Development of EAL Threshold values from NEE-323-CALC-005

Calculated values are provided in Calc-005 as shown below.

Table 3 – Recommended RA1, RS1, and RG1 EAL Thresholds (Modes 1, 2, 3)

Release Point	RA1 µCi/cc	RS1 µCi/cc	RG1 µCi/cc
Turbine Building	1.58E-02	1.58E-01	1.58E+00
Reactor Building	1.22E-02	1.22E-01	1.22E+00
Offgas Stack	4.39E+01	4.39E+02	4.39E+03
LLRPSF	1.51E-02	1.51E-01	1.51E+00*

Table 4 – Recommended RA1, RS1, and RG1 EAL Thresholds (Modes 4, 5)

Release Point	RA1 µCi/cc	RS1 µCi/cc	RG1 µCi/cc
Turbine Building	1.30E-02	1.30E-01	1.30E+00
Reactor Building	1.01E-02	1.01E-01	1.01E+00
Offgas Stack	4.52E+01	4.52E+02	4.52E+03
LLRPSF	1.25E-02	1.25E-01	1.25E+00*

* Per Design Input 5.8 the results in EAL threshold values exceed the range of the monitor.

The following table of threshold values was developed for use in the DAEC EAL scheme by averaging the separate Mode 1-3 and Mode 4-5 thresholds from Calc-005, and then rounding the average values for ease of EAL evaluator use, as well as to provide a step-wise progression through the emergency classification. Resulting values are shown in the Alert, SAE, and GE columns below:

	Monitor	GE	SAE	Alert	NOUE
Gaseous	Reactor Building ventilation rad monitor (Kaman 3/4, 5/6, 7/8)	1.0E+00 uci/cc	1.0E-01 uci/cc	1.0E-02 uci/cc	1.0E-03 uci/cc
	Turbine Building ventilation rad monitor (Kaman 1/2)	1.0E+00 uci/cc	1.0E-01 uci/cc	1.0E-02 uci/cc	1.0E-03 uci/cc
	Offgas Stack rad monitor (Kaman 9/10)	4.5E+03 uci/cc	4.5E+02 uci/cc	4.5E+01 uci/cc	2.0E-01 uci/cc
	LLRPSF rad monitor (Kaman 12)	---*	1.0E-01 uci/cc	1.0E-02 uci/cc	1.0E-03 uci/cc

ENERCON Excellence—Every project. Every day.	CALCULATION COVER SHEET	CALC NO. NEE-323-CALC-005
		REV. 00

Title:	Revised Gaseous Radiological EALs per NEI 99-01 Rev. 06	**Client:**	Duane Arnold Energy Center
		Project Identifier:	NEE-323

Item	Cover Sheet Items	Yes	No
1	Does this calculation contain any open assumptions, including preliminary information, that require confirmation? (If **YES**, identify the assumptions.)	☐	☒
2	Does this calculation serve as an "Alternate Calculation"? (If **YES**, identify the design verified calculation.) **Design Verified Calculation No.** _____	☐	☒
3	Does this calculation supersede an existing Calculation? (If **YES**, identify the design verified calculation.) **Superseded Calculation No.** _____	☐	☒

Scope of Revision:
Initial Issue

Revision Impact on Results:
Initial Issue

Study Calculation ☐ **Final Calculation** ☒

Safety-Related ☐ **Non-Safety-Related** ☒

(Print Name and Sign)

Originator: Ryan Skaggs	**Date:** **12/14/17**
Design Verifier[1] (Reviewer if NSR): Jay Bhatt	**Date:** **12/14/17**
Approver: Zachary Rose	**Date:** **12/14/17**

Note 1: For non-safety-related calculation, design verification can be substituted by review.

ENERCON Excellence—Every project. Every day.	CALCULATION REVISION STATUS SHEET	CALC NO. NEE-323-CALC-005
		REV. 00

CALCULATION REVISION STATUS

REVISION	DATE	DESCRIPTION
00	12/14/17	Initial Issue

PAGE REVISION STATUS

PAGE NO.	REVISION	PAGE NO.	REVISION
All	00		

APPENDIX/ATTACHMENT REVISION STATUS

APPENDIX NO.	NO. OF PAGES	REVISION NO.	ATTACHMENT NO.	NO. OF PAGES	REVISION NO.
A	8	00	1	4	00

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1.0 Purpose and Scope

The DAEC site is implementing new requirements of Revision 6 to the Document NEI 99-01, "Development of Emergency Action Levels for Non-Passive Reactors." One of the changes included in Revision 6 to NEI 99-01 is a new basis for the Emergency Action Level (EAL) RA1. The requirements for RS1 and RG1 did not change from NEI 99-01 Rev. 05 with the implementation of NEI 99-01, Rev. 06.

The following table is extracted from Section 6 of **Revision 6** to NEI 99-01:

ALERT	SITE AREA EMERGENCY	GENERAL EMERGENCY
AA1 Release of gaseous or liquid radioactivity resulting in offsite dose greater than 10 mrem TEDE or 50 mrem thyroid CDE. *Op. Modes: All*	**AS1** Release of gaseous radioactivity resulting in offsite dose greater than 100 mrem TEDE or 500 mrem thyroid CDE. *Op. Modes: All*	**AG1** Release of gaseous radioactivity resulting in offsite dose greater than 1,000 mrem TEDE or 5,000 mrem thyroid CDE. *Op. Modes: All*

AA1, AS1, AG1 compares to DAEC terminology RA1, RS1, RG1, respectively. This calculation determines the effluent radiation monitor readings that correspond to the RA1, RS1, and RG1 thresholds.

2.0 Summary of Results and Conclusions

The results below show the RA1 EAL release concentration thresholds and associated dose rates for each release point for a decay time of five hours and 36 hours. The highlighted dose indicates which threshold was met at the release concentration.

Table 1 – RA1 EAL Release Concentration Thresholds (Decay = 5 hours (Mode 1, 2, 3))

Release Point	Release Concentration µCi/cc	CEDE mrem	EDE mrem	TEDE mrem	CDE Thyroid mrem
Turbine Building	1.58E-02	2.38	0.39	2.77	50.0
Reactor Building	1.22E-02	2.37**	0.39	2.76	49.8**
Offgas Stack	4.39E+01	1.96	8.05*	10.00	41.1
Low-Level Radwaste Processing and Storage Facility (LLRPSF)	1.51E-02	2.37	0.39	2.76	49.7

* Calculation of this value was demonstrated in Section 7.3

** Calculation of this value was demonstrated in Section 7.4

Table 2 – RA1 EAL Release Concentration Thresholds (Decay = 36 hours (Mode 4, 5))

Release Point	Release Concentration µCi/cc	CEDE mrem	EDE mrem	TEDE mrem	CDE Thyroid mrem
Turbine Building	1.30E-02	2.59	0.07	2.67	49.7
Reactor Building	1.01E-02	2.60	0.07	2.68	49.9
Offgas Stack	4.52E+01	2.61	1.41	4.02	50.0
LLRPSF	1.25E-02	2.60	0.07	2.67	49.8

Resultant EAL thresholds:

The tables below show the release concentration threshold for RA1, RS1, and RG1 based on the results above for both a decay time of five hours and a decay time of 36 hours.

From Section 1.0:

RS1 thresholds are 10 times larger than those for RA1

RG1 thresholds are 100 times larger than those for RA1

Table 3 – Recommended RA1, RS1, and RG1 EAL Thresholds (Modes 1, 2, 3)

Release Point	RA1 µCi/cc	RS1 µCi/cc	RG1 µCi/cc
Turbine Building	1.58E-02	1.58E-01	1.58E+00
Reactor Building	1.22E-02	1.22E-01	1.22E+00
Offgas Stack	4.39E+01	4.39E+02	4.39E+03
LLRPSF	1.51E-02	1.51E-01	1.51E+00*

Table 4 – Recommended RA1, RS1, and RG1 EAL Thresholds (Modes 4, 5)

Release Point	RA1 µCi/cc	RS1 µCi/cc	RG1 µCi/cc
Turbine Building	1.30E-02	1.30E-01	1.30E+00
Reactor Building	1.01E-02	1.01E-01	1.01E+00
Offgas Stack	4.52E+01	4.52E+02	4.52E+03
LLRPSF	1.25E-02	1.25E-01	1.25E+00*

* Per Design Input 5.8 the results in EAL threshold values exceed the range of the monitor.

3.0 References

3.1 NEI 99-01, Revision 6, "Development of Emergency Action Levels for Non-Passive Reactors", Nuclear Energy Institute, November 2012.

3.2 NUREG-1940, RASCAL 4: Description of Models and Methods, United States Nuclear Regulatory Commission, Office of Nuclear Security and Incident Response, 2012.

3.3 NUREG-1940 Supplement 1, RASCAL 4.3: Description of Models and Methods, United States Nuclear Regulatory Commission, Office of Nuclear Security and Incident Response, 2015.

3.4 NUREG-1228, Source Term Estimation During Incident Response to Severe Nuclear Power Plant Accidents, United States Nuclear Regulatory Commission, Division of Operational Assessment, 1988.

3.5 NUREG-1465, Accident Source Terms for Light-Water Nuclear Power Plants, United States Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, 1995.

3.6 DAEC UFSAR, Chapter 15-0.

3.7 DAEC UFSAR, Chapter 15-2.

3.8 DAEC Offsite Dose Assessment Manual (ODAM).

3.9 Plant Chemistry Procedure PCP 8.3, Alarm Setpoints and Background Determination for KAMAN Normal Range Monitors.

3.10 DAEC Nuclear Station HRN-HRH Radiation Monitor Operation, Maintenance and Troubleshooting Manual, ©2000, by Engineering Solutions, 310 Luchana Drive, Litchfield Park, Arizona.

3.11 DAEC Emergency Plan, Section 'I', Rev. 27.

3.12 Federal Guidance Report No. 11, Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion and Ingestion Office of Radiation and Indoor Air, 1999.

3.13 Federal Guidance Report No. 12, External Exposure to Radionuclides in Air, Water, and Soil, 1993.

3.14 *Table of Nuclides, http://atom.kaeri.re.kr:8080/ton/index.html, retrieved 10/10/17.*

4.0 Assumptions

The following are assumptions about the receptor:

- No credit is taken for radiation shielding provided by structures.
- No decay in-transit is assumed during the time elapsed between the release point and the receptor.

Both of the above assumptions are acceptable because they will result in a higher dose to the receptor and conservatively lower thresholds.

5.0 Design Inputs

5.1 Core Inventory

The assumed isotopic mixture in Table 5 is taken from Table 1-1 of NUREG-1940.

The core inventory (curies per megawatts thermal) in the table is based on calculations made by the NRC staff in December 2003 using the SAS2H control module of SCALE (Standardized Computer Analyses for Licensing Evaluation), Version 4.4a.

Table 5 – Isotopic Mixture

NUCLIDE	CORE INVENTORY (Ci/MWt)	NUCLIDE	CORE INVENTORY (Ci/MWt)	NUCLIDE	CORE INVENTORY (Ci/MWt)
Ba-139	4.74E+04	La-141	4.33E+04	Te-127	2.36E+03
Ba-140	4.76E+04	La-142	4.21E+04	Te-127m	3.97E+02
Ce-141	4.39E+04	Mo-99	5.30E+04	Te-129	8.26E+03
Ce-143	4.00E+04	Nb-95	4.50E+04	Te-129m	1.68E+03
Ce-144*	3.54E+04	Nd-147	1.75E+04	Te-131m	5.41E+03
Cm-242	1.12E+03	Np-239	5.69E+05	Te-132	3.81E+04
Cs-134	4.70E+03	Pr-143	3.96E+04	Xe-131m	3.65E+02
Cs-136	1.49E+03	Pu-241	4.26E+03	Xe-133	5.43E+04
Cs-137*	3.25E+03	Rb-86	5.29E+01	Xe-133m	1.72E+03
I-131	2.67E+04	Rh-105	2.81E+04	Xe-135	1.42E+04
I-132	3.88E+04	Ru-103	4.34E+04	Xe-135m	1.15E+04
I-133	5.42E+04	Ru-105	3.06E+04	Xe-138	4.56E+04
I-134	5.98E+04	Ru-106*	1.55E+04	Y-90	2.45E+03
I-135	5.18E+04	Sb-127	2.39E+03	Y-91	3.17E+04
Kr-83m	3.05E+03	Sb-129	8.68E+03	Y-92	3.26E+04
Kr-85	2.78E+02	Sr-89	2.41E+04	Y-93	2.52E+04
Kr-85m	6.17E+03	Sr-90	2.39E+03	Zr-95	4.44E+04
Kr-87	1.23E+04	Sr-91	3.01E+04	Zr-97*	4.23E+04
Kr-88	1.70E+04	Sr-92	3.24E+04		
La-140	4.91E+04	Tc-99m	4.37E+04		

5.2 Release Fraction

Table 6 displays release fractions as a function of time taken from Table 1-4 which references Table 3-12 of NUREG-1465.

Table 6 – Release Fraction

NUCLIDE GROUP	BWR CORE INVENTORY RELEASE FRACTION		
	Cladding Failure (Gap Release Phase) (0.5-hour duration)	Core Melt Phase (In-Vessel Phase) (1.5-hour duration)	Postvessel Melt-Through Phase (Ex-Vessel Phase) (3.0-hour duration)
Noble gases (Kr, Xe)	0.05	0.95	0
Halogens (I, Br)	0.05	0.25	0.30
Alkali metals (Cs, Rb)	0.05	0.20	0.35
Tellurium group (Te, Sb, Se)	0	0.05	0.25
Barium, strontium (Ba, Sr)	0	0.02	0.1
Noble metals (Ru, Rh, Pd, Mo, Tc, Co)	0	0.0025	0.0025
Cerium group (Ce, Pu, Np)	0	0.0005	0.005
Lanthanides (La, Zr, Nd, Eu, Nb, Pm, Pr, Sm, Y, Cm, Am)	0	0.0002	0.005

*Reference: Table 3-12 from NUREG-1465.

5.3 Gaseous Dispersion Factors

The dispersion factors are taken from the ODAM Section 3.

Table 7 – Dispersion Factors

	Dose due to Plume/Submersion ODAM Sections 3.5.2.1 and 3.9	Organ Dose Due to Particulates and Iodine ODAM Section 3.8
Offgas Stack	2.8E-7 sec/m^3	3.1E-7 sec/m^3
Building Vents	4.3E-6 sec/m^3	3.9E-6 sec/m^3

5.4 Isotopic half-lives

Isotopic half-lives are taken from NUREG-1940, Supplement 1. For those isotopes missing from that list, denoted by *, half-lives were obtained from the following website which is maintained by the Korea Atomic Energy Research Institute:

http://atom.kaeri.re.kr:8080/ton/index.html

Table 8 contains the half-lives and calculated λ (lambda) values.

Table 8 – Half-lives and Decay Constants

Isotope	T 1/2	T 1/2 units	T 1/2 Hours	Decay Lambda hrs^{-1}
Ba-139	0.0574	days	1.38E+00	5.03E-01
Ba-140	12.7	days	3.05E+02	2.27E-03
Ce-141	32.5	days	7.80E+02	8.89E-04
Ce-143	1.38	days	3.31E+01	2.09E-02
Ce-144	284	days	6.82E+03	1.02E-04
Cm-242	163	days	3.91E+03	1.77E-04
Cs-134	753	days	1.81E+04	3.84E-05
Cs-136	13.1	days	3.14E+02	2.20E-03
Cs-137	11000	days	2.64E+05	2.63E-06
I-131	8.04	days	1.93E+02	3.59E-03
I-132	0.0958	days	2.30E+00	3.01E-01
I-133	0.867	days	2.08E+01	3.33E-02
I-134	0.0365	days	8.76E-01	7.91E-01
I-135	0.275	days	6.60E+00	1.05E-01
Kr-83m*	1.83	hours	1.83E+00	3.79E-01
Kr-85	3910	days	9.38E+04	7.39E-06
Kr-85m	0.187	days	4.49E+00	1.54E-01
Kr-87	0.053	days	1.27E+00	5.45E-01
Kr-88	0.118	days	2.83E+00	2.45E-01
La-140	1.68	days	4.03E+01	1.72E-02
La-141	0.164	days	3.94E+00	1.76E-01
La-142	0.0642	days	1.54E+00	4.50E-01
Mo-99	2.75	days	6.60E+01	1.05E-02
Nb-95	35.2	days	8.45E+02	8.20E-04
Nd-147	11	days	2.64E+02	2.63E-03
Np-239	2.36	days	5.66E+01	1.22E-02
Pr-143	13.6	days	3.26E+02	2.12E-03
Pu-241	5260	days	1.26E+05	5.49E-06
Rb-86	18.7	days	4.49E+02	1.54E-03
Rh-105	1.47	days	3.53E+01	1.96E-02
Ru-103	39.3	days	9.43E+02	7.35E-04
Ru-105	0.185	days	4.44E+00	1.56E-01
Ru-106	368	days	8.83E+03	7.85E-05
Sb-127	3.85	days	9.24E+01	7.50E-03
Sb-129*	4.4	hours	4.40E+00	1.58E-01
Sr-89	50.5	days	1.21E+03	5.72E-04
Sr-90	10600	days	2.54E+05	2.72E-06
Sr-91	0.396	days	9.50E+00	7.29E-02
Sr-92	0.113	days	2.71E+00	2.56E-01
Tc-99m	0.251	days	6.02E+00	1.15E-01
Te-127	0.39	days	9.36E+00	7.41E-02
Te-127m	109	days	2.62E+03	2.65E-04
Te-129	0.0483	days	1.16E+00	5.98E-01
Te-129m	33.6	days	8.06E+02	8.60E-04

Isotope	T 1/2	T 1/2 units	T 1/2 Hours	Decay Lambda hrs^{-1}
Te-131m	1.25	days	3.00E+01	2.31E-02
Te-132	3.26	days	7.82E+01	8.86E-03
Xe-131m*	11.934	days	2.86E+02	2.42E-03
Xe-133	5.25	days	1.26E+02	5.50E-03
Xe-133m*	2.19	days	5.26E+01	1.32E-02
Xe-135	0.379	days	9.10E+00	7.62E-02
Xe-135m*	15.29	minutes	2.55E-01	2.72E+00
Xe-138*	14.08	minutes	2.35E-01	2.95E+00
Y-90	2.67	days	6.41E+01	1.08E-02
Y-91	58.5	days	1.40E+03	4.94E-04
Y-92	0.148	days	3.55E+00	1.95E-01
Y-93	0.421	days	1.01E+01	6.86E-02
Zr-95	64	days	1.54E+03	4.51E-04
Zr-97	0.704	days	1.69E+01	4.10E-02

5.5 Reduction Factor for Sprays

NUREG-1940 Table 1-11 states that when sprays are used for longer than 1.75 hours (but less than 2.25 hours), the following factor is applied to reduce all of the particulate and iodine species.

$$RF_S = Exp^{(-0.64t)}$$

Where t = the amount of times sprays are in service.

Note: This reduction factor does not apply to the noble gases.

For this calculation, sprays are used for a total of 2 hours as described in Section 6.1. The reduction factor is:

$$RF_S = e^{(-0.64*2)} = 0.278$$

5.6 Standby Gas Treatment Filters

NUREG-1940 allows a reduction factor of 0.01 for filters like the standby gas treatment (SBGT) system. This factor is only applied to releases from the Offgas Stack.

$$RF_F = 0.01$$

5.7 Secondary Containment

NUREG-1228 provides a reduction factor for natural removal through settling and plate-out in the secondary containment. For a 0.5 hour holdup period, that reduction factor is 0.4. This factor is applied to the building vent releases but not the release from the Offgas Stack.

$$RF_{SC} = 0.4$$

5.8 Monitor Range and Exhaust Flow Rates

Table 9 is developed from the DAEC Emergency Plan Section "I", ODAM Figure 3-1, and Procedure PCP 8.3.

Table 9 – Monitor Range and Exhaust Flow Rates

Release Point	Monitor Common Name	Equipment ID	Monitor Range µCi/cc	Release Flow CFM
Turbine Building	KAMAN 1/2	RE-5945 / RE-5946	1E-7 to 1E+5	72,000
Reactor Building	KAMAN 3/4 KAMAN 5/6 KAMAN 7/8	RE-7645, RE-7644 RE-7647, RE-7646 RE-7649, RE-7648	1E-7 to 1E+5	93,000
Offgas Stack	KAMAN 9/10	RE-4176, RE-4175	1E-7 to 1E+5	10,000
LLRPSF	KAMAN 12	RE-8801	1E-7 to 3E-1	75,000

5.9 Breathing Rate

From NUREG-1940 and FGR11, the breathing rate is 3.33E-4 m^3/second.

5.10 Exposure-to-Dose Conversion Factors for Inhalation

The "Exposure-to-Dose Conversion Factors for Inhalation" by radionuclide provided in FGR11 Table 2.1 allow the determination of the committed dose equivalent to the thyroid and the effective dose equivalent per unit per unit intake, and are shown in Table 11.

5.11 Dose Coefficients for Air Submersion

The dose coefficients in Sv/Bq*s*m^{-3} from being submersed in air for each radionuclide to an effective dose are taken from Table III.1 of FGR12, and are shown in Table 11.

6.0 Methodology

This calculation will equate a radioactive material release rate as measured at the gaseous effluent radiation monitors with the dose received to a member of the public at an offsite location. The relationship is highly influenced by the mixture of radioisotopes in the effluent and the dispersion of gases after they have left the facility. Primary guidance is provided by NUREG-1940 and NUREG-1228.

6.1 Scenario

The following generalized timeline is used to determine the phenomenon that can affect the mixture of radioisotopes in effluent. This scenario is realistic, but bounds an event that could occur in a shorter total time frame:

- T= 0 hr. Major recirculating system line break occurs. Reactor is shut down.
- T= 1 hr. Core is uncovered.
- T= 1 hr. Sprays are initiated.
- T = 2 hrs. Core is covered.
- T= 4.5 hrs. A catastrophic event causes damage to the drywell and the secondary containment.
    - o The gaseous mixture from the Drywell spreads into the Reactor Building, Turbine Building, and LLRPSF.
    - o Mean average holdup time of the gas in these buildings is 0.5 hours.

Scenario timing will affect the mixture of radioisotopes and is summarized here:

- The core is uncovered for 1 hour.
- Core/Drywell Sprays are running for a total of 2 hours.
- Primary Containment integrity is maintained for 4 hours.
- Source holdup time in secondary containment is 0.5 hours.
- Source decay time from shutdown to the release point is 5 hours.
- When the reactor is in mode 4 or 5, the total decay time is 36 hours.

Other Factors:

- The flow rates from the effluent exhaust points are listed in Design Input 5.8.
- The gaseous effluent radiation monitors are equally efficient for the monitoring of noble gases, particulates, and iodines.
- All releases from the Offgas Stack are filtered by the Standby Gas Treatment system.
- Removal of particulates and iodines by natural process during holdup in secondary containment are credited for releases from the building vents only.

6.2 Receptor

The receptor is an adult located at the ODAM-described location of minimal dispersion who is exposed to the radioactive release for one hour. Due to this relatively short duration, the only exposure pathways are inhalation and submersion. Assumptions related to the receptor are found in Section 4.0.

6.3 General Approach

With a given mixture of radionuclides, the dose received by an individual offsite is a function of the gross activity present in the gaseous mixture.

The resultant dose received by an offsite receptor is dependent not only on the gross radioactivity levels of the effluent but also upon the isotopic mixture present in the gas. This calculation predicts the relative contribution of each radionuclide to the gross radiation monitored by the effluent monitor.

With the fractionation of the mixture of radionuclides understood, a given gross output reading ($\mu Ci/cm^3$) from an effluent radiation monitor can be scaled to determine the concentration of each isotope present in the effluent.

The calculation then uses default dispersion factors described in the Offsite Dose Assessment Manual to determine the resultant concentration of radionuclides to which an individual offsite would be exposed.

Dose conversion factors provided in Federal Guidance Report 11 (FGR11) and 12 (FGR12) are used to determine the dose (mrem) to an individual offsite due to their exposure to the gaseous mixture of radionuclides.

With the given radionuclide mixture and dispersion factors understood, an iterative process can be used to relate the effluent monitor reading to a target offsite dose.

Two types of radiation dose are calculated: 1) TEDE and 2) CDE Thyroid.

CDE or Committed Dose Equivalent is the radiation dose to a specific organ due to an uptake of radioactive material. In this case, the uptake is limited to inhalation of radioactive material in the plume.

TEDE or Total Effective Dose Equivalent is the summation of the Effective Dose Equivalent (EDE) and the Committed Dose Equivalent (CEDE).

$$TEDE = EDE + CEDE.$$

EDE is the dose due to an individual being directly exposed (by submersion) to the radiation present in the gaseous release (shine).

CEDE is the sum of the CDE for each organ of the body with weighting factors applied for each organ. In this calculation, only contributions from the inhalation pathway are considered.

An iterative process is used to determine the gross radiation monitored by the effluent monitors that correspond to the threshold doses.

6.4 Source Term

This calculation will not analyze for the total activity released from the core. It will only analyze for the ratios of the isotopic species that are released from the core. Various phenomena will act to change the composition of the isotopic mixture in the time between reactor shutdown and release from the facility. In summary the removal phenomena addressed here include:

RF_I = Fraction of the activity released from the **inventory** of damaged fuel described in Section 6.5.

RF_S = Fraction of the activity remaining after reduction by containment **spray** from Section 5.5.

RF_R = Fraction of activity remaining after 5 hours or 36 hours of **radioactive** decay described in Section 6.6.

RF_F = Fraction of the activity remaining after filter by SBGT **filters** from Section 5.6.

RF_{SC} = Fraction of activity remaining after natural removal processes in **secondary containment** from Section 5.7.

Combining these factors provides a single fraction to derive a depleted source:

$RF_{Total} = RF_I * RF_S * RF_R * RF_F * RF_{SC}$

6.5 Fuel Damage Release Fractions

Table 6 contains release fractions for three time periods representing the total amount of time the core has been assumed to be uncovered. They are: 0 to 0.5 hours, 0.5 to 2 hours, and 2 to 5 hours. For this calculation, the core is assumed to be uncovered for <u>one hour</u>. A spreadsheet is used to scale the release fraction between the 0.5 hour point and the 2 hour point.

The Reduction Factor, **RF_I**, due to the release fraction is 100% of the release expected in the first 0.5 hour PLUS 1/3 of the amount released as expected in the period between 0.5 hours and 2 hours.

Example for Alkali Metals: $0.05 * \left(\frac{0.5\ hr}{0.5\ hr}\right) + 0.2 * \left(\frac{0.5\ hr}{1.5\ hr}\right) = 0.1167$

Table 10 – Release Fractions by Time Step (Hours)

Group	Time (h) by step		
	0.5	1.5	Cumulative
Alkali Metals	0.050	0.2000	0.1167
Barium Group	0.000	0.0200	0.0067
Cerium Group	0.000	0.0005	0.0002
Halogen	0.050	0.2500	0.1333
Lanthanides	0.000	0.0002	0.0001
Noble Gas	0.050	0.9500	0.3667
Noble Metals	0.000	0.0025	0.0008
Tellurium group	0.000	0.0500	0.0167

6.6 Radioactive Decay

The total amount of time the radioactive source is allowed to decay before being exhausted as an effluent is 5 hours or 36 hours depending on the reactor mode per Section 6.1.

The generalized equation for radioactive decay is:

$$A = A_o e^{(-\lambda t)}$$

Where:

A = decayed activity

A_o = initial activity

λ = isotopic decay constant

t = elapsed time

and

$\lambda = \ln 2 / t_{1/2}$

With an end goal of a total reduction factor RF_{Total}, a radiation decay factor RF_R is derived from the general equation above:

$$RF_R = e^{(-\lambda t)}$$

6.7 Effective Dose Equivalent – Noble Gas Submersion

Submersion dose from noble gases is calculated with guidance provided in FGR12.

The concentration of an isotope ***i*** present in the plume at the receptor is calculated:

$$x_{ir} = x_{iv} * v * \left(\frac{X}{Q}\right)$$

With the isotopic concentration at the receptor known, the dose (mrem) at the receptor is calculated:

$$Dose = \sum_i (x_{ir} * h_{E50i})$$

Where

$x_{ir} =$ concentration of radionuclide ***i*** present at the receptor (Ci/m^3)
Note: Ci/m^3 = µCi/cc

$v =$ volume of gas released (m^3)

$x_{iv} =$ concentration of radionuclide ***i*** released from the stack or building vent. (Ci/m^3)

i = each isotope present in the gaseous release

$\left(\frac{X}{Q}\right) =$ dispersion factor for that release point (sec/m^3)

$h_{E50i} =$ factor converting the gas concentration to effective dose equivalent. $\left(\frac{mrem\ cm^3}{\mu Ci\ sec}\right)$

As described in Section 7.3, a spreadsheet is used to determine the EDE dose contribution for each isotope in the mixture.

6.8 Committed Dose Equivalent: Thyroid

Organ dose from airborne particulates and iodines is calculated with guidance provided in FGR11.

The concentration of an isotope ***i*** present in the plume at the receptor is calculated:

$$x_{ir} = x_{iv} * v * \left(\frac{X}{Q}\right)$$

With the isotopic concentration at the receptor known, the dose (mrem) at the receptor can be calculated:

$$Dose = \sum_i (x_{ir} * B * t * h_{T50i})$$

Where

x_{ir} = concentration of radionuclide ***i*** present at the receptor (Ci/m^3)
Note: Ci/m^3 = µCi/ cm^3

v = volume of gas released (m^3)

x_{iv} = concentration of radionuclide ***i*** released from the stack or building vent. (Ci/m^3)

i = each isotope present in the gaseous release

$\left(\frac{X}{Q}\right)$ = dispersion factor for that release point (sec/m^3)

$\boldsymbol{B}$ = breathing Rate (cm^3/sec)

h_{T50i} = factor converting the gas concentration to effective dose equivalent. (mrem/µCi)

t = time the dose is to be integrated (sec)

As described in Section 7.4, a spreadsheet is used to determine the thyroid CDE dose contribution for each isotope in the mixture.

6.9 Committed Effective Dose Equivalent

Committed Effective Dose Equivalent from airborne particulates and iodines is calculated with guidance provided in FGR11.

The concentration x_{ir} of an isotope ***i*** present in the plume at the receptor is calculated:

$$x_{ir} = x_{iv} * v * \left(\frac{X}{Q}\right)$$

With the isotopic concentration at the receptor known, the dose (mrem) at the receptor can be calculated:

$$Dose = \sum_i (x_{ir} * B * t * h_{E50i})$$

Where

$x_{ir} =$ concentration of radionuclide ***i*** present at the receptor (Ci/m^3)
Note: Ci/m^3 = μCi/ cm^3

$v =$ volume of gas released (m^3)

$x_{iv} =$ concentration of radionuclide ***i*** released from the stack or building vent. (Ci/m^3)

$\boldsymbol{i} =$ each isotope present in the gaseous release

$\left(\frac{X}{Q}\right) =$ dispersion factor for that release point (sec/m^3)

$\boldsymbol{B} =$ breathing Rate (cm^3/sec)

$h_{E50i} =$ factor converting the gas concentration to effective dose equivalent. (mrem/μCi)

$\mathrm{t} =$ time the dose is to be integrated (sec)

As described in Section 7.4, a spreadsheet is used to determine the CEDE dose contribution for each isotope in the mixture.

7.0 Calculation

All calculations were completed using Microsoft Excel. Sample calculations are shown in the subsections that follow.

7.1 Dose Factors

FGR11 and FGR 12 display dose factors in the SI units of Sv/Bq and Sv m^3/ Bq sec, respectively. Traditional units of mrem/µCi and mrem cm^3/µCi sec are desired.

FGR11:

1	~~Sv~~	1E+05	mrem	1	~~Bq~~	~~Ci~~		=	3.70E+09	mrem
	~~Bq~~		~~Sv~~	2.7E-11	~~Ci~~	1.00E+6	µCi			µCi

The conversion factor from Sv/Bq to mrem/µCi is 3.70E+09.

FGR 12:

1	~~Sv~~	~~m^3~~	1E+05	mrem	1	~~Bq~~	1E+06	mL		~~Ci~~	=	3.70E+15	mrem cm^3
	~~Bq~~	sec		~~Sv~~	2.7E-11	~~Ci~~		~~m^3~~	1E+06	µCi			µCi sec

The conversion factor from Sv m^3/Bq sec to mrem cm^3/µCi sec is 3.70E+15.

The thyroid, CEDE, and submersion dose factors in the traditional units for each isotope are calculated in the table below. Column C, D, and H are dose factors from Sections 5.10 and 5.11 and Columns E and I are the conversion factors from above. Column F, G, and J are the h_{T50i}, h_{E50i}, and h_{E50i} factors as described in Sections 6.8, 6.9, and 6.7, respectively. Line 6 of Table 11 illustrates the formulas for Ba-139.

Table 11 – Isotopic Dose Factors

	Isotope	FGR11 Thyroid Sv/Bq	FGR11 CEDE Sv/Bq	Units Conversion Factor	Thyroid mrem/µCi	CEDE mrem/µCi	FGR 12: Sv m^3/Bq sec	Units Conversion Factor	Submersion mrem cc/µCi sec
5	B	C	D	E	F	G	H	I	J
6	*Ba-139*	*2.40E-12*	*4.64E-11*	*3.70E+09*	*=E6*C6*	*=E6*D6*	*2.17E-15*	*3.70E+15*	*=I6*H6*
6	Ba-139	2.40E-12	4.64E-11	3.70E+09	8.88E-03	1.72E-01	2.17E-15	3.7E+15	8.03E+00
7	Ba-140	2.56E-10	1.01E-09	3.70E+09	9.47E-01	3.74E+00	8.58E-15	3.7E+15	3.17E+01
	Ce-141	4.61E-11	2.42E-09	3.70E+09	1.71E-01	8.95E+00	3.43E-15	3.7E+15	1.27E+01
	Ce-143	1.21E-11	9.16E-10	3.70E+09	4.48E-02	3.39E+00	1.29E-14	3.7E+15	4.77E+01
	Ce-144	1.88E-09	1.01E-07	3.70E+09	6.96E+00	3.74E+02	8.53E-16	3.7E+15	3.16E+00
	Cm-242	9.41E-10	4.67E-06	3.70E+09	3.48E+00	1.73E+04	5.69E-18	3.7E+15	2.11E-02
	Cs-134	1.11E-08	1.25E-08	3.70E+09	4.11E+01	4.63E+01	7.57E-14	3.7E+15	2.80E+02
	Cs-136	1.73E-09	1.98E-09	3.70E+09	6.40E+00	7.33E+00	1.06E-13	3.7E+15	3.92E+02
	Cs-137	7.93E-09	8.63E-09	3.70E+09	2.93E+01	3.19E+01	7.74E-18	3.7E+15	2.86E-02
	I-131	2.92E-07	8.89E-09	3.70E+09	1.08E+03	3.29E+01	1.82E-14	3.7E+15	6.73E+01
	I-132	1.74E-09	1.03E-10	3.70E+09	6.44E+00	3.81E-01	1.12E-13	3.7E+15	4.14E+02
	I-133	4.86E-08	1.58E-09	3.70E+09	1.80E+02	5.85E+00	2.94E-14	3.7E+15	1.09E+02

Isotope	FGR11 Thyroid Sv/Bq	FGR11 CEDE Sv/Bq	Units Conversion Factor	Thyroid mrem/µCi	CEDE mrem/µCi	FGR 12: Sv m³/Bq sec	Units Conversion Factor	Submersion mrem cc/µCi sec
I-134	2.88E-10	3.55E-11	3.70E+09	1.07E+00	1.31E-01	1.3E-13	3.7E+15	4.81E+02
I-135	8.46E-09	3.32E-10	3.70E+09	3.13E+01	1.23E+00	7.98E-14	3.7E+15	2.95E+02
Kr-83m						1.5E-18	3.7E+15	5.55E-03
Kr-85						1.19E-16	3.7E+15	4.40E-01
Kr-85m						7.48E-15	3.7E+15	2.77E+01
Kr-87						4.12E-14	3.7E+15	1.52E+02
Kr-88						1.02E-13	3.7E+15	3.77E+02
La-140	1.22E-10	1.31E-09	3.70E+09	4.51E-01	4.85E+00	1.17E-13	3.7E+15	4.33E+02
La-141	9.40E-12	1.57E-10	3.70E+09	3.48E-02	5.81E-01	2.39E-15	3.7E+15	8.84E+00
La-142	8.74E-12	6.84E-11	3.70E+09	3.23E-02	2.53E-01	1.44E-13	3.7E+15	5.33E+02
Mo-99	1.17E-10	1.07E-09	3.70E+09	4.33E-01	3.96E+00	7.28E-15	3.7E+15	2.69E+01
Nb-95	3.58E-10	1.57E-09	3.70E+09	1.32E+00	5.81E+00	3.74E-14	3.7E+15	1.38E+02
Nd-147	1.94E-11	1.85E-09	3.70E+09	7.18E-02	6.85E+00	6.19E-15	3.7E+15	2.29E+01
Np-239	7.62E-12	6.78E-10	3.70E+09	2.82E-02	2.51E+00	7.69E-15	3.7E+15	2.85E+01
Pr-143	1.68E-18	2.19E-09	3.70E+09	6.22E-09	8.10E+00	2.1E-17	3.7E+15	7.77E-02
Pu-241	1.24E-11	2.23E-06	3.70E+09	4.59E-02	8.25E+03	7.25E-20	3.7E+15	2.68E-04
Rb-86	1.33E-09	1.79E-09	3.70E+09	4.92E+00	6.62E+00	4.81E-15	3.7E+15	1.78E+01
Rh-105	2.57E-11	2.58E-10	3.70E+09	9.51E-02	9.55E-01	3.72E-15	3.7E+15	1.38E+01
Ru-103	5.97E-10	2.42E-09	3.70E+09	2.21E+00	8.95E+00	2.25E-14	3.7E+15	8.33E+01
Ru-105	1.50E-11	1.23E-10	3.70E+09	5.55E-02	4.55E-01	3.81E-14	3.7E+15	1.41E+02
Ru-106	1.37E-08	1.29E-07	3.70E+09	5.07E+01	4.77E+02	0	3.7E+15	0.00E+00
Sb-127	1.50E-10	1.63E-09	3.70E+09	5.55E-01	6.03E+00	3.33E-14	3.7E+15	1.23E+02
Sb-129	2.07E-11	1.74E-10	3.70E+09	7.66E-02	6.44E-01	7.14E-14	3.7E+15	2.64E+02
Sr-89	4.16E-10	1.12E-08	3.70E+09	1.54E+00	4.14E+01	7.73E-17	3.7E+15	2.86E-01
Sr-90	2.64E-09	3.51E-07	3.70E+09	9.77E+00	1.30E+03	7.53E-18	3.7E+15	2.79E-02
Sr-91	4.08E-11	4.49E-10	3.70E+09	1.51E-01	1.66E+00	3.45E-14	3.7E+15	1.28E+02
Sr-92	2.19E-11	2.18E-10	3.70E+09	8.10E-02	8.07E-01	6.79E-14	3.7E+15	2.51E+02
Tc-99m	5.01E-11	8.80E-12	3.70E+09	1.85E-01	3.26E-02	5.89E-15	3.7E+15	2.18E+01
Te-127	6.46E-12	8.60E-11	3.70E+09	2.39E-02	3.18E-01	2.42E-16	3.7E+15	8.95E-01
Te-127m	2.39E-10	5.81E-09	3.70E+09	8.84E-01	2.15E+01	1.47E-16	3.7E+15	5.44E-01
Te-129	1.63E-12	2.42E-11	3.70E+09	6.03E-03	8.95E-02	2.75E-15	3.7E+15	1.02E+01
Te-129m	3.95E-10	6.47E-09	3.70E+09	1.46E+00	2.39E+01	1.55E-15	3.7E+15	5.74E+00
Te-131m	3.61E-08	1.73E-09	3.70E+09	1.34E+02	6.40E+00	7.01E-14	3.7E+15	2.59E+02
Te-132	6.28E-08	2.55E-09	3.70E+09	2.32E+02	9.44E+00	1.03E-14	3.7E+15	3.81E+01
Xe-131m						3.89E-16	3.7E+15	1.44E+00
Xe-133						1.56E-15	3.7E+15	5.77E+00
Xe-133m						1.37E-15	3.7E+15	5.07E+00
Xe-135						1.19E-14	3.7E+15	4.40E+01
Xe-135m						2.04E-14	3.7E+15	7.55E+01
Xe-138						5.77E-14	3.7E+15	2.13E+02
Y-90	9.52E-12	2.28E-09	3.70E+09	3.52E-02	8.44E+00	1.9E-16	3.7E+15	7.03E-01
Y-91	1.10E-10	1.32E-08	3.70E+09	4.07E-01	4.88E+01	2.6E-16	3.7E+15	9.62E-01
Y-92	3.69E-12	2.11E-10	3.70E+09	1.37E-02	7.81E-01	1.3E-14	3.7E+15	4.81E+01
Y-93	5.06E-12	5.82E-10	3.70E+09	1.87E-02	2.15E+00	4.8E-15	3.7E+15	1.78E+01
Zr-95	1.44E-09	6.39E-09	3.70E+09	5.33E+00	2.36E+01	3.6E-14	3.7E+15	1.33E+02
Zr-97	9.56E-11	1.17E-09	3.70E+09	3.54E-01	4.33E+00	9.02E-15	3.7E+15	3.34E+01

7.2 Source Term

A spreadsheet is used to determine the total reduction factor **RF_{Total}** for each isotope present in the source term as described in Section 6.4. The activity per megawatt thermal from Section 5.1 is multiplied by **RF_{Total}** to find the source term for each isotope. The spreadsheet for the Offgas Stack release is presented in Table 13.

The relative activity released from damaged fuel (**RF_I**) was determined in Section 6.5.

Table 12 – 2 Hours Reduction Factor (RF_I)

Cumulative	2 Hour
Alkali Metals	0.1167
Barium Group	0.0067
Cerium Group	0.0002
Halogen	0.1333
Lanthanides	0.0001
Noble Gas	0.3667
Noble Metals	0.0008
Tellurium group	0.0167

A Spray Reduction factor of 0.278 for primary containment sprays (**RF_S**) was derived in Section 5.5.

Determination of the Radiation Decay fractions (**RF_R**) was demonstrated in Section 6.6. In the spreadsheets below, the source decay time is 5 hours.

7.2.1 Offgas Stack

For the Offgas Stack release, credit is taken for filtering (**RF_F**) by the Standby Gas Treatment system but not for the natural removal processes that occur in secondary containment (**RF_{SC}**).

Table 13 – Isotopic Depletion and Release for Offgas Stack

			RF_I	RF_S	RF_{SC}	RF_F	RF_R	RF_{Total}	
Form	Isotope	Ci / MWTh	Release Fraction	+ 0.25 hr Sprays Reduction	Secondary Con-tainment	SBGT Filter	Decay Fraction	Total Depletion	Release Ci/MWTh
Barium Group	Ba-139	4.74E+04	0.0067	0.2780	1.0000	0.01	0.0808	1.50E-06	7.10E-02
Barium Group	Ba-140	4.76E+04	0.0067	0.2780	1.0000	0.01	0.9887	1.83E-05	8.72E-01
Cerium Group	Ce-141	4.39E+04	0.0002	0.2780	1.0000	0.01	0.9956	4.61E-07	2.03E-02
Cerium Group	Ce-143	4.00E+04	0.0002	0.2780	1.0000	0.01	0.9006	4.17E-07	1.67E-02
Cerium Group	Ce-144	3.54E+04	0.0002	0.2780	1.0000	0.01	0.9995	4.63E-07	1.64E-02
Lanthanides	Cm-242	1.12E+03	0.0001	0.2780	1.0000	0.01	0.9991	1.85E-07	2.07E-04
Alkali Metals	Cs-134	4.70E+03	0.1167	0.2780	1.0000	0.01	0.9998	3.24E-04	1.52E+00
Alkali Metals	Cs-136	1.49E+03	0.1167	0.2780	1.0000	0.01	0.9890	3.21E-04	4.78E-01
Alkali Metals	Cs-137	3.25E+03	0.1167	0.2780	1.0000	0.01	1.0000	3.24E-04	1.05E+00
Halogen	I-131	2.67E+04	0.1333	0.2780	1.0000	0.01	0.9822	3.64E-04	9.72E+00
Halogen	I-132	3.88E+04	0.1333	0.2780	1.0000	0.01	0.2215	8.21E-05	3.19E+00
Halogen	I-133	5.42E+04	0.1333	0.2780	1.0000	0.01	0.8466	3.14E-04	1.70E+01
Halogen	I-134	5.98E+04	0.1333	0.2780	1.0000	0.01	0.0191	7.09E-06	4.24E-01
Halogen	I-135	5.18E+04	0.1333	0.2780	1.0000	0.01	0.5915	2.19E-04	1.14E+01
Noble Gas	Kr-83m	3.05E+03	0.367	1.0	1.0	1.0	0.1505	5.52E-02	1.68E+02
Noble Gas	Kr-85	2.78E+02	0.367	1.0	1.0	1.0	1.0000	3.67E-01	1.02E+02
Noble Gas	Kr-85m	6.17E+03	0.367	1.0	1.0	1.0	0.4620	1.69E-01	1.05E+03
Noble Gas	Kr-87	1.23E+04	0.367	1.0	1.0	1.0	0.0656	2.40E-02	2.96E+02
Noble Gas	Kr-88	1.70E+04	0.367	1.0	1.0	1.0	0.2941	1.08E-01	1.83E+03
Lanthanides	La-140	4.91E+04	0.0001	0.2780	1.0000	0.01	0.9176	1.70E-07	8.35E-03
Lanthanides	La-141	4.33E+04	0.0001	0.2780	1.0000	0.01	0.4146	7.68E-08	3.33E-03
Lanthanides	La-142	4.21E+04	0.0001	0.2780	1.0000	0.01	0.1055	1.96E-08	8.23E-04
Noble Metals	Mo-99	5.30E+04	0.0008	0.2780	1.0000	0.01	0.9488	2.20E-06	1.17E-01
Lanthanides	Nb-95	4.50E+04	0.0001	0.2780	1.0000	0.01	0.9959	1.85E-07	8.31E-03
Lanthanides	Nd-147	1.75E+04	0.0001	0.2780	1.0000	0.01	0.9870	1.83E-07	3.20E-03
Cerium Group	Np-239	5.69E+05	0.0002	0.2780	1.0000	0.01	0.9406	4.36E-07	2.48E-01
Lanthanides	Pr-143	3.96E+04	0.0001	0.2780	1.0000	0.01	0.9894	1.83E-07	7.26E-03
Cerium Group	Pu-241	4.26E+03	0.0002	0.2780	1.0000	0.01	1.0000	4.63E-07	1.97E-03
Alkali Metals	Rb-86	5.29E+01	0.1167	0.2780	1.0000	0.01	0.9923	3.22E-04	1.70E-02
Noble Metals	Rh-105	2.81E+04	0.0008	0.2780	1.0000	0.01	0.9064	2.10E-06	5.90E-02
Noble Metals	Ru-103	4.34E+04	0.0008	0.2780	1.0000	0.01	0.9963	2.31E-06	1.00E-01
Noble Metals	Ru-105	3.06E+04	0.0008	0.2780	1.0000	0.01	0.4581	1.06E-06	3.25E-02
Noble Metals	Ru-106	1.55E+04	0.0008	0.2780	1.0000	0.01	0.9996	2.32E-06	3.59E-02
Tellurium group	Sb-127	2.39E+03	0.0167	0.2780	1.0000	0.01	0.9632	4.46E-05	1.07E-01
Tellurium group	Sb-129	8.68E+03	0.0167	0.2780	1.0000	0.01	0.4549	2.11E-05	1.83E-01
Barium Group	Sr-89	2.41E+04	0.0067	0.2780	1.0000	0.01	0.9971	1.85E-05	4.45E-01
Barium Group	Sr-90	2.39E+03	0.0067	0.2780	1.0000	0.01	1.0000	1.85E-05	4.43E-02

			RF_I	RF_S	RF_{SC}	RF_F	RF_R	RF_{Total}	
Form	Isotope	Ci / MWTh	Release Fraction	+ 0.25 hr Sprays Reduction	Secondary Con-tainment	SBGT Filter	Decay Fraction	Total Depletion	Release Ci/MWTh
Barium Group	Sr-91	3.01E+04	0.0067	0.2780	1.0000	0.01	0.6944	1.29E-05	3.87E-01
Barium Group	Sr-92	3.24E+04	0.0067	0.2780	1.0000	0.01	0.2786	5.16E-06	1.67E-01
Noble Metals	Tc-99m	4.37E+04	0.0008	0.2780	1.0000	0.01	0.5625	1.30E-06	5.70E-02
Tellurium group	Te-127	2.36E+03	0.0167	0.2780	1.0000	0.01	0.6905	3.20E-05	7.55E-02
Tellurium group	Te-127m	3.97E+02	0.0167	0.2780	1.0000	0.01	0.9987	4.63E-05	1.84E-02
Tellurium group	Te-129	8.26E+03	0.0167	0.2780	1.0000	0.01	0.0503	2.33E-06	1.93E-02
Tellurium group	Te-129m	1.68E+03	0.0167	0.2780	1.0000	0.01	0.9957	4.61E-05	7.75E-02
Tellurium group	Te-131m	5.41E+03	0.0167	0.2780	1.0000	0.01	0.8909	4.13E-05	2.23E-01
Tellurium group	Te-132	3.81E+04	0.0167	0.2780	1.0000	0.01	0.9567	4.43E-05	1.69E+00
Noble Gas	Xe-131m	3.65E+02	0.367	1.0	1.0	1.0	0.9880	3.62E-01	1.32E+02
Noble Gas	Xe-133	5.43E+04	0.367	1.0	1.0	1.0	0.9729	3.57E-01	1.94E+04
Noble Gas	Xe-133m	1.72E+03	0.367	1.0	1.0	1.0	0.9362	3.43E-01	5.90E+02
Noble Gas	Xe-135	1.42E+04	0.367	1.0	1.0	1.0	0.6832	2.50E-01	3.56E+03
Noble Gas	Xe-135m	1.15E+04	0.367	1.0	1.0	1.0	0.0000	4.55E-07	5.23E-03
Noble Gas	Xe-138	4.56E+04	0.367	1.0	1.0	1.0	0.0000	1.41E-07	6.45E-03
Lanthanides	Y-90	2.45E+03	0.0001	0.2780	1.0000	0.01	0.9474	1.76E-07	4.30E-04
Lanthanides	Y-91	3.17E+04	0.0001	0.2780	1.0000	0.01	0.9975	1.85E-07	5.86E-03
Lanthanides	Y-92	3.26E+04	0.0001	0.2780	1.0000	0.01	0.3769	6.99E-08	2.28E-03
Lanthanides	Y-93	2.52E+04	0.0001	0.2780	1.0000	0.01	0.7096	1.32E-07	3.31E-03
Lanthanides	Zr-95	4.44E+04	0.0001	0.2780	1.0000	0.01	0.9977	1.85E-07	8.21E-03
Lanthanides	Zr-97	4.23E+04	0.0001	0.2780	1.0000	0.01	0.8145	1.51E-07	6.39E-03

7.2.2 Building Vents

For releases from Building Vents, no credit is taken for filtering (**RF**$_F$) by the Standby Gas Treatment system. Credit is taken for the natural removal processes that occurs in secondary containment (**RF**$_{sc}$). This source term also has radioactive decay occurring for 5 hours.

Table 14 – Isotopic Depletion and Release for Building Vents

			RF_I	RF_S	RF_{SC}	RF_F	RF_R	RF_{Total}	
Form	Isotope	Ci/MWTh	Release Fraction	+ 0.25 hr Sprays Reduction	Secondary Con-tainment	SBGT Filter	Decay Fraction	Total Depletion	Release Ci/MWTh
Barium Group	Ba-139	4.74E+04	0.0067	0.2780	0.4000	1.00	0.0808	5.99E-05	2.84E+00
Barium Group	Ba-140	4.76E+04	0.0067	0.2780	0.4000	1.00	0.9887	7.33E-04	3.49E+01
Cerium Group	Ce-141	4.39E+04	0.0002	0.2780	0.4000	1.00	0.9956	1.85E-05	8.10E-01
Cerium Group	Ce-143	4.00E+04	0.0002	0.2780	0.4000	1.00	0.9006	1.67E-05	6.68E-01
Cerium Group	Ce-144	3.54E+04	0.0002	0.2780	0.4000	1.00	0.9995	1.85E-05	6.56E-01
Lanthanides	Cm-242	1.12E+03	0.0001	0.2780	0.4000	1.00	0.9991	7.41E-06	8.30E-03
Alkali Metals	Cs-134	4.70E+03	0.1167	0.2780	0.4000	1.00	0.9998	1.30E-02	6.10E+01
Alkali Metals	Cs-136	1.49E+03	0.1167	0.2780	0.4000	1.00	0.9890	1.28E-02	1.91E+01
Alkali Metals	Cs-137	3.25E+03	0.1167	0.2780	0.4000	1.00	1.0000	1.30E-02	4.22E+01
Halogen	I-131	2.67E+04	0.1333	0.2780	0.4000	1.00	0.9822	1.46E-02	3.89E+02
Halogen	I-132	3.88E+04	0.1333	0.2780	0.4000	1.00	0.2215	3.28E-03	1.27E+02
Halogen	I-133	5.42E+04	0.1333	0.2780	0.4000	1.00	0.8466	1.26E-02	6.80E+02
Halogen	I-134	5.98E+04	0.1333	0.2780	0.4000	1.00	0.0191	2.84E-04	1.70E+01
Halogen	I-135	5.18E+04	0.1333	0.2780	0.4000	1.00	0.5915	8.77E-03	4.54E+02
Noble Gas	Kr-83m	3.05E+03	0.367	1.0	1.0	1.0	0.1505	5.52E-02	1.68E+02
Noble Gas	Kr-85	2.78E+02	0.367	1.0	1.0	1.0	1.0000	3.67E-01	1.02E+02
Noble Gas	Kr-85m	6.17E+03	0.367	1.0	1.0	1.0	0.4620	1.69E-01	1.05E+03
Noble Gas	Kr-87	1.23E+04	0.367	1.0	1.0	1.0	0.0656	2.40E-02	2.96E+02
Noble Gas	Kr-88	1.70E+04	0.367	1.0	1.0	1.0	0.2941	1.08E-01	1.83E+03
Lanthanides	La-140	4.91E+04	0.0001	0.2780	0.4000	1.00	0.9176	6.80E-06	3.34E-01
Lanthanides	La-141	4.33E+04	0.0001	0.2780	0.4000	1.00	0.4146	3.07E-06	1.33E-01
Lanthanides	La-142	4.21E+04	0.0001	0.2780	0.4000	1.00	0.1055	7.82E-07	3.29E-02
Noble Metals	Mo-99	5.30E+04	0.0008	0.2780	0.4000	1.00	0.9488	8.79E-05	4.66E+00
Lanthanides	Nb-95	4.50E+04	0.0001	0.2780	0.4000	1.00	0.9959	7.38E-06	3.32E-01
Lanthanides	Nd-147	1.75E+04	0.0001	0.2780	0.4000	1.00	0.9870	7.32E-06	1.28E-01
Cerium Group	Np-239	5.69E+05	0.0002	0.2780	0.4000	1.00	0.9406	1.74E-05	9.92E+00
Lanthanides	Pr-143	3.96E+04	0.0001	0.2780	0.4000	1.00	0.9894	7.34E-06	2.91E-01
Cerium Group	Pu-241	4.26E+03	0.0002	0.2780	0.4000	1.00	1.0000	1.85E-05	7.90E-02
Alkali Metals	Rb-86	5.29E+01	0.1167	0.2780	0.4000	1.00	0.9923	1.29E-02	6.81E-01
Noble Metals	Rh-105	2.81E+04	0.0008	0.2780	0.4000	1.00	0.9064	8.40E-05	2.36E+00
Noble Metals	Ru-103	4.34E+04	0.0008	0.2780	0.4000	1.00	0.9963	9.23E-05	4.01E+00
Noble Metals	Ru-105	3.06E+04	0.0008	0.2780	0.4000	1.00	0.4581	4.25E-05	1.30E+00
Noble Metals	Ru-106	1.55E+04	0.0008	0.2780	0.4000	1.00	0.9996	9.26E-05	1.44E+00
Tellurium group	Sb-127	2.39E+03	0.0167	0.2780	0.4000	1.00	0.9632	1.79E-03	4.27E+00
Tellurium group	Sb-129	8.68E+03	0.0167	0.2780	0.4000	1.00	0.4549	8.43E-04	7.32E+00
Barium Group	Sr-89	2.41E+04	0.0067	0.2780	0.4000	1.00	0.9971	7.39E-04	1.78E+01

			RF_I	RF_S	RF_{SC}	RF_F	RF_R	RF_{Total}	
Form	Isotope	Ci / MWTh	Release Fraction	+ 0.25 hr Sprays Reduction	Secondary Con-tainment	SBGT Filter	Decay Fraction	Total Depletion	Release Ci/MWTh
Barium Group	Sr-90	2.39E+03	0.0067	0.2780	0.4000	1.00	1.0000	7.41E-04	1.77E+00
Barium Group	Sr-91	3.01E+04	0.0067	0.2780	0.4000	1.00	0.6944	5.15E-04	1.55E+01
Barium Group	Sr-92	3.24E+04	0.0067	0.2780	0.4000	1.00	0.2786	2.07E-04	6.69E+00
Noble Metals	Tc-99m	4.37E+04	0.0008	0.2780	0.4000	1.00	0.5625	5.21E-05	2.28E+00
Tellurium group	Te-127	2.36E+03	0.0167	0.2780	0.4000	1.00	0.6905	1.28E-03	3.02E+00
Tellurium group	Te-127m	3.97E+02	0.0167	0.2780	0.4000	1.00	0.9987	1.85E-03	7.35E-01
Tellurium group	Te-129	8.26E+03	0.0167	0.2780	0.4000	1.00	0.0503	9.32E-05	7.70E-01
Tellurium group	Te-129m	1.68E+03	0.0167	0.2780	0.4000	1.00	0.9957	1.85E-03	3.10E+00
Tellurium group	Te-131m	5.41E+03	0.0167	0.2780	0.4000	1.00	0.8909	1.65E-03	8.93E+00
Tellurium group	Te-132	3.81E+04	0.0167	0.2780	0.4000	1.00	0.9567	1.77E-03	6.76E+01
Noble Gas	Xe-131m	3.65E+02	0.367	1.0	1.0	1.0	0.9880	3.62E-01	1.32E+02
Noble Gas	Xe-133	5.43E+04	0.367	1.0	1.0	1.0	0.9729	3.57E-01	1.94E+04
Noble Gas	Xe-133m	1.72E+03	0.367	1.0	1.0	1.0	0.9362	3.43E-01	5.90E+02
Noble Gas	Xe-135	1.42E+04	0.367	1.0	1.0	1.0	0.6832	2.50E-01	3.56E+03
Noble Gas	Xe-135m	1.15E+04	0.367	1.0	1.0	1.0	0.0000	4.55E-07	5.23E-03
Noble Gas	Xe-138	4.56E+04	0.367	1.0	1.0	1.0	0.0000	1.41E-07	6.45E-03
Lanthanides	Y-90	2.45E+03	0.0001	0.2780	0.4000	1.00	0.9474	7.02E-06	1.72E-02
Lanthanides	Y-91	3.17E+04	0.0001	0.2780	0.4000	1.00	0.9975	7.40E-06	2.34E-01
Lanthanides	Y-92	3.26E+04	0.0001	0.2780	0.4000	1.00	0.3769	2.79E-06	9.11E-02
Lanthanides	Y-93	2.52E+04	0.0001	0.2780	0.4000	1.00	0.7096	5.26E-06	1.33E-01
Lanthanides	Zr-95	4.44E+04	0.0001	0.2780	0.4000	1.00	0.9977	7.40E-06	3.28E-01
Lanthanides	Zr-97	4.23E+04	0.0001	0.2780	0.4000	1.00	0.8145	6.04E-06	2.55E-01

7.3 Effective Dose Equivalent – Noble Gas Submersion

Spreadsheets are used to calculate isotopic concentration at the receptor and the resultant radiation dose to the receptor for each of the isotopes in the mixture.

For the example Effective Dose Equivalent calculation, the release point is the Offgas Stack at five hours since shutdown, and a gross concentration of 43.9 μCi/cm^3 (this concentration was determined iteratively to produce 10 mrem TEDE). The secondary containment holdup hours is set at <0.5 because the natural removal process in the Secondary Containment does not occur with the Offgas Stack.

In Table 15, the column labeled "h_{E50i} Submersion mrem cm^3/μCi sec," is the dose factor for air submersion dose and is calculated in Section 7.1.

The column labeled "Depleted Mix Ci/MWTh" is the "Release Ci/MWTh" calculated in Section 7.2 for each isotope.

The "Fraction" column determines the fraction each isotope contributes to the gross activity and is used to scale the activity for each isotope.

The column "x_{iv} Release Conc. µCi/cm³" contains a calculation that scales the "Depleted Mix Ci/MWTh" column to a user entered gross concentration based on the "Fraction". In this case, the gross concentration entered was 43.9 µCi/cm³ (4.39E+1).

Values in the "x_{ir} Receptor Conc. µCi/cm³" column are calculated by multiplying the release concentration by the applicable dispersion factor, the volume of the release, and requisite conversion factors. The basic equation is from Section 6.7:

$$x_{ir} = \quad x_{iv} * v * \left(\frac{X}{Q}\right)$$

For isotope I-131, an example is presented:

x_{iv} Release Conc.		Flow						(X/Q)			Receptor Conc.	
1.57E-02	µCi	10,000	~~ft³~~	2.83E-02	~~m³~~	1	~~min~~	2.80E-07	~~sec~~	=	2.08E-08	µCi
	cm³		~~min~~	1	~~ft³~~	60	~~sec~~		~~m³~~			cm³

Where:

v = 10,000 ft³/min is the rated flow from the Offgas Stack from Design Input 5.8.

(X/Q) = 2.80E-07 is the Noble Gas Dispersion coefficient *(X/Q)* for the Offgas Stack from Design Input 5.3.

2.83E-2 converts ft³ to m³

Values in the "Submersion Dose mrem" (h_{E50i}) column are calculated by multiplying the factors "x_{ir} Receptor Conc. µCi/cm³", a time-units conversion factor, and the dose conversion factor calculated in Section 7.1. The basic equation for a one hour time period is shown in Section 6.7.

$$Dose = \sum_i (x_{ir} * hE_{50i})$$

For isotope I-131, an example is presented:

x_{ir} Receptor Conc.		h_{E50i} Submersion						Submersion Dose mrem	
2.08E-08	~~µCi~~	6.73E+01	mrem	~~cm³~~	3600	~~sec~~	=	5.04E-03	mrem
	~~cm³~~		~~µCi~~	~~sec~~					

For ease of comparison, the spreadsheet row for I-131 is shown here:

Nuclide	h_{E50i} Submersion $\frac{mrem\ cc}{\mu Ci\ sec}$	Depleted Mix $\frac{Ci}{MWTh}$	Fraction	x_{iv} Release Conc. $\frac{\mu Ci}{cm^3}$	x_{ir} Receptor Conc. $\frac{\mu Ci}{cm^3}$	Submersion Dose mrem
I-131	6.73E+1	9.72E+0	3.582E-4	1.57E-2	2.08E-8	5.04E-3

Table 15 – Submersion Dose for Offgas Stack

Nuclide	h_{E50i} Submersion $\frac{mrem\ cm^3}{\mu Ci\ sec}$	Depleted Mix $\frac{Ci}{MWTh}$	Fraction	x_{iv} Release Conc. $\frac{\mu Ci}{cm^3}$	x_{ir} Receptor Conc. $\frac{\mu Ci}{cm^3}$	Submersion Dose mrem
Ba-139	8.03E+0	7.10E-2	2.62E-6	1.15E-4	1.52E-10	4.39E-6
Ba-140	3.17E+1	8.72E-1	3.21E-5	1.41E-3	1.86E-9	2.13E-4
Ce-141	1.27E+1	2.03E-2	7.46E-7	3.28E-5	4.33E-11	1.98E-6
Ce-143	4.77E+1	1.67E-2	6.15E-7	2.70E-5	3.57E-11	6.13E-6
Ce-144	3.16E+0	1.64E-2	6.04E-7	2.65E-5	3.50E-11	3.98E-7
Cm-242	2.11E-2	2.07E-4	7.64E-9	3.35E-7	4.43E-13	3.36E-11
Cs-134	2.80E+2	1.52E+0	5.62E-5	2.47E-3	3.26E-9	3.28E-3
Cs-136	3.92E+2	4.78E-1	1.76E-5	7.73E-4	1.02E-9	1.44E-3
Cs-137	2.86E-2	1.05E+0	3.88E-5	1.70E-3	2.25E-9	2.32E-7
I-131	6.73E+1	9.72E+0	3.582E-4	1.57E-2	2.08E-8	5.04E-3
I-132	4.14E+2	3.19E+0	1.17E-4	5.15E-3	6.81E-9	1.02E-2
I-133	1.09E+2	1.70E+1	6.27E-4	2.75E-2	3.64E-8	1.42E-2
I-134	4.81E+2	4.24E-1	1.56E-5	6.86E-4	9.07E-10	1.57E-3
I-135	2.95E+2	1.14E+1	4.18E-4	1.84E-2	2.43E-8	2.58E-2
Kr-83m	5.55E-3	1.68E+2	6.20E-3	2.72E-1	3.60E-7	7.19E-6
Kr-85	4.40E-1	1.02E+2	3.76E-3	1.65E-1	2.18E-7	3.45E-4
Kr-85m	2.77E+1	1.05E+3	3.85E-2	1.69E+0	2.23E-6	2.23E-1
Kr-87	1.52E+2	2.96E+2	1.09E-2	4.78E-1	6.32E-7	3.47E-1
Kr-88	3.77E+2	1.83E+3	6.75E-2	2.97E+0	3.92E-6	5.32E+0
La-140	4.33E+2	8.35E-3	3.08E-7	1.35E-5	1.78E-11	2.78E-5
La-141	8.84E+0	3.33E-3	1.23E-7	5.38E-6	7.11E-12	2.26E-7
La-142	5.33E+2	8.23E-4	3.03E-8	1.33E-6	1.76E-12	3.37E-6
Mo-99	2.69E+1	1.17E-1	4.29E-6	1.88E-4	2.49E-10	2.41E-5
Nb-95	1.38E+2	8.31E-3	3.06E-7	1.34E-5	1.78E-11	8.84E-6
Nd-147	2.29E+1	3.20E-3	1.18E-7	5.18E-6	6.84E-12	5.64E-7
Np-239	2.85E+1	2.48E-1	9.14E-6	4.01E-4	5.30E-10	5.43E-5
Pr-143	7.77E-2	7.26E-3	2.68E-7	1.17E-5	1.55E-11	4.34E-9
Pu-241	2.68E-4	1.97E-3	7.27E-8	3.19E-6	4.22E-12	4.07E-12
Rb-86	1.78E+1	1.70E-2	6.27E-7	2.75E-5	3.64E-11	2.33E-6
Rh-105	1.38E+1	5.90E-2	2.17E-6	9.54E-5	1.26E-10	6.25E-6
Ru-103	8.33E+1	1.00E-1	3.69E-6	1.62E-4	2.14E-10	6.42E-5
Ru-105	1.41E+2	3.25E-2	1.20E-6	5.25E-5	6.94E-11	3.52E-5
Ru-106	0.00E+0	3.59E-2	1.32E-6	5.81E-5	7.67E-11	0.00E+0
Sb-127	1.23E+2	1.07E-1	3.93E-6	1.73E-4	2.28E-10	1.01E-4
Sb-129	2.64E+2	1.83E-1	6.74E-6	2.96E-4	3.91E-10	3.72E-4
Sr-89	2.86E-1	4.45E-1	1.64E-5	7.20E-4	9.52E-10	9.80E-7
Sr-90	2.79E-2	4.43E-2	1.63E-6	7.16E-5	9.47E-11	9.50E-9
Sr-91	1.28E+2	3.87E-1	1.43E-5	6.27E-4	8.28E-10	3.81E-4
Sr-92	2.51E+2	1.67E-1	6.16E-6	2.71E-4	3.58E-10	3.23E-4
Tc-99m	2.18E+1	5.70E-2	2.10E-6	9.21E-5	1.22E-10	9.55E-6

Nuclide	h_{E50i} Submersion $\frac{mrem\ cm^3}{\mu Ci\ sec}$	Depleted Mix $\frac{Ci}{MWTh}$	Fraction	x_{iv} Release Conc. $\frac{\mu Ci}{cm^3}$	x_{ir} Receptor Conc. $\frac{\mu Ci}{cm^3}$	Submersion Dose mrem
Te-127	8.95E-1	7.55E-2	2.78E-6	1.22E-4	1.61E-10	5.20E-7
Te-127m	5.44E-1	1.84E-2	6.77E-7	2.97E-5	3.93E-11	7.69E-8
Te-129	1.02E+1	1.93E-2	7.09E-7	3.11E-5	4.11E-11	1.51E-6
Te-129m	5.74E+0	7.75E-2	2.86E-6	1.25E-4	1.66E-10	3.42E-6
Te-131m	2.59E+2	2.23E-1	8.23E-6	3.61E-4	4.77E-10	4.46E-4
Te-132	3.81E+1	1.69E+0	6.22E-5	2.73E-3	3.61E-9	4.95E-4
Xe-131m	1.44E+0	1.32E+2	4.87E-3	2.14E-1	2.83E-7	1.46E-3
Xe-133	5.77E+0	1.94E+4	7.14E-1	3.13E+1	4.14E-5	8.60E-1
Xe-133m	5.07E+0	5.90E+2	2.18E-2	9.55E-1	1.26E-6	2.30E-2
Xe-135	4.40E+1	3.56E+3	1.31E-1	5.75E+0	7.60E-6	1.20E+0
Xe-135m	7.55E+1	5.23E-3	1.93E-7	8.46E-6	1.12E-11	3.04E-6
Xe-138	2.13E+2	6.45E-3	2.37E-7	1.04E-5	1.38E-11	1.06E-5
Y-90	7.03E-1	4.30E-4	1.58E-8	6.96E-7	9.19E-13	2.33E-9
Y-91	9.62E-1	5.86E-3	2.16E-7	9.48E-6	1.25E-11	4.34E-8
Y-92	4.81E+1	2.28E-3	8.39E-8	3.68E-6	4.87E-12	8.43E-7
Y-93	1.78E+1	3.31E-3	1.22E-7	5.36E-6	7.08E-12	4.53E-7
Zr-95	1.33E+2	8.21E-3	3.03E-7	1.33E-5	1.75E-11	8.42E-6
Zr-97	3.34E+1	6.39E-3	2.35E-7	1.03E-5	1.36E-11	1.64E-6
		2.71E+04	100.00%	4.39E+01	5.80E-5	**8.05**
				4.39E+1		**mrem**

Given a radiation effluent monitor reading of 43.9 μCi/cm^3, and the assumptions of the scenario, the EDE value is 8.05 mrem.

Spreadsheet cases are run for all four release points. See Section 2.0 for results.

7.4 CEDE and CDE Thyroid

For the example CEDE and CDE Thyroid calculation, the release point is the Reactor Building at five hours since shutdown, and a gross concentration of 1.22E-2 µCi/cc, with a Secondary Containment Holdup time of 0.5 hours per Design Input 5.7 (this concentration was determined iteratively to produce 49.8 mrem Thyroid CDE).

In Table 16, the columns labeled "h_{T50i}Thyroid mrem/µCi" and "h_{E50i} CEDE mrem/µCi" are the dose factors developed in Section 7.1.

The column labeled "Depleted Mix Ci/MWTh" is the "Release Ci/MWTh" calculated above in Section 7.2 for each isotope.

The "Fraction" column determines the fraction each isotope contributes to the gross activity, and is used to scale the activity for each isotope.

The column "x_{iv} Release Conc. µCi/cm^3" contains a calculation that scales the "Depleted Mix" column to a user entered gross concentration based on the "Fraction" and is the variable x_{iv} in the equation below. In this case, the gross concentration entered was 1.22E-2 µCi/cc.

Values in the "x_{ir} Receptor Conc. µCi/cm^3" column are calculated by multiplying the release concentration by the applicable dispersion factor, the volume of the release, and requisite conversion factors. The basic equation from Section 6.8:

$$x_{ir} = \quad x_{iv} * v * \left(\frac{X}{Q}\right)$$

For isotope I-131, an example is presented:

x_{iv} Release Conc.		Flow						(X/Q)			Receptor Conc.	
1.63E-04	µCi	93,000	~~ft³~~	2.83E-02	~~m³~~	1	~~min~~	3.90E-06	~~sec~~	=	2.79E-08	µCi
	cm³		~~min~~	1	~~ft³~~	60	~~sec~~		~~m³~~			cm³

Where:

v = 93,000 ft^3/min is the rated flow from the Reactor Building from Design Input 5.8.

(X/Q) = 3.90E-06 is the Particulate and Iodine dispersion coefficient for the Reactor Building from Design Input 5.8.

Values in the column labeled "Inhalation Thyroid Dose mrem" are calculated by multiplying the following factors: concentration at the receptor, the breathing rate, the time, and the dose conversion factor. The basic equation is shown in Section 6.8.

$$Dose = \sum_i (x_{ir} * B * t * h_{T50i})$$

For isotope I-131, an example is presented:

x_{ir} Receptor Conc.		Time		B Breathing Rate		h_{T50i} Thyroid			Inhalation Thyroid Dose	
2.79E-08	~~µCi~~	1	~~hr~~	1.20E+06	~~cm^3~~	1.08E+03	mrem	=	3.62E+01	mrem
	~~cm^3~~				~~hr~~		~~µCi~~			

Where:

h_{T50i} is the thyroid dose factor for each isotope from Section 7.1.

B = 1.20E+06 cm^3/hr is the breathing rate. This value is equal to 3.33E-4 m^3/sec from Design Input 5.9.

Values in the "Inhalation CEDE Dose mrem" column are calculated by multiplying the following factors: concentration at the receptor, the breathing rate, the time, and the dose conversion factor. The basic equation comes from Section 6.9.

$$Dose = \sum_i (x_{ir} * B * t * h_{E50i})$$

For isotope I-131, an example is presented:

x_{ir} Receptor Conc		Time		B Breathing Rate		h_{E50i} CEDE			Inhalation CEDE Dose	
2.79E-08	~~µCi~~	1	~~hr~~	1.20E+06	~~cm^3~~	3.29E+01	mrem	=	1.10E+00	mrem
	~~cm^3~~				~~hr~~		~~µCi~~			

For ease of comparison, the table row for I-131 is shown here:

Nuclide	h_{T50i} Thyroid mrem/µCi	h_{E50i} CEDE mrem/µCi	Depleted Mix Ci/MWTh	Fraction	x_{iv} Release Conc. µCi/cm^3	x_{ir} Receptor Conc. µCi/cm^3	Inhalation Thyroid Dose mrem	Inhalation CEDE Dose mrem
I-131	1.08E+3	3.29E+1	3.89E+2	1.34E-2	1.63E-4	2.79E-8	3.62E+1	1.10E+0

Table 16 – Inhalation Thyroid and CEDE Dose for Reactor Building

Nuclide	h_{T50i} Thyroid mrem/µCi	h_{E50i} CEDE mrem/µCi	Depleted Mix Ci/MWTh	Fraction	x_{iv} Release Conc. µCi/cm^3	x_{ir} Receptor Conc. µCi/cm^3	Inhalation Thyroid Dose mrem	Inhalation CEDE Dose mrem
Ba-139	8.88E-3	1.72E-1	2.84E+0	9.76E-5	1.19E-6	2.04E-10	2.17E-6	4.20E-5
Ba-140	9.47E-1	3.74E+0	3.49E+1	1.20E-3	1.46E-5	2.50E-9	2.85E-3	1.12E-2
Ce-141	1.71E-1	8.95E+0	8.10E-1	2.78E-5	3.40E-7	5.82E-11	1.19E-5	6.25E-4
Ce-143	4.48E-2	3.39E+0	6.68E-1	2.30E-5	2.80E-7	4.79E-11	2.58E-6	1.95E-4
Ce-144	6.96E+0	3.74E+2	6.56E-1	2.25E-5	2.75E-7	4.71E-11	3.93E-4	2.11E-2

Nuclide	h_{T50i} Thyroid $\frac{mrem}{\mu Ci}$	h_{E50i} CEDE $\frac{mrem}{\mu Ci}$	Depleted Mix $\frac{Ci}{MWTh}$	Fraction	x_{iv} Release Conc. $\frac{\mu Ci}{cm^3}$	x_{ir} Receptor Conc. $\frac{\mu Ci}{cm^3}$	Inhalation Thyroid Dose mrem	Inhalation CEDE Dose mrem
Cm-242	3.48E+0	1.73E+4	8.30E-3	2.85E-7	3.48E-9	5.96E-13	2.49E-6	1.23E-2
Cs-134	4.11E+1	4.63E+1	6.10E+1	2.10E-3	2.56E-5	4.38E-9	2.16E-1	2.43E-1
Cs-136	6.40E+0	7.33E+0	1.91E+1	6.57E-4	8.02E-6	1.37E-9	1.05E-2	1.21E-2
Cs-137	2.93E+1	3.19E+1	4.22E+1	1.45E-3	1.77E-5	3.03E-9	1.07E-1	1.16E-1
I-131	1.08E+3	3.29E+1	3.89E+2	1.34E-2	1.63E-4	2.79E-8	3.62E+1	1.10E+0
I-132	6.44E+0	3.81E-1	1.27E+2	4.38E-3	5.34E-5	9.15E-9	7.07E-2	4.18E-3
I-133	1.80E+2	5.85E+0	6.80E+2	2.34E-2	2.85E-4	4.88E-8	1.05E+1	3.43E-1
I-134	1.07E+0	1.31E-1	1.70E+1	5.83E-4	7.12E-6	1.22E-9	1.56E-3	1.92E-4
I-135	3.13E+1	1.23E+0	4.54E+2	1.56E-2	1.91E-4	3.26E-8	1.23E+0	4.81E-2
Kr-83m	0.00E+0	0.00E+0	1.68E+2	5.79E-3	7.06E-5	1.21E-8	0.00E+0	0.00E+0
Kr-85	0.00E+0	0.00E+0	1.02E+2	3.50E-3	4.27E-5	7.32E-9	0.00E+0	0.00E+0
Kr-85m	0.00E+0	0.00E+0	1.05E+3	3.59E-2	4.38E-4	7.50E-8	0.00E+0	0.00E+0
Kr-87	0.00E+0	0.00E+0	2.96E+2	1.02E-2	1.24E-4	2.12E-8	0.00E+0	0.00E+0
Kr-88	0.00E+0	0.00E+0	1.83E+3	6.30E-2	7.69E-4	1.32E-7	0.00E+0	0.00E+0
La-140	4.51E-1	4.85E+0	3.34E-1	1.15E-5	1.40E-7	2.40E-11	1.30E-5	1.39E-4
La-141	3.48E-2	5.81E-1	1.33E-1	4.58E-6	5.58E-8	9.55E-12	3.99E-7	6.66E-6
La-142	3.23E-2	2.53E-1	3.29E-2	1.13E-6	1.38E-8	2.36E-12	9.17E-8	7.18E-7
Mo-99	4.33E-1	3.96E+0	4.66E+0	1.60E-4	1.95E-6	3.35E-10	1.74E-4	1.59E-3
Nb-95	1.32E+0	5.81E+0	3.32E-1	1.14E-5	1.39E-7	2.39E-11	3.79E-5	1.66E-4
Nd-147	7.18E-2	6.85E+0	1.28E-1	4.40E-6	5.37E-8	9.19E-12	7.92E-7	7.55E-5
Np-239	2.82E-2	2.51E+0	9.92E+0	3.41E-4	4.16E-6	7.12E-10	2.41E-5	2.14E-3
Pr-143	6.22E-9	8.10E+0	2.91E-1	9.99E-6	1.22E-7	2.09E-11	1.56E-13	2.03E-4
Pu-241	4.59E-2	8.25E+3	7.90E-2	2.71E-6	3.31E-8	5.67E-12	3.12E-7	5.61E-2
Rb-86	4.92E+0	6.62E+0	6.81E-1	2.34E-5	2.86E-7	4.89E-11	2.89E-4	3.89E-4
Rh-105	9.51E-2	9.55E-1	2.36E+0	8.11E-5	9.90E-7	1.69E-10	1.93E-5	1.94E-4
Ru-103	2.21E+0	8.95E+0	4.01E+0	1.38E-4	1.68E-6	2.88E-10	7.63E-4	3.09E-3
Ru-105	5.55E-2	4.55E-1	1.30E+0	4.47E-5	5.45E-7	9.33E-11	6.21E-6	5.09E-5
Ru-106	5.07E+1	4.77E+2	1.44E+0	4.94E-5	6.02E-7	1.03E-10	6.27E-3	5.90E-2
Sb-127	5.55E-1	6.03E+0	4.27E+0	1.47E-4	1.79E-6	3.06E-10	2.04E-4	2.22E-3
Sb-129	7.66E-2	6.44E-1	7.32E+0	2.52E-4	3.07E-6	5.25E-10	4.83E-5	4.06E-4
Sr-89	1.54E+0	4.14E+1	1.78E+1	6.12E-4	7.47E-6	1.28E-9	2.36E-3	6.36E-2
Sr-90	9.77E+0	1.30E+3	1.77E+0	6.09E-5	7.43E-7	1.27E-10	1.49E-3	1.98E-1
Sr-91	1.51E-1	1.66E+0	1.55E+1	5.33E-4	6.50E-6	1.11E-9	2.02E-4	2.22E-3
Sr-92	8.10E-2	8.07E-1	6.69E+0	2.30E-4	2.81E-6	4.80E-10	4.67E-5	4.65E-4
Tc-99m	1.85E-1	3.26E-2	2.28E+0	7.83E-5	9.55E-7	1.64E-10	3.64E-5	6.39E-6
Te-127	2.39E-2	3.18E-1	3.02E+0	1.04E-4	1.27E-6	2.17E-10	6.22E-6	8.28E-5
Te-127m	8.84E-1	2.15E+1	7.35E-1	2.53E-5	3.08E-7	5.28E-11	5.60E-5	1.36E-3
Te-129	6.03E-3	8.95E-2	7.70E-1	2.65E-5	3.23E-7	5.53E-11	4.00E-7	5.94E-6
Te-129m	1.46E+0	2.39E+1	3.10E+0	1.07E-4	1.30E-6	2.23E-10	3.90E-4	6.39E-3
Te-131m	1.34E+2	6.40E+0	8.93E+0	3.07E-4	3.75E-6	6.41E-10	1.03E-1	4.93E-3
Te-132	2.32E+2	9.44E+0	6.76E+1	2.32E-3	2.83E-5	4.85E-9	1.35E+0	5.49E-2
Xe-131m	0.00E+0	0.00E+0	1.32E+2	4.55E-3	5.55E-5	9.49E-9	0.00E+0	0.00E+0
Xe-133	0.00E+0	0.00E+0	1.94E+4	6.66E-1	8.12E-3	1.39E-6	0.00E+0	0.00E+0
Xe-133m	0.00E+0	0.00E+0	5.90E+2	2.03E-2	2.48E-4	4.24E-8	0.00E+0	0.00E+0
Xe-135	0.00E+0	0.00E+0	3.56E+3	1.22E-1	1.49E-3	2.55E-7	0.00E+0	0.00E+0
Xe-135m	0.00E+0	0.00E+0	5.23E-3	1.80E-7	2.19E-9	3.75E-13	0.00E+0	0.00E+0
Xe-138	0.00E+0	0.00E+0	6.45E-3	2.22E-7	2.70E-9	4.63E-13	0.00E+0	0.00E+0
Y-90	3.52E-2	8.44E+0	1.72E-2	5.92E-7	7.22E-9	1.24E-12	5.22E-8	1.25E-5
Y-91	4.07E-1	4.88E+1	2.34E-1	8.06E-6	9.83E-8	1.68E-11	8.22E-6	9.86E-4
Y-92	1.37E-2	7.81E-1	9.11E-2	3.13E-6	3.82E-8	6.54E-12	1.07E-7	6.13E-6

Nuclide	h_{T50i} Thyroid mrem/µCi	h_{E50i} CEDE mrem/µCi	Depleted Mix Ci/MWTh	Fraction	x_{iv} Release Conc. µCi/cm³	x_{ir} Receptor Conc. µCi/cm³	Inhalation Thyroid Dose mrem	Inhalation CEDE Dose mrem
Y-93	1.87E-2	2.15E+0	1.33E-1	4.56E-6	5.56E-8	9.52E-12	2.14E-7	2.46E-5
Zr-95	5.33E+0	2.36E+1	3.28E-1	1.13E-5	1.38E-7	2.36E-11	1.51E-4	6.69E-4
Zr-97	3.54E-1	4.33E+0	2.55E-1	8.78E-6	1.07E-7	1.83E-11	7.78E-6	9.53E-5
			2.91E+4	100.00%	1.22E-2 **1.22E-2**	2.09E-6	**50 mrem Thyroid**	**2.37 mrem CEDE**

Given a radiation effluent monitor reading of 1.22E-2 µCi/cm³, and the assumptions of the scenario, the CDE thyroid value is 50 mrem and the CEDE is 2.37 mrem.

Spreadsheet cases are run for all four release points. See Section 2.0 for results.

7.5 Resultant Dose Summary

A single spreadsheet was used to calculate EDE, CEDE, and thyroid CDE. With the given source term, when the user changes the effluent gross concentration value, the spreadsheet calculates resultant doses.

Results and variables for the reactor building case are shown below. As can be seen here, an effluent release rate of 1.22E-02 µCi/cc at the Reactor Building will result in an offsite dose of approximately 50 mrem CDE thyroid. This value corresponds to the new RA1 EAL entry threshold of 50 mrem CDE thyroid.

Dose totals are taken from the tabular spreadsheet data presented on the preceding pages.

Inhalation CEDE:	**2.37**	**mrem**
Submersion EDE:	**0.39**	**mrem**
TEDE :	**2.76**	**mrem**
Inhalation Thyroid CDE:	**49.8**	**mrem**

Release Point:	**Reactor Building**			**SBGT ?:**	**off**	
Effluent Conc.:	**1.22E-02**	µCi/cc		**Release Flow CFM:**	**93,000**	
Release: Hrs. since Rx. Shutdown:	**5**			**Hrs. Core Uncovered:**	**1**	
Exposure Time (hrs.):	**1**			**Secondary Containment Holdup Hrs.:**	**0.5**	
Hours w/ Sprays On:	**2**			cm3 per ft3:	0.0283168	
Submersion X/Q:	**4.30E-06**	sec/m^3		**Inhalation X/Q:**	**3.90E-06**	sec/m$_3$
Breathing Rate	**3.33E-4**	m^3/sec	=	**1.20E+6**	cm^3/hr	

Spreadsheet cases are run for all four release points and for decay times of five hours.

Cases were also run for all four release points for decay times of 36 hours in consideration of EAL entry thresholds that are mode dependent.

The output for all release points and decay times are shown in Appendix 1.

See Section 2.0 for results.

8.0 Computer Software

No computer software is used in this calculation.

9.0 Impact Assessment

This calculation is based on "realistic" assumptions for the purpose of declaring EALs, rather than typical conservative "bounding" type design basis analyses. The calculation documents the EAL threshold values for specific plan monitors to assist Operations and Emergency Response personnel in determining the new basis for EALs RA1, RS1, and RG1 in accordance with NEI 99-01 Rev. 6.

Turbine Building: Modes 1, 2, and 3

Inhalation CEDE:	2.38	mRem
Submersion EDE:	0.39	mRem
TEDE :	2.77	mRem
Inhalation Thyroid CDE:	50.0	mRem

Variables

Release Point:	Turbine Building		SBGT ?:	off	
Effluent Conc.:	1.58E-02	uCi/cc	Release Flow CFM:	72,000	
Release: Hrs. since Rx. Shutdown:	5		Hrs. Core Uncovered:	1	
Exposure Time (hrs.):	1		Secondary Containment Holdup Hrs.:	0.5	
Hours w/ Sprays On:	2		cm3 per ft3:	0.0283168	
Submersion X/Q:	4.30E-06	sec/m3	Inhalation X/Q:	3.90E-06	sec/m3

Breathing Rate	3.33E-4	m3/sec	=	1.20E+6	cm3/hr

Turbine Building: Modes 4 and 5

Inhalation CEDE:	2.59	mRem
Submersion EDE:	0.07	mRem
TEDE :	2.67	mRem
Inhalation Thyroid CDE:	49.7	mRem

Variables

Release Point:	Turbine Building		SBGT ?:	off	
Effluent Conc.:	1.30E-02	uCi/cc	Release Flow CFM:	72,000	
Release: Hrs. since Rx. Shutdown:	36		Hrs. Core Uncovered:	1	
Exposure Time (hrs.):	1		Secondary Containment Holdup Hrs.:	0.5	
Hours w/ Sprays On:	2		cm3 per ft3:	0.0283168	
Submersion X/Q:	4.30E-06	sec/m3	Inhalation X/Q:	3.90E-06	sec/m3
Breathing Rate	3.33E-4	m3/sec	=	1.20E+6	cm3/hr

Reactor Building: Modes 1, 2, and 3

Inhalation CEDE:	2.37	mRem
Submersion EDE:	0.39	mRem
TEDE :	2.76	mRem
Inhalation Thyroid CDE:	49.8	mRem

Variables

Release Point:	Reactor Building		SBGT ?:	off	
Effluent Conc.:	1.22E-02	uCi/cc	Release Flow CFM:	93,000	
Release: Hrs. since Rx. Shutdown:	5		Hrs. Core Uncovered:	1	
Exposure Time (hrs.):	1		Secondary Containment Holdup Hrs.:	0.5	
Hours w/ Sprays On:	2		cm3 per ft3:	0.0283168	
Submersion X/Q:	4.30E-06	sec/m3	Inhalation X/Q:	3.90E-06	sec/m3
Breathing Rate	3.33E-4	m3/sec	=	1.20E+6	cm3/hr

Reactor Building: Modes 4 and 5

Inhalation CEDE:	2.60	mRem
Submersion EDE:	0.07	mRem
TEDE :	2.68	mRem
Inhalation Thyroid CDE:	49.9	mRem

Variables

Release Point:	Reactor Building		SBGT ?:	off	
Effluent Conc.:	1.01E-02	uCi/cc	Release Flow CFM:	93,000	
Release: Hrs. since Rx. Shutdown:	36		Hrs. Core Uncovered:	1	
Exposure Time (hrs.):	1		Secondary Containment Holdup Hrs.:	0.5	
Hours w/ Sprays On:	2		cm3 per ft3:	0.0283168	
Submersion X/Q:	4.30E-06	sec/m3	Inhalation X/Q:	3.90E-06	sec/m3
Breathing Rate	3.33E-4	m3/sec	=	1.20E+6	cm3/hr

Offgas Stack: Modes 1, 2, and 3

Inhalation CEDE:	1.96	mRem
Submersion EDE:	8.05	mRem
TEDE :	10.00	mRem
Inhalation Thyroid CDE:	41.1	mRem

Variables

Release Point:	Offgas Stack		SBGT ?:	on	
Effluent Conc.:	4.39E+01	uCi/cc	Release Flow CFM:	10,000	
Release: Hrs. since Rx. Shutdown:	5		Hrs. Core Uncovered:	1	
Exposure Time (hrs.):	1		Secondary Containment Holdup Hrs.:	<0.5	
Hours w/ Sprays On:	2		cm3 per ft3:	0.0283168	
Submersion X/Q:	2.80E-07	sec/m3	Inhalation X/Q:	3.10E-07	sec/m3
Breathing Rate	3.33E-4	m3/sec	=	1.20E+6	cm3/hr

Offgas Stack: Modes 4 and 5

Inhalation CEDE:	2.61	mRem
Submersion EDE:	1.41	mRem
TEDE :	4.02	mRem
Inhalation Thyroid CDE:	50.0	mRem

Variables

Release Point:	Offgas Stack		SBGT ?:	on	
Effluent Conc.:	4.52E+01	uCi/cc	Release Flow CFM:	10,000	
Release: Hrs. since Rx. Shutdown:	36		Hrs. Core Uncovered:	1	
Exposure Time (hrs.):	1		Secondary Containment Holdup Hrs.:	<0.5	
Hours w/ Sprays On:	2		cm3 per ft3:	0.0283168	
Submersion X/Q:	2.80E-07	sec/m3	Inhalation X/Q:	3.10E-07	sec/m3
Breathing Rate	3.33E-4	m3/sec	=	1.20E+6	cm3/hr

LLRPSF: Modes 1, 2, and 3

Inhalation CEDE:	2.37	mRem
Submersion EDE:	0.39	mRem
TEDE :	2.76	mRem
Inhalation Thyroid CDE:	49.7	mRem

Variables

Release Point:	LLRPSF		SBGT ?:	off	
Effluent Conc.:	1.51E-02	uCi/cc	Release Flow CFM:	75,000	
Release: Hrs. since Rx. Shutdown:	5		Hrs. Core Uncovered:	1	
Exposure Time (hrs.):	1		Secondary Containment Holdup Hrs.:	0.5	
Hours w/ Sprays On:	2		cm3 per ft3:	0.0283168	
Submersion X/Q:	4.30E-06	sec/m3	Inhalation X/Q:	3.90E-06	sec/m3
Breathing Rate	3.33E-4	m3/sec	=	1.20E+6	cm3/hr

LLRPSH: Modes 4 and 5

Inhalation CEDE:	2.60	mRem
Submersion EDE:	0.07	mRem
TEDE :	2.67	mRem
Inhalation Thyroid CDE:	49.8	mRem

Variables

Release Point:	LLRPSF		SBGT ?:	off	
Effluent Conc.:	1.25E-02	uCi/cc	Release Flow CFM:	75,000	
Release: Hrs. since Rx. Shutdown:	36		Hrs. Core Uncovered:	1	
Exposure Time (hrs.):	1		Secondary Containment Holdup Hrs.:	0.5	
Hours w/ Sprays On:	2		cm3 per ft3:	0.0283168	
Submersion X/Q:	4.30E-06	sec/m3	Inhalation X/Q:	3.90E-06	sec/m3
Breathing Rate	3.33E-4	m3/sec	=	1.20E+6	cm3/hr

CHECKLIST ITEMS[1]	YES	NO	N/A
GENERAL REQUIREMENTS			
1. If the calculation is being performed to a client procedure, is the procedure being used the latest revision?	☐	☐	☒
The calculation is being prepared to ENERCON's procedures.			
2. Are the proper forms being used and are they the latest revision?	☒	☐	☐
3. Have the appropriate client review forms/checklists been completed?	☐	☐	☒
The calculation is being prepared to ENERCON's procedures.			
4. Are all pages properly identified with a calculation number, calculation revision and page number consistent with the requirements of the client's procedure?	☒	☐	☐
5. Is all information legible and reproducible?	☒	☐	☐
6. Is the calculation presented in a logical and orderly manner?	☒	☐	☐
7. Is there an existing calculation that should be revised or voided?	☐	☒	☐
This is a new calculation to support implementing NEI 99-01 Rev. 6			
8. Is it possible to alter an existing calculation instead of preparing a new calculation for this situation?	☐	☒	☐
9. If an existing calculation is being used for design inputs, are the key design inputs, assumptions and engineering judgments used in that calculation valid and do they apply to the calculation revision being performed.	☐	☒	☐
10. Is the format of the calculation consistent with applicable procedures and expectations?	☒	☐	☐
11. Were design input/output documents properly updated to reference this calculation?	☐	☐	☒
12. Can the calculation logic, methodology and presentation be properly understood without referring back to the originator for clarification?	☒	☐	☐
OBJECTIVE AND SCOPE			
13. Does the calculation provide a clear concise statement of the problem and objective of the calculation?	☒	☐	☐
14. Does the calculation provide a clear statement of quality classification?	☒	☐	☐
15. Is the reason for performing and the end use of the calculation understood?	☒	☐	☐
16. Does the calculation provide the basis for information found in the plant's license basis?	☒	☐	☐
17. If so, is this documented in the calculation?	☒	☐	☐
18. Does the calculation provide the basis for information found in the plant's design basis documentation?	☐	☒	☐

CHECKLIST ITEMS[1]		YES	NO	N/A
19.	If so, is this documented in the calculation?	☐	☐	☒
20.	Does the calculation otherwise support information found in the plant's design basis documentation?	☐	☒	☐
21.	If so, is this documented in the calculation?	☐	☐	☒
22.	Has the appropriate design or license basis documentation been revised, or has the change notice or change request documents being prepared for submittal?	☐	☐	☒
DESIGN INPUTS				
23.	Are design inputs clearly identified?	☒	☐	☐
24.	Are design inputs retrievable or have they been added as attachments?	☒	☐	☐
25.	If Attachments are used as design inputs or assumptions are the Attachments traceable and verifiable?	☐	☐	☒
26.	Are design inputs clearly distinguished from assumptions?	☒	☐	☐
27.	Does the calculation rely on Attachments for design inputs or assumptions? If yes, are the attachments properly referenced in the calculation?	☐	☒	☐
28.	Are input sources (including industry codes and standards) appropriately selected and are they consistent with the quality classification and objective of the calculation?	☒	☐	☐
29.	Are input sources (including industry codes and standards) consistent with the plant's design and license basis?	☒	☐	☐
30.	If applicable, do design inputs adequately address actual plant conditions?	☒	☐	☐
31.	Are input values reasonable and correctly applied?	☒	☐	☐
32.	Are design input sources approved?	☒	☐	☐
33.	Does the calculation reference the latest revision of the design input source?	☒	☐	☐
34.	Were all applicable plant operating modes considered?	☒	☐	☐
ASSUMPTIONS				
35.	Are assumptions reasonable/appropriate to the objective?	☒	☐	☐
36.	Is adequate justification/basis for all assumptions provided?	☒	☐	☐
37.	Are any engineering judgments used?	☐	☒	☐
38.	Are engineering judgments clearly identified as such?	☐	☐	☒
39.	If engineering judgments are utilized as design inputs, are they reasonable and can they be quantified or substantiated by reference to site or industry standards, engineering principles, physical laws or other appropriate criteria?	☐	☐	☒

CHECKLIST ITEMS[1]		YES	NO	N/A
METHODOLOGY				
40.	Is the methodology used in the calculation described or implied in the plant's licensing basis?	☐	☒	☐
41.	If the methodology used differs from that described in the plant's licensing basis, has the appropriate license document change notice been initiated?	☐	☐	☒
42.	Is the methodology used consistent with the stated objective?	☒	☐	☐
43.	Is the methodology used appropriate when considering the quality classification of the calculation and intended use of the results?	☒	☐	☐
BODY OF CALCULATION				
44.	Are equations used in the calculation consistent with recognized engineering practice and the plant's design and license basis?	☒	☐	☐
45.	Is there reasonable justification provided for the use of equations not in common use?	☐	☐	☒
46.	Are the mathematical operations performed properly and documented in a logical fashion?	☒	☐	☐
47.	Is the math performed correctly?	☒	☐	☐
48.	Have adjustment factors, uncertainties and empirical correlations used in the analysis been correctly applied?	☒	☐	☐
49.	Has proper consideration been given to results that may be overly sensitive to very small changes in input?	☒	☐	☐
SOFTWARE/COMPUTER CODES				
50.	Are computer codes or software languages used in the preparation of the calculation?	☐	☒	☐
51.	Have the requirements of CSP 3.09 for use of computer codes or software languages, including verification of accuracy and applicability been met?	☐	☐	☒
52.	Are the codes properly identified along with source vendor, organization, and revision level?	☐	☐	☒
53.	Is the computer code applicable for the analysis being performed?	☐	☐	☒
54.	If applicable, does the computer model adequately consider actual plant conditions?	☐	☐	☒
55.	Are the inputs to the computer code clearly identified and consistent with the inputs and assumptions documented in the calculation?	☐	☐	☒
56.	Is the computer output clearly identified?	☐	☐	☒
57.	Does the computer output clearly identify the appropriate units?	☐	☐	☒

CHECKLIST ITEMS[1]	YES	NO	N/A
58. Are the computer outputs reasonable when compared to the inputs and what was expected?	☐	☐	☒
59. Was the computer output reviewed for ERROR or WARNING messages that could invalidate the results?	☐	☐	☒
RESULTS AND CONCLUSIONS			
60. Is adequate acceptance criteria specified?	☐	☐	☒
61. Are the stated acceptance criteria consistent with the purpose of the calculation, and intended use?	☒	☐	☐
62. Are the stated acceptance criteria consistent with the plant's design basis, applicable licensing commitments and industry codes, and standards?	☒	☐	☐
63. Do the calculation results and conclusions meet the stated acceptance criteria?	☒	☐	☐
64. Are the results represented in the proper units with an appropriate tolerance, if applicable?	☒	☐	☐
65. Are the calculation results and conclusions reasonable when considered against the stated inputs and objectives?	☒	☐	☐
66. Is sufficient conservatism applied to the outputs and conclusions?	☒	☐	☐
67. Do the calculation results and conclusions affect any other calculations?	☐	☒	☐
68. If so, have the affected calculations been revised?	☐	☐	☒
69. Does the calculation contain any conceptual, unconfirmed or open assumptions requiring later confirmation?	☐	☒	☐
70. If so, are they properly identified?	☐	☐	☒
DESIGN REVIEW			
71. Have alternate calculation methods been used to verify calculation results?	☐	☐	☒
No, a Design Review was performed.			

Note:

1. Where required, provide clarification/justification for answers to the questions in the space provided below each question. An explanation is required for any questions answered as "No' or "N/A".

Originator: Ryan Skaggs — 12/14/17

Print Name and Sign — Date

BEFORE

SF/L-4 ☐ Spent Fuel Pool level drops to **16.36 ft**

↓

SF/L-5 ☐ Operate Spent Fuel Pool sprays (SAMP 712).

- ☛ Use <u>only</u> systems <u>not</u> required for adequate core cooling.

DISCUSSION

If spent fuel pool level cannot be controlled using alternate or external makeup sources, sprays are used to add water to the spent fuel pool, cool exposed bundles, and reduce radioactivity releases. However, spray operation may damage electrical equipment and flood lower elevations of the secondary containment, complicating implementation of other emergency response strategies, and runoff from sprays could spread radioactivity release. Use of sprays is therefore delayed until it is determined that spent fuel pool level cannot be maintained above the top of the fuel racks. As long as the spent fuel assemblies are covered with water , the fuel will not overheat and efforts should focus on providing sufficient makeup flow to keep the assemblies submerged.

The lowest measurable spent fuel pool level using the wide range instrument is 16.16 ft., approximately one foot above the top of the spent fuel racks. The action level in SF/L-4 corresponds to NEI 12-02 Level 3, the level at which fuel remains covered but actions to implement make-up water addition should no longer be deferred. The "before" condition permits appropriate anticipatory action based on the spent fuel pool leakage rate, radiation levels, available resources, and the time required to place sprays in service. Steps to prepare spray equipment for use should be initiated while radiation levels permit access to the refueling floor and timed to optimize use of available resources.

As in Steps SF/T-3 and SF/L-3, available spray sources may be alternated between RPV injection and spent fuel pool spray modes as long as adequate core cooling can be maintained, but maintaining adequate core cooling takes precedence over spent fuel pool cooling (refer to the discussions of Steps SF/T-3 and SF/L-3 above).

Development of EAL Threshold values from NEE-323-CALC-005

Calculated values are provided in Calc-005 as shown below.

Table 3 – Recommended RA1, RS1, and RG1 EAL Thresholds (Modes 1, 2, 3)

Release Point	RA1 µCi/cc	RS1 µCi/cc	RG1 µCi/cc
Turbine Building	1.58E-02	1.58E-01	1.58E+00
Reactor Building	1.22E-02	1.22E-01	1.22E+00
Offgas Stack	4.39E+01	4.39E+02	4.39E+03
LLRPSF	1.51E-02	1.51E-01	1.51E+00*

Table 4 – Recommended RA1, RS1, and RG1 EAL Thresholds (Modes 4, 5)

Release Point	RA1 µCi/cc	RS1 µCi/cc	RG1 µCi/cc
Turbine Building	1.30E-02	1.30E-01	1.30E+00
Reactor Building	1.01E-02	1.01E-01	1.01E+00
Offgas Stack	4.52E+01	4.52E+02	4.52E+03
LLRPSF	1.25E-02	1.25E-01	1.25E+00*

* Per Design Input 5.8 the results in EAL threshold values exceed the range of the monitor.

The following table of threshold values was developed for use in the DAEC EAL scheme by averaging the separate Mode 1-3 and Mode 4-5 thresholds from Calc-005, and then rounding the average values for ease of EAL evaluator use, as well as to provide a step-wise progression through the emergency classification. Resulting values are shown in the Alert, SAE, and GE columns below:

	Monitor	GE	SAE	Alert	NOUE
Gaseous	Reactor Building ventilation rad monitor (Kaman 3/4, 5/6, 7/8)	1.0E+00 uci/cc	1.0E-01 uci/cc	1.0E-02 uci/cc	1.0E-03 uci/cc
	Turbine Building ventilation rad monitor (Kaman 1/2)	1.0E+00 uci/cc	1.0E-01 uci/cc	1.0E-02 uci/cc	1.0E-03 uci/cc
	Offgas Stack rad monitor (Kaman 9/10)	4.5E+03 uci/cc	4.5E+02 uci/cc	4.5E+01 uci/cc	2.0E-01 uci/cc
	LLRPSF rad monitor (Kaman 12)	---*	1.0E-01 uci/cc	1.0E-02 uci/cc	1.0E-03 uci/cc

ENERCON *Excellence—Every project. Every day.*	CALCULATION COVER SHEET	**CALC NO.** NEE-323-CALC-005
		REV. 00
		PAGE NO. 1 of 34

Title:	Revised Gaseous Radiological EALs per NEI 99-01 Rev. 06	**Client:** Duane Arnold Energy Center
		Project Identifier: NEE-323

Item	Cover Sheet Items	Yes	No
1	Does this calculation contain any open assumptions, including preliminary information, that require confirmation? (If **YES**, identify the assumptions.)	☐	☒
2	Does this calculation serve as an "Alternate Calculation"? (If **YES**, identify the design verified calculation.) **Design Verified Calculation No.** _____	☐	☒
3	Does this calculation supersede an existing Calculation? (If **YES**, identify the design verified calculation.) **Superseded Calculation No.** _____	☐	☒

Scope of Revision:

Initial Issue

Revision Impact on Results:

Initial Issue

Study Calculation ☐ **Final Calculation** ☒

Safety-Related ☐ **Non-Safety-Related** ☒

(Print Name and Sign)

Originator: Ryan Skaggs	**Date:** **12/14/17**
Design Verifier[1] **(Reviewer if NSR):** Jay Bhatt	**Date:** **12/14/17**
Approver: Zachary Rose	**Date:** **12/14/17**

Note 1: For non-safety-related calculation, design verification can be substituted by review.

ENERCON Excellence—Every project. Every day.	CALCULATION REVISION STATUS SHEET	CALC NO. NEE-323-CALC-005
		REV. 00

CALCULATION REVISION STATUS

REVISION	DATE	DESCRIPTION
00	12/14/17	Initial Issue

PAGE REVISION STATUS

PAGE NO.	REVISION	PAGE NO.	REVISION
All	00		

APPENDIX/ATTACHMENT REVISION STATUS

APPENDIX NO.	NO. OF PAGES	REVISION NO.	ATTACHMENT NO.	NO. OF PAGES	REVISION NO.
A	8	00	1	4	00

TABLE OF CONTENTS

1.0 Purpose and Scope

The DAEC site is implementing new requirements of Revision 6 to the Document NEI 99-01, "Development of Emergency Action Levels for Non-Passive Reactors." One of the changes included in Revision 6 to NEI 99-01 is a new basis for the Emergency Action Level (EAL) RA1. The requirements for RS1 and RG1 did not change from NEI 99-01 Rev. 05 with the implementation of NEI 99-01, Rev. 06.

The following table is extracted from Section 6 of **Revision 6** to NEI 99-01:

ALERT	SITE AREA EMERGENCY	GENERAL EMERGENCY
AA1 Release of gaseous or liquid radioactivity resulting in offsite dose greater than 10 mrem TEDE or 50 mrem thyroid CDE. *Op. Modes: All*	**AS1** Release of gaseous radioactivity resulting in offsite dose greater than 100 mrem TEDE or 500 mrem thyroid CDE. *Op. Modes: All*	**AG1** Release of gaseous radioactivity resulting in offsite dose greater than 1,000 mrem TEDE or 5,000 mrem thyroid CDE. *Op. Modes: All*

AA1, AS1, AG1 compares to DAEC terminology RA1, RS1, RG1, respectively. This calculation determines the effluent radiation monitor readings that correspond to the RA1, RS1, and RG1 thresholds.

2.0 Summary of Results and Conclusions

The results below show the RA1 EAL release concentration thresholds and associated dose rates for each release point for a decay time of five hours and 36 hours. The highlighted dose indicates which threshold was met at the release concentration.

Table 1 – RA1 EAL Release Concentration Thresholds (Decay = 5 hours (Mode 1, 2, 3))

Release Point	Release Concentration μCi/cc	CEDE mrem	EDE mrem	TEDE mrem	CDE Thyroid mrem
Turbine Building	1.58E-02	2.38	0.39	2.77	50.0
Reactor Building	1.22E-02	2.37**	0.39	2.76	49.8**
Offgas Stack	4.39E+01	1.96	8.05*	10.00	41.1
Low-Level Radwaste Processing and Storage Facility (LLRPSF)	1.51E-02	2.37	0.39	2.76	49.7

* Calculation of this value was demonstrated in Section 7.3

** Calculation of this value was demonstrated in Section 7.4

Table 2 – RA1 EAL Release Concentration Thresholds (Decay = 36 hours (Mode 4, 5))

Release Point	Release Concentration μCi/cc	CEDE mrem	EDE mrem	TEDE mrem	CDE Thyroid mrem
Turbine Building	1.30E-02	2.59	0.07	2.67	49.7
Reactor Building	1.01E-02	2.60	0.07	2.68	49.9
Offgas Stack	4.52E+01	2.61	1.41	4.02	50.0
LLRPSF	1.25E-02	2.60	0.07	2.67	49.8

Resultant EAL thresholds:

The tables below show the release concentration threshold for RA1, RS1, and RG1 based on the results above for both a decay time of five hours and a decay time of 36 hours.

From Section 1.0:

RS1 thresholds are 10 times larger than those for RA1

RG1 thresholds are 100 times larger than those for RA1

Table 3 – Recommended RA1, RS1, and RG1 EAL Thresholds (Modes 1, 2, 3)

Release Point	RA1 μCi/cc	RS1 μCi/cc	RG1 μCi/cc
Turbine Building	1.58E-02	1.58E-01	1.58E+00
Reactor Building	1.22E-02	1.22E-01	1.22E+00
Offgas Stack	4.39E+01	4.39E+02	4.39E+03
LLRPSF	1.51E-02	1.51E-01	1.51E+00*

Table 4 – Recommended RA1, RS1, and RG1 EAL Thresholds (Modes 4, 5)

Release Point	RA1 μCi/cc	RS1 μCi/cc	RG1 μCi/cc
Turbine Building	1.30E-02	1.30E-01	1.30E+00
Reactor Building	1.01E-02	1.01E-01	1.01E+00
Offgas Stack	4.52E+01	4.52E+02	4.52E+03
LLRPSF	1.25E-02	1.25E-01	1.25E+00*

* Per Design Input 5.8 the results in EAL threshold values exceed the range of the monitor.

3.0 References

3.1 NEI 99-01, Revision 6, "Development of Emergency Action Levels for Non-Passive Reactors", Nuclear Energy Institute, November 2012.

3.2 NUREG-1940, RASCAL 4: Description of Models and Methods, United States Nuclear Regulatory Commission, Office of Nuclear Security and Incident Response, 2012.

3.3 NUREG-1940 Supplement 1, RASCAL 4.3: Description of Models and Methods, United States Nuclear Regulatory Commission, Office of Nuclear Security and Incident Response, 2015.

3.4 NUREG-1228, Source Term Estimation During Incident Response to Severe Nuclear Power Plant Accidents, United States Nuclear Regulatory Commission, Division of Operational Assessment, 1988.

3.5 NUREG-1465, Accident Source Terms for Light-Water Nuclear Power Plants, United States Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, 1995.

3.6 DAEC UFSAR, Chapter 15-0.

3.7 DAEC UFSAR, Chapter 15-2.

3.8 DAEC Offsite Dose Assessment Manual (ODAM).

3.9 Plant Chemistry Procedure PCP 8.3, Alarm Setpoints and Background Determination for KAMAN Normal Range Monitors.

3.10 DAEC Nuclear Station HRN-HRH Radiation Monitor Operation, Maintenance and Troubleshooting Manual, ©2000, by Engineering Solutions, 310 Luchana Drive, Litchfield Park, Arizona.

3.11 DAEC Emergency Plan, Section 'I', Rev. 27.

3.12 Federal Guidance Report No. 11, Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion and Ingestion Office of Radiation and Indoor Air, 1999.

3.13 Federal Guidance Report No. 12, External Exposure to Radionuclides in Air, Water, and Soil, 1993.

3.14 *Table of Nuclides, http://atom.kaeri.re.kr:8080/ton/index.html, retrieved 10/10/17.*

4.0 Assumptions

The following are assumptions about the receptor:

- No credit is taken for radiation shielding provided by structures.
- No decay in-transit is assumed during the time elapsed between the release point and the receptor.

Both of the above assumptions are acceptable because they will result in a higher dose to the receptor and conservatively lower thresholds.

5.0 Design Inputs

5.1 Core Inventory

The assumed isotopic mixture in Table 5 is taken from Table 1-1 of NUREG-1940.

The core inventory (curies per megawatts thermal) in the table is based on calculations made by the NRC staff in December 2003 using the SAS2H control module of SCALE (Standardized Computer Analyses for Licensing Evaluation), Version 4.4a.

Table 5 – Isotopic Mixture

NUCLIDE	CORE INVENTORY (Ci/MWt)	NUCLIDE	CORE INVENTORY (Ci/MWt)	NUCLIDE	CORE INVENTORY (Ci/MWt)
Ba-139	4.74E+04	La-141	4.33E+04	Te-127	2.36E+03
Ba-140	4.76E+04	La-142	4.21E+04	Te-127m	3.97E+02
Ce-141	4.39E+04	Mo-99	5.30E+04	Te-129	8.26E+03
Ce-143	4.00E+04	Nb-95	4.50E+04	Te-129m	1.68E+03
Ce-144*	3.54E+04	Nd-147	1.75E+04	Te-131m	5.41E+03
Cm-242	1.12E+03	Np-239	5.69E+05	Te-132	3.81E+04
Cs-134	4.70E+03	Pr-143	3.96E+04	Xe-131m	3.65E+02
Cs-136	1.49E+03	Pu-241	4.26E+03	Xe-133	5.43E+04
Cs-137*	3.25E+03	Rb-86	5.29E+01	Xe-133m	1.72E+03
I-131	2.67E+04	Rh-105	2.81E+04	Xe-135	1.42E+04
I-132	3.88E+04	Ru-103	4.34E+04	Xe-135m	1.15E+04
I-133	5.42E+04	Ru-105	3.06E+04	Xe-138	4.56E+04
I-134	5.98E+04	Ru-106*	1.55E+04	Y-90	2.45E+03
I-135	5.18E+04	Sb-127	2.39E+03	Y-91	3.17E+04
Kr-83m	3.05E+03	Sb-129	8.68E+03	Y-92	3.26E+04
Kr-85	2.78E+02	Sr-89	2.41E+04	Y-93	2.52E+04
Kr-85m	6.17E+03	Sr-90	2.39E+03	Zr-95	4.44E+04
Kr-87	1.23E+04	Sr-91	3.01E+04	Zr-97*	4.23E+04
Kr-88	1.70E+04	Sr-92	3.24E+04		
La-140	4.91E+04	Tc-99m	4.37E+04		

5.2 Release Fraction

Table 6 displays release fractions as a function of time taken from Table 1-4 which references Table 3-12 of NUREG-1465.

Table 6 – Release Fraction

NUCLIDE GROUP	BWR CORE INVENTORY RELEASE FRACTION		
	Cladding Failure (Gap Release Phase) (0.5-hour duration)	Core Melt Phase (In-Vessel Phase) (1.5-hour duration)	Postvessel Melt-Through Phase (Ex-Vessel Phase) (3.0-hour duration)
Noble gases (Kr, Xe)	0.05	0.95	0
Halogens (I, Br)	0.05	0.25	0.30
Alkali metals (Cs, Rb)	0.05	0.20	0.35
Tellurium group (Te, Sb, Se)	0	0.05	0.25
Barium, strontium (Ba, Sr)	0	0.02	0.1
Noble metals (Ru, Rh, Pd, Mo, Tc, Co)	0	0.0025	0.0025
Cerium group (Ce, Pu, Np)	0	0.0005	0.005
Lanthanides (La, Zr, Nd, Eu, Nb, Pm, Pr, Sm, Y, Cm, Am)	0	0.0002	0.005

*Reference: Table 3-12 from NUREG-1465.

5.3 Gaseous Dispersion Factors

The dispersion factors are taken from the ODAM Section 3.

Table 7 – Dispersion Factors

	Dose due to Plume/Submersion ODAM Sections 3.5.2.1 and 3.9	Organ Dose Due to Particulates and Iodine ODAM Section 3.8
Offgas Stack	2.8E-7 sec/m^3	3.1E-7 sec/m^3
Building Vents	4.3E-6 sec/m^3	3.9E-6 sec/m^3

5.4 Isotopic half-lives

Isotopic half-lives are taken from NUREG-1940, Supplement 1. For those isotopes missing from that list, denoted by *, half-lives were obtained from the following website which is maintained by the Korea Atomic Energy Research Institute:

http://atom.kaeri.re.kr:8080/ton/index.html

Table 8 contains the half-lives and calculated λ (lambda) values.

Table 8 – Half-lives and Decay Constants

Isotope	T 1/2	T 1/2 units	T 1/2 Hours	Decay Lambda hrs^{-1}
Ba-139	0.0574	days	1.38E+00	5.03E-01
Ba-140	12.7	days	3.05E+02	2.27E-03
Ce-141	32.5	days	7.80E+02	8.89E-04
Ce-143	1.38	days	3.31E+01	2.09E-02
Ce-144	284	days	6.82E+03	1.02E-04
Cm-242	163	days	3.91E+03	1.77E-04
Cs-134	753	days	1.81E+04	3.84E-05
Cs-136	13.1	days	3.14E+02	2.20E-03
Cs-137	11000	days	2.64E+05	2.63E-06
I-131	8.04	days	1.93E+02	3.59E-03
I-132	0.0958	days	2.30E+00	3.01E-01
I-133	0.867	days	2.08E+01	3.33E-02
I-134	0.0365	days	8.76E-01	7.91E-01
I-135	0.275	days	6.60E+00	1.05E-01
Kr-83m*	1.83	hours	1.83E+00	3.79E-01
Kr-85	3910	days	9.38E+04	7.39E-06
Kr-85m	0.187	days	4.49E+00	1.54E-01
Kr-87	0.053	days	1.27E+00	5.45E-01
Kr-88	0.118	days	2.83E+00	2.45E-01
La-140	1.68	days	4.03E+01	1.72E-02
La-141	0.164	days	3.94E+00	1.76E-01
La-142	0.0642	days	1.54E+00	4.50E-01
Mo-99	2.75	days	6.60E+01	1.05E-02
Nb-95	35.2	days	8.45E+02	8.20E-04
Nd-147	11	days	2.64E+02	2.63E-03
Np-239	2.36	days	5.66E+01	1.22E-02
Pr-143	13.6	days	3.26E+02	2.12E-03
Pu-241	5260	days	1.26E+05	5.49E-06
Rb-86	18.7	days	4.49E+02	1.54E-03
Rh-105	1.47	days	3.53E+01	1.96E-02
Ru-103	39.3	days	9.43E+02	7.35E-04
Ru-105	0.185	days	4.44E+00	1.56E-01
Ru-106	368	days	8.83E+03	7.85E-05
Sb-127	3.85	days	9.24E+01	7.50E-03
Sb-129*	4.4	hours	4.40E+00	1.58E-01
Sr-89	50.5	days	1.21E+03	5.72E-04
Sr-90	10600	days	2.54E+05	2.72E-06
Sr-91	0.396	days	9.50E+00	7.29E-02
Sr-92	0.113	days	2.71E+00	2.56E-01
Tc-99m	0.251	days	6.02E+00	1.15E-01
Te-127	0.39	days	9.36E+00	7.41E-02
Te-127m	109	days	2.62E+03	2.65E-04
Te-129	0.0483	days	1.16E+00	5.98E-01
Te-129m	33.6	days	8.06E+02	8.60E-04

Isotope	T 1/2	T 1/2 units	T 1/2 Hours	Decay Lambda hrs^{-1}
Te-131m	1.25	days	3.00E+01	2.31E-02
Te-132	3.26	days	7.82E+01	8.86E-03
Xe-131m*	11.934	days	2.86E+02	2.42E-03
Xe-133	5.25	days	1.26E+02	5.50E-03
Xe-133m*	2.19	days	5.26E+01	1.32E-02
Xe-135	0.379	days	9.10E+00	7.62E-02
Xe-135m*	15.29	minutes	2.55E-01	2.72E+00
Xe-138*	14.08	minutes	2.35E-01	2.95E+00
Y-90	2.67	days	6.41E+01	1.08E-02
Y-91	58.5	days	1.40E+03	4.94E-04
Y-92	0.148	days	3.55E+00	1.95E-01
Y-93	0.421	days	1.01E+01	6.86E-02
Zr-95	64	days	1.54E+03	4.51E-04
Zr-97	0.704	days	1.69E+01	4.10E-02

5.5 Reduction Factor for Sprays

NUREG-1940 Table 1-11 states that when sprays are used for longer than 1.75 hours (but less than 2.25 hours), the following factor is applied to reduce all of the particulate and iodine species.

$$RF_S = \text{Exp}^{(-0.64t)}$$

Where t = the amount of times sprays are in service.

Note: This reduction factor does not apply to the noble gases.

For this calculation, sprays are used for a total of 2 hours as described in Section 6.1. The reduction factor is:

$$RF_S = e^{(-0.64*2)} = 0.278$$

5.6 Standby Gas Treatment Filters

NUREG-1940 allows a reduction factor of 0.01 for filters like the standby gas treatment (SBGT) system. This factor is only applied to releases from the Offgas Stack.

$$RF_F = 0.01$$

5.7 Secondary Containment

NUREG-1228 provides a reduction factor for natural removal through settling and plate-out in the secondary containment. For a 0.5 hour holdup period, that reduction factor is 0.4. This factor is applied to the building vent releases but not the release from the Offgas Stack.

$$RF_{SC} = 0.4$$

5.8 Monitor Range and Exhaust Flow Rates

Table 9 is developed from the DAEC Emergency Plan Section "I", ODAM Figure 3-1, and Procedure PCP 8.3.

Table 9 – Monitor Range and Exhaust Flow Rates

Release Point	Monitor Common Name	Equipment ID	Monitor Range µCi/cc	Release Flow CFM
Turbine Building	KAMAN 1/2	RE-5945 / RE-5946	1E-7 to 1E+5	72,000
Reactor Building	KAMAN 3/4 KAMAN 5/6 KAMAN 7/8	RE-7645, RE-7644 RE-7647, RE-7646 RE-7649, RE-7648	1E-7 to 1E+5	93,000
Offgas Stack	KAMAN 9/10	RE-4176, RE-4175	1E-7 to 1E+5	10,000
LLRPSF	KAMAN 12	RE-8801	1E-7 to 3E-1	75,000

5.9 Breathing Rate

From NUREG-1940 and FGR11, the breathing rate is 3.33E-4 m^3/second.

5.10 Exposure-to-Dose Conversion Factors for Inhalation

The "Exposure-to-Dose Conversion Factors for Inhalation" by radionuclide provided in FGR11 Table 2.1 allow the determination of the committed dose equivalent to the thyroid and the effective dose equivalent per unit per unit intake, and are shown in Table 11.

5.11 Dose Coefficients for Air Submersion

The dose coefficients in Sv/Bq*s*m^{-3} from being submersed in air for each radionuclide to an effective dose are taken from Table III.1 of FGR12, and are shown in Table 11.

6.0 Methodology

This calculation will equate a radioactive material release rate as measured at the gaseous effluent radiation monitors with the dose received to a member of the public at an offsite location. The relationship is highly influenced by the mixture of radioisotopes in the effluent and the dispersion of gases after they have left the facility. Primary guidance is provided by NUREG-1940 and NUREG-1228.

6.1 Scenario

The following generalized timeline is used to determine the phenomenon that can affect the mixture of radioisotopes in effluent. This scenario is realistic, but bounds an event that could occur in a shorter total time frame:

- T= 0 hr. Major recirculating system line break occurs. Reactor is shut down.
- T= 1 hr. Core is uncovered.
- T= 1 hr. Sprays are initiated.
- T = 2 hrs. Core is covered.
- T= 4.5 hrs. A catastrophic event causes damage to the drywell and the secondary containment.
  - The gaseous mixture from the Drywell spreads into the Reactor Building, Turbine Building, and LLRPSF.
  - Mean average holdup time of the gas in these buildings is 0.5 hours.

Scenario timing will affect the mixture of radioisotopes and is summarized here:

- The core is uncovered for 1 hour.
- Core/Drywell Sprays are running for a total of 2 hours.
- Primary Containment integrity is maintained for 4 hours.
- Source holdup time in secondary containment is 0.5 hours.
- Source decay time from shutdown to the release point is 5 hours.
- When the reactor is in mode 4 or 5, the total decay time is 36 hours.

Other Factors:

- The flow rates from the effluent exhaust points are listed in Design Input 5.8.
- The gaseous effluent radiation monitors are equally efficient for the monitoring of noble gases, particulates, and iodines.
- All releases from the Offgas Stack are filtered by the Standby Gas Treatment system.
- Removal of particulates and iodines by natural process during holdup in secondary containment are credited for releases from the building vents only.

6.2 Receptor

The receptor is an adult located at the ODAM-described location of minimal dispersion who is exposed to the radioactive release for one hour. Due to this relatively short duration, the only exposure pathways are inhalation and submersion. Assumptions related to the receptor are found in Section 4.0.

6.3 General Approach

With a given mixture of radionuclides, the dose received by an individual offsite is a function of the gross activity present in the gaseous mixture.

The resultant dose received by an offsite receptor is dependent not only on the gross radioactivity levels of the effluent but also upon the isotopic mixture present in the gas. This calculation predicts the relative contribution of each radionuclide to the gross radiation monitored by the effluent monitor.

With the fractionation of the mixture of radionuclides understood, a given gross output reading ($\mu Ci/cm^3$) from an effluent radiation monitor can be scaled to determine the concentration of each isotope present in the effluent.

The calculation then uses default dispersion factors described in the Offsite Dose Assessment Manual to determine the resultant concentration of radionuclides to which an individual offsite would be exposed.

Dose conversion factors provided in Federal Guidance Report 11 (FGR11) and 12 (FGR12) are used to determine the dose (mrem) to an individual offsite due to their exposure to the gaseous mixture of radionuclides.

With the given radionuclide mixture and dispersion factors understood, an iterative process can be used to relate the effluent monitor reading to a target offsite dose.

Two types of radiation dose are calculated: 1) TEDE and 2) CDE Thyroid.

CDE or Committed Dose Equivalent is the radiation dose to a specific organ due to an uptake of radioactive material. In this case, the uptake is limited to inhalation of radioactive material in the plume.

TEDE or Total Effective Dose Equivalent is the summation of the Effective Dose Equivalent (EDE) and the Committed Dose Equivalent (CEDE).

$$TEDE = EDE + CEDE.$$

EDE is the dose due to an individual being directly exposed (by submersion) to the radiation present in the gaseous release (shine).

CEDE is the sum of the CDE for each organ of the body with weighting factors applied for each organ. In this calculation, only contributions from the inhalation pathway are considered.

An iterative process is used to determine the gross radiation monitored by the effluent monitors that correspond to the threshold doses.

6.4 Source Term

This calculation will not analyze for the total activity released from the core. It will only analyze for the ratios of the isotopic species that are released from the core. Various phenomena will act to change the composition of the isotopic mixture in the time between reactor shutdown and release from the facility. In summary the removal phenomena addressed here include:

RF_I = Fraction of the activity released from the **inventory** of damaged fuel described in Section 6.5.

RF_S = Fraction of the activity remaining after reduction by containment **spray** from Section 5.5.

RF_R = Fraction of activity remaining after 5 hours or 36 hours of **radioactive** decay described in Section 6.6.

RF_F = Fraction of the activity remaining after filter by SBGT **filters** from Section 5.6.

RF_{SC} = Fraction of activity remaining after natural removal processes in **secondary containment** from Section 5.7.

Combining these factors provides a single fraction to derive a depleted source:

$$RF_{Total} = RF_I * RF_S * RF_R * RF_F * RF_{SC}$$

6.5 Fuel Damage Release Fractions

Table 6 contains release fractions for three time periods representing the total amount of time the core has been assumed to be uncovered. They are: 0 to 0.5 hours, 0.5 to 2 hours, and 2 to 5 hours. For this calculation, the core is assumed to be uncovered for one hour. A spreadsheet is used to scale the release fraction between the 0.5 hour point and the 2 hour point.

The Reduction Factor, **RF_I**, due to the release fraction is 100% of the release expected in the first 0.5 hour PLUS 1/3 of the amount released as expected in the period between 0.5 hours and 2 hours.

Example for Alkali Metals: $0.05 * \left(\frac{0.5\ hr}{0.5\ hr}\right) + 0.2 * \left(\frac{0.5\ hr}{1.5\ hr}\right) = 0.1167$

Table 10 – Release Fractions by Time Step (Hours)

Group	Time (h) by step		
	0.5	1.5	Cumulative
Alkali Metals	0.050	0.2000	0.1167
Barium Group	0.000	0.0200	0.0067
Cerium Group	0.000	0.0005	0.0002
Halogen	0.050	0.2500	0.1333
Lanthanides	0.000	0.0002	0.0001
Noble Gas	0.050	0.9500	0.3667
Noble Metals	0.000	0.0025	0.0008
Tellurium group	0.000	0.0500	0.0167

6.6 Radioactive Decay

The total amount of time the radioactive source is allowed to decay before being exhausted as an effluent is 5 hours or 36 hours depending on the reactor mode per Section 6.1.

The generalized equation for radioactive decay is:

$$A = A_o e^{(-\lambda t)}$$

Where:

A = decayed activity

A_o = initial activity

λ = isotopic decay constant

t = elapsed time

and

$\lambda = \ln 2 / t_{1/2}$

With an end goal of a total reduction factor RF_{Total}, a radiation decay factor RF_R is derived from the general equation above:

$$RF_R = e^{(-\lambda t)}$$

6.7 Effective Dose Equivalent – Noble Gas Submersion

Submersion dose from noble gases is calculated with guidance provided in FGR12.

The concentration of an isotope ***i*** present in the plume at the receptor is calculated:

$$x_{ir} = x_{iv} * v * \left(\frac{X}{Q}\right)$$

With the isotopic concentration at the receptor known, the dose (mrem) at the receptor is calculated:

$$Dose = \sum_i (x_{ir} * h_{E50i})$$

Where

x_{ir} = concentration of radionuclide ***i*** present at the receptor (Ci/m^3)
Note: Ci/m^3 = µCi/cc

v = volume of gas released (m^3)

x_{iv} = concentration of radionuclide ***i*** released from the stack or building vent. (Ci/m^3)

i = each isotope present in the gaseous release

$\left(\frac{X}{Q}\right)$ = dispersion factor for that release point (sec/m^3)

h_{E50i} = factor converting the gas concentration to effective dose equivalent. $\left(\frac{mrem\ cm^3}{\mu Ci\ sec}\right)$

As described in Section 7.3, a spreadsheet is used to determine the EDE dose contribution for each isotope in the mixture.

6.8 Committed Dose Equivalent: Thyroid

Organ dose from airborne particulates and iodines is calculated with guidance provided in FGR11.

The concentration of an isotope ***i*** present in the plume at the receptor is calculated:

$$x_{ir} = x_{iv} * v * \left(\frac{X}{Q}\right)$$

With the isotopic concentration at the receptor known, the dose (mrem) at the receptor can be calculated:

$$Dose = \sum_i (x_{ir} * B * t * h_{T50i})$$

Where

$x_{ir} =$ concentration of radionuclide ***i*** present at the receptor (Ci/m^3)
Note: Ci/m^3 = μCi/ cm^3

$v =$ volume of gas released (m^3)

$x_{iv} =$ concentration of radionuclide ***i*** released from the stack or building vent. (Ci/m^3)

$\boldsymbol{i} =$ each isotope present in the gaseous release

$\left(\frac{X}{Q}\right) =$ dispersion factor for that release point (sec/m^3)

$\boldsymbol{B} =$ breathing Rate (cm^3/sec)

$h_{T50i} =$ factor converting the gas concentration to effective dose equivalent. (mrem/μCi)

t = time the dose is to be integrated (sec)

As described in Section 7.4, a spreadsheet is used to determine the thyroid CDE dose contribution for each isotope in the mixture.

6.9 Committed Effective Dose Equivalent

Committed Effective Dose Equivalent from airborne particulates and iodines is calculated with guidance provided in FGR11.

The concentration x_{ir} of an isotope ***i*** present in the plume at the receptor is calculated:

$$x_{ir} = x_{iv} * v * \left(\frac{X}{Q}\right)$$

With the isotopic concentration at the receptor known, the dose (mrem) at the receptor can be calculated:

$$Dose = \sum_i (x_{ir} * B * t * h_{E50i})$$

Where

$x_{ir} =$ concentration of radionuclide ***i*** present at the receptor (Ci/m^3)
Note: $Ci/m^3 = \mu Ci/cm^3$

$v =$ volume of gas released (m^3)

$x_{iv} =$ concentration of radionuclide ***i*** released from the stack or building vent. (Ci/m^3)

$\boldsymbol{i} =$ each isotope present in the gaseous release

$\left(\frac{X}{Q}\right) =$ dispersion factor for that release point (sec/m^3)

$\boldsymbol{B} =$ breathing Rate (cm^3/sec)

$h_{E50i} =$ factor converting the gas concentration to effective dose equivalent. (mrem/µCi)

$t =$ time the dose is to be integrated (sec)

As described in Section 7.4, a spreadsheet is used to determine the CEDE dose contribution for each isotope in the mixture.

7.0 Calculation

All calculations were completed using Microsoft Excel. Sample calculations are shown in the subsections that follow.

7.1 Dose Factors

FGR11 and FGR 12 display dose factors in the SI units of Sv/Bq and Sv m^3/ Bq sec, respectively. Traditional units of mrem/µCi and mrem cm^3/µCi sec are desired.

FGR11:

1	~~Sv~~	1E+05	mrem	1	~~Bq~~	~~Ci~~		=	3.70E+09	mrem
	~~Bq~~		~~Sv~~	2.7E-11	~~Ci~~	1.00E+6	µCi			µCi

The conversion factor from Sv/Bq to mrem/µCi is 3.70E+09.

FGR 12:

1	~~Sv~~	~~m³~~	1E+05	mrem	1	~~Bq~~	1E+06	mL		~~Ci~~	=	3.70E+15	mrem cm³
	~~Bq~~	sec		~~Sv~~	2.7E-11	~~Ci~~		~~m³~~	1E+06	µCi			µCi sec

The conversion factor from Sv m^3/Bq sec to mrem cm^3/µCi sec is 3.70E+15.

The thyroid, CEDE, and submersion dose factors in the traditional units for each isotope are calculated in the table below. Column C, D, and H are dose factors from Sections 5.10 and 5.11 and Columns E and I are the conversion factors from above. Column F, G, and J are the h_{T50i}, h_{E50i}, and h_{E50i} factors as described in Sections 6.8, 6.9, and 6.7, respectively. Line 6 of Table 11 illustrates the formulas for Ba-139.

Table 11 – Isotopic Dose Factors

	Isotope	FGR11 Thyroid Sv/Bq	FGR11 CEDE Sv/Bq	Units Conversion Factor	Thyroid mrem/µCi	CEDE mrem/µCi	FGR 12: Sv m³/Bq sec	Units Conversion Factor	Submersion mrem cc/µCi sec
5	B	C	D	E	F	G	H	I	J
6	*Ba-139*	*2.40E-12*	*4.64E-11*	*3.70E+09*	*=E6*C6*	*=E6*D6*	*2.17E-15*	*3.70E+15*	*=I6*H6*
6	Ba-139	2.40E-12	4.64E-11	3.70E+09	8.88E-03	1.72E-01	2.17E-15	3.7E+15	8.03E+00
7	Ba-140	2.56E-10	1.01E-09	3.70E+09	9.47E-01	3.74E+00	8.58E-15	3.7E+15	3.17E+01
	Ce-141	4.61E-11	2.42E-09	3.70E+09	1.71E-01	8.95E+00	3.43E-15	3.7E+15	1.27E+01
	Ce-143	1.21E-11	9.16E-10	3.70E+09	4.48E-02	3.39E+00	1.29E-14	3.7E+15	4.77E+01
	Ce-144	1.88E-09	1.01E-07	3.70E+09	6.96E+00	3.74E+02	8.53E-16	3.7E+15	3.16E+00
	Cm-242	9.41E-10	4.67E-06	3.70E+09	3.48E+00	1.73E+04	5.69E-18	3.7E+15	2.11E-02
	Cs-134	1.11E-08	1.25E-08	3.70E+09	4.11E+01	4.63E+01	7.57E-14	3.7E+15	2.80E+02
	Cs-136	1.73E-09	1.98E-09	3.70E+09	6.40E+00	7.33E+00	1.06E-13	3.7E+15	3.92E+02
	Cs-137	7.93E-09	8.63E-09	3.70E+09	2.93E+01	3.19E+01	7.74E-18	3.7E+15	2.86E-02
	I-131	2.92E-07	8.89E-09	3.70E+09	1.08E+03	3.29E+01	1.82E-14	3.7E+15	6.73E+01
	I-132	1.74E-09	1.03E-10	3.70E+09	6.44E+00	3.81E-01	1.12E-13	3.7E+15	4.14E+02
	I-133	4.86E-08	1.58E-09	3.70E+09	1.80E+02	5.85E+00	2.94E-14	3.7E+15	1.09E+02

Isotope	FGR11 Thyroid Sv/Bq	FGR11 CEDE Sv/Bq	Units Conversion Factor	Thyroid mrem/µCi	CEDE mrem/µCi	FGR 12: $\frac{Sv\ m^3}{Bq\ sec}$	Units Conversion Factor	Submersion $\frac{mrem\ cc}{\mu Ci\ sec}$
I-134	2.88E-10	3.55E-11	3.70E+09	1.07E+00	1.31E-01	1.3E-13	3.7E+15	4.81E+02
I-135	8.46E-09	3.32E-10	3.70E+09	3.13E+01	1.23E+00	7.98E-14	3.7E+15	2.95E+02
Kr-83m						1.5E-18	3.7E+15	5.55E-03
Kr-85						1.19E-16	3.7E+15	4.40E-01
Kr-85m						7.48E-15	3.7E+15	2.77E+01
Kr-87						4.12E-14	3.7E+15	1.52E+02
Kr-88						1.02E-13	3.7E+15	3.77E+02
La-140	1.22E-10	1.31E-09	3.70E+09	4.51E-01	4.85E+00	1.17E-13	3.7E+15	4.33E+02
La-141	9.40E-12	1.57E-10	3.70E+09	3.48E-02	5.81E-01	2.39E-15	3.7E+15	8.84E+00
La-142	8.74E-12	6.84E-11	3.70E+09	3.23E-02	2.53E-01	1.44E-13	3.7E+15	5.33E+02
Mo-99	1.17E-10	1.07E-09	3.70E+09	4.33E-01	3.96E+00	7.28E-15	3.7E+15	2.69E+01
Nb-95	3.58E-10	1.57E-09	3.70E+09	1.32E+00	5.81E+00	3.74E-14	3.7E+15	1.38E+02
Nd-147	1.94E-11	1.85E-09	3.70E+09	7.18E-02	6.85E+00	6.19E-15	3.7E+15	2.29E+01
Np-239	7.62E-12	6.78E-10	3.70E+09	2.82E-02	2.51E+00	7.69E-15	3.7E+15	2.85E+01
Pr-143	1.68E-18	2.19E-09	3.70E+09	6.22E-09	8.10E+00	2.1E-17	3.7E+15	7.77E-02
Pu-241	1.24E-11	2.23E-06	3.70E+09	4.59E-02	8.25E+03	7.25E-20	3.7E+15	2.68E-04
Rb-86	1.33E-09	1.79E-09	3.70E+09	4.92E+00	6.62E+00	4.81E-15	3.7E+15	1.78E+01
Rh-105	2.57E-11	2.58E-10	3.70E+09	9.51E-02	9.55E-01	3.72E-15	3.7E+15	1.38E+01
Ru-103	5.97E-10	2.42E-09	3.70E+09	2.21E+00	8.95E+00	2.25E-14	3.7E+15	8.33E+01
Ru-105	1.50E-11	1.23E-10	3.70E+09	5.55E-02	4.55E-01	3.81E-14	3.7E+15	1.41E+02
Ru-106	1.37E-08	1.29E-07	3.70E+09	5.07E+01	4.77E+02	0	3.7E+15	0.00E+00
Sb-127	1.50E-10	1.63E-09	3.70E+09	5.55E-01	6.03E+00	3.33E-14	3.7E+15	1.23E+02
Sb-129	2.07E-11	1.74E-10	3.70E+09	7.66E-02	6.44E-01	7.14E-14	3.7E+15	2.64E+02
Sr-89	4.16E-10	1.12E-08	3.70E+09	1.54E+00	4.14E+01	7.73E-17	3.7E+15	2.86E-01
Sr-90	2.64E-09	3.51E-07	3.70E+09	9.77E+00	1.30E+03	7.53E-18	3.7E+15	2.79E-02
Sr-91	4.08E-11	4.49E-10	3.70E+09	1.51E-01	1.66E+00	3.45E-14	3.7E+15	1.28E+02
Sr-92	2.19E-11	2.18E-10	3.70E+09	8.10E-02	8.07E-01	6.79E-14	3.7E+15	2.51E+02
Tc-99m	5.01E-11	8.80E-12	3.70E+09	1.85E-01	3.26E-02	5.89E-15	3.7E+15	2.18E+01
Te-127	6.46E-12	8.60E-11	3.70E+09	2.39E-02	3.18E-01	2.42E-16	3.7E+15	8.95E-01
Te-127m	2.39E-10	5.81E-09	3.70E+09	8.84E-01	2.15E+01	1.47E-16	3.7E+15	5.44E-01
Te-129	1.63E-12	2.42E-11	3.70E+09	6.03E-03	8.95E-02	2.75E-15	3.7E+15	1.02E+01
Te-129m	3.95E-10	6.47E-09	3.70E+09	1.46E+00	2.39E+01	1.55E-15	3.7E+15	5.74E+00
Te-131m	3.61E-08	1.73E-09	3.70E+09	1.34E+02	6.40E+00	7.01E-14	3.7E+15	2.59E+02
Te-132	6.28E-08	2.55E-09	3.70E+09	2.32E+02	9.44E+00	1.03E-14	3.7E+15	3.81E+01
Xe-131m						3.89E-16	3.7E+15	1.44E+00
Xe-133						1.56E-15	3.7E+15	5.77E+00
Xe-133m						1.37E-15	3.7E+15	5.07E+00
Xe-135						1.19E-14	3.7E+15	4.40E+01
Xe-135m						2.04E-14	3.7E+15	7.55E+01
Xe-138						5.77E-14	3.7E+15	2.13E+02
Y-90	9.52E-12	2.28E-09	3.70E+09	3.52E-02	8.44E+00	1.9E-16	3.7E+15	7.03E-01
Y-91	1.10E-10	1.32E-08	3.70E+09	4.07E-01	4.88E+01	2.6E-16	3.7E+15	9.62E-01
Y-92	3.69E-12	2.11E-10	3.70E+09	1.37E-02	7.81E-01	1.3E-14	3.7E+15	4.81E+01
Y-93	5.06E-12	5.82E-10	3.70E+09	1.87E-02	2.15E+00	4.8E-15	3.7E+15	1.78E+01
Zr-95	1.44E-09	6.39E-09	3.70E+09	5.33E+00	2.36E+01	3.6E-14	3.7E+15	1.33E+02
Zr-97	9.56E-11	1.17E-09	3.70E+09	3.54E-01	4.33E+00	9.02E-15	3.7E+15	3.34E+01

7.2 Source Term

A spreadsheet is used to determine the total reduction factor $\mathbf{RF_{Total}}$ for each isotope present in the source term as described in Section 6.4. The activity per megawatt thermal from Section 5.1 is multiplied by $\mathbf{RF_{Total}}$ to find the source term for each isotope. The spreadsheet for the Offgas Stack release is presented in Table 13.

The relative activity released from damaged fuel ($\mathbf{RF_I}$) was determined in Section 6.5.

Table 12 – 2 Hours Reduction Factor (RF_I)

Cumulative	2 Hour
Alkali Metals	0.1167
Barium Group	0.0067
Cerium Group	0.0002
Halogen	0.1333
Lanthanides	0.0001
Noble Gas	0.3667
Noble Metals	0.0008
Tellurium group	0.0167

A Spray Reduction factor of 0.278 for primary containment sprays ($\mathbf{RF_S}$) was derived in Section 5.5.

Determination of the Radiation Decay fractions ($\mathbf{RF_R}$) was demonstrated in Section 6.6. In the spreadsheets below, the source decay time is 5 hours.

7.2.1 Offgas Stack

For the Offgas Stack release, credit is taken for filtering (**RF**$_F$) by the Standby Gas Treatment system but not for the natural removal processes that occur in secondary containment (**RF**$_{SC}$).

Table 13 – Isotopic Depletion and Release for Offgas Stack

			RF_I	RF_S	RF_{SC}	RF_F	RF_R	RF_{Total}	
Form	Isotope	Ci/MWTh	Release Fraction	+ 0.25 hr Sprays Reduction	Secondary Con-tainment	SBGT Filter	Decay Fraction	Total Depletion	Release Ci/MWTh
Barium Group	Ba-139	4.74E+04	0.0067	0.2780	1.0000	0.01	0.0808	1.50E-06	7.10E-02
Barium Group	Ba-140	4.76E+04	0.0067	0.2780	1.0000	0.01	0.9887	1.83E-05	8.72E-01
Cerium Group	Ce-141	4.39E+04	0.0002	0.2780	1.0000	0.01	0.9956	4.61E-07	2.03E-02
Cerium Group	Ce-143	4.00E+04	0.0002	0.2780	1.0000	0.01	0.9006	4.17E-07	1.67E-02
Cerium Group	Ce-144	3.54E+04	0.0002	0.2780	1.0000	0.01	0.9995	4.63E-07	1.64E-02
Lanthanides	Cm-242	1.12E+03	0.0001	0.2780	1.0000	0.01	0.9991	1.85E-07	2.07E-04
Alkali Metals	Cs-134	4.70E+03	0.1167	0.2780	1.0000	0.01	0.9998	3.24E-04	1.52E+00
Alkali Metals	Cs-136	1.49E+03	0.1167	0.2780	1.0000	0.01	0.9890	3.21E-04	4.78E-01
Alkali Metals	Cs-137	3.25E+03	0.1167	0.2780	1.0000	0.01	1.0000	3.24E-04	1.05E+00
Halogen	I-131	2.67E+04	0.1333	0.2780	1.0000	0.01	0.9822	3.64E-04	9.72E+00
Halogen	I-132	3.88E+04	0.1333	0.2780	1.0000	0.01	0.2215	8.21E-05	3.19E+00
Halogen	I-133	5.42E+04	0.1333	0.2780	1.0000	0.01	0.8466	3.14E-04	1.70E+01
Halogen	I-134	5.98E+04	0.1333	0.2780	1.0000	0.01	0.0191	7.09E-06	4.24E-01
Halogen	I-135	5.18E+04	0.1333	0.2780	1.0000	0.01	0.5915	2.19E-04	1.14E+01
Noble Gas	Kr-83m	3.05E+03	0.367	1.0	1.0	1.0	0.1505	5.52E-02	1.68E+02
Noble Gas	Kr-85	2.78E+02	0.367	1.0	1.0	1.0	1.0000	3.67E-01	1.02E+02
Noble Gas	Kr-85m	6.17E+03	0.367	1.0	1.0	1.0	0.4620	1.69E-01	1.05E+03
Noble Gas	Kr-87	1.23E+04	0.367	1.0	1.0	1.0	0.0656	2.40E-02	2.96E+02
Noble Gas	Kr-88	1.70E+04	0.367	1.0	1.0	1.0	0.2941	1.08E-01	1.83E+03
Lanthanides	La-140	4.91E+04	0.0001	0.2780	1.0000	0.01	0.9176	1.70E-07	8.35E-03
Lanthanides	La-141	4.33E+04	0.0001	0.2780	1.0000	0.01	0.4146	7.68E-08	3.33E-03
Lanthanides	La-142	4.21E+04	0.0001	0.2780	1.0000	0.01	0.1055	1.96E-08	8.23E-04
Noble Metals	Mo-99	5.30E+04	0.0008	0.2780	1.0000	0.01	0.9488	2.20E-06	1.17E-01
Lanthanides	Nb-95	4.50E+04	0.0001	0.2780	1.0000	0.01	0.9959	1.85E-07	8.31E-03
Lanthanides	Nd-147	1.75E+04	0.0001	0.2780	1.0000	0.01	0.9870	1.83E-07	3.20E-03
Cerium Group	Np-239	5.69E+05	0.0002	0.2780	1.0000	0.01	0.9406	4.36E-07	2.48E-01
Lanthanides	Pr-143	3.96E+04	0.0001	0.2780	1.0000	0.01	0.9894	1.83E-07	7.26E-03
Cerium Group	Pu-241	4.26E+03	0.0002	0.2780	1.0000	0.01	1.0000	4.63E-07	1.97E-03
Alkali Metals	Rb-86	5.29E+01	0.1167	0.2780	1.0000	0.01	0.9923	3.22E-04	1.70E-02
Noble Metals	Rh-105	2.81E+04	0.0008	0.2780	1.0000	0.01	0.9064	2.10E-06	5.90E-02
Noble Metals	Ru-103	4.34E+04	0.0008	0.2780	1.0000	0.01	0.9963	2.31E-06	1.00E-01
Noble Metals	Ru-105	3.06E+04	0.0008	0.2780	1.0000	0.01	0.4581	1.06E-06	3.25E-02
Noble Metals	Ru-106	1.55E+04	0.0008	0.2780	1.0000	0.01	0.9996	2.32E-06	3.59E-02
Tellurium group	Sb-127	2.39E+03	0.0167	0.2780	1.0000	0.01	0.9632	4.46E-05	1.07E-01
Tellurium group	Sb-129	8.68E+03	0.0167	0.2780	1.0000	0.01	0.4549	2.11E-05	1.83E-01
Barium Group	Sr-89	2.41E+04	0.0067	0.2780	1.0000	0.01	0.9971	1.85E-05	4.45E-01
Barium Group	Sr-90	2.39E+03	0.0067	0.2780	1.0000	0.01	1.0000	1.85E-05	4.43E-02

			RF_I	RF_S	RF_{SC}	RF_F	RF_R	RF_{Total}	
Form	Isotope	Ci / MWTh	Release Fraction	+ 0.25 hr Sprays Reduction	Secondary Con-tainment	SBGT Filter	Decay Fraction	Total Depletion	Release Ci/MWTh
Barium Group	Sr-91	3.01E+04	0.0067	0.2780	1.0000	0.01	0.6944	1.29E-05	3.87E-01
Barium Group	Sr-92	3.24E+04	0.0067	0.2780	1.0000	0.01	0.2786	5.16E-06	1.67E-01
Noble Metals	Tc-99m	4.37E+04	0.0008	0.2780	1.0000	0.01	0.5625	1.30E-06	5.70E-02
Tellurium group	Te-127	2.36E+03	0.0167	0.2780	1.0000	0.01	0.6905	3.20E-05	7.55E-02
Tellurium group	Te-127m	3.97E+02	0.0167	0.2780	1.0000	0.01	0.9987	4.63E-05	1.84E-02
Tellurium group	Te-129	8.26E+03	0.0167	0.2780	1.0000	0.01	0.0503	2.33E-06	1.93E-02
Tellurium group	Te-129m	1.68E+03	0.0167	0.2780	1.0000	0.01	0.9957	4.61E-05	7.75E-02
Tellurium group	Te-131m	5.41E+03	0.0167	0.2780	1.0000	0.01	0.8909	4.13E-05	2.23E-01
Tellurium group	Te-132	3.81E+04	0.0167	0.2780	1.0000	0.01	0.9567	4.43E-05	1.69E+00
Noble Gas	Xe-131m	3.65E+02	0.367	1.0	1.0	1.0	0.9880	3.62E-01	1.32E+02
Noble Gas	Xe-133	5.43E+04	0.367	1.0	1.0	1.0	0.9729	3.57E-01	1.94E+04
Noble Gas	Xe-133m	1.72E+03	0.367	1.0	1.0	1.0	0.9362	3.43E-01	5.90E+02
Noble Gas	Xe-135	1.42E+04	0.367	1.0	1.0	1.0	0.6832	2.50E-01	3.56E+03
Noble Gas	Xe-135m	1.15E+04	0.367	1.0	1.0	1.0	0.0000	4.55E-07	5.23E-03
Noble Gas	Xe-138	4.56E+04	0.367	1.0	1.0	1.0	0.0000	1.41E-07	6.45E-03
Lanthanides	Y-90	2.45E+03	0.0001	0.2780	1.0000	0.01	0.9474	1.76E-07	4.30E-04
Lanthanides	Y-91	3.17E+04	0.0001	0.2780	1.0000	0.01	0.9975	1.85E-07	5.86E-03
Lanthanides	Y-92	3.26E+04	0.0001	0.2780	1.0000	0.01	0.3769	6.99E-08	2.28E-03
Lanthanides	Y-93	2.52E+04	0.0001	0.2780	1.0000	0.01	0.7096	1.32E-07	3.31E-03
Lanthanides	Zr-95	4.44E+04	0.0001	0.2780	1.0000	0.01	0.9977	1.85E-07	8.21E-03
Lanthanides	Zr-97	4.23E+04	0.0001	0.2780	1.0000	0.01	0.8145	1.51E-07	6.39E-03

7.2.2 Building Vents

For releases from Building Vents, no credit is taken for filtering (**RF$_F$**) by the Standby Gas Treatment system. Credit is taken for the natural removal processes that occurs in secondary containment (**RF$_{SC}$**). This source term also has radioactive decay occurring for 5 hours.

Table 14 – Isotopic Depletion and Release for Building Vents

			RF$_I$	RF$_S$	RF$_{SC}$	RF$_F$	RF$_R$	RF$_{Total}$	
Form	Isotope	Ci / MWTh	Release Fraction	+ 0.25 hr Sprays Reduction	Secondary Con-tainment	SBGT Filter	Decay Fraction	Total Depletion	Release Ci/MWTh
Barium Group	Ba-139	4.74E+04	0.0067	0.2780	0.4000	1.00	0.0808	5.99E-05	2.84E+00
Barium Group	Ba-140	4.76E+04	0.0067	0.2780	0.4000	1.00	0.9887	7.33E-04	3.49E+01
Cerium Group	Ce-141	4.39E+04	0.0002	0.2780	0.4000	1.00	0.9956	1.85E-05	8.10E-01
Cerium Group	Ce-143	4.00E+04	0.0002	0.2780	0.4000	1.00	0.9006	1.67E-05	6.68E-01
Cerium Group	Ce-144	3.54E+04	0.0002	0.2780	0.4000	1.00	0.9995	1.85E-05	6.56E-01
Lanthanides	Cm-242	1.12E+03	0.0001	0.2780	0.4000	1.00	0.9991	7.41E-06	8.30E-03
Alkali Metals	Cs-134	4.70E+03	0.1167	0.2780	0.4000	1.00	0.9998	1.30E-02	6.10E+01
Alkali Metals	Cs-136	1.49E+03	0.1167	0.2780	0.4000	1.00	0.9890	1.28E-02	1.91E+01
Alkali Metals	Cs-137	3.25E+03	0.1167	0.2780	0.4000	1.00	1.0000	1.30E-02	4.22E+01
Halogen	I-131	2.67E+04	0.1333	0.2780	0.4000	1.00	0.9822	1.46E-02	3.89E+02
Halogen	I-132	3.88E+04	0.1333	0.2780	0.4000	1.00	0.2215	3.28E-03	1.27E+02
Halogen	I-133	5.42E+04	0.1333	0.2780	0.4000	1.00	0.8466	1.26E-02	6.80E+02
Halogen	I-134	5.98E+04	0.1333	0.2780	0.4000	1.00	0.0191	2.84E-04	1.70E+01
Halogen	I-135	5.18E+04	0.1333	0.2780	0.4000	1.00	0.5915	8.77E-03	4.54E+02
Noble Gas	Kr-83m	3.05E+03	0.367	1.0	1.0	1.0	0.1505	5.52E-02	1.68E+02
Noble Gas	Kr-85	2.78E+02	0.367	1.0	1.0	1.0	1.0000	3.67E-01	1.02E+02
Noble Gas	Kr-85m	6.17E+03	0.367	1.0	1.0	1.0	0.4620	1.69E-01	1.05E+03
Noble Gas	Kr-87	1.23E+04	0.367	1.0	1.0	1.0	0.0656	2.40E-02	2.96E+02
Noble Gas	Kr-88	1.70E+04	0.367	1.0	1.0	1.0	0.2941	1.08E-01	1.83E+03
Lanthanides	La-140	4.91E+04	0.0001	0.2780	0.4000	1.00	0.9176	6.80E-06	3.34E-01
Lanthanides	La-141	4.33E+04	0.0001	0.2780	0.4000	1.00	0.4146	3.07E-06	1.33E-01
Lanthanides	La-142	4.21E+04	0.0001	0.2780	0.4000	1.00	0.1055	7.82E-07	3.29E-02
Noble Metals	Mo-99	5.30E+04	0.0008	0.2780	0.4000	1.00	0.9488	8.79E-05	4.66E+00
Lanthanides	Nb-95	4.50E+04	0.0001	0.2780	0.4000	1.00	0.9959	7.38E-06	3.32E-01
Lanthanides	Nd-147	1.75E+04	0.0001	0.2780	0.4000	1.00	0.9870	7.32E-06	1.28E-01
Cerium Group	Np-239	5.69E+05	0.0002	0.2780	0.4000	1.00	0.9406	1.74E-05	9.92E+00
Lanthanides	Pr-143	3.96E+04	0.0001	0.2780	0.4000	1.00	0.9894	7.34E-06	2.91E-01
Cerium Group	Pu-241	4.26E+03	0.0002	0.2780	0.4000	1.00	1.0000	1.85E-05	7.90E-02
Alkali Metals	Rb-86	5.29E+01	0.1167	0.2780	0.4000	1.00	0.9923	1.29E-02	6.81E-01
Noble Metals	Rh-105	2.81E+04	0.0008	0.2780	0.4000	1.00	0.9064	8.40E-05	2.36E+00
Noble Metals	Ru-103	4.34E+04	0.0008	0.2780	0.4000	1.00	0.9963	9.23E-05	4.01E+00
Noble Metals	Ru-105	3.06E+04	0.0008	0.2780	0.4000	1.00	0.4581	4.25E-05	1.30E+00
Noble Metals	Ru-106	1.55E+04	0.0008	0.2780	0.4000	1.00	0.9996	9.26E-05	1.44E+00
Tellurium group	Sb-127	2.39E+03	0.0167	0.2780	0.4000	1.00	0.9632	1.79E-03	4.27E+00
Tellurium group	Sb-129	8.68E+03	0.0167	0.2780	0.4000	1.00	0.4549	8.43E-04	7.32E+00
Barium Group	Sr-89	2.41E+04	0.0067	0.2780	0.4000	1.00	0.9971	7.39E-04	1.78E+01

			RF_I	RF_S	RF_{SC}	RF_F	RF_R	RF_{Total}	
Form	Isotope	Ci / MWTh	Release Fraction	+ 0.25 hr Sprays Reduction	Secondary Con-tainment	SBGT Filter	Decay Fraction	Total Depletion	Release Ci/MWTh
Barium Group	Sr-90	2.39E+03	0.0067	0.2780	0.4000	1.00	1.0000	7.41E-04	1.77E+00
Barium Group	Sr-91	3.01E+04	0.0067	0.2780	0.4000	1.00	0.6944	5.15E-04	1.55E+01
Barium Group	Sr-92	3.24E+04	0.0067	0.2780	0.4000	1.00	0.2786	2.07E-04	6.69E+00
Noble Metals	Tc-99m	4.37E+04	0.0008	0.2780	0.4000	1.00	0.5625	5.21E-05	2.28E+00
Tellurium group	Te-127	2.36E+03	0.0167	0.2780	0.4000	1.00	0.6905	1.28E-03	3.02E+00
Tellurium group	Te-127m	3.97E+02	0.0167	0.2780	0.4000	1.00	0.9987	1.85E-03	7.35E-01
Tellurium group	Te-129	8.26E+03	0.0167	0.2780	0.4000	1.00	0.0503	9.32E-05	7.70E-01
Tellurium group	Te-129m	1.68E+03	0.0167	0.2780	0.4000	1.00	0.9957	1.85E-03	3.10E+00
Tellurium group	Te-131m	5.41E+03	0.0167	0.2780	0.4000	1.00	0.8909	1.65E-03	8.93E+00
Tellurium group	Te-132	3.81E+04	0.0167	0.2780	0.4000	1.00	0.9567	1.77E-03	6.76E+01
Noble Gas	Xe-131m	3.65E+02	0.367	1.0	1.0	1.0	0.9880	3.62E-01	1.32E+02
Noble Gas	Xe-133	5.43E+04	0.367	1.0	1.0	1.0	0.9729	3.57E-01	1.94E+04
Noble Gas	Xe-133m	1.72E+03	0.367	1.0	1.0	1.0	0.9362	3.43E-01	5.90E+02
Noble Gas	Xe-135	1.42E+04	0.367	1.0	1.0	1.0	0.6832	2.50E-01	3.56E+03
Noble Gas	Xe-135m	1.15E+04	0.367	1.0	1.0	1.0	0.0000	4.55E-07	5.23E-03
Noble Gas	Xe-138	4.56E+04	0.367	1.0	1.0	1.0	0.0000	1.41E-07	6.45E-03
Lanthanides	Y-90	2.45E+03	0.0001	0.2780	0.4000	1.00	0.9474	7.02E-06	1.72E-02
Lanthanides	Y-91	3.17E+04	0.0001	0.2780	0.4000	1.00	0.9975	7.40E-06	2.34E-01
Lanthanides	Y-92	3.26E+04	0.0001	0.2780	0.4000	1.00	0.3769	2.79E-06	9.11E-02
Lanthanides	Y-93	2.52E+04	0.0001	0.2780	0.4000	1.00	0.7096	5.26E-06	1.33E-01
Lanthanides	Zr-95	4.44E+04	0.0001	0.2780	0.4000	1.00	0.9977	7.40E-06	3.28E-01
Lanthanides	Zr-97	4.23E+04	0.0001	0.2780	0.4000	1.00	0.8145	6.04E-06	2.55E-01

7.3 Effective Dose Equivalent – Noble Gas Submersion

Spreadsheets are used to calculate isotopic concentration at the receptor and the resultant radiation dose to the receptor for each of the isotopes in the mixture.

For the example Effective Dose Equivalent calculation, the release point is the Offgas Stack at five hours since shutdown, and a gross concentration of 43.9 μCi/cm^3 (this concentration was determined iteratively to produce 10 mrem TEDE). The secondary containment holdup hours is set at <0.5 because the natural removal process in the Secondary Containment does not occur with the Offgas Stack.

In Table 15, the column labeled "h_{E50i} Submersion mrem cm^3/μCi sec," is the dose factor for air submersion dose and is calculated in Section 7.1.

The column labeled "Depleted Mix Ci/MWTh" is the "Release Ci/MWTh" calculated in Section 7.2 for each isotope.

The "Fraction" column determines the fraction each isotope contributes to the gross activity and is used to scale the activity for each isotope.

The column "x_{iv} Release Conc. µCi/cm^3" contains a calculation that scales the "Depleted Mix Ci/MWTh" column to a user entered gross concentration based on the "Fraction". In this case, the gross concentration entered was 43.9 µCi/cm^3 (4.39E+1).

Values in the "x_{ir} Receptor Conc. µCi/cm^3" column are calculated by multiplying the release concentration by the applicable dispersion factor, the volume of the release, and requisite conversion factors. The basic equation is from Section 6.7:

$$x_{ir} = \quad x_{iv} * v * \left(\frac{X}{Q}\right)$$

For isotope I-131, an example is presented:

x_{iv} Release Conc.		Flow						(X/Q)			Receptor Conc.	
1.57E-02	µCi	10,000	~~ft³~~	2.83E-02	~~m³~~	1	~~min~~	2.80E-07	~~sec~~	=	2.08E-08	µCi
	cm³		~~min~~	1	~~ft³~~	60	~~sec~~		~~m³~~			cm³

Where:

v = 10,000 ft^3/min is the rated flow from the Offgas Stack from Design Input 5.8.

(X/Q) = 2.80E-07 is the Noble Gas Dispersion coefficient *(X/Q)* for the Offgas Stack from Design Input 5.3.

2.83E-2 converts ft^3 to m^3

Values in the "Submersion Dose mrem" (h_{E50i}) column are calculated by multiplying the factors "x_{ir} Receptor Conc. µCi/cm^3", a time-units conversion factor, and the dose conversion factor calculated in Section 7.1. The basic equation for a one hour time period is shown in Section 6.7.

$$Dose = \sum_i (x_{ir} * hE_{50i})$$

For isotope I-131, an example is presented:

x_{ir} Receptor Conc.		h_{E50i} Submersion						Submersion Dose mrem	
2.08E-08	~~µCi~~	6.73E+01	mrem	~~cm³~~	3600	~~sec~~	=	5.04E-03	mrem
	~~cm³~~		~~µCi~~	~~sec~~					

For ease of comparison, the spreadsheet row for I-131 is shown here:

Nuclide	h_{E50i} Submersion $\frac{mrem\ cc}{\mu Ci\ sec}$	Depleted Mix $\frac{Ci}{MWTh}$	Fraction	x_{iv} Release Conc. $\frac{\mu Ci}{cm^3}$	x_{ir} Receptor Conc. $\frac{\mu Ci}{cm^3}$	Submersion Dose mrem
I-131	6.73E+1	9.72E+0	3.582E-4	1.57E-2	2.08E-8	5.04E-3

Table 15 – Submersion Dose for Offgas Stack

Nuclide	h_{E50i} Submersion $\frac{mrem\ cm^3}{\mu Ci\ sec}$	Depleted Mix $\frac{Ci}{MWTh}$	Fraction	x_{iv} Release Conc. $\frac{\mu Ci}{cm^3}$	x_{ir} Receptor Conc. $\frac{\mu Ci}{cm^3}$	Submersion Dose mrem
Ba-139	8.03E+0	7.10E-2	2.62E-6	1.15E-4	1.52E-10	4.39E-6
Ba-140	3.17E+1	8.72E-1	3.21E-5	1.41E-3	1.86E-9	2.13E-4
Ce-141	1.27E+1	2.03E-2	7.46E-7	3.28E-5	4.33E-11	1.98E-6
Ce-143	4.77E+1	1.67E-2	6.15E-7	2.70E-5	3.57E-11	6.13E-6
Ce-144	3.16E+0	1.64E-2	6.04E-7	2.65E-5	3.50E-11	3.98E-7
Cm-242	2.11E-2	2.07E-4	7.64E-9	3.35E-7	4.43E-13	3.36E-11
Cs-134	2.80E+2	1.52E+0	5.62E-5	2.47E-3	3.26E-9	3.28E-3
Cs-136	3.92E+2	4.78E-1	1.76E-5	7.73E-4	1.02E-9	1.44E-3
Cs-137	2.86E-2	1.05E+0	3.88E-5	1.70E-3	2.25E-9	2.32E-7
I-131	6.73E+1	9.72E+0	3.582E-4	1.57E-2	2.08E-8	5.04E-3
I-132	4.14E+2	3.19E+0	1.17E-4	5.15E-3	6.81E-9	1.02E-2
I-133	1.09E+2	1.70E+1	6.27E-4	2.75E-2	3.64E-8	1.42E-2
I-134	4.81E+2	4.24E-1	1.56E-5	6.86E-4	9.07E-10	1.57E-3
I-135	2.95E+2	1.14E+1	4.18E-4	1.84E-2	2.43E-8	2.58E-2
Kr-83m	5.55E-3	1.68E+2	6.20E-3	2.72E-1	3.60E-7	7.19E-6
Kr-85	4.40E-1	1.02E+2	3.76E-3	1.65E-1	2.18E-7	3.45E-4
Kr-85m	2.77E+1	1.05E+3	3.85E-2	1.69E+0	2.23E-6	2.23E-1
Kr-87	1.52E+2	2.96E+2	1.09E-2	4.78E-1	6.32E-7	3.47E-1
Kr-88	3.77E+2	1.83E+3	6.75E-2	2.97E+0	3.92E-6	5.32E+0
La-140	4.33E+2	8.35E-3	3.08E-7	1.35E-5	1.78E-11	2.78E-5
La-141	8.84E+0	3.33E-3	1.23E-7	5.38E-6	7.11E-12	2.26E-7
La-142	5.33E+2	8.23E-4	3.03E-8	1.33E-6	1.76E-12	3.37E-6
Mo-99	2.69E+1	1.17E-1	4.29E-6	1.88E-4	2.49E-10	2.41E-5
Nb-95	1.38E+2	8.31E-3	3.06E-7	1.34E-5	1.78E-11	8.84E-6
Nd-147	2.29E+1	3.20E-3	1.18E-7	5.18E-6	6.84E-12	5.64E-7
Np-239	2.85E+1	2.48E-1	9.14E-6	4.01E-4	5.30E-10	5.43E-5
Pr-143	7.77E-2	7.26E-3	2.68E-7	1.17E-5	1.55E-11	4.34E-9
Pu-241	2.68E-4	1.97E-3	7.27E-8	3.19E-6	4.22E-12	4.07E-12
Rb-86	1.78E+1	1.70E-2	6.27E-7	2.75E-5	3.64E-11	2.33E-6
Rh-105	1.38E+1	5.90E-2	2.17E-6	9.54E-5	1.26E-10	6.25E-6
Ru-103	8.33E+1	1.00E-1	3.69E-6	1.62E-4	2.14E-10	6.42E-5
Ru-105	1.41E+2	3.25E-2	1.20E-6	5.25E-5	6.94E-11	3.52E-5
Ru-106	0.00E+0	3.59E-2	1.32E-6	5.81E-5	7.67E-11	0.00E+0
Sb-127	1.23E+2	1.07E-1	3.93E-6	1.73E-4	2.28E-10	1.01E-4
Sb-129	2.64E+2	1.83E-1	6.74E-6	2.96E-4	3.91E-10	3.72E-4
Sr-89	2.86E-1	4.45E-1	1.64E-5	7.20E-4	9.52E-10	9.80E-7
Sr-90	2.79E-2	4.43E-2	1.63E-6	7.16E-5	9.47E-11	9.50E-9
Sr-91	1.28E+2	3.87E-1	1.43E-5	6.27E-4	8.28E-10	3.81E-4
Sr-92	2.51E+2	1.67E-1	6.16E-6	2.71E-4	3.58E-10	3.23E-4
Tc-99m	2.18E+1	5.70E-2	2.10E-6	9.21E-5	1.22E-10	9.55E-6

Nuclide	h_{E50i} Submersion $\frac{mrem\ cm^3}{\mu Ci\ sec}$	Depleted Mix $\frac{Ci}{MWTh}$	Fraction	x_{iv} Release Conc. $\frac{\mu Ci}{cm^3}$	x_{ir} Receptor Conc. $\frac{\mu Ci}{cm^3}$	Submersion Dose mrem
Te-127	8.95E-1	7.55E-2	2.78E-6	1.22E-4	1.61E-10	5.20E-7
Te-127m	5.44E-1	1.84E-2	6.77E-7	2.97E-5	3.93E-11	7.69E-8
Te-129	1.02E+1	1.93E-2	7.09E-7	3.11E-5	4.11E-11	1.51E-6
Te-129m	5.74E+0	7.75E-2	2.86E-6	1.25E-4	1.66E-10	3.42E-6
Te-131m	2.59E+2	2.23E-1	8.23E-6	3.61E-4	4.77E-10	4.46E-4
Te-132	3.81E+1	1.69E+0	6.22E-5	2.73E-3	3.61E-9	4.95E-4
Xe-131m	1.44E+0	1.32E+2	4.87E-3	2.14E-1	2.83E-7	1.46E-3
Xe-133	5.77E+0	1.94E+4	7.14E-1	3.13E+1	4.14E-5	8.60E-1
Xe-133m	5.07E+0	5.90E+2	2.18E-2	9.55E-1	1.26E-6	2.30E-2
Xe-135	4.40E+1	3.56E+3	1.31E-1	5.75E+0	7.60E-6	1.20E+0
Xe-135m	7.55E+1	5.23E-3	1.93E-7	8.46E-6	1.12E-11	3.04E-6
Xe-138	2.13E+2	6.45E-3	2.37E-7	1.04E-5	1.38E-11	1.06E-5
Y-90	7.03E-1	4.30E-4	1.58E-8	6.96E-7	9.19E-13	2.33E-9
Y-91	9.62E-1	5.86E-3	2.16E-7	9.48E-6	1.25E-11	4.34E-8
Y-92	4.81E+1	2.28E-3	8.39E-8	3.68E-6	4.87E-12	8.43E-7
Y-93	1.78E+1	3.31E-3	1.22E-7	5.36E-6	7.08E-12	4.53E-7
Zr-95	1.33E+2	8.21E-3	3.03E-7	1.33E-5	1.75E-11	8.42E-6
Zr-97	3.34E+1	6.39E-3	2.35E-7	1.03E-5	1.36E-11	1.64E-6
		2.71E+04	100.00%	4.39E+01	5.80E-5	**8.05**
				4.39E+1		**mrem**

Given a radiation effluent monitor reading of 43.9 μCi/cm^3, and the assumptions of the scenario, the EDE value is 8.05 mrem.

Spreadsheet cases are run for all four release points. See Section 2.0 for results.

7.4 CEDE and CDE Thyroid

For the example CEDE and CDE Thyroid calculation, the release point is the Reactor Building at five hours since shutdown, and a gross concentration of 1.22E-2 µCi/cc, with a Secondary Containment Holdup time of 0.5 hours per Design Input 5.7 (this concentration was determined iteratively to produce 49.8 mrem Thyroid CDE).

In Table 16, the columns labeled "h_{T50i}Thyroid mrem/µCi" and "h_{E50i} CEDE mrem/µCi" are the dose factors developed in Section 7.1.

The column labeled "Depleted Mix Ci/MWTh" is the "Release Ci/MWTh" calculated above in Section 7.2 for each isotope.

The "Fraction" column determines the fraction each isotope contributes to the gross activity, and is used to scale the activity for each isotope.

The column "x_{iv} Release Conc. µCi/cm³" contains a calculation that scales the "Depleted Mix" column to a user entered gross concentration based on the "Fraction" and is the variable x_{iv} in the equation below. In this case, the gross concentration entered was 1.22E-2 µCi/cc.

Values in the "x_{ir} Receptor Conc. µCi/cm³" column are calculated by multiplying the release concentration by the applicable dispersion factor, the volume of the release, and requisite conversion factors. The basic equation from Section 6.8:

$$x_{ir} = x_{iv} * v * \left(\frac{X}{Q}\right)$$

For isotope I-131, an example is presented:

x_{iv} Release Conc.		Flow						(X/Q)			Receptor Conc.	
1.63E-04	µCi	93,000	~~ft³~~	2.83E-02	~~m³~~	1	~~min~~	3.90E-06	~~sec~~	=	2.79E-08	µCi
	cm³		~~min~~	1	~~ft³~~	60	~~sec~~		~~m³~~			cm³

Where:

v = 93,000 ft³/min is the rated flow from the Reactor Building from Design Input 5.8.

(X/Q) = 3.90E-06 is the Particulate and Iodine dispersion coefficient for the Reactor Building from Design Input 5.8.

Values in the column labeled "Inhalation Thyroid Dose mrem" are calculated by multiplying the following factors: concentration at the receptor, the breathing rate, the time, and the dose conversion factor. The basic equation is shown in Section 6.8.

$$Dose = \sum_i (x_{ir} * B * t * h_{T50i})$$

For isotope I-131, an example is presented:

x_{ir} Receptor Conc.		Time		B Breathing Rate		h_{T50i} Thyroid			Inhalation Thyroid Dose	
2.79E-08	~~µCi~~	1	~~hr~~	1.20E+06	~~cm³~~	1.08E+03	mrem	=	3.62E+01	mrem
	~~cm³~~				~~hr~~		~~µCi~~			

Where:

h_{T50i} is the thyroid dose factor for each isotope from Section 7.1.

B = 1.20E+06 cm^3/hr is the breathing rate. This value is equal to 3.33E-4 m^3/sec from Design Input 5.9.

Values in the "Inhalation CEDE Dose mrem" column are calculated by multiplying the following factors: concentration at the receptor, the breathing rate, the time, and the dose conversion factor. The basic equation comes from Section 6.9.

$$Dose = \sum_i (x_{ir} * B * t * h_{E50i})$$

For isotope I-131, an example is presented:

x_{ir} Receptor Conc		Time		B Breathing Rate		h_{E50i} CEDE			Inhalation CEDE Dose	
2.79E-08	~~µCi~~	1	~~hr~~	1.20E+06	~~cm³~~	3.29E+01	mrem	=	1.10E+00	mrem
	~~cm³~~				~~hr~~		~~µCi~~			

For ease of comparison, the table row for I-131 is shown here:

Nuclide	h_{T50i} Thyroid mrem/µCi	h_{E50i} CEDE mrem/µCi	Depleted Mix Ci/MWTh	Fraction	x_{iv} Release Conc. µCi/cm³	x_{ir} Receptor Conc. µCi/cm³	Inhalation Thyroid Dose mrem	Inhalation CEDE Dose mrem
I-131	1.08E+3	3.29E+1	3.89E+2	1.34E-2	1.63E-4	2.79E-8	3.62E+1	1.10E+0

Table 16 – Inhalation Thyroid and CEDE Dose for Reactor Building

Nuclide	h_{T50i} Thyroid mrem/µCi	h_{E50i} CEDE mrem/µCi	Depleted Mix Ci/MWTh	Fraction	x_{iv} Release Conc. µCi/cm³	x_{ir} Receptor Conc. µCi/cm³	Inhalation Thyroid Dose mrem	Inhalation CEDE Dose mrem
Ba-139	8.88E-3	1.72E-1	2.84E+0	9.76E-5	1.19E-6	2.04E-10	2.17E-6	4.20E-5
Ba-140	9.47E-1	3.74E+0	3.49E+1	1.20E-3	1.46E-5	2.50E-9	2.85E-3	1.12E-2
Ce-141	1.71E-1	8.95E+0	8.10E-1	2.78E-5	3.40E-7	5.82E-11	1.19E-5	6.25E-4
Ce-143	4.48E-2	3.39E+0	6.68E-1	2.30E-5	2.80E-7	4.79E-11	2.58E-6	1.95E-4
Ce-144	6.96E+0	3.74E+2	6.56E-1	2.25E-5	2.75E-7	4.71E-11	3.93E-4	2.11E-2

Nuclide	h_{T50i} Thyroid mrem/µCi	h_{E50i} CEDE mrem/µCi	Depleted Mix Ci/MWTh	Fraction	x_{iv} Release Conc. µCi/cm^3	x_{ir} Receptor Conc. µCi/cm^3	Inhalation Thyroid Dose mrem	Inhalation CEDE Dose mrem
Cm-242	3.48E+0	1.73E+4	8.30E-3	2.85E-7	3.48E-9	5.96E-13	2.49E-6	1.23E-2
Cs-134	4.11E+1	4.63E+1	6.10E+1	2.10E-3	2.56E-5	4.38E-9	2.16E-1	2.43E-1
Cs-136	6.40E+0	7.33E+0	1.91E+1	6.57E-4	8.02E-6	1.37E-9	1.05E-2	1.21E-2
Cs-137	2.93E+1	3.19E+1	4.22E+1	1.45E-3	1.77E-5	3.03E-9	1.07E-1	1.16E-1
I-131	1.08E+3	3.29E+1	3.89E+2	1.34E-2	1.63E-4	2.79E-8	3.62E+1	1.10E+0
I-132	6.44E+0	3.81E-1	1.27E+2	4.38E-3	5.34E-5	9.15E-9	7.07E-2	4.18E-3
I-133	1.80E+2	5.85E+0	6.80E+2	2.34E-2	2.85E-4	4.88E-8	1.05E+1	3.43E-1
I-134	1.07E+0	1.31E-1	1.70E+1	5.83E-4	7.12E-6	1.22E-9	1.56E-3	1.92E-4
I-135	3.13E+1	1.23E+0	4.54E+2	1.56E-2	1.91E-4	3.26E-8	1.23E+0	4.81E-2
Kr-83m	0.00E+0	0.00E+0	1.68E+2	5.79E-3	7.06E-5	1.21E-8	0.00E+0	0.00E+0
Kr-85	0.00E+0	0.00E+0	1.02E+2	3.50E-3	4.27E-5	7.32E-9	0.00E+0	0.00E+0
Kr-85m	0.00E+0	0.00E+0	1.05E+3	3.59E-2	4.38E-4	7.50E-8	0.00E+0	0.00E+0
Kr-87	0.00E+0	0.00E+0	2.96E+2	1.02E-2	1.24E-4	2.12E-8	0.00E+0	0.00E+0
Kr-88	0.00E+0	0.00E+0	1.83E+3	6.30E-2	7.69E-4	1.32E-7	0.00E+0	0.00E+0
La-140	4.51E-1	4.85E+0	3.34E-1	1.15E-5	1.40E-7	2.40E-11	1.30E-5	1.39E-4
La-141	3.48E-2	5.81E-1	1.33E-1	4.58E-6	5.58E-8	9.55E-12	3.99E-7	6.66E-6
La-142	3.23E-2	2.53E-1	3.29E-2	1.13E-6	1.38E-8	2.36E-12	9.17E-8	7.18E-7
Mo-99	4.33E-1	3.96E+0	4.66E+0	1.60E-4	1.95E-6	3.35E-10	1.74E-4	1.59E-3
Nb-95	1.32E+0	5.81E+0	3.32E-1	1.14E-5	1.39E-7	2.39E-11	3.79E-5	1.66E-4
Nd-147	7.18E-2	6.85E+0	1.28E-1	4.40E-6	5.37E-8	9.19E-12	7.92E-7	7.55E-5
Np-239	2.82E-2	2.51E+0	9.92E+0	3.41E-4	4.16E-6	7.12E-10	2.41E-5	2.14E-3
Pr-143	6.22E-9	8.10E+0	2.91E-1	9.99E-6	1.22E-7	2.09E-11	1.56E-13	2.03E-4
Pu-241	4.59E-2	8.25E+3	7.90E-2	2.71E-6	3.31E-8	5.67E-12	3.12E-7	5.61E-2
Rb-86	4.92E+0	6.62E+0	6.81E-1	2.34E-5	2.86E-7	4.89E-11	2.89E-4	3.89E-4
Rh-105	9.51E-2	9.55E-1	2.36E+0	8.11E-5	9.90E-7	1.69E-10	1.93E-5	1.94E-4
Ru-103	2.21E+0	8.95E+0	4.01E+0	1.38E-4	1.68E-6	2.88E-10	7.63E-4	3.09E-3
Ru-105	5.55E-2	4.55E-1	1.30E+0	4.47E-5	5.45E-7	9.33E-11	6.21E-6	5.09E-5
Ru-106	5.07E+1	4.77E+2	1.44E+0	4.94E-5	6.02E-7	1.03E-10	6.27E-3	5.90E-2
Sb-127	5.55E-1	6.03E+0	4.27E+0	1.47E-4	1.79E-6	3.06E-10	2.04E-4	2.22E-3
Sb-129	7.66E-2	6.44E-1	7.32E+0	2.52E-4	3.07E-6	5.25E-10	4.83E-5	4.06E-4
Sr-89	1.54E+0	4.14E+1	1.78E+1	6.12E-4	7.47E-6	1.28E-9	2.36E-3	6.36E-2
Sr-90	9.77E+0	1.30E+3	1.77E+0	6.09E-5	7.43E-7	1.27E-10	1.49E-3	1.98E-1
Sr-91	1.51E-1	1.66E+0	1.55E+1	5.33E-4	6.50E-6	1.11E-9	2.02E-4	2.22E-3
Sr-92	8.10E-2	8.07E-1	6.69E+0	2.30E-4	2.81E-6	4.80E-10	4.67E-5	4.65E-4
Tc-99m	1.85E-1	3.26E-2	2.28E+0	7.83E-5	9.55E-7	1.64E-10	3.64E-5	6.39E-6
Te-127	2.39E-2	3.18E-1	3.02E+0	1.04E-4	1.27E-6	2.17E-10	6.22E-6	8.28E-5
Te-127m	8.84E-1	2.15E+1	7.35E-1	2.53E-5	3.08E-7	5.28E-11	5.60E-5	1.36E-3
Te-129	6.03E-3	8.95E-2	7.70E-1	2.65E-5	3.23E-7	5.53E-11	4.00E-7	5.94E-6
Te-129m	1.46E+0	2.39E+1	3.10E+0	1.07E-4	1.30E-6	2.23E-10	3.90E-4	6.39E-3
Te-131m	1.34E+2	6.40E+0	8.93E+0	3.07E-4	3.75E-6	6.41E-10	1.03E-1	4.93E-3
Te-132	2.32E+2	9.44E+0	6.76E+1	2.32E-3	2.83E-5	4.85E-9	1.35E+0	5.49E-2
Xe-131m	0.00E+0	0.00E+0	1.32E+2	4.55E-3	5.55E-5	9.49E-9	0.00E+0	0.00E+0
Xe-133	0.00E+0	0.00E+0	1.94E+4	6.66E-1	8.12E-3	1.39E-6	0.00E+0	0.00E+0
Xe-133m	0.00E+0	0.00E+0	5.90E+2	2.03E-2	2.48E-4	4.24E-8	0.00E+0	0.00E+0
Xe-135	0.00E+0	0.00E+0	3.56E+3	1.22E-1	1.49E-3	2.55E-7	0.00E+0	0.00E+0
Xe-135m	0.00E+0	0.00E+0	5.23E-3	1.80E-7	2.19E-9	3.75E-13	0.00E+0	0.00E+0
Xe-138	0.00E+0	0.00E+0	6.45E-3	2.22E-7	2.70E-9	4.63E-13	0.00E+0	0.00E+0
Y-90	3.52E-2	8.44E+0	1.72E-2	5.92E-7	7.22E-9	1.24E-12	5.22E-8	1.25E-5
Y-91	4.07E-1	4.88E+1	2.34E-1	8.06E-6	9.83E-8	1.68E-11	8.22E-6	9.86E-4
Y-92	1.37E-2	7.81E-1	9.11E-2	3.13E-6	3.82E-8	6.54E-12	1.07E-7	6.13E-6

Nuclide	h_{T50i} Thyroid mrem/µCi	h_{E50i} CEDE mrem/µCi	Depleted Mix Ci/MWTh	Fraction	x_{iv} Release Conc. µCi/cm^3	x_{ir} Receptor Conc. µCi/cm^3	Inhalation Thyroid Dose mrem	Inhalation CEDE Dose mrem
Y-93	1.87E-2	2.15E+0	1.33E-1	4.56E-6	5.56E-8	9.52E-12	2.14E-7	2.46E-5
Zr-95	5.33E+0	2.36E+1	3.28E-1	1.13E-5	1.38E-7	2.36E-11	1.51E-4	6.69E-4
Zr-97	3.54E-1	4.33E+0	2.55E-1	8.78E-6	1.07E-7	1.83E-11	7.78E-6	9.53E-5
			2.91E+4	100.00%	1.22E-2 **1.22E-2**	2.09E-6	**50 mrem Thyroid**	**2.37 mrem CEDE**

Given a radiation effluent monitor reading of 1.22E-2 µCi/cm^3, and the assumptions of the scenario, the CDE thyroid value is 50 mrem and the CEDE is 2.37 mrem.

Spreadsheet cases are run for all four release points. See Section 2.0 for results.

7.5 Resultant Dose Summary

A single spreadsheet was used to calculate EDE, CEDE, and thyroid CDE. With the given source term, when the user changes the effluent gross concentration value, the spreadsheet calculates resultant doses.

Results and variables for the reactor building case are shown below. As can be seen here, an effluent release rate of 1.22E-02 µCi/cc at the Reactor Building will result in an offsite dose of approximately 50 mrem CDE thyroid. This value corresponds to the new RA1 EAL entry threshold of 50 mrem CDE thyroid.

Dose totals are taken from the tabular spreadsheet data presented on the preceding pages.

Inhalation CEDE:	**2.37**	**mrem**
Submersion EDE:	**0.39**	**mrem**
TEDE :	**2.76**	**mrem**
Inhalation Thyroid CDE:	**49.8**	**mrem**

Release Point:	**Reactor Building**		**SBGT ?:**	**off**	
Effluent Conc.:	**1.22E-02**	µCi/cc	**Release Flow CFM:**	**93,000**	
Release: Hrs. since Rx. Shutdown:	**5**		**Hrs. Core Uncovered:**	**1**	
Exposure Time (hrs.):	**1**		**Secondary Containment Holdup Hrs.:**	**0.5**	
Hours w/ Sprays On:	**2**		cm3 per ft3:	0.0283168	
Submersion X/Q:	**4.30E-06**	sec/m³	**Inhalation X/Q:**	**3.90E-06**	sec/m3
Breathing Rate	**3.33E-4**	m³/sec	=	**1.20E+6**	cm³/hr

Spreadsheet cases are run for all four release points and for decay times of five hours.

Cases were also run for all four release points for decay times of 36 hours in consideration of EAL entry thresholds that are mode dependent.

The output for all release points and decay times are shown in Appendix 1.

See Section 2.0 for results.

8.0 Computer Software

No computer software is used in this calculation.

9.0 Impact Assessment

This calculation is based on "realistic" assumptions for the purpose of declaring EALs, rather than typical conservative "bounding" type design basis analyses. The calculation documents the EAL threshold values for specific plan monitors to assist Operations and Emergency Response personnel in determining the new basis for EALs RA1, RS1, and RG1 in accordance with NEI 99-01 Rev. 6.

Turbine Building: Modes 1, 2, and 3

Inhalation CEDE:	**2.38**	**mRem**
Submersion EDE:	**0.39**	**mRem**
TEDE :	**2.77**	**mRem**
Inhalation Thyroid CDE:	**50.0**	**mRem**

Variables

Release Point:	Turbine Building		**SBGT ?:**	**off**	
Effluent Conc.:	**1.58E-02**	uCi/cc	**Release Flow CFM:**	**72,000**	
Release: Hrs. since Rx. Shutdown:	**5**		**Hrs. Core Uncovered:**	**1**	
Exposure Time (hrs.):	**1**		**Secondary Containment Holdup Hrs.:**	**0.5**	
Hours w/ Sprays On:	**2**		cm3 per ft3:	0.0283168	
Submersion X/Q:	**4.30E-06**	sec/m3	**Inhalation X/Q:**	**3.90E-06**	sec/m3
Breathing Rate	**3.33E-4**	m3/sec	=	**1.20E+6**	cm3/hr

Turbine Building: Modes 4 and 5

Inhalation CEDE:	**2.59**	**mRem**
Submersion EDE:	**0.07**	**mRem**
TEDE :	**2.67**	**mRem**
Inhalation Thyroid CDE:	**49.7**	**mRem**

Variables

Release Point:	Turbine Building		**SBGT ?:**	**off**	
Effluent Conc.:	**1.30E-02**	uCi/cc	**Release Flow CFM:**	**72,000**	
Release: Hrs. since Rx. Shutdown:	**36**		**Hrs. Core Uncovered:**	**1**	
Exposure Time (hrs.):	**1**		**Secondary Containment Holdup Hrs.:**	**0.5**	
Hours w/ Sprays On:	**2**		cm3 per ft3:	0.0283168	
Submersion X/Q:	**4.30E-06**	sec/m3	**Inhalation X/Q:**	**3.90E-06**	sec/m3
Breathing Rate	**3.33E-4**	m3/sec =	**1.20E+6**	cm3/hr	

Reactor Building: Modes 1, 2, and 3

Inhalation CEDE:	**2.37**	**mRem**
Submersion EDE:	**0.39**	**mRem**
TEDE :	**2.76**	**mRem**
Inhalation Thyroid CDE:	**49.8**	**mRem**

Variables

Release Point:	**Reactor Building**		**SBGT ?:**	**off**
Effluent Conc.:	**1.22E-02**	uCi/cc	**Release Flow CFM:**	**93,000**
Release: Hrs. since Rx. Shutdown:	**5**		**Hrs. Core Uncovered:**	**1**
Exposure Time (hrs.):	**1**		**Secondary Containment Holdup Hrs.:**	**0.5**
Hours w/ Sprays On:	**2**		cm3 per ft3:	0.0283168
Submersion X/Q:	**4.30E-06**	sec/m3	**Inhalation X/Q:**	**3.90E-06** sec/m3
Breathing Rate	**3.33E-4**	m3/sec	=	**1.20E+6** cm3/hr

Reactor Building: Modes 4 and 5

Inhalation CEDE:	2.60	mRem
Submersion EDE:	0.07	mRem
TEDE :	2.68	mRem
Inhalation Thyroid CDE:	49.9	mRem

Variables

Release Point:	Reactor Building		SBGT ?:	off	
Effluent Conc.:	1.01E-02	uCi/cc	Release Flow CFM:	93,000	
Release: Hrs. since Rx. Shutdown:	36		Hrs. Core Uncovered:	1	
Exposure Time (hrs.):	1		Secondary Containment Holdup Hrs.:	0.5	
Hours w/ Sprays On:	2		cm3 per ft3:	0.0283168	
Submersion X/Q:	4.30E-06	sec/m3	Inhalation X/Q:	3.90E-06	sec/m3
Breathing Rate	3.33E-4	m3/sec	=	1.20E+6	cm3/hr

Offgas Stack: Modes 1, 2, and 3

Inhalation CEDE:	1.96	mRem
Submersion EDE:	8.05	mRem
TEDE :	10.00	mRem
Inhalation Thyroid CDE:	41.1	mRem

Variables

Release Point:	Offgas Stack		SBGT ?:	on	
Effluent Conc.:	4.39E+01	uCi/cc	Release Flow CFM:	10,000	
Release: Hrs. since Rx. Shutdown:	5		Hrs. Core Uncovered:	1	
Exposure Time (hrs.):	1		Secondary Containment Holdup Hrs.:	<0.5	
Hours w/ Sprays On:	2		cm3 per ft3:	0.0283168	
Submersion X/Q:	2.80E-07	sec/m3	Inhalation X/Q:	3.10E-07	sec/m3
Breathing Rate	3.33E-4	m3/sec	=	1.20E+6	cm3/hr

Offgas Stack: Modes 4 and 5

Inhalation CEDE:	2.61	mRem
Submersion EDE:	1.41	mRem
TEDE :	4.02	mRem
Inhalation Thyroid CDE:	50.0	mRem

Variables

Release Point:	Offgas Stack		SBGT ?:	on	
Effluent Conc.:	4.52E+01	uCi/cc	Release Flow CFM:	10,000	
Release: Hrs. since Rx. Shutdown:	36		Hrs. Core Uncovered:	1	
Exposure Time (hrs.):	1		Secondary Containment Holdup Hrs.:	<0.5	
Hours w/ Sprays On:	2		cm3 per ft3:	0.0283168	
Submersion X/Q:	2.80E-07	sec/m3	Inhalation X/Q:	3.10E-07	sec/m3
Breathing Rate	3.33E-4	m3/sec	=	1.20E+6	cm3/hr

LLRPSF: Modes 1, 2, and 3

Inhalation CEDE:	2.37	mRem
Submersion EDE:	0.39	mRem
TEDE :	2.76	mRem
Inhalation Thyroid CDE:	49.7	mRem

Variables

Release Point:	LLRPSF		SBGT ?:	off	
Effluent Conc.:	1.51E-02	uCi/cc	Release Flow CFM:	75,000	
Release: Hrs. since Rx. Shutdown:	5		Hrs. Core Uncovered:	1	
Exposure Time (hrs.):	1		Secondary Containment Holdup Hrs.:	0.5	
Hours w/ Sprays On:	2		cm3 per ft3:	0.0283168	
Submersion X/Q:	4.30E-06	sec/m3	Inhalation X/Q:	3.90E-06	sec/m3
Breathing Rate	3.33E-4	m3/sec	=	1.20E+6	cm3/hr

LLRPSH: Modes 4 and 5

Inhalation CEDE:	2.60	mRem
Submersion EDE:	0.07	mRem
TEDE :	2.67	mRem
Inhalation Thyroid CDE:	49.8	mRem

Variables

Release Point:	LLRPSF		SBGT ?:	off	
Effluent Conc.:	1.25E-02	uCi/cc	Release Flow CFM:	75,000	
Release: Hrs. since Rx. Shutdown:	36		Hrs. Core Uncovered:	1	
Exposure Time (hrs.):	1		Secondary Containment Holdup Hrs.:	0.5	
Hours w/ Sprays On:	2		cm3 per ft3:	0.0283168	
Submersion X/Q:	4.30E-06	sec/m3	Inhalation X/Q:	3.90E-06	sec/m3
Breathing Rate	3.33E-4	m3/sec	=	1.20E+6	cm3/hr

CHECKLIST ITEMS[1]	YES	NO	N/A
GENERAL REQUIREMENTS			
1. If the calculation is being performed to a client procedure, is the procedure being used the latest revision?	☐	☐	☒
The calculation is being prepared to ENERCON's procedures.			
2. Are the proper forms being used and are they the latest revision?	☒	☐	☐
3. Have the appropriate client review forms/checklists been completed?	☐	☐	☒
The calculation is being prepared to ENERCON's procedures.			
4. Are all pages properly identified with a calculation number, calculation revision and page number consistent with the requirements of the client's procedure?	☒	☐	☐
5. Is all information legible and reproducible?	☒	☐	☐
6. Is the calculation presented in a logical and orderly manner?	☒	☐	☐
7. Is there an existing calculation that should be revised or voided?	☐	☒	☐
This is a new calculation to support implementing NEI 99-01 Rev. 6			
8. Is it possible to alter an existing calculation instead of preparing a new calculation for this situation?	☐	☒	☐
9. If an existing calculation is being used for design inputs, are the key design inputs, assumptions and engineering judgments used in that calculation valid and do they apply to the calculation revision being performed.	☐	☒	☐
10. Is the format of the calculation consistent with applicable procedures and expectations?	☒	☐	☐
11. Were design input/output documents properly updated to reference this calculation?	☐	☐	☒
12. Can the calculation logic, methodology and presentation be properly understood without referring back to the originator for clarification?	☒	☐	☐
OBJECTIVE AND SCOPE			
13. Does the calculation provide a clear concise statement of the problem and objective of the calculation?	☒	☐	☐
14. Does the calculation provide a clear statement of quality classification?	☒	☐	☐
15. Is the reason for performing and the end use of the calculation understood?	☒	☐	☐
16. Does the calculation provide the basis for information found in the plant's license basis?	☒	☐	☐
17. If so, is this documented in the calculation?	☒	☐	☐
18. Does the calculation provide the basis for information found in the plant's design basis documentation?	☐	☒	☐

ENERCON Excellence—Every project. Every day.	**Attachment 1** CALCULATION PREPARATION CHECKLIST	CALC NO.	NEE-323-CALC-005
		REV.	00

	CHECKLIST ITEMS[1]	YES	NO	N/A
19.	If so, is this documented in the calculation?	☐	☐	☒
20.	Does the calculation otherwise support information found in the plant's design basis documentation?	☐	☒	☐
21.	If so, is this documented in the calculation?	☐	☐	☒
22.	Has the appropriate design or license basis documentation been revised, or has the change notice or change request documents being prepared for submittal?	☐	☐	☒
DESIGN INPUTS				
23.	Are design inputs clearly identified?	☒	☐	☐
24.	Are design inputs retrievable or have they been added as attachments?	☒	☐	☐
25.	If Attachments are used as design inputs or assumptions are the Attachments traceable and verifiable?	☐	☐	☒
26.	Are design inputs clearly distinguished from assumptions?	☒	☐	☐
27.	Does the calculation rely on Attachments for design inputs or assumptions? If yes, are the attachments properly referenced in the calculation?	☐	☒	☐
28.	Are input sources (including industry codes and standards) appropriately selected and are they consistent with the quality classification and objective of the calculation?	☒	☐	☐
29.	Are input sources (including industry codes and standards) consistent with the plant's design and license basis?	☒	☐	☐
30.	If applicable, do design inputs adequately address actual plant conditions?	☒	☐	☐
31.	Are input values reasonable and correctly applied?	☒	☐	☐
32.	Are design input sources approved?	☒	☐	☐
33.	Does the calculation reference the latest revision of the design input source?	☒	☐	☐
34.	Were all applicable plant operating modes considered?	☒	☐	☐
ASSUMPTIONS				
35.	Are assumptions reasonable/appropriate to the objective?	☒	☐	☐
36.	Is adequate justification/basis for all assumptions provided?	☒	☐	☐
37.	Are any engineering judgments used?	☐	☒	☐
38.	Are engineering judgments clearly identified as such?	☐	☐	☒
39.	If engineering judgments are utilized as design inputs, are they reasonable and can they be quantified or substantiated by reference to site or industry standards, engineering principles, physical laws or other appropriate criteria?	☐	☐	☒

CHECKLIST ITEMS[1]	YES	NO	N/A
METHODOLOGY			
40. Is the methodology used in the calculation described or implied in the plant's licensing basis?	☐	☒	☐
41. If the methodology used differs from that described in the plant's licensing basis, has the appropriate license document change notice been initiated?	☐	☐	☒
42. Is the methodology used consistent with the stated objective?	☒	☐	☐
43. Is the methodology used appropriate when considering the quality classification of the calculation and intended use of the results?	☒	☐	☐
BODY OF CALCULATION			
44. Are equations used in the calculation consistent with recognized engineering practice and the plant's design and license basis?	☒	☐	☐
45. Is there reasonable justification provided for the use of equations not in common use?	☐	☐	☒
46. Are the mathematical operations performed properly and documented in a logical fashion?	☒	☐	☐
47. Is the math performed correctly?	☒	☐	☐
48. Have adjustment factors, uncertainties and empirical correlations used in the analysis been correctly applied?	☒	☐	☐
49. Has proper consideration been given to results that may be overly sensitive to very small changes in input?	☒	☐	☐
SOFTWARE/COMPUTER CODES			
50. Are computer codes or software languages used in the preparation of the calculation?	☐	☒	☐
51. Have the requirements of CSP 3.09 for use of computer codes or software languages, including verification of accuracy and applicability been met?	☐	☐	☒
52. Are the codes properly identified along with source vendor, organization, and revision level?	☐	☐	☒
53. Is the computer code applicable for the analysis being performed?	☐	☐	☒
54. If applicable, does the computer model adequately consider actual plant conditions?	☐	☐	☒
55. Are the inputs to the computer code clearly identified and consistent with the inputs and assumptions documented in the calculation?	☐	☐	☒
56. Is the computer output clearly identified?	☐	☐	☒
57. Does the computer output clearly identify the appropriate units?	☐	☐	☒

CHECKLIST ITEMS[1]	YES	NO	N/A
58. Are the computer outputs reasonable when compared to the inputs and what was expected?	☐	☐	☒
59. Was the computer output reviewed for ERROR or WARNING messages that could invalidate the results?	☐	☐	☒
RESULTS AND CONCLUSIONS			
60. Is adequate acceptance criteria specified?	☐	☐	☒
61. Are the stated acceptance criteria consistent with the purpose of the calculation, and intended use?	☒	☐	☐
62. Are the stated acceptance criteria consistent with the plant's design basis, applicable licensing commitments and industry codes, and standards?	☒	☐	☐
63. Do the calculation results and conclusions meet the stated acceptance criteria?	☒	☐	☐
64. Are the results represented in the proper units with an appropriate tolerance, if applicable?	☒	☐	☐
65. Are the calculation results and conclusions reasonable when considered against the stated inputs and objectives?	☒	☐	☐
66. Is sufficient conservatism applied to the outputs and conclusions?	☒	☐	☐
67. Do the calculation results and conclusions affect any other calculations?	☐	☒	☐
68. If so, have the affected calculations been revised?	☐	☐	☒
69. Does the calculation contain any conceptual, unconfirmed or open assumptions requiring later confirmation?	☐	☒	☐
70. If so, are they properly identified?	☐	☐	☒
DESIGN REVIEW			
71. Have alternate calculation methods been used to verify calculation results?	☐	☐	☒
No, a Design Review was performed.			

Note:

1. Where required, provide clarification/justification for answers to the questions in the space provided below each question. An explanation is required for any questions answered as “No’ or “N/A”.

Originator: Ryan Skaggs 12/14/17

Print Name and Sign Date