OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT CALCULATION COVER SHEET

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Of: 11

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DOE High-Level Vitrified Waste Dose Calculation

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1. PURPOSE

The purpose of this engineering calculation is to provide the radiological dose at 5,000 meters from the surface facilities of the Monitored Geologic Repository (MGR) resulting from a drop of one High-Level Waste (HLW) canister containing vitrified high-level waste glass during handling operations in the Waste Handling Building (WHB). High-level vitrified wastes from Savannah River Site (SRS), Hanford Works, West Valley, New York, and Idaho National Engineering and Environmental Laboratory (INEEL) are evaluated. This calculation will provide input data for future safety analyses for handling of Department of Energy (DOE) high-level waste in the MGR.

This calculation has been prepared in accordance with procedure AP-3.12Q, *Calculations*.

2. METHOD

Regulatory requirements applicable to the MGR (64 FR 8640, Section 10 CFR 63.111) specify four dose measures for Category 2 design basis events (DBEs).

The total effective dose equivalent (TEDE)-The TEDE is equal to the committed effective dose equivalent (CEDE) plus the deep dose equivalent (DDE) per the definition in 10 CFR 20.1003. The CEDE is calculated using the "effective" inhalation dose conversion factor (DCF). The DDE is calculated using the "effective" air submersion DCF.

The highest of the seven committed dose equivalents (CDEs) plus the DDE-The seven organs evaluated to find the highest CDE are the lungs, breasts, gonads, red marrow, bone surface, thyroid, and remainder. The DDE which is added to the highest CDE is equal to that used to calculate the TEDE, as per the definition of DDE in 10 CFR 20.1003.

Lens of the Eye-No doses are calculated for this limit in this calculation, as none of the HLW canister isotopes have lens of the eye DCFs given in either Federal Guidance Report 11 (EPA 1988) or Federal Guidance Report 12 (EPA 1993). In the two Federal Guidance Reports only Kr-83m (an isotope not contained in any DOE waste form) has a lens of the eye DCF (EPA 1988, p. 182).

Skin-The shallow dose equivalent to the skin is only due to the air submersion dose pathway.

The steps used to calculate the dose measures are as follows:

1. Identify the source term of the waste form (see Attachment III).
2. Identify the dose conversion factors applicable to the radionuclides present in the waste form (see Attachment IV).
3. Identify the release fraction (i.e., pulverization factor [PULF]) for the glass waste form. The PULF is the fraction of the total inventory of radionuclides that will be released from the HLW canister as airborne and respirable (units are dimensionless) (see Attachment V).
4. Identify mitigating factors to be considered, such as filtration by High-Efficiency Particulate Air (HEPA) filters or elevated releases (units are dimensionless).
5. Identify the breathing rate for an adult person or worker during the event (units are m^3/s) (see Section 5.2.3).

6. Identify the atmospheric dispersion factor (χ/Q) appropriate for the exposure conditions assumed for an adult person or worker at a specified distance from the release point consistent with the conservative assumption of an instantaneous radionuclide release (units are s/m^3) (see Section 5.2.4).
7. Calculate the inhalation and air submersion doses specified in the regulatory criteria that an individual receives resulting from exposure to the released radionuclides (units are rems) (see Attachments VI, VII, and VIII).

2.1 DOSE CALCULATION

Equations (1) through (5) were used to calculate the inhalation and air submersion radiological doses and are based on those recommended by the NRC in Regulatory Guide 1.109 (NRC 1977), Sections C.2 and C.3. Equation (1) is used to calculate the inhalation dose to an individual from each isotope in the source term of the waste form.

$$D_{j,k}(I) = [S_j * N] * RF_j * BR * \chi/Q * DCF_{j,k}(I) * \text{Conv}(I) \quad (1)$$

Equation (2) is used to calculate the air submersion dose.

$$D_{j,k}(S) = [S_j * N] * RF_j * \chi/Q * DCF_{j,k}(S) * \text{Conv}(S) \quad (2)$$

where

- $D_{j,k}(I)$ = radiation dose from the j^{th} isotope to the k^{th} organ due to inhalation (rem)
- $D_{j,k}(S)$ = radiation dose from the j^{th} isotope to the k^{th} organ due to air submersion (rem)
- k = organ index, where organs are gonads, breast, lungs, red marrow, bone surface, thyroid, remainder, effective, and skin (dimensionless)
- S_j = amount of the j^{th} isotope in the waste form that is released to the environment per canister (Ci/can)
- N = number of canisters that are breached (dimensionless) (1 for this calculation)
- RF_j = respirable fraction of the j^{th} isotope (dimensionless)
- BR = breathing rate (m^3/sec)
- χ/Q = atmospheric dispersion factor (sec/m^3)
- $DCF_{j,k}(I)$ = inhalation dose conversion factor of the j^{th} isotope for the k^{th} organ (Sv/Bq)
- $DCF_{j,k}(S)$ = air submersion dose conversion factor of the j^{th} isotope for the k^{th} organ ($[\text{Sv m}^3]/[\text{Bq s}]$)
- $\text{Conv}(I)$ = DCF unit conversion factor = $3.7\text{E}+12$ (rem Bq/Ci Sv) = $3.7\text{E}+10$ (Bq/Ci) * 100 (rem/Sv)
- $\text{Conv}(S)$ = DCF unit conversion factor = $3.7\text{E}+12$ (rem Bq/Ci Sv) = $3.7\text{E}+10$ (Bq/Ci) * 100 (rem/Sv)

2.2 DOSE CONVERSION FACTORS

The inhalation DCFs used in this analysis are taken from Federal Guidance Report 11 (EPA 1988). The inhalation DCF of an isotope is dependent in part on its chemical form. This dependence is accounted for by the lung clearance class (D – daily, W – Weekly, Y – Yearly) used to evaluate the DCF of a given isotope. Some isotopes have only one lung clearance class, others have multiple lung clearance classes. For isotopes with multiple lung clearance classes, the lung clearance class that yields the highest DCF is assumed on a per organ basis. For example, Pu-238 (which has W- and Y-clearance classes) has the highest lung inhalation DCF for the Y-clearance class, while all of the other organs have the highest inhalation DCF for the W-clearance class.

The air submersion DCFs used in this analysis are taken from Federal Guidance Report 12 (EPA 1993). The inhalation DCFs from Federal Guidance Report 11 (EPA 1988) account for the presence of short-lived daughter products; however, the air submersion DCFs from Federal Guidance Report 12 (EPA 1993) do not. For example, the inhalation DCF for Cs-137 accounts for the presence of Ba-137m (Cs-137 has a DCF listed for it, while Ba-137m does not); however, separate air submersion DCFs are listed for each isotope. Air submersion DCFs for Cs-137, Ru-106, and Ac-227 used in this analysis are taken from *DOE SNF Screening Dose Analysis* (CRWMS M&O 1999a, page 7 and Attachment IX) to account for the presence of short-lived daughter products.

2.3 CDE, DDE, CEDE, AND TEDE CALCULATIONS

The equations used to produce dose equivalents in terms of the radiation doses calculated in Section 5 and Attachments VI and VIII follow.

The TEDE and the CDE + DDE dose measures, ignoring the ingestion dose pathway (Assumption 3.3), are expressed as Equations (3) and (4):

$$\text{TEDE} = \text{CEDE} + \text{DDE} = \sum D_{j,\text{effective}}(\text{I}) + \sum D_{j,\text{effective}}(\text{S}) \quad (3)$$

$$\text{CDE}_k + \text{DDE} = \sum D_{j,k}(\text{I}) + \sum D_{j,\text{effective}}(\text{S}) \text{ where } k \neq \text{effective or skin} \quad (4)$$

where,

TEDE = total effective dose equivalent (rem)

CEDE = committed effective dose equivalent (rem)

DDE = deep dose equivalent (rem)

CDE_k = committed dose equivalent to the kth organ (rem)

The skin dose is calculated using Equation (5):

$$\text{SKIN} = \sum D_{j,\text{skin}}(\text{S}) \quad (5)$$

where,

SKIN = dose to the skin (rem)

3. ASSUMPTIONS

- 3.1 A restricted area boundary of 5,000 meters will be established around the WHB. This assumption is based on the restricted area boundary established in the *MGR Requirements Document* (YMP 1999, Section 3.3.J). This assumption is used for selection of the site-specific atmospheric dispersion factor used in the dose calculations in Attachments VI and VIII.
- 3.2 It is assumed that after the breach of the HLW canister, the release of radionuclides occurs within a 2-hour period. This is a conservative assumption based on Nuclear Regulatory Commission (NRC) Regulatory Guide 1.25, *Assumptions Used for Evaluating the Potential Radiological Consequences of a Fuel Handling Accident in the Fuel Handling and Storage Facility for Boiling and Pressurized Water Reactors* (NRC 1972, Section C.i). This assumption is used in the dose calculations in Attachments VI and VIII.
- 3.3 It is assumed that the potential doses from ingestion, water immersion, and contaminated soil are negligible. Only inhalation and air submersion doses are considered in this calculation. This assumption is based on the doses from ingestion, water immersion, and contaminated soil being negligible in comparison to the combined inhalation and air submersion dose and/or the receptors at the assumed site boundary are evacuated shortly after the postulated event, thus precluding these source term pathways. This assumption is used in the offsite dose calculations in Attachments VI and VIII.
- 3.4 For isotopes with multiple clearance classes, the lung clearance class that yields the highest inhalation DCF is assumed on a per organ basis. This assumption is based on using the maximum calculated inhalation doses. This assumption is used in the offsite dose calculations in Attachments VI and VIII.
- 3.5 It is assumed that the Deep Dose Equivalent (DDE) is equal to the effective dose equivalent from air submersion, and that the external dose contribution from water immersion and contaminated soil is negligible. This assumption is based on these doses being negligible in comparison to the combined inhalation and air submersion dose and/or the receptors at the assumed site boundary are evacuated shortly after the postulated event, thus precluding these source term pathways. This assumption is used in the offsite dose calculations in Attachments VI and VIII.
- 3.6 It is assumed that the impact energy is evenly distributed throughout the waste form. This assumption is required to maintain similarity between the small-scale tests upon which the PULF correlation is based and the large-scale waste form. This assumption is based on the PULF calculational method recommended in *Airborne Release Fractions at Non-Reactor Nuclear Facilities* (ANS 1998, page 15). This assumption is used in the offsite dose calculations in Attachments VI and VIII.
- 3.7 It is assumed that the non-conservatism in the air submersion dose calculation has a negligible impact on the final dose results. The air submersion dose should be calculated based on the entire (i.e. both respirable and non-respirable portions) source term. Since the source term calculated using the PULF does not include the non-respirable portion of the source term, the air submersion doses are non-conservative. This assumption is based on the non-conservatism being negligible because, generally, air submersion doses are at least two orders of magnitude below the inhalation doses. This assumption is used in the calculation of the air submersion doses in Attachments VI and VIII.

- 3.8 The energy partition factor is conservatively assumed to be 1.0 (or no energy partitioning) for HLW canister PULF calculation. The energy partition factor is based on small-scale tests on uranium dioxide (UO₂) and glass that established a preliminary correlation for the percentage of respirable size fractions created during impacts (ANS 1998, page 15). This assumption is used in the calculation of the inhalation and air submersion doses in Attachments VI and VIII.
- 3.9 It is assumed that the maximum glass density for Hanford, West Valley, and INEEL glass HLW used in the PULF calculation is less than the maximum glass density for SRS HLW glass. This assumption is based on each waste form being borosilicate glass and that the density of borosilicate glass in each waste form being similar. However, this impact is expected to be minimal because the SRS HLW TEDE dose is a factor of 2 greater than the next highest TEDE dose (i.e., Hanford HLW) (see Attachment VII), and the Hanford waste form is not expected to be a factor of 2 more dense than the SRS waste form. This assumption is used in the calculation of the inhalation and air submersion doses in Attachments VI and VIII.

4. USE OF COMPUTER SOFTWARE

No scientific or engineering software or software routines are used in this calculation.

5. CALCULATION

5.1 CALCULATION DESCRIPTION

The calculations as described in Section 2 are performed in Microsoft Excel.

The HLW canister has a potential to be dropped during handling operations in the WHB. Dose calculations using various drop heights were performed (i.e., 80, 264, 330, and 448 inches). Doses to individual organs and to the whole body are calculated for exposure via inhalation. Doses to individual organs, the whole body, and skin are calculated for exposure via air submersion. No worker doses are calculated.

Doses were also calculated assuming HEPA filtration as a mitigating factor. No other mitigating factors were used in the calculations.

5.2 INPUT PARAMETERS

- 5.2.1 Post-irradiated isotopic concentrations of SRS, Hanford, West Valley, and INEEL high-level waste forms were obtained from *Source Terms from DHLW Canisters for Waste Package Design* (CRWMS M&O 1999b, Attachment VI). Decay times of 5 years were selected for use this calculation.

Basis: CRWMS M&O (1999b).

Data Status: Qualified. This input data is qualified data based on preparation in accordance with an approved QA program as specified in Procedure AP-SIII.2Q, *Qualification of Unqualified Data and the Documentation of Rationale for Accepted Data*.

- 5.2.2 Inhalation and air submersion DCFs are from Federal Guidance Report 11 (EPA 1988) and Federal Guidance Report 12 (EPA 1993), respectively. The Sv/Bq to rem/Ci unit conversion factor is taken from Federal Guidance Report 11. A listing of the DCFs used in this analysis is provided in Attachment IV.

Basis: EPA (1988), Table 2.1, pages 121-153 and EPA (1993), Table III.1, pages 57-73.

Data Status: Accepted. This input data is accepted data based on its existence as established fact as defined by Procedure AP-SIII.2Q, *Qualification of Unqualified Data and the Documentation of Rationale for Accepted Data*. DCFs generated by the EPA are data that is generally accepted by the engineering and scientific community and found to be technically defensible by those using it.

- 5.2.3 An adult breathing rate of $3.33\text{E-}4 \text{ m}^3/\text{s}$ (20 l/min) is used for inhalation dose calculations. This assumption is based on the Reference Man breathing rate established in the ICRP 23, *Report of the Task Group on Reference Man* (ICRP 1974, page 346), breathing rate for the volume intake of air for "light activity" and is considered to be appropriate for DBE accident scenarios resulting in short-term (≤ 8 -hour) exposures to the public at a 5,000-meter site boundary.

Basis: ICRP (1974), page 346.

Data Status: Accepted. This input data is accepted data based on its existence as established fact as defined by Procedure AP-SIII.2Q, *Qualification of Unqualified Data and the Documentation of Rationale for Accepted Data*. Data produced by the ICRP regarding radiological dose calculations are generally accepted by the engineering and scientific community and found to be technically defensible by those using it.

- 5.2.4 An atmospheric dispersion factor (χ/Q) of $4.68\text{E-}05 \text{ sec}/\text{m}^3$ is used for dose calculations for the assumed 5,000 meter dose receptor. This value is obtained from an Inter-Office Correspondence from Walt Schalk and Doug Landwehr to Kelvin Montague, "Preliminary χ/Q Concentration Estimates Using NRC Regulatory Guide 1.145 as Implemented by the XQ145 Software Routine" (Schalk, W. and Landwehr D. 1998, Table 3). The maximum values that were exceeded 0.5% of the time were used for dispersion calculations in this report, and are assumed applicable to mechanistic and non-mechanistic events.

Basis: Schalk, W. and Landwehr D. (1998).

Data Status: Unqualified.

- 5.2.5 The density of the vitrified waste forms used in this calculation is $2.75 \text{ g}/\text{cm}^3$ (WSRC 1997, Section 6.2.2, page 22). This density is based on the vitrified waste form maximum density provided in the *DWPF Waste Form Compliance Plan* (WSRC 1997, page 22 of 29).

Basis: WSRC (1997), page 22.

Data Status: Unqualified.

- 5.2.6 Particulate formation is based on small-scale empirical results as presented in *Airborne Release Fractions at Non-Reactor Nuclear Facilities* (ANS 1998, page 15). This calculation is based on small-scale tests on UO_2 and glass that established preliminary correlation for the percentage of respirable size fractions created during impacts.

Basis: ANS (1998), page 15.

Data Status: Accepted. This input data is accepted data based on its existence as established fact as defined by Procedure AP-SIII.2Q, *Qualification of Unqualified Data and the Documentation of Rationale for Accepted Data*. Data produced by the ANS regarding radiological dose calculations are generally accepted by the engineering and scientific community and found to be technically defensible by those using it.

5.3 SAMPLE CALCULATIONS

Inhalation Dose-Following is an example inhalation dose calculation for an SRS HLW canister drop:

The inhalation dose due to a release from an SRS HLW canister during a 448-inch drop from Cs-134 to the gonad can be found as follows (see Attachment VI, page VI-1):

1. The Cs-134 SRS HLW canister source term is found in Attachment III as $6.28\text{E}+01$ Ci/can.
2. The pulverization factor is calculated as shown in Attachment V for 448 inches (i.e., $6.14\text{E}-05$).
3. The breathing rate is $3.33\text{E}-4$ m³/sec (see Section 5.2.3).
4. The atmospheric dispersion factor (i.e., χ/Q) for a restricted boundary with ground release and no depletion for 5,000 meters is $4.68\text{E}-05$ sec/m³ (see Section 5.2.4).
5. The gonad Dose Conversion Factor (DCF) for Cs-134 is $1.30\text{E}-08$ Sv/Bq from Attachment IV. To convert the DCF to rem/Ci, multiply by $3.70\text{E}+12$. See Section 5.2.2.
6. Using Equation (1), the product of the six factors above is the dose to the gonad from Cs-134 at a 5,000-meter restricted area boundary from a drop of an SRS HLW canister:

$$\begin{aligned} D &= (6.28\text{E}+01) \times (6.14\text{E}-05) \times (3.33\text{E}-04) \times (4.68\text{E}-05) \times (1.30\text{E}-08) \times (3.70\text{E}+12) \\ &= 2.89\text{E}-06 \text{ rem (to the gonad from Cs-134)} \end{aligned}$$

This dose is calculated in Attachment VI, page VI-1 of VI-8:

Air Submersion Dose-Following is an example air submersion dose calculation for a West Valley HLW canister drop:

The air submersion dose due to a release from a West Valley HLW canister during a 448-inch drop from Ru-106 to the breast can be found as follows (see Attachment VI, page VI-6):

1. The Ru-106 West Valley HLW canister source term is found in Attachment III as $1.82\text{E}-03$ Ci/canister.
2. The pulverization factor is calculated as shown in Attachment V for 448 inches (i.e., $6.14\text{E}-05$).
3. The atmospheric dispersion factor (i.e., χ/Q) for a restricted boundary with ground release and no depletion for 5,000 meters is $4.68\text{E}-05$ sec/m³ (see Section 5.2.4).

4. The breast Dose Conversion Factor (DCF) for Ru-106 is $1.23\text{E-}14$ Sv/Bq from Attachment IV. To convert the DCF to rem/Ci, multiply by $3.70\text{E+}12$. See Section 5.2.2.
5. Using Equation (2), the product of the five factors above is the potential dose to the breast from Ru-106 at a 5,000-meter restricted area boundary from a drop of a West Valley HLW canister:

$$\begin{aligned} D &= (1.82\text{E-}03) \times (6.14\text{E-}05) \times (4.68\text{E-}05) \times (1.23\text{E-}14) \times (3.70\text{E+}12) \\ &= 2.38\text{E-}13 \text{ rem (to the breast from Ru-106)} \end{aligned}$$

This dose is calculated in Attachment VI, page VI-6 of VI-8.

6. RESULTS

6.1 RESULTS

The results of dose calculations for a 448-inch drop are shown in Attachments VI and VII. As can be seen in Attachment VII, the SRS HLW canister doses are higher than those for Hanford, West Valley, or INEEL HLW canisters. The SRS HLW canister was then used to calculate offsite doses for drop heights of 80, 264, and 330 inches. These results are shown in Attachment VIII and the TEDE and the maximum CDE+DDE doses for the various drop heights are plotted in Attachment IX.

6.2 DISCUSSION OF UNQUALIFIED INPUT

The assumption that the impact energy is evenly distributed throughout the waste form must be verified before License Application. This assumption directly affects the calculated value of the PULF, and therefore, the calculated offsite doses in this calculation. See Assumption 3.6.

The χ/Q value used in this calculation for the 5,000 m dose receptor was obtained from an unconfirmed MGR calculation. See Section 5.2.4. A change in this value will result in a direct change in the offsite dose at the assumed 5,000 m site boundary. See Assumption 3.1.

The contribution of the non-respirable portion of the source term to the total offsite dose is assumed to be negligible. This assumption needs to be verified to insure increases in the total offsite dose are negligible. See Assumption 3.7.

The maximum glass density of 2.75 g/cm^3 for SRS HLW used in the PULF calculation is assumed to be applicable for Hanford, West Valley, and INEEL waste forms. A change in this assumption will result in higher doses for Hanford, West Valley, and INEEL waste forms. See Assumption 3.9.

A change in the assumed restricted area boundary of 5,000 meters will result in different values for the doses calculated by this document. See Assumption 3.1.

7. ATTACHMENTS

Attachment I	Document Input Reference Sheets
Attachment II	Acronyms
Attachment III	Radionuclide Content of HLW Canisters
Attachment IV	Dose Conversion Factors
Attachment V	Particulate Formation Calculation
Attachment VI	HLW Radiological Doses from a Canister Drop
Attachment VII	Summary of HLW Radiological Doses
Attachment VIII	SRS Radiological Dose for Various Drop Heights
Attachment IX	Drop Height vs. Offsite Dose

DOCUMENT INPUT REFERENCE SHEET

Attachment I
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Document Identifier No./Rev.: CAL-WPS-SE-000002 REV 00			Change: N/A	Title: DOE High-Level Vitrified Waste Dose Calculation					
Input Document							TBV Due To		
No.	Technical Product Input Source Title & Identifiers with Version	Section	Input Status	Section Used In	Input Description	TBV/ TBD Priority	Unqual.	From Uncontrolled Source	Unconfirmed
1	CRWMS M&O (Civilian Radioactive Waste Management and Operating Contractor) 1999a. <i>DOE SNF Screening Dose Analysis</i> . BBA000000-01717- 0210-00047 REV 0 ICN 0. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990602.0176. Initial Use.	Page 7 Att. IX	TBV-3096	2.2 Att. IV	Air Submersion DCFs for CS-137, Ru-106, and Ac-227	2	N/A	X	N/A
2	CRWMS M&O 1999b. <i>Source Terms from DHLW Canisters for Waste Package Design</i> . BBA000000-01717-0210-00044 REV 0 ICN 0. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990222.0176. Initial Use.	Att. VI	TBV-3097	5.2.1 Att. III	Isotopes and Curie values for those isotopes in SRS, Hanford, West Valley, and INEEL waste forms for 5-year decay time	2	N/A	X	N/A
3	64 FR (Federal Register) 8640. Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, Nevada. Proposed rule: 10 CFR 63.	10 CFR 63.111	N/A	2	Draft 10 CFR 63 requirements for MGR documents until final acceptance	N/A	N/A	N/A	N/A
4	It is assumed that the impact energy is evenly distributed throughout the waste form. Initial Use.	N/A	TBV-3081	3.6 Att. VI Att. VIII	It is assumed that the impact energy is evenly distributed throughout the waste form.	2	X	N/A	N/A
5	Schalk, Walt and Landwehr, Doug 1998. "Preliminary χ/Q Concentration Estimates Using NRC Regulatory Guide 1.145 as Implemented by the XQ145 Software Routine." Walt Schalk and Doug Landwehr (CRWMS M&O) Interoffice Correspondence to Kelvin Montague (CRWMS M&O). LV.EAP.WWS.12/98-004. December 16, 1998. ACC: MOL.19990222.0117. Initial Use.	Table 3	TBV-3082	5.2.4	Atmospheric dispersion factor (χ/Q) of 4.68E-5 at an 5,000 m distance from radioactive release for 0.50 percent exceeded	2	X	X	N/A

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Attachment I
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Input Document							TBV Due To		
No.	Technical Product Input Source Title & Identifiers with Version	Section	Input Status	Section Used In	Input Description	TBV/TBD Priority	Unqual.	From Uncontrolled Source	Unconfirmed
6	YMP (Yucca Mountain Site Characterization Office) 1999. <i>Monitored Geologic Repository Requirements Document</i> . YMP/CM-0025, Rev. 3, DCN 01. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL. 19990429.0228. Initial Use.	3.3.J	TBV-3098	3.1	Site Boundary will be 5,000 m from WHB ventilation release point and 5,000 m from emplacement area ventilation exhaust shaft.	2	X	N/A	N/A
7	WSRC (Westinghouse Savannah River Company) 1993. <i>DWPF Waste Form Compliance Plan</i> . WSRC-IM-91-116-3 Revision C. Aiken, South Carolina: WSRC Savannah River Site. ACC: MOV.19970604.0391. Initial Use.	6.2.2, page 22 of 29.	TBV-3099	5.2.7 Att. V.	Maximum density of glass waste form will not exceed 2.75 g/cm ³ .	2	X	N/A	N/A
8	ANS (American Nuclear Society) 1998. <i>Airborne Release Fractions at Non-Reactor Nuclear Facilities</i> . ANSI/ANS-5.10-1998. LaGrange Park, Illinois: American Nuclear Society. TIC: 235073.	Page 15	N/A	5.2.6 Att. V 3.6 3.8	Calculation method to find particulate fraction (PULF) of glass during drop impact	N/A	N/A	N/A	N/A
9	EPA (Environmental Protection Agency) 1988. <i>Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion</i> . Federal Guidance Report No. 11, EPA-520/1-88-020. Washington, D.C: Office of Radiation Programs, U.S. EPA. TIC: 203350. Initial Use.	Table 2.1 Pages 121-153, and 182	TBV-3100	2 2.2 5.2.2 Att. IV	Dose Conversion Factors for Inhalation	2	N/A	N/A	X
10	EPA 1993. <i>External Exposure to Radionuclides in Air, Water, and Soil</i> . Federal Guidance Report No. 12, EPA 402-R-93-081. Washington, D.C: U.S. EPA, Office of Radiation and Indoor Air. TIC: 225472. Initial Use.	Table III.1 Pages 57-73	TBV-3101	2 2.2 5.2.2 Att. IV	Dose Conversion Factors for Air Submersion	2	N/A	N/A	X

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Document Identifier No./Rev.: CAL-WPS-SE-000002 REV 00			Change: N/A	Title: DOE High-Level Vitrified Waste Dose Calculation					
Input Document							TBV Due To		
No.	Technical Product Input Source Title & Identifiers with Version	Section	Input Status	Section Used in	Input Description	TBV/ TBD Priority	Unqual.	From Uncontrolled Source	Unconfirmed
11	ICRP (International Commission on Radiological Protection) 1974. <i>Report of the Task Group on Reference Man</i> , International Commission on Radiological Protection Publication No. 23. Oxford, England: Pergamon Press. TIC: 237218. Initial Use.	Page 346	TBV-3102	5.2.3	20 l/min breathing rate for the volume intake of air for "light activity".	2	N/A	N/A	X
12	NRC 1972. <i>Assumptions Used for Evaluating the Potential Radiological Consequences of a Fuel Handling Accident in the Fuel Handling and Storage Facility for Boiling and Pressurized Water Reactors</i> . Regulatory Guide 1.25. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 238372. Initial Use.	Section C.i	TBV-3103	3.2	Release of radionuclides occurs over a 2-hour period.	2	N/A	N/A	X
13	AP-SIII.2Q, Rev. 0, ICN 0. <i>Qualification of Unqualified Data and the Documentation of Rationale for Accepted Data</i> . MOL.19990702.0308.	3.1 & 3.2	N/A	5.2	Definitions of Qualified and Accepted Data	N/A	N/A	N/A	N/A
14	Avallone, Eugene A. and Baumeister, Theodore III 1987. <i>Marks' Standard Handbook for Mechanical Engineers</i> . Ninth Edition. New York, New York: McGraw-Hill Book Co. TIC: 206891.	Page 1-26	N/A	Att. V Att. VI Att. VIII	Acceleration of gravity	N/A	N/A	N/A	N/A
15	AP-3.12Q, Revision 0, ICN 0. <i>Calculations</i> . MOL.19990702.0312.	Entire	N/A	Entire	Procedure for preparation of document	N/A	N/A	N/A	N/A
16	10 CFR 20. Energy. Standards for Protection Against Radiation. January 1, 1999.	10CFR2 0.1003	N/A	2.0	Definitions of dose measures.	N/A	N/A	N/A	N/A

DOCUMENT INPUT REFERENCE SHEET

Attachment I
Page: I-4 of I-4

Document Identifier No./Rev.: CAL-WPS-SE-000002 REV 00			Change: N/A	Title: DOE High-Level Vitrified Waste Dose Calculation					
Input Document							TBV Due To		
No.	Technical Product Input Source Title & Identifiers with Version	Section	Input Status	Section Used In	Input Description	TBV/ TBD Priority	Unqual.	From Uncontrolled Source	Unconfirmed
17	NRC 1977. <i>Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I.</i> Regulatory Guide 1.109. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 222641. Initial Use.	C.2 and C.3	TBV-3104	2.1	Derivation of dose equations are based on this Regulatory Guide.	2	N/A	N/A	X
18	It is assumed that the non-conservatism in the air submersion dose calculation has a negligible impact on the final dose results. Initial Use.	N/A	TBV-3083	3.7 Att. VI Att. VIII	It is assumed that the non-conservatism in the air submersion dose calculation has a negligible impact on the final dose results.	2	X	N/A	N/A
19	It is assumed that the maximum glass density for Hanford, West Valley, and INEEL glass HLW used in the PULF calculation is less than the maximum glass density for SRS HLW glass. Initial Use.	N/A	TBV-3084	3.9 Att. VI Att. VIII	It is assumed that the maximum glass density for Hanford, West Valley, and INEEL glass HLW used in the PULF calculation is less than the maximum glass density for SRS HLW glass.	2	X	N/A	N/A

ACRONYMS

ANS	American Nuclear Society
CDE	Committed Dose Equivalent
CEDE	Committed Effective Dose Equivalent
CFR	Code of Federal Regulations
CRWMS	Civilian Radioactive Waste Management System
DBE	Design Basis Event
DCF	Dose Conversion Factor
DDE	Deep Dose Equivalent
DOE	U. S. Department of Energy
DWPF	Defense Waste Processing Facility
EPA	U. S. Environmental Protection Agency
HEPA	High-Efficiency Particulate Air
HLW	High-Level Waste
ICRP	International Commission on Radiological Protection
INEEL	Idaho National Engineering and Environmental Laboratory
M&O	Management and Operating Contractor
MGR	Monitored Geologic Repository
NRC	U. S. Nuclear Regulatory Commission
PULF	Pulverization Factor (for particulate formation)
QARD	Quality Assurance Requirements Document
TBD	To Be Determined
TBV	To Be Verified
TEDE	Total Effective Dose Equivalent
WHB	Waste Handling Building
WSRC	Westinghouse Savannah River Company
YMP	Yucca Mountain Site Characterization Project

RADIONUCLIDE CONTENT OF HLW CANISTERS

Isotope	SRS (Ci)	Hanford (Ci)	West Valley (Ci)	INEEL (Ci)
Ac-227	0.00E+00	0.00E+00	9.07E-03	0.00E+00
Am-241	2.28E+01	5.72E+02	2.10E+02	2.61E+00
Am-242m	0.00E+00	0.00E+00	1.23E+00	0.00E+00
Am-243	0.00E+00	0.00E+00	1.36E+00	0.00E+00
Cd-113m	0.00E+00	1.18E+01	6.75E+00	0.00E+00
Ce-144	1.16E+02	3.50E+02	0.00E+00	1.23E+02
Cm-243	0.00E+00	0.00E+00	4.67E-01	0.00E+00
Cm-244	8.89E+01	1.03E+01	2.48E+01	5.48E-01
Co-60	8.80E+01	0.00E+00	1.57E+00	0.00E+00
Eu-154	4.14E+02	2.24E+02	2.51E+02	1.54E+02
Eu-155	2.40E+02	0.00E+00	0.00E+00	0.00E+00
Np-237	0.00E+00	2.00E-01	9.22E-02	0.00E+00
Pa-231	0.00E+00	0.00E+00	5.97E-02	0.00E+00
Pm-147	6.46E+03	1.06E+04	0.00E+00	4.09E+03
Pu-238	1.43E+03	7.40E-01	3.14E+01	8.60E+01
Pu-239	1.29E+01	1.41E+00	6.38E+00	8.92E-01
Pu-240	8.70E+00	5.46E-01	4.67E+00	8.27E-01
Pu-241	1.32E+03	2.03E+01	2.50E+02	1.61E+02
Th-228	0.00E+00	0.00E+00	3.43E-02	0.00E+00
U-232	0.00E+00	0.00E+00	2.68E-02	0.00E+00
I-129	0.00E+00	1.63E-05	0.00E+00	0.00E+00
Cs-134	6.28E+01	2.23E+02	3.78E+00	7.85E+02
Cs-137	3.87E+04	4.54E+04	2.52E+04	1.48E+04
Ru-106	7.40E+01	1.64E+02	1.82E-03	4.07E+01
Sr-90	4.28E+04	3.82E+04	2.41E+04	1.52E+04
Y-90	4.28E+04	3.82E+04	2.41E+04	1.52E+04

Reference: "Source Terms from DHLW Canisters for Waste Package Design." (CRWMS M&O 1999b)

DOSE CONVERSION FACTORS

Inhalation DCFs (Sv/Bq)

Isotope	Gonads	Breast	Lungs	Red Marrow	Bone Surface	Thyroid	Remainder	Effective	Skin
Ac-227	3.96E-04	6.66E-08	1.54E-03	2.57E-03	3.21E-02	3.59E-08	1.47E-03	1.81E-03	0.00E+00
Am-241	3.25E-05	2.67E-09	1.84E-05	1.74E-04	2.17E-03	1.60E-09	7.82E-05	1.20E-04	0.00E+00
Am-242m	3.21E-05	1.38E-09	4.20E-06	1.69E-04	2.12E-03	5.64E-10	7.48E-05	1.15E-04	0.00E+00
Am-243	3.26E-05	1.52E-08	1.78E-05	1.73E-04	2.17E-03	8.29E-09	7.74E-05	1.19E-04	0.00E+00
Cd-113m	3.32E-08	3.32E-08	4.09E-07	3.32E-08	3.32E-08	3.32E-08	1.30E-06	4.13E-07	0.00E+00
Ce-144	1.93E-09	1.97E-09	7.91E-07	2.67E-08	4.54E-08	1.88E-09	1.03E-07	1.01E-07	0.00E+00
Cm-243	2.07E-05	6.29E-09	1.94E-05	1.18E-04	1.47E-03	3.83E-09	5.76E-05	8.30E-05	0.00E+00
Cm-244	1.59E-05	1.04E-09	1.93E-05	9.38E-05	1.17E-03	1.01E-09	4.78E-05	6.70E-05	0.00E+00
Co-60	4.76E-09	1.84E-08	3.45E-07	1.72E-08	1.35E-08	1.62E-08	3.60E-08	5.91E-08	0.00E+00
Eu-154	1.17E-08	1.55E-08	7.92E-08	1.06E-07	5.23E-07	7.14E-09	1.13E-07	7.73E-08	0.00E+00
Eu-155	3.56E-10	6.14E-10	1.19E-08	1.43E-08	1.52E-07	2.40E-10	1.11E-08	1.12E-08	0.00E+00
Np-237	2.96E-05	1.69E-08	1.61E-05	2.62E-04	3.27E-03	1.34E-08	2.34E-05	1.46E-04	0.00E+00
Pa-231	6.90E-09	8.79E-09	7.47E-04	6.97E-04	8.70E-03	7.64E-09	2.87E-07	3.47E-04	0.00E+00
Pm-147	1.88E-14	3.60E-14	7.74E-08	8.16E-09	1.02E-07	1.98E-14	5.89E-09	1.06E-08	0.00E+00
Pu-238	2.80E-05	1.00E-09	3.20E-04	1.52E-04	1.90E-03	9.62E-10	7.02E-05	1.06E-04	0.00E+00
Pu-239	3.18E-05	9.22E-10	3.23E-04	1.69E-04	2.11E-03	9.03E-10	7.56E-05	1.16E-04	0.00E+00
Pu-240	3.18E-05	9.51E-10	3.23E-04	1.69E-04	2.11E-03	9.05E-10	7.56E-05	1.16E-04	0.00E+00
Pu-241	6.82E-07	3.06E-11	3.18E-06	3.36E-06	4.20E-05	1.24E-11	1.31E-06	2.23E-06	0.00E+00
Th-228	1.35E-06	1.35E-06	6.91E-04	1.12E-04	1.37E-03	1.34E-06	3.44E-06	9.23E-05	0.00E+00
U-232	8.00E-08	8.06E-08	1.48E-03	4.06E-06	6.42E-05	7.85E-08	3.11E-06	1.78E-04	0.00E+00
I-129	8.69E-11	2.09E-10	3.14E-10	1.40E-10	1.38E-10	1.56E-06	1.18E-10	4.69E-08	0.00E+00
Cs-134	1.30E-08	1.08E-08	1.18E-08	1.18E-08	1.10E-08	1.11E-08	1.39E-08	1.25E-08	0.00E+00
Cs-137	8.76E-09	7.84E-09	8.82E-09	8.30E-09	7.94E-09	7.93E-09	9.12E-09	8.63E-09	0.00E+00
Ru-106	1.38E-08	1.37E-08	1.04E-06	1.37E-08	1.37E-08	1.37E-08	1.69E-08	1.29E-07	0.00E+00
Sr-90	2.64E-09	2.64E-09	2.86E-06	3.36E-07	7.27E-07	2.64E-09	5.73E-09	3.51E-07	0.00E+00
Y-90	9.52E-12	9.52E-12	9.31E-09	2.79E-10	2.78E-10	9.52E-12	3.87E-09	2.28E-09	0.00E+00

Reference: "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion." Federal Guidance Report No. 11, EPA-520/1-88-020. (EPA 1988)

DOSE CONVERSION FACTORS

Air Submersion DCFs (Sv m³/Bq s) [includes contribution of implicit daughters]

Isotope	Gonads	Breast	Lungs	Red Marrow	Bone Surface	Thyroid	Remainder	Effective	Skin
Ac-227	3.75E-17	4.45E-17	3.38E-17	2.94E-17	1.04E-16	3.65E-17	3.18E-17	3.74E-17	3.28E-16
Am-241	8.58E-16	1.07E-15	6.74E-16	5.21E-16	2.87E-15	7.83E-16	6.34E-16	8.18E-16	1.28E-15
Am-242m	3.80E-17	6.01E-17	1.72E-17	1.72E-17	7.94E-17	2.95E-17	1.94E-17	3.17E-17	1.36E-16
Am-243	2.19E-15	2.61E-15	1.92E-15	1.55E-15	7.47E-15	2.09E-15	1.79E-15	2.18E-15	2.75E-15
Cd-113m	7.17E-18	8.76E-18	5.93E-18	5.01E-18	2.10E-17	6.76E-18	5.63E-18	6.94E-18	8.48E-15
Ce-144	2.73E-15	3.13E-15	2.64E-15	2.51E-15	5.44E-15	2.75E-15	2.53E-15	2.77E-15	8.57E-14
Cm-243	5.77E-15	6.68E-15	5.50E-15	5.00E-15	1.50E-14	5.76E-15	5.19E-15	5.88E-15	9.79E-15
Cm-244	6.90E-18	1.33E-17	7.08E-19	1.46E-18	8.82E-18	4.19E-18	1.81E-18	4.91E-18	3.91E-17
Co-60	1.23E-13	1.39E-13	1.24E-13	1.23E-13	1.78E-13	1.27E-13	1.20E-13	1.26E-13	1.45E-13
Eu-154	6.00E-14	6.81E-14	5.99E-14	5.87E-14	9.43E-14	6.15E-14	5.75E-14	6.14E-14	8.29E-14
Eu-155	2.49E-15	2.95E-15	2.22E-15	1.85E-15	8.09E-15	2.41E-15	2.07E-15	2.49E-15	3.39E-15
Np-237	1.04E-15	1.26E-15	9.02E-16	7.69E-16	3.20E-15	9.94E-16	8.50E-16	1.03E-15	1.54E-15
Pa-231	1.71E-15	1.99E-15	1.62E-15	1.52E-15	3.64E-15	1.70E-15	1.54E-15	1.72E-15	2.44E-15
Pm-147	7.48E-19	9.56E-19	5.45E-19	4.46E-19	2.18E-18	6.75E-19	5.26E-19	6.93E-19	8.11E-16
Pu-238	6.56E-18	1.27E-17	1.06E-18	1.68E-18	9.30E-18	4.01E-18	1.99E-18	4.88E-18	4.09E-17
Pu-239	4.84E-18	7.55E-18	2.65E-18	2.67E-18	9.47E-18	3.88E-18	2.86E-18	4.24E-18	1.86E-17
Pu-240	6.36E-18	1.23E-17	1.09E-18	1.65E-18	9.26E-18	3.92E-18	1.96E-18	4.75E-18	3.92E-17
Pu-241	7.19E-20	8.67E-20	6.48E-20	5.63E-20	2.19E-19	6.98E-20	6.09E-20	7.25E-20	1.17E-19
Th-228	9.12E-17	1.09E-16	8.33E-17	7.32E-17	2.64E-16	8.88E-17	7.84E-17	9.20E-17	1.50E-16
U-232	1.55E-17	2.32E-17	9.84E-18	8.99E-18	3.86E-17	1.29E-17	1.00E-17	1.42E-17	5.92E-17
I-129	4.83E-16	6.66E-16	2.14E-16	1.64E-16	1.10E-15	3.86E-16	2.30E-16	3.80E-16	1.10E-15
Cs-134	7.40E-14	8.43E-14	7.37E-14	7.19E-14	1.20E-13	7.57E-14	7.06E-14	7.57E-14	9.45E-14
Cs-137	2.67E-14	3.05E-14	2.65E-14	2.58E-14	4.38E-14	2.73E-14	2.54E-14	2.73E-14	4.39E-14
Ru-106	1.07E-14	1.23E-14	1.03E-14	9.65E-15	2.46E-14	1.08E-14	9.79E-15	1.09E-14	1.32E-14
Sr-90	7.78E-18	9.49E-18	6.44E-18	5.44E-18	2.28E-17	7.33E-18	6.11E-18	7.53E-18	9.20E-15
Y-90	1.89E-16	2.20E-16	1.77E-16	1.62E-16	4.44E-16	1.87E-16	1.68E-16	1.90E-16	6.24E-14

Reference: "External Exposures to Radionuclides in Air, Water, and Soil." Federal Guidance Report No. 12,
EPA-402-R-93-081. (EPA 1993)

See also, "DOE SNF Screening Dose Analysis" (CRWMS M&O 1999a) and Section 2.2 for Cs-137, Ru-106, and AC-227 DCFs.

Particulate Formation Calculation

The formation of particulates from an impact breach of a HLW canister is based on *Airborne Release Fractions at Non-Reactor Nuclear Facilities* (ANS 1998, page 15). The results are based on empirical measurements of impact tests on UO₂, ceramic, and glass simulated waste forms. Small-scale tests established primary correlations for the percentage of respirable size fractions created during impacts. This method used the available results to develop a method to estimate the fractions of HLW canister glass that could be released as airborne particulates.

Based on the methods discussed in the previous paragraph, the fraction of respirable airborne particulates or PULF formed following an impact can be estimated as follows:

$$\text{PULF} = 2\text{E-}4 \text{ cm}^3/\text{Joule} * \text{E/V} \quad (\text{V-1})$$

where

PULF = fraction pulverized into respirable sizes ($\leq 10 \mu\text{m}$) from a drop event
(units = dimensionless)

E/V = impact energy density in impacted fuel, $\rho * g * h$
(units = Joule/cm³)

where

ρ = density of the fuel dropped
= 2.75 g/cm³ (see Section 5.2.7)

g = gravitational constant
= 980.7 cm/s² (Avallone and Baumeister 1987)

h = height dropped (cm)

PULF for HLW Canister Drop

From Equation (V-1):

$$\begin{aligned} \text{PULF} = & 2\text{E-}4 \text{ cm}^3/\text{J} * 2.75 \text{ g/cm}^3 * 980.7 \text{ cm/s}^2 * 1\text{E-}7 \text{ J/dyne-cm} \\ & * 1 \text{ dyne-cm-s}^2/\text{g-cm}^2 * (\text{drop height}) \text{ cm} \end{aligned}$$

As shown in Section 5.2.7, the energy partition factor is 1.0 (or no energy partitioning) for HLW canisters. The PULF fractions for respirable particles are used in the offsite dose calculations in Attachments VI and VIII.

Calculated PULF fractions for selected drop heights are listed below:

<u>Drop Height</u>	<u>PULF Fraction</u>
80 inches/203 cm	1.10E-05
264 inches/671 cm	3.62E-05
330 inches/838 cm	4.52E-05
448 inches/1138 cm	6.14E-05

HLW RADIOLOGICAL DOSES FROM A CANISTER DROP

SRS Inhalation Dose for 448-Inch Drop (rem/can)

Isotope	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body
Ac-227	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-241	2.62E-03	2.15E-07	1.48E-03	1.40E-02	1.75E-01	1.29E-07	6.31E-03	9.68E-03
Am-242m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd-113m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-144	7.92E-07	8.09E-07	3.25E-04	1.10E-05	1.86E-05	7.72E-07	4.23E-05	4.15E-05
Cm-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cm-244	5.00E-03	3.27E-07	6.07E-03	2.95E-02	3.68E-01	3.18E-07	1.50E-02	2.11E-02
Co-60	1.48E-06	5.73E-06	1.07E-04	5.36E-06	4.20E-06	5.05E-06	1.12E-05	1.84E-05
Eu-154	1.71E-05	2.27E-05	1.16E-04	1.55E-04	7.66E-04	1.05E-05	1.66E-04	1.13E-04
Eu-155	3.02E-07	5.22E-07	1.01E-05	1.21E-05	1.29E-04	2.04E-07	9.43E-06	9.51E-06
Np-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pa-231	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm-147	4.30E-10	8.23E-10	1.77E-03	1.87E-04	2.33E-03	4.53E-10	1.35E-04	2.42E-04
Pu-238	1.42E-01	5.06E-06	1.62E+00	7.69E-01	9.62E+00	4.87E-06	3.55E-01	5.36E-01
Pu-239	1.45E-03	4.21E-08	1.47E-02	7.72E-03	9.63E-02	4.12E-08	3.45E-03	5.30E-03
Pu-240	9.79E-04	2.93E-08	9.95E-03	5.20E-03	6.50E-02	2.79E-08	2.33E-03	3.57E-03
Pu-241	3.19E-03	1.43E-07	1.49E-02	1.57E-02	1.96E-01	5.79E-08	6.12E-03	1.04E-02
Th-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-134	2.89E-06	2.40E-06	2.62E-06	2.62E-06	2.44E-06	2.47E-06	3.09E-06	2.78E-06
Cs-137	1.20E-03	1.07E-03	1.21E-03	1.14E-03	1.09E-03	1.09E-03	1.25E-03	1.18E-03
Ru-106	3.61E-06	3.59E-06	2.72E-04	3.59E-06	3.59E-06	3.59E-06	4.43E-06	3.38E-05
Sr-90	4.00E-04	4.00E-04	4.33E-01	5.09E-02	1.10E-01	4.00E-04	8.68E-04	5.32E-02
Y-90	1.44E-06	1.44E-06	1.41E-03	4.23E-05	4.21E-05	1.44E-06	5.86E-04	3.45E-04
Totals	1.57E-01	1.52E-03	2.11E+00	8.94E-01	1.06E+01	1.52E-03	3.92E-01	6.42E-01

HLW RADIOLOGICAL DOSES FROM A CANISTER DROP

SRS Air Submersion Dose for 448-Inch Drop (rem/can)

Isotope	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body	Skin
Ac-227	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-241	2.08E-10	2.59E-10	1.63E-10	1.26E-10	6.95E-10	1.90E-10	1.54E-10	1.98E-10	3.10E-10
Am-242m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd-113m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-144	3.36E-09	3.86E-09	3.25E-09	3.09E-09	6.71E-09	3.39E-09	3.12E-09	3.42E-09	1.06E-07
Cm-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cm-244	6.52E-12	1.26E-11	6.69E-13	1.38E-12	8.33E-12	3.96E-12	1.71E-12	4.64E-12	3.69E-11
Co-60	1.15E-07	1.30E-07	1.16E-07	1.15E-07	1.66E-07	1.19E-07	1.12E-07	1.18E-07	1.36E-07
Eu-154	2.64E-07	3.00E-07	2.64E-07	2.58E-07	4.15E-07	2.71E-07	2.53E-07	2.70E-07	3.65E-07
Eu-155	6.35E-09	7.52E-09	5.66E-09	4.72E-09	2.06E-08	6.15E-09	5.28E-09	6.35E-09	8.65E-09
Np-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pa-231	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm-147	5.14E-11	6.56E-11	3.74E-11	3.06E-11	1.50E-10	4.63E-11	3.61E-11	4.76E-11	5.57E-08
Pu-238	9.97E-11	1.93E-10	1.61E-11	2.55E-11	1.41E-10	6.09E-11	3.02E-11	7.42E-11	6.22E-10
Pu-239	6.64E-13	1.04E-12	3.63E-13	3.66E-13	1.30E-12	5.32E-13	3.92E-13	5.81E-13	2.55E-12
Pu-240	5.88E-13	1.14E-12	1.01E-13	1.53E-13	8.56E-13	3.62E-13	1.81E-13	4.39E-13	3.62E-12
Pu-241	1.01E-12	1.22E-12	9.09E-13	7.90E-13	3.07E-12	9.79E-13	8.54E-13	1.02E-12	1.64E-12
Th-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-134	4.94E-08	5.63E-08	4.92E-08	4.80E-08	8.01E-08	5.05E-08	4.71E-08	5.05E-08	6.31E-08
Cs-137	1.10E-05	1.25E-05	1.09E-05	1.06E-05	1.80E-05	1.12E-05	1.04E-05	1.12E-05	1.81E-05
Ru-106	8.42E-09	9.67E-09	8.10E-09	7.59E-09	1.93E-08	8.49E-09	7.70E-09	8.57E-09	1.04E-08
Sr-90	3.54E-09	4.32E-09	2.93E-09	2.47E-09	1.04E-08	3.33E-09	2.78E-09	3.43E-09	4.18E-06
Y-90	8.60E-08	1.00E-07	8.05E-08	7.37E-08	2.02E-07	8.51E-08	7.64E-08	8.64E-08	2.84E-05
Totals	1.15E-05	1.31E-05	1.14E-05	1.11E-05	1.89E-05	1.18E-05	1.09E-05	1.18E-05	5.14E-05

HLW RADIOLOGICAL DOSES FROM A CANISTER DROP

Hanford Inhalation Dose for 448-Inch Drop (rem/can)

Isotope	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body
Ac-227	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-241	6.58E-02	5.41E-06	3.72E-02	3.52E-01	4.39E+00	3.24E-06	1.58E-01	2.43E-01
Am-242m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd-113m	1.39E-06	1.39E-06	1.71E-05	1.39E-06	1.39E-06	1.39E-06	5.43E-05	1.72E-05
Ce-144	2.39E-06	2.44E-06	9.80E-04	3.31E-05	5.62E-05	2.33E-06	1.28E-04	1.25E-04
Cm-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cm-244	5.80E-04	3.79E-08	7.04E-04	3.42E-03	4.27E-02	3.68E-08	1.74E-03	2.44E-03
Co-60	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Eu-154	9.28E-06	1.23E-05	6.28E-05	8.40E-05	4.15E-04	5.66E-06	8.96E-05	6.13E-05
Eu-155	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Np-237	2.10E-05	1.20E-08	1.14E-05	1.85E-04	2.31E-03	9.48E-09	1.66E-05	1.03E-04
Pa-231	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm-147	7.05E-10	1.35E-09	2.90E-03	3.06E-04	3.83E-03	7.43E-10	2.21E-04	3.98E-04
Pu-238	7.33E-05	2.62E-09	8.38E-04	3.98E-04	4.98E-03	2.52E-09	1.84E-04	2.78E-04
Pu-239	1.59E-04	4.60E-09	1.61E-03	8.43E-04	1.05E-02	4.51E-09	3.77E-04	5.79E-04
Pu-240	6.15E-05	1.84E-09	6.24E-04	3.27E-04	4.08E-03	1.75E-09	1.46E-04	2.24E-04
Pu-241	4.90E-05	2.20E-09	2.28E-04	2.41E-04	3.02E-03	8.91E-10	9.41E-05	1.60E-04
Th-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-129	5.01E-15	1.21E-14	1.81E-14	8.08E-15	7.96E-15	9.00E-11	6.81E-15	2.71E-12
Cs-134	1.03E-05	8.52E-06	9.31E-06	9.31E-06	8.68E-06	8.76E-06	1.10E-05	9.87E-06
Cs-137	1.41E-03	1.26E-03	1.42E-03	1.33E-03	1.28E-03	1.27E-03	1.47E-03	1.39E-03
Ru-106	8.01E-06	7.95E-06	6.04E-04	7.95E-06	7.95E-06	7.95E-06	9.81E-06	7.49E-05
Sr-90	3.57E-04	3.57E-04	3.87E-01	4.54E-02	9.83E-02	3.57E-04	7.75E-04	4.75E-02
Y-90	1.29E-06	1.29E-06	1.26E-03	3.77E-05	3.76E-05	1.29E-06	5.23E-04	3.08E-04
Totals	6.85E-02	1.66E-03	4.35E-01	4.05E-01	4.56E+00	1.66E-03	1.64E-01	2.97E-01

HLW RADIOLOGICAL DOSES FROM A CANISTER DROP

Hanford Air Submersion Dose for 448-Inch Drop (rem/can)

Isotope	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body	Skin
Ac-227	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-241	5.22E-09	6.50E-09	4.10E-09	3.17E-09	1.74E-08	4.76E-09	3.85E-09	4.97E-09	7.78E-09
Am-242m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd-113m	8.99E-13	1.10E-12	7.44E-13	6.28E-13	2.63E-12	8.48E-13	7.06E-13	8.70E-13	1.06E-09
Ce-144	1.01E-08	1.16E-08	9.82E-09	9.33E-09	2.02E-08	1.02E-08	9.43E-09	1.03E-08	3.19E-07
Cm-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cm-244	7.55E-13	1.46E-12	7.75E-14	1.60E-13	9.66E-13	4.59E-13	1.98E-13	5.37E-13	4.28E-12
Co-60	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Eu-154	1.43E-07	1.62E-07	1.43E-07	1.40E-07	2.25E-07	1.46E-07	1.37E-07	1.46E-07	1.97E-07
Eu-155	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Np-237	2.21E-12	2.68E-12	1.92E-12	1.63E-12	6.80E-12	2.11E-12	1.81E-12	2.19E-12	3.27E-12
Pa-231	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm-147	8.43E-11	1.08E-10	6.14E-11	5.02E-11	2.46E-10	7.60E-11	5.93E-11	7.81E-11	9.14E-08
Pu-238	5.16E-14	9.99E-14	8.34E-15	1.32E-14	7.31E-14	3.15E-14	1.57E-14	3.84E-14	3.22E-13
Pu-239	7.25E-14	1.13E-13	3.97E-14	4.00E-14	1.42E-13	5.81E-14	4.29E-14	6.35E-14	2.79E-13
Pu-240	3.69E-14	7.14E-14	6.33E-15	9.57E-15	5.37E-14	2.27E-14	1.14E-14	2.76E-14	2.27E-13
Pu-241	1.55E-14	1.87E-14	1.40E-14	1.21E-14	4.72E-14	1.51E-14	1.31E-14	1.56E-14	2.52E-14
Th-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-129	8.37E-17	1.15E-16	3.71E-17	2.84E-17	1.91E-16	6.69E-17	3.98E-17	6.58E-17	1.91E-16
Cs-134	1.75E-07	2.00E-07	1.75E-07	1.70E-07	2.84E-07	1.79E-07	1.67E-07	1.79E-07	2.24E-07
Cs-137	1.29E-05	1.47E-05	1.28E-05	1.25E-05	2.11E-05	1.31E-05	1.22E-05	1.31E-05	2.12E-05
Ru-106	1.87E-08	2.14E-08	1.80E-08	1.68E-08	4.29E-08	1.88E-08	1.71E-08	1.90E-08	2.30E-08
Sr-90	3.16E-09	3.85E-09	2.61E-09	2.21E-09	9.26E-09	2.98E-09	2.48E-09	3.06E-09	3.74E-06
Y-90	7.67E-08	8.93E-08	7.19E-08	6.58E-08	1.80E-07	7.59E-08	6.82E-08	7.71E-08	2.53E-05
Totals	1.33E-05	1.52E-05	1.32E-05	1.29E-05	2.19E-05	1.36E-05	1.26E-05	1.36E-05	5.11E-05

HLW RADIOLOGICAL DOSES FROM A CANISTER DROP

West Valley Inhalation Dose for 448-Inch Drop (rem/can)

Isotope	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body
Ac-227	1.27E-05	2.14E-09	4.94E-05	8.25E-05	1.03E-03	1.15E-09	4.72E-05	5.81E-05
Am-241	2.42E-02	1.98E-06	1.37E-02	1.29E-01	1.61E+00	1.19E-06	5.81E-02	8.92E-02
Am-242m	1.40E-04	6.01E-09	1.83E-05	7.36E-04	9.23E-03	2.46E-09	3.26E-04	5.01E-04
Am-243	1.57E-04	7.32E-08	8.57E-05	8.33E-04	1.04E-02	3.99E-08	3.73E-04	5.73E-04
Cd-113m	7.93E-07	7.93E-07	9.77E-06	7.93E-07	7.93E-07	7.93E-07	3.11E-05	9.87E-06
Ce-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cm-243	3.42E-05	1.04E-08	3.21E-05	1.95E-04	2.43E-03	6.33E-09	9.52E-05	1.37E-04
Cm-244	1.40E-03	9.13E-08	1.69E-03	8.23E-03	1.03E-01	8.86E-08	4.20E-03	5.88E-03
Co-60	2.64E-08	1.02E-07	1.92E-06	9.56E-08	7.50E-08	9.00E-08	2.00E-07	3.28E-07
Eu-154	1.04E-05	1.38E-05	7.04E-05	9.42E-05	4.65E-04	6.34E-06	1.00E-04	6.87E-05
Eu-155	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Np-237	9.66E-06	5.51E-09	5.25E-06	8.55E-05	1.07E-03	4.37E-09	7.64E-06	4.76E-05
Pa-231	1.46E-09	1.86E-09	1.58E-04	1.47E-04	1.84E-03	1.61E-09	6.06E-08	7.33E-05
Pm-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pu-238	3.11E-03	1.11E-07	3.56E-02	1.69E-02	2.11E-01	1.07E-07	7.80E-03	1.18E-02
Pu-239	7.18E-04	2.08E-08	7.29E-03	3.82E-03	4.76E-02	2.04E-08	1.71E-03	2.62E-03
Pu-240	5.26E-04	1.57E-08	5.34E-03	2.79E-03	3.49E-02	1.50E-08	1.25E-03	1.92E-03
Pu-241	6.03E-04	2.71E-08	2.81E-03	2.97E-03	3.72E-02	1.10E-08	1.16E-03	1.97E-03
Th-228	1.64E-07	1.64E-07	8.39E-05	1.36E-05	1.66E-04	1.63E-07	4.18E-07	1.12E-05
U-232	7.59E-09	7.64E-09	1.40E-04	3.85E-07	6.09E-06	7.45E-09	2.95E-07	1.69E-05
I-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-134	1.74E-07	1.44E-07	1.58E-07	1.58E-07	1.47E-07	1.48E-07	1.86E-07	1.67E-07
Cs-137	7.81E-04	6.99E-04	7.87E-04	7.40E-04	7.08E-04	7.07E-04	8.13E-04	7.70E-04
Ru-106	8.89E-11	8.82E-11	6.70E-09	8.82E-11	8.82E-11	8.82E-11	1.09E-10	8.31E-10
Sr-90	2.25E-04	2.25E-04	2.44E-01	2.87E-02	6.20E-02	2.25E-04	4.89E-04	2.99E-02
Y-90	8.12E-07	8.12E-07	7.94E-04	2.38E-05	2.37E-05	8.12E-07	3.30E-04	1.94E-04
Totals	3.19E-02	9.43E-04	3.13E-01	1.96E-01	2.14E+00	9.42E-04	7.68E-02	1.46E-01

HLW RADIOLOGICAL DOSES FROM A CANISTER DROP

West Valley Air Submersion Dose for 448-Inch Drop (rem/can)

Isotope	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body	Skin
Ac-227	3.62E-15	4.29E-15	3.26E-15	2.84E-15	9.99E-15	3.52E-15	3.07E-15	3.61E-15	3.17E-14
Am-241	1.91E-09	2.39E-09	1.50E-09	1.16E-09	6.41E-09	1.75E-09	1.42E-09	1.83E-09	2.86E-09
Am-242m	4.97E-13	7.86E-13	2.25E-13	2.25E-13	1.04E-12	3.86E-13	2.54E-13	4.14E-13	1.78E-12
Am-243	3.17E-11	3.77E-11	2.78E-11	2.24E-11	1.08E-10	3.02E-11	2.59E-11	3.15E-11	3.97E-11
Cd-113m	5.14E-13	6.28E-13	4.25E-13	3.59E-13	1.51E-12	4.85E-13	4.04E-13	4.98E-13	6.08E-10
Ce-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cm-243	2.86E-11	3.32E-11	2.73E-11	2.48E-11	7.45E-11	2.86E-11	2.58E-11	2.92E-11	4.86E-11
Cm-244	1.82E-12	3.51E-12	1.87E-13	3.85E-13	2.32E-12	1.10E-12	4.77E-13	1.29E-12	1.03E-11
Co-60	2.05E-09	2.32E-09	2.07E-09	2.05E-09	2.97E-09	2.12E-09	2.00E-09	2.10E-09	2.42E-09
Eu-154	1.60E-07	1.82E-07	1.60E-07	1.57E-07	2.52E-07	1.64E-07	1.53E-07	1.64E-07	2.21E-07
Eu-155	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Np-237	1.02E-12	1.23E-12	8.84E-13	7.54E-13	3.14E-12	9.74E-13	8.33E-13	1.01E-12	1.51E-12
Pa-231	1.08E-12	1.26E-12	1.03E-12	9.64E-13	2.31E-12	1.08E-12	9.77E-13	1.09E-12	1.55E-12
Pm-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pu-238	2.19E-12	4.24E-12	3.54E-13	5.61E-13	3.10E-12	1.34E-12	6.64E-13	1.63E-12	1.36E-11
Pu-239	3.28E-13	5.12E-13	1.80E-13	1.81E-13	6.42E-13	2.63E-13	1.94E-13	2.88E-13	1.26E-12
Pu-240	3.16E-13	6.10E-13	5.41E-14	8.19E-14	4.60E-13	1.95E-13	9.73E-14	2.36E-13	1.95E-12
Pu-241	1.91E-13	2.30E-13	1.72E-13	1.50E-13	5.82E-13	1.85E-13	1.62E-13	1.93E-13	3.11E-13
Th-228	3.32E-14	3.97E-14	3.04E-14	2.67E-14	9.62E-14	3.24E-14	2.86E-14	3.35E-14	5.47E-14
U-232	4.41E-15	6.61E-15	2.80E-15	2.56E-15	1.10E-14	3.67E-15	2.85E-15	4.04E-15	1.69E-14
I-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-134	2.97E-09	3.39E-09	2.96E-09	2.89E-09	4.82E-09	3.04E-09	2.84E-09	3.04E-09	3.80E-09
Cs-137	7.15E-06	8.16E-06	7.09E-06	6.92E-06	1.17E-05	7.30E-06	6.79E-06	7.30E-06	1.18E-05
Ru-106	2.07E-13	2.38E-13	1.99E-13	1.87E-13	4.76E-13	2.09E-13	1.89E-13	2.11E-13	2.55E-13
Sr-90	1.99E-09	2.43E-09	1.65E-09	1.39E-09	5.84E-09	1.88E-09	1.57E-09	1.93E-09	2.36E-06
Y-90	4.84E-08	5.64E-08	4.53E-08	4.15E-08	1.14E-07	4.79E-08	4.30E-08	4.87E-08	1.60E-05
Totals	7.37E-06	8.41E-06	7.31E-06	7.12E-06	1.21E-05	7.52E-06	7.00E-06	7.52E-06	3.03E-05

HLW RADIOLOGICAL DOSES FROM A CANISTER DROP

INEEL Inhalation Dose for 448-Inch Drop (rem/can)

Isotope	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body
Ac-227	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-241	3.00E-04	2.47E-08	1.70E-04	1.61E-03	2.00E-02	1.48E-08	7.22E-04	1.11E-03
Am-242m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd-113m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-144	8.40E-07	8.58E-07	3.44E-04	1.16E-05	1.98E-05	8.18E-07	4.48E-05	4.40E-05
Cm-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cm-244	3.08E-05	2.02E-09	3.74E-05	1.82E-04	2.27E-03	1.96E-09	9.27E-05	1.30E-04
Co-60	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Eu-154	6.38E-06	8.45E-06	4.32E-05	5.78E-05	2.85E-04	3.89E-06	6.16E-05	4.21E-05
Eu-155	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Np-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pa-231	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm-147	2.72E-10	5.21E-10	1.12E-03	1.18E-04	1.48E-03	2.87E-10	8.53E-05	1.53E-04
Pu-238	8.52E-03	3.04E-07	9.74E-02	4.63E-02	5.78E-01	2.93E-07	2.14E-02	3.23E-02
Pu-239	1.00E-04	2.91E-09	1.02E-03	5.34E-04	6.66E-03	2.85E-09	2.39E-04	3.66E-04
Pu-240	9.31E-05	2.78E-09	9.45E-04	4.95E-04	6.18E-03	2.65E-09	2.21E-04	3.40E-04
Pu-241	3.89E-04	1.74E-08	1.81E-03	1.91E-03	2.39E-02	7.07E-09	7.46E-04	1.27E-03
Th-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-134	3.61E-05	3.00E-05	3.28E-05	3.28E-05	3.06E-05	3.08E-05	3.86E-05	3.47E-05
Cs-137	4.59E-04	4.11E-04	4.62E-04	4.35E-04	4.16E-04	4.15E-04	4.78E-04	4.52E-04
Ru-106	1.99E-06	1.97E-06	1.50E-04	1.97E-06	1.97E-06	1.97E-06	2.43E-06	1.86E-05
Sr-90	1.42E-04	1.42E-04	1.54E-01	1.81E-02	3.91E-02	1.42E-04	3.08E-04	1.89E-02
Y-90	5.12E-07	5.12E-07	5.01E-04	1.50E-05	1.50E-05	5.12E-07	2.08E-04	1.23E-04
Totals	1.01E-02	5.95E-04	2.58E-01	6.97E-02	6.79E-01	5.96E-04	2.46E-02	5.52E-02

HLW RADIOLOGICAL DOSES FROM A CANISTER DROP

INEEL Air Submersion Dose for 448-Inch Drop (rem/can)

Isotope	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body	Skin
Ac-227	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-241	2.38E-11	2.97E-11	1.87E-11	1.45E-11	7.96E-11	2.17E-11	1.76E-11	2.27E-11	3.55E-11
Am-242m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd-113m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-144	3.56E-09	4.09E-09	3.45E-09	3.28E-09	7.11E-09	3.60E-09	3.31E-09	3.63E-09	1.12E-07
Cm-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cm-244	4.02E-14	7.75E-14	4.12E-15	8.50E-15	5.14E-14	2.44E-14	1.05E-14	2.86E-14	2.28E-13
Co-60	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Eu-154	9.82E-08	1.11E-07	9.80E-08	9.61E-08	1.54E-07	1.01E-07	9.41E-08	1.00E-07	1.36E-07
Eu-155	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Np-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pa-231	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm-147	3.25E-11	4.16E-11	2.37E-11	1.94E-11	9.48E-11	2.93E-11	2.29E-11	3.01E-11	3.53E-08
Pu-238	6.00E-12	1.16E-11	9.69E-13	1.54E-12	8.50E-12	3.67E-12	1.82E-12	4.46E-12	3.74E-11
Pu-239	4.59E-14	7.16E-14	2.51E-14	2.53E-14	8.98E-14	3.68E-14	2.71E-14	4.02E-14	1.76E-13
Pu-240	5.59E-14	1.08E-13	9.58E-15	1.45E-14	8.14E-14	3.45E-14	1.72E-14	4.18E-14	3.45E-13
Pu-241	1.23E-13	1.48E-13	1.11E-13	9.63E-14	3.75E-13	1.19E-13	1.04E-13	1.24E-13	2.00E-13
Th-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-134	6.17E-07	7.03E-07	6.15E-07	6.00E-07	1.00E-06	6.32E-07	5.89E-07	6.32E-07	7.88E-07
Cs-137	4.20E-06	4.79E-06	4.17E-06	4.06E-06	6.89E-06	4.29E-06	3.99E-06	4.29E-06	6.91E-06
Ru-106	4.63E-09	5.32E-09	4.46E-09	4.17E-09	1.06E-08	4.67E-09	4.23E-09	4.71E-09	5.71E-09
Sr-90	1.26E-09	1.53E-09	1.04E-09	8.79E-10	3.68E-09	1.18E-09	9.87E-10	1.22E-09	1.49E-06
Y-90	3.05E-08	3.55E-08	2.86E-08	2.62E-08	7.17E-08	3.02E-08	2.71E-08	3.07E-08	1.01E-05
Totals	4.95E-06	5.65E-06	4.92E-06	4.79E-06	8.14E-06	5.06E-06	4.71E-06	5.06E-06	1.96E-05

SUMMARY OF HLW RADIOLOGICAL DOSES

Organs	SRS Inhalation Dose at 5,000 m (rem)	Hanford Inhalation Dose at 5,000 m (rem)	West Valley Inhalation Dose at 5,000 m (rem)	INEEL Inhalation Dose at 5,000 m (rem)	Dose Term for Regulation	SRS Air Submersion/ External Dose at 5,000 m (rem)	Hanford Air Submersion/ External Dose at 5,000 m (rem)	West Valley Air Submersion/ External Dose at 5,000 m (rem)	INEEL Air Submersion/ External Dose at 5,000 m (rem)	Dose Term for Regulation
Gonad	1.57E-01	6.85E-02	3.19E-02	1.01E-02	<CDE	1.15E-05	1.33E-05	7.37E-06	4.95E-06	<DDE
Breast	1.52E-03	1.66E-03	9.43E-04	5.95E-04		1.31E-05	1.52E-05	8.41E-06	5.65E-06	
Lung	2.11E+00	4.35E-01	3.13E-01	2.58E-01		1.14E-05	1.32E-05	7.31E-06	4.92E-06	
R Marrow	8.94E-01	4.05E-01	1.96E-01	6.97E-02		1.11E-05	1.29E-05	7.12E-06	4.79E-06	
B Surface	1.06E+01	4.56E+00	2.14E+00	6.79E-01		1.89E-05	2.19E-05	1.21E-05	8.14E-06	
Thyroid	1.52E-03	1.66E-03	9.42E-04	5.96E-04	<CEDE	1.18E-05	1.36E-05	7.52E-06	5.06E-06	<Eye
Remainder	3.92E-01	1.64E-01	7.68E-02	2.46E-02		1.09E-05	1.26E-05	7.00E-06	4.71E-06	
Whole Body	6.42E-01	2.97E-01	1.46E-01	5.52E-02		1.18E-05	1.36E-05	7.52E-06	5.06E-06	
Eye Lens	N/A	N/A	N/A	N/A		0.00E+00	0.00E+00	0.00E+00	0.00E+00	
Skin	N/A	N/A	N/A	N/A		5.14E-05	5.11E-05	3.03E-05	1.96E-05	<Skin

TEDE = Total Effective Dose Equivalent - equal to the CEDE plus the DDE.

CEDE = Committed Effective Dose Equivalent - equal to whole body dose by inhalation.

DDE = Deep Dose Equivalent - equal to whole body by submersion.

CDE = Committed Dose Equivalent - equal to maximum inhalation dose to any one organ.

Eye Lens = No doses are calculated in this calculation because none of the HLW isotopes have lens of the eye DCFs.

Skin = The dose to the skin and extremities is only due to the air submersion dose pathway.

HLW TYPE	Regulatory Dose		
	TEDE	DDE + CDE*	Skin
SRS	6.42E-01	1.06E+01	5.14E-05
Hanford	2.97E-01	4.56E+00	5.11E-05
West Valley	1.46E-01	2.14E+00	3.03E-05
INEEL	5.52E-02	6.79E-01	1.96E-05

* Note: Bolded quantities are added together to determine DDE + CDE.

SRS RADIOLOGICAL DOSE FOR VARIOUS DROP HEIGHTS

SRS Inhalation Dose for 80-Inch Drop (rem/can)

Isotope	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body
Ac-227	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-241	4.68E-04	3.85E-08	2.65E-04	2.51E-03	3.13E-02	2.31E-08	1.13E-03	1.73E-03
Am-242m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd-113m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-144	1.41E-07	1.44E-07	5.80E-05	1.96E-06	3.33E-06	1.38E-07	7.55E-06	7.40E-06
Cm-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cm-244	8.93E-04	5.84E-08	1.08E-03	5.27E-03	6.57E-02	5.67E-08	2.69E-03	3.76E-03
Co-60	2.65E-07	1.02E-06	1.92E-05	9.57E-07	7.51E-07	9.01E-07	2.00E-06	3.29E-06
Eu-154	3.06E-06	4.06E-06	2.07E-05	2.77E-05	1.37E-04	1.87E-06	2.96E-05	2.02E-05
Eu-155	5.40E-08	9.31E-08	1.80E-06	2.17E-06	2.31E-05	3.64E-08	1.68E-06	1.70E-06
Np-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pa-231	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm-147	7.68E-11	1.47E-10	3.16E-04	3.33E-05	4.16E-04	8.08E-11	2.40E-05	4.33E-05
Pu-238	2.53E-02	9.04E-07	2.89E-01	1.37E-01	1.72E+00	8.69E-07	6.34E-02	9.58E-02
Pu-239	2.59E-04	7.52E-09	2.63E-03	1.38E-03	1.72E-02	7.36E-09	6.16E-04	9.46E-04
Pu-240	1.75E-04	5.23E-09	1.78E-03	9.29E-04	1.16E-02	4.98E-09	4.16E-04	6.38E-04
Pu-241	5.69E-04	2.55E-08	2.65E-03	2.80E-03	3.50E-02	1.03E-08	1.09E-03	1.86E-03
Th-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-134	5.16E-07	4.29E-07	4.68E-07	4.68E-07	4.37E-07	4.41E-07	5.52E-07	4.96E-07
Cs-137	2.14E-04	1.92E-04	2.16E-04	2.03E-04	1.94E-04	1.94E-04	2.23E-04	2.11E-04
Ru-106	6.45E-07	6.41E-07	4.86E-05	6.41E-07	6.41E-07	6.41E-07	7.90E-07	6.03E-06
Sr-90	7.14E-05	7.14E-05	7.74E-02	9.09E-03	1.97E-02	7.14E-05	1.55E-04	9.49E-03
Y-90	2.58E-07	2.58E-07	2.52E-04	7.55E-06	7.52E-06	2.58E-07	1.05E-04	6.17E-05
Totals	2.80E-02	2.71E-04	3.76E-01	1.60E-01	1.90E+00	2.71E-04	6.99E-02	1.15E-01

SRS RADIOLOGICAL DOSE FOR VARIOUS DROP HEIGHTS

SRS Air Submersion Dose for 80-Inch Drop (rem/can)

Isotope	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body	Skin
Ac-227	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-241	3.71E-11	4.63E-11	2.92E-11	2.25E-11	1.24E-10	3.39E-11	2.74E-11	3.54E-11	5.54E-11
Am-242m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd-113m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-144	6.00E-10	6.89E-10	5.81E-10	5.52E-10	1.20E-09	6.06E-10	5.58E-10	6.10E-10	1.89E-08
Cm-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cm-244	1.16E-12	2.24E-12	1.19E-13	2.46E-13	1.49E-12	7.07E-13	3.05E-13	8.28E-13	6.60E-12
Co-60	2.05E-08	2.32E-08	2.07E-08	2.05E-08	2.97E-08	2.12E-08	2.00E-08	2.10E-08	2.42E-08
Eu-154	4.71E-08	5.35E-08	4.71E-08	4.61E-08	7.41E-08	4.83E-08	4.52E-08	4.82E-08	6.51E-08
Eu-155	1.13E-09	1.34E-09	1.01E-09	8.43E-10	3.68E-09	1.10E-09	9.43E-10	1.13E-09	1.54E-09
Np-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pa-231	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm-147	9.17E-12	1.17E-11	6.68E-12	5.47E-12	2.67E-11	8.28E-12	6.45E-12	8.50E-12	9.94E-09
Pu-238	1.78E-11	3.45E-11	2.88E-12	4.56E-12	2.52E-11	1.09E-11	5.40E-12	1.32E-11	1.11E-10
Pu-239	1.18E-13	1.85E-13	6.49E-14	6.54E-14	2.32E-13	9.50E-14	7.00E-14	1.04E-13	4.55E-13
Pu-240	1.05E-13	2.03E-13	1.80E-14	2.72E-14	1.53E-13	6.47E-14	3.24E-14	7.84E-14	6.47E-13
Pu-241	1.80E-13	2.17E-13	1.62E-13	1.41E-13	5.49E-13	1.75E-13	1.53E-13	1.82E-13	2.93E-13
Th-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-134	8.82E-09	1.00E-08	8.78E-09	8.57E-09	1.43E-08	9.02E-09	8.41E-09	9.02E-09	1.13E-08
Cs-137	1.96E-06	2.24E-06	1.95E-06	1.90E-06	3.22E-06	2.00E-06	1.86E-06	2.00E-06	3.23E-06
Ru-106	1.50E-09	1.73E-09	1.45E-09	1.36E-09	3.45E-09	1.52E-09	1.37E-09	1.53E-09	1.85E-09
Sr-90	6.32E-10	7.71E-10	5.23E-10	4.42E-10	1.85E-09	5.95E-10	4.96E-10	6.12E-10	7.47E-07
Y-90	1.54E-08	1.79E-08	1.44E-08	1.32E-08	3.61E-08	1.52E-08	1.36E-08	1.54E-08	5.07E-06
Totals	2.06E-06	2.35E-06	2.04E-06	1.99E-06	3.38E-06	2.10E-06	1.95E-06	2.10E-06	9.17E-06

SRS RADIOLOGICAL DOSE FOR VARIOUS DROP HEIGHTS

SRS Inhalation Dose for 264-Inch Drop (rem/can)

Isotope	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body
Ac-227	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-241	1.55E-03	1.27E-07	8.75E-04	8.27E-03	1.03E-01	7.61E-08	3.72E-03	5.71E-03
Am-242m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd-113m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-144	4.67E-07	4.77E-07	1.91E-04	6.46E-06	1.10E-05	4.55E-07	2.49E-05	2.44E-05
Cm-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cm-244	2.95E-03	1.93E-07	3.58E-03	1.74E-02	2.17E-01	1.87E-07	8.86E-03	1.24E-02
Co-60	8.74E-07	3.38E-06	6.33E-05	3.16E-06	2.48E-06	2.97E-06	6.61E-06	1.08E-05
Eu-154	1.01E-05	1.34E-05	6.84E-05	9.15E-05	4.52E-04	6.16E-06	9.76E-05	6.67E-05
Eu-155	1.78E-07	3.07E-07	5.96E-06	7.16E-06	7.61E-05	1.20E-07	5.56E-06	5.61E-06
Np-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pa-231	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm-147	2.53E-10	4.85E-10	1.04E-03	1.10E-04	1.37E-03	2.67E-10	7.94E-05	1.43E-04
Pu-238	8.35E-02	2.98E-06	9.54E-01	4.53E-01	5.67E+00	2.87E-06	2.09E-01	3.16E-01
Pu-239	8.56E-04	2.48E-08	8.69E-03	4.55E-03	5.68E-02	2.43E-08	2.03E-03	3.12E-03
Pu-240	5.77E-04	1.73E-08	5.86E-03	3.07E-03	3.83E-02	1.64E-08	1.37E-03	2.10E-03
Pu-241	1.88E-03	8.42E-08	8.75E-03	9.25E-03	1.16E-01	3.41E-08	3.61E-03	6.14E-03
Th-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-134	1.70E-06	1.41E-06	1.55E-06	1.55E-06	1.44E-06	1.45E-06	1.82E-06	1.64E-06
Cs-137	7.07E-04	6.33E-04	7.12E-04	6.70E-04	6.41E-04	6.40E-04	7.36E-04	6.97E-04
Ru-106	2.13E-06	2.11E-06	1.61E-04	2.11E-06	2.11E-06	2.11E-06	2.61E-06	1.99E-05
Sr-90	2.36E-04	2.36E-04	2.55E-01	3.00E-02	6.49E-02	2.36E-04	5.11E-04	3.13E-02
Y-90	8.50E-07	8.50E-07	8.31E-04	2.49E-05	2.48E-05	8.50E-07	3.45E-04	2.04E-04
Totals	9.23E-02	8.94E-04	1.24E+00	5.27E-01	6.26E+00	8.93E-04	2.31E-01	3.78E-01

SRS RADIOLOGICAL DOSE FOR VARIOUS DROP HEIGHTS

SRS Air Submersion Dose for 264-Inch Drop (rem/can)

Isotope	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body	Skin
Ac-227	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-241	1.23E-10	1.53E-10	9.62E-11	7.44E-11	4.10E-10	1.12E-10	9.05E-11	1.17E-10	1.83E-10
Am-242m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd-113m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-144	1.98E-09	2.27E-09	1.92E-09	1.82E-09	3.95E-09	2.00E-09	1.84E-09	2.01E-09	6.23E-08
Cm-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cm-244	3.84E-12	7.41E-12	3.94E-13	8.13E-13	4.91E-12	2.33E-12	1.01E-12	2.73E-12	2.18E-11
Co-60	6.78E-08	7.66E-08	6.83E-08	6.78E-08	9.81E-08	7.00E-08	6.61E-08	6.94E-08	7.99E-08
Eu-154	1.56E-07	1.77E-07	1.55E-07	1.52E-07	2.45E-07	1.59E-07	1.49E-07	1.59E-07	2.15E-07
Eu-155	3.74E-09	4.43E-09	3.34E-09	2.78E-09	1.22E-08	3.62E-09	3.11E-09	3.74E-09	5.10E-09
Np-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pa-231	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm-147	3.03E-11	3.87E-11	2.21E-11	1.80E-11	8.82E-11	2.73E-11	2.13E-11	2.80E-11	3.28E-08
Pu-238	5.88E-11	1.14E-10	9.49E-12	1.50E-11	8.33E-11	3.59E-11	1.78E-11	4.37E-11	3.66E-10
Pu-239	3.91E-13	6.10E-13	2.14E-13	2.16E-13	7.65E-13	3.13E-13	2.31E-13	3.43E-13	1.50E-12
Pu-240	3.47E-13	6.70E-13	5.94E-14	8.99E-14	5.05E-13	2.14E-13	1.07E-13	2.59E-13	2.14E-12
Pu-241	5.94E-13	7.17E-13	5.36E-13	4.65E-13	1.81E-12	5.77E-13	5.03E-13	5.99E-13	9.67E-13
Th-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-134	2.91E-08	3.32E-08	2.90E-08	2.83E-08	4.72E-08	2.98E-08	2.78E-08	2.98E-08	3.72E-08
Cs-137	6.47E-06	7.39E-06	6.42E-06	6.26E-06	1.06E-05	6.60E-06	6.15E-06	6.60E-06	1.06E-05
Ru-106	4.96E-09	5.70E-09	4.77E-09	4.47E-09	1.14E-08	5.01E-09	4.54E-09	5.05E-09	6.12E-09
Sr-90	2.09E-09	2.54E-09	1.73E-09	1.46E-09	6.11E-09	1.96E-09	1.64E-09	2.02E-09	2.47E-06
Y-90	5.07E-08	5.90E-08	4.74E-08	4.34E-08	1.19E-07	5.01E-08	4.50E-08	5.09E-08	1.67E-05
Totals	6.79E-06	7.75E-06	6.73E-06	6.56E-06	1.12E-05	6.93E-06	6.45E-06	6.93E-06	3.03E-05

SRS RADIOLOGICAL DOSE FOR VARIOUS DROP HEIGHTS

SRS Inhalation Dose for 330-Inch Drop (rem/can)

Isotope	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body
Ac-227	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-241	1.93E-03	1.59E-07	1.09E-03	1.03E-02	1.29E-01	9.51E-08	4.65E-03	7.13E-03
Am-242m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd-113m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-144	5.84E-07	5.96E-07	2.39E-04	8.07E-06	1.37E-05	5.69E-07	3.11E-05	3.05E-05
Cm-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cm-244	3.68E-03	2.41E-07	4.47E-03	2.17E-02	2.71E-01	2.34E-07	1.11E-02	1.55E-02
Co-60	1.09E-06	4.22E-06	7.91E-05	3.95E-06	3.10E-06	3.72E-06	8.26E-06	1.36E-05
Eu-154	1.26E-05	1.67E-05	8.55E-05	1.14E-04	5.64E-04	7.71E-06	1.22E-04	8.34E-05
Eu-155	2.23E-07	3.84E-07	7.45E-06	8.95E-06	9.51E-05	1.50E-07	6.95E-06	7.01E-06
Np-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pa-231	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm-147	3.17E-10	6.06E-10	1.30E-03	1.37E-04	1.72E-03	3.33E-10	9.92E-05	1.79E-04
Pu-238	1.04E-01	3.73E-06	1.19E+00	5.67E-01	7.08E+00	3.59E-06	2.62E-01	3.95E-01
Pu-239	1.07E-03	3.10E-08	1.09E-02	5.68E-03	7.10E-02	3.04E-08	2.54E-03	3.90E-03
Pu-240	7.21E-04	2.16E-08	7.33E-03	3.83E-03	4.79E-02	2.05E-08	1.71E-03	2.63E-03
Pu-241	2.35E-03	1.05E-07	1.09E-02	1.16E-02	1.45E-01	4.27E-08	4.51E-03	7.67E-03
Th-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-134	2.13E-06	1.77E-06	1.93E-06	1.93E-06	1.80E-06	1.82E-06	2.28E-06	2.05E-06
Cs-137	8.84E-04	7.91E-04	8.90E-04	8.37E-04	8.01E-04	8.00E-04	9.20E-04	8.71E-04
Ru-106	2.66E-06	2.64E-06	2.01E-04	2.64E-06	2.64E-06	2.64E-06	3.26E-06	2.49E-05
Sr-90	2.95E-04	2.95E-04	3.19E-01	3.75E-02	8.11E-02	2.95E-04	6.39E-04	3.92E-02
Y-90	1.06E-06	1.06E-06	1.04E-03	3.11E-05	3.10E-05	1.06E-06	4.32E-04	2.54E-04
Totals	1.15E-01	1.12E-03	1.55E+00	6.58E-01	7.83E+00	1.12E-03	2.88E-01	4.73E-01

SRS RADIOLOGICAL DOSE FOR VARIOUS DROP HEIGHTS

SRS Air Submersion Dose for 330-Inch Drop (rem/can)

Isotope	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body	Skin
Ac-227	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-241	1.53E-10	1.91E-10	1.20E-10	9.30E-11	5.12E-10	1.40E-10	1.13E-10	1.46E-10	2.28E-10
Am-242m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cd-113m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-144	2.47E-09	2.84E-09	2.40E-09	2.28E-09	4.94E-09	2.50E-09	2.30E-09	2.52E-09	7.79E-08
Cm-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cm-244	4.80E-12	9.26E-12	4.93E-13	1.02E-12	6.14E-12	2.92E-12	1.26E-12	3.42E-12	2.72E-11
Co-60	8.47E-08	9.58E-08	8.54E-08	8.47E-08	1.23E-07	8.75E-08	8.27E-08	8.68E-08	9.99E-08
Eu-154	1.94E-07	2.21E-07	1.94E-07	1.90E-07	3.06E-07	1.99E-07	1.86E-07	1.99E-07	2.69E-07
Eu-155	4.68E-09	5.54E-09	4.17E-09	3.48E-09	1.52E-08	4.53E-09	3.89E-09	4.68E-09	6.37E-09
Np-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pa-231	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm-147	3.78E-11	4.83E-11	2.76E-11	2.26E-11	1.10E-10	3.41E-11	2.66E-11	3.50E-11	4.10E-08
Pu-238	7.34E-11	1.42E-10	1.19E-11	1.88E-11	1.04E-10	4.49E-11	2.23E-11	5.46E-11	4.58E-10
Pu-239	4.89E-13	7.62E-13	2.68E-13	2.70E-13	9.56E-13	3.92E-13	2.89E-13	4.28E-13	1.88E-12
Pu-240	4.33E-13	8.38E-13	7.42E-14	1.12E-13	6.31E-13	2.67E-13	1.33E-13	3.24E-13	2.67E-12
Pu-241	7.43E-13	8.96E-13	6.70E-13	5.82E-13	2.26E-12	7.21E-13	6.29E-13	7.49E-13	1.21E-12
Th-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-134	3.64E-08	4.14E-08	3.62E-08	3.53E-08	5.90E-08	3.72E-08	3.47E-08	3.72E-08	4.65E-08
Cs-137	8.09E-06	9.23E-06	8.03E-06	7.83E-06	1.33E-05	8.26E-06	7.68E-06	8.26E-06	1.33E-05
Ru-106	6.20E-09	7.13E-09	5.97E-09	5.59E-09	1.43E-08	6.26E-09	5.67E-09	6.31E-09	7.65E-09
Sr-90	2.61E-09	3.18E-09	2.16E-09	1.82E-09	7.64E-09	2.46E-09	2.05E-09	2.52E-09	3.08E-06
Y-90	6.33E-08	7.37E-08	5.93E-08	5.43E-08	1.49E-07	6.27E-08	5.63E-08	6.37E-08	2.09E-05
Totals	8.48E-06	9.68E-06	8.42E-06	8.20E-06	1.40E-05	8.66E-06	8.06E-06	8.66E-06	3.78E-05

SRS RADIOLOGICAL DOSE FOR VARIOUS DROP HEIGHTS

Summary of SRS Dose at 5,000 m for Various Drop Heights

Organs	80-Inch Drop SRS Inhalation Dose (rem)	264-Inch Drop SRS Inhalation Dose (rem)	330-Inch Drop SRS Inhalation Dose (rem)	448-Inch Drop SRS Inhalation Dose (rem)	Dose Term for Regulation	80-Inch Drop SRS Air Submersion/ External Dose (rem)	264-Inch Drop SRS Air Submersion/ External Dose (rem)	330-Inch Drop SRS Air Submersion/ External Dose (rem)	448-Inch Drop SRS Air Submersion/ External Dose (rem)	Dose Term for Regulation
Gonad	2.80E-02	9.23E-02	1.15E-01	1.57E-01	<CDE	2.06E-06	6.79E-06	8.48E-06	1.15E-05	<DDE
Breast	2.71E-04	8.94E-04	1.12E-03	1.52E-03		2.35E-06	7.75E-06	9.68E-06	1.31E-05	
Lung	3.76E-01	1.24E+00	1.55E+00	2.11E+00		2.04E-06	6.73E-06	8.42E-06	1.14E-05	
R Marrow	1.60E-01	5.27E-01	6.58E-01	8.94E-01		1.99E-06	6.56E-06	8.20E-06	1.11E-05	
B Surface	1.90E+00	6.26E+00	7.83E+00	1.06E+01		3.38E-06	1.12E-05	1.40E-05	1.89E-05	
Thyroid	2.71E-04	8.93E-04	1.12E-03	1.52E-03		2.10E-06	6.93E-06	8.66E-06	1.18E-05	
Remainder	6.99E-02	2.31E-01	2.88E-01	3.92E-01		1.95E-06	6.45E-06	8.06E-06	1.09E-05	
Whole Body	1.15E-01	3.78E-01	4.73E-01	6.42E-01	<CEDE	2.10E-06	6.93E-06	8.66E-06	1.18E-05	<DDE
Eye Lens	N/A	N/A	N/A	N/A		0.00E+00	0.00E+00	0.00E+00	0.00E+00	<Eye
Skin	N/A	N/A	N/A	N/A		9.17E-06	3.03E-05	3.78E-05	5.14E-05	<Skin

TEDE = Total Effective Dose Equivalent - equal to the CEDE plus the DDE.

CEDE = Committed Effective Dose Equivalent - equal to whole body dose by inhalation.

DDE = Deep Dose Equivalent - equal to whole body dose by submersion.

CDE = Committed Dose Equivalent - equal to maximum inhalation dose to any one organ.

Eye Lens = No doses are calculated in this calculation because none of the HLW isotopes have lens of the eye DCFs.

Skin = The dose to the skin and extremities is only due to the air submersion dose pathway.

HLW DROP	Regulatory Dose		
	TEDE	DDE + CDE*	Skin
80"	1.15E-01	1.90E+00	9.17E-06
264"	3.78E-01	6.26E+00	3.03E-05
330"	4.73E-01	7.83E+00	3.78E-05
448"	6.42E-01	1.06E+01	5.14E-05

* Note: Bolded quantities are added to determine DDE + CDE.

Drop Height vs. Offsite Dose