Nine Mile Point Unit 2
Alternative Source Term

Calculation H21C-101

"U2 MSLB, AST Methodology"

Engineering Services	**CALCULATION COVER SHEET**	Page 1 (Next 2) Total 24 Last Attachment 2

Project: NINE MILE POINT NUCLEAR STATION Unit (1,2 or 0=Both): 2 Discipline: CR

Title	Calculation No. H21C-101			
U2 MSLB, AST Methodology	(Sub)system(s) N/A	Building N/A	Floor Elev. N/A	Index No. N/A
Originator(s) M. Berg				
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Purpose

This calculation analyzes the Main Steam Line Break (MSLB) Accident for Nine Mile Point for both offsite and Control Room doses.

Summary of Results

Table 1 – MSLB Summary of Dose Results

	4 µCi/gm I131 DE TEDE (rem)
U1 MSLB/U2 Control Room	2.32E-01
U2 MSLB/U1 Control Room	3.81E-01
U2 MSLB/U2 Control Room	2.96E+00
U2 MSLB EAB	3.92E-01
U2 MSLB LPZ	5.34E-02

The offsite cases meet all of the applicable TEDE limits (2.5 rem EAB/LPZ at the normal coolant activity of 0.2 µCi/gm DE I131 per the Proposed Technical Specification [Ref. 4, Item 1.9] and 25 rem EAB/LPZ at the pre-incident spike coolant activity of 4.0 µCi/gm, or iodine spiking factor of 20*0.2 µCi/gm [Ref 4., Item 1.10]). The Control Room meets the TEDE limit of 5 rem for either coolant activity or for the normal proposed Tech Spec coolant activity.

This dose analysis fully complies with NRC Regulatory Guide 1.183 [Ref 1].

Methodology

The MSLB accident is initiated from hot stand-by conditions in order to conservatively maximize the mass of coolant released from the break and thus maximizing the activity released. Following accident initiation, the radionuclide inventory from the released coolant is assumed to reach the environment instantaneously.

The TEDE values obtained for these analyses are compared with the 2.5/25 rem for offsite doses and the 5 rem TEDE limit for the Control Room [Ref 1]. The 2.5 rem offsite value is for the 0.2 uCi/g I-131 limit and the 25 rem value corresponds to the 4 uCi/g I-131 limit caused by an iodine spiking factor of 20.

For the control room analyses, there are three cases: Unit 1 MSLB to Unit 2 control room, Unit 2 MSLB to Unit 1 control room, and Unit 2 MSLB to Unit 2 control room.

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Assumptions

Assumption 1: There is no holdup in the Reactor Building.
Justification: Per Reference 1, there should be no holdup credited.

Assumption 2: In the calculation of the activity release, the entire released coolant mass is conservatively used as per Reference 1 (rather than just the liquid mass).
Justification: Reference 4 for Unit 1 and Reference 5 for unit 2

Assumption 3: There is no fuel damage for a Unit 1 or Unit 2 MSLB. Therefore, there is no impact of Extended Power Uprate or AST on the dose analysis other than the use of TEDE as the dose measure.
Justification: Reference 4. Since there is no fuel damage, AST has no impact on the activity released. Extended Power Uprate has no impact because the analysis is conducted at zero power hot standby.

Assumption 4: An infinite exchange rate between the Control Room and the environment is assumed.
Justification: Conservative

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. J.V. Ramsdell Jr., et al., "Atmospheric Relative Concentrations in Building Wakes", NUREG/CR-6331 Revision1 (PNNL-10521 Revision 1), May 1997

3. "Atmospheric Relative Concentrations for Control Room Radiological Habitability Assessments at Nuclear Power Plants", US NRC Regulatory Guide 1.194, Revision 0 June 2003

4. PSAT 4026CF.QA.03, "Design Database For the Application of the Revised DBA Source Term to Nine Mile Point U1", Revision 1

5. PSAT 3101CF.QA.03, "Design Database For the Application of the Revised DBA Source Term to Nine Mile Point U2", Revision 0

Ref.

Design Inputs

Design Input Data (Reference 4 for Unit 1 with item numbers given in brackets, Reference 5 for Unit 2 with item numbers given in double brackets)

Control Room Free Volume: U1: 1.35E+05 ft^3, [3.9]
Control Room Free Volume: U2: 3.81E+05 ft^3 *0.529 occupied fraction = 2.0235E+05 ft^3 [[3.2,3.3]]

X/Q values in sec/m^3 *:

U1 MSLB EAB:	1.90E-04 (ground-level)	[5.1]
U1 MSLB LPZ:	1.63E-05 (ground level)	[5.2]
U2 MSLB EAB:	1.19E-04 (ground-level)	[[5.1]]
U2 MSLB LPZ:	1.62E-05 (ground level)	[[5.2]]
U1 MSLB to U2 CR	1.31E-04 (ground-level)	[[5.5]]
U2 MSLB to U1 CR	1.90E-04 (ground-level)	[[5.3]]
U2 MSLB to U2 CR	1.47E-03 (ground-level)	[[5.5]]

*This analysis qualifies as a puff release as per defined in Reference 3 [ie release lasts less then 1 minute], so the use of ground level and puff X/Q's are justified.

Breathing Rate in m^3/s (from start of release for CR): 3.5E-4 [5.4], [[5.6]]

Total mass of coolant released:U1 MSLB: 1.0715E+05 lbm, U2: 7.10E6 gm steam +1.58E7 gm flashed liquid +2.56E7 liquid [1.8], [[1.8]]

Reactor Steam: U1 MSLB: 24.5% of total mass of coolant, U2: 14.6% (=7.10E6/(7.10E6+1.58E7+2.56E7) [1.8], [[1.8]]

Coolant DE-I-131 Activity per Unit Mass (microCurie/gram): 0.2 µCi/gm [1.9], [[1.9]]

Spiking Multiplier for Coolant DE I-131 Activity: 20 [1.10], [[1.10]]

I131 DCF: 3.29E+04 Rem/Ci [[9.2]]

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Activity Releases: [1.11 & 1.12]

Unit 1

REACTOR COOLANT AND MAIN STEAM RADIONUCLIDE CONCENTRATIONS (uCi / gm)		
[A] ISOTOPE	[B] REACTOR COOLANT	[C] MAIN STEAM
KR-83M		9.1E-04
KR-85M	NOBLE	1.6E-03
KR-85		5.0E-06
KR-87	GASES	5.5E-03
KR-88		5.5E-03
KR-89	EXIST	3.4E-02
KR-90		7.5E-02
KR-91	ONLY IN	9.1E-02
KR-92		9.1E-02
KR-93	VAPOR	2.4E-02
KR-94		5.9E-03
KR-95	STATE,	5.5E-04
KR-97		3.6E-06
XE-131M		3.9E-06
XE-133M	SO, THERE	7.5E-05
XE-133		2.1E-03
XE-135M	ARE NO	7.0E-03
XE-135		6.0E-03
XE-137	NOBLE GAS	3.9E-02
XE-138		2.3E-02
XE-139	COOLANT	7.5E-02
XE-140		8.0E-02
XE-141	CONCEN-	6.5E-02
XE-142		1.9E-02
XE-143	TRATIONS.	3.2E-03
XE-144		1.5E-04

REACTOR COOLANT AND MAIN STEAM RADIONUCLIDE CONCENTRATIONS (uCi / gm)		
[A] ISOTOPE	[B] REACTOR COOLANT	[C] MAIN STEAM
BR-83	1.6E-03	2.5E-05
BR-84	2.2E-03	3.1E-05
BR-85	9.9E-04	1.7E-05
I-131	8.6E-04	1.4E-05
I-132	1.6E-02	2.4E-04
I-133	1.2E-02	1.9E-04
I-134	2.9E-02	5.8E-04
I-135	1.2E-02	2.0E-04
RB-89	1.6E-03	1.6E-06
CS-134	5.6E-06	5.6E-09
CS-136	3.7E-06	3.7E-09
CS-137	1.5E-05	1.5E-08
CS-138	3.1E-03	3.1E-06

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Unit 2 [[1.11]]

ISOTOPE	DESIGN COOLANT ACTIVITY (μCi/gm)	DESIGN STEAM ACTIVITY (μCi/gm)	ISOTOPE	DESIGN COOLANT ACTIVITY (μCi/gm)	DESIGN STEAM ACTIVITY (μCi/gm)
I-131	1.3E-2	2.6E-4	KR-83M	NONE	6.4E-3
I-132	2.2E-1	3.3E-3	KR-85M	NONE	1.1E-2
I-133	1.6E-1	2.6E-3	KR-85	NONE	3.5E-5
I-134	4.0E-1	7.8E-3	KR-87	NONE	3.9E-2
I-135	1.7E-1	2.8E-3	KR-88	NONE	3.9E-2
CS-134	8.5E-5	8.5E-8	XE-131M	NONE	2.8E-5
CS-136	5.5E-5	5.5E-8	XE-133M	NONE	5.3E-4
CS-137	2.2E-4	2.2E-7	XE-133	NONE	1.5E-2
CS-138	1.6E-1	1.6E-4	XE-135M	NONE	5.0E-2
			XE-135	NONE	4.2E-2
			XE-138	NONE	1.6E-1

Ref.

Calculation

Offsite and control room doses were calculated using the spreadsheet methodology outlined in Appendix A.

Calculation of the Source (Column 1 of Appendix A spreadsheet)

The reactor coolant at the equilibrium level was analyzed for 0.2 µCi/gm I-131 dose equivalent. The spike concentration of 20 is used as scaling factor in the spreadsheet to report doses as 4 µCi/gm I-131 dose equivalent.

The I-131 dose conversion factor is 3.29E+04 Rem/Ci [Ref 4]. Therefore, 0.2 µCi/gm I-131 equivalent is 0.2 * 3.29E+04 Rem/Ci = 6.58 mRem/gm. For a MSLB the expected iodine activity has to be adjusted to yield 6.58 mRem/gm. This adjustment is performed in the table below where the iodine activity (µCi/gm) that is equivalent to 0.2 µCi/gm is calculated:

Table 2a: Unit 1 Calculated Dose Equivalents (Iodine)

C1	C2	C3	C4	C5	C6
					(0.2 uCi/
					gm I131 DE)
Nuclide	Expected		Converted	Expected	Adjusted
	uCi/gm	Rem/Ci	mRem/uCi	mRem/gm	uCi/gm
I131	8.60E-04	3.29E+04	3.29E+01	2.83E-02	4.60E-02
I132	1.60E-02	3.81E+02	3.81E-01	6.10E-03	8.55E-01
I133	1.20E-02	5.85E+03	5.85E+00	7.02E-02	6.41E-01
I134	2.90E-02	1.31E+02	1.31E-01	3.80E-03	1.55E+00
I135	1.20E-02	1.23E+03	1.23E+00	1.48E-02	6.41E-01
Total	**6.99E-02**			**1.23E-01**	**3.73E+00**
	[Ref 4, Item 1.12]	[Ref 4, Item 9.2]	C3/1000	C2*C4	C2*(6.58/1.23E-01)

The remaining isotope activities must are adjusted by the same factor (0.2 µCi/gm Unit 1 case: 6.5786/0.1231) as the iodine.

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Table 2b: Unit 2 Calculated Dose Equivalents (Iodine)

C1	C2	C3	C4	C5	C6
					(0.2 uCi/ gm I131 DE)
Nuclide	Expected		Converted	Expected	Adjusted
	uCi/gm	Rem/Ci	mRem/uCi	mRem/gm	uCi/gm
I131	1.30E-02	3.29E+04	3.29E+01	4.28E-01	5.01E-02
I132	2.20E-01	3.81E+02	3.81E-01	8.38E-02	8.47E-01
I133	1.60E-01	5.85E+03	5.85E+00	9.36E-01	6.16E-01
I134	4.00E-01	1.31E+02	1.31E-01	5.24E-02	1.54E+00
I135	1.70E-01	1.23E+03	1.23E+00	2.09E-01	6.55E-01
Total	**9.63E-01**			**1.71E+00**	**3.71E+00**
	[Ref 4, Item 1.12]	[Ref 4, Item 9.2]	C3/1000	C2*C4	C2*(6.58/1.23E-01)

The remaining isotope activities must are adjusted by the same factor (0.2 µCi/gm Unit 2 case: 6.5786/1.71) as the iodine.

Ref.

Table 3a: Unit 1 Isotope 0.2 uCi/gm I131 DE

Isotope	Expected Reactor Coolant (uCi/gm)	Expected Main Steam (uCi/gm)	(0.2 uCi/gm I131 DE) Reactor Coolant (uCi/gm)	Main Steam (uCi/gm)	Weighted Average* (uCi/gm)
I131	8.60E-04	1.40E-05	4.60E-02	7.49E-04	3.49E-02
I132	1.60E-02	2.40E-04	8.56E-01	1.28E-02	6.49E-01
I133	1.20E-02	1.90E-04	6.42E-01	1.02E-02	4.87E-01
I134	2.90E-02	5.80E-04	1.55E+00	3.10E-02	1.18E+00
I135	1.20E-02	2.00E-04	6.42E-01	1.07E-02	4.87E-01
Cs134	5.60E-06	5.60E-09	3.00E-04	3.00E-07	2.26E-04
Cs136	3.70E-06	3.70E-09	1.98E-04	1.98E-07	1.49E-04
Cs137	1.50E-05	1.50E-08	8.02E-04	8.02E-07	6.06E-04
Cs138	3.10E-03	3.10E-06	1.66E-01	1.66E-04	1.25E-01
Kr83m	0.00E+00	9.10E-04	0.00E+00	4.87E-02	1.19E-02
Kr85m	0.00E+00	1.60E-03	0.00E+00	8.56E-02	2.10E-02
Kr85	0.00E+00	5.00E-06	0.00E+00	2.67E-04	6.55E-05
Kr87	0.00E+00	5.50E-03	0.00E+00	2.94E-01	7.21E-02
Kr88	0.00E+00	5.50E-03	0.00E+00	2.94E-01	7.21E-02
Xe131m	0.00E+00	3.90E-06	0.00E+00	2.09E-04	5.11E-05
Xe133m	0.00E+00	7.50E-05	0.00E+00	4.01E-03	9.83E-04
Xe133	0.00E+00	2.10E-03	0.00E+00	1.12E-01	2.75E-02
Xe135m	0.00E+00	7.00E-03	0.00E+00	3.74E-01	9.17E-02
Xe135	0.00E+00	6.00E-03	0.00E+00	3.21E-01	7.86E-02
X138	0.00E+00	2.30E-02	0.00E+00	1.23E+00	3.01E-01

*Weighted average values were calculated using the following:
$[(1\text{-}0.245)*(\text{uCi/gm})_{\text{Reactor Coolant}}] + [(0.245)*(\text{uCi/gm})_{\text{Main Steam}}]$

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Table 3b: Unit 2 Isotope 0.2 uCi/gm I131 DE

	Expected	Expected	(0.2 uCi/gm I131 DE)		
	Reactor Coolant	Main Steam	Reactor Coolant	Main Steam	Weighted Average*
Isotope	(uCi/gm)	(uCi/gm)	(uCi/gm)	(uCi/gm)	(uCi/gm)
I131	1.30E-02	2.60E-04	5.00E-02	1.00E-03	4.29E-02
I132	2.20E-01	3.30E-03	8.46E-01	1.27E-02	7.25E-01
I133	1.60E-01	2.60E-03	6.16E-01	1.00E-02	5.27E-01
I134	4.00E-01	7.80E-03	1.54E+00	3.00E-02	1.32E+00
I135	1.70E-01	2.80E-03	6.54E-01	1.08E-02	5.60E-01
Cs134	8.50E-05	8.50E-08	3.27E-04	3.27E-07	2.79E-04
Cs136	5.50E-05	5.50E-08	2.12E-04	2.12E-07	1.81E-04
Cs137	2.20E-04	2.20E-07	8.46E-04	8.46E-07	7.23E-04
Cs138	1.60E-01	1.60E-04	6.16E-01	6.16E-04	5.26E-01
Kr83m	0.00E+00	6.40E-03	0.00E+00	2.46E-02	3.59E-03
Kr85m	0.00E+00	1.10E-02	0.00E+00	4.23E-02	6.18E-03
Kr85	0.00E+00	3.50E-05	0.00E+00	1.35E-04	1.97E-05
Kr87	0.00E+00	3.90E-02	0.00E+00	1.50E-01	2.19E-02
Kr88	0.00E+00	3.90E-02	0.00E+00	1.50E-01	2.19E-02
Xe131m	0.00E+00	2.80E-05	0.00E+00	1.08E-04	1.57E-05
Xe133m	0.00E+00	5.30E-04	0.00E+00	2.04E-03	2.98E-04
Xe133	0.00E+00	1.50E-02	0.00E+00	5.77E-02	8.43E-03
Xe135m	0.00E+00	5.00E-02	0.00E+00	1.92E-01	2.81E-02
Xe135	0.00E+00	4.20E-02	0.00E+00	1.62E-01	2.36E-02
X138	0.00E+00	1.60E-01	0.00E+00	6.16E-01	8.99E-02

*Weighted average values were calculated using the following:
$[(1-0.146)*(\text{ uCi/gm})_{\text{Reactor Coolant}}] + [(0.146)*(\text{ uCi/gm})_{\text{Main Steam}}]$

Ref.

Table 4a through 4c are the MSLB specific spreadsheet using the methodology in Appendix A to determine doses at the offsite and control room locations. The spreadsheet inputs are described below.

Scaling Factors (Rows 4, 5 & 6):
Scaling Factor 1 is the mass of coolant in grams, used to convert the core inventory concentration to total activity. Scaling Factor 2 is the multiplier on the coolant DE I131 activity, (It should be noted that using a multiplying factor of 20, the dose results are for 4 μCi/gm I131 DE), and Scaling Factor 3 is the conversion between Ci and uCi.

DF (Row 7)
The DF's are set to unity for this analysis.

Source in Ci/MW(t) (column 2):
The weighted average uCi/gm values from Table 3 were used.
The negligible amounts of Rb86, Kr89, Organic Iodine, and Xe137 were set to zero in this table.

Nuclide Specific Scaling Factor (column 3):
The Nuclide Specific Scaling Factor for noble gases in this calculation are set to 0.05. This value compensates for the short term spiking multiplier of 20, (scaling factor 2) which noble gas is not subject to. All other nuclide specific scaling factors are set to unity.

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Table 4a: U1 MSLB to U2 Control Room Dose Calculation

NMP1 MSLB/U2 CR	EAB	LPZ	CR		
Dispersion (X/Qs) =	1.90E-04	1.63E-05	1.31E-04	sec/m3	
CR Vol = 2.02E+05	ft3 w/ finite volume gamma correction =				0.052955
Scaling Factor 1 =	4.86E+07	Mass of Coolant in Grams			
Scaling Factor 2 =	20	Multiplier on Tech Spec Activity			
Scaling Factor 3 =	1.00E-06	Ci/uCi			
DF for Elemental I =	1	DF for Alkali Metals =		1	

Units >> Nuclide	Source: uCi/g	Nuclide-Specific Scaling Factor	WB DCF rem-m3 / Ci-sec	CEDE DCF rem/Ci	TEDE DCF rem-m3 / Ci-sec	CR DCF rem-m3 / Ci-sec	EAB TEDE rem	LPZ TEDE rem	CR TEDE rem
Kr83m	0.011927	0.05	5.55E-06	0	5.55E-06	2.94E-07	6.11E-10	5.24E-11	2.23E-11
Kr85m	0.02097	0.05	0.0277	0	0.0277	0.001467	5.36E-06	4.60E-07	1.96E-07
Kr85	6.55E-05	0.05	0.00044	0	0.00044	2.33E-05	2.66E-10	2.28E-11	9.72E-12
Kr87	0.072086	0.05	0.152	0	0.152	0.008049	1.01E-04	8.68E-06	3.69E-06
Kr88	0.072086	0.05	0.501	8.36E+01	0.53026	0.055791	3.53E-04	3.03E-05	2.56E-05
Kr89	0	0.05	0.323	0	0.323	0.017105	0.00E+00	0.00E+00	0.00E+00
Xe131m	5.11E-05	0.05	0.00144	0	0.00144	7.63E-05	6.79E-10	5.83E-11	2.48E-11
Xe133m	0.000983	0.05	0.00507	0	0.00507	0.000268	4.60E-08	3.95E-09	1.68E-09
Xe133	0.027524	0.05	0.00577	0	0.00577	0.000306	1.47E-06	1.26E-07	5.35E-08
Xe135m	0.091746	0.05	0.0755	0	0.0755	0.003998	6.39E-05	5.48E-06	2.33E-06
Xe135	0.078639	0.05	0.044	0	0.044	0.00233	3.19E-05	2.74E-06	1.17E-06
Xe137	0	0.05	0.0303	0	0.0303	0.001605	0.00E+00	0.00E+00	0.00E+00
Xe138	0.30145	0.05	0.213	0	0.213	0.01128	5.93E-04	5.08E-05	2.16E-05
I131Org	0	1	0.0673	3.29E+04	11.5823	11.51856	0.00E+00	0.00E+00	0.00E+00
I132Org	0	1	0.414	3.81E+02	0.54735	0.155274	0.00E+00	0.00E+00	0.00E+00
I133Org	0	1	0.109	5.85E+03	2.1565	2.053272	0.00E+00	0.00E+00	0.00E+00
I134Org	0	1	0.481	1.31E+02	5.27E-01	0.071322	0.00E+00	0.00E+00	0.00E+00
I135Org	0	1	0.307	1.23E+03	0.7375	0.446757	0.00E+00	0.00E+00	0.00E+00
I131Elem	0.034883	1	0.0673	3.29E+04	11.5823	11.51856	7.46E-02	6.40E-03	5.11E-02
I132Elem	0.648711	1	0.414	3.81E+02	0.54735	0.155274	6.55E-02	5.62E-03	1.28E-02
I133Elem	0.486664	1	0.109	5.85E+03	2.1565	2.053272	1.94E-01	1.66E-02	1.27E-01
I134Elem	1.177687	1	0.481	1.31E+02	0.52685	0.071322	1.15E-01	9.83E-03	1.07E-02
I135Elem	0.486795	1	0.307	1.23E+03	7.38E-01	0.446757	6.63E-02	5.69E-03	2.77E-02
Rb86	0	1	0.0178	6.62E+03	2.3348	2.317943	0.00E+00	0.00E+00	0.00E+00
Cs134	0.000226	1	0.28	4.63E+04	16.485	16.21983	6.88E-04	5.90E-05	4.67E-04
Cs136	0.000149	1	0.392	7.33E+03	2.9575	2.586259	8.15E-05	6.99E-06	4.92E-05
Cs137	0.000605	1	0.101	3.19E+04	11.266	11.17035	1.26E-03	1.08E-04	8.61E-04
Cs138	0.12512	1	0.4255	1.15E+02	0.465904	0.062937	1.08E-02	9.23E-04	1.00E-03
						Tot TEDE =	5.29E-01	4.53E-02	2.32E-01

Project: Nine Mile Point Nuclear Station Unit: 2 Disposition: ____

Originator/Date	Reviewer/Date	Calculation No.	Revision
M. Berg 5/29/07	H. Pustulka 5/29/07	H21C-101	0

Ref.

Table 4b: U2 MSLB to U1 Control Room Dose Calculation

NMP2 MSLB/U1 CR		EAB	LPZ	CR		
Dispersion (X/Qs) =		1.19E-04	1.62E-05	1.90E-04	sec/m3	
CR Vol =	135000	ft3 w/ finite volume gamma correction =				0.046212
Scaling Factor 1 =		4.85E+07	Mass of Coolant in Grams			
Scaling Factor 2 =		20	Multiplier on Tech Spec Activity			
Scaling Factor 3 =		1.00E-06	Ci/uCi			
DF for Elemental I =		1	DF for Alkali Metals =		1	

Units >> Nuclide	Source: uCi/g	Nuclide-Specific Scaling Factor	WB DCF rem-m3/Ci-sec	CEDE DCF rem/Ci	TEDE DCF rem-m3/Ci-sec	CR DCF rem-m3/Ci-sec	EAB TEDE rem	LPZ TEDE rem	CR TEDE rem
Kr83m	0.003595	0.05	5.55E-06	0	5.55E-06	2.56E-07	1.15E-10	1.57E-11	8.50E-12
Kr85m	0.006178	0.05	0.0277	0	0.0277	0.00128	9.88E-07	1.34E-07	7.29E-08
Kr85	1.97E-05	0.05	0.00044	0	0.00044	2.03E-05	4.99E-11	6.80E-12	3.68E-12
Kr87	0.021906	0.05	0.152	0	0.152	0.007024	1.92E-05	2.62E-06	1.42E-06
Kr88	0.021906	0.05	0.501	8.36E+01	0.53026	0.052412	6.70E-05	9.13E-06	1.06E-05
Kr89	0	0.05	0.323	0	0.323	0.014926	0.00E+00	0.00E+00	0.00E+00
Xe131m	1.57E-05	0.05	0.00144	0	0.00144	6.65E-05	1.31E-10	1.78E-11	9.64E-12
Xe133m	0.000298	0.05	0.00507	0	0.00507	0.000234	8.71E-09	1.19E-09	6.43E-10
Xe133	0.008425	0.05	0.00577	0	0.00577	0.000267	2.81E-07	3.82E-08	2.07E-08
Xe135m	0.028084	0.05	0.0755	0	0.0755	0.003489	1.22E-05	1.67E-06	9.03E-07
Xe135	0.023591	0.05	0.044	0	0.044	0.002033	5.99E-06	8.16E-07	4.42E-07
Xe137	0	0.05	0.0303	0	0.0303	0.0014	0.00E+00	0.00E+00	0.00E+00
Xe138	0.089869	0.05	0.213	0	0.213	0.009843	1.10E-04	1.50E-05	8.15E-06
I131Org	0	1	0.0673	3.29E+04	11.5823	11.51811	0.00E+00	0.00E+00	0.00E+00
I132Org	0	1	0.414	3.81E+02	0.54735	0.152482	0.00E+00	0.00E+00	0.00E+00
I133Org	0	1	0.109	5.85E+03	2.1565	2.052537	0.00E+00	0.00E+00	0.00E+00
I134Org	0	1	0.481	1.31E+02	5.27E-01	0.068078	0.00E+00	0.00E+00	0.00E+00
I135Org	0	1	0.307	1.23E+03	0.7375	0.444687	0.00E+00	0.00E+00	0.00E+00
I131Elem	0.042857	1	0.0673	3.29E+04	11.5823	11.51811	5.73E-02	7.80E-03	9.10E-02
I132Elem	0.724653	1	0.414	3.81E+02	0.54735	0.152482	4.58E-02	6.23E-03	2.04E-02
I133Elem	0.527133	1	0.109	5.85E+03	2.1565	2.052537	1.31E-01	1.79E-02	1.99E-01
I134Elem	1.318562	1	0.481	1.31E+02	0.52685	0.068078	8.02E-02	1.09E-02	1.65E-02
I135Elem	0.5601	1	0.307	1.23E+03	7.38E-01	0.444687	4.77E-02	6.49E-03	4.59E-02
Rb86	0	1	0.0178	6.62E+03	2.3348	2.317823	0.00E+00	0.00E+00	0.00E+00
Cs134	0.000279	1	0.28	4.63E+04	16.485	16.21794	5.31E-04	7.24E-05	8.35E-04
Cs136	0.000181	1	0.392	7.33E+03	2.9575	2.583615	6.17E-05	8.40E-06	8.61E-05
Cs137	0.000723	1	0.101	3.19E+04	11.266	11.16967	9.40E-04	1.28E-04	1.49E-03
Cs138	0.525762	1	0.4255	1.15E+02	0.465904	0.060067	2.83E-02	3.85E-03	5.82E-03
						Tot TEDE =	3.92E-01	5.34E-02	3.81E-01

Project: Nine Mile Point Nuclear Station Unit: __2__ Disposition: ____

Originator/Date	Reviewer/Date	Calculation No.	Revision
M. Berg 5/29/07	H. Pustulka 5/29/07	H21C-101	0

Ref.

Table 4c: U2 MSLB to U2 Control Room Dose Calculation

NMP2 MSLB/U2 CR	EAB	LPZ	CR		
Dispersion (X/Qs) =	1.19E-04	1.62E-05	1.47E-03	sec/m3	
CR Vol = 2.02E+05	ft3 w/ finite volume gamma correction =				0.052955
Scaling Factor 1 =	4.85E+07	Mass of Coolant in Grams			
Scaling Factor 2 =	20	Multiplier on Tech Spec Activity			
Scaling Factor 3 =	1.00E-06	Ci/uCi			
DF for Elemental I =	1	DF for Alkali Metals =			1

Units >> Nuclide	Source: uCi/g	Nuclide-Specific Scaling Factor	WB DCF rem-m3/Ci-sec	CEDE DCF rem/Ci	TEDE DCF rem-m3/Ci-sec	CR DCF rem-m3/Ci-sec	EAB TEDE rem	LPZ TEDE rem	CR TEDE rem
Kr83m	0.00359	0.05	5.55E-06	0	5.55E-06	2.94E-07	1.15E-10	1.57E-11	7.53E-11
Kr85m	0.00618	0.05	0.0277	0	0.0277	0.001467	9.88E-07	1.34E-07	6.46E-07
Kr85	2E-05	0.05	0.00044	0	0.00044	2.33E-05	4.99E-11	6.80E-12	3.27E-11
Kr87	0.02191	0.05	0.152	0	0.152	0.008049	1.92E-05	2.62E-06	1.26E-05
Kr88	0.02191	0.05	0.501	8.36E+01	0.53026	0.055791	6.70E-05	9.13E-06	8.71E-05
Kr89	0	0.05	0.323	0	0.323	0.017105	0.00E+00	0.00E+00	0.00E+00
Xe131m	1.6E-05	0.05	0.00144	0	0.00144	7.63E-05	1.31E-10	1.78E-11	8.55E-11
Xe133m	0.0003	0.05	0.00507	0	0.00507	0.000268	8.71E-09	1.19E-09	5.70E-09
Xe133	0.00843	0.05	0.00577	0	0.00577	0.000306	2.81E-07	3.82E-08	1.84E-07
Xe135m	0.02808	0.05	0.0755	0	0.0755	0.003998	1.22E-05	1.67E-06	8.01E-06
Xe135	0.02359	0.05	0.044	0	0.044	0.00233	5.99E-06	8.16E-07	3.92E-06
Xe137	0	0.05	0.0303	0	0.0303	0.001605	0.00E+00	0.00E+00	0.00E+00
Xe138	0.08987	0.05	0.213	0	0.213	0.01128	1.10E-04	1.50E-05	7.23E-05
I131Org	0	1	0.0673	3.29E+04	11.5823	11.51856	0.00E+00	0.00E+00	0.00E+00
I132Org	0	1	0.414	3.81E+02	0.54735	0.155274	0.00E+00	0.00E+00	0.00E+00
I133Org	0	1	0.109	5.85E+03	2.1565	2.053272	0.00E+00	0.00E+00	0.00E+00
I134Org	0	1	0.481	1.31E+02	5.27E-01	0.071322	0.00E+00	0.00E+00	0.00E+00
I135Org	0	1	0.307	1.23E+03	0.7375	0.446757	0.00E+00	0.00E+00	0.00E+00
I131Elem	0.04286	1	0.0673	3.29E+04	11.5823	11.51856	5.73E-02	7.80E-03	7.04E-01
I132Elem	0.72465	1	0.414	3.81E+02	0.54735	0.155274	4.58E-02	6.23E-03	1.60E-01
I133Elem	0.52713	1	0.109	5.85E+03	2.1565	2.053272	1.31E-01	1.79E-02	1.54E+00
I134Elem	1.31856	1	0.481	1.31E+02	0.52685	0.071322	8.02E-02	1.09E-02	1.34E-01
I135Elem	0.5601	1	0.307	1.23E+03	7.38E-01	0.446757	4.77E-02	6.49E-03	3.57E-01
Rb86	0	1	0.0178	6.62E+03	2.3348	2.317943	0.00E+00	0.00E+00	0.00E+00
Cs134	0.00028	1	0.28	4.63E+04	16.485	16.21983	5.31E-04	7.24E-05	6.46E-03
Cs136	0.00018	1	0.392	7.33E+03	2.9575	2.586259	6.17E-05	8.40E-06	6.66E-04
Cs137	0.00072	1	0.101	3.19E+04	11.266	11.17035	9.40E-04	1.28E-04	1.15E-02
Cs138	0.52576	1	0.4255	1.15E+02	0.465904	0.062937	2.83E-02	3.85E-03	4.72E-02
						Tot TEDE =	3.92E-01	5.34E-02	2.96E+00

Project: *Nine Mile Point Nuclear Station* Unit: __2__ Disposition: ____

Originator/Date	Reviewer/Date	Calculation No.	Revision
M. Berg 5/29/07	H. Pustulka 5/29/07	H21C-101	0

Ref.

Conclusions

The TEDE doses resulting from a design basis Main Steam Line Break (MSLB) at Nine Mile Point Unit 2 analyzed using the alternative source term assumptions as given in Regulatory Guide 1.183 [Ref 1] are found to be well below the accepted limit. The limiting Control Room dose is the Unit 2 MSLB affecting the Unit 2 Control Room.

Ref.

Appendix A
A Spreadsheet for the Calculation of Offsite and Control Room Doses

Background/Methodology

It is desirable for simplicity in many cases to calculate a bounding radiation dose for a given accident using several basic assumptions. These are as follows:

- It is assumed that the release of activity may be defined at the outset (i.e., there are no time-dependent mechanisms that modify the amount of activity that's released; e.g., no delayed filtration or holdup).
- It is assumed that the release is instantaneous and complete, and the transport to the receptor is instantaneous, as well. Therefore, no radioactive decay needs to be considered. Note that the activity release, A, may, in fact, occur over a given time duration, t, at a rate A/t. As long as the exposure time is equal to duration of the release, time cancels out of the integrated dose analysis.
- It is assumed that the release is limited to coolant and/or gap activity (i.e., only a limited number of radionuclides are included in the sheet).
- It is assumed that the chemical/physical form of the iodine as it is released is limited to organic and elemental.
- No credit for control room emergency ventilation (i.e., filtration) is assumed.
- It is assumed that the atmospheric dispersion for the duration of the release may be characterized by a single value of X/Q for each location (EAB, LPZ, and control room).
- It is assumed that the exchange rate of the control room with the environment is infinite so that the concentration of activity inside the control room is equal to that in the atmosphere.
- It is assumed that the breathing rate of exposed individuals is a constant 3.5E-4 m^3/sec. Effectively, this means the release actually must occur over a period of no more than eight hours in order for the LPZ dose not to be overstated.
- It is assumed that the control room occupancy factor is unity.

In addition, for the spreadsheet to be consistent with Reference 1, Dose Conversion Factors (DCFs) based on References 2 and 3 must be used. These are taken from the default TID.INP and FGR60.INP default files of Reference 4. Breathing rates and occupancy factors are taken from Reference 1.

The following section describes the development of such an Excel spreadsheet.

Ref.

Spreadsheet Development

The spreadsheet is displayed at the end of this section, just before the references.

At the top of the spreadsheet (in the first row) is the title. An example might be "NMP1 MSLB". In the second row may be found the EAB, LPZ, and control room X/Qs in units of seconds/m^3. The control room volume in ft^3 is given in the third column. It is included to provide the basis for the finite volume correction factor for gamma shine dose provided by Reference 1 (calculated to the right of the control room volume).

The next three rows provide scaling factors that apply equally to all of the radionuclides listed and to all of the calculated doses (EAB, LPZ, and control room). For example, in an FHA analysis, if the core-wide activity available for release is expressed as Ci/MWt, one scaling factor may be the power of the core, a second may be the peaking factor to account for the fact that the specific activity in the affected fuel bundles may be greater than the core average, and the third may be the fraction of the core's activity that is released from the damaged bundles (i.e., the fraction of the core activity assumed to be in the gap multiplied by the fraction of the core fuel bundles that are damaged by the drop). Space is available next to each scaling factor to annotate what each value represents.

DFs are specifically provided in the next row after the scaling factors. One DF is provided for elemental iodine and one for alkali metals (i.e., Cs and Rb).

The "Source" column (i.e., the second column) has already been mentioned. One space is provided under "Source" to identify the units of "Source". For each of the coolant and/or gap release radionuclides identified in the first column, a "Source" entry may be made.

In the third column, there is a place for scaling factors unique to individual radionuclides. For example, gap fractions that differ from the general gap fraction may be accommodated using these radionuclide-specific scaling factors. If the I-131 gap fraction is 8% vs. the general value of 5%, then the "Source" for I-131 would have to be increased by a factor of 1.6 to account for that difference. That factor may be entered in the third column.

In the fourth column, the DCFs for immersion dose are provided. As noted previously, these are taken from Reference 4 TID.INP and FGR60.INP with the multiplication of "Cloudshine-Effective" by 3.7E12 to convert Sv-m^3/Bq-sec to rem-m^3/Ci-sec. In the fifth column, the "Inhaled-Chronic-Effective" values from FGR60.INP have been multiplied by the same 3.7E12 to convert Sv/Bq to rem/Ci. Note that these DCFs include short-lived decay daughters as long as (1) the daughter has a half-life less than 90 minutes and (2) the daughter has a half-life less than 0.1 times the parent. One exception has been made to this rule. Because of its importance as a decay daughter, the DCFs for Rb-88 have been added to those for Kr-88 even though the half-life of Rb-88 (17.8 minutes) is slightly greater than 10% of its parent Kr-88 (170.4 minutes).

Ref.

In the sixth column, a TEDE DCF is prepared which is the sum of the immersion DCF and the inhalation DCF times the assumed breathing rate of 3.5E-4 m^3/sec.

In the seventh column, a control room DCF is defined which is similar to the TEDE DCF. However, the immersion DSF is diminished by the finite volume correction factor defined as the following in Reference 1:

$$DDE_{finite} = \frac{DDE_{\infty} V^{0.338}}{1173}$$

For a control room volume of 135,000 ft^3, for example, the factor is 0.0462. Note that this factor appears next to the control room volume at the top of the spreadsheet. It is ~unity for a control room volume of 1.2E9 ft^3.

The eighth column is the EAB dose, the product of Columns 2, 3, and 6, the three general scaling factors, and the EAB X/Q. Note that if a release of the activity, A, in Column 2 occurs over time, t, the release rate is A/t assuming a unit scaling factor in Column 3. When multiplied by the X/Q, the product is the concentration present at the X/Q location for the time, t (i.e., for the duration of the release). When multiplied by the DCF (Column 6) in units of rem-volume/Ci-time, the result is a dose rate for the duration, t. As long as it is assumed that the exposure duration, t', is the same as release duration, t, then the immersion + inhalation dose is simply the product as just described. In the last row of Column 8, the EAB dose is summed for all radionuclides in Column 1. Note that in calculating the EAB dose, the elemental iodine dose is reduced by the DF for elemental iodine and the alkali metal dose is reduced by the DF for alkali metals.

In Column 9, the Column 8 results are adjusted by the ratio of the LPZ X/Q to the EAB X/Q to obtain the LPZ dose.

Finally, in Column 10, the Column 8 results are adjusted by the ratio of the control room X/Q to the EAB X/Q and by the ratio of the control room DCF to the TEDE DCF to obtain the control room dose contribution for each radionuclide. As with the EAB and the LPZ doses, these are summed at the bottom of column to obtain the total control room TEDE.

ENGINEERING SERVICES	CALCULATION CONTINUATION SHEET	Page A4 (Next A5)

Project: Nine Mile Point Nuclear Station Unit: 2 Disposition: ____

Originator/Date	Reviewer/Date	Calculation No.	Revision
M. Berg 5/29/07	H. Pustulka 5/29/07	H21C-101	0

Ref.

Spreadsheet for Simplified Dose Evaluation

TITLE	EAB	LPZ	CR		
Dispersion (X/Qs) =	x.xxE-xx	x.xxE-xx	x.xxE-xx	sec/m3	
CR Vol = 1.20E+09	ft3 w/ finite volume gamma correction =				0.999
Scaling Factor 1 =	1				
Scaling Factor 2 =	1				
Scaling Factor 3 =	1				
DF for Elemental I =	1	DF for Alkali Metals =	1		

Units >> Nuclide	Source:	Nuclide-Specific Scaling Factor	WB DCF rem-m3/Ci-sec	CEDE DCF rem/Ci	TEDE DCF rem-m3/Ci-sec	CR DCF rem-m3/Ci-sec	EAB TEDE rem	LPZ TEDE rem	CR TEDE rem
Kr83m	0	1	5.55E-06	0	5.55E-06	5.54E-06	0.00E+00	0.00E+00	0.00E+00
Kr85m	0	1	0.0277	0	0.0277	0.027666	0.00E+00	0.00E+00	0.00E+00
Kr85	0	1	0.00044	0	0.00044	0.000439	0.00E+00	0.00E+00	0.00E+00
Kr87	0	1	0.152	0	0.152	0.151813	0.00E+00	0.00E+00	0.00E+00
Kr88	0	1	0.501	8.36E+01	0.53026	0.529643	0.00E+00	0.00E+00	0.00E+00
Kr89	0	1	0.323	0	0.323	0.322603	0.00E+00	0.00E+00	0.00E+00
Xe131m	0	1	0.00144	0	0.00144	0.001438	0.00E+00	0.00E+00	0.00E+00
Xe133m	0	1	0.00507	0	0.00507	0.005064	0.00E+00	0.00E+00	0.00E+00
Xe133	0	1	0.00577	0	0.00577	0.005763	0.00E+00	0.00E+00	0.00E+00
Xe135m	0	1	0.0755	0	0.0755	0.075407	0.00E+00	0.00E+00	0.00E+00
Xe135	0	1	0.044	0	0.044	0.043946	0.00E+00	0.00E+00	0.00E+00
Xe137	0	1	0.0303	0	0.0303	0.030263	0.00E+00	0.00E+00	0.00E+00
Xe138	0	1	0.213	0	0.213	0.212738	0.00E+00	0.00E+00	0.00E+00
I131Org	0	1	0.0673	3.29E+04	11.5823	11.58222	0.00E+00	0.00E+00	0.00E+00
I132Org	0	1	0.414	3.81E+02	0.54735	0.546841	0.00E+00	0.00E+00	0.00E+00
I133Org	0	1	0.109	5.85E+03	2.1565	2.156366	0.00E+00	0.00E+00	0.00E+00
I134Org	0	1	0.481	1.31E+02	5.27E-01	0.526258	0.00E+00	0.00E+00	0.00E+00
I135Org	0	1	0.307	1.23E+03	0.7375	0.737122	0.00E+00	0.00E+00	0.00E+00
I131Elem	0	1	0.0673	3.29E+04	11.5823	11.58222	0.00E+00	0.00E+00	0.00E+00
I132Elem	0	1	0.414	3.81E+02	0.54735	0.546841	0.00E+00	0.00E+00	0.00E+00
I133Elem	0	1	0.109	5.85E+03	2.1565	2.156366	0.00E+00	0.00E+00	0.00E+00
I134Elem	0	1	0.481	1.31E+02	0.52685	0.526258	0.00E+00	0.00E+00	0.00E+00
I135Elem	0	1	0.307	1.23E+03	7.38E-01	0.737122	0.00E+00	0.00E+00	0.00E+00
Rb86	0	1	0.0178	6.62E+03	2.3348	2.334778	0.00E+00	0.00E+00	0.00E+00
Cs134	0	1	0.28	4.63E+04	16.485	16.48466	0.00E+00	0.00E+00	0.00E+00
Cs136	0	1	0.392	7.33E+03	2.9575	2.957018	0.00E+00	0.00E+00	0.00E+00
Cs137	0	1	0.101	3.19E+04	11.266	11.26588	0.00E+00	0.00E+00	0.00E+00
Cs138	0	1	0.4255	1.15E+02	0.465904	0.46538	0.00E+00	0.00E+00	0.00E+00
						Total TEDE	**0.00E+00**	**0.00E+00**	**0.00E+00**

Ref.

References

A-1 Regulatory Guide 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors", July 2000

A-2 K.F. Eckerman et al., "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion," Federal Guidance Report 11, EPA-520/1-88-020, Environmental Protection Agency, 1988.

A-3 K.F. Eckerman and J.C. Ryman, "External Exposure to Radionuclides in Air, Water, and Soil," Federal Guidance Report 12, EPA-402-R-93-081, Environmental Protection Agency, 1993

A-4 NUREG/CR-6604, "RADTRAD: A Simplified Model for RADionuclide Transport and Removal And Dose Estimation", December 1997

H21C-101

ATTACHMENT 1: DESIGN VERIFICATION REPORT

Document being design-verified: ❑ DCP ☒ Calc ❑ Spec ❑ NER ❑ DBD ❑ Other

Doc#, Rev and Title: H21C-101, Revision 0 : U2 MSLB, AST Methodology

Extent of Design Verification (Briefly describe):

This calculation was design verified by 1) validating all input with respect to the input database making sure the appropriate input values were used; 2) validating that all assumptions are conservative and conform to RG 1.183 AST requirements; 3) validating the calculation methodology and calculation tools (i.e. spreadsheet) as being acceptable for the task; and 4) validating final results to make sure that they are as expected. Additional check calculations were also performed.

Method of Design Verification:

☒ Design Review ❑ Qualification Testing
❑ Alternate Calculations ❑ Applicability of Proven Design

Results of Design Verification:

☒ Fully acceptable with no issues identified
❑ Fully acceptable based on the following issues identified and resolved:

All inputs used were found to be appropriate and assumptions were sound. No further assumptions were necessary. The use of a spreadsheet methodology was appropriate for this calculation. Resulting values conform to the expected results. Conservatism was built into this calculation (no credit for filters, infinite exchange between the Control Room and the environment, etc). Minor concerns were commented on and addressed before the final draft of the calculation was issued.

❑ Continuation Page Follows

Discipline Involvement and Approvals:

	Name	Signature	Date
Lead Design Verifier:	H. Pustulka	Heather Pustulka	5/29/07

Discipline Design Verifiers, if required:
N/A

Discipline	Name	Signature	Date

ATTACHMENT 2: DESIGN VERIFICATION CHECKLIST

The following questions are required to be addressed based on the Nine Mile Point commitment to NQA-1 (1983) for design verification activities. This checklist is intended to assist when using the Design Review method of design verification to ensure relevant items are addressed in the verification effort. Each "No" answer will require correction or resolution by the originator of the document being verified prior to full acceptance by the design verifier(s).

Doc #: H21C-101 Lead Design Verifiers Name: H. Pustulka

Items Addressed with Basis of Review Answer	Review Check		
	Yes	No	N/A
1. Were the inputs correctly selected ?	X		
2. Are assumptions necessary to perform the design activity adequately described and reasonable ? Where necessary, are the assumptions identified for subsequent re-verifications when the detailed activities are completed ?	X		
3. Was an appropriate design method used?	X		
4. Were the design inputs correctly incorporated into the design ?	X		
5. Is the design output reasonable compared to design inputs ?	X		
6. Are the necessary design input and verification requirements for interfacing organizations specified in the design documents or in supporting procedures or instructions?			X