BSC	Design Calculation or Analysis Cover Sheet	1. QA: QA
	Complete only applicable items.	2. Page 1

3. System	4. Document Identifier
Monitored Geologic Repository	000-PSA-MGR0-01200-000-00C

5. Title

GROA Airborne Release Dose Calculation

6. Group

Preclosure Safety Analyses

7. Document Status Designation

☐ Preliminary ☒ Committed ☐ Confirmed ☐ Cancelled/Superseded

8. Notes/Comments

The Preclosure Safety Analyses department should be consulted before any use of information herein for any purpose other than that stated herein or before being used by any individual other than authorized personnel in the department.

Revision C is an extensive revision; therefore, no revision bars have been used.

Attachments	Total Number of Pages
ATTACHMENT I. ELECTRONIC FILE ON COMPACT DISC	2+CD

RECORD OF REVISIONS

9. No.	10. Reason For Revision	11. Total # of Pgs.	12. Last Pg. #	13. Originator (Print/Sign/Date)	14. Checker (Print/Sign/Date)	15. EGS (Print/Sign/Date)	16. Approved/Accepted (Print/Sign/Date)
00A	Initial Issue	54	II-1	J. Wang	J. Tang	S. Tsai	M. Wisenburg
00B	Revision to incorporate updated exhaust and intake locations	54	I-2	K. Ashley	J. Schulz	S. Tsai	M. Wisenburg
00C	Incorporate CACN-001 and CACN -002 (which addresses CR 11843) and to fix an error in the worksheet calculating PWR-Inhalation dose and the total dose (documented in CR 11900). Removed postulated Category 1 event sequences.	44	I-2	K. Ashley K. Ashley 3/26/2008	J. Schulz [signature] for J. Schulz 3/26/2008	S. Tsai [signature] 3/26/2008	~~D. Beckman~~ M. Frank [signature] for D. Beckman 3/26/2008

DISCLAIMER

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CONTENTS (CONT.)

TABLES

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ACRONYMS

ALARA	as low as is reasonably achievable
ARF	airborne release fraction
BWR	boiling water reactor
CEDE	committed effective dose equivalent
DDE	deep dose equivalent
DOE	U.S. Department of Energy
DPCs	dual-purpose canisters
ECRB	enhanced characterization of the repository block (drift)
GROA	geologic repository operations area
HEPA	high-efficiency particulate air filters
LDE	lens dose equivalent
LPF	leak path factor
MAR	material-at-risk
MTHM	metric tons of heavy metal
NRC	U.S. Nuclear Regulatory Commission
PWR	pressurized water reactor
RF	respirable fraction
SDE	shallow or skin dose equivalent
SNF	spent nuclear fuel
TAD	transportation, aging and disposal
TEDE	total effective dose equivalent
TODE	total organ dose equivalent
WHF	Wet Handling Facility

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1 PURPOSE

The purpose of this calculation is to evaluate potential dose consequences to the onsite workers from surface and subsurface facility releases during normal operations. This calculation is required to support the preclosure safety analyses to verify that the estimated doses are within the performance objectives of 10 CFR 63.111 (Reference 2.3.1).

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2.3 DESIGN CONSTRAINTS

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2.3.2 10 CFR 20. 2007. Energy: Standards for Protection Against Radiation.

2.3.3 49 CFR 173. 2006. Transportation: Shippers--General Requirements for Shipments and Packagings.

2.4 DESIGN OUTPUTS

This calculation does not support a specific engineering drawing, specification, or design list. The results of this calculation may be used in other preclosure safety analyses.

3 ASSUMPTIONS

3.1 ASSUMPTIONS REQUIRING VERIFICATION

None.

3.2 ASSUMPTIONS NOT REQUIRING VERIFICATION

3.2.1 Radionuclides Released from Aging Pads

Airborne effluents from the Aging Facility under normal operations are the surface contamination resuspended from transportation, aging, disposal (TAD) canisters and dual purpose canisters (DPCs) inside aging overpacks. The non-fixed (removable) radioactive surface contamination for the TAD canisters and DPCs is assumed to be the same as the surface contamination limits for transportation packages (Design Input 6.1.1). For simplicity, ^{60}Co is used to bound the dose contribution of beta-gamma emitters and low-toxicity alpha emitters and ^{241}Am is used to bound the dose contribution of all other alpha emitters.

Rationale: Transportation casks that ship uncanistered fuel are placed in the fuel pool for loading of the fuel assemblies and the surface of the casks are surveyed for contamination and decontaminated, if necessary, to meet the limits established for transportation packages (Design Input 6.1.1). TAD canisters and DPCs are loaded in the same manner, so it is reasonable to assume that the surface contamination limits TAD canisters and DPCs are the same as the limits for transportation packages. The assumption for the radionuclides is reasonable and conservative for the inhalation pathway for evaluating onsite worker doses because the dose coefficients for ^{60}Co and ^{241}Am are the highest among the radionuclides in their respective activity types (Reference 2.2.1).

3.2.2 Respirable Fraction

All respirable fractions (RF) are assumed to be 1.0 for normal operations.

Rationale: Normal releases from the WHF will be through high-efficiency particulate air (HEPA) filters. It is bounding to assume that the average particle size of airborne releases during normal operations is reduced following HEPA filtration so that the respirable fraction is 1.0, meaning that all releases are respirable. The releases from the Subsurface Facility and the releases from resuspended surface contaminates from the Aging Facility are also assumed to have a respirable fraction of 1.0, which is bounding.

3.2.3 Number of Aging Casks

It is assumed that the aging pads are at full capacity.

Rationale: Having the aging pads at full capacity is a bounding assumption.

3.2.4 Contaminated Area of Aging Cask

The surface area of 33 m^2 represents the available contamination area of a typical canister at the Aging Facility.

Rationale: The potential airborne release during normal operations at the Aging Facility is from resuspension of surface contamination of the TAD canisters and DPCs inside aging overpacks. It is reasonable to assume that all aging overpacks contain TAD canisters because any difference in the size of the DPCs is bounded by other conservative inputs and assumptions (e.g., Assumptions 3.2.2 and 3.2.3).

The TAD canister has a maximum diameter of 66.5 in. and a maximum length of 212 in. (Reference 2.2.2, Section 3.1.1(1)). Therefore, the surface area of a TAD canister is equal to 33 m^2 $[(\pi \times 66.5 \text{ in.} \times 212 \text{ in.} + 2 \times \pi \times (66.5 \text{ in.})^2 / 4) \times (0.0254 \text{ m/in.})^2]$.

3.2.5 Damage Ratio

The damage ratio is the fraction of the material at risk actually affected by a normal operation process or an event sequence. For normal operations involving commercial SNF, the damage ratio is equal to the fuel rod breakage percentage of 1%. Thus, the damage ratio for commercial SNF during normal operations is 0.01. Because crud releases can occur from all fuel rods, not just those with rod damage, the damage ratio for crud is 1.0.

Rationale: The 1% fuel rod breakage percentage is from Interim Safety Guide-5 (Reference 2.2.3, Attachment, p. 7) for normal operations.

3.2.6 Release Time and Exposure Time for Event Sequences

The release time and exposure time for event sequences are assumed to be the same.

Rationale: The duration of airborne release for event sequences is usually either instantaneous or shorter than a few hours. When considering onsite worker dose, the major concerns are inhalation and air submersion when the contaminated plume passes through the location. Therefore, it is conservative to assume that the release duration and the duration of worker exposure to radiation for event sequences are the same. For annual doses, the release duration is the entire year and the exposure is also the entire year. See Design Input 6.1.2 for the definition of the annual work year.

3.2.7 Subsurface Facility Releases

The subsurface releases are equally released from all exhaust shafts.

Rationale: There are six exhaust shafts for subsurface releases (Design Input 6.1.15). For normal operations, it is reasonable to assume that the releases are equally distributed among the six exhaust shafts.

3.2.8 Doses to Onsite Public and Workers from Ground Contamination

Doses to onsite public and workers from ground contamination are not considered.

Rationale: The surface and subsurface facilities are under the control of the licensee and are monitored for potential radiation contamination. If elevated radiation levels are found, appropriate remedial steps will be taken to reduce the radiation levels.

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4 METHODOLOGY

4.1 QUALITY ASSURANCE

This calculation was performed in accordance with EG-PRO-3DP-G04B-00037, *Calculations and Analyses* (Reference 2.1.1), and LS-PRO-0201, *Preclosure Safety Analysis Process* (Reference 2.1.2). The results of this calculation will be used in calculations and analyses to demonstrate compliance of the repository design to the performance objectives of 10 CFR 63.111 (Reference 2.3.1). Therefore, the approved version is designated as QA: QA.

4.2 USE OF SOFTWARE

The commercially available Microsoft® Excel 2003, which is a component of Microsoft® Office 2003 Professional, is used in this calculation to perform standard mathematical functions, which do not depend on the particular software program. The formulas used in this analysis are presented in sufficient detail in Section 4.3 and elsewhere at the point of use to allow the independent check to reproduce and verify the results using hand calculations, which was performed. Usage of Microsoft® Office 2003 Professional in this calculation constitutes Level 2 software usage, as defined in IT-PRO-0011 (Reference 2.1.3, Attachment 12), and as such are listed in the current *Level 2 Usage Controlled Software Report*. The operating environment used was Microsoft® Windows 2003 installed on a Dell OPTIPLEX GX620.

The software of *ICRP Database of Dose Coefficients* (Software Tracking Number: 610362-2.01-00) (Reference 2.2.1) is used solely as an electronic lookup table to obtain inhalation dose coefficients from ICRP Publication 68 (Reference 2.2.4), which was verified by visual inspection. Usage of the ICRP database in this calculation constitutes Level 2 software usage, as defined in IT-PRO-0011 (Ref. 2.1.3, Attachment 12). The operating environment used was Microsoft® Windows 2003 installed on a Dell OPTIPLEX GX620.

4.3 DOSE METHODOLOGY

Dose contributions to workers only include the assessment of occupational dose during a normal work period, which is 2,000 hours (Design Input 6.1.2) and includes dose assessment from airborne releases and direct exposure. This calculation only performs the airborne release dose assessment. Potential airborne radionuclide releases and worker doses are calculated using equations described in this section, design inputs in Section 6.1, and assumptions in Section 3.

4.3.1 Dose Estimate Methodology

Total effective dose equivalent to radiation workers is defined in 10 CFR 63.2 (Reference 2.3.1) as the sum of the deep dose equivalent for external exposures and the committed effective dose equivalent for internal exposures. *Use of the Effective Dose Equivalent in Place of the Deep Dose Equivalent in Dose Assessments* (Reference 2.2.5, p. 2) states that the effective dose equivalent should be used instead of the deep dose equivalent in situations that do not involve dose measurements using personnel dosimetry, such as in dose assessments made prior to actual operations that are based on calculations. Thus, the total effective dose equivalent is equal to the sum of the effective dose equivalent for external exposures plus the committed effective dose equivalent for internal exposures.

Total effective dose equivalent has five components: inhalation and ingestion, which are the committed effective dose equivalent portions of the dose, ground shine and air submersion, which are external doses from airborne releases, and external direct shine from contained sources. The last three are the effective dose equivalent portions of the dose. The total effective dose equivalent dose measure, described in Reference 2.2.3 (Attachment, p. 10) with effective dose equivalent used in place of deep dose equivalent (Reference 2.2.5, p. 2), for dose assessment is expressed in Equation 1, without the contributor of direct shine from contained sources.

$$\begin{aligned} TEDE &= CEDE + EDE \\ &= \sum_j D_{j,effective}^{inh} + \sum_j D_{j,effective}^{ing} + \sum_j D_j^{ext} \end{aligned} \qquad \text{Equation 1}$$

where

$TEDE$	=	total effective dose equivalent (rem)
$CEDE$	=	committed effective dose equivalent (rem)
EDE	=	effective dose equivalent (rem)
$D_{j,effective}^{inh}$	=	whole body effective inhalation dose from the j^{th} nuclide (rem)
$D_{j,effective}^{ing}$	=	whole body effective ingestion dose from the j^{th} nuclide (rem)
D_j^{ext}	=	whole body effective external dose from the jth nuclide (rem).

The ingestion dose is calculated from the ingestion of food crops and animal products contaminated with radionuclides as a result of an airborne release. In addition, no food crops are located onsite; therefore, ingestion is not part of worker dose assessment.

The inhalation dose in Equation 1 is expressed as (Reference 2.2.3, Attachment, pp. 9 and 10):

$$D_{j,effective}^{inh} = \frac{ST_j}{\Delta t} \times T \times \frac{\chi}{Q} \times BR \times conv \times DCF_{j,effective}^{inh} \qquad \text{Equation 2}$$

where

$D_{j,effective}^{inh}$	=	whole body effective inhalation radiation dose from the j^{th} nuclide (rem)
ST_j	=	release source term for the j^{th} nuclide (Ci)
Δt	=	release duration (s)
T	=	exposure duration (s)
$\frac{\chi}{Q}$	=	atmospheric dispersion factor (s/m^3)
BR	=	breathing rate (m^3/s)
$conv$	=	units conversion factor: 3.7×10^{12} [(rem ·Bq)/(Ci ·Sv)]
$DCF_{j,effective}^{inh}$	=	whole body effective inhalation dose coefficient of the j^{th} nuclide (Sv/Bq).

The external dose in Equation 1 is from airborne releases and is the sum of the ground shine dose and air submersion dose.

$$D_j^{ext} = D_j^{grd} + D_j^{sub} \qquad \text{Equation 3}$$

where

D_j^{grd} = ground shine dose from the j^{th} nuclide (rem)

D_j^{sub} = air submersion dose from the j^{th} nuclide (rem).

The ground shine dose is calculated from the ground concentration of the j^{th} nuclide as a result of deposition of radionuclides onto the ground from an airborne release as the plume passes. No ground shine dose is calculated for radiation workers (Assumption 3.2.8).

The air submersion dose is calculated from the air concentration of the j^{th} nuclide from an airborne release.

$$D_j^{sub} = \frac{ST_j}{\Delta t} \times T \times \frac{\chi}{Q} \times conv \times DCF_j^{sub} \qquad \text{Equation 4}$$

where

D_j^{sub} = air submersion dose from the j^{th} nuclide (rem)

DCF_j^{sub} = air submersion dose coefficient of the j^{th} nuclide [(Sv ·m^3)/(Bq ·s)].

Total Organ Dose Equivalent - The total organ dose equivalent dose measure, described in Reference 2.2.3 (Attachment, p. 10) with EDE used in place of DDE (Reference 2.2.5, p. 2), for dose assessment is expressed as:

$$TODE_k = CDE_k + EDE = \sum_j D_{j,k}^{inh} + \sum_j D_{j,k}^{ing} + \sum_j D_j^{ext} \qquad \text{Equation 5}$$

where k ≠ effective or skin

where

$TODE_k$ = total organ dose equivalent to the k^{th} organ (rem)

CDE_k = committed dose equivalent to the k^{th} organ (rem)

EDE = effective dose equivalent (rem)

$D_{j,k}^{inh}$ = inhalation dose from the j^{th} nuclide to the k^{th} organ (rem)

$D_{j,k}^{ing}$ = ingestion dose from the j^{th} nuclide to the k^{th} organ (rem)

D_{j}^{ext} = radiation dose from the j^{th} nuclide from external exposure (rem)

k = organ index, where organs are gonads, breast, lung, red marrow, bone surface, thyroid, colon, stomach wall, liver, bladder wall, esophagus, and remainder.

The inhalation dose in Equation 5 is expressed as (Reference 2.2.3, Attachment, pp. 9 and 10):

$$D_{j,k}^{inh} = \frac{ST_j}{\Delta t} \times T \times \frac{\chi}{Q} \times BR \times conv \times DCF_{j,k}^{inh} \qquad \text{Equation 6}$$

where

$D_{j,k}^{inh}$ = inhalation dose from the j^{th} nuclide to the k^{th} organ (rem)

$DCF_{j,k}^{inh}$ = inhalation dose coefficient of the j^{th} nuclide for the k^{th} organ (Sv/Bq).

For the radiation worker dose assessment, the term from ingestion is dropped from Equation 5

Shallow Dose Equivalent to Skin - The shallow dose equivalent to skin (SDE) is from the air submersion. The SDE is defined for occupational exposures as applying to "the skin of the whole body or the skin to any extremity" (Reference 2.3.2, 10 CFR 20.1201(a)(2)(ii)). The SDE is cited in 10 CFR 63 as "the shallow dose equivalent to skin" (Reference 2.3.1, 10 CFR 63.111(b)(2)).

$$SDE = \sum_j D_{j,skin}^{sub} \qquad \text{Equation 7}$$

where

SDE = shallow dose equivalent to skin (rem)

$D_{j,skin}^{sub}$ = air submersion dose from the j^{th} nuclide to skin (rem).

Lens Dose Equivalent - The lens dose equivalent (LDE) is calculated by summing the SDE and the TEDE. This approach is consistent with the guidance provided by the Reference 2.2.3 (Attachment, p. 10):

$$LDE = TEDE + SDE \qquad \text{Equation 8}$$

where

LDE = lens dose equivalent (rem)

$TEDE$ = total effective dose equivalent (Equation 1) (rem)

SDE = shallow dose equivalent to skin (Equation 7) (rem).

4.3.2 Airborne Release from Normal Operations

Airborne releases from normal surface repository operations are primarily from commercial SNF radionuclides released during operations in the Wet Handling Facility (WHF) and contamination resuspension from canisters located at the Aging Facility. Subsurface releases from normal repository operations are from resuspension of waste package surface contamination, and neutron activation of ventilated air and silica dust from host rock in the emplacement drifts.

The source term released during normal operations is a function of the material at risk, damage ratio, airborne release fraction, respirable fraction, and leak path factors for various confinement barriers as shown in the following equation (Reference 2.2.6, p. 1-2).

$$ST_j = MAR_j \times DR \times ARF_j \times RF_j \times LPF_{sys} \qquad \text{Equation 9}$$

where

ST_j	=	release source term for the j^{th} nuclide (Ci)
MAR_j	=	material at risk for the j^{th} nuclide (Ci)
DR	=	damage ratio (unitless)
ARF_j	=	airborne release fraction for the j^{th} nuclide (unitless)
RF_j	=	respirable fraction for the j^{th} nuclide (unitless)
LPF_{sys}	=	cumulative leak path factor for the system of confinement barriers (unitless).

The MAR is the amount of radionuclides initially available for release during normal operations. The concentration or inventory of each radionuclide in the radioactive waste is expressed in curies.

The damage ratio is the fraction of the MAR actually affected by a normal operation. For normal operation process involving commercial SNF, the damage ratio is 1% for fuel releases and 100% for crud releases (Assumption 3.2.5).

The airborne release fraction is the coefficient used to estimate the amount of a radioactive material suspended in air as an aerosol and thus available for transport. The respirable fraction is the fraction of airborne radionuclides as particles that can be transported through air and inhaled into the human respiratory and is conservatively assumed to be 1.0 (Assumption 3.2.2). The ARFs are given in Design Input 6.1.7.

Leak path factors are the fractions of material transported out from a confinement barrier after the action of any depletion mechanisms. Depletion mechanisms include plate-out, precipitation, gravitational settling, filtration, and agglomeration of airborne particulate material. Confinement barriers include spent fuel cladding, transportation casks, canisters, waste packages, WHF pool water, buildings, and HEPA filters. For normal surface operations, only the HEPA leak path factor is used. For the subsurface releases and resuspension of surface contamination from the Aging Facility, no LPFs are used in the dose assessment.

4.4 REGULATIONS

4.4.1 10 CFR Part 20 and 10 CFR Part 63

Radiation dose performance objectives for normal operations and Category 1 event sequences before permanent closure are specified in 10 CFR Part 63 (Reference 2.3.1) and 10 CFR Part 20 (Reference 2.3.2). These regulations, summarized in Table 1, specify worker dose limits during normal operations and for Category 1 event sequences. No Category 1 event sequences are postulated (Reference 2.2.22, Table 6.8-3; References 2.2.23, 2.2.24, 2.2.25, 2.2.26, and 2.2.27; Tables 6.8-2).

Table 1. Worker Dose Standards for Normal Operations and Category 1 Event Sequences

Event Sequence Type	Dose Type	Dose Performance Objectives
Normal operations and Category 1 event sequences [Aggregate Radiation exposures for Category 1 event sequences per 10 CFR 63.111(b)(1)]	Annual TEDE during normal operations and for Category 1 event sequences	ALARA
	TEDE 5	rem/yr
	The highest of the TODE	50 rem/yr
	LDE 15	rem/yr
	SDE 50	rem/yr

NOTES: ALARA = as low as is reasonably achievable, LDE = lens dose equivalent, SDE = skin dose equivalent, TEDE = total effective dose equivalent, TODE = total organ dose equivalent.

Sources: 10 CFR 63.111 (Reference 2.3.1)
10 CFR 20.1201 (Reference 2.3.2)

5 LIST OF ATTACHMENTS

		Number of Pages
Attachment I.	Electronic File on Compact Disc	2

6 BODY OF CALCULATION

All calculations are performed using a Microsoft Excel spreadsheet. The Microsoft Excel workbook *Release.xls* containing these calculations is on the CD provided in Attachment I.

6.1 INPUT PARAMETERS

6.1.1 Surface Contamination Limit for Transportation Casks

Table 2 lists the maximum permissible surface contamination limits on the exterior of a shipping package. The values are used as the surface contamination limits of TAD canisters and DPCs in aging overpacks (Assumption 3.2.1).

Table 2. Non-Fixed External Radioactive Contamination Limits for Packages

Contaminant	Maximum permissible limits		
	Bq/cm^2	µCi/cm^2	dpm/cm^2
Beta and gamma emitters and low toxicity alpha emitters	4 10	$^{-4}$ 220	
All other alpha emitting radionuclides	0.4	10^{-5} 22	

Source: Reference 2.3.3 (49 CFR 173.443, Table 9).

6.1.2 Facility Worker Work Hours for Normal Operations

The repository worker during normal operations works full time, which is equivalent to 2,000 hrs per year, inside the geologic repository operations area (GROA). Two thousand hours per year is the definition of the working year given in 10 CFR 20.1003 (Reference 2.3.2).

6.1.3 Breathing Rate

The breathing rate is given as 2.0×10^4 milliliter per minute (3.3×10^{-4} m^3/s) in 10 CFR Part 20 (Reference 2.3.2, Appendix B).

6.1.4 Inhalation Dose Coefficients

The inhalation dose coefficients for 26 organs and one effective dose equivalent used in this calculation are obtained from ICRP-68 (Reference 2.2.4) using the ICRP database (Software Tracking Number: 610362-2.01-00) (Reference 2.2.1).

The inhalation dose coefficients are based on the solubility classes in Design Input 6.1.6. Dose coefficients for two specific chemical elements are selected based on their special features. Hydrogen is in the HTO (tritiated water) chemical form and carbon is in the CO_2 chemical form, consistent with the methodology provided in Reference 2.2.7 (Section 4.1.7.5). A value of 2.7 x 10^{-11} (Sv/Bq) (i.e. 1.8 x 10^{-11} (Sv/Bq) × 1.5) is used for ^{3}H inhalation DCFs for all organs in this calculation, consistent with the methodology provided in Reference 2.2.7 (Section 4.1.7.7).

Strontium-90 is listed in Table 3 for medium solubility class, which is not available in ICRP-68 (Reference 2.2.4). Slow solubility class was chosen for ^{90}Sr because it had the highest effective and organ dose. Inhalation dose coefficients are listed in worksheet *ICRP68* of *Release.xls* on the attached CD.

6.1.5 Air Submersion Dose Coefficients

Dose coefficients for submersion in contaminated air are taken from the U.S. Environmental Protection Agency Federal Guidance Report No. 12 (Reference 2.2.8, Table III.1) and arranged in worksheet *FGR12* of *Release.xls* on the attached CD. Federal Guidance Report No. 12 is included in the CD supplement of Federal Guidance Report No. 13 (Reference 2.2.9). Small differences in the organs for the external dose coefficients provided by Federal Guidance Report No. 12 are documented in worksheet *FGR12* of *Release.xls* on the attached CD.

6.1.6 Lung Solubility Class

The lung solubility classes of all elements from site-specific inputs for Yucca Mountain Project application are listed on Table 3 (Reference 2.2.7, Table 107).

Table 3. Lung Solubility Class Used in the Airborne Inhalation Dose Calculation

Element	Atomic No.	Lung Solubility Class	Element	Atomic No.	Lung Solubility Class	Element	Atomic No.	Lung Solubility Class
Hydrogen	1	Vapor	Rubidium	37	fast	Ytterbium	70	slow
Beryllium	4	Slow	Strontium	38	medium	Lutetium	71	slow
Carbon	6	Gas	Yttrium	39	slow	Hafnium	72	medium
Nitrogen	7	Gas	Zirconium	40	medium	Tantalum	73	slow
Oxygen	8	Gas	Niobium	41	medium	Tungsten	74	fast
Fluorine	9	Slow	Molybdenum	42	medium	Rhenium	75	medium
Neon	10	Gas	Technetium	43	medium	Osmium	76	slow
Sodium	11	Fast	Ruthenium	44	medium	Iridium	77	slow
Magnesium	12	Medium	Rhodium	45	slow	Platinum	78	fast
Aluminum	13	Medium	Palladium	46	slow	Gold	79	slow
Silicon	14	Medium	Silver	47	medium	Mercury	80	medium
Phosphorus	15	Fast	Cadmium	48	slow	Thallium	81	fast
Sulfur	16	Fast	Indium	49	medium	Lead	82	medium
Chlorine	17	Medium	Tin	50	medium	Bismuth	83	medium
Argon	18	Gas	Antimony	51	medium	Polonium	84	medium
Potassium	19	Fast	Tellurium	52	medium	Astatine	85	medium
Calcium	20	Medium	Iodine	53	fast	Radon	86	gas
Scandium	21	Slow	Xenon	54	gas	Francium	87	fast
Titanium	22	Medium	Cesium	55	fast	Radium	88	medium
Vanadium	23	Medium	Barium	56	medium	Actinium	89	slow
Chromium	24	Slow	Lanthanum	57	medium	Thorium	90	slow
Manganese	25	Medium	Cerium	58	medium	Protactinium	91	slow
Iron	26	Medium	Praseodymium	59	slow	Uranium	92	slow
Cobalt	27	Slow	Neodymium	60	slow	Neptunium	93	medium
Nickel	28	Medium	Promethium	61	slow	Plutonium	94	slow
Copper	29	Slow	Samarium	62	medium	Americium	95	medium
Zinc	30	Slow	Europium	63	medium	Curium	96	medium
Gallium	31	Medium	Gadolinium	64	medium	Berkelium	97	medium
Germanium	32	Medium	Terbium	65	medium	Californium	98	medium
Arsenic	33	Medium	Dysprosium	66	medium	Einsteinium	99	medium
Selenium	34	Fast	Holmium	67	medium	Fermium	100	medium
Bromine	35	Medium	Erbium	68	medium	Mendelevium	101	medium
Krypton	36	Gas	Thulium	69	medium	OBT	-	slow

Source: Reference 2.2.7, Table 107.

6.1.7 Airborne Release Fractions

The airborne release fractions used for the WHF during normal operation are provided Reference 2.2.10 and listed in Table 4.

Table 4. Airborne Release Fractions and Respirable Fractions for Commercial SNF

Radionuclides	Airborne Release Fraction	
	Low Burnup Fuel[a]	High Burnup Fuel (>45 GWd/MTU)[b]
	Intact & Failed Commercial SNF Assembly Cladding Burst	Intact & Failed Commercial SNF Assembly Cladding Burst
^{3}H 0.3		0.3
^{85}Kr 0.3		0.3
^{129}I 0.3		0.3
All Cs	2×10^{-4} 2	$\times 10^{-3}$
^{90}Sr	3×10^{-5} 3	$\times 10^{-5}$
^{106}Ru	2×10^{-4} 2	$\times 10^{-3}$
Fuel Fines	3×10^{-5} 3	$\times 10^{-5}$
Crud (^{60}Co & ^{55}Fe)	0.015 0.015	

NOTES: [a]Use for normal operations.
[b]Use for event sequences.
SNF = spent nuclear fuel

Source: Reference 2.2.10, Table 18.

6.1.8 Leak Path Factors

Leak path factors (LPFs) are the fractions of material transported out from a confinement barrier after the action of any depletion mechanisms. For normal WHF operations, only the HEPA leak path factor is used.

For a two-stage HEPA filtration system, a $(LPF)_{HEPA}$ of 1×10^{-4} is used (Reference 2.2.11, Section 7.1).

6.1.9 Capacity of Aging Facility

The Aging Facility is composed of two pads, 17P and 17R (References 2.2.12, 2.2.13, and 2.2.14). Aging Pad 17P has an “L” shape layout consisting of 7 sub-pads, each of which consists of groups of 4 × 4 (or 16) cask spots (Reference 2.2.13). For the purpose of this calculation, Aging Pad 17P has been divided into two subsections. Aging Pad 17PN has three sub-pads; one sub-pad with eight 4 × 4 groups and two sub pads with nine 4 × 4 groups each for a total of 416 aging casks. Aging Pad 17PS has 4 sub-pads with thirteen 4 × 4 groups each for a total of 832 aging casks. Aging Pad 17R is rectangular consisting of two identical halves, designated as 17RE and 17RW. For each half, the front row can store 50 horizontal aging modules. Behind the horizontal modules there are 4 sub-pads, each consisting of 9 groups of 4 × 4 cask spots (Reference 2.2.14). The capacity of Aging Pads 17RE and 17RW is each 626 [50 + (9 × 4 × 16)] aging casks each. The aging pads are assumed to be at full capacity (Assumption 3.2.3), thus the numbers of aging casks on Aging Pads 17PN, 17PS, 17RE and 17RW are 416, 832, 626, and 626, respectively.

6.1.10 Resuspension Rate from Aging Pads

A resuspension rate of 4×10^{-5} hr^{-1} is used for resuspension of surface contamination on TAD canisters and DPCs inside aging overpacks at the Aging Facility during normal operations. This value is a recommended bounding value for indoor or outdoor ambient conditions (Reference 2.2.6, p. 5-7).

6.1.11 Throughput at Wet Handling Facility

The repository is designed such that at least 90% of the commercial spent nuclear fuel (SNF) is received in TAD canisters, and the remaining 10% is received either in dual-purpose canisters (DPCs) or as bare, intact assemblies in transportation casks (Reference 2.2.15, Section 2.2.1.3), which will be processed in the WHF (Reference 2.2.15, Section 1.2.2).

With a 20% increase above the design basis annual receipt rate of 3,000 metric tons of heavy metal (MTHM) of commercial SNF at the repository (Reference 2.2.15, Section 2.2.1.2) and 10% processed at the WHF, the annual throughput at the WHF is 360 MTHM per year (= 3000 × 120% × 10%). This provides a margin to estimate WHF worker doses from normal operation releases.

6.1.12 Commercial Spent Nuclear Fuel Radionuclide Inventories

Radionuclide inventories in curies per fuel assembly (Ci/fuel assembly) for the representative pressurized water reactor (PWR) SNF and boiling water reactor (BWR) SNF are presented in Table 5 and are based on the fuel characteristics presented in Table 6 (Reference 2.2.16, Section 7 and Attachment II). Representative fuel inventories are used for normal WHF operations. No Category 1 event sequences are postulated (Reference 2.2.22, Table 6.8-3; References 2.2.23, 2.2.24, 2.2.25, 2.2.26, and 2.2.27; Tables 6.8-2).

Crud is activated corrosion products found on the exterior surface of commercial fuel assemblies. Crud can be released to the environment during normal operation involving commercial SNF. Crud activities have been calculated in Reference 2.2.16 and are included in Table 5.

Table 5. Boiling Water Reactor and Pressurized Water Reactor Radionuclide Inventories

Radionuclide Re	presentative PWR (Ci/fuel assembly)	Representative BWR (Ci/fuel assembly)
^{241}Am	1.18×10^{3}	3.73×10^{2}
^{242}Am	7.27 2.87	
^{242m}Am	7.30 2.88	
^{243}Am	2.30×10^{1} 8.63	
^{137m}Ba	5.70×10^{4}	2.27×10^{4}
^{14}C	4.21×10^{-1}	2.12×10^{-1}
^{113m}Cd	1.39×10^{1} 5.24	
^{144}Ce	7.26×10^{1}	1.73×10^{1}
^{36}Cl	8.49×10^{-3}	3.48×10^{-3}
^{242}Cm	6.03 2.38	
^{243}Cm	1.57×10^{1} 5.55	
^{244}Cm	2.59×10^{3}	9.23×10^{2}
^{245}Cm	3.37×10^{-1}	9.07×10^{-2}
^{246}Cm	1.16×10^{-1}	4.26×10^{-2}
^{60}Co (crud)	1.69×10^{1}	5.66×10^{1}
^{134}Cs	4.08×10^{3}	1.31×10^{3}
^{135}Cs	3.74×10^{-1}	1.81×10^{-1}
^{137}Cs	6.04×10^{4}	2.41×10^{4}
^{154}Eu	2.36×10^{3}	7.73×10^{2}
^{155}Eu	4.94×10^{2}	1.92×10^{2}
^{55}Fe (crud)	2.09×10^{2}	9.84×10^{1}
^{3}H	2.44×10^{2}	1.05×10^{2}
^{129}I	2.27×10^{-2}	9.22×10^{-3}
^{85}Kr	3.11×10^{3}	1.17×10^{3}
^{93m}Nb	3.44×10^{-1}	1.58×10^{-1}
^{94}Nb	6.31×10^{-5}	2.56×10^{-5}
^{237}Np	2.53×10^{-1}	8.74×10^{-2}
^{239}Np	2.30×10^{1} 8.63	
^{231}Pa	3.00×10^{-5}	1.86×10^{-5}
^{107}Pd	8.65×10^{-2}	3.45×10^{-2}
^{147}Pm	6.36×10^{3}	2.11×10^{3}
^{144}Pr	7.26×10^{1}	1.73×10^{1}
^{238}Pu	2.77×10^{3}	1.02×10^{3}
^{239}Pu	1.80×10^{2}	5.41×10^{1}
^{240}Pu	3.20×10^{2}	1.27×10^{2}
^{241}Pu	5.20×10^{4}	1.57×10^{4}
^{242}Pu	1.68	7.08×10^{-1}
^{106}Ru	3.40×10^{2}	9.05×10^{1}
^{125}Sb	3.90×10^{2}	1.20×10^{2}
^{79}Se	4.75×10^{-2}	1.97×10^{-2}
^{151}Sm	2.45×10^{2}	6.73×10^{1}
^{126}Sn	3.97×10^{-1}	1.61×10^{-1}

Table 5. Boiling Water Reactor and Pressurized Water Reactor Radionuclide Inventories (cont.)

Radionuclide Re	presentative PWR (Ci/fuel assembly)	Representative BWR (Ci/fuel assembly)
^{90}Sr	4.10×10^{4}	1.66×10^{4}
^{99}Tc	9.32 3.88	
^{230}Th	6.45×10^{-5}	3.06×10^{-5}
^{232}U	2.44×10^{-2}	8.74×10^{-3}
^{233}U	2.46×10^{-5} 0.00	
^{234}U	6.01×10^{-1}	2.39×10^{-1}
^{235}U	7.66×10^{-3}	2.11×10^{-3}
^{236}U	1.81×10^{-1}	7.45×10^{-2}
^{238}U	1.47×10^{-1}	6.24×10^{-2}
^{90}Y	4.10×10^{4}	1.66×10^{4}
^{93}Zr	8.34×10^{-1}	3.49×10^{-1}

NOTE: BWR = boiling water reactor; Ci = curies; PWR = pressurized water reactor.

Source: Reference 2.2.16, Table 20.

Table 6. Commercial Spent Nuclear Fuel Assembly Characteristics

Assembly Initia	l Enrichment (%)	Initial MTHM/Assembly	Burnup (GWd/MTU)	Decay Time (years)
Representative PWR	4.2	0.475	50	10
Representative BWR	4.0	0.200	50	10

NOTES: BWR = boiling water reactor; GWd/MTU = gigawatt days/metric ton uranium; MTHM = metric ton heavy metal; PWR = pressurized water reactor

Sources: Reference 2.2.16, Table 19.
Reference 2.2.17, Section 5.5 for PWR fuel and Reference 2.2.18, Section 5.5.3 for BWR fuel for initial MTHM/assembly.

6.1.13 Average MTHM Per Fuel Assembly

The value of 0.475 MTHM per Pressurized Water Reactor (PWR) fuel assembly and 0.200 MTHM per Boiling Water Reactor (BWR) fuel assembly are used to estimate the number of fuel assemblies processed at the WHF. The MTHU per assembly is consistent with the fuel characteristics of the representative fuel which is used to determine the radionuclide inventory, as shown in Section 6.1.12 (Reference 2.2.16, Section 7).

6.1.14 Potential Subsurface Facility Releases

Under normal operations of the Subsurface Facility, there are three mechanisms with potential to generate airborne releases of radioactive materials, which are:

- Resuspension of waste package surface contamination
- Neutron activation of ventilating air inside the emplacement drifts
- Neutron activation of silica dust generated from host rock in the emplacement drifts.

Annual releases from the Subsurface Facility (Table 7) are based on these three mechanisms (Reference 2.2.19, Table 13). Although shown in Table 7, nitrogen-16 (^{16}N) is not considered in the dose assessment because of its 7.13 seconds half-life, (Reference 2.2.20, p. 41), which is very short when compared to the plume travel time from the release point to the surface locations.

Table 7. Annual Releases from Subsurface Facility Normal Operation

Normal Operations Release (Ci/yr)	
Waste Package Surface Contamination	
^{241}Am	4.9×10^{-5}
^{243}Am	5.5×10^{-7}
^{243}Cm	2.6×10^{-7}
^{244}Cm	3.4×10^{-5}
Crud ^{60}Co	2.9×10^{-3}
^{60}Co	7.8×10^{-6}
^{137}Cs	6.8×10^{-3}
^{154}Eu	1.7×10^{-5}
^{63}Ni	6.3×10^{-6}
^{147}Pm	3.0×10^{-6}
^{241}Pu	6.2×10^{-4}
^{238}Pu	5.7×10^{-5}
^{239}Pu	4.4×10^{-6}
^{240}Pu	7.9×10^{-6}
^{151}Sm	5.3×10^{-6}
^{90}Sr	6.8×10^{-4}
^{90}Y	6.8×10^{-4}
Activated Air	
^{41}Ar	1.5×10^{1}
^{16}N	5.8×10^{0}
Activated Dust	
^{28}Al	4.0×10^{-3}
^{55}Fe	8.2×10^{-5}
^{42}K	8.0×10^{-4}
^{16}N	2.1×10^{-5}
^{24}Na	3.7×10^{-3}
^{31}Si	5.2×10^{-4}

Source: Reference 2.2.19, Table 13.

6.1.15 Atmospheric Dispersion Factors

Atmospheric dispersion factors (χ/Qs) are provided in Reference 2.2.21. Table 8 contains the annual average χ/Qs that are used for normal operations. The table is a matrix of the χ/Q from one facility to another facility. Table 9 contains the facility names for the facility codes used in Table 8.

Table 8. Onsite Annual Average Atmospheric Dispersion Factor Values

Receptor Location	Annual Average Atmospheric Dispersion Factor (s/m^3) for Release from Facility										
	50	160	17RE	17RW	17PN	17PS	ES1	ES2	ES3N	ES3S	ES4	ECRB
60	2.15E-05	1.53E-05	3.47E-06	4.12E-06	2.26E-06	2.50E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
70	6.53E-06	5.49E-06	6.04E-06	5.50E-06	2.89E-06	3.32E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
80	4.42E-06	4.05E-06	6.79E-06	5.26E-06	3.15E-06	3.64E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
200	1.52E-05	9.33E-06	4.58E-06	4.62E-06	2.51E-06	2.86E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
50	1.83E-03	4.90E-05	1.56E-06	2.81E-06	1.59E-06	1.59E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
51A	9.84E-06	3.48E-06	1.14E-06	1.74E-06	1.15E-06	1.12E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
160	2.35E-05	5.53E-05	1.42E-06	3.09E-06	1.62E-06	1.47E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
17RE	6.65E-06	4.82E-06	NA	7.87E-06	7.17E-06	1.03E-05	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
17RW	6.86E-06	5.47E-06	2.66E-06	NA	3.92E-06	3.51E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
17PN	4.46E-06	1.72E-06	2.24E-06	2.38E-06	NA	1.06E-05	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
17PS	5.34E-06	2.08E-06	3.82E-06	3.52E-06	3.22E-05	NA	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
IS2	2.40E-08	1.70E-08	1.39E-07	1.50E-07	1.48E-07	1.43E-07	4.58E-06	4.22E-07	8.66E-07	1.03E-06	2.29E-06	1.13E-06
IS3	3.33E-08	3.03E-08	1.57E-07	1.79E-07	1.65E-07	1.59E-07	5.07E-07	1.95E-07	1.27E-05	9.13E-07	5.90E-07	3.25E-07
IS4	1.10E-08	9.45E-09	1.11E-07	1.18E-07	1.17E-07	1.15E-07	4.25E-06	2.65E-07	4.33E-07	3.25E-07	1.47E-05	8.27E-07
NC	1.53E-06	6.29E-07	4.34E-07	6.09E-07	4.40E-07	4.11E-07	3.33E-07	2.08E-07	2.21E-06	6.53E-07	4.25E-07	2.63E-07
NP	1.00E-05	2.40E-06	8.66E-07	1.41E-06	9.91E-07	9.08E-07	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
SP	6.87E-06	9.03E-07	3.82E-07	4.67E-07	4.15E-07	4.08E-07	1.12E-06	9.37E-07	7.97E-07	1.05E-06	9.57E-07	1.24E-06
220	1.28E-05	4.24E-06	9.84E-07	1.65E-06	1.09E-06	1.05E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
240	6.72E-06	2.86E-06	1.63E-06	2.38E-06	1.51E-06	1.51E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
230	5.23E-06	2.33E-06	1.82E-06	2.26E-06	1.51E-06	1.59E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
25A	1.10E-06	9.17E-07	3.11E-06	3.03E-06	2.03E-06	2.22E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
620	1.26E-06	8.46E-07	3.53E-06	3.27E-06	2.23E-06	2.46E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
71A	1.50E-06	7.78E-07	4.13E-06	3.50E-06	2.46E-06	2.76E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
30A	1.16E-06	1.12E-06	3.15E-06	3.23E-06	2.06E-06	2.25E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
30B	5.42E-06	2.34E-06	1.47E-06	1.51E-06	1.22E-06	1.26E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
30C	3.88E-06	2.84E-06	9.58E-06	6.17E-06	3.75E-06	4.55E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
27A	1.57E-05	5.58E-06	1.03E-06	1.42E-06	1.04E-06	1.04E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
780	1.95E-06	1.12E-06	1.99E-06	2.03E-06	1.52E-06	1.64E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
33A	5.73E-06	2.35E-06	1.52E-06	1.84E-06	1.36E-06	1.39E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
33B	5.29E-06	2.23E-06	1.51E-06	1.66E-06	1.26E-06	1.30E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07

NOTE: See Table 9 for facility codes.
Source: Reference 2.2.21, Table 32.

Table 9. Facility Code

Release or Receptor Code	Facility Description
17PN	Aging Pad P – North
17PS	Aging Pad P – South
17RE	Aging Pad R – East
17RW	Aging Pad R - West
25A	Utilities Facility
27A	Switchyard
30A	Central Security Station
30B	Cask Receipt Security Station
30C	North Perimeter Security Station
33A	Rail Buffer Area
33B	Truck Buffer Area
50	Wet Handling Facility

51A	Initial Handling Facility
60	Canister Receipt and Closure Facility-1
70	Canister Receipt and Closure Facility-2
71A Craft	Shops
80	Canister Receipt and Closure Facility-3
160	Low-Level Waste Facility
200 Recei	pt Facility
220	Heavy Equipment Maintenance Facility
230	Warehouse and Non-Nuclear Receipt Facility
240	Central Communications Control Facility
620 Administr	ation Facility
780	Lower Muck Yard
ES1	Exhaust Shaft 1
ES2	Exhaust Shaft 2
ES3N	Exhaust Shaft 3N
ES3S	Exhaust Shaft 3S
ES4	Exhaust Shaft 4
ECRB	ECRB Exhaust Shaft (enhanced characterization of the repository block (drift))
IS2	Intake Shaft 2
IS3	Intake Shaft 3
IS4	Intake Shaft 4 (Formerly Intake Shaft 1)
NC	North Construction Portal
NP North	Portal
SP South	Portal

6.2 CALCULATION OF AIRBORNE RELEASES

6.2.1 Normal Operation Releases from Wet Handling Facility

The WHF is expected to have potential airborne releases during normal operations. With an annual throughput of 360 MTHM (Design Input 6.1.11) processed in the WHF and using 0.475 MTHM/assembly (Design Input 6.1.13), the number of PWR fuel assemblies processed through the WHF, if all fuel processed were PWR, is 758 fuel assemblies (360 MTHM/yr / 0.475 MTHM/assembly rounded to a whole number). For BWR fuel using 0.200 MTHM/assembly, if all fuel processed were BWR fuel, 1,800 fuel assemblies are processed in the WHF each year (360 MTHM/yr / 0.200 MTHM/assembly).

The release of radionuclides to the environment as a result of normal operations at the surface facilities is estimated using Equation 9. The material at risk is the radionuclide inventory per representative fuel assembly from Table 5 multiplied by the number of assemblies processed each year. The damage ratio is 0.01 for fuel releases and 1.0 for crud releases (Assumption 3.2.5). The low burnup airborne release fractions are used from Table 4. The cutoff between low-burnup fuel and high-burnup fuel in Reference 2.2.10 is 45 GWd/MTU. The radionuclide inventories for representative PWR and BWR SNF assemblies are conservatively evaluated at a burnup of 50 GWd/MTU (Reference 2.2.16, Section 7). However, using the low-burnup release fractions is appropriate because the fuel characteristics of the representative fuel provide margin to the fuel inventory in that the average PWR assembly from the full inventory is 41.70 GWd/MTU (Reference 2.2.17, Section 5.5) and the average BWR assembly from the full inventory is 33.6 GWd/MTU (Reference 2.2.18, Section 5.5.3).

The respirable fraction is 1 (Assumption 3.2.2) and the HEPA LPF is 1×10^{-4} (Design Input 6.1.8). The PWR source terms are calculated and presented in Column K of worksheet *PWR-Source Term* and the BWR source terms are calculated and presented in Column K of worksheet *BWR-Source Term* of spreadsheet *Releases.xls*.

6.2.2 Normal Operation Releases from Aging Pads

Calculations of annual normal operation releases from the aging pads are shown in Table 10. Potential airborne releases from the aging pads under normal operational conditions are the surface contamination resuspended from TAD canisters and DPCs within aging overpacks on Aging Pads 17PN, 17PS 17RE, and 17RW. To simplify the calculation, ^{60}Co is conservatively used to represent beta-gamma emitters and ^{241}Am is conservatively used to represent alpha emitters (Assumption 3.2.1).

Excel worksheet is used to calculate the radionuclide release rate from the Aging Facility. As an example, the following is the calculation of the alpha emitter (^{241}Am) release from aging pad 17PN. From Design Input 6.1.1, the activity concentration on the surface of the canister is 1×10^{-5} μCi/cm^2, the area is 33 m^2 (Assumption 3.2.4), the capacity of pad 17PN is 416 canisters (Design Input 6.1.9) and the resuspension rate is 4×10^{-5} hr^{-1} (Design Input 6.1.10). Thus the release rate for ^{241}Am from aging pad 17PN is 4.81×10^{-4} Ci/yr.

$$4.81\times10^{-4}\,\frac{Ci}{yr}=\frac{10^{-5}\,\mu Ci}{cm^2}\times\frac{33m^2}{canister}\times 416 canisters\times\frac{4\times10^{-5}}{hr}\times\frac{10^4\,cm^2}{m^2}\times\frac{8760hr}{yr}\times\frac{Ci}{10^6\,\mu Ci}$$

The airborne releases from the Aging Facility are calculated in worksheet *Aging Facility* of spreadsheet *Releases.xls* and presented in Table 10.

Table 10. Annual Airborne Releases from Aging Pads During Normal Operations

Aging Pad	Number of Canisters	β–γ Release rate (^{60}Co) (Ci/yr)	α Release rate (^{241}Am) (Ci/yr)
17PN	416	4.81×10^{-3}	4.81×10^{-4}
17PS	832	9.62×10^{-3}	9.62×10^{-4}
17RE	626	7.24×10^{-3}	7.24×10^{-4}
17RW	626	7.24×10^{-3}	7.24×10^{-4}
Total Release Rate		2.89×10^{-2}	2.89×10^{-3}

Source: W orksheet *Aging Facility* of *Release.xls.*

6.2.3 Normal Operation Releases from Subsurface Facility

Potential airborne releases from the Subsurface Facility during normal operations are the radionuclides resuspended from waste package surface contamination and those generated by neutron activation of ventilated air and silica dust inside the emplacement drifts. The annual release rates from the Subsurface Facility are provided in Design Input 6.1.14. The sum of the radionuclide releases are given in Table 11.

Table 11. Dispersion of Subsurface Release from Normal Operations

Radionuclide	Activated Air (Ci/yr)	Activated Dust (Ci/yr)	Waste Package Surface Contamination (Ci/yr)	Total Release (Ci/yr)
^{28}Al		4.0×10^{-3}		4.0×10^{-3}
^{241}Am			4.9×10^{-5}	4.9×10^{-5}
^{243}Am			5.5×10^{-7}	5.5×10^{-7}
^{41}Ar	1.5×10^{1}			1.5×10^{1}
^{243}Cm			2.6×10^{-7}	2.6×10^{-7}
^{244}Cm			3.4×10^{-5}	3.4×10^{-5}
^{60}Co			2.9×10^{-3}	2.9×10^{-3}
^{137}Cs			6.8×10^{-3}	6.8×10^{-3}
^{154}Eu			1.7×10^{-5}	1.7×10^{-5}
^{55}Fe		8.2×10^{-5}		8.2×10^{-5}
^{42}K		8.0×10^{-4}		8.0×10^{-4}
^{16}N	5.8	2.1×10^{-5}		5.8
^{24}Na		3.7×10^{-3}		3.7×10^{-3}
^{63}Ni			6.3×10^{-6}	6.3×10^{-6}
^{147}Pm			3.0×10^{-6}	3.0×10^{-6}
^{238}Pu			5.7×10^{-5}	5.7×10^{-5}
^{239}Pu			4.4×10^{-6}	4.4×10^{-6}
^{240}Pu			7.9×10^{-6}	7.9×10^{-6}
^{241}Pu			6.2×10^{-4}	6.2×10^{-4}
^{31}Si		5.2×10^{-4}		5.2×10^{-4}
^{151}Sm			5.3×10^{-6}	5.3×10^{-6}
^{90}Sr			6.8×10^{-4}	6.8×10^{-4}
^{90}Y			6.8×10^{-4}	6.8×10^{-4}

NOTE: *Per Design Input 6.1.14, ^{16}N is not used in the dose calculations.

Source: Table 7 and worksheet *Subsurface* of *Release.xls*.

6.3 CALCULATION OF WORKER DOSES

Using the methodology outlined in Section 4.3.1, only the inhalation and air submersion portion of the dose is used to determine worker dose. The TEDE dose is the sum of the effective inhalation dose (Equation 2) and the effective air submersion dose (Equation 4) per Equation 1. The TODE is calculated as the sum of the organ inhalation dose (Equation 6) and the organ air submersion dose (Equation 4) per Equation 5. The SDE is calculated as shown in Equation 7 and the LDE is calculated as shown in Equation 8.

The normal operation dose is the sum of the dose contributions from the normal releases from the WHF, the normal airborne releases from the Subsurface Facility, and the resuspension of surface contaminants from the Aging Facility. The doses from the postulated Category 1 events are calculated separately.

6.3.1 Normal Operation Dose

The inputs to Equation 2, Equation 4, and Equation 6 are the source terms in Ci/yr, calculated in Section 6.2.1, the time that the worker is exposed (1 year) (Design Input 6.1.2), the release duration of one year (Assumption 3.2.6), the annual average atmospheric dispersion factors in s/m^3 (Table 8), the breathing rate in m^3/s (Design Input 6.1.3), and the dose conversion factors in Sv/Bq for inhalation and $(Sv\text{-}m^3)/(Bq\text{-}s)$ for air submersion (Design Inputs 6.1.4 and 6.1.5).

6.3.1.1 Wet Handling Facility Releases

The χ/Qs from the WHF to the facilities shown in Table 8 are used as input to the dose calculations. The other inputs outlined in Section 6.3.1 remain the same. Dose calculations are performed for both the representative PWR fuel and the representative BWR fuel. Worksheet *PWR- Inhalation Dose* in the Excel workbook *Release.xls* on the attached CD contains the calculations for the inhalation dose for the PWR fuel for each surface facility using Equation 2. Worksheet *BWR- Inhalation Dose* contains the inhalation dose for the BWR fuel. Worksheet *PWR- Sub-Total* contains the PWR submersion dose using Equation 4 and the sum of the inhalation and submersion doses for TEDE, TODE, LDE and SDE, while worksheet *BWR- Sub-Total* contains the same for BWR fuel. As shown in Table 12, PWR fuel results in the highest TEDE dose, and therefore, the results from PWR fuel will be summed with the dose contribution from the Aging Facility and subsurface releases for the total normal operations dose.

Table 12. Airborne Release Dose from Normal Releases from Wet Handling Facility

PWR					BWR			
Facility Number[a]	**TEDE (mrem/yr)**	**TODE[b] (mrem/yr)**	**Skin (mrem/yr)**	**Lens (mrem/yr)**	**TEDE (mrem/yr)**	**TODE[b] (mrem/yr)**	**Skin (mrem/yr)**	**Lens (mrem/yr)**
60	1.61E-01	2.46E+00	1.79E+00	1.95E+00	1.79E-01	2.16E+00	1.61E+00	1.79E+00
70	4.89E-02	7.46E-01	5.43E-01	5.92E-01	5.43E-02	6.55E-01	4.90E-01	5.44E-01
80	3.31E-02	5.05E-01	3.67E-01	4.01E-01	3.68E-02	4.43E-01	3.32E-01	3.68E-01
200	1.14E-01	1.74E+00	1.26E+00	1.38E+00	1.26E-01	1.52E+00	1.14E+00	1.27E+00
50	1.37E+01	2.09E+02	1.52E+02	1.66E+02	1.52E+01	1.84E+02	1.37E+02	1.53E+02
51A	7.37E-02	1.12E+00	8.18E-01	8.92E-01	8.18E-02	9.87E-01	7.38E-01	8.20E-01
160	1.76E-01	2.69E+00	1.95E+00	2.13E+00	1.95E-01	2.36E+00	1.76E+00	1.96E+00
17RE	4.98E-02	7.60E-01	5.53E-01	6.03E-01	5.53E-02	6.67E-01	4.99E-01	5.54E-01
17RW	5.14E-02	7.84E-01	5.70E-01	6.22E-01	5.70E-02	6.88E-01	5.15E-01	5.72E-01
17PN	3.34E-02	5.10E-01	3.71E-01	4.04E-01	3.71E-02	4.47E-01	3.35E-01	3.72E-01
17PS	4.00E-02	6.10E-01	4.44E-01	4.84E-01	4.44E-02	5.36E-01	4.01E-01	4.45E-01
IS2	1.80E-04	2.74E-03	2.00E-03	2.18E-03	2.00E-04	2.41E-03	1.80E-03	2.00E-03
IS3	2.50E-04	3.80E-03	2.77E-03	3.02E-03	2.77E-04	3.34E-03	2.50E-03	2.78E-03
IS4	8.24E-05	1.26E-03	9.14E-04	9.97E-04	9.15E-05	1.10E-03	8.25E-04	9.17E-04
NC	1.15E-02	1.75E-01	1.27E-01	1.39E-01	1.27E-02	1.53E-01	1.15E-01	1.28E-01
NP	7.49E-02	1.14E+00	8.31E-01	9.06E-01	8.31E-02	1.00E+00	7.50E-01	8.33E-01
SP	5.15E-02	7.85E-01	5.71E-01	6.23E-01	5.71E-02	6.89E-01	5.15E-01	5.73E-01
220	9.59E-02	1.46E+00	1.06E+00	1.16E+00	1.06E-01	1.28E+00	9.60E-01	1.07E+00
240	5.04E-02	7.68E-01	5.59E-01	6.09E-01	5.59E-02	6.74E-01	5.04E-01	5.60E-01
230	3.92E-02	5.98E-01	4.35E-01	4.74E-01	4.35E-02	5.25E-01	3.92E-01	4.36E-01
25A	8.24E-03	1.26E-01	9.14E-02	9.97E-02	9.15E-03	1.10E-01	8.25E-02	9.17E-02
620	9.44E-03	1.44E-01	1.05E-01	1.14E-01	1.05E-02	1.26E-01	9.45E-02	1.05E-01
71A	1.12E-02	1.71E-01	1.25E-01	1.36E-01	1.25E-02	1.50E-01	1.13E-01	1.25E-01
30A	8.69E-03	1.33E-01	9.64E-02	1.05E-01	9.64E-03	1.16E-01	8.70E-02	9.67E-02
30B	4.06E-02	6.19E-01	4.51E-01	4.91E-01	4.51E-02	5.44E-01	4.07E-01	4.52E-01
30C	2.91E-02	4.43E-01	3.23E-01	3.52E-01	3.23E-02	3.89E-01	2.91E-01	3.23E-01
27A	1.18E-01	1.79E+00	1.31E+00	1.42E+00	1.31E-01	1.57E+00	1.18E+00	1.31E+00
780	1.46E-02	2.23E-01	1.62E-01	1.77E-01	1.62E-02	1.96E-01	1.46E-01	1.63E-01
33A	4.29E-02	6.55E-01	4.76E-01	5.19E-01	4.76E-02	5.75E-01	4.30E-01	4.78E-01
33B	3.96E-02	6.04E-01	4.40E-01	4.79E-01	4.40E-02	5.31E-01	3.97E-01	4.41E-01

NOTES: [a]See Table 9 for facility names.
[b]Highest organ dose is to the bone surface.
BWR = boiling water reactor; PWR = pressurized water reactor; TEDE = total effective dose equivalent; TODE= total organ dose equivalent.

Sources: Worksheet *PWR- Sub-Total* for PWR results and worksheet *BWR- Sub-Total* for BWR results of *Release.xls.*

6.3.1.2 Aging Facility Releases

The χ/Qs from the Aging Facility to the facilities shown in Table 8 are used as input to the dose calculations. The other inputs outlined in Section 6.3.1 remain the same. Worksheet *Aging Facility* in the Microsoft® Excel workbook *Release.xls* on the attached CD contains the calculations for the dose from the aging pads to each surface facility using Equation 2 and Equation 4. The χ/Qs shown in Table 8 provide χ/Qs for four sub-pads of the Aging Facility.

These χ/Qs are weighted by the number of canisters on each aging pad to provide a total dose to the facility locations.

Table 13. Airborne Release Dose from Normal Releases from Aging Facility

Facility Number[a]	TEDE (mrem/yr)	TODE[b] (mrem/yr)	Skin (mrem/yr)	Lens (mrem/yr)
60	9.84E-02	4.01	6.91E-03	1.05E-01
70	1.42E-01	5.77	9.94E-03	1.52E-01
80	1.51E-01	6.13	1.06E-02	1.61E-01
200	1.16E-01	4.74	8.16E-03	1.24E-01
50	5.98E-02	2.43	4.20E-03	6.40E-02
51A	4.07E-02	1.66	2.86E-03	4.36E-02
160	5.98E-02	2.43	4.20E-03	6.40E-02
17RE	2.09E-01	8.50	1.46E-02	2.23E-01
17RW	7.87E-02	3.21	5.53E-03	8.43E-02
17PN	1.48E-01	6.04	1.04E-02	1.59E-01
17PS	2.28E-01	9.28	1.60E-02	2.44E-01
IS2	4.58E-03	1.86E-01	3.21E-04	4.90E-03
IS3	5.21E-03	2.12E-01	3.66E-04	5.57E-03
IS4	3.64E-03	1.48E-01	2.56E-04	3.90E-03
NC	1.49E-02	6.08E-01	1.05E-03	1.60E-02
NP	3.28E-02	1.34	2.30E-03	3.51E-02
SP	1.32E-02	5.38E-01	9.28E-04	1.41E-02
220	3.77E-02	1.53	2.65E-03	4.03E-02
240	5.57E-02	2.27	3.91E-03	5.96E-02
230	5.71E-02	2.32	4.00E-03	6.11E-02
25A	8.28E-02	3.37	5.81E-03	8.86E-02
620	9.16E-02	3.73	6.43E-03	9.80E-02
71A	1.03E-01	4.18	7.20E-03	1.10E-01
30A	8.52E-02	3.47	5.97E-03	9.11E-02
30B	4.33E-02	1.76	3.04E-03	4.64E-02
30C	4.07E-02	1.66	2.86E-03	4.36E-02
27A	3.59E-02	1.46	2.52E-03	3.84E-02
780	5.72E-02	2.33	4.01E-03	6.12E-02
33A	4.85E-02	1.97	3.40E-03	5.19E-02
33B	4.55E-02	1.85	3.19E-03	4.87E-02

NOTES: [a]See Table 9 for facility names.
[b]Highest organ dose is to the bone surface.
TEDE = total effective dose equivalent; TODE= total organ dose equivalent.

Sources: Worksheet *Aging Facility* of *Release.xls.*

6.3.1.3 Subsurface Releases

The χ/Qs from the exhaust shafts of the Subsurface Facility to the facilities shown in Table 8 are used as input to the dose calculations. There are six exhaust shafts from the subsurface. Per Assumption 3.2.7, the total release from the subsurface is equally released from the six exhaust shafts; therefore, the χ/Qs from these locations are summed to provide a total dose to the facility locations. The other inputs outlined in Section 6.3.1 remain the same. Worksheet *Subsurface* in the Microsoft® Excel workbook *Release.xls* on the attached CD contains the calculations using Equation 2 and Equation 4. From worksheet *Subsurface* columns BP to CU, the highest organ dose from inhalation is to the bone surface and the highest organ dose from air submersion is to the skin. The highest of the sum of the skin dose from both contributors and the sum of bone surface dose from both contributors is reported for the total organ dose, which is the dose to the bone surface.

Table 14. Airborne Release Dose from Normal Releases from Subsurface Facility

Facility Number[a]	**TEDE (mrem/yr)**	**TODE[b] (mrem/yr)**	**Skin (mrem/yr)**	**Lens (mrem/yr)**
60	1.12E-02	2.03E-01	7.76E-03	1.89E-02
70	1.12E-02	2.03E-01	7.76E-03	1.89E-02
80	1.12E-02	2.03E-01	7.76E-03	1.89E-02
200	1.12E-02	2.03E-01	7.76E-03	1.89E-02
50	1.12E-02	2.03E-01	7.76E-03	1.89E-02
51A	1.12E-02	2.03E-01	7.76E-03	1.89E-02
160	1.12E-02	2.03E-01	7.76E-03	1.89E-02
17RE	1.12E-02	2.03E-01	7.76E-03	1.89E-02
17RW	1.12E-02	2.03E-01	7.76E-03	1.89E-02
17PN	1.12E-02	2.03E-01	7.76E-03	1.89E-02
17PS	1.12E-02	2.03E-01	7.76E-03	1.89E-02
IS2	2.00E-02	3.63E-01	1.39E-02	3.39E-02
IS3	2.95E-02	5.36E-01	2.05E-02	5.00E-02
IS4	4.03E-02	7.33E-01	2.80E-02	6.83E-02
NC	7.93E-03	1.44E-01	5.51E-03	1.34E-02
NP	1.12E-02	2.03E-01	7.76E-03	1.89E-02
SP	1.18E-02	2.15E-01	8.22E-03	2.00E-02
220	1.12E-02	2.03E-01	7.76E-03	1.89E-02
240	1.12E-02	2.03E-01	7.76E-03	1.89E-02
230	1.12E-02	2.03E-01	7.76E-03	1.89E-02
25A	1.12E-02	2.03E-01	7.76E-03	1.89E-02
620	1.12E-02	2.03E-01	7.76E-03	1.89E-02
71A	1.12E-02	2.03E-01	7.76E-03	1.89E-02
30A	1.12E-02	2.03E-01	7.76E-03	1.89E-02
30B	1.12E-02	2.03E-01	7.76E-03	1.89E-02
30C	1.12E-02	2.03E-01	7.76E-03	1.89E-02
27A	1.12E-02	2.03E-01	7.76E-03	1.89E-02
780	1.12E-02	2.03E-01	7.76E-03	1.89E-02
33A	1.12E-02	2.03E-01	7.76E-03	1.89E-02
33B	1.12E-02	2.03E-01	7.76E-03	1.89E-02

NOTES: [a]See Table 9 for facility names.
[b]Highest organ dose is to the bone surface.
TEDE = total effective dose equivalent; TODE= total organ dose equivalent.

Sources: Worksheet *Subsurface* of *Release.xls*.

7 RESULTS AND CONCLUSION

Two potential airborne release source terms are estimated for the surface facilities during normal operations. They are releases from the WHF and resuspension of surface contamination from contained sources on the Aging Facility. Three potential airborne release source terms are estimated for the Subsurface Facility during normal operations. They are the resuspension of waste package surface contamination and airborne radionuclides generated by neutron activation of ventilated air and silica dust inside the emplacement drifts. With the χ/Qs and the releases derived in this document, the onsite worker doses at various locations are calculated.

Table 15 contains the total airborne release dose from normal operations, which is the sum of the dose contribution from normal operations at the WHF, the airborne releases from the Subsurface Facility (Table 14), and the resuspension of surface contamination from the Aging Facility (Table 13). The TEDE dose from BWR fuel is higher than the TEDE doses from PWR fuel (Table 12), therefore the doses from BWR fuel are used in the total for all dose results. The highest organ dose for all three contributors is to the bone surface, thus dose from the bone surface is summed to provide TODE dose.

The calculated results of worker doses are reasonable compared to the inputs, and the results are suitable for use in consequence analysis to demonstrate compliance with preclosure performance objectives in 10 CFR 63.111 (Section 4.4.1). The results are well below all applicable regulatory and operational performance objectives. The uncertainties are taken into account by consistently using a conservative approach; the calculations, therefore, yield a conservatively bounding set of results.

Table 15. Total Airborne Release Dose from Normal Operations

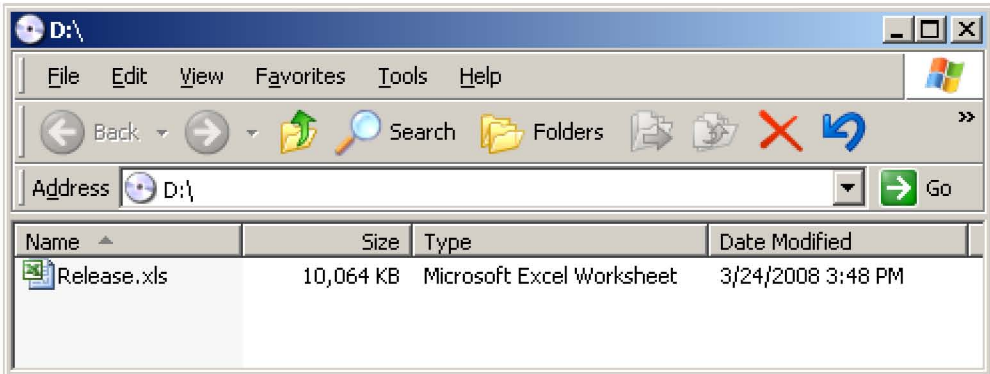
Facility Number	Facility Name	TEDE (mrem/yr)	TODE[a] (mrem/yr)	Skin (mrem/yr)	Lens (mrem/yr)
60	Canister Receipt and Closure Facility-1	2.88E-01	6.37E+00	1.63E+00	1.92E+00
70	Canister Receipt and Closure Facility-2	2.07E-01	6.63E+00	5.08E-01	7.15E-01
80	Canister Receipt and Closure Facility-3	1.98E-01	6.77E+00	3.50E-01	5.48E-01
200	Receipt Facility	2.54E-01	6.46E+00	1.16E+00	1.41E+00
50	Wet Handling Facility	1.53E+01	1.86E+02	1.37E+02	1.53E+02
51A	Initial Handling Facility	1.34E-01	2.85E+00	7.49E-01	8.83E-01
160	Low-Level Waste Facility	2.66E-01	4.99E+00	1.77E+00	2.04E+00
17RE	Aging Pad R – East	2.75E-01	9.37E+00	5.21E-01	7.96E-01
17RW	Aging Pad R - West	1.47E-01	4.10E+00	5.28E-01	6.75E-01
17PN	Aging Pad P – North	1.97E-01	6.69E+00	3.53E-01	5.49E-01
17PS	Aging Pad P – South	2.83E-01	1.00E+01	4.24E-01	7.08E-01
IS2	Intake Shaft 2	2.48E-02	5.52E-01	1.60E-02	4.08E-02
IS3	Intake Shaft 3	3.50E-02	7.52E-01	2.34E-02	5.84E-02
IS4	Intake Shaft 4	4.40E-02	8.82E-01	2.91E-02	7.31E-02
NC	North Construction Portal	3.56E-02	9.05E-01	1.21E-01	1.57E-01
NP	North Portal	1.27E-01	2.54E+00	7.60E-01	8.87E-01
SP	South Portal	8.22E-02	1.44E+00	5.25E-01	6.07E-01
220	Heavy Equipment Maintenance Facility	1.55E-01	3.02E+00	9.71E-01	1.13E+00
240	Central Communications Control Facility	1.23E-01	3.14E+00	5.16E-01	6.39E-01
230	Warehouse and Non-Nuclear Receipt Facility	1.12E-01	3.05E+00	4.04E-01	5.16E-01
25A	Utilities Facility	1.03E-01	3.68E+00	9.61E-02	1.99E-01
620	Administration Facility	1.13E-01	4.06E+00	1.09E-01	2.22E-01
71A	Craft Shops	1.26E-01	4.53E+00	1.27E-01	2.54E-01
30A	Central Security Station	1.06E-01	3.79E+00	1.01E-01	2.07E-01
30B	Cask Receipt Security Station	9.96E-02	2.51E+00	4.17E-01	5.17E-01
30C	North Perimeter Security Station	8.41E-02	2.25E+00	3.02E-01	3.86E-01
27A	Switchyard	1.78E-01	3.24E+00	1.19E+00	1.37E+00
780	Lower Muck Yard	8.45E-02	2.73E+00	1.58E-01	2.43E-01
33A	Rail Buffer Area	1.07E-01	2.75E+00	4.41E-01	5.48E-01
33B	Truck Buffer Area	1.01E-01	2.59E+00	4.08E-01	5.08E-01

NOTE: [a]Highest organ dose is to the bone surface.
TEDE = total effective dose equivalent; TODE= total organ dose equivalent.

Sources: Worksheet *Summary of Normal Results* of *Release.xls*.

ATTACHMENT I ELECTRONIC FILE ON COMPACT DISC

The electronic file provided on a compact disc is listed below.



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BSC

Calculation/Analysis Change Notice

Complete only applicable items.

1. QA: QA

3. Document Identifier:	4. Rev.:	5. CACN:
000-PSA-MGR0-01200-000	00C	001

6. Title:
GROA Airborne Release Dose Calculation

7. Reason for Change:
This CACN is associated with CR 12381-002.

Calculation 000-PSA-MGR0-01200-000-00C calculates potential doses to onsite workers from surface and subsurface facility airborne releases during normal operations in the GROA (Geological Repository Operation Area). The radionuclide inventory for representative PWR (pressurized water reactor) is an input to dose calculations for normal operation releases from the WHF (Wet Handling Facility). That inventory has been revised for three light elements, C-14, Cl-36 and H-3, in Calculation 000-PSA-MGR0-00700-000-00A CACN001. As a result, the GROA airborne release dose for normal operations with PWR spent fuel is affected.

This CACN corrects the PWR inventory for C-14, Cl-36 and H-3 in spreadsheet *Release.xls*, worksheet *PWR-Source Term* and subsequent worker doses.

Note: Both PWR and BWR (boiling water reactor) release doses are calculated, but only the higher of the PWR and BWR doses (based on total effective dose equivalent, TEDE) are included in the total dose tabulation. Because the BWR release doses (TEDE) are higher, they are limiting and are tabulated in the normal operations dose. Therefore, the reported normal operation doses are not affected by this CACN.

8. Supersedes Change Notice: ☐ Yes If, Yes, CACN No.: ____________ ☒ No

9. Change Impact:

Inputs Changed:	☒ Yes	☐ No	Results Impacted:	☒ Yes	☐ No
Assumptions Changed:	☐ Yes	☒ No	Design Impacted:	☐ Yes	☒ No

10. Description of Change:
There is no change to the calculation method of this calculation by this CACN.

The Excel spreadsheet *Release.xls*, worksheet *PWR-Source Term* was updated for the three light elements, C-14, Cl-36 and H-3 inventories. The updated inventories for those radionuclides and corresponding doses were incorporated into Tables 5 and 12, respectively. Attachment I was also updated with the spreadsheet information.

To implement the changes: replace pages 28, 29, 38 and I-1 with the attached pages and replace the CD (compact disc) with the attached CD that includes the updated Excel spreadsheet *Release.xls.*

This CACN also carries out the action plan for CR 12381-002.

11. REVIEWS AND APPROVAL

Printed Name	Signature	Date
11a. Originator: John H. Wang	[signature]	10/13/2008
11b. Checker: Dale T. Dexheimer	[signature]	10/13/08
11c. EGS: Sen-Sung Tsai	[signature]	10/13/08
11d. DEM: Michael V. Frank	[signature]	10/21/08
11e. Design Authority: Barbara Rusinko	[signature]	10/23/08

Table 5. Boiling Water Reactor and Pressurized Water Reactor Radionuclide Inventories

Radionuclide	Representative PWR (Ci/fuel assembly)	Representative BWR (Ci/fuel assembly)
^{241}Am	1.18×10^{3}	3.73×10^{2}
^{242}Am	7.27	2.87
^{242m}Am	7.30	2.88
^{243}Am	2.30×10^{1}	8.63
^{137m}Ba	5.70×10^{4}	2.27×10^{4}
^{14}C	3.35×10^{-1}	2.12×10^{-1}
^{113m}Cd	1.39×10^{1}	5.24
^{144}Ce	7.26×10^{1}	1.73×10^{1}
^{36}Cl	6.84×10^{-3}	3.48×10^{-3}
^{242}Cm	6.03	2.38
^{243}Cm	1.57×10^{1}	5.55
^{244}Cm	2.59×10^{3}	9.23×10^{2}
^{245}Cm	3.37×10^{-1}	9.07×10^{-2}
^{246}Cm	1.16×10^{-1}	4.26×10^{-2}
^{134}Cs	4.08×10^{3}	1.31×10^{3}
^{135}Cs	3.74×10^{-1}	1.81×10^{-1}
^{137}Cs	6.04×10^{4}	2.41×10^{4}
^{154}Eu	2.36×10^{3}	7.73×10^{2}
^{155}Eu	4.94×10^{2}	1.92×10^{2}
^{3}H	2.70×10^{2}	1.05×10^{2}
^{129}I	2.27×10^{-2}	9.22×10^{-3}
^{85}Kr	3.11×10^{3}	1.17×10^{3}
^{93m}Nb	3.44×10^{-1}	1.58×10^{-1}
^{94}Nb	6.31×10^{-5}	2.56×10^{-5}
^{237}Np	2.53×10^{-1}	8.74×10^{-2}
^{239}Np	2.30×10^{1}	8.63
^{231}Pa	3.00×10^{-5}	1.86×10^{-5}
^{107}Pd	8.65×10^{-2}	3.45×10^{-2}
^{147}Pm	6.36×10^{3}	2.11×10^{3}
^{144}Pr	7.26×10^{1}	1.73×10^{1}
^{238}Pu	2.77×10^{3}	1.02×10^{3}
^{239}Pu	1.80×10^{2}	5.41×10^{1}
^{240}Pu	3.20×10^{2}	1.27×10^{2}
^{241}Pu	5.20×10^{4}	1.57×10^{4}
^{242}Pu	1.68	7.08×10^{-1}
^{106}Ru	3.40×10^{2}	9.05×10^{1}
^{125}Sb	3.90×10^{2}	1.20×10^{2}
^{79}Se	4.75×10^{-2}	1.97×10^{-2}
^{151}Sm	2.45×10^{2}	6.73×10^{1}
^{126}Sn	3.97×10^{-1}	1.61×10^{-1}

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Table 5. Boiling Water Reactor and Pressurized Water Reactor Radionuclide Inventories (cont.)

Radionuclide	Representative PWR (Ci/fuel assembly)	Representative BWR (Ci/fuel assembly)
^{90}Sr	4.10×10^{4}	1.66×10^{4}
^{99}Tc	9.32	3.88
^{230}Th	6.45×10^{-5}	3.06×10^{-5}
^{232}U	2.44×10^{-2}	8.74×10^{-3}
^{233}U	2.46×10^{-5}	0.00
^{234}U	6.01×10^{-1}	2.39×10^{-1}
^{235}U	7.66×10^{-3}	2.11×10^{-3}
^{236}U	1.81×10^{-1}	7.45×10^{-2}
^{238}U	1.47×10^{-1}	6.24×10^{-2}
^{90}Y	4.10×10^{4}	1.66×10^{4}
^{93}Zr	8.34×10^{-1}	3.49×10^{-1}

NOTE: BWR = boiling water reactor; Ci = curies; PWR = pressurized water reactor.

Source: Reference 2.2.16, Table 20. (As modified by CACN 001 to Reference 2.2.16)

J.W. 10/23/2008

Table 12. Airborne Release Dose from Normal Releases from Wet Handling Facility

	PWR				BWR			
Facility Number[a]	TEDE (mrem/yr)	TODE[b] (mrem/yr)	Skin (mrem/yr)	Lens (mrem/yr)	TEDE (mrem/yr)	TODE[b] (mrem/yr)	Skin (mrem/yr)	Lens (mrem/yr)
60	1.71E-01	2.47E+00	1.80E+00	1.97E+00	1.79E-01	2.16E+00	1.61E+00	1.79E+00
70	5.18E-02	7.49E-01	5.46E-01	5.98E-01	5.43E-02	6.55E-01	4.90E-01	5.44E-01
80	3.51E-02	5.07E-01	3.69E-01	4.04E-01	3.68E-02	4.43E-01	3.32E-01	3.68E-01
200	1.21E-01	1.74E+00	1.27E+00	1.39E+00	1.26E-01	1.52E+00	1.14E+00	1.27E+00
50	1.45E+01	2.10E+02	1.53E+02	1.67E+02	1.52E+01	1.84E+02	1.37E+02	1.53E+02
51A	7.80E-02	1.13E+00	8.22E-01	9.00E-01	8.18E-02	9.87E-01	7.38E-01	8.20E-01
160	1.86E-01	2.70E+00	1.96E+00	2.15E+00	1.95E-01	2.36E+00	1.76E+00	1.96E+00
17RE	5.27E-02	7.63E-01	5.56E-01	6.09E-01	5.53E-02	6.67E-01	4.99E-01	5.54E-01
17RW	5.44E-02	7.87E-01	5.73E-01	6.28E-01	5.70E-02	6.88E-01	5.15E-01	5.72E-01
17PN	3.54E-02	5.12E-01	3.73E-01	4.08E-01	3.71E-02	4.47E-01	3.35E-01	3.72E-01
17PS	4.24E-02	6.13E-01	4.46E-01	4.89E-01	4.44E-02	5.36E-01	4.01E-01	4.45E-01
IS2	1.90E-04	2.75E-03	2.01E-03	2.20E-03	2.00E-04	2.41E-03	1.80E-03	2.00E-03
IS3	2.64E-04	3.82E-03	2.78E-03	3.05E-03	2.77E-04	3.34E-03	2.50E-03	2.78E-03
IS4	8.72E-05	1.26E-03	9.19E-04	1.01E-03	9.15E-05	1.10E-03	8.25E-04	9.17E-04
NC	1.21E-02	1.76E-01	1.28E-01	1.40E-01	1.27E-02	1.53E-01	1.15E-01	1.28E-01
NP	7.93E-02	1.15E+00	8.36E-01	9.15E-01	8.31E-02	1.00E+00	7.50E-01	8.33E-01
SP	5.45E-02	7.88E-01	5.74E-01	6.29E-01	5.71E-02	6.89E-01	5.15E-01	5.73E-01
220	1.02E-01	1.47E+00	1.07E+00	1.17E+00	1.06E-01	1.28E+00	9.60E-01	1.07E+00
240	5.33E-02	7.71E-01	5.62E-01	6.15E-01	5.59E-02	6.74E-01	5.04E-01	5.60E-01
230	4.15E-02	6.00E-01	4.37E-01	4.79E-01	4.35E-02	5.25E-01	3.92E-01	4.36E-01
25A	8.72E-03	1.26E-01	9.19E-02	1.01E-01	9.15E-03	1.10E-01	8.25E-02	9.17E-02
620	9.99E-03	1.45E-01	1.05E-01	1.15E-01	1.05E-02	1.26E-01	9.45E-02	1.05E-01
71A	1.19E-02	1.72E-01	1.25E-01	1.37E-01	1.25E-02	1.50E-01	1.13E-01	1.25E-01
30A	9.20E-03	1.33E-01	9.70E-02	1.06E-01	9.64E-03	1.16E-01	8.70E-02	9.67E-02
30B	4.30E-02	6.22E-01	4.53E-01	4.96E-01	4.51E-02	5.44E-01	4.07E-01	4.52E-01
30C	3.08E-02	4.45E-01	3.24E-01	3.55E-01	3.23E-02	3.89E-01	2.91E-01	3.23E-01
27A	1.25E-01	1.80E+00	1.31E+00	1.44E+00	1.31E-01	1.57E+00	1.18E+00	1.31E+00
780	1.55E-02	2.24E-01	1.63E-01	1.78E-01	1.62E-02	1.96E-01	1.46E-01	1.63E-01
33A	4.54E-02	6.57E-01	4.79E-01	5.24E-01	4.76E-02	5.75E-01	4.30E-01	4.78E-01
33B	4.20E-02	6.07E-01	4.42E-01	4.84E-01	4.40E-02	5.31E-01	3.97E-01	4.41E-01

NOTES: [a]See Table 9 for facility names.
[b]Highest organ dose is to the bone surface.
BWR = boiling water reactor; PWR = pressurized water reactor; TEDE = total effective dose equivalent; TODE= total organ dose equivalent.

Sources: Worksheet *PWR- Sub-Total* for PWR results and worksheet *BWR- Sub-Total* for BWR results of *Release.xls*.

J.W.
10/23/2008

ATTACHMENT I. ELECTRONIC FILE ON COMPACT DISC

The electronic file provided on a compact disc is listed below.