusp
reevolution_rate
Time  NobleGas    ElemIodine   OrgIodine    PartIodine   Solubles     Insolubles
120   0           0            0            0            0            0
end_reevolution_rate
end_junction

junction
junction_type                          AIR_JUNCTION
downstream_location                    AIR_SPACE
upstream                         RB
downstream                       environment
has_filter                       false
flow_rate
Time   (hr)  Value (cfm)
96           0
96.1         3.84
96.6         1.25
97.1         2
98           6.5
120          0
end_flow_rate
X_over_Q_4_site_boundary
Time   (hr)  Value (s/m*3)
96     0
96.1   1.7e-3
96.6   2.03e-4
97.1   1.54e-4
98     9.17e-5
120    0.0
end_X_over_Q_4_site_boundary
```

```
X_over_Q_4_low_population_zone
Time  (hr)  Value (s/m*3)
120     0.0
end_X_over_Q_4_low_population_zone
X_over_Q_4_ctrl_room
Time  (hr)  Value (s/m*3)
96    0.0
96.1  5.89e-3
96.6  2.39e-4
97.1  1.05e-6
98    8.70e-7
120     0.0
end_X_over_Q_4_ctrl_room
end_junction

junction
junction_type                       AIR_JUNCTION
downstream_location                 AIR_SPACE
upstream                            environment
downstream                          Control_Room
has_filter                          false
flow_rate
Time (hr)       Value (cfm)
120               3700
end_flow_rate
end_junction

junction
junction_type                       AIR_JUNCTION
downstream_location                 AIR_SPACE
upstream                            Control_Room
downstream                          environment
has_filter                          false
flow_rate
Time (hr)       Value (cfm)
120               3700
end_flow_rate
X_over_Q_4_ctrl_room
Time (hr)       Value (s/m*3)
120             0
end_X_over_Q_4_ctrl_room
X_over_Q_4_site_boundary
Time (hr)       Value (s/m*3)
120             0
end_X_over_Q_4_site_boundary
X_over_Q_4_low_population_zone
Time (hr)       Value (s/m*3)
120             0
end_X_over_Q_4_low_population_zone
end_junction

environment
breathing_rate_sb
Time (hr)       Value (cms)
96          0.0
98          0.00035
120             0.0
end_breathing_rate_sb
breathing_rate_lpz
Time (hr)       Value (cms)
120             0.0
```

```
edit_time
0.0 0.01 95.9833 96.0 120.0
end_edit_time

participating_isotopes
Kr83m   Kr85m   Kr85    Kr87    Kr88    Kr89
Xe131m  Xe133m  Xe133   Xe135m  Xe135   Xe137   Xe138
I131Org     I132Org     I133Org     I134Org     I135Org
Te131m      Te132
end_participating_isotopes

core
thermal_power                   1950
elemental_iodine_frac                 0.0
organic_iodine_frac                   1.0
particulate_iodine_frac         0.0
release_frac
to_control_volume GAP
Time   N_Gas  I_Grp  CsGrp  TeGrp  BaGrp  NMtls  CeGrp  LaGrp  SrGrp
0.01   8.25   8.25   0      8.25   0      0      0      0      0
120    0      0      0      0      0      0      0      0      0
end_to_control_volume
end_release_frac
end_core

control_volume
obj_type                        OBJ_CV
name                            GAP
air_volume                      100
water_volume                          0
surface_area                          0
has_recirc_filter               false
end_control_volume

control_volume
obj_type                        OBJ_CV
name                            RB
air_volume                      100
water_volume                          0
surface_area                          0
has_recirc_filter               false
end_control_volume

control_volume
obj_type                        OBJ_CR
name                            Control_Room
air_volume                      4.15e+004
water_volume                    0
surface_area                    0
has_recirc_filter               false
breathing_rate
Time (hr)        Value (cms)
120              0.00035
end_breathing_rate
occupancy_factor
Time (hr)        Value (frac)
120               1
end_occupancy_factor
end_control_volume

junction
```

```
end_breathing_rate_lpz
end_environment
```

Appendix B - Minimum Decay Time Giving Acceptable Control Room Dose Results without Credit for Containment

From the main body of the calculation, one may note that for 24 hours of decay, about 88% of the control room dose is from I131 (Tables 3 and 4). With 96 hours of decay, it is 98% (Tables 5 and 6). At even later decay times (decay times that will give acceptable control room doses without any credit for containment), one may assume that the control room dose will be due entirely to I131.

At 96 hours, the CR dose is 2.2 rem with 20% ground-level release (Table 6). Nearly all of this 2.2 rem (except for less than 0.1 rem) is due to that 20% ground-level contribution. Therefore, the dose for 100% ground-level release would be about 11 rem (very slightly conservative) at 96 hours. To have the control room dose be less than the 5 rem control room dose limit at some later time, the I131 release would have to decrease to 5/11 (i.e., to 45%) of its inventory at 4 days. With a decay constant of about 1E-6 per second, this would require about 8E5 seconds or just over 9 days. Therefore, with a measure of conservatism, it can be confidently asserted that no containment would be needed after 14 days from the time of shutdown to have the control room dose be less than the 5 rem TEDE limit for the FHA.

QAP 6.1
Revision 0
4/28/95
Attachment 4

Form QA-007
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