3. HAZARD AND ACCIDENT ANALYSIS

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3. HAZARD AND ACCIDENT ANALYSIS

3.1 Introduction

Hazard analysis considers the complete spectrum of accidents that may occur because of facility operations; analyzes potential accident consequences to the public and workers; estimates the likelihood of occurrence; identifies associated preventive and mitigative features; identifies safety-class and safety-significant SSCs; and identifies a selected subset of accidents designated design-basis accidents (DBAs) to be formally defined in accident analysis. The subsequent accident analysis evaluates these DBAs for comparison with evaluation guidelines to identify and assess the adequacy of safety SSCs.

3.2 Requirements

The following codes, standards, regulations, and DOE orders are specific to this subsection:

- 10 CFR 830 Subpart B, "Safety Basis Requirements"[1]
- DOE Order 420.1A, "Facility Safety"[2]
- DOE-ID Order 420.D, "Requirements and Guidance for Safety Analysis"[3]
- DOE-STD-1027-92, "Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports"[4]
- DOE-STD-3009-94, "Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses."[5]

3.3 Hazard Analysis

This section describes the hazard identification and evaluation performed for ISV operations at the SDA. Accidents are identified and grouped (binned) in accordance with DOE-STD-3009-94. This discussion leads to the selection of a limited set of bounding accidents (DBAs) that are further developed in Section 3.4, "Accident Analysis." The evaluation also identifies preventive and mitigative features that must be considered in the design of ISV.

3.3.1 Methodology

This subsection presents the methodology used to identify and characterize hazards and to perform a systematic evaluation of basic accidents.

3.3.1.1 Hazard Identification. A hazard is defined as a source of danger (i.e., material, energy source, or operation) with the potential to cause illness, injury, or death to personnel, or damage to an operation or the environment without considering the likelihood or credibility of accident scenarios or consequence mitigation. Potential hazards were identified through a review of existing safety documentation and a review of the designs and process descriptions. Operating history is another source used for identifying applicable hazards. The DOE Occurrence Reporting and Processing System (ORPS) computer database was searched to obtain applicable operational occurrence information.

A what-if checklist-type analysis is performed to identify hazards. The result of this hazard identification process is a comprehensive list of applicable hazards.

3.3.1.2 Hazard Evaluation. A qualitative hazard evaluation was performed for the hazards that can result in an uncontrolled release of radioactive or hazardous material and affect the off-Site public, co-located workers, facility workers, or the environment.

The likelihood (anticipated, unlikely, extremely unlikely, or beyond extremely unlikely) of each hazard without controls is qualitatively estimated using the definitions in Table 3-1. No credit is taken for controls (design or administrative) that prevent or mitigate the scenario. The likelihood category is based on available data, prior studies, operating experience, and engineering judgment. Scenarios caused by human error are generally assigned to the anticipated category in the absence of controls (that is, assuming no procedures or training). Unless there are specific failure rate data or history that justify a different likelihood category, scenarios caused by equipment failure are generally assigned to the anticipated category. If there is uncertainty in the likelihood category, the higher frequency category will be conservatively assumed. The consequence categories are defined in Table 3-2. The numerical consequence category guidelines for the off-Site public located at the Site boundary nearest to the RWMC, co-located workers assumed to be located 100 m from the release, and facility workers are based on the evaluation guidelines and criteria for the selection of safety SSCs and TSRs established in DOE-ID Order 420.D for INEEL nonreactor nuclear facilities.

A qualitative estimate for each hazard is made of the potential unmitigated consequences to the off-Site public, co-located workers, facility workers, and the environment. Unmitigated means that a material's quantity, form, location, dispersibility, and interaction with available energy sources are considered, but no credit is taken for safety features (such as, ventilation system and fire suppression) that could prevent or lessen a hazard. This does not require ignoring passive design features that confine radioactive or hazardous material if failure is not postulated by the initiating scenario. The qualitative estimates of consequence category are based on developed estimates or engineering judgment. If there is uncertainty in the consequence category, then the more severe consequence category is assumed.

Table 3-1. Qualitative likelihood categories.

Likelihood Category	Description	Frequency of Occurrence (annually)
Anticipated	Events that have occurred or are expected to occur during the lifetime of the facility (frequency between once in 10 and once in 100 years).	10^{-2} to 10^{-1}
Unlikely	Events that may occur but are not anticipated in the lifetime of the facility (frequency between once in 100 and once in 10,000 years).	10^{-4} to 10^{-2}
Extremely unlikely	Events that while possible will probably not occur in the lifetime of the facility (frequency between once in 10,000 and once in 1,000,000 years).	10^{-6} to 10^{-4}
Beyond extremely unlikely	Events that are considered too improbable to warrant further consideration (frequency less than once in 1,000,000 years).	$<10^{-6}$

Table 3-2. Qualitative consequence categories.

Consequence Category	Off-Site Public[a]	Co-located[b] Workers	Facility Workers[c]	Environment
High (H)	>25 rem[d] or >ERPG[e]-2	>100 rem[d] or >ERPG[e]-3 or >Δ10 psi[f]	>100 rem[d] or >ERPG[e]-3 or >Δ10 psi[f]	Off-Site contamination or major liquid release to the groundwater.
Moderate (M)	5 to 25 rem[d] or ERPG[e]-1 to ERPG[e]-2	25 to 100 rem[d] or ERPG[e]-2 to ERPG[e]-3	25 to 100 rem[d] or ERPG[e]-2 to ERPG[e]-3	On-Site contamination.
Low (L)	0.5 to 5 rem[d] or TLV–TWA[g,h] to ERPG-1	5 to 25 rem[d] or ERPG[e]-1 to ERPG[e]-2	5 to 25 rem[d] or ERPG[e]-1 to ERPG[e]-2	Site area contamination outside the facility.
Negligible (N)	<0.5 rem or <TLV–TWA[g,h]	<5 rem[d] or <ERPG[e]-1	<5 rem[d] or <ERPG[e]-1	No contamination outside the facility.

a. The off-Site public is a hypothetical maximally exposed individual at the nearest INEEL Site boundary.

b. The co-located worker is located outside the facility and is assumed 100 m from the release.

c. The facility worker is inside the facility (e.g., in the immediate vicinity of the release).

d. Radiation doses (rem) are TEDE.

e. Emergency Response Planning Guideline values are intended to provide estimates of concentration ranges where one might reasonably anticipate observing adverse effects, as described in the definitions of ERPG-1, ERPG-2, and ERPG-3 as a consequence of exposure to the specific substance.

- The ERPG-1 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hr without experiencing other than mild transient adverse health effects or perceiving a clearly defined, objectionable odor.
- The ERPG-2 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hr without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective actions.
- The ERPG-3 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hr without experiencing or developing life-threatening health effects.

f. Explosion overpressure is expressed as the differential pressure (Δ psi) of the shock wave from a detonation.

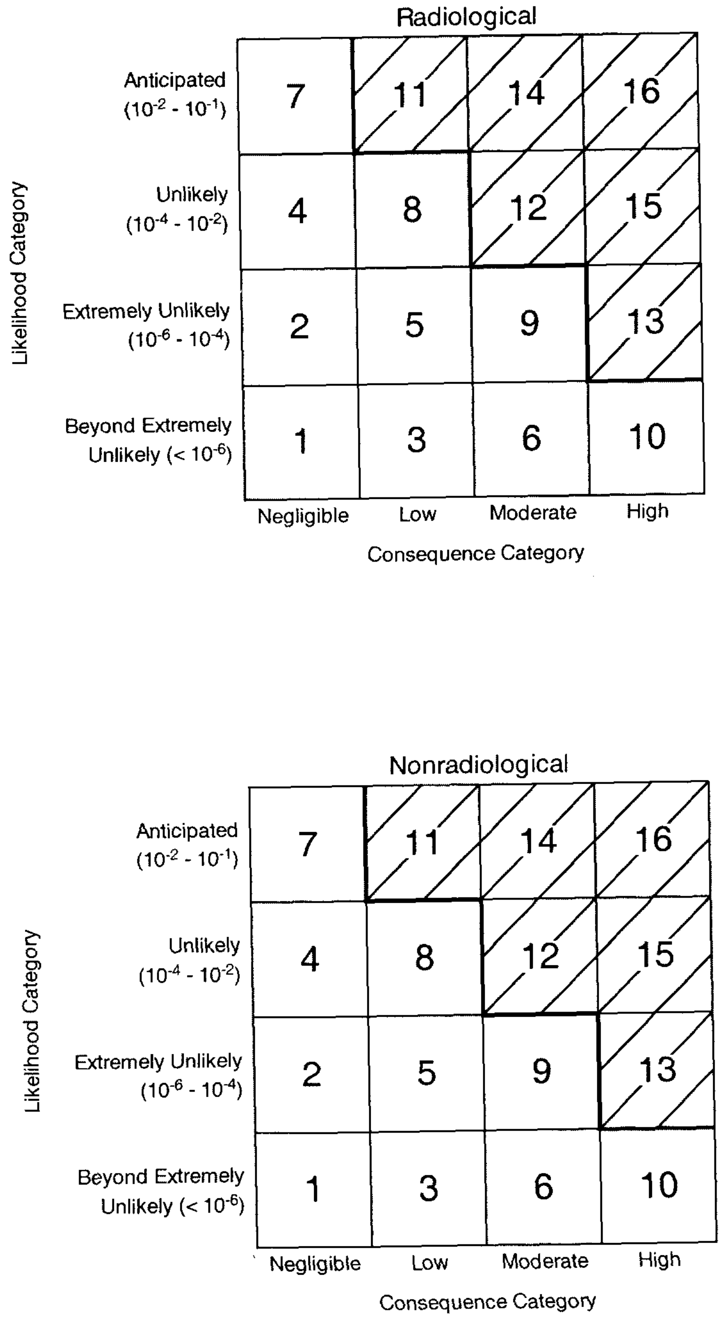
g. The TLV-TWA is the TWA concentration for a normal 8-hr workday and a 40-hr workweek to which nearly all workers may be repeatedly exposed, day after day, without adverse effects.

h. If a TLV-TWA or ERPG value for a specific substance has not been established, TEELs are used. The TEELs for specific chemicals are taken from *ERPGs and TEELs for Chemicals of Concern*.[6]

ERPG	Emergency Response Planning Guide	INEEL	Idaho National Engineering and Environmental Laboratory
TEDE	total effective dose equivalent	TEEL	temporary emergency exposure limit
TLV–TWA	threshold limit value-time–weighted average		

Based on the likelihood and consequence categories, a risk bin number is assigned using the qualitative risk matrices in Figures 3-1, 3-2, and 3-3. No risk bin number is identified for environmental effects, because environmental protection is not specifically addressed by the evaluation guidelines and only environmental controls are necessary to manage the risk to the environment. Environmental controls are determined based on a qualitative assessment of the likelihood of the scenario and the potential consequences to the environment. The risk bin numbers in the risk matrices indicate whether safety SSCs, TSRs, or safety requirements should be identified to manage the risk.

Consequence Category	Off-Site Public
High (H)	greater than 25 rem or greater than ERPG-2
Moderate (M)	5 rem to 25 rem or ERPG-1 to ERPG-2
Low (L)	0.5 rem to 5 rem or TLV-TWA to ERPG-1
Negligible (N)	less than 0.5 rem or less than TLV-TWA



KEY

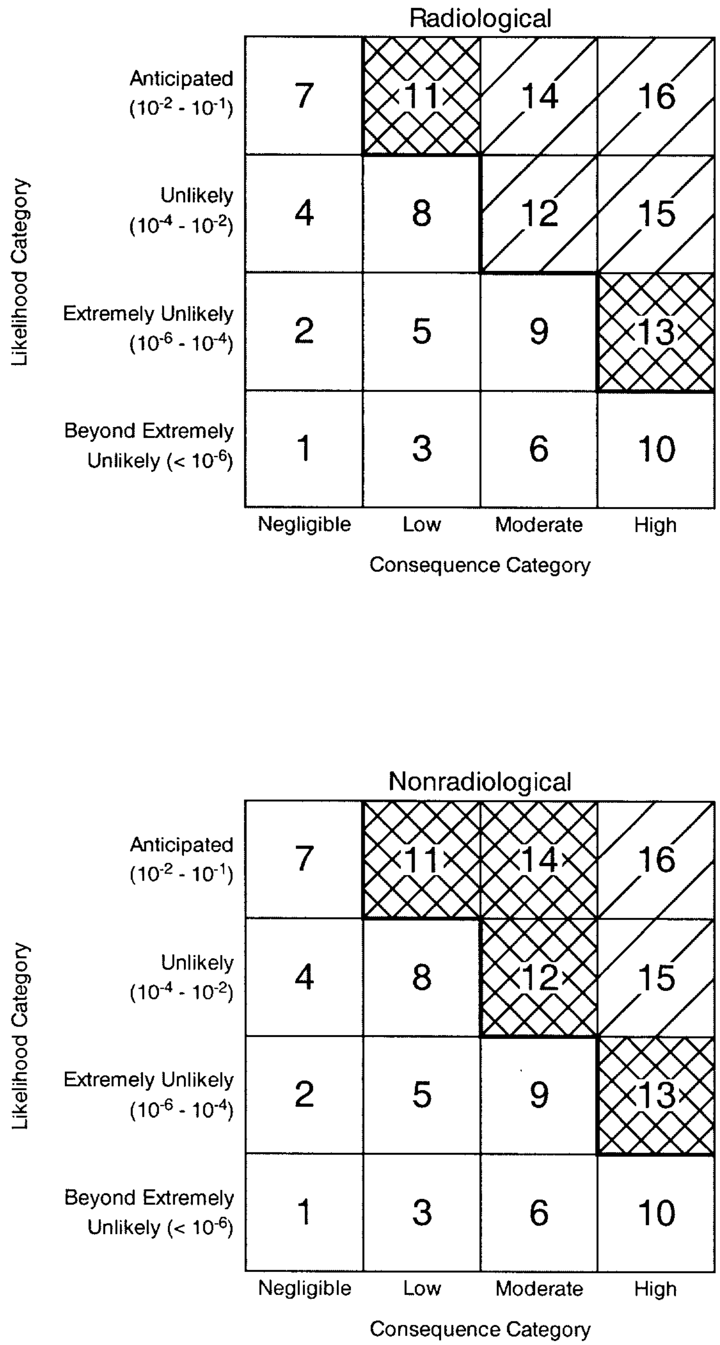
Safety-class SSCs and/or TSRs should be identified to manage off-site public risk; accident analysis may be needed.

Safety-class SSCs or TSRs are generally not required to manage off-site public risk.

02-GA51330-01

Figure 3-1. Qualitative risk matrices for the off-site public.

Consequence Category	On-Site (Co-located) Workers
High (H)	greater than 100 rem or greater than ERPG-3 or greater than ▲10 psi
Moderate (M)	25 rem to 100 rem or ERPG-2 to ERPG-3
Low (L)	5 rem to 25 rem or ERPG-1 to ERPG-2
Negligible (N)	less than 5 rem or less than ERPG-1



KEY

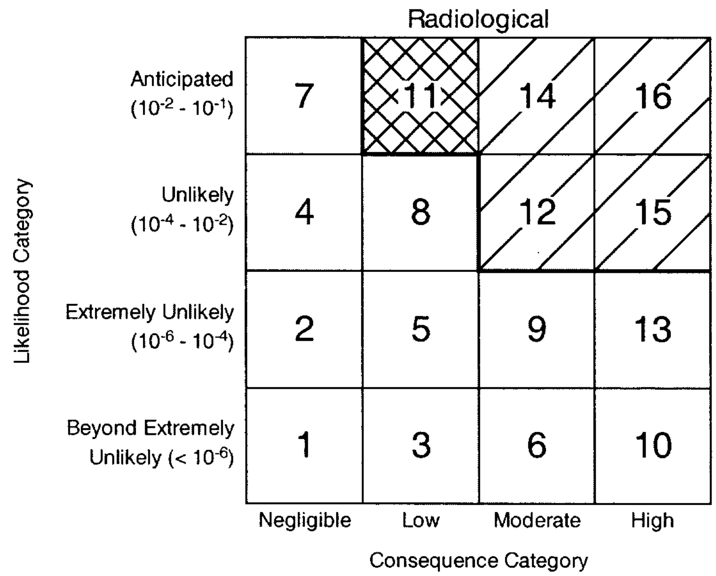
Safety-significant SSCs and/or TSRs should be identified to manage co-located worker risk; accident analysis may be needed.

Safety requirements should be identified to manage co-located worker risk.

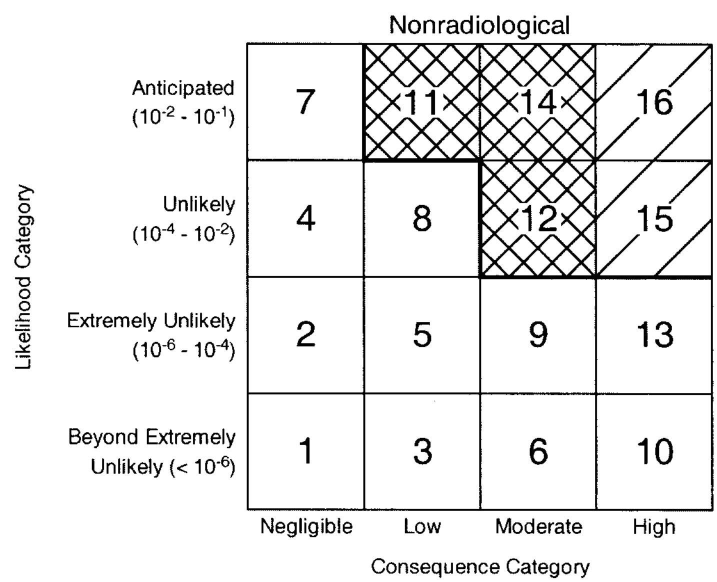
Safety SSCs, TSRs, or safety requirements are generally not required to manage co-located worker risk.

02-GA51330-02

Figure 3-2. Qualitative risk matrices for co-located workers.



Consequence Category	Facility Workers
High (H)	greater than 100 rem or greater than ERPG-3 or greater than ▲10 psi
Moderate (M)	25 rem to 100 rem or ERPG-2 to ERPG-3
Low (L)	5 rem to 25 rem or ERPG-1 to ERPG-2
Negligible (N)	less than 5 rem or less than ERPG-1



KEY

Safety-significant SSCs and/or TSRs should be identified to manage facility worker risk.

Safety requirements should be identified to manage facility worker risk.

Safety SSCs, TSRs, or safety requirements are generally not required to manage facility worker risk.

02-GA51330-03

Figure 3-3. Qualitative risk matrices for facility workers.

Potential scenarios initiated by natural events are evaluated in accordance with the requirements and guidelines in DOE Order 420.1A and the referenced DOE standards.

3.3.2 Hazard Analysis Results

This subsection identifies the applicable hazards and includes the hazard categorization. The safety-significant SSCs and the major features for worker safety and protection of the environment are discussed, and unique and representative accidents are identified based on the results of this hazard evaluation.

3.3.2.1 Hazard Identification

3.3.2.1.1 Applicable Hazards—A review of the operational history of ISV indicates that a significant hazard is a melt expulsion. Melt expulsions are initiated by conditions below the surface of the melt. A melt expulsion at the SDA could be caused by: (1) Rapid depressurization of a pressurized sealed container (sealed drums or gas cylinders, (2) Steam pressurization (resulting from the presence of significant quantities of moisture) at some depth beneath the molten body, and (3) Deflagration resulting from mixing of nitrate salts and pyrolyzed combustibles or finely divided graphite.

The ISV system will be designed and constructed to meet SDA remediation requirements. The system description in this FS PDSA is based on the current design of the GeoMelt technology licensed by AMEC Earth & Environmental, Inc. According to a report prepared for ISV at LANL, "the operating experience of traditional ISV is extensive, including over 300 test, demonstration and commercial melts covering a wide array of contaminants, soil types, and inclusions (debris) types. More than 80 of those melts have been performed at full field-scale."[7] Melt expulsions have occurred in at least five of these events. Table 3-3 describes each of these events, identifies the causes, discusses the consequences of each, and discusses the applicability of each event to ISV processing in the SDA. Of the five expulsion events, two were caused by pressure buildup in sealed containers, two were caused by pressure buildup in saturated water beneath the melt, and one was caused by an explosive in the debris trench. All five events resulted in minor damage to the hood, negligible airborne releases (contamination remains fixed in the melt), and minor environmental damage.

Table 3-4 contains a checklist that identifies the applicable occupational hazards, including standard industrial hazards, and the DOE-prescribed occupational safety and health (OSH) standards that prevent or protect against them. Standard industrial hazards are hazards that are routinely encountered in general industry and construction; for these, national consensus codes or standards (such as the Occupational Safety and Health Administration [OSHA]) exist to guide safe design and operation. No special analysis of these occupational hazards is required unless they are possible initiators for an uncontrolled exposure to radioactive or nonradioactive hazardous materials.

Table 3-3. A history of expulsion events during large-scale ISV operations.

Event	Operator	Date	Description	Effect	Cause	Applicability to WAG 7 TRU Pits & Trenches
Operational Acceptance Test – 2 (Geosafe Test Site)	Geosafe	1991	ISV processing of 55-gal drums full of water-saturated soil	1. Major damage to fabric off-gas hood (total loss) 2. Melt ejectate and splatter 3. Negligible environmental concerns	Pressurized release of water vapor from sealed drums in test pit exacerbated by flammable fabric hood	Sealed drums filled with vaporizable substances are anticipated in WAG 7 TRU pits and trenches.
ORNL Large-Scale ISV Tank Test	PNNL	1991	First large-scale ISV test on a subsurface tank	1. Minor damage to hood 2. Melt ejectate and splatter 3. Negligible environmental concerns	Release of pressurized vapors in subsurface tank, following loss of graphite vent	Subsurface tanks are anticipated in WAG 7 TRU pits and trenches.
Wasatch Chemical (2nd melt)	Geosafe	1994	Event occurred after ISV processing though the evaporation pond floor and into the aquifer	1. Minor damage to hood 2. Minimal environmental concerns 3. Normal operations resume within 1 week	Insufficient de-watering around the evaporation pond	Small potential at INEEL is due to potential saturated water zone near basalt layer beneath WAG 7 TRU pits and trenches (aquifer issue not applicable). The saturated water zone near the basalt layer may be of greater concern during spring run-off or following heavy precipitation.
ORNL Radioactive Seepage Trench	PNNL	1996	Melt expulsion occurred near end of ISV process, as melt encountered shale surrounding the seepage trench	1. Radioactive release ~0.1 µCi (off-gas) 2. 2 ton of glass flowed outside of hood (Contamination was fixed in melt) 3. Minor fire damage to hood	Significant head of water surrounding ISV melt (shallow water table) resulted in over-pressurization when melt approached the impermeable shale layer surrounding the trench	Small potential at INEEL due to potential saturated water zone near basalt layer beneath WAG 7 TRU pits and trenches (aquifer issue not applicable).
Maralinga (15th melt)	Geosafe	1999	Explosives in or surrounding the waste pit caused ejection of buried waste materials to melt surface	1. Contamination remained fixed in melt splatter/ejectate 2. Damage to electrode feeder 3. Some buried waste brought to surface	Presence of ANFO (explosive) in debris trench	High explosives are not in the inventory. However, potential mixtures of nitrate salts and pyrolyzed combustibles or finely divided graphite can produce deflagrations.

Table 3-4. Hazard identification results.

Hazard	DOE-Prescribed Program and OSH standards	Hazard Source(s)	Concern	Applicable Facilities/Operations	Addressed Further? (Yes/No)[a]
Electrical	29 CFR 1910.137 29 CFR 1910.147 29 CFR 1910 Subpart S; 29 CFR 1926 Subparts K and V NEC 70	Electric equipment (>600 VAC)	Electrocution Fire	Transmission Lines SDA power loop Off-gas hood Support trailer	No
		Electric distribution system and equipment (<600 VAC)	Electrocution Fire	Off-gas treatment system Process control trailer Support trailer	No
		Buried cable	Electrocution Fire	SDA power loop	No
		On-ground cable (for example, mining cable)	Electrocution Fire	ISV treatment area	No
		Low-hanging wires	Electrocution Fire	SDA	No
		Buried metal items that may contact melt	Electrocution Fire	Buried metal items that extend beyond exclusion area	No
Volatile, flammable, or reactive gases or liquids	29 CFR 1910 Subpart H,.106,.144,.1200 29 CFR 1926.152	Propane tank	Asphyxiation, burns, BLEVE, fuel-air explosion	Propane storage tank Heaters Thermal oxidizer	No for asphyxiation and burns.[b] Yes for BLEVE, fuel-air explosion.
		Flammable/combustible liquids (including oil storage)	Burns	None	No[b]
		Hydrogen gas Gasoline and diesel	Deflagration Burns	Buried waste Emergency backup power supply	Yes Yes
Explosive materials	29 CFR 1910.109 29 CFR 1926 Subpart U DOE Explosive Safety Manual (DOE M 440-1)	Explicit explosives	Detonation	None	No
		Nitrate salts and pyrolyzed combustibles or finely divided graphite	Deflagration	Buried waste	Yes
Combustible materials	29 CFR 1910 Subpart L 29 CFR 1926 Subpart F	Combustible materials in treatment area	Fire in ISV equipment	SDA Off-gas hood Off-gas treatment system Trailers	Yes
Cryogenic systems	DOE Order 440.1A	Liquid nitrogen	Frostbite	None	No
Piping and vessels	ASME Boiler and Pressure Vessel Code, ANSI/ASME	Fired and unfired pressure vessels	Projectiles	Propane tank	No

Table 3-4. (continued).

Hazard	DOE-Prescribed Program and OSH standards	Hazard Source(s)	Concern	Applicable Facilities/Operations	Addressed Further? (Yes/No)[a]
Piping and vessels (cont.)	Standard B31	Break in off-gas piping	Personnel exposure	ISV off-gas system	Yes
Pressurized liquid systems	National Fire Protection Association	Pressurized water (for example, firewater)	Personnel injury	SDA	No
		Hydraulic system	Personnel injury	Support equipment	No
Compressed gas	29 CFR 1910.101 and Subpart M CGA P-1 (1965), Safe Handling of Compressed Gases	Cylinders of various gases, compressed air supply	Projectiles Melt expulsion	SDA	Yes
		Buried compressed gas cylinders	Projectiles Melt expulsion	SDA	Yes
		Hydrogen buildup in sealed containers	Projectiles Melt expulsion	SDA	Yes
Low pressure		Not Applicable	Not Applicable	None	No
Inert and low-oxygen atmospheres	29 CFR 1910.120, .1200 29 CFR 1926.651 and Subparts D, E	Confined space	Asphyxiation	None	No
Nonradioactive hazardous materials	29 CFR 1910.119,.120, .1200, and Subpart Z 1926.353 and Subparts D, E, Z; ACGIH TLVs	Asbestos	Personnel exposure	Buried waste	Yes
		Carbon monoxide	Personnel exposure	Off-gas hood Off-gas treatment system	Yes
		Chemical hazards (cleaning, and so forth)	Personnel exposure, poisoning	None	No
		Buried chemicals	Personnel exposure, poisoning	Buried waste	Yes
		Subsidence exposes buried waste	Personnel exposure	SDA	Yes
		Freon 22, Halon	Frostbite, asphyxiation, cardiac effects	None	No
		Lead	Personnel exposure, poisoning	Buried waste	Yes
		Hazardous (mixed) waste	Personnel exposure, poisoning	Buried waste	Yes
		VOCs	Personnel exposure, poisoning	Buried waste	Yes
Nonionizing radiation	29 CFR 1910.97 29 CFR 1926.54 ACGIH TLVs, ANSI Z 136	Barcode scanning laser	Eye damage	Controlled entry	No

Table 3-4. (continued).

Hazard	DOE-Prescribed Program and OSH standards	Hazard Source(s)	Concern	Applicable Facilities/Operations	Addressed Further? (Yes/No)[a]
Nonionizing radiation (cont.)		Electromagnetic fields generated by power systems	Health effects	Support trailer	No
High-intensity magnetic fields	ACGIH TLVs	Not applicable	Not applicable	None	No
High noise levels	29 CFR 1910.95, .1200 29 CFR 1926.52; ACGIH TLVs	High noise from operating equipment	Hearing damage	Off-gas treatment system	No
Mechanical and moving equipment dangers	29 CFR 1910.147, .211 through .219; 29 CFR 1910 Subparts O, P, Q; 29 CFR 1926 Subparts N, O, W	Rotating equipment (that is, HVAC equipment, belts, conveyors)	Personnel injury	Off-gas hood Off-gas treatment system	No
		Vehicle/forklift traffic	Impact with personnel Damage to off-gas hood and off-gas treatment system	SDA Off-gas hood Off-gas treatment system	No[c]
Working at heights	29 CFR 1910.25, .28 29 CFR 1926.951, .451	Ladders/platforms, bridges, high equipment, pits	Personnel falling	Off-gas hood Off-gas treatment system Trailers	No
Excavation	29 CFR 1926 Subpart P	Disposal areas	Falls, walls collapsing	SDA	No
		Disposal areas	Buried waste uncovered during electrode or starter path placement	SDA	Yes
Material handling dangers	29 CFR 1910.120, .176 through .182 29 CFR 1926.953; DOE-STD-1090-2001 Hoisting and Rigging	Cranes, forklifts	Crushing personnel	SDA Movement of ISV equipment to new treatment area	No
Material transportation (on-Site and off-Site)	Hazardous Material Transportation Program, DOE Orders 460.1A and 460.2	Hazardous materials	Personnel exposure	None	No
Pesticide, herbicide, and rodenticide use	29 CFR 1910.1200	Pesticides, herbicides, rodenticides	Poisoning	None	No

Table 3-4. (continued).

Hazard	DOE-Prescribed Program and OSH standards	Hazard Source(s)	Concern	Applicable Facilities/Operations	Addressed Further? (Yes/No)[a]
Temperature extremes (high and low temperatures during activities)	29 CFR 1910.120, 29 CFR1910.132(a), 29 CFR1910.133(a), 29 CFR1910.138(a), .Z1200; ACGIH TLVs	Ambient temperatures	Hypothermia, frostbite, heat stress Fire Burns	ISV treatment area Off-gas hood Off-gas treatment system	No
		Molten material beneath overburden	Heat stress Fire Burns	ISV treatment area Off-gas hood	Yes
		Off-gases	Heat stress Fire Burns	ISV treatment area Off-gas hood Off-gas treatment system	Yes
Inadequate illumination	29 CFR 1910.37, .68,.110,.120, .177 through .179, .219, .303 29 CFR 1926.C26	Inadequate lighting	Tripping or falling	Off-gas hood Trailers Outside ISV work areas	No
Construction	29 CFR 1926	General construction hazards	Personnel injury	None	No
Ionizing radiation	29 CFR 1926.53, Occupational Radiation Protection, 10 CFR 835	Radioactive waste	Personnel exposure	SDA Off-gas hood Off-gas treatment system	Yes
	ANSI N43.3	Ionizing radiation generating devices	Personnel exposure	None	No
Radioactive materials	Radiation Protection Program 10 CFR 835	Radioactive waste	Personnel exposure	SDA Off-gas hood Off-gas treatment system	Yes
		Subsidence exposes buried waste	Personnel exposure	SDA	Yes
Fissile materials	Criticality Safety Program DOE Order 420.1A	Sources (in a storage cabinet)	Criticality	None	No
	DOE-STD-3007	Radioactive waste	Criticality	None	No
Reactive materials: alkali metal and corrosives	Chemical Safety Program DOE Order 5480.4; 29 CFR 1910.Z1200, .Z1450	Pyrophoric materials in buried waste	Fire	SDA	Yes
Structural or natural phenomena	DOE Order 420.1, DOE-ID AE Standards DOE-GDE-420.1-2 29 CFR 1910.H119, Subpart E	Lightning, strong wind, tornado, earthquake, etc.	Other material and energy sources listed in this table, these are initiators.	SDA Off-gas hood Off-gas treatment system Trailers	Yes

Table 3-4. (continued).

Hazard	DOE-Prescribed Program and OSH standards	Hazard Source(s)	Concern	Applicable Facilities/Operations	Addressed Further? (Yes/No)[a]
Fire	Fire Protection Program, DOE Order 420.1	Combustibles (solids and gases)	Burns Failure of off-gas system	SDA ISV treatment area	Yes[d]
Biological agents	DOE Order 440.1A	Hantavirus	Personnel exposure	SDA	No
		Biological assays	Personnel exposure	None	No
		Sewage	Personnel exposure	None	No
Other	29 CFR 1910, DOE Order 440.1A	Low overhead	Head injury	None	No
		Pinch point (carts, doors, shrink wrap equipment)	Injury to extremities	Off-gas hood Off-gas treatment system Trailers	No
		Uneven or slick walking surfaces, trip/fall hazards	Tripping or falling	SDA	No
		Objects at height (for example, shelves, overhead crane work, waste handling)	Objects falling onto personnel	None	No
		Water heater, boiler, tank, soldering surface	Burns	None	No
		Exhaust pipe	Burns	Support equipment	No
External events	Not applicable	The AMWTP is a potential source for hazards addressed in the previous rows. No hazards unique to the AMWTP were identified.	Not applicable	SDA	No
		Loss of commercial power	Failure of off-gas system	Off-gas hood Off-gas treatment system	Yes[e]
		Range fire	Causes failure of off-gas system	Off-gas hood Off-gas treatment system	Yes[e]
		Aircraft (helicopter and fixed wing) crash	Impact, fire, initiator for another hazard	ISV treatment area Off-gas hood Off-gas treatment system Trailers	Yes[e]

Table 3-4. (continued).

a. This question pertains to further consideration of the hazard identified here and not to initiators for another hazard. All hazards, even those dismissed here, are considered as initiators for other hazards. For example, fires from propane tanks or batteries are not considered further as a direct hazard, but they are considered as initiators for waste fires that could result in release of radioactive or hazardous material.
b. Flammable gases or liquids are considered later as a fuel source for fires that could result in a release of radioactive and chemically hazardous materials.
c. External events are considered as initiators for release of radioactive and chemically hazardous materials.
d. Fire is considered as a potential cause for the release of radioactive and chemically hazardous materials.
e. External events are considered as initiators for release of radioactive and chemically hazardous materials.

ACGIH	American Conference of Government Industrial Hygienists
AE	architectural engineering
AMWTP	Advanced Mixed Waste Treatment Project
ANSI	America National Standards Institute
ASME	American Society of Mechanical Engineers
BLEVE	boiling liquid-expansion vapor explosion
CFR	Code of Federal Regulations
CGA	Compressed Gas Association
DOE	Department of Energy
DOE-ID	Department of Energy Idaho Operations Office
HVAC	heating, ventilating, and air conditioning
ISV	in situ vitrification
NEC	National Electric Code
OSH	occupational safety and health
SDA	Subsurface Disposal Area
TLV	threshold limit value
VOC	volatile organic compound

***3.3.2.1.2 Radioactive and Nonradioactive Hazardous Material Inventory*—**This section discusses the radioactive and nonradioactive hazardous material inventories that will be used for the hazard and accident analyses in this document. The inventory in the SDA generally consists of solid radioactive waste from the INEEL, the RFP, and other off-Site generators. The SDA inventory is described in Engineering Design File (EDF)-3543, "SDA Inventory Evaluation for ISG, ISV, and ISTD PDSA Source Terms."[8] Guidance for calculating the inventory for accidents involving a specific treatment option is given in EDF-3543. The radioactive and nonradioactive hazardous material inventories for ISV are calculated in EDF-3563, "Radiological Dose and Nonradiological Exposure Calculations for ISV Accident Scenarios,"[9] using the guidance presented in EDF-3543. Three different inventory likelihoods are evaluated. These likelihoods are anticipated for average inventories, unlikely for limiting inventories, and extremely unlikely for upper bound inventories.

The total inventory in the SDA is estimated using the historical data task (HDT)[10] and recent and projected data task (RPDT)[11] reports. The HDT report contains best estimate, lower bound, and upper bound total quantities of radioactive and nonradioactive hazardous materials buried between 1952 and 1983. The RPDT report contains similar historical information for 1984 through 1993, and projected quantities from 1994 through 2003. The RPDT has been updated with the actual disposals to 1999.[12] The total activity for some radionuclides has also been updated to reflect currently accepted values reported in Table 3-7 of the ancillary basis for risk analysis (ABRA) report.[13] Carbon tetrachloride, tetrachloroethylene, trichloroethylene, and 1,1,1-trichloroethane contents have been updated from a study by Varvel.[14]

The development of these inventories and sources is described in EDF-3543.8 The EDF addresses all waste types buried in the RWMC SDA, including TRU waste and non-TRU (contact-handled [CH] LLW and remote-handled [RH] LLW). It also addresses nonradioactive contaminants that are part of the mixed TRU and non-TRU waste.

The ISV technology is being considered for remediation of the RFP TRU waste in the pits (1-6, 9-12) and trenches (1-15) and on Pad A. The waste on Pad A will not be treated there, but may be transferred to a pit for disposal and treatment. This inventory does not include TRU waste stored in the TSA.

Radioactive Hazardous Material Inventory

The total quantities of radioactive hazardous materials are shown in Table 3-5. The table shows the quantity of each radionuclide disposed for each time period and the total for all time periods. The total best estimate activities have been updated to reflect current data from the ABRA report.[13] Because the data from the ABRA report are cumulative, the updated total best estimate activity value for a radionuclide is not necessarily equal to the sum of the activity values for the time intervals. Activity levels are those at the time of disposal, without consideration of radioactive decay.

Table 3-5. Radioactive hazardous materials in the RWMC SDA

Radionuclide	52-83 Best Estimate (Ci)	84 - 93 Best Estimate (Ci)	94 - 99 Best Estimate (Ci)	Total Best Estimate (Ci)	Percent of Total Activity (%)
Am-241	1.5E+05	3.7E+00	1.8E+00	1.83E+05	1.3E+00
Pu-239	6.6E+04	2.4E+00	1.8E-01	6.49E+04	4.8E-01
Pu-241	4.0E+05	1.7E+01	1.0E+01	9.74E+05	7.1E+00
Pu-240	1.5E+04	5.7E-02	1.0E-01	1.71E+04	1.3E-01
Pu-238	2.5E+03	3.6E-01	1.7E-01	1.71E+04	1.3E-01
Sr-90	4.5E+05	5.8E+02	6.2E+01	6.44E+05	4.7E+00
Co-60	2.8E+06	1.4E+06	2.8E+04	2.20E+06	1.6E+01
Am-243	2.3E-01	None	6.8E-06	1.34E+02	9.8E-04
Ce-144	1.5E+05	2.1E+02	1.4E+01	1.5E+05	1.1E+00
Cm-244	8.0E+01	7.6E-02	9.2E-02	8.0E+01	5.9E-04
Cs-137	7.0E+05	3.1E+03	7.2E+01	6.17E+05	4.5E+00
U-238	1.1E+02	1.6E+00	1.2E+00	1.17E+02	8.6E-04
Fe-55	3.8E+06	1.6E+05	2.1E+04	4.0E+06	2.9E+01
U-234	6.4E+01	3.5E+00	2.5E+00	6.74E+01	4.9E-04
Ni-63	7.4E+05	4.8E+05	5.3E+04	1.32E+06	9.7E+00
U-232	8.4E+00	2.2E+00	5.1E-03	1.06E+01	7.8E-05
Pu-242	9.9E-01	1.2E-08	4.2E-08	1.65E+01	1.2E-04
Co-58	1.6E+05	2.0E+05	1.9E+03	3.6E+05	2.7E+00
Th-228	None	1.0E+01	7.7E-03	1.02E+01	7.5E-05
Ru-106	6.8E+03	6.4E+01	4.5E+00	6.9E+03	5.0E-02
Th-232	1.3E+00	None	2.6E-02	1.34E+00	9.8E-06
Mn-54	1.8E+05	1.2E+05	2.3E+03	3.0E+05	2.2E+00
Zr-95	7.6E+04	2.1E+03	1.2E+02	7.8E+04	5.7E-01
Sb-125	1.3E+05	2.9E+03	1.5E+03	1.3E+05	9.9E-01
Cm-242	9.1E+01	8.8E-02	1.3E-01	9.1E+01	6.7E-04
Fe-59	9.1E+04	1.5E+04	2.7E+00	1.1E+05	7.8E-01
Np-237	2.4E+00	3.7E-03	9.4E-03	2.64E+00	1.9E-05
Eu-154	3.0E+03	3.3E+00	1.5E+02	3.00E+03	2.2E-02
Ta-182	8.5E+00	1.8E+04	4.1E+02	1.8E+04	1.4E-01
U-235	5.1E+00	1.6E-01	2.7E-01	5.54E+00	4.1E-05
Eu-155	1.5E+04	3.9E+01	8.2E+01	1.5E+04	1.1E-01
Ra-226	5.9E+01	1.1E+00	7.9E-02	6.00E+01	4.4E-04
Nb-94	4.9E+01	2.0E-01	2.8E-01	1.00E+03	7.3E-03
U-236	2.5E+00	2.3E-03	4.7E-03	2.86E+00	2.1E-05
Cr-51	7.3E+05	4.7E+04	6.1E+02	7.8E+05	5.7E+00
Sn-119m	2.7E+04	8.8E+03	9.1E+00	3.6E+04	2.6E-01
U-233	1.1E+00	None	3.6E-01	1.51E+00	1.1E-05
Y-90	1.9E+04	2.0E+02	2.4E+01	1.9E+04	1.4E-01
Cs-134	2.2E+03	1.4E+02	3.2E+00	2.3E+03	1.7E-02
H-3	1.2E+06	3.0E+05	4.4E+03	1.50E+06	1.1E+01
Co-57	4.8E+00	1.5E+00	7.2E+03	7.2E+03	5.3E-02

Table 3-5. (continued).

Radionuclide	52-83 Best Estimate (Ci)	84 - 93 Best Estimate (Ci)	94 - 99 Best Estimate (Ci)	Total Best Estimate (Ci)	Percent of Total Activity (%)
Eu-152	2.4E+02	4.1E+00	2.5E+01	2.7E+02	2.0E-03
Hf-181	3.6E-01	3.4E+03	8.4E+00	3.4E+03	2.5E-02
Sb-124	1.8E+03	1.1E-02	5.1E-01	1.8E+03	1.3E-02
Nb-95	2.4E+03	3.8E+03	1.6E+00	6.2E+03	4.6E-02
Zn-65	3.6E+02	1.0E+03	2.2E+03	1.36E+03	1.0E-02
Y-91	5.3E+02	None	8.6E-06	5.3E+02	3.9E-03
Ni-59	5.1E+03	1.4E+03	4.4E+02	6.9E+03	5.1E-02
Sr-89	4.7E+02	3.0E+00	8.8E+00	4.10E+02	3.0E-03
Hf-175	None	2.8E+03	4.2E-02	2.8E+03	2.1E-02
Th-230	1.8E-02	None	1.3E-02	3.13E-02	2.3E-07
Ce-141	7.6E+02	2.9E+00	1.5E-01	7.6E+02	5.6E-03
Pr-143	6.2E+02	None	None	6.2E+02	4.6E-03
W-185	None	6.4E+03	None	6.4E+03	4.7E-02
Pm-147	8.1E+01	2.4E+00	2.6E+01	1.1E+02	8.1E-04
Sc-46	5.3E+01	5.0E+01	3.4E+01	1.4E+02	1.0E-03
La-140	7.7E+02	2.8E+00	6.6E-02	7.7E+02	5.7E-03
Ir-192	5.4E+01	6.6E-01	7.0E+01	1.2E+02	9.1E-04
Ru-103	3.6E+02	1.9E-01	1.1E-02	3.6E+02	2.6E-03
Na-22	3.0E-01	5.4E-01	3.7E+02	3.7E+02	2.7E-03
Ba-140	6.6E+02	2.4E+00	6.8E-02	6.6E+02	4.9E-03
Pr-144	4.2E+04	1.1E+02	2.2E+00	4.2E+04	3.1E-01
Cf-252	1.0E-02	None	None	1.0E-02	7.3E-08
Be-10	4.3E+01	None	1.0E-10	4.3E+01	3.2E-04
Zr-93	4.0E+00	None	3.1E-05	4.0E+00	2.9E-05
C-14	1.6E+04	4.0E+01	1.8E+01	5.00E+02	3.7E-03
Cd-109	4.1E-01	1.1E-02	5.2E-04	4.2E-01	3.1E-06
Tc-99	2.6E+02	5.0E-01	9.0E-01	6.05E+01	4.4E-04
Sn-117m	None	1.2E+02	1.7E-09	1.2E+02	8.8E-04
Te-125m	None	4.2E+01	1.0E-02	4.2E+01	3.1E-04
Sn-113	None	2.4E+01	4.6E+00	2.9E+01	2.1E-04
Tm-170	3.4E+00	None	None	3.4E+00	2.5E-05
I-131	1.5E+00	1.1E-01	6.0E-02	1.7E+00	1.2E-05
Rb-86	7.1E+00	None	None	7.1E+00	5.2E-05
Gd-153	None	1.3E+00	8.7E-02	1.4E+00	1.0E-05
I-129	9.9E-02	2.1E-03	5.3E-03	1.58E-01	1.2E-06
Cl-36	3.1E-01	None	9.2E-02	1.11E+00	8.1E-06
Ag-108m	None	1.1E-07	7.1E-02	7.1E-02	5.2E-07
Mn-56	2.7E+01	1.3E+00	None	2.8E+01	2.1E-04
Cs-136	7.7E-01	None	None	7.7E-01	5.7E-06
Mo-99	1.0E+00	2.3E-02	2.2E-02	1.0E+00	7.7E-06
Na-24	None	2.7E+00	1.6E-02	2.7E+00	2.0E-05
Ag-110m	None	1.8E-02	2.8E-01	3.0E-01	2.2E-06

Table 3-5. (continued).

Radionuclide	52-83 Best Estimate (Ci)	84 - 93 Best Estimate (Ci)	94 - 99 Best Estimate (Ci)	Total Best Estimate (Ci)	Percent of Total Activity (%)
V-48	None	2.0E-01	None	2.0E-01	1.5E-06
P-32	9.2E-02	None	1.4E-11	9.2E-02	6.8E-07
Rh-103m	2.7E+02	None	1.3E-02	2.7E+02	2.0E-03
Y-88	2.5E-02	3.0E-03	7.1E-05	2.8E-02	2.1E-07
I-125	2.9E-02	None	8.2E-04	3.0E-02	2.2E-07
Se-75	None	4.5E-02	2.9E-02	7.4E-02	5.4E-07
Am-242	7.6E-03	None	None	7.6E-03	5.6E-08
I-132	None	1.0E+00	1.5E-01	1.2E+00	8.4E-06
I-133	5.0E-02	1.5E-03	None	5.2E-02	3.8E-07
S-35	8.8E-02	None	1.2E-02	1.0E-01	7.4E-07
Y-93	None	1.1E-01	None	1.1E-01	8.1E-07
Sr-85	2.9E-02	None	7.8E-04	3.0E-02	2.2E-07
Be-7	3.5E-01	None	None	3.5E-01	2.6E-06
Hg-203	1.2E-02	None	None	1.2E-02	8.8E-08
Po-210	7.5E+01	None	5.1E-07	9.10E-06	6.7E-11
Au-198	None	2.4E-02	None	2.4E-02	1.8E-07
Te-132	None	5.6E-03	6.7E-17	5.6E-03	4.1E-08
Ra-225	2.0E-06	None	2.5E-06	4.5E-06	3.3E-11
Pb-212	2.0E-05	None	1.7E-04	1.9E-04	1.4E-09
Re-188	None	9.3E-03	None	9.3E-03	6.8E-08
Er-169	7.6E-03	None	None	7.6E-03	5.6E-08
Sc-44	2.5E-02	None	None	2.5E-02	1.8E-07
Sr-91	None	4.4E-03	None	4.4E-03	3.2E-08
Pb-210	9.1E-06	None	5.1E-07	5.10E-07	3.7E-12
Ba-133	5.4E-04	None	3.4E-04	8.8E-04	6.4E-09
Ca-45	6.7E-04	None	None	6.7E-04	4.9E-09
In-113m	None	8.2E-02	6.4E-04	8.3E-02	6.1E-07
Ce-139	None	3.0E-04	2.8E-06	3.0E-04	2.2E-09
Tl-204	6.7E-04	None	None	6.7E-04	4.9E-09
Br-82	None	1.0E-03	None	1.0E-03	7.3E-09
Sr-92	None	1.6E-03	None	1.6E-03	1.2E-08
Mn-53	1.0E-03	None	None	1.0E-03	7.3E-09
Cd-104	1.5E-07	None	None	1.5E-07	1.1E-12
Ag-110	8.4E-01	1.9E+00	5.9E-03	2.7E+00	2.0E-05
Ba-137m	3.4E+00	4.6E+00	8.5E+00	1.6E+01	1.2E-04
Kr-85	1.3E+00	None	1.9E-03	1.3E+00	9.6E-06
Rh-106	6.8E+03	6.1E+01	1.8E+00	6.9E+03	5.0E-02
Rn-222	1.0E-06	None	5.8E-07	1.6E-06	1.2E-11
Xe-133	None	None	None	None	None
Yb-164	7.6E-03	None	None	7.6E-03	5.6E-08

Transuranic Waste

TRU waste is radioactive waste that contains alpha-emitting radionuclides with an atomic number greater than 92 (elements heavier than uranium) and a half-life greater than 20 years. During the period when TRU waste was buried in the SDA, TRU was defined to have an activity concentration greater than 10 nCi/g. TRU waste is of particular concern because of its long-lived radioactivity and high radiological dose consequences when inhaled. TRU waste disposal was terminated at the SDA in 1970.

SDA Pits 1–6 and 9–12, and trenches 1–10 are known to contain TRU waste. Trenches 11–15 are also suspected to contain TRU waste. RFP waste in drums and boxes was disposed in Pits 11 and 12 through 1972. Later, these drums were retrieved and the TRU drums placed in the TSA. The boxes were left in Pits 11 and 12, so TRU could have been disposed then. Also there are a small number of TRU drums on Pad A.

TRU waste consists of a wide variety of materials including large quantities of solidified nitrate salt and organic sludges, gloves, paper, plastics, rags, and other combustible wastes; various tools and other light metal or steel wastes; heavy metal wastes such as tantalum molds and funnels; graphite mold materials (chunks and fines); glass; and other items used in day-to-day RFP glovebox operations.

The majority of metal drums in the SDA are assumed breached, because of corrosion or physical damage to the drum during dumping and burial, and can no longer provide adequate waste containment of the contents.[15] Although most recent RFP waste drums have a poly drum liner, the poly drum liners were not used until late 1972, and therefore, none are assumed present in the SDA. Earlier retrieval efforts did observe some leaking containers indicating unabsorbed or desorbed free liquid drums.[16]

The radioactive hazardous material inventory for accidents involving TRU drums with likelihood categories of anticipated, unlikely, and extremely unlikely are shown in Table 3-6. Information about drum inventories has been derived from the following:

- Acceptable knowledge reports based on shipping records
- Data from assaying stored drums being shipped to the Waste Isolation Pilot Plant (WIPP)
- Data from SDA subsurface probes.

Direct Radiation Sources

SDA shipping records show the SDA pits and trenches contain 861 packages with surface radiation dose rates above 1 R/h at the time of disposal. Dose rates for materials in the soil vaults have not been characterized, but are expected to be similar. Sixty-seven of the packages in the pits and trenches had surface dose rates of 100 R/h or greater. Most of the RH sources are from the INEEL. Only eight of these packages were buried in the pits, with the rest in trenches. The last RH disposal in a trench was September 25, 1981. After that, RH packages were disposed in soil and concrete vaults. The predominant known radionuclide is Co-60, and the unknown radionuclides are also believed to be mostly Co-60, but include a variety of fission and activation products.

Table 3-6. Inventory for accident scenarios involving a single TRU drum.

Single Drum Cases	Mass Content (g)		Activity Content (Ci)		Data Source
	Pu-239-eq	Am-241	Pu-239-eq	Am-241	
Upper Bound Drum (extremely unlikely)	2,217	71	140	240	Probe Data for Pu Acceptable knowledge for Am
Limiting Drum (unlikely)	510	31	31.8	105	Haefner Report[17] for Pu-equiv Acceptable knowledge for Am
Average Drum (anticipated)	58	0.22	3.6	0.74	Haefner Report for Pu-equiv Acceptable knowledge for Am

Notes:

1. Pu-239-eq is amount Pu-239 equivalent to a quantity of Rocky Flats plutonium (Pu-238 through Pu-242 radionuclides and ingrown Am-241).[17]
2. Use either Pu-239-eq or Am-241, but not both. Haefner report includes Am-241 in calculating Pu-239-eq. For upper bound and limiting drums, finding both bounding inventories in the same drum is considered beyond extremely unlikely. An average drum would be expected to contain either Pu-239-eq or Am-241 alone, but not both.
3. Pu-239-eq curies converted to grams using the specific activity of 0.062 Ci Pu-239-eq / gm. Pu-239-eq from Haefner.

The highest dose package was 150,000 R/h at the surface. Since it is identified as Co-60 with a disposal date of January 17, 1963, its current dose rate is approximately 800 R/h. The next highest surface dose rate is 24,000 R/h from unknown radionuclides. Since the radionuclide is unknown, its decay cannot be accurately calculated. Thus, the direct radiation surface dose rate for potential accident calculations is conservatively bounded at 24,000 R/h. RH-LLW was disposed of in many different packages and configurations. The largest commonly used package is an internal canister that fits the 55-ton cask. The package has a diameter of 46.6 in. Thus, it is conservatively assumed the surface of the 24,000 R/h package is 2 ft from the center axis.

Non-TRU Waste

Non-TRU waste is LLW waste that contains beta and gamma emitting radionuclides. LLW is still being disposed. Non-TRU wastes from the INEEL are in all pits and trenches, and include activation products and fission products from reactor operations at the site. The wastes include various reactor core, vessel, and loop components, and resins and discarded laboratory materials. Beryllium blocks, expended fuel, and contaminated metal and debris from demolition projects at the INEEL are also buried in the SDA. Non-TRU waste from off-Site generators includes biological wastes, laboratory wastes, and other items contaminated with radioactive material.

LLW is classified by its handling requirements as CH-LLW or RH-LLW. RH-LLW has dose rates above 500 mR/h at a 1-m distance from the waste package surface. RH-LLW was buried in pits, trenches, and soil vaults. Trenches received high-radiation waste until trench disposal was discontinued in 1981. Soil vault disposals were conducted until 1995. RH-LLW is currently disposed of in the active pits and in concrete vaults located in the active pits.

The TRU drum inventories in Table 3-6 do not include the fission and activation products because:

- Most fission and activation products are not contained in the same drums and boxes as TRU
- Most activation products are expected to be discrete RH LLW packages buried in the trenches and vaults

- Most fission products are probably in resins or nuclear fuel-related material that would be discrete from activation products or TRU packages.

The direct radiation information is used to estimate the maximum quantity of LLW activation products in a single package. If the 24,000 R/h source term were entirely Co-60, the Co-60 content would be 17,500 Ci, without taking credit for decay. This inventory would be bounding for the pits and trenches. Packages in the soil vaults have not been characterized but are expected to be similar.

Information on average LLW inventories in the SDA is shown in Table 3-7. The radionuclides in Table 3-7 are the fission and activation products that comprise at least 1% of the total inventory. Some volatile radionuclides, such as antimony, iodine, krypton, cadmium, lead, and mercury are not included because of their lower inventory and relatively low inhalation hazard.

Table 3-7. Estimated inventory for significant LLW radionuclides at the SDA.

Radionuclide	Total Upper Bound Inventory (Ci)	Bounding Average Inventory (Ci/ ft^2)	Total Best Estimate Inventory (Ci)	Best Estimate Average Inventory (Ci/ ft^2)
Co-60	9.4E+06	2.4E+01	2.2E+06	1.8E+00
Fe-55	6.3E+06	1.6E+01	4.0E+06	3.3E+00
Cr-51	4.8E+06	1.2E+01	7.8E+05	6.4E-01
H-3	3.8E+06	9.7E+00	1.5E+06	1.2E+00
Ni-63	2.2E+06	5.7E+00	1.3E+06	1.1E+00
Co-58	1.7E+06	4.4E+00	3.6E+05	3.0E-01
Mn-54	1.4E+06	3.6E+00	3.0E+05	2.5E-01
Sr-90	1.3E+06	3.3E+00	6.4E+05	5.3E-01
Cs-137	9.6E+05	2.5E+00	6.2E+05	5.1E-01
Ce-144	5.2E+05	1.3E+00	1.5E+05	1.2E-01

Nonradioactive Hazardous Material Inventory

The RWMC contains large quantities of nonradioactive contaminants. Table 3-8 lists the nonradioactive contaminants in the SDA ordered alphabetically. Updated best estimate values for carbon tetrachloride, tetrachloroethylene, trichloroethylene, and 1,1,1-trichloroethane are from Varvel.[14]

The most abundant and hazardous contaminants are sodium and potassium nitrates; organics, particularly carbon tetrachloride; and metals such as lead, beryllium, and zirconium. The nitrates (primarily 745 sludge) resulted from evaporation of high nitrate waste in ponds at RFP. Because of the landfill disposal methods used during the 1960s, potassium or sodium nitrates were dumped into the same area as organic materials. A mixture of nitrates and organics is seen as potentially explosive.

Table 3-8. Nonradioactive hazardous material inventory.

Contaminant	Bounding Inventory (g)	Bounding Inventory Density (g/drum)	Bounding Inventory Density (g/ft^2)	Average Inventory Density (g/drum)	Average Inventory Density (g/ft^2)
1,1,1-trichloroethane	1.2E+08	3.9E+04	1.4E+04	3.2E+02	1.7E+02
1,1,2-trichloro-1,2,2-trifluoroethane	9.5E+06	3.1E+03	1.1E+03	2.5E+01	1.3E+01
2-butanone	4.0E+04	1.3E+01	4.6E+00	1.1E-01	5.6E-02
Acetone	1.3E+05	4.2E+01	1.5E+01	3.4E-01	1.8E-01
Aluminum nitrate nonahydrate	2.4E+08	7.7E+04	2.7E+04	6.4E+02	3.4E+02
Ammonia	1.8E+06	5.8E+02	2.1E+02	4.8E+00	2.5E+00
Anthracene	4.6E+02	1.5E-01	5.3E-02	1.2E-03	6.5E-04
Antimony	1.0E+03	3.2E-01	1.1E-01	2.7E-03	1.4E-03
Aqua regia	3.2E+01	1.0E-02	3.7E-03	8.5E-05	4.5E-05
Arsenic	1.1E+00	3.6E-04	1.3E-04	3.0E-06	1.6E-06
Asbestos	4.8E+06	1.5E+03	5.5E+02	1.3E+01	6.7E+00
Barium	1.2E+01	3.9E-03	1.4E-03	3.2E-05	1.7E-05
Benzine	4.8E+03	1.5E+00	5.5E-01	1.3E-02	6.7E-03
Beryllium	7.3E+07	2.4E+04	8.4E+03	1.9E+02	1.0E+02
Butyl alcohol	1.1E+05	3.5E+01	1.3E+01	2.9E-01	1.5E-01
Cadmium	2.3E+06	7.4E+02	2.6E+02	6.1E+00	3.2E+00
Carbon tetrachloride	8.2E+08	1.3E+05	4.7E+04	2.2E+03	1.2E+03
Cerium chloride	6.2E+05	2.0E+02	7.1E+01	1.6E+00	8.7E-01
Chloroform	3.7E+01	1.2E-02	4.2E-03	9.8E-05	5.2E-05
Chromium	1.6E+03	5.1E-01	1.8E-01	4.2E-03	2.2E-03
Copper	4.5E+04	1.5E+01	5.2E+00	1.2E-01	6.3E-02
Copper nitrate	4.1E+02	1.3E-01	4.7E-02	1.1E-03	5.8E-04
Ethyl alcohol	2.8E+04	9.0E+00	3.2E+00	7.4E-02	3.9E-02
Formaldehyde	1.5E+05	4.8E+01	1.7E+01	4.0E-01	2.1E-01
Hydrazine	2.3E+03	7.4E-01	2.6E-01	6.1E-03	3.2E-03
Hydrofluoric acid	9.4E+06	3.0E+03	1.1E+03	2.5E+01	1.3E+01
Lead	7.8E+08	2.5E+05	8.9E+04	2.1E+03	1.1E+03
Magnesium	1.1E+07	3.5E+03	1.3E+03	2.9E+01	1.5E+01
Magnesium fluoride	1.4E+05	4.5E+01	1.6E+01	3.7E-01	2.0E-01
Mercury	2.0E+06	7.1E+03	2.5E+03	5.2E+00	2.7E+00
Mercury nitrate monohydrate	1.0E+06	3.2E+02	1.1E+02	2.7E+00	1.4E+00
Methyl alcohol	2.5E+05	8.0E+01	2.9E+01	6.6E-01	3.5E-01
Methyl isobutyl ketone	1.1E+07	3.5E+03	1.3E+03	2.9E+01	1.5E+01
Methylene chloride	1.5E+07	4.8E+03	1.7E+03	4.0E+01	2.1E+01
Nickel	4.1E+03	1.3E+00	4.7E-01	1.1E-02	5.8E-03
Nitric acid	6.1E+07	2.0E+04	7.0E+03	1.6E+02	8.6E+01
Potassium chloride	9.1E+07	2.9E+04	1.0E+04	2.4E+02	1.3E+02
Potassium dichromate	3.0E+06	9.6E+02	3.4E+02	8.0E+00	4.2E+00
Potassium nitrate	2.4E+09	7.7E+05	2.7E+05	6.4E+03	3.4E+03
Potassium phosphate	1.3E+07	4.2E+03	1.5E+03	3.4E+01	1.8E+01
Potassium sulfate	9.1E+07	2.9E+04	1.0E+04	2.4E+02	1.3E+02
Silver	7.3E+03	2.3E+00	8.4E-01	1.9E-02	1.0E-02
Sodium	7.5E+04	2.4E+01	8.6E+00	2.0E-01	1.1E-01
Sodium chloride	1.8E+08	5.8E+04	2.1E+04	4.8E+02	2.5E+02
Sodium cyanide	1.9E+03	6.1E-01	2.2E-01	5.0E-03	2.7E-03

Table 3-8. (continued).

Contaminant	Bounding Inventory (g)	Bounding Inventory Density		Average Inventory Density	
		(g/drum)	(g/ft^2)	(g/drum)	(g/ft^2)
Sodium dichromate	5.4E+06	1.7E+03	6.2E+02	1.4E+01	7.6E+00
Sodium hydroxide	3.4E+02	1.1E-01	3.9E-02	9.0E-04	4.8E-04
Sodium nitrate	4.6E+09	1.5E+06	5.3E+05	1.2E+04	6.5E+03
Sodium phosphate	2.7E+07	8.7E+03	3.1E+03	7.2E+01	3.8E+01
Sodium potassium	2.3E+06	7.4E+02	2.6E+02	6.1E+00	3.2E+00
Sodium sulfate	2.1E+08	6.7E+04	2.4E+04	5.6E+02	2.9E+02
Sulfuric acid	1.5E+05	4.8E+01	1.7E+01	4.0E-01	2.1E-01
Terphenyl	1.0E+06	3.2E+02	1.1E+02	2.7E+00	1.4E+00
Tetrachloroethylene	9.8E+07	3.1E+04	1.1E+04	2.6E+02	1.4E+02
Toluene	2.5E+05	8.0E+01	2.9E+01	6.6E-01	3.5E-01
Tributyl phosphate	1.3E+06	4.2E+02	1.5E+02	3.4E+00	1.8E+00
Trichloroethylene	1.2E+08	3.9E+04	1.4E+04	3.2E+02	1.7E+02
Trimethylolpropane-triester	1.6E+06	5.1E+02	1.8E+02	4.2E+00	2.2E+00
Uranium	5.4E+08	1.7E+05	6.2E+04	1.4E+03	7.6E+02
Uranyl nitrate	2.8E+05	9.0E+01	3.2E+01	7.4E-01	3.9E-01
Versenes (EDTA)	1.4E+06	4.5E+02	1.6E+02	7.4E+01	3.1E+01
Xylene	9.8E+05	3.1E+02	1.1E+02	2.6E+00	1.4E+00
Zirconium	2.3E+07	7.4E+03	2.6E+03	6.1E+01	3.2E+01
Zirconium alloys	7.3E+06	2.3E+03	8.4E+02	1.9E+01	1.0E+01
Zirconium oxide	5.3E+03	1.7E+00	6.1E-01	1.4E-02	7.4E-03

Most of the organic chemicals found in RFP wastes are from organic setups. Organic setups (primarily 743 sludge) were produced from treatment of liquid organic wastes generated by various plutonium and nonplutonium operations at the RFP. The organic wastes were mixed with calcium silicate to form a grease or paste-like material. Small amounts of Oil Dri (trade name) absorbent were usually mixed with the waste. Studies have been performed to determine the maximum quantity of carbon tetrachloride that could be present in a 743-sludge drum.[18] These studies show carbon tetrachloride quantity could be as high as 128 kg (20.9 gal). Therefore, for work specifically involving 743-sludge drums, this is considered the bounding quantity of carbon tetrachloride.

Large quantities of zirconium and zirconium alloy, which is technically considered a combustible metal, are buried at the SDA, but the combustibility of zirconium decreases as the average particle size increases. As large bars, narrow plates, and long strips, zirconium can withstand extremely high temperatures without igniting. Spontaneous ignition or explosions of zirconium during handling are not likely unless the metal is very finely divided. Beryllium (although not pyrophoric) when in dust or flake form and mixed with carbon tetrachloride, trichloroethane, or trichloroethylene will form flammable gases that can spark or flash. For beryllium in sludge form, the same argument used for uranium would apply. As large blocks, beryllium is not likely to form flammable gases.

There is no evidence that ordnance or explicit explosives were buried at the SDA. However, oxidizers in the form of nitrates and dichromates, which can be explosive when mixed with oils, are present in the pits. There is little evidence that pyrophoric metals are buried at the SDA in a form that either will spontaneously ignite or be easily ignited and self-sustaining.

Based on experience with the stored waste inventory, hydrogen gas may be present due to radiological decomposition in wastes containing water or organic materials. Hydrogen gas will disperse over time through poly bags; however, it could be contained in sealed drums that remain in good condition. It is believed that most of the metal drums will have corroded over 36 years of burial or were damaged during disposal to the point that they could not contain hydrogen gas. However, there is a remote possibility that some have maintained integrity and could contain ignitable concentrations of hydrogen gas.

3.3.2.2 Hazard Categorization—The 10 CFR 830 Subpart B requires the categorization of DOE facilities based on the level of potential hazard the facility poses to the on-Site workers and the off-Site public. The RWMC SDA is classified as a Hazard Category 2 facility in accordance with the guidelines in DOE Order 5480.23, "Nuclear Safety Analysis Report,"[19] DOE Standard DOE-STD-1027-92, "Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports," and DOE-ID Order 420.D, "Requirements and Guidance for Safety Analysis." The ISV operations at the RWMC SDA are categorized as Hazard Category 2, based on the RWMC SDA categorization and confirmed by the hazard and accident analysis in this chapter.

3.3.2.3 Hazard Evaluation. This section presents the results of the hazard evaluation performed using the methodology described in Section 3.3.1.2. Based on the hazards identified in Section 3.3.2.1, all the hazards determined to be significant (potential for a release of radioactive or hazardous material) or not routinely encountered are analyzed further. The hazards considered for further evaluation are shown in Table 3-9 and include:

1. Fissile material
2. Ionizing radiation
3. Radioactive material/hazardous chemicals (mixed wastes)
4. Fire/explosion
5. Natural phenomena
6. External events.

Qualitative estimates for the likelihood and consequences from releases of radioactive and nonradioactive hazardous materials are shown. The categorization of likelihood, consequence, and risk are based on the criteria provided in Section 3.3.1.2. The likelihood, consequence, and risk categorization are based on unmitigated events (that is, without preventive or mitigative controls). Table 3-9 also lists possible design and administrative barriers to the occurrences. When warranted by the risk bin, safety-class SSCs, safety-significant SSCs and TSRs are identified in ***bold italics***.

As shown in Table 3-9, for all hazardous scenarios where the estimated risk could exceed established evaluation guidelines (that is, risk bins in the shaded area of Figures 3-1, 3-2, and 3-3), safety SSCs or TSRs are designated or identified to reduce the risk below the INEEL risk evaluation guidelines from DOE-ID Order 420.D.

Table 3-9. Hazards considered for evaluation.

Hazard	Hazardous Event	Initiator/Cause	Applicable Facilities or Functions	Likelihood, Consequence, and Risk Without Controls: Likelihood Category[a]	Consequence Category[b]	Risk Bin Number[c]	Preventive and Mitigative Controls: Design[d]	Administrative[e]
1. Fissile material	a. Criticality	i. During ISV operations, any initiator/cause results in a criticality.	ISV treatment area, off-gas system	Beyond Extremely Unlikely	Off-Site public: N Co-located workers: N Facility workers: M Environment: L	1 1 6 –	See Chapter 6.	See Chapter 6.
2. Ionizing radiation	a. Excess worker dose from direct radiation	i. During any activity and due to any initiator/cause, a worker is too close, remains too long, or does not have adequate shielding from remote-handled waste.	ISV treatment area	Unlikely	Off-Site public: N Co-located workers: N Facility workers: M Environment: N	4 4 ***12*** –		***Radiation Protection Program***, procedures, and training. Maintenance of overburden soil depth.
3. Radioactive and nonradioactive hazardous material	a. Excavation of contaminated soil	i. During excavation, due to any initiator/cause, a worker is exposed to radioactive or nonradioactive hazardous material.	ISV treatment area	Anticipated	<u>Radioactive:</u> Off-Site public: N Co-located workers: N Facility workers: L Environment: N <u>Nonradioactive:</u> Off-Site public: N Co-located workers: N Facility workers: L Environment: N	 7 7 11 – 7 7 11 –		Procedures and training. Exclusion zone. Radiation Protection Program. Industrial Hygiene Program. Industrial Safety Program.
3. Radioactive and nonradioactive hazardous material	b. Loss of ventilation	i. During ISV operations, any initiator/cause results in failure of the primary off-gas ventilation systems.	Off-gas treatment system	Anticipated	<u>Radioactive:</u> Off-Site public: N Co-located workers: N Facility workers: L Environment: N <u>Nonradioactive:</u> Off-Site public: N Co-located workers: N Facility workers: M Environment: N	 7 7 11 – 7 7 14 –	Design of secondary off-gas ventilation system. Backup power supply. Confinement of material in melt.	Maintenance and inspection program, training, and Emergency Preparedness Program. Radiation Protection Program. Industrial Hygiene Program. Industrial Safety Program.

Table 3-9. (continued).

				Likelihood, Consequence, and Risk Without Controls			Preventive and Mitigative Controls	
Hazard	Hazardous Event	Initiator/Cause	Applicable Facilities or Functions	Likelihood Category[a]	Consequence Category[b]	Risk Bin Number[c]	Design[d]	Administrative[e]
3. Radioactive and nonradioactive hazardous material	c. Breach of confinement	i. Due to any initiator/cause, the off-gas hood or the off-gas treatment system fails (upper bound source term).	Off-gas hood	Extremely Unlikely	Radioactive: Off-Site public: N Co-located workers: M Facility workers: M Environment: L Nonradioactive: Off-Site public: H Co-located workers: H Facility workers: H Environment: H	 2 9 9 – ***13*** 13 13 –	***Design of the off-gas hood and the off-gas treatment system.*** Confinement of material in melt.	***Remote operations, maintenance and inspection program, and Emergency Preparedness Program.*** Procedures and training. No ignition sources. Limit combustible material. Explosive-proof electrical equipment. Hood water spray. Off-gas deflection barrier. Minimize entry into exclusion zone. Shield combustible material. Radiation Protection Program. Industrial Hygiene Program. Industrial Safety Program.

Table 3-9. (continued).

Hazard	Hazardous Event	Initiator/Cause	Applicable Facilities or Functions	Likelihood, Consequence, and Risk Without Controls: Likelihood Category[a]	Consequence Category[b]	Risk Bin Number[c]	Preventive and Mitigative Controls: Design[d]	Administrative[e]
3. Radioactive and nonradioactive hazardous material	c. Breach of confinement	ii. Due to any initiator/cause, the off-gas hood or the off-gas treatment system fails (limiting source term).	Off-gas hood, off-gas treatment system, trailers	Unlikely	<u>Radioactive:</u> Off-Site public: N Co-located workers: L Facility workers: L Environment: L <u>Nonradioactive:</u> Off-Site public: H Co-located workers: H Facility workers: H Environment: H	 4 8 8 – ***15*** ***15*** ***15*** –	***Design of the off-gas hood and the off-gas treatment system.*** Confinement of material in the melt.	***Remote operations***. ***Emergency Preparedness Program. Maintenance and inspection program.*** Procedures and training. No ignition sources. Limit combustible material. Explosive-proof electrical equipment. Hood water spray. Off-gas deflection barrier. Minimize entry into exclusion zone. Shield combustible material. Radiation Protection Program. Industrial Hygiene Program. Industrial Safety Program.

Table 3-9. (continued).

Hazard	Hazardous Event	Initiator/Cause	Applicable Facilities or Functions	Likelihood, Consequence, and Risk Without Controls: Likelihood Category[a]	Consequence Category[b]	Risk Bin Number[c]	Preventive and Mitigative Controls: Design[d]	Administrative[e]
3. Radioactive and nonradioactive hazardous material	c. Breach of confinement	iii. Due to any initiator/cause, the off-gas hood or the off-gas treatment system fails (average source term).	Off-gas hood, off-gas treatment system, trailers	Unlikely	<u>Radioactive:</u> Off-Site public: N Co-located workers: L Facility workers: L Environment: L <u>Nonradioactive:</u> Off-site public: L Co-located workers: L Facility workers: L Environment: L	 4 8 8 – 8 8 8 –	Design of the off-gas hood and the off-gas treatment system. Confinement of material in the melt.	Remote operations. Emergency Preparedness Program. Maintenance and inspection program. Procedures and training. No ignition sources. Limit combustible material. Explosive-proof electrical equipment. Hood water spray. Off-gas deflection barrier. Minimize entry into exclusion zone. Shield combustible material. Radiation Protection Program. Industrial Hygiene Program. Industrial Safety Program.
3. Radioactive and nonradioactive hazardous material	d. Melt expulsion	i. Due to any initiator/cause, a melt expulsion occurs (upper bound source term).	ISV treatment area	Extremely Unlikely	<u>Radioactive:</u> Off-Site public: L Co-located workers: H Facility workers: H Environment: M <u>Nonradioactive:</u> Off-Site public: M Co-located workers: H Facility workers: H Environment: H	 5 13 13 – 9 13 13 –	Design and construction of the off-gas hood and off-gas treatment system. Confinement of material in the melt.	Emergency Preparedness Program. Remote operations. Thermal preconditioning. Electrode control. Planar melting. Internal barrier. Overburden thickness. Controlled access to the hood and operating areas near the hood. Controlled melt rate. PPE. Procedures and training. Radiation Protection Program. Industrial Hygiene Program. Industrial Safety Program.

Table 3-9. (continued).

				Likelihood, Consequence, and Risk Without Controls			Preventive and Mitigative Controls	
Hazard	Hazardous Event	Initiator/Cause	Applicable Facilities or Functions	Likelihood Category[a]	Consequence Category[b]	Risk Bin Number[c]	Design[d]	Administrative[e]
3. Radioactive and nonradioactive hazardous material	d. Melt expulsion	ii. Due to any initiator/cause, a melt expulsion occurs (limiting source term).	ISV treatment area	Unlikely	<u>Radioactive:</u> Off-Site public: L Co-located workers: H Facility workers: H Environment: M <u>Nonradioactive:</u> Off-Site public: H Co-located workers: H Facility workers: H Environment: H	 8 ***15*** ***15*** – ***15*** ***15*** ***15*** –	***Design and construction of the off-gas hood and off-gas treatment system.*** Confinement of material in the melt.	***Emergency Preparedness Program. Remote operations.*** Thermal preconditioning. Electrode control. Planar melting. Internal barrier. Overburden thickness. Controlled access to the hood and operating areas near the hood. Controlled melt rate. PPE. Procedures and training. Radiation Protection Program. Industrial Hygiene Program. Industrial Safety Program.
3. Radioactive and nonradioactive hazardous material	d. Melt expulsion	iii. Due to any initiator/cause, a melt expulsion occurs (average source term).	ISV treatment area	Unlikely	<u>Radioactive:</u> Off-Site public: L Co-located workers: H Facility workers: H Environment: M <u>Nonradioactive:</u> Off-Site public: L Co-located workers: H Facility workers: H Environment: H	 8 ***15*** ***15*** – 8 ***15*** ***15*** –	***Design and construction of the off-gas hood and off-gas treatment system.*** Confinement of material in the melt.	***Emergency Preparedness Program. Remote operations.*** Thermal preconditioning. Electrode control. Planar melting. Internal barrier. Overburden thickness. Controlled access to the hood and operating areas near the hood. Controlled melt rate. PPE. Procedures and training. Radiation Protection Program. Industrial Hygiene Program. Industrial Safety Program.

Table 3-9. (continued).

Hazard	Hazardous Event	Initiator/Cause	Applicable Facilities or Functions	Likelihood, Consequence, and Risk Without Controls: Likelihood Category[a]	Consequence Category[b]	Risk Bin Number[c]	Preventive and Mitigative Controls: Design[d]	Administrative[e]
3. Radioactive and nonradioactive hazardous material	e. Fire	i. A fire from any initiator/cause results in a surface fire in the ISV system.	ISV treatment area, off-gas hood, off-gas treatment system, trailers	Unlikely	Radioactive: Off-Site public: N Co-located workers: N Facility workers: L Environment: L Nonradioactive: Off-Site public: N Co-located workers: N Facility workers: M Environment: L	 4 4 8 – 4 4 12 –	Backup power for off-gas treatment system. Confinement of material in the melt. High temperature HEPA and roughing filters. Design and construction of the HEPA filter housing. Low quantity of combustible material.	Remote operations. Emergency Preparedness Program. Exclusion zone. Maintenance and inspection program, operating procedures, Fire Protection Program, training, and Radiation Protection Program. Industrial Hygiene Program. Industrial Safety Program.
3. Radioactive and nonradioactive hazardous material	e. Fire	ii. During ISV operations, any initiator/cause results in an underground fire (upper bound source term).	ISV treatment area	Beyond Extremely Unlikely	Radioactive: Off-Site public: N Co-located workers: L Facility workers: L Environment: L Nonradioactive: Off-Site public: M Co-located workers: H Facility workers: H Environment: L	 1 3 3 – 6 10 10 –	Toxic gas monitors. Design and construction of the off-gas hood and off-gas treatment system.	Remote operations. Emergency Preparedness Program. Exclusion zone. Air flow across treatment area into hood. Radiation Protection Program. Industrial Hygiene Program. Industrial Safety Program.

Table 3-9. (continued).

				Likelihood, Consequence, and Risk Without Controls			Preventive and Mitigative Controls	
Hazard	Hazardous Event	Initiator/Cause	Applicable Facilities or Functions	Likelihood Category[a]	Consequence Category[b]	Risk Bin Number[c]	Design[d]	Administrative[e]
3. Radioactive and nonradioactive hazardous material	e. Fire	iii. During ISV operations, any initiator/cause results in an underground fire (limiting source term).	ISV treatment area	Beyond Extremely Unlikely	Radioactive: Off-Site public: N Co-located workers: L Facility workers: L Environment: L Nonradioactive: Off-Site public: M Co-located workers: H Facility workers: H Environment: L	 1 3 3 – 6 10 10 –	Toxic gas monitors. Design and construction of the off-gas hood and off-gas treatment system.	Remote operations. Emergency Preparedness Program. Exclusion zone. Air flow across treatment area into hood. Radiation Protection Program. Industrial Hygiene Program. Industrial Safety Program.
3. Radioactive and nonradioactive hazardous material	e. Fire	iv. During ISV operations, any initiator/cause results in an underground fire (average source term).	ISV treatment area	Extremely Unlikely	Radioactive: Off-Site public: N Co-located workers: L Facility workers: L Environment: L Nonradioactive: Off-Site public: L Co-located workers: H Facility workers: H Environment: L	 2 5 5 – 5 13 13 –	Toxic gas monitors. Design and construction of the off-gas hood and off-gas treatment system.	Remote operations. Emergency Preparedness Program. Exclusion zone. Air flow across treatment area into hood. Radiation Protection Program. Industrial Hygiene Program. Industrial Safety Program.
3. Radioactive and nonradioactive hazardous material	f. Deflagration	i. During ISV operations, any initiator/cause results in a surface deflagration.	ISV treatment area, off-gas hood, off-gas treatment system	Unlikely	Radioactive: Off-Site public: N Co-located workers: M Facility workers: H Environment: L Nonradioactive: Off-Site public: H Co-located workers: H Facility workers: H Environment: H	 4 ***12*** ***15*** – ***15*** ***15*** ***15*** –	***Design and construction of the off-gas hood and off-gas treatment system.*** Confinement of material in the melt.	***Remote operations. Emergency Preparedness Program. Maintenance and inspection program.*** Exclusion zone. Procedures and training. Fire Protection Program. Radiation Protection Program. Industrial Hygiene Program. Industrial Safety Program.

Table 3-9. (continued).

				Likelihood, Consequence, and Risk Without Controls			Preventive and Mitigative Controls	
Hazard	Hazardous Event	Initiator/Cause	Applicable Facilities or Functions	Likelihood Category[a]	Consequence Category[b]	Risk Bin Number[c]	Design[d]	Administrative[e]
3. Radioactive and nonradioactive hazardous material	f. Deflagration	ii. During ISV operations, any initiator/cause results in a subsurface deflagration (upper bound source term).	ISV treatment area	Beyond Extremely Unlikely	Radioactive: Off-Site public: L Co-located workers: M Facility workers: M Environment: M Nonradioactive: Off-Site public: M Co-located workers: H Facility workers: H Environment: M	 3 6 6 – 6 10 10 –	Design and construction of the off-gas hood and off-gas treatment system. Toxic gas monitors.	Remote operations. Exclusion zone. Controlled access to the hood and operating areas near the hood. Radiation Protection Program. PPE. Procedures and training. Air flow across treatment area into hood. Emergency Preparedness Program. Industrial Hygiene Program. Industrial Safety Program.
3. Radioactive and nonradioactive hazardous material	f. Deflagration	iii. During ISV operations, any initiator/cause results in a subsurface deflagration (limiting source term).	ISV treatment area	Extremely Unlikely	Radioactive: Off-Site public: L Co-located workers: M Facility workers: M Environment: M Nonradioactive: Off-Site public: M Co-located workers: H Facility workers: H Environment: L	 5 9 9 – 8 13 13 –	Design and construction of the off-gas hood and off-gas treatment system. Toxic gas monitors.	Remote operations. Exclusion zone. Controlled access to the hood and operating areas near the hood. Radiation Protection Program. PPE. Procedures and training. Air flow across treatment area into hood. Emergency Preparedness Program. Industrial Hygiene Program. Industrial Safety Program.

Table 3-9. (continued).

				Likelihood, Consequence, and Risk Without Controls			Preventive and Mitigative Controls	
Hazard	Hazardous Event	Initiator/Cause	Applicable Facilities or Functions	Likelihood Category[a]	Consequence Category[b]	Risk Bin Number[c]	Design[d]	Administrative[e]
3. Radioactive and nonradioactive hazardous material	f. Deflagration	iv. During ISV operations, any initiator/cause results in a subsurface deflagration (average source term).	ISV treatment area	Unlikely	<u>Radioactive:</u> Off-Site public: N Co-located workers: L Facility workers: L Environment: L <u>Nonradioactive:</u> Off-Site public: L Co-located workers: H Facility workers: H Environment: L	 4 8 8 – 8 ***15*** ***15*** –	***Design and construction of the off-gas hood and off-gas treatment system***. ***Toxic gas monitors.***	***Remote operations***. ***Exclusion zone. Controlled access to the hood and operating areas near the hood***. ***Radiation Protection Program***. PPE. Procedures and training. Air flow across treatment area into hood. Emergency Preparedness Program. Industrial Hygiene Program. Industrial Safety Program.
3. Radioactive and nonradioactive hazardous material	g. Detonation	i. During any ISV operation, any initiator/cause results in a surface detonation.	ISV treatment area, off-gas hood, off-gas treatment system	Extremely Unlikely	<u>Radioactive:</u> Off-Site public: N Co-located workers: M Facility workers: H Environment: L <u>Nonradioactive:</u> Off-Site public: H Co-located workers: H Facility workers: H Environment: H	 2 9 13 – ***13*** 13 13 –	Design and construction of the off-gas hood and off-gas treatment system. ***Primary and secondary off-gas ventilation systems. Combustible gas monitoring system. Backup power supply.*** Confinement of material in the melt.	***Maintenance and inspection program. Emergency Preparedness Program. Remote operations.*** Exclusion zone. Fire Protection Program. Radiation Protection Program. Industrial Hygiene Program. Industrial Safety Program.

Table 3-9. (continued).

				Likelihood, Consequence, and Risk Without Controls			Preventive and Mitigative Controls	
Hazard	Hazardous Event	Initiator/Cause	Applicable Facilities or Functions	Likelihood Category[a]	Consequence Category[b]	Risk Bin Number[c]	Design[d]	Administrative[e]
3. Radioactive and nonradioactive hazardous material	g. Detonation	ii. During any ISV operation, any initiator/cause results in an underground detonation.	ISV treatment area	Extremely Unlikely	<u>Radioactive:</u> Off-Site public: L Co-located workers: M Facility workers: M Environment: M <u>Nonradioactive:</u> Off-Site public: L Co-located workers: L Facility workers: H Environment: L	 5 9 9 – 5 5 13 –	Design and construction of the off-gas hood and off-gas treatment system.	Remote operations. Exclusion zone. PPE. Training. Emergency Preparedness Program. Radiation Protection Program. Industrial Hygiene Program. Industrial Safety Program.
4. Fire/explosion	a. BLEVE	i. BLEVE from as yet unsized propane tank due to any initiator/cause.	Off-gas hood, off-gas treatment system, trailers	Unlikely	Off-Site public: N Co-located workers: H Facility workers: H Environment: N	4 ***15*** ***15*** –	***System designed to meet requirements of NFPA 58.***	***Emergency Preparedness, Fire protection program***, ***procedures for monitoring and maintenance of the propane system***, training.
4. Fire/explosion	b. Fuel-air explosion	i. Leak or rupture in as yet unsized propane tank or lines is undetected and ignited when LEL is reached.	Off-gas hood, off-gas treatment system, trailers	Unlikely	Off-Site public: N Co-located workers: H Facility workers: H Environment: N	4 ***15*** ***15*** –	***System designed to meet requirements of NFPA 58.*** Propane detectors and alarm.	***Emergency Preparedness, Fire protection program, procedures for monitoring and maintenance of the propane system***, training.
5. Natural phenomena	a. Lightning	i. Lightning causes failure of the off-gas system.	Off-gas hood, off-gas treatment system, trailers	Extremely Unlikely	Off-Site public: N Co-located workers: L Facility workers: M Environment: L	F f f f	Backup power for off-gas treatment system. Design and construction of the off-gas system (lightning protection).	Remote operations. Fire Protection Program. Emergency Preparedness Program. Procedures and training.

Table 3-9. (continued).

				Likelihood, Consequence, and Risk Without Controls			Preventive and Mitigative Controls	
Hazard	Hazardous Event	Initiator/Cause	Applicable Facilities or Functions	Likelihood Category[a]	Consequence Category[b]	Risk Bin Number[c]	Design[d]	Administrative[e]
5. Natural phenomena	b. Volcanic activity	i. Lava flow encroaches upon ISV activities.	Off-gas hood, off-gas treatment system, trailers	Extremely Unlikely	Off-Site public: N Co-located workers: H Facility workers: H Environment: M	f f f f		Advance notice provides time to secure facilities, and possibly take some mitigating emergency action.
5. Natural phenomena	c. Flood	i. Flooding occurs as a result of surface water run-off or flooding bodies of water surrounding the RWMC.	ISV treatment area	Unlikely	Off-Site public: N Co-located workers: N Facility workers: N Environment: N	f f f f	INEEL and SDA flood control system design and maintenance.	Monitoring of meteorological conditions. Procedures for maintenance and inspection of culverts, dikes, and drainage channels. Emergency Preparedness Program.
5. Natural phenomena	d. Earthquake	i. An earthquake results in a loss of power or damages the off-gas system.	Off-gas hood, off-gas treatment system, trailers	Unlikely	Off-Site public: N Co-located workers: L Facility workers: M Environment: L	f f f f	Backup power for off-gas treatment system. Design and construction of the off-gas hood and off-gas treatment system.	Remote operations. Maintenance and inspection program. Fire Protection Program. Emergency Preparedness Program.
5. Natural phenomena	e. High wind	i. High winds and windborne missiles damage or pressurize the off-gas system.	ISV treatment area	Unlikely	Off-Site public: N Co-located workers: L Facility workers: M Environment: L	f f f f	Backup power for off-gas treatment system. Design and construction of the off-gas hood and off-gas treatment system.	Remote operations. Monitoring of meteorological conditions. Operating procedures. Emergency Preparedness Program.

Table 3-9. (continued).

Hazard	Hazardous Event	Initiator/Cause	Applicable Facilities or Functions	Likelihood, Consequence, and Risk Without Controls			Preventive and Mitigative Controls	
				Likelihood Category[a]	Consequence Category[b]	Risk Bin Number[c]	Design[d]	Administrative[e]
5. Natural phenomena	f. Extreme snow load	i. Snow load collapses the off-gas system.	Off-gas hood, off-gas treatment system, trailers	Unlikely	Off-Site public: N Co-located workers: N Facility workers: N Environment: N	f f f f	Backup power for off-gas treatment system. Design and construction of the off-gas hood and off-gas treatment system. Process heat.	Remote operations. Monitoring of meteorological conditions. Operating procedures. Emergency Preparedness Program.
6. External events	a. Accident in co-located facility	i. Any initiator/cause of an accident in a co-located facility.	ISV treatment area	Unlikely	Off-Site public: N Co-located workers: L Facility workers: L Environment: N	4 8 8 –	Confinement provided by co-located facility.	Emergency notification and response systems. Fire Protection Program. Radiation Protection Program. Industrial Hygiene Program.
6. External events	b. Loss of commercial power	i. Due to any initiator/cause, the commercial power supply is interrupted.	Off-gas treatment system	Anticipated	Off-Site public: N Co-located workers: N Facility workers: L Environment: N	7 7 11 –	Backup power for off-gas treatment system.	Remote operations. Operating procedures. Emergency Preparedness Program.
6. External events	c. Aircraft impact	i. An aircraft flying over the RWMC area crashes near ISV operations and damages confinements and filters.	ISV treatment area, off-gas system	Beyond Extremely Unlikely	Off-Site public: N Co-located workers: H Facility workers: H Environment: M	1 10 10 –		Flight frequency is minimal over the RWMC. Emergency Preparedness Program. Fire Protection Program.
6. External events	d. Range fire	i. Range fire causes failure of the off-gas hood, the off-gas treatment system, or the trailer mounted equipment.	Off-gas hood, off-gas treatment system, trailers	Anticipated	Off-Site public: N Co-located workers: L Facility workers: L Environment: L	7 11 11 –		Emergency Preparedness Program. Advance notice provides time to secure ISV operations. Fire Protection Program. Fire department response. Worker training.

Table 3-9. (continued).

a. The likelihood categories are listed and described in Table 3-1.
b. The consequence categories are denoted with the following: N – negligible, L – low, M – moderate, and H – high and are described in Table 3-2.
c. Risk bin numbers are highlighted in bold italics if they indicate that safety SSCs and/or TSRs should be identified to manage risk (see Figures 3-1, 3-2, and 3-3).
d. SSCs designated as safety-class or safety-significant SSCs are highlighted in bold italics. See Chapter 4 for information on these safety SSCs.
e. TSR-level controls are highlighted in bold italics. See Chapter 5 for information on TSRs.
f. NPH-initiated events are not assigned risk bin numbers. See discussion for each of the natural phenomena hazards in Item 5 above.

BLEVE	boiling liquid-expansion vapor explosion
HEPA	high-efficiency particulate air
INEEL	Idaho National Engineering and Environmental Laboratory
ISV	in situ vitrification
LEL	lower explosive limit
NPH	natural phenomena hazard
NFPA	National Fire Protection Association
PPE	personal protective equipment
RWMC	Radioactive Waste Management Complex
SDA	Subsurface Disposal Area
SSC	structure, system, and component
TSR	technical safety requirement

Each of the hazardous events and initiators/causes in Table 3-9 is discussed in the following paragraphs. The alpha-numeric identifiers provide the cross-reference to Table 3-9. Three different inventory likelihoods are evaluated. These likelihoods are anticipated for average inventories, unlikely for limiting inventories, and extremely unlikely for upper bound inventories. Administrative controls for implementation of radiation protection, hazardous material protection, industrial safety, and QA programs are not included as TSR-level controls, because requirements to develop and implement safety programs at nuclear facilities are given in the CFRs.

1.a.i Fissile material — Inadvertent criticality

Criticality is beyond extremely unlikely for ISV in the SDA primarily because fissile radionuclides would be dispersed (rather than concentrated) throughout the vitrified mass. Criticality events are addressed in greater detail in Section 6 and are only included here for completeness. Criticality is not a credible event for ISV activities as determined in Section 6.3.

2.a.i Ionizing Radiation — Excess worker dose from direct radiation

Waste objects that emit ionizing radiation were buried in the SDA. The radiation fields are highly variable, but sometimes quite high. The SDA contains 861 packages with surface radiation dose rates above 1 R/h at the time of disposal. Shielding is provided by overburden materials unless an object is exposed due to pit subsidence or excavation to place electrodes. During excavation or as a result of pit subsidence, workers could be exposed to an unshielded direct radiation source. Excavation equipment and the off-gas hood inherently provide considerable separation for the worker, but the radiation fields could still be quite high. The unmitigated consequences to a worker are categorized as moderate (that is, between 25 and 100 rem) and the likelihood is categorized as unlikely.

Safety-class or safety-significant SSCs are not identified for this scenario. Technical safety requirement (TSR)-level controls are not required. The radiation protection program is implemented at the RWMC as required per 10 CFR 835 as a control for worker protection.

3.a.i Radioactive and Nonradioactive Hazardous Materials — Excavation of Contaminated Soil

During excavation activities to place the electrodes or establish the starter path in the clean overburden, the possibility of encountering contaminated soil exists. Puncturing of a buried waste container while installing the electrodes or preconditioning the area could result in exposure to contaminated soil. Subsidences at the SDA are checked for exposure of waste materials and contamination spread. Even though the contamination spread from subsidences to date has been negligible, the contamination could be the result of past activities that resulted in contamination not previously detected. The likelihood of this event is categorized as anticipated.

The consequences of this event are categorized as low for facility workers and negligible for all other receptors, because the radioactive material would have a low concentration in the soil. This event does not require safety-class SSCs, safety-significant SSCs, or TSRs. A safety requirement is identified for procedures and training to protect the facility workers from the potential radioactive and nonradioactive hazards associated with excavations in the overburden and waste zone materials.

3b.i Radioactive and Nonradioactive Hazardous Materials — Loss of Ventilation

A loss of off-gas system ventilation can occur because of equipment malfunction (such as a mechanical breakdown in the fan motor), because of a loss of electrical power caused by a power system component failure, or because of natural event scenarios (such as high winds). The review of occurrences on the DOE ORPS indicates that losses of ventilation are common occurrences at plutonium-handling facilities. For these reasons, the hazard analysis assesses the probability for all the loss-of-ventilation scenarios as anticipated.

The consequences of releasing radioactive hazardous material as a result of this event are categorized as low for facility workers and negligible for all other receptors, because the radioactive hazardous material would tend to remain in the melt. The consequences of releasing nonradioactive hazardous material as a result of this event are categorized as moderate for facility workers and negligible for all other receptors, because the nonradioactive hazardous material would be more likely to leave the melt and enter the off-gas system. This event does not require safety-class SSCs, safety-significant SSCs, or TSRs. A safety requirement is identified for maintenance and inspection of the off-gas ventilation system to ensure that it can be relied on to perform its function and protect the facility workers from the potential radioactive and nonradioactive hazards of a failure of the system.

3.c Radioactive and Nonradioactive Hazardous Materials — Breach of Confinement

3.c.i Confinement breaches result from failures involving the off-gas hood and the off-gas treatment system. Breaches from operational scenarios are primarily the result of equipment malfunctions and human error when operating lifting equipment or excavating equipment or when changing the HEPA filters in the off-gas treatment system. Natural subsidence in the pit is another possible initiator. These types of initiating scenarios are most always considered anticipated, based on operational experience at the RWMC and other DOE laboratories and subsidence observations at the SDA. When the anticipated event likelihood is combined with the extremely unlikely source term likelihood, the resulting scenario likelihood is extremely unlikely.

For an upper bound source term, the consequences of releasing radioactive hazardous material as a result of this event are categorized as moderate for facility workers and co-located workers and negligible for the public receptors, because the radioactive hazardous material would tend to remain in the melt. The consequences of releasing nonradioactive hazardous material as a result of this event are categorized as high for all receptors, because the nonradioactive hazardous material would be more likely to leave the melt and enter the off-gas system. This event requires safety-class SSCs and TSRs because of the high risk from nonradioactive hazardous materials. Therefore, the off-gas hood and the off-gas treatment system are safety-class. Remote operations, the emergency preparedness program, and the maintenance and inspection program are TSR-level controls.

3.c.ii Confinement breaches result from failures involving the off-gas hood and the off-gas treatment system. Breaches from operational scenarios are primarily the result of equipment malfunctions and human error when operating lifting equipment or excavating equipment or when changing the HEPA filters in the off-gas treatment system. Natural subsidence in the pit is another possible initiator. These types of initiating scenarios are most always considered anticipated, based on operational experience at the RWMC and other DOE laboratories and subsidence observations at the SDA. When the anticipated event likelihood is combined with the unlikely source term likelihood, the resulting scenario likelihood is unlikely.

For a limiting source term, the consequences of releasing radioactive hazardous material as a result of this event are categorized as low for facility workers and co-located workers and negligible for the public receptors because the radioactive hazardous material would tend to remain in the melt. The consequences of releasing nonradioactive hazardous material as a result of this event are categorized as high for all receptors, because the nonradioactive hazardous material would be more likely to leave the melt and enter the off-gas system. This event requires safety-class SSCs and TSRs because of the high risk from nonradioactive hazardous materials. Therefore, the off-gas hood and the off-gas treatment system are safety-class. Remote operations, the emergency preparedness program, and the maintenance and inspection program are TSR-level controls.

3.c.iii Confinement breaches result from failures involving the off-gas hood and the off-gas treatment system. Breaches from operational scenarios are primarily the result of equipment malfunctions and human error when operating lifting equipment or excavating equipment or when changing the HEPA filters in the off-gas treatment system. Natural subsidence in the pit is another possible initiator. These types of initiating scenarios are most always considered anticipated, based on operational experience at the RWMC and other DOE laboratories and subsidence observations at the SDA. When the anticipated event likelihood is combined with the anticipated source term likelihood, the resulting scenario likelihood is unlikely.

For an average source term, the consequences of releasing radioactive hazardous material as a result of this event are categorized as low for facility workers and co-located workers, and negligible for the public receptors, because the radioactive hazardous material would tend to remain in the melt. The consequences of releasing nonradioactive hazardous material as a result of this event are categorized as low for all receptors, because the quantity of nonradioactive hazardous material is smaller for the average source term. This event does not require safety SSCs or TSRs.

3.d Radioactive and Nonradioactive Hazardous Materials — Melt Expulsion

3.d.i Melt expulsion events have occurred during past ISV operations because molten glass is an incompressible, impermeable fluid that prevents dissipation of pressurized gas into void spaces in the surrounding unmelted waste and soil. Gases released within molten glass are buoyant, and thus are released at the glass surface, sometimes with forces sufficient to cause melt expulsion events. Large melt expulsion events pose risks of severe burn hazards, inhalation hazards, and nonradioactive material exposure hazards created when particulates and gases are released. The likelihood of melt expulsion scenarios is considered to be anticipated. When the anticipated event likelihood is combined with the extremely unlikely source term likelihood, the resulting scenario likelihood is extremely unlikely.

For an upper bound source term, the consequences of releasing radioactive and nonradioactive hazardous material as a result of this event are categorized as high for facility and co-located workers. For the off-Site public, the consequences are low for radioactive materials and moderate for nonradioactive materials. This event does not require safety SSCs or TSRs for protection of the public and workers. Safety requirements are identified for procedures and training for protection of the facility workers from the potential radioactive and nonradioactive hazards, should a melt expulsion occur.

3.d.ii Melt expulsion events have occurred during past ISV operations because molten glass is an incompressible, impermeable fluid that prevents dissipation of pressurized gas into void spaces in the surrounding unmelted waste and soil. Gases released within molten glass are buoyant, and thus are released at the glass surface, sometimes with forces sufficient to cause melt expulsion events. Large melt expulsion events pose risks of severe burn hazards, inhalation hazards, and nonradioactive material exposure hazards created when particulates and gases are released. The likelihood of melt expulsion scenarios is considered to be anticipated. When the anticipated event likelihood is combined with the unlikely source term likelihood, the resulting scenario likelihood is unlikely.

For a limiting source term, the consequences of releasing radioactive and nonradioactive hazardous material as a result of this event are categorized as high for facility and co-located workers. For the off-Site public, the consequences are low for radioactive materials and high for nonradioactive materials. This event requires safety-class SSCs and TSRs for protection of the public and workers. Therefore, the off-gas hood and off-gas treatment systems are designated safety class. The emergency preparedness program and remote operations are TSR-level controls.

3.d.iii Melt expulsion events have occurred during past ISV operations because molten glass is an incompressible, impermeable fluid that prevents dissipation of pressurized gas into void spaces in the surrounding unmelted waste and soil. Gases released within molten glass are buoyant, and thus are released at the glass surface, sometimes with forces sufficient to cause melt expulsion events. Large melt expulsion events pose risks of severe burn hazards, inhalation hazards, and nonradioactive material exposure hazards created when particulates and gases are released. The likelihood of melt expulsion scenarios is considered to be anticipated. When the anticipated event likelihood is combined with the anticipated source term likelihood, the resulting scenario likelihood is unlikely.

For an average source term, the consequences of releasing radioactive and nonradioactive hazardous material as a result of this event are categorized as high for facility and co-located workers. For the off-Site public, the consequences are low for radioactive materials and low for nonradioactive materials. This event requires safety-significant SSCs and TSRs for protection of the workers. Therefore, the off-gas hood and off-gas treatment systems are designated safety significant. The emergency preparedness program and remote operations are TSR-level controls.

3.e Radioactive and Nonradioactive Hazardous Materials — Fire

3.e.i Combustible or flammable materials in the ISV treatment area may provide fuel for a surface fire. The combustible and flammable materials may include diesel/gasoline/propane from a vehicle, propane from storage tanks, and propane from distribution systems. Additionally, concentrations of combustible gases in the off-gases produced when melting RFP waste types could exceed the lower flammability limits in the off-gas hood. Implementation of a fire protection program is the most important fire prevention feature.

Potential initiators/causes include a collision or any other event that may release diesel/gasoline/propane from a vehicle, propane from storage tanks, and propane from distribution systems. The initiators of a surface fire also include maintenance activities such as welding or cutting near combustible materials, malfunctions in facility electrical equipment, lightning, heat from the thermal treatment process, brush fires initiated within the RWMC, and brush fires outside the RWMC fence. Operating experience at the INEEL and other DOE sites indicates that arcing of electrical equipment, fires during maintenance activities, and brush fires are expected. Fires have occurred in the ISV off-gas hood during earlier processing operations. A fire caused by an earthquake is assessed as being within the unlikely range of frequencies, based on earthquake qualification criteria in DOE-STD-1020-2002, "Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities."[20] Fires on excavation or material-handling equipment are anticipated; however, a fire from large fuel spills that breaches confinement is considered to be beyond extremely unlikely since equipment for moving the off-gas hood and preparing the ISV site would not be operating near the off-gas hood during ISV processing.

Lightning strikes are classified into two categories: (1) a cold strike, in which the return strike is of short duration and has a mechanical or explosive effect that tends to shatter and strip bark from trees and rip clothing from human victims and (2) a hot strike, where the current is of longer duration that tends to start fires. The probability that a lightning strike is a cold or hot strike is 0.5.[21] The accident analysis is concerned with hot strikes because of the potential for a fire. The following equation is used to determine the frequency of fires initiated by hot lightning strikes:

Frequency = strikes/year/mi^2 $\times$ facility area mi^2 $\times$ 0.5.

The number of strikes per year per square mile can be determined based on readings from lightning strike detection field instruments operated by the Bureau of Land Management of the National Interagency Fire Center. From 1985 to 2000, the Bureau of Land Management instruments recorded 76 lightning strikes in the 5-mi^2 area around the RWMC.[22] None of the strikes was in the SDA. The number of lightning strikes per year per square mile is 76/15/5 or 1 strike/year/mi^2. The area of an ISV treatment area is 900 ft^2 or approximately 3.2E-05 mi^2. Therefore, the frequency of a strike on an ISV treatment area is approximately 1.6E-05/year, which is within the extremely unlikely range of occurrences.

The likelihood of a surface fire is considered to be unlikely. The consequences of releasing radioactive hazardous material as a result of this event are categorized as low for facility workers and negligible for all other receptors because the radioactive hazardous material would tend to remain in the melt. The consequences of releasing nonradioactive hazardous material as a result of this event are categorized as moderate for facility workers and negligible for all other receptors, because the nonradioactive hazardous material would be more likely to leave the melt and enter the off-gas system. This event does not require safety-class SSCs or safety-significant SSCs. A safety requirement is identified for remote operations for protection of the facility workers from the potential radioactive and nonradioactive hazards, should a fire occur. A safety requirement for a fire protection program is identified as a fire prevention measure.

3.e.ii The initiator of an underground fire is heat from the thermal treatment process. The waste contains combustible material. In addition, nitration reactions and mixtures with free flammable or combustible liquids may have increased the flammability of the combustible materials. Flammable and combustible liquids, mainly oils in both damaged and intact containers, are expected.

A fire could also result from the accumulation of a flammable mixture of hydrogen plus an ignition source. Some TRU waste buried in the SDA has the potential for generating explosive mixtures of hydrogen gas. The possible mechanisms for gas generation in TRU waste include radiolysis, thermal degradation, bacteriological decomposition, chemical corrosion, and alpha decay. Only radiolysis has been observed to produce H_2.[23] Mixtures of 4.0 to 75% H_2 by volume in air (a minimum of 5% O_2 must be present in the air) can be flammable.[24]

There is little evidence that pyrophoric metals are buried at the SDA in a form that either will spontaneously ignite or be easily ignited and self-sustaining. The Series 741 through 745 sludges contain a precipitate of magnesium oxide, but in this state, it is not ignitable. Sodium and potassium are buried in the SDA, but as part of compounds, not as distinct pyrophoric metals. There may be some lithium batteries in 742 sludge drums. These batteries may be a combustible threat if intact and then punctured, but they are a small energy source and easily contained.

Aluminum and iron are buried in the SDA, but they are not combustible when in a massive form. Large quantities of zirconium and zirconium alloy that are technically considered combustible metals are buried at the SDA, but the combustibility of zirconium decreases as the average particle size increases. As large bars, narrow plates, and long strips, zirconium can withstand extremely high temperatures without igniting. Spontaneous ignition or explosions of zirconium during handling are not likely unless the metal is very finely divided. Zirconium fines in the 3-micron size will ignite at room temperature. Fines in the 6-micron size will ignite at approximately 374°F.

The surface of uranium contaminants would likely be oxidized and not be metallic pyrophoric powder. A mitigating condition that reduces the fire hazard by this source is that the waste form containing the uranium is sludge. The general form of the waste matrix is a slurry comprised of 50–70 wt% water when packaged.[25] In the process of forming the sludge, it would seem that the uranium contaminants would be dispersed in the material and that this dispersion would act as a barrier to fire propagation.

Beryllium (although not pyrophoric), when in dust or flake form and mixed with carbon tetrachloride, trichloroethane, or trichloroethylene, will form flammable gases that can spark or flash. For beryllium in sludge form,[25] the same argument used for uranium would apply. As large blocks, beryllium is not likely to form flammable gases.

Nitrocellulose is a highly flammable solid that may be found in a highly impure form and limited quantities in the SDA. Nitrocellulose is capable of spontaneous ignition, particularly when dry. Based on an evaluation of waste streams and factors that must be in place to form nitrocellulose, nitrocellulose formation is highly improbable. Thus, Einerson and Thomas[26] conclude that the nitrocellulose quantity is estimated as zero for Pit 9. The conclusion that the nitrocellulose quantity in Pit 9 is zero is based on an analysis of RFP waste.[27] Since the majority of the waste to be treated with ISV is from RFP, this same estimation can be made for the SDA as a whole.

The frequency for a lightning strike on an ISV treatment area was shown to be in the extremely unlikely range of occurrences. The likelihood of a lightning strike initiating an underground fire is considered to be beyond extremely unlikely.

The likelihood of an underground fire is considered to be extremely unlikely. When the extremely unlikely event likelihood is combined with the extremely unlikely source term likelihood, the resulting scenario likelihood is beyond extremely unlikely.

For an upper bound source term, the consequences of releasing radioactive hazardous material as a result of this event are categorized as low for facility and co-located workers, and negligible for the off-Site public, because the radioactive hazardous material would tend to remain underground. The consequences of releasing nonradioactive hazardous material as a result of this event are categorized as high for facility workers and co-located workers, and moderate for the public receptors, because an underground fire is assumed to be fairly small and most likely would not release large quantities of nonradioactive hazardous materials. This event does not require safety SSCs, safety requirements, or TSRs.

3.e.iii As discussed for 3.e.ii, the likelihood of an underground fire is considered to be extremely unlikely. When the extremely unlikely event likelihood is combined with the unlikely source term likelihood, the resulting scenario likelihood is beyond extremely unlikely.

For a limiting source term, the consequences of releasing radioactive hazardous material as a result of this event are categorized as low for facility and co-located workers, and negligible for the off-Site public, because the radioactive hazardous material would tend to remain underground. The consequences of releasing nonradioactive hazardous material as a result of this event are categorized as high for facility workers and co-located workers, and moderate for the public receptors, because an underground fire is assumed to be fairly small and most likely would not release large quantities of nonradioactive hazardous materials. This event does not require safety SSCs, safety requirements, or TSRs.

3.e.iv As discussed for 3.e.ii, the likelihood of an underground fire is considered to be extremely unlikely. When the extremely unlikely event likelihood is combined with the anticipated source term likelihood, the resulting scenario likelihood is extremely unlikely.

For an average source term, the consequences of releasing radioactive hazardous material as a result of this event are categorized as low for facility and co-located workers, and negligible for the off-Site public, because the radioactive hazardous material would tend to remain underground. The consequences of releasing nonradioactive hazardous material as a result of this event are categorized as high for facility workers and co-located workers, and low for the public receptors, because an underground fire is assumed to be fairly small and because the source term is based on the average inventory of nonradioactive hazardous materials. This event does not require safety SSCs or TSRs. A safety requirement is identified to require a toxic gas monitoring system around the periphery of the off-gas hood and in occupied areas.

3.f Radioactive and Nonradioactive Hazardous Materials — Deflagration

3.f.i Combustible materials in the ISV treatment area may provide fuel for a surface deflagration. The combustible materials and the initiators that may contribute to a deflagration are the same as those described in 3.e.i. A deflagration differs from a fire in that the rate of combustion is much faster.

The likelihood of a surface deflagration is considered to be unlikely. The consequences of releasing radioactive hazardous material as a result of this event are categorized as high for facility workers, moderate for co-located workers, and negligible for the off-Site public, because the radioactive hazardous material would tend to remain in the melt. The consequences of releasing nonradioactive hazardous material as a result of this event are categorized as high for all receptors, because the nonradioactive hazardous material would be more likely to leave the melt and enter the off-gas system. This event requires safety-class SSCs and TSRs because of the high risk from nonradioactive hazardous materials. Therefore, the off-gas hood and the off-gas treatment system are identified as safety-class SSCs. Those TSR-level administrative controls that provide for remote operations, an emergency preparedness program, and a maintenance and inspection program are instituted for protection of the off-site public and the facility and co-located workers.

3.f.ii The initiator of an underground deflagration is heat from the thermal treatment process. A deflagration could result from the accumulation of an explosive mixture of hydrogen plus an ignition source. As discussed in 3.e.ii, some TRU waste buried in the SDA has the potential for generating explosive mixtures of hydrogen gas. Mixtures of 13 to 18% H_2 by volume in air can be explosive.

The likelihood of an underground deflagration is considered to be unlikely. When the unlikely event likelihood is combined with the extremely unlikely source term likelihood, the resulting scenario likelihood is beyond extremely unlikely.

For an upper bound source term, the consequences of releasing radioactive hazardous material as a result of this event are categorized as moderate for facility and co-located workers, and low for the off-Site public, because the radioactive hazardous material would tend to remain underground. The consequences of releasing nonradioactive hazardous material as a result of this event are categorized as high for facility workers and co-located workers, and moderate for the public receptors, because an underground deflagration would be expected to release more material than an underground fire. This event does not require safety SSCs, safety requirements, or TSRs.

3.f.iii As discussed for 3.f.ii, the likelihood of an underground deflagration is considered to be unlikely. When the unlikely event likelihood is combined with the unlikely source term likelihood, the resulting scenario likelihood is extremely unlikely.

For a limiting source term, the consequences of releasing radioactive hazardous material as a result of this event are categorized as moderate for facility and co-located workers, and low for the off-Site public, because the radioactive hazardous material would tend to remain underground. The consequences of releasing nonradioactive hazardous material as a result of this event are categorized as high for facility workers and co-located workers, and moderate for the public receptors, because an underground deflagration would be expected to release more material than an underground fire. A safety requirement is identified for procedures and training to protect the co-located workers from the potential radioactive and nonradioactive hazards associated with an underground deflagration.

3.f.iv As discussed for 3.f.ii, the likelihood of an underground deflagration is considered to be unlikely. When the unlikely event likelihood is combined with the anticipated source term likelihood, the resulting scenario likelihood is unlikely.

For an average source term, the consequences of releasing radioactive hazardous material as a result of this event with an average source term are categorized as low for facility and co-located workers, and negligible for the off-Site public, because the radioactive hazardous material would tend to remain underground. The consequences of releasing nonradioactive hazardous material as a result of this event are categorized as high for facility workers and co-located workers, and low for the public receptors, because the source term is based on the average inventory. This event requires safety-significant SSCs. The off-gas hood, the off-gas treatment system, and the toxic gas monitors are designated as safety-significant SSCs. Remote operations, exclusion zone, and controlled access to the hood and operating areas near the hood are TSR-level controls.

3.g Radioactive and Nonradioactive Hazardous Materials — Detonation

3.g.i Combustible materials in the ISV treatment area may provide fuel for a surface detonation. The combustible materials and the initiators that may contribute to a detonation are the same as those described in 3.f.i. A detonation differs from a deflagration in that the detonation creates a shock wave.

The likelihood of a surface detonation is considered to be extremely unlikely. The consequences of releasing radioactive hazardous material as a result of this event are categorized as high for facility workers, moderate for co-located workers, and negligible for the off-Site public, because the radioactive hazardous material would tend to remain in the melt. The consequences of releasing nonradioactive hazardous material as a result of this event are categorized as high for all receptors, because the nonradioactive hazardous material would be more likely to leave the melt and enter the off-gas system. This event requires safety-class SSCs and TSRs because of the high risk from nonradioactive hazardous materials. Therefore, the off-gas hood and the off-gas treatment system are identified as safety-class SSCs. Those TSR-level administrative controls that provide for remote operations, an emergency preparedness program, and a maintenance and inspection program are instituted for protection of the off-Site public and the facility and co-located workers.

3.g.ii Underground detonations may involve (1) combinations of nitrates with carbonaceous materials such as charcoal, graphite, and cellulose, (2) treating a buried drum containing a flammable mixture of hydrogen and oxygen, (3) accumulation and ignition of flammable VOCs in the treatment area, (4) or treating volumes containing pockets of methane or hydrogen gas that have been produced by bacterial action on the buried waste. A detonation differs from a deflagration in that the detonation creates a shock wave.

Based on experience with the stored waste inventory, hydrogen gas may be present in waste containing water or organic materials because of radiolysis. This gas will disperse over time through any polyethylene bags; however, it could be contained in unvented sealed drums that remain in good condition. Most of the buried metal drums are believed to have corroded to the point where they will not contain hydrogen gas. This belief is further supported by recent observations through visual probes in OU 7-10 that indicate drums are completely corroded away.

An evaluation has been performed on the generation and retention of methane and hydrogen gases because of microbial activity on the waste zone materials. This evaluation involved collection of gas samples from Pit 10, which is representative of OU 7-10, and performing an analysis of the potential for methane and hydrogen gas generation.[28] This analysis concludes that (1) very little methane or hydrogen gas is produced and retained because high concentrations of polychlorinated hydrocarbons are microbial poisons, (2) even under the most conservative conditions the methane oxidation rate and the methane generation rate are almost identical, and (3) methane and hydrogen gas diffuse through the overburden.

The likelihood of an underground detonation is considered to be extremely unlikely. The consequences of releasing radioactive hazardous material as a result of this event are categorized as moderate for facility and co-located workers, and low for the off-Site public, because the radioactive hazardous material would tend to remain underground. The consequences of releasing nonradioactive hazardous material as a result of this event are categorized as high for facility workers, and low for all other receptors, because an underground detonation would be expected to release more material than an underground fire. This event does not require safety-class or safety-significant SSCs. No TSRs or safety requirements are required.

4.a.i Fire/explosions — Propane tank fire/BLEVE

A BLEVE could occur at the as yet unsized propane tank. The likelihood of this event is categorized as unlikely. This event could be an initiator for the waste fire events addressed previously. The consequences of this event are categorized as negligible to the off-Site public, and high to both the co-located and facility worker. This determination is based on the potential to impact the off-gas hood and the off-gas treatment system, and the close proximity of workers to the event.

Because of the impact from this event on the co-located/facility workers, safety-significant SSCs, or TSR-level administrative controls are required. The system is designed to meet the requirements of NFPA 58. These design features are designated safety significant to protect the facility and co-located workers. TSR-level controls are identified for emergency preparedness, a fire protection program, and procedures for monitoring and maintenance of the propane system.

4.b.i Fire/explosions — Fuel-air explosion

A fuel-air explosion could occur in the ISV treatment area as a result of a leak or rupture in the propane line to the off-gas treatment system. The likelihood of this event is categorized as unlikely. Personnel injuries or deaths are possible from this event. The consequences of this event are categorized as negligible to the off-Site public, and high to both the co-located and facility worker. This determination is based on the potential to impact the off-gas hood and the off-gas treatment system and the close proximity to the explosion to the workers.

Because of the impact from this event on the co-located/facility workers safety-significant SSCs, or TSR controls are required. The system is designed to meet the requirements of NFPA 58. These design features are designated safety significant to protect the facility and co-located workers. TSR-level controls are identified for emergency preparedness, a fire protection program, and procedures for monitoring and maintenance of the propane system.

5 Natural Events

The consequence assessments of a lightning strike, volcanic eruption, high winds, snow loading, and tornadoes are based on the potential energies of the events and potential for a release. The bases for the consequence assessments are found in the RWMC SAR. Some scenarios have the potential for moderate environmental damage because of the potential for spreading contamination over a large area.

Safety-significant SSCs and SSCs that perform emergency functions to preserve the health and safety of the workers are generally classified as Performance Category (PC)-2, in accordance with DOE-STD-1021-93, "Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components."[29] The natural event hazard probabilities associated with design goals for PC-2 SSCs are (1) 1E-03 for earthquake and (2) 1E-02 for wind.[20] The PC-2 criteria for flooding are beyond design basis for the project. The INEEL volcanism working group[30] and Hackett and Smith[31] estimated the conditional probability of basaltic volcanism to affect a south-central INEEL site as being less than 1E-05 per year. Lightning strikes and snow-loading scenarios are credible scenarios for the RWMC and project facility operations.

5.a.i Lightning is one of the potential fire initiators covered previously. The likelihood of an accident initiated by lightning is extremely unlikely (see discussion in 3.e.i). The consequences of this event to facility workers and co-located workers are categorized as moderate and low, respectively. This is based on the potential impact to the ISV equipment as a result of a fire.

The ISV equipment has lightning protection to prevent this scenario. Other controls include the remote operations, the Fire Protection Program, the Emergency Preparedness Program, procedures, and training.

5.b.i Volcanic activity has occurred in the area in the geologically recent past and could occur again. A lava flow is categorized as extremely unlikely (see Chapter 1, SAR-100). The consequences of a lava flow are categorized as high for facility workers and co-located workers, if no preventive or mitigative actions were taken. However, advance notice may provide sufficient time to divert the flow or secure the facilities.

5.c.i Flooding scenarios are initiated by natural events such as heavy rain and snowmelt. Floods have previously occurred at the SDA. The consequences to workers and co-located workers are categorized as negligible, since there were no consequences resulting from previous flooding of the SDA and advance notice would provide sufficient time to secure the facilities. The 100-yr flood does not approach the RWMC, and hence is not a relevant scenario. The 10,000-yr flood and the Mackay Dam failure would both reach the SDA. These events are categorized as unlikely. There are two existing diversion dikes that are assumed to fail for the Mackay Dam failure.

The flood control design and flood control maintenance program provide preventive and mitigative measures. There is an existing dike around the SDA that would prevent either flood from impacting the radioactive materials. Some overtopping may occur in the southwest corner of the SDA dike during the Mackay Dam flood. Improvements have been made to the dikes and RWMC drainage system to protect aboveground waste against a credible flood. Because of the low risk, none of the preventive or mitigative measures are safety significant or safety class, and none require TSRs.

5.d.i A design basis earthquake (DBE) can result in the initiation of fires, which can result in the release of radioactive and hazardous material. A DBE is a potential initiator for fires and breaches. The consequences of this event to workers and co-located workers are categorized as moderate for facility workers, and low for co-located workers. A DBE is categorized as unlikely. The off-gas hood and the off-gas treatment system are seismically qualified and meet or exceed Seismic Zone 2 standards.

5.e.i High winds have the potential to result directly in personnel injury and death. High winds can also damage the ISV equipment and potentially initiate fires. The consequences of this event to workers and co-located workers are categorized as moderate for facility workers, and low for co-located workers. High winds are categorized as unlikely. The consequences and controls associated with tornadoes are similar to those for high winds. DOE-1020-2002 and SAR-100 state that, for the INEEL, tornados are not to be considered in the design of nuclear facilities. ISV processing is not performed during extreme conditions. Remote operations, monitoring of meteorological conditions, procedures, and the Emergency Preparedness Program would reduce the likelihood and consequences of high-wind initiated events.

5.f.i The consequences, and controls associated with extreme snow loads are negligible for all receptors. The process heat keeps the equipment free from snow, and monitoring of meteorological conditions allow sufficient time to secure the equipment.

6 External events

6.a.i Accidents in a co-located facility are an unlikely initiator of accidents in the ISV treatment area. The consequences are categorized as negligible for the off-Site public, and low for the facility worker and the co-located worker. This event does not require safety-significant SSCs or TSRs., The emergency notification and response systems, the Fire Protection Program, the Radiation Protection Program, and the Industrial Hygiene Program reduce the likelihood and consequences of this event.

6.b.i A loss of commercial power is an anticipated event for ISV processing and could be an initiator for an accident in the off-gas treatment system. The off-gas hood and the off-gas treatment system are identified as safety-class SSCs for protection of the off-Site public. The backup power supply is included in off-gas treatment system (see 3.e.i and 3.f.i for additional information).

6.c.i Releases from aircraft collisions into the ISV treatment area are evaluated as being beyond extremely unlikely occurrences. Because such a scenario would be highly energetic, the consequences are assumed to be high for the facility and co-located workers. The consequences are categorized as negligible for the off-Site public.

No preventive controls are in place for this scenario. The only mitigative control would be emergency actions on the part of the RWMC and the INEEL to protect workers once the scenario occurs. Because of the low risk, none of the preventive or mitigative measures are safety significant or safety class, and none require TSRs.

6.d.i Range fires have occurred at the INEEL and are categorized as anticipated for the SDA. Range fires are one of the initiators for the fire and BLEVE scenarios previously discussed, and the consequence of this event are categorized as moderate for facility workers and co-located workers (see 3.e.i and 4.a.i for additional information). For failure of the off-gas hood, the emergency preparedness program is identified as a safety requirement for protection of the facility and co-located workers.

***3.3.2.3.1 Planned Design and Operational Safety Improvements*—**The design includes the necessary safety features to ensure worker safety. The hazard evaluation does not identify the need for improvements to the design of project facilities or operational safety.

***3.3.2.3.2 Defense in-Depth*—**The defense-in-depth approach builds in levels of safety so that no one level, no matter how good, is completely relied upon. The first level of safety is the design of SSCs or administrative controls to ensure that hazards are safely contained. The second level is the automatic alarms and detection systems if the first level fails and an accident initiates. The third level is mitigation (such as secondary confinement, personal protective equipment [PPE], and the Emergency Preparedness Program).

Each of the three levels of the defense-in-depth approach to overall safety of project operations applies to radioactive hazardous materials, criticality, nonradioactive hazardous materials, fire and explosion, and natural event hazards. The intent is to identify the broad purpose and importance of defense-in-depth features for these hazards, not the details of design or implementation. These features are identified in Table 3-10. The hazard evaluation results demonstrate that the project facilities are designed and operated with a defense-in-depth approach that protects the off-Site public, co-located workers, facility workers, and the environment from the potential hazards. Based on the results of the qualitative hazard evaluation results in Table 3-9, safety-class SSCs have been identified for protection of the off-Site public and safety-significant SSCs have been identified for protection of facility and co-located workers. Safety SSCs are discussed in the following section.

The following defense-in-depth features should be considered to prevent or mitigate the consequences of a melt expulsion accident:

1. Perform thermal preconditioning by developing an optimum melt rate such that any vapors will be released to the surface before the pressure buildup is such that a melt expulsion would occur. A lower melting rate would reduce the vapor generation rate, thus reducing pressure within the given vapor pathway.

2. Hold electrodes above the pit bottom, and stop the melt advance before it contacts the pit bottom to enable a dry-out period of the region between the melt and the pit bottom. It is recognized that it is not possible to abruptly stop the advance of a melt by reducing or terminating power. The melt will continue to advance as it cools to the melting temperature of the media being treated. Thus, it will be necessary to recognize that the melt will coast some after reducing power; and this will have to be factored into the determination of when and where to reduce power.

3. Use planar-ISV technology for ISV operations. This process initiates melting from the side of the waste instead of from the top down. This technique provides a direct path to the ISV off-gas system between each planar-melt for vaporizable material in the waste seam. This provides an additional release path through the soil between the melt as an alternate to passing through the soil around the

Table 3-10. Defense-in-depth features.

Scenario Group	First Level (Design, worker training, procedures, safety programs)	Second Level (Automatic detection)	Third Level (Accident mitigation)
Release of radioactive hazardous materials	Remote operations, vitrified material, off-gas system, HEPA filters, HEPA filter housing, controlled melt rate, worker training, operating procedures, maintenance and inspection, radiological protection program.	Radiological monitoring, combustible gas monitor, negative pressure monitors, ΔP monitors, backup power.	Emergency response, PPE.
Criticality	Remote operations, worker training, operating procedures, criticality protection program.	None required.	Emergency response.
Release of nonradiological hazardous materials	Remote operations, vitrified materials, off-gas system, HEPA filters (particulate only), HEPA filter housing (particulate only), controlled melt rate, worker training, operating procedures, maintenance and inspection, industrial hygiene program.	Nonradiological hazardous material monitoring, combustible gas monitor, toxic gas monitors, negative pressure monitors, ΔP monitors (particulate only), backup power, secondary off-gas treatment system.	Exclusion zone around hood, emergency response, PPE.
Fire and explosion	Class I, Division I electrical components in off-gas hood and off-gas treatment system, remote operations, high-temperature HEPA and roughing filters, design and construction of the hood, low combustible material loading, off-gas system, planar melting, controlled melt rate, worker training, operating procedures, maintenance procedures, fire protection program.	Backup power, combustible gas monitor.	Exclusion zone around hood, emergency response, portable fire extinguishers, PPE.
Natural phenomena	RWMC, SDA, and INEEL flood control system, remote operations, design of off-gas systems, emergency preparedness program, worker training, operating procedures.	Meteorological and seismic monitoring systems external to the ISV project, backup power.	Emergency response.

HEPA high-efficiency particulate air
INEEL Idaho National Engineering and Environmental Laboratory
ISV in situ vitrification
PEP personal protective equipment
RWMC Radioactive Waste Management Complex
SDA Subsurface Disposal Area

melt. In addition, by melting in from the side, there is not a molten glass pool above the vaporized material. This melting technique substantially reduces the potential of a melt expulsion. Optimize the planar-ISV technology for ISV operations (that is, by electrode geometry or feed rate) to increase the capability of off-gas venting and efficiency for melt operation.

4. Provide an internal barrier (metal berm ring, soil berm) to prevent melt from contacting the hood skin panels. This barrier would help contain any melt overflows or melt splattering.

5. Maintain the overburden thickness.

The following defense-in-depth features should be considered to prevent or mitigate the consequences of a loss of confinement accident.

1. Ignition sources should not be allowed to contact untreated off-gas effluents (such as locate the oxidizer downstream of the treatment system)

2. The use of combustible materials should be eliminated or minimized (such as use of metal tubing for pneumatic lines rather than rubber tubing; use of high-temperature, metallic-braid thermocouple wire rather than plastic sheath; and use of ceramic insulation)

3. Explosive-proof electrical equipment should be used inside the off-gas hood

4. As a means of minimizing hood damage due to overheating events, an external hood water spray system could be implemented to cool the hood during a thermal excursion event in order to protect equipment (and personnel) from further heat exposure

5. An off-gas deflection barrier (earthen berms) between the off-gas hood and occupied areas (such as the control trailer) could divert hot gases away from areas occupied by personnel in case of a loss of confinement accident

6. Minimize the need for personnel entry into the exclusion zone

7. Provide shielding or guards around any combustible material (such as cable insulation) that is in the vicinity of the off-gas hood.

The following defense-in-depth features should be considered to prevent or mitigate the consequences of an underground fire or an underground deflagration.

1. Design the off-gas hood to draw air across the treatment area surrounding the off-gas hood.

Safety SSCs. Twelve scenarios have risk bin numbers high enough that safety-significant SSCs or TSRs should be identified to protect the worker. Two of the scenarios relate to a melt expulsion. Seven of the scenarios relate to confinement system failures. The remaining three scenarios include direct-radiation exposure, a BLEVE involving the off-gas treatment propane storage tank, and a fuel-air explosion involving the off-gas treatment propane storage tank. Five scenarios have risk bin numbers high enough that safety-class SSCs should be identified to protect the off-Site public. These scenarios relate to a melt expulsion and to off-gas hood and off-gas treatment system failures. However, a future off-gas analysis may show that the consequences are not great enough to warrant safety-class SSCs.

To protect the health and safety of the public, the following SSCs are identified as safety class:

- Off-gas hood
- Off-gas treatment system
- Primary and secondary off-gas ventilation systems
- Combustible gas monitors
- Backup power supply.

To protect the health and safety of the facility workers and the co-located workers, the following SSCs are identified as safety significant:

- Toxic gas monitors
- Propane system design.

Technical Safety Requirements—Programs required by CFRs (such as the radiation protection, industrial safety, hazardous material protection, and quality assurance [QA] programs) are not addressed as TSRs. TSR-level safety limits and the associated limiting control settings (LCSs), and limiting conditions for operations (LCOs) may potentially be required for the following:

- Off-gas hood
- Off-gas treatment system (includes primary and secondary off-gas ventilation systems and combustible gas monitoring systems)
- Primary and secondary off-gas ventilation systems
- Backup power supply
- Combustible gas monitoring system
- Toxic gas monitoring system.

TSR-level administrative controls may potentially be required for the following:

- Emergency preparedness program
- Procedures and training
- Remote ISV operations
- Exclusion zone
- Controlled access to the off-gas hood and operating areas near the hood
- Monitoring for toxic gas around the periphery of the off-gas hood and in occupied areas

- Minimum staffing for ISV operations
- Hoisting and rigging program
- Maintenance and inspection program
- Fire protection program
- Maintenance of overburden thickness.[a]

3.3.2.3.3 Worker Safety—Worker safety is ensured by the safety-significant SSCs, TSRs, worker safety programs, and worker safety requirements identified by the hazard evaluation. Unique and important worker safety requirements include:

- Remote operations
- Exclusion zone
- Controlled access to the off-gas hood and areas near the off-gas hood
- Toxic gas monitoring system
- Procedures and training.

3.3.2.3.4 Environmental Protection—The results of the hazard evaluation show that impacts to the environment resulting from ISV operations will be minor. Over the 20-year history of ISV operations, several melt expulsions have occurred, but none resulted in significant environmental damage (Table 3-3). However, there is some potential for minor contamination of the SDA. The planar melting process and the overburden greatly reduce the environmental and worker hazards associated with melt expulsions. There are high concentrations of hazardous materials in the off-gases. The ISV off-gas treatment system ensures that off-gases from the melt are collected, filtered, and treated before release to the atmosphere. The design features and administrative controls outlined in the previous sections also apply to environmental protection.

3.3.2.3.5 Accident Selection—This section identifies a limited set of bounding and representative accidents for further quantitative analysis in Section 3.4.2. Operational scenarios are dominated by breaches of confinement, failures of the off-gas treatment system, and fires/deflagrations. The direct-radiation exposure, container deflagration, underground fire, melt expulsion, and loss of confinement scenarios have higher risk bin numbers, and therefore, are chosen as the bounding and representative accidents. The direct radiation exposure, underground fire, and loss of confinement scenarios are bounding for operational events. The loss of confinement scenario is bounding for external accidents. The loss of confinement scenario is also representative and bounding for all breach scenarios because it assumes a loss of ventilation and no confinement. These accidents also bound the natural event scenarios.

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a. 10-cm overburden thickness assumed in the accident analyses of Section 3.4.

3.4 Accident Analysis

The accident analysis consists of a formal description of the accident scenarios selected as bounding and representative in the hazard analysis. Additionally, all major assumptions in the scenarios are identified and source terms are determined for each scenario. Each scenario also contains a consequence analysis and a comparison with the evaluation guidelines for the co-located worker and the off-Site public. Technical safety requirements or safety SSCs are identified if the evaluation guidelines are exceeded. The final part of this section evaluates, in a qualitative manner, accidents beyond the design basis. The technical review of the methodologies, source term development, and consequence assessments are documented in an EDF that provides verification of the dose and exposure calculations.[9]

3.4.1 Methodology

The accident analysis consists of a formal description of the accident scenarios selected as representative and bounding. Each scenario also contains an evaluation of the source terms, unmitigated consequence analysis, and a comparison of doses and concentrations with the evaluation guidelines. The likelihood for the accident scenarios is the product of the event likelihood and the source term likelihood.

3.4.1.1 Radioactive Material Consequences. As discussed in EDF-3563,[9] a source term is determined and the downwind radioactive material consequences are calculated. The source term is the amount of radioactive material released during the accident. The source terms are determined using the following equation.[32]

$$ST = MAR \times DR \times ARF \times RF \times LPF$$

where

ST	=	source term (Ci)
MAR	=	material at risk (Ci)
DR	=	damage ratio
ARF	=	airborne release fraction
RF	=	respirable fraction
LPF	=	leak path factor.

Material at Risk—The MAR is the total waste inventory impacted for a given accident scenario and is expressed in terms of total quantity at risk.

Damage Ratio—The DR represents the fraction of the MAR that could be affected by the postulated accident and is a function of the accident initiator and the operational scenario being evaluated.

Respirable Fraction—The RF is the fraction of airborne particles that can be transported through air and inhaled into the pulmonary region of the human respiratory system. The RF includes particles having a 10-µm aerodynamic equivalent diameter or less.

Airborne Release Fraction—The ARF is the coefficient used to estimate the amount of material suspended in air as an aerosol, and thus, available for transport. The ARF is related to the physical stresses of a specific accident and the physical characteristics of the material involved in the accident.

Leak Path Factor—The LPF is the fraction of the material in the aerosol transported through some confinement deposition or filtration mechanism.

Calculating Downwind Radioactive Material Doses— As discussed in EDF-3563,[9] the Radiological Safety Analysis Computer Program (RSAC)-6 is used to quantify the consequences of the postulated accidents.[33] RSAC-6 calculates the consequences of the release of radionuclides to the atmosphere. The RSAC-6 input parameters are summarized in Table 3-11.

Table 3-11. Radiological Safety Analysis Computer program input parameters.

RSAC-6 Input Parameters	
Release elevation (m)	0
Stability class	F
Wind speed (m/s)	1.04
Diffusion coefficients	Markee and Hilsmeier-Gifford sigmas
Downwind receptor distance (m)	10 m, 100 m, 3 km, and 6 km
Breathing rate (m^3/second)	3.33E-04 (default parameter)

RSAC Radiological Safety Analysis Computer Program

Receptor locations are at 100 m (328 ft) for the co-located worker, 3 km (9,843 ft or 1.9 mi) for visitors at the EBR-I, and 6 km (19,685 ft or 3.7 mi) at the nearest Site boundary located to the south of the RWMC. A public rest area located on U.S. Highway 20/26 is located 6 km (19,685 ft or 3.7 mi) to the north of the RWMC. Ground releases are assumed for all scenarios including fire. All receptors are exposed during the entire duration of the plume. Assuming a failure to evacuate, all receptors are assumed to be exposed to ground-surface doses for two hours per DOE-STD-3009-94.[5]

Doses are calculated for inhalation, ground surface, and air immersion exposure pathways for the on-Site workers and off-Site public. Calculation of doses for the ingestion pathway is specifically excluded by DOE-STD-3009-94. The sum of the inhalation, ground surface, and air-immersion doses is referred to as the total effective dose equivalent (TEDE). The importance of the inhalation pathway is discussed in DOE-HDBK-3010-94 which states, "the airborne pathway is of primary interest for nonreactor nuclear facilities." DOE-STD-1027-92[4] quotes observations of the Nuclear Regulatory Commission (NRC) to the effect that, "for all materials of greatest interest for fuel cycle and other radioactive material licenses, the dose from the inhalation pathway will dominate the (overall) dose" (NUREG-1140).

3.4.1.2 Nonradioactive Hazardous Material Consequences. As discussed in EDF-3563,[9] the release rate of each nonradioactive hazardous material is determined from the following equation.

RR = (MAR)(CF)(DR)(ARF)(RF)(LPF)/(RT)

where

RR = release rate of each chemical (mg/s)

MAR = material at risk (g)

CF = conversion factor (1,000 mg/g)

DR = damage ratio

ARF = airborne release fraction

RF = respirable fraction

LPF = leak path factor

RT = release time(s).

The release rate is equivalent to the source term and is used to determine downwind and worker consequences expressed in terms of concentrations at the receptor locations. Multiplying the RR by the dispersion coefficient (χ/Q) calculated by RSAC-6 gives the concentration at each receptor location. Therefore, the downwind concentrations are calculated as follows:

Downwind concentrations = (RR) (χ/Q).

The (χ/Q) values from RSAC-6 with the Hilsmeier-Gifford model are 3.217E-02 s/m^3 at 100 m, 1.202E-04 s/m^3 at 3 km, and 4.407E-05 s/m^3 at 6 km. The (χ/Q) values from RSAC-6 with the Markee model are 4.081E-03 s/m^3 at 100 m, 7.445E-05 s/m^3 at 3 km, and 3.355E-05 s/m^3 at 6 km.[9]

3.4.1.3 Evaluation Guidelines. The evaluation guidelines for on- and off-Site receptors are found in DOE-ID Order 420.D. These guidelines are summarized in Section 3.3.1.2. The guideline values are compared to analysis results for the radioactive and nonradioactive hazardous materials of concern in Section 3.4.2.

3.4.2 Design-Basis Accidents

This subsection develops the design-basis and evaluation-basis accidents for the facility worker in the immediate area, the co-located worker, and the off-Site public. In accordance with direction in DOE-STD-3009-94, consequences to the facility workers have been qualitatively assessed, and safety-significant equipment has been identified in the hazard evaluation (see Table 3-9).

3.4.2.1 Direct Radiation Exposure. The hazard analysis in Section 3.3 identified the potential for a direct-radiation exposure to a high-radiation source.

3.4.2.1.1 Scenario Development—This scenario assumes a high-radiation source buried in the SDA is uncovered and exposes workers to direct gamma radiation emanating from the buried object. The object could be exposed during excavation to install the electrodes for ISV processing or as a result of subsidence.

3.4.2.1.2 Occurrence Likelihood—The likelihood of exposure to a high radiation source is judged to be unlikely.

3.4.2.1.3 Source Term Analysis—The source term for exposure to a high radiation source is the radiation emanating from the buried object. As discussed in EDF-3563, the highest dose rate from a package is 24,000 R/h at 2 ft.

3.4.2.1.4 Consequence Analysis—There are no consequences resulting from exposure to nonradioactive hazardous materials for this scenario. Assuming a $1/r^2$ geometric attenuation and a 1-hr exposure time, the co-located worker at 100 m (328 ft) receives a dose of 890 mR. The dose to a public receptor at 6,000 m (19,685 ft) is 0.25 mR.

3.4.2.1.5 Comparison to the Evaluation Guideline—For an unlikely event, the evaluation guidelines are not exceeded or challenged for either the co-located worker or the off-Site receptor.

3.4.2.1.6 Summary of Safety-Class SSCs and TSR Controls—No safety SSCs are required to protect the co-located worker or the off-Site public.

3.4.2.2 Container Deflagration. The hazard analysis in Section 3.3 identified the potential for a deflagration in a buried waste container.

3.4.2.2.1 Scenario Development—This scenario involves the deflagration of a container containing nitrate salts that interact with pyrolyzed combustible wastes or finely divided graphite waste, hydrogen resulting from radiolytic decomposition of organics and plastics, pyrophoric or reactive materials, or pressurized cylinders containing a flammable gas. The analysis includes the original contaminants in the SDA and an estimate of phosgene and hydrochloric acid generation, but does not include any other products resulting from the incomplete combustion of nonradioactive contaminants. To provide a more realistic assessment of the scenario, future studies should include an analysis of products in ISV off-gas. The container is postulated to burst as a result of heat supplied by the ISV process. This reaction has the potential for release of radioactive and nonradioactive hazardous materials and kinetic impact on equipment that has been inserted into the ground.

3.4.2.2.2 Occurrence Likelihood—The likelihood of a container deflagration is estimated to be unlikely. When combined with the unlikely event likelihood, the resulting scenario likelihood is beyond extremely unlikely for an extremely unlikely source term, extremely unlikely for an unlikely source term, and unlikely for an anticipated source term.

3.4.2.2.3 Source Term Analysis—The radioactive and nonradioactive hazardous material source terms are calculated in EDF-3563.[9] The source term is developed for a single drum. However, results of this analysis can be applied to a deflagration with a larger number of drum equivalents by multiplying the consequences reported for this scenario by the number of drum equivalents.

The damage ratio is based on the results of drum explosion tests while the airborne release factors and respirable factors are values from DOE-HDBK-3010-94 for venting of pressurized volumes. The airborne release fraction could be reduced for the activation products in the inventory since the radionuclides would be expected to reside in solid metal objects. However, to be conservative, the airborne release fraction is not reduced for activation products.

The existing overburden provides some filtration of the radioactive material. A deflagration would be expected to loosen but not completely expel the overburden above the deflagration location. The assumption is based on the fact that upper drums would have approximately 3 ft of soil cover, while the average depth of drums would be on the order of 10 ft. If the deflagration resulted from nitrates melting, nitrates would be expected to flow to the next lower level of drums. From these observations, the soil is assumed to behave as a granular bed filter. Based on an analysis of granular bed filters,[34] 10 cm (4 in.) of overburden gives a leak path factor of 0.1. DOE-STD-3009-94 allows the unmitigated analysis to "take credit for passive safety features that are assessed to survive accident conditions where that capability is necessary in order to define a physically meaningful scenario."

For the nonradioactive hazardous material source term, nonvolatile chemicals are treated as radionuclides per DOE-HDBK-3010-94. Volatile chemicals are conservatively assumed to be completely released to the atmosphere.

The asbestos, beryllium, cadmium, and lead in the SDA is considered to be in large pieces and not dispersible. The MAR for asbestos, beryllium, cadmium, and lead is set to 0. Phosgene and hydrochloric acid might be generated by the heat of the deflagration. The analysis assumes that 10% of the chlorinated hydrocarbons decompose to hydrochloric acid and 1% of the halogenated compounds convert to phosgene gas with a molecular conversion ratio of 1.19.[9] To implement the assumption, the quantity of hydrochloric acid is calculated by multiplying the sum of the RR for the chlorinated hydrocarbons (1,1,1-trichloroethane, 1,1,2-trichloro-1,2,2-trifluoroethane, methylene chloride, tetrachloroethylene, trichloroethylene) by 0.1 while the quantity of phosgene is calculated by multiplying the sum of the RR for the halogenated compounds (1,1,1-trichloroethane, 1,1,2-trichloro-1,2,2-trifluoroethane, carbon tetrachloride, chloroform, methylene chloride, tetrachloroethylene, trichloroethylene) by 0.0119. Using the total quantity of chlorinated hydrocarbons and the total quantity of halogenated compounds is extremely conservative since all of the materials would not be expected to simultaneously exist in the same treatment area.

The resulting limiting and average radioactive source terms are listed in Table 3-12, and the limiting and average nonradioactive hazardous material source terms are listed in Table 3-13.

3.4.2.2.4 Consequence Analysis—The dose and concentration consequences from the container deflagration with a 15-min release duration are shown in Tables 3-14 and 3-15. The consequences are calculated using the Hilsmeier-Gifford dispersion model. Doses are presented for the co-located worker at 100 m and the off-site public at 6 km. Concentrations for the co-located worker and the public are presented for the ten nonradioactive materials with the largest ratio of 6 km concentration to 6 km evaluation guideline.

3.4.2.2.5 Comparison to the Evaluation Guideline—The dose and concentration consequences in the container deflagration scenario are compared to the extremely unlikely and unlikely evaluation guidelines in Tables 3-14 and 3-15. Consequences that exceed the corresponding evaluation guideline are shown in ***bold italics***.

3.4.2.2.6 Summary of Safety-Class SSCs and TSR Controls—Based on the accident analyses, safety-significant SSCs are required.

The off-gas hood, the off-gas treatment system, and the toxic gas monitors are designated as safety-significant to protect co-located workers. Requirements for remote operations, an exclusion zone, and controlled access to the hood and operating areas near the hood are TSR-level controls.

3.4.2.3 Underground Fires

The ISV processing would heat up nitrate salts, combustibles, organic materials, and to a smaller extent pyrophoric materials (such as Al powders, Zr powders, or lathe turnings). As the melt-front advances slowly (1 to 2 in./h), temperatures will increase well above the decomposition temperatures of most materials. Moisture in the soil, organic solvents, and oil would be driven off and organic solvents and oil would evaporate and then condense in the soil overburden because of cooler temperatures. Heated mixtures of nitrate salts and combustible materials can potentially burn and deflagrate.

Table 3-12. Limiting and average radioactive hazardous material source terms for the unmitigated underground container deflagration scenario.

Radionuclide	MAR (Ci)	DR	ARF	RF	LPF	ST (Ci)
			Limiting (Unlikely)			
Am-241	1.1E+02	0.33	5.E-03	0.4	0.1	7.0E-03
Co-60	1.7E+02	0.33	5.E-03	0.4	0.1	1.1E-02
Fe-55	1.1E+02	0.33	5.E-03	0.4	0.1	7.5E-03
Cr-51	8.4E+01	0.33	5.E-03	0.4	0.1	5.6E-03
H-3	6.8E+01	0.33	5.E-03	0.4	0.1	4.5E-03
Ni-63	4.0E+01	0.33	5.E-03	0.4	0.1	2.7E-03
Co-58	3.1E+01	0.33	5.E-03	0.4	0.1	2.1E-03
Mn-54	2.5E+01	0.33	5.E-03	0.4	0.1	1.7E-03
Sr-90	2.3E+01	0.33	5.E-03	0.4	0.1	1.5E-03
Cs-137	1.8E+01	0.33	5.E-03	0.4	0.1	1.2E-03
Ce-144	9.1E+00	0.33	5.E-03	0.4	0.1	6.1E-04
			Average (Anticipated)			
Am-241	7.4E-01	0.33	5.E-03	0.4	0.1	4.9E-05
Co-60	1.3E+01	0.33	5.E-03	0.4	0.1	8.4E-04
Fe-55	2.3E+01	0.33	5.E-03	0.4	0.1	1.5E-03
Cr-51	4.5E+00	0.33	5.E-03	0.4	0.1	3.0E-04
H-3	8.4E+00	0.33	5.E-03	0.4	0.1	5.6E-04
Ni-63	7.7E+00	0.33	5.E-03	0.4	0.1	5.1E-04
Co-58	2.1E+00	0.33	5.E-03	0.4	0.1	1.4E-04
Mn-54	1.8E+00	0.33	5.E-03	0.4	0.1	1.2E-04
Sr-90	3.7E+00	0.33	5.E-03	0.4	0.1	2.5E-04
Cs-137	3.6E+00	0.33	5.E-03	0.4	0.1	2.4E-04
Ce-144	8.4E-01	0.33	5.E-03	0.4	0.1	5.6E-05

Table 3-13. Limiting and average nonradioactive hazardous material source terms for the unmitigated underground container deflagration scenario.

Material	MAR (g)	DR	ARF	RF	LPF	RR (mg/s)
						Limiting (Unlikely)
1,1,1-trichloroethane	3.9E+04	0.33	1	1.0	1	1.4E+04
1,1,2-trichloro-1,2,2-trifluoroethane	3.1E+03	0.33	1	1.0	1	1.1E+03
2-butanone	1.3E+01	0.33	1	1.0	1	4.8E+00
Acetone	4.2E+01	0.33	1	1.0	1	1.6E+01
Aluminum nitrate nonahydrate	7.7E+04	0.33	5.E-03	1.0	0.1	1.4E+01
Ammonia	5.8E+02	0.33	1	1.0	1	2.1E+02
Anthracene	1.5E-01	0.33	5.E-03	1.0	0.1	2.8E-05
Antimony	3.2E-01	0.33	5.E-03	1.0	0.1	5.9E-05
Aqua regia	1.0E-02	0.33	1	1.0	1	3.7E-03
Arsenic	3.6E-04	0.33	5.E-03	1.0	0.1	6.7E-08
Asbestos	0.0E+00	0.33	5.E-03	1.0	0.1	0.0E+00
Barium	3.9E-03	0.33	5.E-03	1.0	0.1	7.2E-07
Benzine	1.5E+00	0.33	1	1.0	1	5.6E-01
Beryllium	0.0E+00	0.33	5.E-03	1.0	0.1	0.0E+00
Butyl alcohol	3.5E+01	0.33	1	1.0	1	1.3E+01
Cadmium	0.0E+00	0.33	5.E-03	1.0	0.1	0.0E+00
Carbon tetrachloride	1.3E+05	0.33	1	1.0	1	4.8E+04
Cerium chloride	2.0E+02	0.33	5.E-03	1.0	0.1	3.7E-02
Chloroform	1.2E-02	0.33	1	1.0	1	4.4E-03
Chromium	5.1E-01	0.33	5.E-03	1.0	0.1	9.4E-05
Copper	1.5E+01	0.33	5.E-03	1.0	0.1	2.8E-03
Copper nitrate	1.3E-01	0.33	5.E-03	1.0	0.1	2.4E-05
Ethyl alcohol	9.0E+00	0.33	1	1.0	1	3.3E+00
Formaldehyde	4.8E+01	0.33	1	1.0	1	1.8E+01
Hydrazine	7.4E-01	0.33	1	1.0	1	2.7E-01
Hydrofluoric acid	3.0E+03	0.33	1	1.0	1	1.1E+03
Lead	0.0E+00	0.33	5.E-03	1.0	0.1	0.0E+00
Magnesium	3.5E+03	0.33	5.E-03	1.0	0.1	6.5E-01
Magnesium fluoride	4.5E+01	0.33	5.E-03	1.0	0.1	8.3E-03
Mercury	7.1E+01	0.33	5.E-03	1.0	0.1	1.3E-02
Mercury nitrate monohydrate	3.2E+02	0.33	5.E-03	1.0	0.1	5.9E-02
Methyl alcohol	8.0E+01	0.33	1	1.0	1	3.0E+01
Methyl isobutyl ketone	3.5E+03	0.33	1	1.0	1	1.3E+03
Methylene chloride	4.8E+03	0.33	1	1.0	1	1.8E+03
Nickel	1.3E+00	0.33	5.E-03	1.0	0.1	2.4E-04
Nitric acid	2.0E+02	0.33	1	1.0	1	7.4E+01
Potassium chloride	2.9E+04	0.33	5.E-03	1.0	0.1	5.4E+00
Potassium dichromate	9.6E+02	0.33	5.E-03	1.0	0.1	1.8E-01
Potassium nitrate	7.7E+05	0.33	5.E-03	1.0	0.1	1.4E+02
Potassium phosphate	4.2E+03	0.33	5.E-03	1.0	0.1	7.8E-01
Potassium sulfate	2.9E+04	0.33	5.E-03	1.0	0.1	5.4E+00
Silver	2.3E+00	0.33	5.E-03	1.0	0.1	4.3E-04
Sodium	2.4E+01	0.33	5.E-03	1.0	0.1	4.4E-03
Sodium chloride	5.8E+04	0.33	5.E-03	1.0	0.1	1.1E+01
Sodium cyanide	6.1E-01	0.33	5.E-03	1.0	0.1	1.1E-04
Sodium dichromate	1.7E+03	0.33	5.E-03	1.0	0.1	3.1E-01

Table 3-13. (continued).

Material	MAR (g)	DR	ARF	RF	LPF	RR (mg/s)
Sodium hydroxide	1.1E-01	0.33	5.E-03	1.0	0.1	2.0E-05
Sodium nitrate	1.5E+06	0.33	5.E-03	1.0	0.1	2.8E+02
Sodium phosphate	8.7E+03	0.33	5.E-03	1.0	0.1	1.6E+00
Sodium potassium	7.4E+02	0.33	5.E-03	1.0	0.1	1.4E-01
Sodium sulfate	6.7E+04	0.33	5.E-03	1.0	0.1	1.2E+01
Sulfuric acid	4.8E+01	0.33	1	1.0	1	1.8E+01
Terphenyl	3.2E+02	0.33	5.E-03	1.0	0.1	5.9E-02
Tetrachloroethylene	3.1E+04	0.33	1	1.0	1	1.1E+04
Toluene	8.0E+01	0.33	1	1.0	1	3.0E+01
Tributyl phosphate	4.2E+02	0.33	1	1.0	1	1.6E+02
Trichloroethylene	3.9E+04	0.33	1	1.0	1	1.4E+04
Trimethylolpropane-triester	5.1E+02	0.33	5.E-03	1.0	0.1	9.4E-02
Uranium	1.5E+05	0.33	5.E-03	1.0	0.1	2.7E+01
Uranyl nitrate	9.0E+01	0.33	5.E-03	1.0	0.1	1.7E-02
Versenes (EDTA)	4.5E+02	0.33	5.E-03	1.0	0.1	8.3E-02
Xylene	3.1E+02	0.33	1	1.0	1	1.1E+02
Zirconium	7.4E+03	0.33	5.E-03	1.0	0.1	1.4E+00
Zirconium alloys	2.3E+03	0.33	5.E-03	1.0	0.1	4.3E-01
Zirconium oxide	1.7E+00	0.33	5.E-03	1.0	0.1	3.1E-04
Hydrochloric Acid						4.3E+03
Phosgene						1.1E+03
	Average (Anticipated)					
1,1,1-trichloroethane	3.2E+02	0.33	1	1.0	1	1.2E+02
1,1,2-trichloro-1,2,2-trifluoroethane	2.5E+01	0.33	1	1.0	1	9.3E+00
2-butanone	1.1E-01	0.33	1	1.0	1	4.1E-02
Acetone	3.4E-01	0.33	1	1.0	1	1.3E-01
Aluminum nitrate nonahydrate	6.4E+02	0.33	5.E-03	1.0	0.1	1.2E-01
Ammonia	4.8E+00	0.33	1	1.0	1	1.8E+00
Anthracene	1.2E-03	0.33	5.E-03	1.0	0.1	2.2E-07
Antimony	2.7E-03	0.33	5.E-03	1.0	0.1	5.0E-07
Aqua regia	8.5E-05	0.33	1	1.0	1	3.1E-05
Arsenic	3.0E-06	0.33	5.E-03	1.0	0.1	5.6E-10
Asbestos	0.0E+00	0.33	5.E-03	1.0	0.1	0.0E+00
Barium	3.2E-05	0.33	5.E-03	1.0	0.1	5.9E-09
Benzine	1.3E-02	0.33	1	1.0	1	4.8E-03
Beryllium	0.0E+00	0.33	5.E-03	1.0	0.1	0.0E+00
Butyl alcohol	2.9E-01	0.33	1	1.0	1	1.1E-01
Cadmium	0.0E+00	0.33	5.E-03	1.0	0.1	0.0E+00
Carbon tetrachloride	2.2E+03	0.33	1	1.0	1	8.1E+02
Cerium chloride	1.6E+00	0.33	5.E-03	1.0	0.1	3.0E-04
Chloroform	9.8E-05	0.33	1	1.0	1	3.6E-05
Chromium	4.2E-03	0.33	5.E-03	1.0	0.1	7.8E-07
Copper	1.2E-01	0.33	5.E-03	1.0	0.1	2.2E-05
Copper nitrate	1.1E-03	0.33	5.E-03	1.0	0.1	2.0E-07
Ethyl alcohol	7.4E-02	0.33	1	1.0	1	2.7E-02
Formaldehyde	4.0E-01	0.33	1	1.0	1	1.5E-01
Hydrazine	6.1E-03	0.33	1	1.0	1	2.3E-03
Hydrofluoric acid	2.5E+01	0.33	1	1.0	1	9.3E+00
Lead	0.0E+00	0.33	5.E-03	1.0	0.1	0.0E+00

Table 3-13. (continued).

Material	MAR (g)	DR	ARF	RF	LPF	RR (mg/s)
Magnesium	2.9E+01	0.33	5.E-03	1.0	0.1	5.4E-03
Magnesium fluoride	3.7E-01	0.33	5.E-03	1.0	0.1	6.9E-05
Mercury	5.2E-02	0.33	5.E-03	1.0	0.1	9.6E-06
Mercury nitrate monohydrate	2.7E+00	0.33	5.E-03	1.0	0.1	5.0E-04
Methyl alcohol	6.6E-01	0.33	1	1.0	1	2.4E-01
Methyl isobutyl ketone	2.9E+01	0.33	1	1.0	1	1.1E+01
Methylene chloride	4.0E+01	0.33	1	1.0	1	1.5E+01
Nickel	1.1E-02	0.33	5.E-03	1.0	0.1	2.0E-06
Nitric acid	1.6E+00	0.33	1	1.0	1	5.9E-01
Potassium chloride	2.4E+02	0.33	5.E-03	1.0	0.1	4.4E-02
Potassium dichromate	8.0E+00	0.33	5.E-03	1.0	0.1	1.5E-03
Potassium nitrate	6.4E+03	0.33	5.E-03	1.0	0.1	1.2E+00
Potassium phosphate	3.4E+01	0.33	5.E-03	1.0	0.1	6.3E-03
Potassium sulfate	2.4E+02	0.33	5.E-03	1.0	0.1	4.4E-02
Silver	1.9E-02	0.33	5.E-03	1.0	0.1	3.5E-06
Sodium	2.0E-01	0.33	5.E-03	1.0	0.1	3.7E-05
Sodium chloride	4.8E+02	0.33	5.E-03	1.0	0.1	8.9E-02
Sodium cyanide	5.0E-03	0.33	5.E-03	1.0	0.1	9.3E-07
Sodium dichromate	1.4E+01	0.33	5.E-03	1.0	0.1	2.6E-03
Sodium hydroxide	9.0E-04	0.33	5.E-03	1.0	0.1	1.7E-07
Sodium nitrate	1.2E+04	0.33	5.E-03	1.0	0.1	2.2E+00
Sodium phosphate	7.2E+01	0.33	5.E-03	1.0	0.1	1.3E-02
Sodium potassium	6.1E+00	0.33	5.E-03	1.0	0.1	1.1E-03
Sodium sulfate	5.6E+02	0.33	5.E-03	1.0	0.1	1.0E-01
Sulfuric acid	4.0E-01	0.33	1	1.0	1	1.5E-01
Terphenyl	2.7E+00	0.33	5.E-03	1.0	0.1	5.0E-04
Tetrachloroethylene	2.6E+02	0.33	1	1.0	1	9.6E+01
Toluene	6.6E-01	0.33	1	1.0	1	2.4E-01
Tributyl phosphate	3.4E+00	0.33	1	1.0	1	1.3E+00
Trichloroethylene	3.2E+02	0.33	1	1.0	1	1.2E+02
Trimethylolpropane-triester	4.2E+00	0.33	5.E-03	1.0	0.1	7.8E-04
Uranium	1.2E+03	0.33	5.E-03	1.0	0.1	2.2E-01
Uranyl nitrate	7.4E-01	0.33	5.E-03	1.0	0.1	1.4E-04
Versenes (EDTA)	7.4E+01	0.33	5.E-03	1.0	0.1	1.4E-02
Xylene	2.6E+00	0.33	1	1.0	1	9.6E-01
Zirconium	6.1E+01	0.33	5.E-03	1.0	0.1	1.1E-02
Zirconium alloys	1.9E+01	0.33	5.E-03	1.0	0.1	3.5E-03
Zirconium oxide	1.4E-02	0.33	5.E-03	1.0	0.1	2.6E-06
Hydrochloric Acid						3.6E+01
Phosgene						1.4E+01

Table 3-14. Dose consequences in the unmitigated underground container deflagration scenario.

Frequency Category	Co-located Worker Total Effective Dose Equivalent (rem)	Co-located Worker Evaluation Guidelines for Total Effective Dose Equivalent (rem)	Public (6 km) Total Effective Dose Equivalent (rem)	Public Evaluation Guidelines for Total Effective Dose Equivalent (rem)
Extremely Unlikely	33	100	0.046	25
Unlikely	0.24	25	0.00033	5

NOTE: Bold italics denotes evaluation guideline exceeded.

Table 3-15. Concentration consequences in the unmitigated underground container deflagration scenario.

Frequency Category	Material	Co-located Worker Exposure Concentration (mg/m^3)	Co-located Worker Evaluation Guidelines (mg/m^3)	Public (6 km) Exposure Concentration (mg/m^3)	Public Evaluation Guidelines (mg/m^3)
			ERPG-3		ERPG-2
Extremely Unlikely	Phosgene	***35***	4	0.048	0.8
	Hydrochloric acid	140	224	0.19	30
	Carbon tetrachloride	1500	4790	2.1	639
	Hydrofluoric acid	36	41	0.049	16.4
	Sodium nitrate	8.9	100	0.012	7.5
	Uranium	0.87	10	0.0012	1
	Tributyl phosphate	5.0	300	0.0069	10
	Tetrachloroethylene	370	6890	0.51	1378
	Potassium nitrate	4.6	500	0.0063	20
	Trichloroethylene	460	26900	0.63	2690
			ERPG-3		ERPG-1
Unlikely	Phosgene	0.45	4	0.00061	0.4
	Hydrochloric acid	1.1	224	0.0016	4.5
	Carbon tetrachloride	26	4790	0.036	128
	Hydrofluoric acid	0.30	41	0.00041	1.5
	Sodium nitrate	0.071	100	9.8E-05	1
	Uranium	0.0072	10	9.8E-06	0.6
	Potassium nitrate	0.038	500	5.2E-05	3.5
	Trichloroethylene	3.8	26900	0.0052	538
	Tributyl phosphate	0.041	300	5.5E-05	6
	Nitric acid	0.019	200	2.6E-05	3

NOTE: Bold italics denotes evaluation guideline exceeded

The exothermic pyrolytic decomposition of combustible materials would occur above 280°C. Hence, most combustibles would undergo pyrolytic decomposition. Potential sources for oxygen are decomposed nitrate salts. Air intrusion from the surface to the subsurface at least 7.5 ft below the grade will not supply a sufficient quantity of air to maintain a fire. Hence, in the anaerobic subsurface condition, combustion of combustible materials and/or pyrolyzates will not occur, unless a sufficient quantity of oxygen can be supplied and a significant surface area for combustion is available.

Another safety issue is additional off-gas evolving from the fire and exceeding the capacity of the off-gas treatment system.

3.4.2.3.1 Scenario Development—A seam of waste drums containing nitrate and other organic fuel material may be ignited by the thermal front of the ISV process and produce a smoldering underground fire. The analysis includes the original contaminants in the SDA and an estimate of phosgene and hydrochloric acid generation, but does not include any other products resulting from the incomplete combustion of nonradioactive contaminants. To provide a more realistic assessment of the scenario, future studies should include an analysis of products in ISV off-gas. Analysis for the underground fire scenario is bounded by an unmitigated release from a 900-ft^2 (30 × 30-ft) treatment area. Use of a 900-ft^2 treatment area is justified based on electrode spacing and hood diameter. Electrode spacing[7] may range from 7 to 25 ft and the hood diameter[35] is 60 ft.

3.4.2.3.2 Occurrence Likelihood—The likelihood of having mixtures of combustible materials and sufficient oxygen to support combustion is considered to be extremely unlikely. When the extremely unlikely event likelihood is combined with the source term likelihood, the resulting scenario likelihood is beyond extremely unlikely for an extremely unlikely source term, beyond extremely unlikely for an unlikely source term, and extremely unlikely for an anticipated source term.

3.4.2.3.3 Source Term Analysis—The radioactive and nonradioactive hazardous material source terms are calculated in EDF-3563.[9] The source term is developed for a MAR that includes the bounding 900-ft^2 ISV treatment area.

The damage ratio is based on the affected area of the ISV treatment area. The underground fire is expected to affect only a small area of the ISV treatment area since oxygen is limited. The underground fire is assumed to occur in a 25-ft^2 (5 by 5-ft) area. The damage ratio, calculated as the ratio of the affected area to the treatment area, is 0.028 (25 ft^2/900 ft^2).

The airborne release factors and respirable factors are values from DOE-HDBK-3010-94 for contaminated, combustible solids exposed to thermal stress. The airborne release fraction could be reduced for the activation products in the inventory since the radionuclides would be expected to reside in solid metal objects. However, to be conservative, the airborne release fraction is not reduced for activation products.

The existing overburden provides some filtration of the radioactive material. The soil is assumed to behave as a granular bed filter. Based on an analysis of granular bed filters,[34] 10 cm (4 in.) of overburden gives a leak path factor of 0.1. DOE STD-3009-946 allows the unmitigated analysis to "take credit for passive safety features that are assessed to survive accident conditions where that capability is necessary in order to define a physically meaningful scenario."

For the nonradioactive hazardous material source term, nonvolatile chemicals are treated as radionuclides, per DOE-HDBK-3010-94. Volatile chemicals are conservatively assumed to be completely released to the atmosphere. In addition to the volatile organic compounds, antimony, arsenic, cadmium, lead, and mercury have the potential to volatilize. The boiling points for antimony, arsenic, cadmium, lead, and mercury are 1,438°C, 610°C, 765°C, 1,738°C, and 357°C, respectively. Based on the magnitude of the boiling points, only mercury is assumed to volatilize in the underground fire and is treated as a volatile chemical.

The asbestos in the SDA is considered to be in large pieces and not dispersible. The beryllium, cadmium, and lead are expected to remain in large pieces and are not dispersible. The inventory for asbestos, beryllium, cadmium, and lead is therefore set to 0. No organic destruction is assumed to occur during the underground fire. Phosgene and hydrochloric acid might be generated by the heat of the underground fire. The analysis assumes that 10% of the chlorinated hydrocarbons decompose to hydrochloric acid and 1% of the halogenated compounds convert to phosgene gas with a molecular conversion ratio of 1.19.[9] To implement the assumption, the quantity of hydrochloric acid is calculated by multiplying the sum of the RR for the chlorinated hydrocarbons (1,1,1-trichloroethane, 1,1,2-trichloro-1,2,2-trifluoroethane, methylene chloride, tetrachloroethylene, trichloroethylene) by 0.1 while the quantity of phosgene is calculated by multiplying the sum of the RR for the halogenated compounds (1,1,1-trichloroethane, 1,1,2-trichloro-1,2,2-trifluoroethane, carbon tetrachloride, chloroform, methylene chloride, tetrachloroethylene, trichloroethylene) by 0.0119. Using the total quantity of chlorinated hydrocarbons and the total quantity of halogenated compounds is extremely conservative since all of the materials would not be expected to simultaneously exist in the same treatment area.

The resulting average radioactive source term is listed in Table 3-16, and the average nonradioactive hazardous material source term is listed in Table 3-17.

Table 3-16. Average radioactive hazardous material source terms for the unmitigated underground fire scenario.

Radionuclide	MAR (Ci)	DR	ARF	RF	LPF	ST (Ci)
			Average (Anticipated)			
Pu-239	9.4E+02	0.028	5.E-04	1.0	0.1	1.3E-03
Co-60	1.6E+03	0.028	5.E-04	1.0	0.1	2.3E-03
Fe-55	3.0E+03	0.028	5.E-04	1.0	0.1	4.2E-03
Cr-51	5.8E+02	0.028	5.E-04	1.0	0.1	8.1E-04
H-3	1.1E+03	0.028	5.E-04	1.0	0.1	1.5E-03
Ni-63	9.9E+02	0.028	5.E-04	1.0	0.1	1.4E-03
Co-58	2.7E+02	0.028	5.E-04	1.0	0.1	3.8E-04
Mn-54	2.3E+02	0.028	5.E-04	1.0	0.1	3.2E-04
Sr-90	4.8E+02	0.028	5.E-04	1.0	0.1	6.7E-04
Cs-137	4.6E+02	0.028	5.E-04	1.0	0.1	6.4E-04
Cs-144	1.1E+02	0.028	5.E-04	1.0	0.1	1.5E-04

Table 3-17. Average nonradioactive hazardous material source terms for the unmitigated underground fire scenario.

Material	MAR (g)	DR	ARF	RF	LPF	RR (mg/s)
	Average (Anticipated)					
1,1,1-trichloroethane	1.5E+05	0.028	1	1.0	1	1.2E+03
1,1,2-trichloro-1,2,2-trifluoroethane	1.2E+04	0.028	1	1.0	1	9.1E+01
2-butanone	5.0E+01	0.028	1	1.0	1	3.9E-01
Acetone	1.6E+02	0.028	1	1.0	1	1.3E+00
Aluminum nitrate nonahydrate	3.1E+05	0.028	5.E-04	1.0	0.1	1.2E-01
Ammonia	2.3E+03	0.028	1	1.0	1	1.8E+01
Anthracene	5.9E-01	0.028	5.E-04	1.0	0.1	2.3E-07
Antimony	1.3E+00	0.028	5.E-04	1.0	0.1	4.9E-07
Aqua regia	4.1E-02	0.028	1	1.0	1	3.2E-04
Arsenic	1.4E-03	0.028	5.E-04	1.0	0.1	5.6E-10
Asbestos	0.0E+00	0.028	5.E-04	1.0	0.1	0.0E+00
Barium	1.5E-02	0.028	5.E-04	1.0	0.1	6.0E-09
Benzine	6.0E+00	0.028	1	1.0	1	4.7E-02
Beryllium	0.0E+00	0.028	5.E-04	1.0	0.1	0.0E+00
Butyl alcohol	1.4E+02	0.028	1	1.0	1	1.1E+00
Cadmium	0.0E+00	0.028	5.E-04	1.0	0.1	0.0E+00
Carbon tetrachloride	1.1E+06	0.028	1	1.0	1	8.4E+03
Cerium chloride	7.8E+02	0.028	5.E-04	1.0	0.1	3.0E-04
Chloroform	4.7E-02	0.028	1	1.0	1	3.6E-04
Chromium	2.0E+00	0.028	5.E-04	1.0	0.1	7.7E-07
Copper	5.7E+01	0.028	5.E-04	1.0	0.1	2.2E-05
Copper nitrate	5.2E-01	0.028	5.E-04	1.0	0.1	2.0E-07
Ethyl alcohol	3.5E+01	0.028	1	1.0	1	2.7E-01
Formaldehyde	1.9E+02	0.028	1	1.0	1	1.5E+00
Hydrazine	2.9E+00	0.028	1	1.0	1	2.2E-02
Hydrofluoric acid	1.2E+04	0.028	1	1.0	1	9.1E+01
Lead	0.0E+00	0.028	5.E-04	1.0	0.1	0.0E+00
Magnesium	1.4E+04	0.028	5.E-04	1.0	0.1	5.3E-03
Magnesium fluoride	1.8E+02	0.028	5.E-04	1.0	0.1	7.0E-05
Mercury	2.4E+01	0.028	1	1.0	1	1.9E-01
Mercury nitrate monohydrate	1.3E+03	0.028	5.E-04	1.0	0.1	4.9E-04
Methyl alcohol	3.2E+02	0.028	1	1.0	1	2.5E+00
Methyl isobutyl ketone	1.4E+04	0.028	1	1.0	1	1.1E+02
Methylene chloride	1.9E+04	0.028	1	1.0	1	1.5E+02
Nickel	5.2E+00	0.028	5.E-04	1.0	0.1	2.0E-06
Nitric acid	7.7E+02	0.028	1	1.0	1	6.0E+00
Potassium chloride	1.2E+05	0.028	5.E-04	1.0	0.1	4.6E-02
Potassium dichromate	3.8E+03	0.028	5.E-04	1.0	0.1	1.5E-03
Potassium nitrate	3.1E+06	0.028	5.E-04	1.0	0.1	1.2E+00
Potassium phosphate	1.6E+04	0.028	5.E-04	1.0	0.1	6.3E-03
Potassium sulfate	1.2E+05	0.028	5.E-04	1.0	0.1	4.6E-02
Silver	9.0E+00	0.028	5.E-04	1.0	0.1	3.5E-06
Sodium	9.9E+01	0.028	5.E-04	1.0	0.1	3.9E-05
Sodium chloride	2.3E+05	0.028	5.E-04	1.0	0.1	8.8E-02
Sodium cyanide	2.4E+00	0.028	5.E-04	1.0	0.1	9.5E-07

Table 3-17. (continued).

Material	MAR (g)	DR	ARF	RF	LPF	RR (mg/s)
Sodium dichromate	6.8E+03	0.028	5.E-04	1.0	0.1	2.7E-03
Sodium hydroxide	4.3E-01	0.028	5.E-04	1.0	0.1	1.7E-07
Sodium nitrate	5.8E+06	0.028	5.E-04	1.0	0.1	2.3E+00
Sodium phosphate	3.4E+04	0.028	5.E-04	1.0	0.1	1.3E-02
Sodium potassium	2.9E+03	0.028	5.E-04	1.0	0.1	1.1E-03
Sodium sulfate	2.6E+05	0.028	5.E-04	1.0	0.1	1.0E-01
Sulfuric acid	1.9E+02	0.028	1	1.0	1	1.5E+00
Terphenyl	1.3E+03	0.028	5.E-04	1.0	0.1	4.9E-04
Tetrachloroethylene	1.3E+05	0.028	1	1.0	1	9.8E+02
Toluene	3.2E+02	0.028	1	1.0	1	2.5E+00
Tributyl phosphate	1.6E+03	0.028	1	1.0	1	1.3E+01
Trichloroethylene	1.5E+05	0.028	1	1.0	1	1.2E+03
Trimethylolpropane-triester	2.0E+03	0.028	5.E-04	1.0	0.1	7.7E-04
Uranium	5.9E+05	0.028	5.E-04	1.0	0.1	2.3E-01
Uranyl nitrate	3.5E+02	0.028	5.E-04	1.0	0.1	1.4E-04
Versenes (EDTA)	2.8E+04	0.028	5.E-04	1.0	0.1	1.1E-02
Xylene	1.3E+03	0.028	1	1.0	1	9.8E+00
Zirconium	2.9E+04	0.028	5.E-04	1.0	0.1	1.1E-02
Zirconium alloys	9.0E+03	0.028	5.E-04	1.0	0.1	3.5E-03
Zirconium oxide	6.7E+00	0.028	5.E-04	1.0	0.1	2.6E-06
Hydrochloric Acid						3.6E+02
Phosgene						1.4E+02

3.4.2.3.4 Consequence Analysis—The bounding dose and exposure consequences from the underground fire with a 1-hr release duration are shown in Tables 3-18 and 3-19. The consequences are calculated using the Markee dispersion model. Doses are presented for the co-located worker at 100 m and the off-Site public at 6 km. Concentrations for the co-located worker and the public are presented for the ten nonradioactive materials with the largest ratio of 6 km concentration to 6 km evaluation guideline.

3.4.2.3.5 Comparison to the Evaluation Guideline—The dose and concentration consequences in the underground fire scenario are compared to the extremely unlikely evaluation guidelines in Tables 3-18 and 3-19. Consequences that exceed the corresponding evaluation guideline are shown in ***bold italics***. None of the evaluation guidelines are exceeded for radioactive or nonradioactive material releases.

Table 3-18. Dose consequences in the unmitigated underground fire scenario.

Frequency Category	Co-located Worker Total Effective Dose Equivalent (rem)	Co-located Worker Evaluation Guidelines for Total Effective Dose Equivalent (rem)	Public (6 km) Total Effective Dose Equivalent (rem)	Public Evaluation Guidelines for Total Effective Dose Equivalent (rem)
Extremely Unlikely	0.77	100	0.0063	25

Table 3-19. Concentration consequences in the unmitigated underground fire scenario.

Frequency Category	Material	Co-located Worker Exposure Concentration (mg/m^3)	Co-located Worker Evaluation Guidelines (mg/m^3)	Public (6 km) Exposure Concentration (mg/m^3)	Public Evaluation Guidelines (mg/m^3)
			ERPG-3		ERPG-2
Extremely Unlikely	Phosgene	0.58	4	0.0048	0.8
	Carbon tetrachloride	34	4790	0.28	639
	Hydrochloric Acid	1.5	224	0.012	30
	Hydrofluoric acid	0.37	41	0.0031	16.4
	Tributyl phosphate	0.051	300	0.00042	10
	Tetrachloroethylene	4.0	6890	0.033	1378
	Trichloroethylene	4.8	26900	0.040	2690
	Nitric acid	0.025	200	0.00020	15
	1,1,1-trichloroethane	4.9	19250	0.040	3850
	Sodium nitrate	0.0093	100	7.6E-05	7.5

3.4.2.3.6 Summary of Safety-Class SSCs and TSR Controls— Based on the bounding accident analyses, safety SSCs and TSRs are not required.

3.4.2.4 Melt Expulsion. The hazard analysis in Section 3.3 identified the potential for a melt expulsion accident. The melt expulsion scenario assumes that pressures build beneath the melt and cause melt expulsion.

Sludge drums received from the RFP contain both organic and inorganic compounds. An expulsion could occur due to the heating of co-mingled nitrate salts and pyrolyzed combustibles as a result of the melting process. The majority of the glass involved in an expulsion event will simply overflow onto the surface of the ground around the subsidence volume. Some splattering may occur, with small globules of melt thrown from the melt zone. This will only occur when there is a clear pathway for the ejectate to pass through. Hazardous gases and radioactive materials would be released to the atmosphere.

Though not commonly buried in transuranic pits and trenches at the SDA, there is a small chance that a partially full, sealed-gas cylinder may be encountered during ISV processing at the SDA. A melt expulsion could occur upon the sudden depressurization of such a sealed-gas cylinder.

High water saturation may exist above the basalt seam in each treatment area. The basalt sublayer may not be permeable enough to allow sufficient venting as the ISV melt moves into it. If that is the case, there is a chance of a melt expulsion occurring as the ISV melt moves into the basalt sublayer.

In order for ISV melt expulsion to occur, a source of water or other liquids must be present. Preconditioning of the waste material could break down barriers in the waste seam and provide flow paths that would cause off-gases to be released. In addition, the soil at the SDA is much less moist and the water table is significantly below the bottom of the melt thus the amount of water will be limited to that of discontinuous perched water bodies that may be present in the soil areas directly above the basalt sublayer.

3.4.2.4.1 Scenario Development—Two fundamental criteria are critical to the development of a melt expulsion. These criteria are: (1) buildup of pressure that exceeds the static hydraulic pressure of the molten body and the weight of the overburden, and (2) the existence of barriers that would prevent the venting of the vapor and allow sufficient buildup of the pressure.

The materials being melted in the ISV area are the soil backfill material, buried waste containers, and the layer of soil underburden. The primary target of ISV is the seam of waste drums and boxes and the backfilling soil between containers. Most drums contain pyrolyzable materials that are not full, and would become voids as the ISV melting proceeds. The different melting methods are discussed in Section 2.5.1.

The analysis includes the original contaminants in SDA and an estimate of phosgene and hydrochloric acid generation but does not include any other products resulting from the incomplete combustion of nonradioactive contaminants. To provide a more realistic assessment of the scenario, future studies should include an analysis of products in ISV off-gas. Analysis for the melt expulsion scenario is bounded by an unmitigated release from a 900-ft^2 (30 by 30-ft) treatment area. Use of a 900-ft^2 treatment area is justified based on electrode spacing and hood diameter. Electrode spacing[7] may range from 7 to 25 ft, and the hood diameter[35] is 60 ft.

***3.4.2.4.2 Occurrence Likelihood*—**By using planar-ISV, rather than top-down ISV, two distinct melt bodies are formed rather than of one. These melts grow in both the lateral and downward directions during the process. With the judicious placement and orientation of the starter planes, the process can be performed so that much of the waste zone is processed before the melts merge into one monolith. Consequently, there is always a column of porous, permeable soil through which the gases generated by the melt process must migrate before introduction to the off-gas treatment system. Therefore, the potential of a melt expulsion is almost negated. In addition, any gas generation or pressure relief processes that may develop during this phase will have a reduced impact on the system, as only half the total melt volume is affected. The likelihood of a melt expulsion occurring with subsurface planar ISV is considered extremely unlikely. To account for the possibility that the likelihood of a melt expulsion could be greater if one of the other ISV methods is chosen, the likelihood of a melt expulsion accident is considered to be anticipated. When combined with the anticipated event likelihood, the resulting scenario likelihood is extremely unlikely for an extremely unlikely source term (10^{-1} x 10^{-4} = 10^{-5}), unlikely for an unlikely source term (10^{-1} x 10^{-2} = 10^{-3}), and unlikely for an anticipated source term (10^{-1} x 10^{-1} = 10^{-2}).

***3.4.2.4.3 Source Term Analysis*—**The radioactive and nonradioactive hazardous material source terms are calculated in EDF-3563.[9] The source term is developed for a MAR that includes the bounding 900-ft^2 ISV treatment area.

The damage ratio is based on the affected volume of material. A melt expulsion that occurred at the ORNL in 1996 is assumed to be a typical melt expulsion event. The melt expulsion at ORNL expelled 20 ton of melt and matrix material.[36] Assuming that the glass density is 177 lb/ft^3, the volume of glass is 225 ft^3 (20 ton × 2,000 lb/ton/177 lb/ft^3). Assuming that the ISV treatment area at the SDA is 10 ft thick, the volume in the treatment area is 9,000 ft^3 (900 ft^2 × 10 ft). The damage ratio, calculated as the ratio of the affected volume to the treatment area volume, is 0.025 (255 ft^3/9,000 ft^3).

The airborne release factors and respirable factors are values from DOE-HDBK-3010-94 for "accelerated gas flows in area without significant pressurization." The airborne release fraction could be reduced for the activation products in the inventory, since the radionuclides would be expected to reside in solid metal objects. However, to be conservative, the airborne release fraction is not reduced for activation products.

An LPF of 1 is assigned because the material breaches the surface of the treatment area.

For the nonradioactive hazardous material source term, nonvolatile chemicals are treated as radionuclides per DOE-HDBK-3010-94. Volatile chemicals are conservatively assumed to be completely released to the atmosphere. In addition to the volatile organic compounds, antimony, arsenic, cadmium, lead, and mercury have the potential to volatilize. The boiling points for antimony, arsenic, cadmium, lead, and mercury are 1,438°C, 610°C, 765°C, 1,738°C, and 357°C, respectively. The temperatures associated with the melt expulsion could be as high as 2,000°C. However, any lead that melted would be expected to partition to a region below the glass and any lead that was not melted would be expected to be in large chunks and not dispersible. Based on these considerations, antimony, arsenic, cadmium, and mercury are assumed to volatilize in the melt expulsion, and are treated as volatile chemicals.

The asbestos in the SDA is considered to be in large pieces and not dispersible. The MAR for asbestos is set to 0. Normally the organic destruction efficiency is greater than 99%[37] during ISV processing. Because some of the organics would be destroyed prior to a melt expulsion, only 50% of the organics in the nonradioactive inventory are assumed to be at risk of release and included in the MAR. Phosgene and hydrochloric acid might be generated because the melt expulsion occurs before the chlorinated hydrocarbons and halogenated compounds are completely destroyed. The analysis assumes that 10% of the chlorinated hydrocarbons decompose to hydrochloric acid and 1% of the halogenated compounds convert to phosgene gas with a molecular conversion ratio of 1.19.[9] To implement the assumption, the quantity of hydrochloric acid is calculated by multiplying the sum of the release rate for the chlorinated hydrocarbons (1,1,1-trichloroethane, 1,1,2-trichloro-1,2,2-trifluoroethane, methylene chloride, tetrachloroethylene, trichloroethylene) by 0.1 while the quantity of phosgene is calculated by multiplying the sum of the release rate for the halogenated compounds (1,1,1-trichloroethane, 1,1,2-trichloro-1,2,2-trifluoroethane, carbon tetrachloride, chloroform, methylene chloride, tetrachloroethylene, trichloroethylene) by 0.0119. Using the total quantity of chlorinated hydrocarbons and the total quantity of halogenated compounds is extremely conservative, since all of the materials would not be expected to simultaneously exist in the same treatment area.

The resulting limiting and average radioactive source terms are listed in Table 3-20 while the limiting and average nonradioactive hazardous material source terms are listed in Table 3-21.

3.4.2.4.4 Consequence Analysis—The greatest danger in a melt expulsion incident is on the ground surface around the perimeter of the hood; the jetting of hot off-gas and flow of molten material occurs in this zone. The dose and concentration consequences from the melt expulsion with a 15-min release duration are shown in Tables 3-22 and 3-23. The consequences are calculated using the Hilsmeier-Gifford dispersion model. Doses are presented for the co-located worker at 100 m and the off-Site public at 6 km. Concentrations for the co-located worker and the public are presented for the ten nonradioactive materials with the largest ratio of 6 km concentration to 6 km evaluation guideline.

Table 3-20. Upper bound, limiting, and average radioactive hazardous material source term for the unmitigated melt expulsion scenario.

Radionuclide	MAR (Ci)	DR	ARF	RF	LPF	ST (Ci)
			Upper Bound (Extremely Unlikely)			
Pu-239	2.8E+03	0.025	5.E-03	0.3	1	1.1E-01
Co-60	3.9E+04	0.025	5.E-03	0.3	1	1.5E+00
Fe-55	1.4E+04	0.025	5.E-03	0.3	1	5.4E-01
Cr-51	1.1E+04	0.025	5.E-03	0.3	1	4.1E-01
H-3	8.7E+03	0.025	5.E-03	0.3	1	3.3E-01
Ni-63	5.1E+03	0.025	5.E-03	0.3	1	1.9E-01
Co-58	4.0E+03	0.025	5.E-03	0.3	1	1.5E-01
Mn-54	3.2E+03	0.025	5.E-03	0.3	1	1.2E-01
Sr-90	3.0E+03	0.025	5.E-03	0.3	1	1.1E-01
Cs-137	2.3E+03	0.025	5.E-03	0.3	1	8.4E-02
Ce-144	1.2E+03	0.025	5.E-03	0.3	1	4.4E-02
			Limiting (Unlikely)			
Pu-239	9.7E+02	0.025	5.E-03	0.3	1	3.6E-02
Co-60	2.2E+04	0.025	5.E-03	0.3	1	8.1E-01
Fe-55	1.4E+04	0.025	5.E-03	0.3	1	5.4E-01
Cr-51	1.1E+04	0.025	5.E-03	0.3	1	4.1E-01
H-3	8.7E+03	0.025	5.E-03	0.3	1	3.3E-01
Ni-63	5.1E+03	0.025	5.E-03	0.3	1	1.9E-01
Co-58	4.0E+03	0.025	5.E-03	0.3	1	1.5E-01
Mn-54	3.2E+03	0.025	5.E-03	0.3	1	1.2E-01
Sr-90	3.0E+03	0.025	5.E-03	0.3	1	1.1E-01
Cs-137	2.3E+03	0.025	5.E-03	0.3	1	8.4E-02
Ce-144	1.2E+03	0.025	5.E-03	0.3	1	4.4E-02
			Average (Anticipated)			
Pu-239	9.4E+02	0.025	5.E-03	0.3	1	3.5E-02
Co-60	1.6E+03	0.025	5.E-03	0.3	1	6.1E-02
Fe-55	3.0E+03	0.025	5.E-03	0.3	1	1.1E-01
Cr-51	5.8E+02	0.025	5.E-03	0.3	1	2.2E-02
H-3	1.1E+03	0.025	5.E-03	0.3	1	4.1E-02
Ni-63	9.9E+02	0.025	5.E-03	0.3	1	3.7E-02
Co-58	2.7E+02	0.025	5.E-03	0.3	1	1.0E-02
Mn-54	2.3E+02	0.025	5.E-03	0.3	1	8.4E-03
Sr-90	4.8E+02	0.025	5.E-03	0.3	1	1.8E-02
Cs-137	4.6E+02	0.025	5.E-03	0.3	1	1.7E-02
Ce-144	1.1E+02	0.025	5.E-03	0.3	1	4.1E-03

Table 3-21. Upper bound, limiting, and average nonradioactive hazardous material source term for the unmitigated melt expulsion scenario.

Material	MAR (g)	DR	ARF	RF	LPF	RR (mg/s)
		Upper Bound (Extremely Unlikely)				
1,1,1-trichloroethane	6.3E+06	0.025	1	1.0	1	1.8E+05
1,1,2-trichloro-1,2,2-trifluoroethane	5.0E+05	0.025	1	1.0	1	1.4E+04
2-butanone	2.1E+03	0.025	1	1.0	1	5.8E+01
Acetone	6.8E+03	0.025	1	1.0	1	1.9E+02
Aluminum nitrate nonahydrate	2.4E+07	0.025	5.E-03	1.0	1	3.4E+03
Ammonia	1.9E+05	0.025	1	1.0	1	5.3E+03
Anthracene	4.8E+01	0.025	5.E-03	1.0	1	6.6E-03
Antimony	9.9E+01	0.025	1	1.0	1	2.8E+00
Aqua regia	3.3E+00	0.025	1	1.0	1	9.3E-02
Arsenic	1.2E-01	0.025	1	1.0	1	3.3E-03
Asbestos	0.0E+00	0.025	5.E-03	1.0	1	0.0E+00
Barium	1.3E+00	0.025	5.E-03	1.0	1	1.8E-04
Benzine	2.5E+02	0.025	1	1.0	1	6.9E+00
Beryllium	7.6E+04	0.025	5.E-03	1.0	1	1.1E+01
Butyl alcohol	1.2E+04	0.025	1	1.0	1	3.3E+02
Cadmium	9.7E+03	0.025	1	1.0	1	2.7E+02
Carbon tetrachloride	2.1E+07	0.025	1	1.0	1	5.9E+05
Cerium chloride	6.4E+04	0.025	5.E-03	1.0	1	8.9E+00
Chloroform	1.9E+00	0.025	1	1.0	1	5.3E-02
Chromium	1.6E+02	0.025	5.E-03	1.0	1	2.3E-02
Copper	4.7E+03	0.025	5.E-03	1.0	1	6.5E-01
Copper nitrate	4.2E+01	0.025	5.E-03	1.0	1	5.9E-03
Ethyl alcohol	2.9E+03	0.025	1	1.0	1	8.0E+01
Formaldehyde	1.5E+04	0.025	1	1.0	1	4.3E+02
Hydrazine	2.3E+02	0.025	1	1.0	1	6.5E+00
Hydrofluoric acid	9.9E+05	0.025	1	1.0	1	2.8E+04
Lead	2.2E+07	0.025	5.E-03	1.0	1	3.1E+03
Magnesium	1.2E+06	0.025	5.E-03	1.0	1	1.6E+02
Magnesium fluoride	1.4E+04	0.025	5.E-03	1.0	1	2.0E+00
Mercury	2.3E+04	0.025	1	1.0	1	6.3E+02
Mercury nitrate monohydrate	9.9E+04	0.025	5.E-03	1.0	1	1.4E+01
Methyl alcohol	2.6E+04	0.025	1	1.0	1	7.3E+02
Methyl isobutyl ketone	1.2E+06	0.025	1	1.0	1	3.3E+04
Methylene chloride	7.7E+05	0.025	1	1.0	1	2.1E+04
Nickel	4.2E+02	0.025	5.E-03	1.0	1	5.9E-02
Nitric acid	6.3E+04	0.025	1	1.0	1	1.8E+03
Potassium chloride	9.0E+06	0.025	5.E-03	1.0	1	1.3E+03
Potassium dichromate	3.1E+05	0.025	5.E-03	1.0	1	4.3E+01
Potassium nitrate	2.4E+08	0.025	5.E-03	1.0	1	3.4E+04
Potassium phosphate	1.4E+06	0.025	5.E-03	1.0	1	1.9E+02
Potassium sulfate	9.0E+06	0.025	5.E-03	1.0	1	1.3E+03
Silver	7.6E+02	0.025	5.E-03	1.0	1	1.1E-01
Sodium	7.7E+03	0.025	5.E-03	1.0	1	1.1E+00
Sodium chloride	1.9E+07	0.025	5.E-03	1.0	1	2.6E+03
Sodium cyanide	2.0E+02	0.025	5.E-03	1.0	1	2.8E-02

Table 3-21. (continued).

Material	MAR (g)	DR	ARF	RF	LPF	RR (mg/s)
Sodium dichromate	5.6E+05	0.025	5.E-03	1.0	1	7.8E+01
Sodium hydroxide	3.5E+01	0.025	5.E-03	1.0	1	4.9E-03
Sodium nitrate	4.8E+08	0.025	5.E-03	1.0	1	6.6E+04
Sodium phosphate	2.8E+06	0.025	5.E-03	1.0	1	3.9E+02
Sodium potassium	2.3E+05	0.025	5.E-03	1.0	1	3.3E+01
Sodium sulfate	2.2E+07	0.025	5.E-03	1.0	1	3.0E+03
Sulfuric acid	1.5E+04	0.025	1	1.0	1	4.3E+02
Terphenyl	9.9E+04	0.025	5.E-03	1.0	1	1.4E+01
Tetrachloroethylene	5.0E+06	0.025	1	1.0	1	1.4E+05
Toluene	1.3E+04	0.025	1	1.0	1	3.6E+02
Tributyl phosphate	1.4E+05	0.025	1	1.0	1	3.8E+03
Trichloroethylene	6.3E+06	0.025	1	1.0	1	1.7E+05
Trimethylolpropane-triester	1.6E+05	0.025	5.E-03	1.0	1	2.3E+01
Uranium	4.8E+07	0.025	5.E-03	1.0	1	6.7E+03
Uranyl nitrate	2.9E+04	0.025	5.E-03	1.0	1	4.0E+00
Versenes (EDTA)	1.4E+05	0.025	5.E-03	1.0	1	2.0E+01
Xylene	5.0E+04	0.025	1	1.0	1	1.4E+03
Zirconium	2.3E+06	0.025	5.E-03	1.0	1	3.3E+02
Zirconium alloys	7.6E+05	0.025	5.E-03	1.0	1	1.1E+02
Zirconium oxide	5.5E+02	0.025	5.E-03	1.0	1	7.6E-02
Hydrochloric Acid						5.2E+04
Phosgene						1.3E+04
			Limiting (Unlikely)			
1,1,1-trichloroethane	6.3E+06	0.025	1	1.0	1	1.8E+05
1,1,2-trichloro-1,2,2-trifluoroethane	5.0E+05	0.025	1	1.0	1	1.4E+04
2-butanone	2.1E+03	0.025	1	1.0	1	5.8E+01
Acetone	6.8E+03	0.025	1	1.0	1	1.9E+02
Aluminum nitrate nonahydrate	2.4E+07	0.025	5.E-03	1.0	1	3.4E+03
Ammonia	1.9E+05	0.025	1	1.0	1	5.3E+03
Anthracene	4.8E+01	0.025	5.E-03	1.0	1	6.6E-03
Antimony	9.9E+01	0.025	1	1.0	1	2.8E+00
Aqua regia	3.3E+00	0.025	1	1.0	1	9.3E-02
Arsenic	1.2E-01	0.025	1	1.0	1	3.3E-03
Asbestos	0.0E+00	0.025	5.E-03	1.0	1	0.0E+00
Barium	1.3E+00	0.025	5.E-03	1.0	1	1.8E-04
Benzine	2.5E+02	0.025	1	1.0	1	6.9E+00
Beryllium	7.6E+04	0.025	5.E-03	1.0	1	1.1E+01
Butyl alcohol	1.2E+04	0.025	1	1.0	1	3.3E+02
Cadmium	9.7E+03	0.025	1	1.0	1	2.7E+02
Carbon tetrachloride	2.1E+07	0.025	1	1.0	1	5.9E+05
Cerium chloride	6.4E+04	0.025	5.E-03	1.0	1	8.9E+00
Chloroform	1.9E+00	0.025	1	1.0	1	5.3E-02
Chromium	1.6E+02	0.025	5.E-03	1.0	1	2.3E-02
Copper	4.7E+03	0.025	5.E-03	1.0	1	6.5E-01
Copper nitrate	4.2E+01	0.025	5.E-03	1.0	1	5.9E-03
Ethyl alcohol	2.9E+03	0.025	1	1.0	1	8.0E+01
Formaldehyde	1.5E+04	0.025	1	1.0	1	4.3E+02
Hydrazine	2.3E+02	0.025	1	1.0	1	6.5E+00

Table 3-21. (continued).

Material	MAR (g)	DR	ARF	RF	LPF	RR (mg/s)
Hydrofluoric acid	9.9E+05	0.025	1	1.0	1	2.8E+04
Lead	2.2E+07	0.025	5.E-03	1.0	1	3.1E+03
Magnesium	1.2E+06	0.025	5.E-03	1.0	1	1.6E+02
Magnesium fluoride	1.4E+04	0.025	5.E-03	1.0	1	2.0E+00
Mercury	2.3E+04	0.025	1	1.0	1	6.3E+02
Mercury nitrate monohydrate	9.9E+04	0.025	5.E-03	1.0	1	1.4E+01
Methyl alcohol	2.6E+04	0.025	1	1.0	1	7.3E+02
Methyl isobutyl ketone	1.2E+06	0.025	1	1.0	1	3.3E+04
Methylene chloride	7.7E+05	0.025	1	1.0	1	2.1E+04
Nickel	4.2E+02	0.025	5.E-03	1.0	1	5.9E-02
Nitric acid	6.3E+04	0.025	1	1.0	1	1.8E+03
Potassium chloride	9.0E+06	0.025	5.E-03	1.0	1	1.3E+03
Potassium dichromate	3.1E+05	0.025	5.E-03	1.0	1	4.3E+01
Potassium nitrate	2.4E+08	0.025	5.E-03	1.0	1	3.4E+04
Potassium phosphate	1.4E+06	0.025	5.E-03	1.0	1	1.9E+02
Potassium sulfate	9.0E+06	0.025	5.E-03	1.0	1	1.3E+03
Silver	7.6E+02	0.025	5.E-03	1.0	1	1.1E-01
Sodium	7.7E+03	0.025	5.E-03	1.0	1	1.1E+00
Sodium chloride	1.9E+07	0.025	5.E-03	1.0	1	2.6E+03
Sodium cyanide	2.0E+02	0.025	5.E-03	1.0	1	2.8E-02
Sodium dichromate	5.6E+05	0.025	5.E-03	1.0	1	7.8E+01
Sodium hydroxide	3.5E+01	0.025	5.E-03	1.0	1	4.9E-03
Sodium nitrate	4.8E+08	0.025	5.E-03	1.0	1	6.6E+04
Sodium phosphate	2.8E+06	0.025	5.E-03	1.0	1	3.9E+02
Sodium potassium	2.3E+05	0.025	5.E-03	1.0	1	3.3E+01
Sodium sulfate	2.2E+07	0.025	5.E-03	1.0	1	3.0E+03
Sulfuric acid	1.5E+04	0.025	1	1.0	1	4.3E+02
Terphenyl	9.9E+04	0.025	5.E-03	1.0	1	1.4E+01
Tetrachloroethylene	5.0E+06	0.025	1	1.0	1	1.4E+05
Toluene	1.3E+04	0.025	1	1.0	1	3.6E+02
Tributyl phosphate	1.4E+05	0.025	1	1.0	1	3.8E+03
Trichloroethylene	6.3E+06	0.025	1	1.0	1	1.7E+05
Trimethylolpropane-triester	1.6E+05	0.025	5.E-03	1.0	1	2.3E+01
Uranium	4.8E+07	0.025	5.E-03	1.0	1	6.7E+03
Uranyl nitrate	2.9E+04	0.025	5.E-03	1.0	1	4.0E+00
Versenes (EDTA)	1.4E+05	0.025	5.E-03	1.0	1	2.0E+01
Xylene	5.0E+04	0.025	1	1.0	1	1.4E+03
Zirconium	2.3E+06	0.025	5.E-03	1.0	1	3.3E+02
Zirconium alloys	7.6E+05	0.025	5.E-03	1.0	1	1.1E+02
Zirconium oxide	5.5E+02	0.025	5.E-03	1.0	1	7.6E-02
Hydrochloric Acid						5.2E+04
Phosgene						1.3E+04
			Average (Anticipated)			
1,1,1-trichloroethane	7.7E+04	0.025	1	1.0	1	2.1E+03
1,1,2-trichloro-1,2,2-trifluoroethane	5.9E+03	0.025	1	1.0	1	1.6E+02
2-butanone	2.5E+01	0.025	1	1.0	1	7.0E-01
Acetone	8.1E+01	0.025	1	1.0	1	2.3E+00
Aluminum nitrate nonahydrate	3.1E+05	0.025	5.E-03	1.0	1	4.3E+01

Table 3-21. (continued).

Material	MAR (g)	DR	ARF	RF	LPF	RR (mg/s)
Ammonia	2.3E+03	0.025	1	1.0	1	6.3E+01
Anthracene	5.9E-01	0.025	5.E-03	1.0	1	8.1E-05
Antimony	1.3E+00	0.025	1	1.0	1	3.5E-02
Aqua regia	4.1E-02	0.025	1	1.0	1	1.1E-03
Arsenic	1.4E-03	0.025	1	1.0	1	4.0E-05
Asbestos	0.0E+00	0.025	5.E-03	1.0	1	0.0E+00
Barium	1.5E-02	0.025	5.E-03	1.0	1	2.1E-06
Benzine	3.0E+00	0.025	1	1.0	1	8.4E-02
Beryllium	9.0E+02	0.025	5.E-03	1.0	1	1.3E-01
Butyl alcohol	1.4E+02	0.025	1	1.0	1	3.8E+00
Cadmium	1.2E+02	0.025	1	1.0	1	3.3E+00
Carbon tetrachloride	5.4E+05	0.025	1	1.0	1	1.5E+04
Cerium chloride	7.8E+02	0.025	5.E-03	1.0	1	1.1E-01
Chloroform	2.3E-02	0.025	1	1.0	1	6.5E-04
Chromium	2.0E+00	0.025	5.E-03	1.0	1	2.8E-04
Copper	5.7E+01	0.025	5.E-03	1.0	1	7.9E-03
Copper nitrate	5.2E-01	0.025	5.E-03	1.0	1	7.3E-05
Ethyl alcohol	3.5E+01	0.025	1	1.0	1	9.8E-01
Formaldehyde	1.9E+02	0.025	1	1.0	1	5.3E+00
Hydrazine	2.9E+00	0.025	1	1.0	1	8.0E-02
Hydrofluoric acid	1.2E+04	0.025	1	1.0	1	3.3E+02
Lead	2.8E+05	0.025	5.E-03	1.0	1	3.9E+01
Magnesium	1.4E+04	0.025	5.E-03	1.0	1	1.9E+00
Magnesium fluoride	1.8E+02	0.025	5.E-03	1.0	1	2.5E-02
Mercury	2.4E+01	0.025	1	1.0	1	6.8E-01
Mercury nitrate monohydrate	1.3E+03	0.025	5.E-03	1.0	1	1.8E-01
Methyl alcohol	3.2E+02	0.025	1	1.0	1	8.8E+00
Methyl isobutyl ketone	1.4E+04	0.025	1	1.0	1	3.8E+02
Methylene chloride	9.5E+03	0.025	1	1.0	1	2.6E+02
Nickel	5.2E+00	0.025	5.E-03	1.0	1	7.3E-04
Nitric acid	7.7E+02	0.025	1	1.0	1	2.2E+01
Potassium chloride	1.2E+05	0.025	5.E-03	1.0	1	1.6E+01
Potassium dichromate	3.8E+03	0.025	5.E-03	1.0	1	5.3E-01
Potassium nitrate	3.1E+06	0.025	5.E-03	1.0	1	4.3E+02
Potassium phosphate	1.6E+04	0.025	5.E-03	1.0	1	2.3E+00
Potassium sulfate	1.2E+05	0.025	5.E-03	1.0	1	1.6E+01
Silver	9.0E+00	0.025	5.E-03	1.0	1	1.3E-03
Sodium	9.9E+01	0.025	5.E-03	1.0	1	1.4E-02
Sodium chloride	2.3E+05	0.025	5.E-03	1.0	1	3.1E+01
Sodium cyanide	2.4E+00	0.025	5.E-03	1.0	1	3.4E-04
Sodium dichromate	6.8E+03	0.025	5.E-03	1.0	1	9.5E-01
Sodium hydroxide	4.3E-01	0.025	5.E-03	1.0	1	6.0E-05
Sodium nitrate	5.8E+06	0.025	5.E-03	1.0	1	8.1E+02
Sodium phosphate	3.4E+04	0.025	5.E-03	1.0	1	4.8E+00
Sodium potassium	2.9E+03	0.025	5.E-03	1.0	1	4.0E-01
Sodium sulfate	2.6E+05	0.025	5.E-03	1.0	1	3.6E+01
Sulfuric acid	1.9E+02	0.025	1	1.0	1	5.3E+00
Terphenyl	1.3E+03	0.025	5.E-03	1.0	1	1.8E-01

Table 3-21. (continued).

Material	MAR (g)	DR	ARF	RF	LPF	RR (mg/s)
Tetrachloroethylene	6.3E+04	0.025	1	1.0	1	1.8E+03
Toluene	1.6E+02	0.025	1	1.0	1	4.4E+00
Tributyl phosphate	1.6E+03	0.025	1	1.0	1	4.5E+01
Trichloroethylene	7.6E+04	0.025	1	1.0	1	2.1E+03
Trimethylolpropane-triester	2.0E+03	0.025	5.E-03	1.0	1	2.8E-01
Uranium	5.9E+05	0.025	5.E-03	1.0	1	8.2E+01
Uranyl nitrate	3.5E+02	0.025	5.E-03	1.0	1	4.9E-02
Versenes (EDTA)	2.8E+04	0.025	5.E-03	1.0	1	3.9E+00
Xylene	6.3E+02	0.025	1	1.0	1	1.8E+01
Zirconium	2.9E+04	0.025	5.E-03	1.0	1	4.0E+00
Zirconium alloys	9.0E+03	0.025	5.E-03	1.0	1	1.3E+00
Zirconium oxide	6.7E+00	0.025	5.E-03	1.0	1	9.3E-04
Hydrochloric Acid						6.4E+02
Phosgene						2.5E+02

Table 3-22. Dose consequences in the unmitigated melt expulsion scenario.

Frequency Category	Co-located Worker Total Effective Dose Equivalent (rem)	Co-located Worker Evaluation Guidelines for Total Effective Dose Equivalent (rem)	Public (6 km) Total Effective Dose Equivalent (rem)	Public Evaluation Guidelines for Total Effective Dose Equivalent (rem)
Extremely Unlikely	***490***	100	0.68	25
Unlikely	***170***	25	0.23	5
Unlikely	***160***	25	0.22	5

NOTE: Bold italics denotes evaluation guideline exceeded.

Table 3-23. Concentration consequences in the unmitigated melt expulsion scenario.

Frequency Category	Material	Co-located Worker Exposure Concentration (mg/m^3)	Co-located Worker Evaluation Guidelines (mg/m^3)	Public (6 km) Exposure Concentration (mg/m^3)	Public Evaluation Guidelines (mg/m^3)
			ERPG-3		ERPG-2
Extremely Unlikely	Phosgene	***430***	4	0.58	0.8
	Lead	***100***	100	0.14	0.25
	Sodium nitrate	***2,100***	100	2.9	7.5
	Uranium	***220***	10	0.29	1
	Hydrochloric acid	***1,700***	224	2.3	30
	Potassium nitrate	***1,100***	500	1.5	20
	Hydrofluoric acid	***890***	41	1.2	16.4
	Carbon tetrachloride	***19,000***	4790	26	639
	Cadmium	***8.7***	7.5	0.012	0.5
	Beryllium	***0.34***	0.1	0.00046	0.025
			ERPG-3		ERPG-1
Unlikely	Sodium nitrate	***2,100***	100	***2.9***	1
	Phosgene	***420***	4	***0.58***	0.4
	Lead	***100***	100	0.14	0.15
	Hydrofluoric acid	***880***	41	1.2	1.5
	Hydrochloric acid	***1,700***	224	2.3	4.5
	Uranium	***210***	10	0.29	0.6
	Potassium nitrate	***1,100***	500	1.5	3.5
	Cadmium	***8.6***	7.5	0.012	0.03
	Mercury	***20***	4.1	0.028	0.1
	Carbon tetrachloride	***19,000***	4790	26	128
			ERPG-3		ERPG-1
Unlikely	Sodium nitrate	26	100	0.036	1
	Phosgene	***8.2***	4	0.011	0.4
	Lead	1.2	100	0.0017	0.15
	Hydrofluoric acid	10	41	0.014	1.5
	Hydrochloric acid	21	224	0.028	4.5
	Uranium	2.6	10	0.0036	0.6
	Potassium nitrate	14	500	0.019	3.5
	Carbon tetrachloride	480	4,790	0.66	128
	Cadmium	0.11	7.5	0.00015	0.03
	Beryllium	0.0040	0.1	5.5E-06	0.005

NOTE: *Bold italics denotes evaluation guideline exceeded.*

3.4.2.4.5 Comparison to the Evaluation Guideline—The dose and concentration consequences in the melt expulsion scenario are compared to the extremely unlikely and unlikely evaluation guidelines in Tables 3-22 and 3-23. Consequences that exceed the corresponding evaluation guideline are shown in ***bold italics***. The future off-gas analysis may show that the consequences of the melt expulsion accident are less than shown in the current calculations.

3.4.2.4.6 Summary of Safety-Class SSCs and TSR Controls—Based on the bounding accident analyses, the off-gas hood and the off-gas treatment system are designated safety-class SSCs. Requirements for an emergency preparedness program and for remote operations are TSR-level controls.

3.4.2.5 Loss of Confinement. The off-gas treatment system maintains the off-gas hood in a negative pressure with respect to the environment at a nominal differential pressure of 0.5 in. w.g., and scrubs the exiting off-gas to minimize the radioactive and hazardous effluent from the ISV. The off-gas treatment system consists of the off-gas hood and the off-gas treatment equipment, such as scrubbers, quenchers, and HEPA filters. The off-gas treatment system also includes primary and secondary off-gas ventilation systems, the combustible gas monitors, and the backup power supply. The hazard analysis in Section 3.3 identified the potential for an accident involving a loss of confinement.

3.4.2.5.1 Scenario Development—The loss of confinement scenario involves failure of the off-gas hood or the off-gas treatment system. The off-gas hood confinement could be lost as a result of damage sustained from an earthquake, winds, or floods as well as heavy equipment or crane load impact. Hood confinement could also be lost due to blower failure, lost power, combustion of off-gas in the hood, or a pressure surge caused by excessive off-gas generation during ISV operation. Sources of excessive off-gas generation are the rapid depressurization of compressed gas cylinders or intact drums with liquid, or large quantities of nitrate salts/pyrolyzed combustibles in one location. Failures in the off-gas treatment system can result from an off-gas containment pipe break, a deflagration in the off-gas hood, or a HEPA-filter fire.

The off-gas treatment system includes a compressed air system that supplies a high-pressure air to pneumatic flow control valves. The process control system controls the direction of off-gas flow and diverts flow through alternate paths depending on measured temperatures and pressures. The failure of the compressed air system could cause a loss of hood confinement. Hood confinement could also be lost due to blower failure and/or lost power.

The off-gas treatment system is equipped with two stages of HEPA filters immediately upstream of the blowers. If the off-gas entering the filters contains sufficient moisture, the filter would become plugged and off-gas flow would be reduced and a rupture could potentially occur. The debris from the rupture could cause the blowers to fail and subsequently cause a loss of hood vacuum.

The hood itself could fail when seals are damaged, deteriorated, and overused. Loads dropped from an overhead crane would also cause significant damage to the hood and subsequent loss of vacuum. The loss of hood confinement would cause off-gas to be released through openings from hood structure damage.

A malfunction of the ventilation or electrical power source could result in the build up of off gases in the off-gas system. The combustible gases could be ignited by the thermal oxidizer or by electrical discharge. The resulting deflagration could cause damage to the off-gas system, system overpressures, and a release of radiological and nonradiological hazardous materials.

The analysis includes the original contaminants in the SDA and an estimate of phosgene and hydrochloric acid generation but does not include any other products resulting from the incomplete combustion of nonradioactive contaminants. To provide a more realistic assessment of the scenario, future studies should include an analysis of products in ISV off-gas. Analysis for the loss of confinement scenario is bounded by an unmitigated release from a 900-ft^2 (30 by 30-ft) treatment area. Use of a 900-ft^2 treatment area is justified based on electrode spacing and hood diameter. Electrode spacing[7] may range from 7 to 25 ft and the hood diameter[35] is 60 ft.

3.4.2.5.2 Occurrence Likelihood—Many safeguards inherent to the off-gas treatment system guard against component failures. A backup off-gas treatment system is available for treating the off-gas until the ISV process can be completely shut down. Loss of hood integrity due to seal failure would only create relatively small leakage openings. Larger openings may be made by a crane handling accident. As long as the treatment blowers are in operation, a negative pressure difference would be maintained across the opening and releases would not result. However a total loss of power could result in loss of confinement. Total loss of power requires loss of commercial power and failure of the backup power supply. Since a loss of commercial power is an anticipated event, the likelihood of a loss of confinement is judged to be anticipated. When combined with the anticipated event likelihood, the resulting scenario likelihood is extremely unlikely for an extremely unlikely source term ($10^{-1} \times 10^{-4} = 10^{-5}$), unlikely for an unlikely source term ($10^{-1} \times 10^{-2} = 10^{-3}$), and unlikely for an anticipated source term ($10^{-1} \times 10^{-1} = 10^{-2}$).

3.4.2.5.3 Source Term Analysis—The radioactive and nonradioactive hazardous material source terms are calculated in EDF-3563.[9] The source term is developed for a MAR that includes the bounding 900-ft^2 ISV treatment area.

The damage ratio for the scenario is based on factors relating to the dry zone. During ISV processing, off-gases are released through the dry zone, which is approximately 1 ft wide.[37] The dry zone is a volume located at the edge of the melt that contains no liquid-phase water and has maximum soil-void volume. [37] The dry zone is the path of least resistance for movement of materials to the surface. As melting proceeds, the dry zone moves away from the melt center. The largest dry zone area is farthest away from the center of the treatment area. To account for the dry zone with the most influence on the accident scenario, the damage ratio is calculated as the ratio of the dry zone area around the perimeter of the treatment area to the total treatment area. This approach to calculating the damage ratio can be used because the whole MAR is affected over a long period of time. The melt front advances at a rate of a few cm/hr with an estimated time for completing a melt of eight days.[38] Assuming that the treatment area is circular, the diameter of a 900-ft^2 area is 33.9 ft. With a 1-ft-wide dry zone, the surface area of the dry zone is 52.5 ft^2 ($\pi \times [[33.9\ ft]^2 - [32.9\ ft]^2]/4$) and the damage ratio is 0.058 (52.5 ft^2/900 ft^2).

The airborne release factors and respirable factors are values from DOE-HDBK-3010-94 for contaminated, combustible solids exposed to thermal stress. The airborne release fraction could be reduced for the activation products in the inventory, since the radionuclides would be expected to reside in solid metal objects. However, to be conservative, the airborne release fraction is not reduced for activation products.

The existing overburden provides some filtration of the radioactive material. The soil is assumed to behave as a granular bed filter. Based on an analysis of granular bed filters,[34] 10 cm (4 in.) of overburden gives a leak path factor of 0.1. DOE-STD-3009-94 allows the unmitigated analysis to "take credit for passive safety features that are assessed to survive accident conditions where that capability is necessary in order to define a physically meaningful scenario."

For the nonradioactive hazardous material source term, nonvolatile chemicals are treated as radionuclides per DOE-HDBK-3010-94. Volatile chemicals are conservatively assumed to be completely released to the atmosphere. In addition to the VOCs, antimony, arsenic, cadmium, lead, and mercury have the potential to volatilize. The boiling points for antimony, arsenic, cadmium, lead, and mercury are 1,438°C, 610°C, 765°C, 1,738°C, and 357°C, respectively. The temperatures associated with ISV melting could be as high as 2,000°C. However, the soil cover would tend to cool these materials before they reach the ground surface. Lead is expected to remain in the melt[39] and is not treated as a volatile chemical. Antimony, arsenic, cadmium, and mercury may volatilize[39] and are treated as volatile chemicals.

The asbestos in the SDA is considered to be in large pieces and not dispersible. The MAR for asbestos is set to 0. Because the organic destruction efficiency is greater than 99%[37] during ISV processing, only 1% of the organics in the nonradioactive inventory is assumed to be at risk of release and included in the MAR. Phosgene and hydrochloric acid might be generated by the heat of ISV processing. The analysis assumes that 10% of the chlorinated hydrocarbons decompose to hydrochloric acid and 1% of the halogenated compounds convert to phosgene gas with a molecular conversion ratio of 1.19.[9] To implement the assumption, the quantity of hydrochloric acid is calculated by multiplying the sum of the release rate for the chlorinated hydrocarbons (1,1,1-trichloroethane, 1,1,2-trichloro-1,2,2-trifluoroethane, methylene chloride, tetrachloroethylene, trichloroethylene) by 0.1 while the quantity of phosgene is calculated by multiplying the sum of the release rate for the halogenated compounds (1,1,1-trichloroethane, 1,1,2-trichloro-1,2,2-trifluoroethane, carbon tetrachloride, chloroform, methylene chloride, tetrachloroethylene, trichloroethylene) by 0.0119. Using the total quantity of chlorinated hydrocarbons and the total quantity of halogenated compounds is extremely conservative, since all of the materials would not be expected to simultaneously exist in the same treatment area.

The resulting upper bound, limiting, and average radioactive source terms are listed in Table 3-24 while the upper bound, limiting, and average nonradioactive hazardous material source terms are listed in Table 3-25.

3.4.2.5.4 Consequence Analysis**—**The dose and concentration consequences from the loss of confinement with a 15-min release duration are shown in Tables 3-26 and 3-27. Use of the 15-min release duration allows the scenario to bound the consequences from a hood deflagration. The consequences are calculated using the Hilsmeier-Gifford dispersion model. Doses are presented for the co-located worker at 100 m and the off-Site public at 6 km. Concentrations for the co-located worker and the public are presented for the ten nonradioactive materials with the largest ratio of 6 km concentration to 6 km evaluation guideline.

3.4.2.5.5 Comparison to the Evaluation Guideline**—**The dose and concentration consequences in the loss of confinement scenario are compared to the extremely unlikely and unlikely evaluation guidelines in Tables 3-26 and 3-27. Consequences that exceed the corresponding evaluation guideline are shown in ***bold italics***. Hydrofluoric acid, cadmium, mercury, sodium nitrate, and phosgene pose the greatest hazard to the off-Site public. The future off-gas analysis may show that the consequences of the loss of confinement accident are less than that shown in the current calculations.

3.4.2.5.6 Summary of Safety-Class SSCs and TSR Controls**—**Based on the accident analyses, the off-gas hood and off-gas treatment system are designated as safety-class SSCs. Equipment specifically included in the off-gas treatment system includes the primary and secondary off-gas ventilation system, the backup power supply, and the combustible gas monitoring system. Requirements for remote operations, an emergency preparedness program, and the maintenance and inspection program are TSR-level controls.

Table 3-24. Upper bound, limiting, and average radioactive hazardous material source term for the unmitigated loss of confinement scenario.

Radionuclide	MAR (Ci)	DR	ARF	RF	LPF	ST (Ci)
			Upper Bound (Extremely Unlikely)			
Pu-239	2.8E+03	0.058	5.E-04	1.0	0.1	8.2E-03
Co-60	3.9E+04	0.058	5.E-04	1.0	0.1	1.1E-01
Fe-55	1.4E+04	0.058	5.E-04	1.0	0.1	4.2E-02
Cr-51	1.1E+04	0.058	5.E-04	1.0	0.1	3.1E-02
H-3	8.7E+03	0.058	5.E-04	1.0	0.1	2.5E-02
Ni-63	5.1E+03	0.058	5.E-04	1.0	0.1	1.5E-02
Co-58	4.0E+03	0.058	5.E-04	1.0	0.1	1.1E-02
Mn-54	3.2E+03	0.058	5.E-04	1.0	0.1	9.4E-03
Sr-90	3.0E+03	0.058	5.E-04	1.0	0.1	8.6E-03
Cs-137	2.3E+03	0.058	5.E-04	1.0	0.1	6.5E-03
Ce-144	1.2E+03	0.058	5.E-04	1.0	0.1	3.4E-03
			Limiting (Unlikely)			
Pu-239	9.7E+02	0.058	5.E-04	1.0	0.1	2.8E-03
Co-60	2.2E+04	0.058	5.E-04	1.0	0.1	6.3E-02
Fe-55	1.4E+04	0.058	5.E-04	1.0	0.1	4.2E-02
Cr-51	1.1E+04	0.058	5.E-04	1.0	0.1	3.1E-02
H-3	8.7E+03	0.058	5.E-04	1.0	0.1	2.5E-02
Ni-63	5.1E+03	0.058	5.E-04	1.0	0.1	1.5E-02
Co-58	4.0E+03	0.058	5.E-04	1.0	0.1	1.1E-02
Mn-54	3.2E+03	0.058	5.E-04	1.0	0.1	9.4E-03
Sr-90	3.0E+03	0.058	5.E-04	1.0	0.1	8.6E-03
Cs-137	2.3E+03	0.058	5.E-04	1.0	0.1	6.5E-03
Ce-144	1.2E+03	0.058	5.E-04	1.0	0.1	3.4E-03
			Average (Anticipated)			
Pu-239	9.4E+02	0.058	5.E-04	1.0	0.1	2.7E-03
Co-60	1.6E+03	0.058	5.E-04	1.0	0.1	4.7E-03
Fe-55	3.0E+03	0.058	5.E-04	1.0	0.1	8.6E-03
Cr-51	5.8E+02	0.058	5.E-04	1.0	0.1	1.7E-03
H-3	1.1E+03	0.058	5.E-04	1.0	0.1	3.1E-03
Ni-63	9.9E+02	0.058	5.E-04	1.0	0.1	2.9E-03
Co-58	2.7E+02	0.058	5.E-04	1.0	0.1	7.8E-04
Mn-54	2.3E+02	0.058	5.E-04	1.0	0.1	6.5E-04
Sr-90	4.8E+02	0.058	5.E-04	1.0	0.1	1.4E-03
Cs-137	4.6E+02	0.058	5.E-04	1.0	0.1	1.3E-03
Ce-144	1.1E+02	0.058	5.E-04	1.0	0.1	3.1E-04

Table 3-25. Upper bound, limiting, and average nonradioactive hazardous material source term for the unmitigated loss of confinement scenario.

Material	MAR (g)	DR	ARF	RF	LPF	RR (mg/s)
	Upper Bound (Extremely Unlikely)					
1,1,1-trichloroethane	1.3E+05	0.058	1	1.0	1	8.1E+03
1,1,2-trichloro-1,2,2-trifluoroethane	9.9E+03	0.058	1	1.0	1	6.4E+02
2-butanone	4.2E+01	0.058	1	1.0	1	2.7E+00
Acetone	1.4E+02	0.058	1	1.0	1	8.7E+00
Aluminum nitrate nonahydrate	2.4E+07	0.058	5.E-04	1.0	0.1	7.9E+01
Ammonia	1.9E+05	0.058	1	1.0	1	1.2E+04
Anthracene	4.8E+01	0.058	5.E-04	1.0	0.1	1.5E-04
Antimony	9.9E+01	0.058	1	1.0	1	6.4E+00
Aqua regia	3.3E+00	0.058	1	1.0	1	2.2E-01
Arsenic	1.2E-01	0.058	1	1.0	1	7.6E-03
Asbestos	0.0E+00	0.058	5.E-04	1.0	0.1	0.0E+00
Barium	1.3E+00	0.058	5.E-04	1.0	0.1	4.1E-06
Benzine	5.0E+00	0.058	1	1.0	1	3.2E-01
Beryllium	7.6E+04	0.058	5.E-04	1.0	0.1	2.4E-01
Butyl alcohol	1.2E+04	0.058	1	1.0	1	7.6E+02
Cadmium	9.7E+03	0.058	1	1.0	1	6.2E+02
Carbon tetrachloride	4.2E+05	0.058	1	1.0	1	2.7E+04
Cerium chloride	6.4E+04	0.058	5.E-04	1.0	0.1	2.1E-01
Chloroform	3.8E-02	0.058	1	1.0	1	2.4E-03
Chromium	1.6E+02	0.058	5.E-04	1.0	0.1	5.2E-04
Copper	4.7E+03	0.058	5.E-04	1.0	0.1	1.5E-02
Copper nitrate	4.2E+01	0.058	5.E-04	1.0	0.1	1.4E-04
Ethyl alcohol	2.9E+03	0.058	1	1.0	1	1.9E+02
Formaldehyde	1.5E+04	0.058	1	1.0	1	9.9E+02
Hydrazine	2.3E+02	0.058	1	1.0	1	1.5E+01
Hydrofluoric acid	9.9E+05	0.058	1	1.0	1	6.4E+04
Lead	2.3E+07	0.058	5.E-04	1.0	0.1	7.3E+01
Magnesium	1.2E+06	0.058	5.E-04	1.0	0.1	3.8E+00
Magnesium fluoride	1.4E+04	0.058	5.E-04	1.0	0.1	4.7E-02
Mercury	2.3E+04	0.058	1	1.0	1	1.5E+03
Mercury nitrate monohydrate	9.9E+04	0.058	5.E-04	1.0	0.1	3.2E-01
Methyl alcohol	2.6E+04	0.058	1	1.0	1	1.7E+03
Methyl isobutyl ketone	1.2E+06	0.058	1	1.0	1	7.6E+04
Methylene chloride	1.5E+04	0.058	1	1.0	1	9.9E+02
Nickel	4.2E+02	0.058	5.E-04	1.0	0.1	1.4E-03
Nitric acid	6.3E+04	0.058	1	1.0	1	4.1E+03
Potassium chloride	9.0E+06	0.058	5.E-04	1.0	0.1	2.9E+01
Potassium dichromate	3.1E+05	0.058	5.E-04	1.0	0.1	9.9E-01
Potassium nitrate	2.4E+08	0.058	5.E-04	1.0	0.1	7.9E+02
Potassium phosphate	1.4E+06	0.058	5.E-04	1.0	0.1	4.4E+00
Potassium sulfate	9.0E+06	0.058	5.E-04	1.0	0.1	2.9E+01
Silver	7.6E+02	0.058	5.E-04	1.0	0.1	2.4E-03
Sodium	7.8E+03	0.058	5.E-04	1.0	0.1	2.5E-02
Sodium chloride	1.9E+07	0.058	5.E-04	1.0	0.1	6.1E+01
Sodium cyanide	2.0E+02	0.058	5.E-04	1.0	0.1	6.4E-04
Sodium dichromate	5.6E+05	0.058	5.E-04	1.0	0.1	1.8E+00

Table 3-25. (continued).

Material	MAR (g)	DR	ARF	RF	LPF	RR (mg/s)
Sodium hydroxide	3.5E+01	0.058	5.E-04	1.0	0.1	1.1E-04
Sodium nitrate	4.8E+08	0.058	5.E-04	1.0	0.1	1.5E+03
Sodium phosphate	2.8E+06	0.058	5.E-04	1.0	0.1	9.0E+00
Sodium potassium	2.3E+05	0.058	5.E-04	1.0	0.1	7.6E-01
Sodium sulfate	2.2E+07	0.058	5.E-04	1.0	0.1	7.0E+01
Sulfuric acid	1.5E+04	0.058	1	1.0	1	9.9E+02
Terphenyl	9.9E+04	0.058	5.E-04	1.0	0.1	3.2E-01
Tetrachloroethylene	9.9E+04	0.058	1	1.0	1	6.4E+03
Toluene	2.6E+02	0.058	1	1.0	1	1.7E+01
Tributyl phosphate	1.4E+05	0.058	1	1.0	1	8.7E+03
Trichloroethylene	1.3E+05	0.058	1	1.0	1	8.1E+03
Trimethylolpropane-triester	1.6E+05	0.058	5.E-04	1.0	0.1	5.2E-01
Uranium	4.8E+07	0.058	5.E-04	1.0	0.1	1.6E+02
Uranyl nitrate	2.9E+04	0.058	5.E-04	1.0	0.1	9.3E-02
Versenes (EDTA)	1.4E+05	0.058	5.E-04	1.0	0.1	4.7E-01
Xylene	9.9E+02	0.058	1	1.0	1	6.4E+01
Zirconium	2.3E+06	0.058	5.E-04	1.0	0.1	7.6E+00
Zirconium alloys	7.6E+05	0.058	5.E-04	1.0	0.1	2.4E+00
Zirconium oxide	5.5E+02	0.058	5.E-04	1.0	0.1	1.8E-03
Hydrochloric acid						2.4E+03
Phosgene						6.1E+02
	Limiting (Unlikely)					
1,1,1-trichloroethane	1.3E+05	0.058	1	1.0	1	8.1E+03
1,1,2-trichloro-1,2,2-trifluoroethane	9.9E+03	0.058	1	1.0	1	6.4E+02
2-butanone	4.1E+01	0.058	1	1.0	1	2.7E+00
Acetone	1.4E+02	0.058	1	1.0	1	8.7E+00
Aluminum nitrate nonahydrate	2.4E+07	0.058	5.E-04	1.0	0.1	7.8E+01
Ammonia	1.9E+05	0.058	1	1.0	1	1.2E+04
Anthracene	4.8E+01	0.058	5.E-04	1.0	0.1	1.5E-04
Antimony	9.9E+01	0.058	1	1.0	1	6.4E+00
Aqua regia	3.3E+00	0.058	1	1.0	1	2.1E-01
Arsenic	1.2E-01	0.058	1	1.0	1	7.5E-03
Asbestos	0.0E+00	0.058	5.E-04	1.0	0.1	0.0E+00
Barium	1.3E+00	0.058	5.E-04	1.0	0.1	4.1E-06
Benzine	5.0E+00	0.058	1	1.0	1	3.2E-01
Beryllium	7.6E+04	0.058	5.E-04	1.0	0.1	2.4E-01
Butyl alcohol	1.2E+04	0.058	1	1.0	1	7.5E+02
Cadmium	9.7E+03	0.058	1	1.0	1	6.2E+02
Carbon tetrachloride	4.2E+05	0.058	1	1.0	1	2.7E+04
Cerium chloride	6.4E+04	0.058	5.E-04	1.0	0.1	2.1E-01
Chloroform	3.8E-02	0.058	1	1.0	1	2.4E-03
Chromium	1.6E+02	0.058	5.E-04	1.0	0.1	5.2E-04
Copper	4.7E+03	0.058	5.E-04	1.0	0.1	1.5E-02
Copper nitrate	4.2E+01	0.058	5.E-04	1.0	0.1	1.4E-04
Ethyl alcohol	2.9E+03	0.058	1	1.0	1	1.9E+02
Formaldehyde	1.5E+04	0.058	1	1.0	1	9.9E+02
Hydrazine	2.3E+02	0.058	1	1.0	1	1.5E+01
Hydrofluoric acid	9.9E+05	0.058	1	1.0	1	6.4E+04
Lead	2.2E+07	0.058	5.E-04	1.0	0.1	7.2E+01

Table 3-25. (continued).

Material	MAR (g)	DR	ARF	RF	LPF	RR (mg/s)
Magnesium	1.2E+06	0.058	5.E-04	1.0	0.1	3.8E+00
Magnesium fluoride	1.4E+04	0.058	5.E-04	1.0	0.1	4.6E-02
Mercury	2.3E+04	0.058	1	1.0	1	1.5E+03
Mercury nitrate monohydrate	9.9E+04	0.058	5.E-04	1.0	0.1	3.2E-01
Methyl alcohol	2.6E+04	0.058	1	1.0	1	1.7E+03
Methyl isobutyl ketone	1.2E+06	0.058	1	1.0	1	7.5E+04
Methylene chloride	1.5E+04	0.058	1	1.0	1	9.9E+02
Nickel	4.2E+02	0.058	5.E-04	1.0	0.1	1.4E-03
Nitric acid	6.3E+04	0.058	1	1.0	1	4.1E+03
Potassium chloride	9.0E+06	0.058	5.E-04	1.0	0.1	2.9E+01
Potassium dichromate	3.1E+05	0.058	5.E-04	1.0	0.1	9.9E-01
Potassium nitrate	2.4E+08	0.058	5.E-04	1.0	0.1	7.8E+02
Potassium phosphate	1.4E+06	0.058	5.E-04	1.0	0.1	4.4E+00
Potassium sulfate	9.0E+06	0.058	5.E-04	1.0	0.1	2.9E+01
Silver	7.6E+02	0.058	5.E-04	1.0	0.1	2.4E-03
Sodium	7.7E+03	0.058	5.E-04	1.0	0.1	2.5E-02
Sodium chloride	1.9E+07	0.058	5.E-04	1.0	0.1	6.1E+01
Sodium cyanide	2.0E+02	0.058	5.E-04	1.0	0.1	6.4E-04
Sodium dichromate	5.6E+05	0.058	5.E-04	1.0	0.1	1.8E+00
Sodium hydroxide	3.5E+01	0.058	5.E-04	1.0	0.1	1.1E-04
Sodium nitrate	4.8E+08	0.058	5.E-04	1.0	0.1	1.5E+03
Sodium phosphate	2.8E+06	0.058	5.E-04	1.0	0.1	9.0E+00
Sodium potassium	2.3E+05	0.058	5.E-04	1.0	0.1	7.5E-01
Sodium sulfate	2.2E+07	0.058	5.E-04	1.0	0.1	7.0E+01
Sulfuric acid	1.5E+04	0.058	1	1.0	1	9.9E+02
Terphenyl	9.9E+04	0.058	5.E-04	1.0	0.1	3.2E-01
Tetrachloroethylene	9.9E+04	0.058	1	1.0	1	6.4E+03
Toluene	2.6E+02	0.058	1	1.0	1	1.7E+01
Tributyl phosphate	1.4E+05	0.058	1	1.0	1	8.7E+03
Trichloroethylene	1.3E+05	0.058	1	1.0	1	8.1E+03
Trimethylolpropane-triester	1.6E+05	0.058	5.E-04	1.0	0.1	5.2E-01
Uranium	4.8E+07	0.058	5.E-04	1.0	0.1	1.5E+02
Uranyl nitrate	2.9E+04	0.058	5.E-04	1.0	0.1	9.3E-02
Versenes (EDTA)	1.4E+05	0.058	5.E-04	1.0	0.1	4.6E-01
Xylene	9.9E+02	0.058	1	1.0	1	6.4E+01
Zirconium	2.3E+06	0.058	5.E-04	1.0	0.1	7.5E+00
Zirconium alloys	7.6E+05	0.058	5.E-04	1.0	0.1	2.4E+00
Zirconium oxide	5.5E+02	0.058	5.E-04	1.0	0.1	1.8E-03
Hydrochloric acid						2.4E+03
Phosgene						6.1E+02
	Average (Anticipated)					
1,1,1-trichloroethane	1.5E+03	0.058	1	1.0	1	9.9E+01
1,1,2-trichloro-1,2,2-trifluoroethane	1.2E+02	0.058	1	1.0	1	7.5E+00
2-butanone	5.0E-01	0.058	1	1.0	1	3.2E-02
Acetone	1.6E+00	0.058	1	1.0	1	1.0E-01
Aluminum nitrate nonahydrate	3.1E+05	0.058	5.E-04	1.0	0.1	9.9E-01
Ammonia	2.3E+03	0.058	1	1.0	1	1.5E+02
Anthracene	5.9E-01	0.058	5.E-04	1.0	0.1	1.9E-06
Antimony	1.3E+00	0.058	1	1.0	1	8.1E-02

Table 3-25. (continued).

Material	MAR (g)	DR	ARF	RF	LPF	RR (mg/s)
Aqua regia	4.1E-02	0.058	1	1.0	1	2.6E-03
Arsenic	1.4E-03	0.058	1	1.0	1	9.3E-05
Asbestos	0.0E+00	0.058	5.E-04	1.0	0.1	0.0E+00
Barium	1.5E-02	0.058	5.E-04	1.0	0.1	4.9E-08
Benzine	6.0E-02	0.058	1	1.0	1	3.9E-03
Beryllium	9.0E+02	0.058	5.E-04	1.0	0.1	2.9E-03
Butyl alcohol	1.4E+02	0.058	1	1.0	1	8.7E+00
Cadmium	1.2E+02	0.058	1	1.0	1	7.7E+00
Carbon tetrachloride	1.1E+04	0.058	1	1.0	1	7.0E+02
Cerium chloride	7.8E+02	0.058	5.E-04	1.0	0.1	2.5E-03
Chloroform	4.7E-04	0.058	1	1.0	1	3.0E-05
Chromium	2.0E+00	0.058	5.E-04	1.0	0.1	6.4E-06
Copper	5.7E+01	0.058	5.E-04	1.0	0.1	1.8E-04
Copper nitrate	5.2E-01	0.058	5.E-04	1.0	0.1	1.7E-06
Ethyl alcohol	3.5E+01	0.058	1	1.0	1	2.3E+00
Formaldehyde	1.9E+02	0.058	1	1.0	1	1.2E+01
Hydrazine	2.9E+00	0.058	1	1.0	1	1.9E-01
Hydrofluoric acid	1.2E+04	0.058	1	1.0	1	7.5E+02
Lead	2.8E+05	0.058	5.E-04	1.0	0.1	9.0E-01
Magnesium	1.4E+04	0.058	5.E-04	1.0	0.1	4.4E-02
Magnesium fluoride	1.8E+02	0.058	5.E-04	1.0	0.1	5.8E-04
Mercury	2.4E+01	0.058	1	1.0	1	1.6E+00
Mercury nitrate monohydrate	1.3E+03	0.058	5.E-04	1.0	0.1	4.1E-03
Methyl alcohol	3.2E+02	0.058	1	1.0	1	2.0E+01
Methyl isobutyl ketone	1.4E+04	0.058	1	1.0	1	8.7E+02
Methylene chloride	1.9E+02	0.058	1	1.0	1	1.2E+01
Nickel	5.2E+00	0.058	5.E-04	1.0	0.1	1.7E-05
Nitric acid	7.7E+02	0.058	1	1.0	1	5.0E+01
Potassium chloride	1.2E+05	0.058	5.E-04	1.0	0.1	3.8E-01
Potassium dichromate	3.8E+03	0.058	5.E-04	1.0	0.1	1.2E-02
Potassium nitrate	3.1E+06	0.058	5.E-04	1.0	0.1	9.9E+00
Potassium phosphate	1.6E+04	0.058	5.E-04	1.0	0.1	5.2E-02
Potassium sulfate	1.2E+05	0.058	5.E-04	1.0	0.1	3.8E-01
Silver	9.0E+00	0.058	5.E-04	1.0	0.1	2.9E-05
Sodium	9.9E+01	0.058	5.E-04	1.0	0.1	3.2E-04
Sodium chloride	2.3E+05	0.058	5.E-04	1.0	0.1	7.3E-01
Sodium cyanide	2.4E+00	0.058	5.E-04	1.0	0.1	7.8E-06
Sodium dichromate	6.8E+03	0.058	5.E-04	1.0	0.1	2.2E-02
Sodium hydroxide	4.3E-01	0.058	5.E-04	1.0	0.1	1.4E-06
Sodium nitrate	5.8E+06	0.058	5.E-04	1.0	0.1	1.9E+01
Sodium phosphate	3.4E+04	0.058	5.E-04	1.0	0.1	1.1E-01
Sodium potassium	2.9E+03	0.058	5.E-04	1.0	0.1	9.3E-03
Sodium sulfate	2.6E+05	0.058	5.E-04	1.0	0.1	8.4E-01
Sulfuric acid	1.9E+02	0.058	1	1.0	1	1.2E+01
Terphenyl	1.3E+03	0.058	5.E-04	1.0	0.1	4.1E-03
Tetrachloroethylene	1.3E+03	0.058	1	1.0	1	8.1E+01
Toluene	3.2E+00	0.058	1	1.0	1	2.0E-01
Tributyl phosphate	1.6E+03	0.058	1	1.0	1	1.0E+02
Trichloroethylene	1.5E+03	0.058	1	1.0	1	9.8E+01

Table 3-25. (continued).

Material	MAR (g)	DR	ARF	RF	LPF	RR (mg/s)
Trimethylolpropane-triester	2.0E+03	0.058	5.E-04	1.0	0.1	6.4E-03
Uranium	5.9E+05	0.058	5.E-04	1.0	0.1	1.9E+00
Uranyl nitrate	3.5E+02	0.058	5.E-04	1.0	0.1	1.1E-03
Versenes (EDTA)	2.8E+04	0.058	5.E-04	1.0	0.1	9.0E-02
Xylene	1.3E+01	0.058	1	1.0	1	8.1E-01
Zirconium	2.9E+04	0.058	5.E-04	1.0	0.1	9.3E-02
Zirconium alloys	9.0E+03	0.058	5.E-04	1.0	0.1	2.9E-02
Zirconium oxide	6.7E+00	0.058	5.E-04	1.0	0.1	2.1E-05
Hydrochloric acid						3.0E+01
Phosgene						1.2E+01

Table 3-26. Dose consequences in the unmitigated loss of confinement scenario.

Frequency Category	Co-located Worker Total Effective Dose Equivalent (rem)	Co-located Worker Evaluation Guidelines for Total Effective Dose Equivalent (rem)	Public (6 km) Total Effective Dose Equivalent (rem)	Public Evaluation Guidelines for Total Effective Dose Equivalent (rem)
Extremely Unlikely	38	100	0.052	25
Unlikely	13	25	0.018	5
Unlikely	13	25	0.017	5

NOTE: Bold italics denotes evaluation guideline exceeded.

Table 3-27. Concentration consequences in the unmitigated loss of confinement scenario.

Frequency Category	Material	Co-located Worker Exposure Concentration (mg/m^3)	Co-located Worker Evaluation Guidelines (mg/m^3)	Public (6 km) Exposure Concentration (mg/m^3)	Public Evaluation Guidelines (mg/m^3)
			ERPG-3		ERPG-2
Extremely Unlikely	Hydrofluoric acid	***2,100***	41	2.8	16.4
	Cadmium	***20***	7.5	0.028	0.5
	Tributyl phosphate	280	300	0.38	10
	Phosgene	***20***	4	0.027	0.8
	Mercury	***47***	4.1	0.064	2.05
	Lead	2.3	100	0.0032	0.25
	Nitric acid	130	200	0.18	15
	Sodium nitrate	49	100	0.068	7.5
	Uranium	5.0	10	0.0068	1
	Ammonia	390	525	0.54	105
			ERPG-3		ERPG-1
Unlikely	Hydrofluoric acid	***2,100***	41	***2.8***	1.5
	Cadmium	***20***	7.5	0.027	0.03
	Mercury	***47***	4.1	0.064	0.1
	Sodium nitrate	49	100	0.068	1
	Phosgene	***20***	4	0.027	0.4
	Tributyl phosphate	280	300	0.38	6
	Nitric acid	130	200	0.18	3
	Formaldehyde	***32***	30	0.043	1.25
	Ammonia	390	525	0.54	17.5
	Hydrochloric acid	78	224	0.11	4.5
			ERPG-3		ERPG-1
Unlikely	Hydrofluoric acid	24	41	0.033	1.5
	Cadmium	0.25	7.5	0.00034	0.03
	Phosgene	0.38	4	0.00052	0.4
	Sodium nitrate	0.60	100	0.00083	1
	Tributyl phosphate	3.4	300	0.0046	6
	Nitric acid	1.6	200	0.0022	3
	Mercury	0.050	4.1	6.9E-05	0.1
	Formaldehyde	0.39	30	0.00054	1.25
	Ammonia	4.7	525	0.0064	17.5
	Hydrochloric acid	0.96	224	0.0013	4.5

NOTE: *Bold italics denotes evaluation guideline exceeded.*

3.4.3 Beyond Design Basis Accidents

The DOE-STD-3009-94 requires the evaluation of beyond design basis scenarios to provide a perspective of the residual risk associated with ISV operations in the SDA. The intent is to provide insight into the magnitude of consequences of scenarios beyond the design basis scenarios discussed in Section 3.4.2. The natural-event earthquake scenario is selected as the bounding beyond design basis scenario. Per guidance in DOE-STD-3009-94, beyond design basis events are not assessed for external accident scenarios and the results are neither compared to evaluation guidelines nor used in the assessment of safety SSCs and TSRs.

3.4.3.1 Natural Event Earthquake. For purposes of the beyond design basis earthquake scenario, an earthquake scenario much larger than the design basis is assumed to occur. The exposures from this scenario would be about the same as for the extremely unlikely design basis earthquake scenario; however, there would be much more damage to confinements and mitigating systems. The off-gas hood and ducting are assumed to collapse and primary power is assumed to fail, as would all alternate power systems. Fires are assumed to occur. The consequences would be equal to the sum of the consequences from the underground fire, loss of confinement, and deflagration in the off-gas hood accidents.

3.4.4 Conclusions

The off-gas hood, the off-gas treatment system (includes the primary and secondary off-gas ventilation systems, the combustible gas monitoring system, and the backup power supply) are identified as safety-class SSCs that must be incorporated into the design. Toxic gas monitors and the propane system are identified as safety-significant design features. Prior to completing the final DSA for ISV operations on buried RFP TRU waste in the SDA, the following must be completed:

- An off-gas analysis is necessary to understand the type and quantity of emissions from normal and abnormal ISV processing operations. The analysis will specifically evaluate phosgene and hydrochloric acid concentrations and will bound the hazards related to an uncontrolled subsurface fire. The analysis will aid in determining risks from ISV processing.

- The capacity of the secondary blower in the off-gas ventilation system is described as one quarter the capacity of the primary blower. An analysis must be completed to determine if this secondary blower capacity provides adequate ventilation of the off-gas hood to maintain hood-gas concentrations below the LFL.

Measures that could be implemented to negate the need for safety-class SSCs include the following:

- A more detailed evaluation of contaminant transport during ISV processing to determine if safety-class SSCs could be replaced by safety-significant SSCs.

- A detailed evaluation of the distribution of the SDA inventory to identify areas that could be treated safely using ISV without safety-class SSCs.

If ISV is selected in the decision-making process for the SDA, cold and hot testing will be required during remedial design to address the following objectives:

- Understand performance, safety, and cost implications of ISV processing in waste zone voids and in heterogeneous debris and sludge waste characteristic of RFP disposals in the SDA.

- Quantify the hazards associated with processing nonradioactive hazardous materials that may be co-located with RFP TRU waste.

- Ensure that the off-gas hood and the off-gas treatment system are adequately sized to capture, contain, and treat off gases from routine operations and from accident events.

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