OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT ANALYSIS/MODEL COVER SHEET

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Page: 1 of: 51

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Revision 00A of this analysis used the definitions of DBE categories and dose criteria from the proposed rule 10 CFR 63 (64 FR 8640), Sections 2 and 111, respectively. Revision 00B of this analysis used the same data from the Revised DOE Interim Guidance (Dyer 1999), dated September 3, 1999. A review and evaluation of the definitions of DBE categories and dose criteria in these two documents was conducted and it was concluded that using Dyer (1999) in Revision 00B has no impact on the analysis results or conclusion.

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
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Initial Issue

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ACRONYMS AND ABBREVIATIONS

ARF	Airborne Release Fraction
ATS	Assembly Transfer System
BDBE	Beyond Design Basis Event
CDE	Committed Dose Equivalent
CEDE	Committed Effective Dose Equivalent
CFR	Code of Federal Regulations
CHS	Carrier/Cask Handling System
CPB	Carrier Preparation Building
CRWMS	Civilian Radioactive Waste Management System
CSNF	Commercial Spent Nuclear Fuel
CTS	Canister Transfer System
DBE	Design Basis Event
DC	Disposal Container
DCF	Dose Conversion Factor
DCHS	Disposal Container Handling System
DDE	Deep Dose Equivalent
DIRS	Document Input Reference Sheets
DSNF	DOE Spent Nuclear Fuel
DOE	Department of Energy
DPC	Dual-Purpose Canisters
DR	Damage Ratio
HEPA	High-Efficiency Particulate Air
HIC	High Integrity Container
HLW	High Level Waste
HLW/PU	Pu Can-in-Canister
ICRP	International Commission on Radiological Protection
LA	License Application
MAR	Material at Risk
MCO	Multi Canister Overpack
M&O	Management and Operating Contractor
MFD	Mechanical Flow Diagram
MGR	Monitored Geologic Repository
MPC	Multi-Purpose Canister
NRC	Nuclear Regulatory Commission

NSNFP	National Spent Nuclear Fuel Program
QA	Quality Assurance
QARD	Quality Assurance Requirements and Description
RF	Respirable Fraction
SC	Shipping Cask
SFA	Spent Fuel Assembly
SNF	Spent Nuclear Fuel
SR	Site Recommendation
SSC	Structure, System, and Component
TBD	To Be Determined
TBV	To Be Verified
TEDE	Total Effective Dose Equivalent
VA	Viability Assessment
WHB	Waste Handling Building
WP	Waste Package

1. PURPOSE

The purpose of this document is to perform a preliminary design basis event (DBE) analysis of the DOE Spent Nuclear Fuel (SNF) waste form. The objective of the analysis is to determine any preclosure safety impacts of the waste form on the Monitored Geologic Repository (MGR). The scope of this analysis is to determine the offsite dose consequences and associated frequencies of selected DBEs for systems handling disposable canisters that bound all surface and subsurface off-normal events, and to compare these results against regulatory limits. The results of this work are preliminary and are intended to be used to establish a set of preliminary MGR and waste form requirements, to identify mitigation or prevention features that may be required to meet regulatory limits, and to provide input to the Site Recommendation (SR) report. This document is prepared in accordance with the associated development plan (Civilian Radioactive Waste Management System Management and Operating Contractor [CRWMS M&O] 1999g).

2. QUALITY ASSURANCE

The Quality Assurance (QA) program applies to this analysis. The work reported in this document is part of the analysis of MGR DBEs. The work done for this analysis was evaluated according to QAP-2-0, *Conduct of Activities*. This Activity Evaluation determined that such activities are subject to the requirements of *Quality Assurance Requirements and Description* (QARD) (DOE 1998a).

This analysis is quality affecting because the results may be used to support analyses of MGR structures, systems, and components (SSCs) in accordance with QAP-2-3, *Classification of Permanent Items*.

Inputs and their sources are identified and documented in accordance with AP-3.15Q, *Managing Technical Product Inputs*.

3. COMPUTER SOFTWARE AND MODEL USAGE

3.1 Scientific and Engineering Software

Not applicable, since no software, routines, macros or models subject to the QARD were produced to support this analysis. This analysis relied solely on Excel 97 spreadsheets for all dose and frequency calculations.

3.2 Computational Support Software

Excel 97 for Windows

All dose calculations performed to support this analysis were generated with Excel 97 spreadsheets and run on Pentium personal computers. A spreadsheet was used to calculate doses for the DBE scenarios analyzed. The methodology used to perform the dose and frequency calculations is described in Sections 6.4 and 6.5. Results were verified by visual inspection and/or hand calculations.

4. INPUTS

Design inputs apply to the preliminary design. These design inputs will require subsequent qualification before the analysis can be used to support procurement, fabrication, or construction activities. Unverified inputs are tracked in accordance with AP-3.15Q, *Managing Technical Product Inputs*.

4.1 Data and Parameters

4.1.1 Canister Related DBEs

A complete list of canister related DBEs was obtained from the *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a, Table 7).

4.1.2 Bounding DOE SNF Data

All data related to the selection of bounding DOE SNF was obtained from the *DOE SNF Screening Dose Analysis* (CRWMS M&O 1999e).

4.1.3 Bounding Dose Consequences

The bounding doses to the maximally exposed offsite individual on a per canister basis of DOE SNF, Navy SNF, and HLW waste forms are shown in Tables 6.4-1, 6.4-2, and 6.4-3. These data were obtained from the *DOE SNF DBE Offsite Dose Calculations* (CRWMS M&O 1999d) and the *DOE High-Level Vitrified Waste Dose Calculation* (CRWMS M&O 1999c).

4.1.4 Number of Canisters

Shipping casks and DCs may contain DOE SNF only, DOE SNF co-disposed with HLW, or Multicanister Overpacks (MCOs). The maximum number of DOE SNF canisters in a shipping cask is nine, one, and four, for the separate disposal DSNF, the co-disposal DSNF, and the DSNF MCO shipping casks, respectively (CRWMS M&O 1999b and Figure 3). The maximum number of DOE SNF canisters in a DC is nine, one, and four, for the separate disposal DSNF, the co-disposal DSNF, and the DSNF MCO DCs, respectively. Per CRWMS M&O (1997g, Tables F-2 and 5-9), the maximum number of DOE SNF canisters in a DC is six, one, and four for the separate disposal DSNF, the co-disposal DSNF, and the DSNF MCO DCs, respectively. Therefore, the maximum number of nine DOE SNF canisters in a DC used in this analysis is a bounding value. The maximum number of naval fuel canisters in a shipping cask (CRWMS M&O 1999b, Section 3.1.5.3) or a DC (CRWMS M&O 1997g, Table F-2) is one.

4.1.5 Frequency Data

All frequency related data was obtained from the *MGR Event Tree Analysis for Cask, Canister and Container Drop Events* (CRWMS M&O 1999b).

4.2 Criteria

The primary criteria applicable to this analysis are the regulatory dose limits for radiation protection of the public as specified in the *Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations for Yucca Mountain, Nevada* (Dyer 1999) and in Title 10 of the Code of Federal Regulations Part 20 (10 CFR 20), Section 1301. This analysis compares the regulatory criteria against calculated doses at assumed boundary distances for the preclosure boundary area to determine if the MGR can be operated without exceeding the regulatory dose limits. The applicable dose criteria are listed in Table 4.2-1.

Table 4.2-1: Dose Criteria for MGR DBEs

DBE Type	Dose Type	Dose Criteria
Category 1	Cumulative Dose from all pathways and all Category 1 DBEs	25 mrem/yr
Category 2	TEDE	5 rem/event
Category 2	CDE + DDE	50 rem/event
Category 2	Lens of the Eye	15 rem/event
Category 2	Skin & Extremities	50 rem/event

In Table 4.2-1, TEDE refers to the total effective dose equivalent, CDE refers to the committed dose equivalent, and DDE refers to the deep dose equivalent. TEDE is equivalent to the committed effective dose equivalent (CEDE) plus DDE where CEDE is based on the "effective" inhalation dose conversion factors (DCFs) and DDE is based on the air submersion dose conversion factor (DCF). The CDE is based on the inhalation DCFs for the lungs, breast, gonads, red marrow, bone surface, thyroid, and remainder. The remainder includes five remaining organs or tissues (such as liver, kidneys, spleen, brain, small intestine, upper large intestine, lower large intestine, etc., but excluding skin, lenses of the eye, and the extremities) receiving the highest doses. The dose to the lens of the eye is based on the presence of Kr-83m, which is the only radioisotope to have a DCF for the eye. The dose to the skin and extremities is solely based on air submersion DCFs. No ingestion dose was considered for Category 2 events.

4.3 Codes and Standards

- 4.3.1 10 CFR 20. *Standards for Protection Against Radiation*, U.S. Nuclear Regulatory Commission, Washington, DC, January 1, 1998. TIC: 238505.
- 4.3.2 Dyer 1999. *Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations for Yucca Mountain, Nevada*, Letter from J. Russell Dyer (DOE) to D. R. Wilkins (YMP), U.S. Department of Energy, North Las Vegas, Nevada, September 9, 1999. ACC: MOL.19990910.0079.

5. ASSUMPTIONS

- 5.1 Only those surface and subsurface events identified in Table 6.2-1 are credible and have the potential to result in a radioactive material release. *Basis: Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a, Table 7) table labeled Internal Events with Potential Releases. *Usage:* Used in Section 6.2, "Selection of Bounding DBEs."
- 5.2 There are no credible events that can cause a cart tipover or the Shipping Cask (SC) to breach as a result of a cart tipover (TBV-3122). *Basis: Plutonium Can-in-Canister - Design Basis Event Analysis* (CRWMS M&O 1999f). *Usage:* Used in Section 6.2, "Selection of Bounding DBEs."
- 5.3 Facility controls are employed to ensure that the drop of any handling equipment cannot cause a SC, a canister, or a canister inside a disposal container (DC) to breach (TBV-3123). *Basis: Plutonium Can-in-Canister - Design Basis Event Analysis* (CRWMS M&O 1999f). *Usage:* Used in Section 6.2, "Selection of Bounding DBEs."
- 5.4 There are no credible events that can cause the lag storage rack to fail resulting in a canister breach (TBV-3124). *Basis: Plutonium Can-in-Canister - Design Basis Event Analysis* (CRWMS M&O 1999f). *Usage:* Used in Section 6.2, "Selection of Bounding DBEs."
- 5.5 Facility controls are employed to ensure that the collision of a canister with another canister cannot cause either canister to breach (TBV-3125). *Basis: Plutonium Can-in-Canister - Design Basis Event Analysis* (CRWMS M&O 1999f). *Usage:* Used in Section 6.2, "Selection of Bounding DBEs."
- 5.6 There are no credible events that can cause a cart tipover or the DC to breach as a result of a cart tipover (TBV-3126). *Basis: Plutonium Can-in-Canister - Design Basis Event Analysis* (CRWMS M&O 1999f). *Usage:* Used in Section 6.2, "Selection of Bounding DBEs."
- 5.7 A Waste Package (WP) is designed to not breach if dropped from normal handling heights, and a WP is not certified to withstand a drop from the two-block height associated with the Disposal Container Handling System crane (TBV-1342). *Basis: MGR Event Tree Analysis for Cask, Canister and Container Drop Events* (CRWMS M&O 1999b). *Usage:* Used in Section 6.2, "Selection of Bounding DBEs."
- 5.8 Varying the distance from 5,000 m to 10,000 m, the atmospheric dispersion factor, χ/Q , decreases by a factor of 2 (TBV-3114). *Basis: Preliminary χ/Q Concentration Estimates Using NRC Regulatory Guide 1.145 as Implemented by the XQ145 Software Routine* (CRWMS M&O 1998a). *Usage:* Used in Section 6.8.1, "Additional Consequence Analysis Option."
- 5.9 The preclosure period is assumed to be 100 years (TBV-690). *Basis: Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a). *Usage:* Used in Section 6.5.1, "DBE Category Definitions."
- 5.10 It is assumed that the airborne release fractions, respirable fractions, and other input parameters for the DOE SNF waste form are equal to the values given in Attachment IV (TBV-3235, TBV-3237, TBV-3238, TBV-3309, TBV-3238, and TBV-3475). *Basis:*

DOE SNF DBE Offsite Dose Calculations (CRWMS M&O 1999d, Sections 3 and 5.2). *Usage:* Used in Section 6.4, "Consequence Analysis."

- 5.11 A breathing rate of 20 liters/min for the volume intake of air for "light activity" is assumed (TBV-3102). *Basis:* *Report of the Task Group on Reference Man. ICRP Publication 23* (ICRP 1974). *Usage:* Used in Section 6.4, "Consequence Analysis."
- 5.12 The MGR is designed to withstand the following subsurface DBEs: an uncontrolled transporter descent, WP horizontal drop onto sharp object, and fuel rod rupture/internal pressurization (TBV-245). *Basis:* *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a). *Usage:* Used in Section 6.2.1, "Bounding DBE Determination."
- 5.13 It is assumed that rockfall exceeding WP design basis is a Beyond Design Basis Event (TBV-684). *Basis:* *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a). *Usage:* Used in Section 6.2.1, "Bounding DBE Determination."
- 5.14 It is assumed that a fire in subsurface facilities is a Beyond Design Basis Event (TBV-688). *Basis:* *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a). *Usage:* Used in Section 6.2.1, "Bounding DBE Determination."
- 5.15 It is assumed that the frequency of preclosure early failure of a WP is very low and the consequences associated with the event are negligible (TBV-3116). *Basis:* *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a). *Usage:* Used in Section 6.2.1, "Bounding DBE Determination."
- 5.16 In calculating the fraction of radionuclide inventory at-risk, it is assumed that all of the DOE SNF canisters of a given fuel type have the same isotopic composition (TBV-3240). *Basis:* *DOE SNF DBE Offsite Dose Calculations* (CRWMS M&O 1999d). If the isotopic data are not sufficiently skewed to adequately account for variation in the isotopic composition of a given fuel type this assumption is non-conservative. Uncertainty analysis needs to be performed to determine the effect of non-homogeneous isotopic composition on the consequence analysis results. *Usage:* Used in Section 6.4, "Consequence Analysis."

6. ANALYSIS

The purpose of this section is to document the preliminary DBE analysis of the DOE SNF waste form. The objective of the analysis is to determine any preclosure safety impacts of the waste form on the MGR.

The DBE analysis includes identification of the bounding DBEs, calculation of the associated frequencies and consequences, comparison of the results to criteria, and identification of facility and waste form requirements. Figure 1 provides a flowchart of the DBE analysis process, and Figure 2 provides a flowchart of the supporting documents.

6.1 Overview of Canister Handling Operations

This section presents an overview of the MGR canister handling operations.

Figure 1: DBE Analysis Process Flowchart

Figure 2: Calculational Interfaces for DOE SNF DBE Analysis

6.1.1 Carrier/Cask Transport System

Canisters are transported to the MGR inside a shipping cask (SC) on a carrier (e.g., a rail car) and are received by the Carrier/Cask Transport System. The site prime mover is attached to the carrier, and the SC and carrier are transported to the Carrier Preparation Building (CPB). The personnel barrier and impact limiters are not removed from the SC during this operation. These operations are based on the mechanical flow diagram (MFD) for the Carrier/Cask Transport System (CRWMS M&O 1997a).

6.1.2 Carrier Preparation Building

In the CPB, the personnel barrier and impact limiters are removed from the SC while the SC remains on the carrier. The SC and carrier are then transported to the carrier bay of the Waste Handling Building (WHB). These operations are based on the MFD for the CPB material handling system (CRWMS M&O 1997b).

6.1.3 Carrier/Cask Handling System

In the carrier bay, the SC is upended on the carrier by the Carrier/Cask Handling System (CHS) bridge crane and transferred from the carrier to a transfer cart. The SC on the transfer cart is then transported to the Canister Transfer System (CTS). These operations are based on the MFD for the CHS (CRWMS M&O 1997c).

6.1.4 Canister Transfer System

The CTS receives the SC on the transfer cart from the CHS. The CTS consists of a cask preparation and decontamination area and a canister handling area. The cask preparation and decontamination area consists of a cask preparation station and a cask decontamination station. In the cask preparation operation, flexible hoses are attached to the cask; the cask interior is sampled, vented, and purged; and the lid bolts are de-tensioned and removed. The lid handler is positioned above the cask, and the cask lid is removed. If required, the cask is then decontaminated and moved to the canister handling area by the transfer cart.

The canister handling area consists of a delid/transfer station and a DC loading station. The cask lid lifting fixture is moved into position over the cask in the delid/transfer station, lifting bolt holes in the cask lid are engaged, and the lid is lifted off the cask. The canister bridge crane remotely attaches the lifting fixture, mates with the canister, and transfers a DOE SNF canister to the canister staging rack or directly into the DC on a transfer cart. The transfer cart and loaded DC are then transported to the Disposal Container Handling System (DCHS). These operations are based on the MFDs for the CTS (CRWMS M&O 1997d; CRWMS M&O 1997e).

6.1.5 Disposal Container Handling System

The DC is transferred from the transfer cart to the welding station turntable for final closure operations. After final closure operations, the DC, now called a WP, is transferred to a tilting fixture for loading onto a horizontal transfer cart. The WP is then transferred horizontally from the transfer cart to the WP transporter. The WP transporter is then transported through the

transfer corridor to the emplacement ramp and then to the underground emplacement area. These operations are based on the MFDs for the DCHS (CRWMS M&O 1997f).

6.2 Selection of Bounding DBEs

This section identifies and defines in detail the applicable bounding DBEs for each system that directly or indirectly handles disposable canisters. This section addresses steps 1 and 2 of Figure 1.

6.2.1 Bounding DBE Determination

The bounding DBEs were determined from the *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a, Tables 6, 7, 9, and 10). That analysis identifies all DBEs by system for the MGR without regard to the waste form. It identifies four categories of events: Preliminary External DBEs, Internal Events with Potential Releases, Internal Events with No Release, and Beyond Design Basis Events (BDBEs). These event categories were reviewed to determine the bounding DBEs to be analyzed in Sections 6.4 through 6.7.

The first category of events reviewed in the *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a, Table 6) includes Preliminary External DBEs. External MGR DBEs are events initiated by an external event such as an earthquake. All applicable External DBEs were removed from the list of DBEs requiring further analysis because all externally induced canister related DBEs are prevented by design (CRWMS M&O 1999a). For example, an earthquake could cause the WHB to collapse, resulting in damage to the casks and canisters contained within it. However, the WHB is designed to not collapse during a design basis earthquake. Therefore, this event (building collapse due to earthquake) is prevented by design, and the associated DBE does not require further evaluation in this analysis.

The second category of events reviewed in the *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a, Table 7) are Internal Events with Potential Releases and they are shown in Table 6.2-1. Internal events are caused by events within the MGR such as an equipment malfunction or an operator error. Only those surface and subsurface events identified in Table 6.2-1 are credible and have the potential to result in a radioactive material release (Assumption 5.1). These events were reviewed and three events were identified as requiring further evaluation in this analysis as bounding DBEs. These bounding DBEs are as follows:

- Shipping Cask Drop (no impact limiters)
- Canister Drop onto Floor
- Unsealed DC Drop and Slapdown

The reasons for screening out other events are provided in Table 6.2-1. Events for systems that do not handle disposable canisters are screened out because they do not apply to DOE SNF.

The third category of events listed in the *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a, Table 9) includes Internal DBEs with No Release. Similar to the Preliminary External DBEs, these events were removed from the list of DBEs requiring further evaluation in this analysis because they are prevented by design from resulting in a release.

The fourth category of events listed in the *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a, Table 10) includes Beyond Design Basis Events. Beyond Design Basis Events are those events that are expected to occur with a frequency of less than one time in a

million years. Based on the event definitions provided in the *Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations for Yucca Mountain, Nevada* (Dyer 1999), consequence analysis of Beyond Design Basis Events is not required. Section 6.5 of this analysis provides more information related to the event definitions. Thus, all of the events in this category except the two-block events (SC, canister, or DC drops from the maximum lift height) and the Unsealed DC Drop (from normal lift height) were removed from the list of events requiring further evaluation in this analysis. Discussion of the two-block event is provided below.

In the *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a), an assumption was made that SSCs could be incorporated into the MGR design and operation to ensure that the two-block event is a Beyond Design Basis Event. While this may be possible, it may place unnecessary requirements on the MGR design and operations. Thus, this analysis did not take credit for that assumption and conservatively considered a two-block event to be credible and included it as another initiator of a shipping cask, canister, or DC drop event.

Additionally, the assumption that a two-block event is a Beyond Design Basis Event in the *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a) resulted in removing the waste package drop event from the list of events with potential releases. Since this analysis did not take credit for this assumption and considers that a two-block event is credible, and also assumes that a waste package is not certified to withstand a drop from the two-block height associated with the DCHS crane (Assumption 5.7), a waste package drop event is further evaluated. Thus, a waste package drop was included as part of the DC Drop Analysis.

Note that the first, second, third, and fourth categories of events listed in the *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a) also include subsurface events. All subsurface events involve waste packages. The first category of events that could involve subsurface facilities includes loss-of-offsite power to MGR, earthquake, and flood. As stated above these events are prevented by design from resulting in breach of a WP. The second category of events includes a subsurface event, i.e., preclosure early failure of a WP. Table 6.2-1 provides the rationale for excluding this event (Assumption 5.15) from further evaluation in this analysis. The third category of events has three subsurface events, i.e., an uncontrolled transporter descent, WP horizontal drop onto sharp object, and fuel rod rupture/internal pressurization. These three events were removed from the list of DBEs requiring further analysis because they are prevented by design from resulting in breach of a WP (Assumption 5.12). The fourth category of events has two subsurface events, i.e., a fire in subsurface facilities and rockfall exceeding WP design basis. These two events were removed from the list of DBEs requiring further analysis because they are Beyond Design Basis Events (Assumptions 5.13 and 5.14). Therefore, no subsurface events are evaluated in this analysis.

Thus, the bounding DBEs are as follows:

- Carrier/Cask Transport System – No bounding DBE has been identified (Shipping Cask with impact limiters ensures no breach can occur).
- Cask Preparation Building – No bounding DBE has been identified.
- Carrier/Cask Handling System – Shipping Cask Drop (no impact limiters)
- Canister Transfer System – Canister Drop onto Floor
- Disposal Container Handling System – Unsealed DC Drop and Slapdown, and Two-Block DC/WP Drop

The specific inputs and assumptions made for this screening analysis to determine the bounding DBEs are listed in Sections 4 and 5.

Table 6.2-1: Internal Events-DBE Screening Analysis

#	DBE Description	Location	Screened Out	Reason for Screening
1	Shipping Cask Drop (no impact limiters)	Carrier Bay	No	Not screened. Analyzed as a DBE
2	Shipping Cask Tipover/Slapdown (no impact limiters)	Carrier Bay	Yes	Event caused by earthquake. Cart designed to not tipover during earthquake (Assumption 5.2). Therefore, this event is designed for.
3	Shipping Cask Drop into Cask Preparation Pit	Cask Prep Pit	Yes	Not part of disposable canister handling systems.
4	Shipping Cask Drop into Cask Unloading Pit	ATS Pool	Yes	Not part of disposable canister handling systems.
5	SFA Drop onto Pool Floor	ATS Pool	Yes	Not part of disposable canister handling systems.
6	SFA Drop onto Another SFA in Pool Staging Rack	ATS Pool	Yes	Not part of disposable canister handling systems.
7	SFA Collision	ATS Pool or ATS Hot Cell	Yes	Not part of disposable canister handling systems.
8	Handling Equipment Drops onto SFA	ATS Pool or ATS Hot Cell	Yes	Not part of disposable canister handling systems.
9	SFA Drop onto Hot Cell Floor	ATS Hot Cell	Yes	Not part of disposable canister handling systems.
10	SFA Drop into Empty DC	ATS Hot Cell	Yes	Not part of disposable canister handling systems.
11	SFA Drop onto Another SFA in DC or Dryer	ATS Hot Cell	Yes	Not part of disposable canister handling systems.
12	SFA Basket Drop onto Pool Floor	ATS Pool	Yes	Not part of disposable canister handling systems.
13	SFA Basket Collision	ATS Pool or Hot Cell	Yes	Not part of disposable canister handling systems.
14	Uncontrolled Descent of Loaded Incline Basket Transfer Cart	ATS Pool	Yes	Not part of disposable canister handling systems.
15	SFA Basket Drop onto Hot Cell Floor	ATS Hot Cell	Yes	Not part of disposable canister handling systems.
16	Handling Equipment Drops onto SFA Basket	ATS Pool or ATS Hot Cell	Yes	Not part of disposable canister handling systems.

Table 6.2-1: Internal Events-DBE Screening Analysis

#	DBE Description	Location	Screened Out	Reason for Screening
17	SFA Basket Drop onto Another SFA Basket in Dryer	ATS Hot Cell	Yes	Not part of disposable canister handling systems.
18	Canister Drop onto Floor	CTS Hot Cell	No	Not Screened. Analyzed as a DBE.
19	Handling Equipment Drop onto Canister	CTS Hot Cell	Yes	Canister does not breach. Analysis and facility controls employed to ensure no breach (Assumption 5.3).
20	Canister Tipover/Slapdown	CTS Hot Cell	Yes	Event caused by earthquake. Rack designed for earthquake (Assumption 5.4). Therefore, this event is designed against.
21	Canister Drop onto Sharp Object	CTS Hot Cell	Yes	Subset of Canister Drop onto floor event (#18). Frequency of all drops included in event #18 without regard to orientation of drop and without regard to impacted surface. Consequence bounded by event #18 as that event uses conservative release fraction that covers drops onto other objects.
22	Canister Drop onto DC	CTS Hot Cell	Yes	Subset of Canister Drop onto floor event (#18). Frequency of all drops included in event #18 without regard to orientation of drop and without regard to impacted surface. Consequence bounded by event #18 as that event uses conservative release fraction that covers drops onto other object.
23	Canister Collision	CTS Hot Cell	Yes	Canister does not breach. Analysis and facility controls employed to ensure no breach (Assumption 5.5).

Table 6.2-1: Internal Events-DBE Screening Analysis

#	DBE Description	Location	Screened Out	Reason for Screening
24	Small Canister Drop onto Another Small Canister	CTS Hot Cell	Yes	Subset of Canister Drop onto floor event (#18). Frequency of all drops included in event #18 without regard to orientation of drop and without regard to impacted surface. Consequence bounded by event #18 as that event uses conservative release fraction that covers drops onto other objects. In addition, material at risk included in #18 consequence calculation includes the material at risk of two canisters.
25	Unsealed DC Drop and Slapdown	DC Hot Cell	No	Not screened. Analyzed as a DBE.
26	Handling Equipment Drop onto Unsealed DC	DC Hot Cell	Yes	Canister does not breach. Analysis and facility controls employed to ensure no breach (Assumption 5.3).
27	Unsealed DC Tipover/Slapdown	DC Hot Cell	Yes	Event caused by earthquake. Cart designed to not tipover during earthquake (Assumption 5.6). Therefore, this event is designed against.
28	Preclosure "Early Failure" of a WP	Subsurface	Yes	Early failure of a WP has a very low frequency because multiple barriers must be corroded/damaged before a release can occur and only gases and volatile elements could be released, resulting in negligible consequences (Assumption 5.15). Thus, further evaluation of this event in this analysis is not required.

6.2.2 Bounding DBE Descriptions

This section provides a detailed description of the bounding DBEs that involve DOE SNF canisters.

6.2.2.1 CHS - Shipping Cask Drop (No Impact Limiters)

In the CHS, a SC without impact limiters has a potential to be dropped from the bridge crane while it is being lifted off the carrier and lowered onto a transfer cart. The drop of a fully loaded shipping cask onto the facility floor could result in a breached shipping cask. The drop may occur as a result of an operator error or mechanical failure of the crane (e.g., hoist failure). The shipping cask could drop from different heights onto an unyielding surface or onto a sharp object, and could drop in any vertical, horizontal, or corner orientation. Shipping casks can contain DOE SNF only, DOE SNF co-disposed with HLW, or Multicanister Overpacks (MCOs) as shown in Figure 3. The normal handling heights for all DOE SNF shipping casks are 0 to 80 inches and the maximum handling heights are 275 inches, 357 inches, and 357 inches for the separate disposal DSNF, the co-disposal DSNF, and the DSNF MCO shipping casks respectively (CRWMS M&O 1999b). The maximum number of DOE SNF canisters in a shipping cask is nine, one, and four, for the separate disposal DSNF, the co-disposal DSNF, and DSNF MCO shipping casks respectively (CRWMS M&O 1999b).

Airborne release fractions associated with this event and other bounding events were selected to be bounding and are not dependent on drop height, angle of orientation, or impact with other objects. Thus, these variables do not need to be described as part of the DBE scenario. The airborne release fractions used in the consequence analysis are given in Attachment IV.

6.2.2.2 CTS - Canister Drop onto Floor

The DOE SNF canister has the potential to be dropped by the CTS bridge crane when it is lifted out of the SC, transferred to either the lag storage rack or directly to the DC, lowered into either the lag storage rack or the DC, lifted from the lag storage rack, or transferred to the DC from the lag storage rack. Based on the assumption that a DOE SNF canister may fail if dropped from above the height at which it is certified, the drop of a fully loaded canister onto the facility floor could result in a breached canister. This drop may occur as a result of an operator error or mechanical failure of the crane (e.g., hoist failure). The DOE SNF canister could drop from different heights onto an unyielding surface, onto a sharp object, onto a shipping cask, onto a DC, onto another canister, and could drop in any vertical, horizontal, or corner orientation. DOE SNF is shipped in three canister types, large, small, and the MCO. The normal handling heights for all canisters are 0 to 248 inches and the maximum handling heights are 385 inches, 448 inches, and 401 inches for the large, small, and MCO canisters respectively (CRWMS M&O 1999b).

DOE SNF canister drops onto the CTS floor will bound drops into an SC or DC or onto an empty lag storage rack, which would provide some drop-force dampening for the DOE SNF canisters through either rack plastic deformation or through a piston-like effect in SCs/DCs. All impact orientations of the DOE SNF canister are considered in this analysis. For DOE SNF canister drops onto a canister located in the lag storage rack, the potential for breaching two canisters is considered.

Figure 3: Shipping Cask Configurations (Naval Cask Not Shown)

6.2.2.3 DCHS - Unsealed Disposal Container/Waste Package Drop

The DCHS handles both DCs and WPs; thus, this event considers a drop of either one. The unsealed DC drop could occur while the DC is being lifted off the transfer cart and transferred to the welding station turntable. The WP drop could occur as it is moved from the welding station to the tilting station. All other WP drops are prevented by design since the maximum lift height is below the WP certified height (CRWMS M&O 1999a). The drop of a fully loaded unsealed DC onto the facility floor could result in a breached canister. The drop may occur as a result of operator error or mechanical failure of the crane (e.g., hoist failure). The DC could drop from different heights onto an unyielding surface or onto a sharp object, and could drop in any vertical, horizontal, or corner orientation. Disposal containers can contain DOE SNF separately disposed, DOE SNF co-disposed with HLW, or MCOs. The normal handling heights for all DCs are 0 to 60 inches and the maximum handling heights are 192 inches, 254 inches, and 192 inches for the DOE SNF separately disposed, the co-disposal, and the MCO DCs respectively (CRWMS M&O 1999b). The maximum number of DOE SNF canisters in a DC is nine, one, and four, for the DOE SNF only, co-disposal, and MCO DCs respectively (CRWMS M&O 1999b). DC drops onto the DCHS floor will bound the drops onto the transfer cart, the staging fixture, the welding station, or the tilting fixture, which would provide some drop-force dampening for the DC/WP, as well as reduce the drop heights. All impact orientations of the DC/WP are considered in this analysis.

Even though the MAR contained in the majority of DSNF canisters is well below those selected as bounding, all canisters are assumed to contain a full canister of the bounding fuel type as described in Section 6.3. MCOs are assumed to contain the bounding N-Reactor fuel type.

6.3 **Selection of Bounding DOE SNF**

This section identifies the bounding DOE spent nuclear fuel for each of the six DBE groups currently defined by National Spent Nuclear Fuel Program (NSNFP).

6.3.1 **DBE Grouping of DOE SNF**

DOE SNF consists of over 250 fuel types. The NSNFP conducted an evaluation to segregate the various fuels into a few representative groups tailored for DBE analysis. NSNFP proposed three preliminary groups for identification of candidate fuel types for DBE analyses. Because the release fractions for degraded fuels may differ from those of intact fuels, NSNFP further divided each of the three groups into those with intact fuels and those with non-intact (degraded) fuels. This results in six DBE groups: Stable Metal, Intact Group; Stable Metal, Not Intact Group; Non-Metal, Intact Group; Non-Metal, Not Intact Group; Other, Intact Group; and Other, Not Intact Group.

The Stable Metal Group includes fuel types with mechanically and chemically stable fuel matrix materials such that essentially no fuel fines would be released from the fuel matrix during a DBE.

The Non-Metal Group includes fuels that are expected to release particulate during a DBE because of the brittle or fragile nature of the fuel matrix.

The Other Group includes fuels with chemical properties that could increase the radionuclide release fraction as a result of chemical reactions that may occur prior to, during, or after a DBE.

The Intact and Not Intact categories are based on the characteristics of the fuel cladding. If the cladding condition is known to be "good" (cladding intact) or "fair" (known or suspected leakers but cladding otherwise intact), the fuel condition is presumed intact. If the cladding condition is "poor", "declad", or "unknown", the fuel condition is presumed "non-intact".

Each of the DOE spent nuclear fuel types listed in *DOE SNF Screening Dose Analysis* (CRWMS M&O 1999e) is placed into one of these DBE groups. All fuels in a DBE group are assumed to behave the same manner during a DBE, and therefore are expected to have the same airborne release fraction (ARF) and respirable fraction (RF).

6.3.2 DOE SNF Bounding Fuel Selection Process

The bounding fuel is defined as the fuel that has the highest normalized bounding offsite dose potential in a DBE group. The potential offsite consequences have been identified for each fuel in the *DOE SNF Screening Dose Analysis* (CRWMS M&O 1999e). The bounding normalized offsite dose is equal to the higher of the total effective dose equivalent (TEDE) divided by the whole body dose limit (i.e., 5-rem TEDE) or the highest of the seven committed dose equivalents (CDEs) plus the Deep Dose Equivalent (DDE) divided by the organ dose limit (i.e., 50-rem CDE plus DDE).

Ranking of the DOE SNF types by the DBE group and by the bounding normalized dose (i.e., the bounding dose to dose limit ratio) was performed in *DOE SNF Screening Dose Analysis* (CRWMS M&O 1999e) for all DBE groups.

The following steps were taken to select the bounding fuel for each DBE group.

1. Obtain a list of fuel types in a DBE group from the *DOE SNF Screening Dose Analysis* (CRWMS M&O 1999e).
2. Screen out bare fuels that will be handled through the wet line of the MGR.
3. Identify the fuel type with the highest offsite dose consequence in each DBE group.
4. Determine if any special circumstances apply to the selected fuel type. If not, it is the bounding fuel. If special circumstances apply, then discard this fuel type and return to step 3.

6.3.3 DOE SNF Bounding Fuels

The results of the bounding fuel selection are as follows:

The Stable Metal, Intact fuel type with the highest normalized offsite dose is HWCTR (U/TH) [112]. There are no special circumstances regarding this fuel type. Thus, it is selected as the bounding fuel type for the Stable Metal, Intact fuel group.

The Stable Metal, Not Intact fuel type with the highest normalized offsite dose is SRE (U/TH) [215]. However, this fuel consists of three fuel types of which a majority is scheduled to be processed and not shipped for disposal at the MGR. The remaining SRE fuel has low burnup characteristics that are not accurately represented by the dose screening analysis. If necessary, this fuel will be stored in a High Integrity Container (HIC). The fuel type in this group with the next highest normalized offsite dose is Alum Clad SNF [411]. There are no special circumstances regarding this fuel type. Thus, it is

selected as the bounding fuel type for the Stable Metal, Not Intact fuel group.

The Non-Metal, Intact fuel type with the highest normalized offsite dose is EBWR MOX [63]. However, there is only one quarter of a can of this fuel, and if necessary, this fuel will be disposed of in a HIC. The fuel type in this group with the next highest normalized offsite dose is Shippingport PWR Core II [193]. The offsite dose potential is nearly 90% of the EBWR MOX [63], there are 24 cans of this fuel type, and the characteristics of this fuel type are better known than those associated with EBWR MOX [63]. Thus, Shippingport PWR Core II [193] is selected as the bounding fuel type for the Non-Metal, Intact fuel group.

The Non-Metal, Not Intact fuel type with the highest normalized offsite dose is Saxton MOX [787]. There are no special circumstances associated with this fuel type. Thus, it is selected as the bounding fuel type for the Non-Metal, Not Intact fuel group.

The Other, Intact fuel type with the highest normalized offsite dose is Miscellaneous Fuel [366]. However, there is only one can of this fuel and the fuel is not sufficiently known or characterized to allow a meaningful analysis. If necessary, this fuel will be disposed of in a HIC. The fuel type in this group with the next highest normalized offsite dose is FFTF-TFA-FSP-1 & FSP-1R [327]. However, there are only two cans of this fuel and the fuel is not sufficiently known or characterized to allow a meaningful analysis. If necessary, this fuel will also be disposed of in a HIC. The fuel type in this group with the next highest normalized offsite dose is EBWR (U Metal) LEU [64]. The offsite dose potential is approximately 49% of the Miscellaneous Fuel Type [366], there are eleven cans of this fuel type, and the characteristics of this fuel type are better known than those associated with Miscellaneous Fuel Type [366]. Thus, EBWR (U Metal) LEU [64] is selected as the bounding fuel type for the Other, Intact fuel group.

The Other, Not Intact fuel type with the highest normalized offsite dose is EBR-II [438]. However, there are less than two cans of this fuel and this fuel may be processed and not shipped for disposal at the MGR. If necessary, EBR-II [438] fuel will be disposed of in a HIC. The fuel type in this group with the next highest normalized offsite dose is N Reactor [147]. There are 195 cans of this fuel type and the fuel characteristics are well known. Thus, N Reactor [147] is selected as the bounding fuel type for the Other, Not Intact fuel group.

A summary of the bounding fuel selections is provided in Attachment III.

6.4 Consequence Analysis

The bounding DBEs were determined in Section 6.2; they are

- A drop of a fully loaded shipping cask on to the floor of the Cask/Carrier Handling System resulting in a breached shipping cask. A fully loaded shipping cask contains nine standard canisters or four MCOs.
- A drop of a fully loaded canister on to another fully loaded canister in the Canister Transfer System resulting in two breached canisters (i.e. two breached standard canisters or two breached MCOs).
- A drop of a fully loaded disposal container on to the floor of the Disposal Container Handling System resulting in a breached disposal container. A fully loaded disposal container

contains nine standard canisters, or four MCOs, or four HLW canisters and one standard canister.

The offsite consequences from these DBEs are calculated for each bounding DOE SNF type (as determined in Section 6.3) by using the per-canister offsite dose results for the fuels inventories involved in these events as developed in *DOE SNF DBE Offsite Dose Calculations* (CRWMS M&O 1999d). The per-canister DOE SNF dose results shown in Table 6.4-1 are for unfiltered releases, while those in Table 6.4-2 account for HEPA filtration of the DOE SNF source term before it is released to the environment (CRWMS M&O 1999d). The per-canister DOE SNF offsite doses were calculated using the input parameters given in Attachment IV. It is assumed that the airborne release fractions and respirable fractions for the DOE SNF waste form are equal to the values given in Attachment IV (Assumption 5.10) and the breathing rate is equal to 20 liters/min (Assumption 5.11). Table 6.4-3 contains the unfiltered and HEPA filtered per canister offsite dose for HLW (CRWMS M&O 1999c). The number and types of canisters involved in each of the bounding DBEs are shown in Table 6.4-4.

The offsite doses for the bounding DBEs are calculated by multiplying the per-canister offsite doses (Tables 6.4-1, 6.4-2, and 6.4-3) by the number of canisters involved in a given bounding DBE (see Table 6.4-5). The bounding DBE results for both the unfiltered and HEPA-filtered are shown in Table 6.4-5 for the Cask/Carrier Handling System, Table 6.4-6 for the Canister Transfer System, and Tables 6.4-7 and 6.4-8 for the Disposal Canister Handling System. Special consideration is given when calculating the consequences of DBEs involving more than standard canisters for the Other, Not Intact fuel group. Since the bounding fuel for this group (i.e., N-Reactor [147]) is in an MCO, it is non-mechanistically assumed that each standard canister contains the inventory of one MCO. For example, a shipping cask containing nine standard canisters (CRWMS M&O 1999b) of Other, Not Intact fuel is non-mechanistically modeled as containing the inventory of nine MCOs in order to conservatively bound the remaining Other, Not Intact fuels.

Since the number of naval fuel canisters in a shipping cask or a DC is one, the TEDE, highest CDE plus DDE, and skin dose are the same for the three bounding DBEs listed in Table 6.4-4. For the unfiltered case in Table 6.4-1, the TEDE, highest CDE plus DDE, and skin dose for the three bounding DBEs are 8.72×10^{-4} rem, 4.96×10^{-5} rem, and 7.05×10^{-6} rem, respectively. For the HEPA-filtered case in Table 6.4-2, the TEDE, highest CDE plus DDE, and skin dose for the three bounding DBEs are 3.13×10^{-7} rem, 1.54×10^{-6} rem, and 2.90×10^{-9} rem, respectively. These unfiltered and filtered offsite doses are bounded by the offsite doses resulting from the bounding fuel in six DBE groups due to the robustness of the Navy fuel and its insignificant source term.

6.5 Design Basis Event Categories

This section defines the DBE category for each bounding DBE. The DBE category is based on the frequency of the DBE and is used to determine the dose criteria applicable to each DBE. The DBE category definitions, DBE category frequency analysis method, and DBE category frequency analysis results are presented. This section performs steps 4, 5, and 6 of Figure 1.

6.5.1 DBE Category Definitions

The DBE category definitions are based on the definitions provided in the document titled *Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations for Yucca Mountain, Nevada* (Dyer 1999) as follows:

Table 6.4-1. Per Canister DOE SNF Offsite Dose Results
for Source Terms Released Unfiltered to the Environment.

Bounding Fuel	Fuel Type	Fuel Condition	Canister Type	TEDE [rem]	Highest of CDEs + DDE [rem] (a)	Skin [rem]
HWCTR (U/TH) [112]	stable metal	intact	std can.	4.29E-02	4.52E-01	6.25E-04
ALUM CLAD SNF [411]	stable metal	not intact	std can.	1.64E+00	2.41E+01	1.02E-03
Shippingport PWR Core II [193]	non-metal	intact	std can.	1.44E+01	2.50E+02	8.35E-03
Saxton (MOX) [787]	non-metal	not intact	std can.	1.13E+02	1.99E+03	9.36E-03
EBWR (U Metal) LEU [64]	other	intact	std can.	2.58E+01	4.46E+02	2.00E-02
N Reactor [147]	other	not intact	MCO	4.30E+01	7.30E+02	4.59E-02
Navy SNF	N/A	N/A	naval can.	8.72E-04	4.96E-03	7.05E-06

(a) highest CDE is to the bone surface

Table 6.4-2. Per Canister DOE SNF Offsite Dose Results
for HEPA-Filtered Source Terms Released to the Environment.

Bounding Fuel	Fuel Type	Fuel Condition	Canister Type	TEDE [rem]	Highest of CDEs + DDE [rem] (a)	Skin [rem]
HWCTR (U/TH) [112]	stable metal	intact	std can.	4.32E-04	5.18E-04	2.32E-04
ALUM CLAD SNF [411]	stable metal	not intact	std can.	2.28E-02	2.78E-02	7.86E-04
Shippingport PWR Core II [193]	non-metal	intact	std can.	1.42E-02	8.41E-02	1.60E-03
Saxton (MOX) [787]	non-metal	not intact	std can.	2.85E-01	8.29E-01	5.58E-03
EBWR (U Metal) LEU [64]	other	intact	std can.	1.99E-02	1.45E-01	6.18E-04
N Reactor [147]	other	not intact	MCO	8.18E-02	2.82E-01	1.59E-03
Navy SNF	N/A	N/A	naval can.	3.13E-07	1.54E-06	2.90E-09

(a) highest CDE is to the bone surface

Table 6.4-3. Per Canister HLW Offsite Dose Results
for Source Terms Released to the Environment.

SRS HLW	TEDE [rem]	Highest of CDEs + DDE [rem] (a)	Skin [rem]
per HLW canister unfiltered source term release	6.42E-01	1.06E+01	5.14E-05
per HLW canister HEPA-filtered source term release (b)	1.93E-04	3.18E-03	1.54E-08

- (a) Bone surface is the bounding organ.
(b) unfiltered dose multiplied by a HEPA filter LPF of 3.0E-04 (CRWMS M&O 1999d, Section 5.2)

Table 6.4-4. Number and Types of Canisters Involved in the Bounding DBEs.

Bounding DBE	DOE SNF canisters only	DOE SNF/HLW co-disposal	MCOs	Navy SNF
Cask/Carrier Handling System cask drop onto floor	9	n/a	4	1
Canister Transfer System canister drop onto floor	2	n/a	2	1
Disposal Container System DC drop onto floor	9	1/5	4	1

Note: See Section 4.1.4 for the discussions of the number and types of canisters in a SC or a DC.

Table 6.4-5. Offsite Doses for the Cask/Carrier Handling System Bounding DBE

Cask drop					No HEPAs		
Bounding Fuel	Fuel Type	Fuel Condition	Can. Type	# of Cans Involved	TEDE [rem]	Highest of CDEs + DDE [rem] (a)	Skin [rem]
HWCTR (U/TH) [112]	stable metal	intact	std. can.	9	3.86E-01	4.07E+00	5.63E-03
ALUM CLAD SNF [411]	stable metal	not intact	std. can.	9	1.48E+01	2.17E+02	9.18E-03
Shippingport PWR Core II [193]	non-metal	intact	std. can.	9	1.30E+02	2.25E+03	7.52E-02
Saxton (MOX) [787]	non-metal	not intact	std. can.	9	1.02E+03	1.79E+04	8.42E-02
EBWR (U Metal) LEU [64]	other	intact	std. can.	9	2.32E+02	4.01E+03	1.80E-01
N Reactor [147]	other	not intact	std. can. MCO	9(b) 4	3.87E+02 1.72E+02	6.57E+03 2.92E+03	4.13E-01 1.84E-01

Cask drop					HEPAs		
Bounding Fuel	Fuel Type	Fuel Condition	Can. Type	# of Cans Involved	TEDE [rem]	Highest of CDEs + DDE [rem] (a)	Skin [rem]
HWCTR (U/TH) [112]	stable metal	intact	std. can.	9	3.89E-03	4.66E-03	2.09E-03
ALUM CLAD SNF [411]	stable metal	not intact	std. can.	9	2.05E-01	2.50E-01	7.07E-03
Shippingport PWR Core II [193]	non-metal	intact	std. can.	9	1.28E-01	7.57E-01	1.44E-02
Saxton (MOX) [787]	non-metal	not intact	std. can.	9	2.57E+00	7.46E+00	5.02E-02
EBWR (U Metal) LEU [64]	other	intact	std. can.	9	1.79E-01	1.31E+00	5.56E-03
N Reactor [147]	other	not intact	std. can. MCO	9(b) 4	7.36E-01 3.27E-01	2.54E+00 1.13E+00	1.43E-02 6.36E-03

(a) bone surface is the bounding organ

(b) For the bounding DBE for other/not intact fuel the nine standard canisters are non-mechanistically assumed to contain the inventory of nine MCOs.

Table 6.4-6. Offsite Doses for the CTS Bounding DBE

CTS drop					No HEPAs		
Bounding Fuel	Fuel Type	Fuel Condition	Can. Type	# of Cans Involved	TEDE [rem]	Highest of CDEs + DDE [rem] (a)	Skin [rem]
HWCTR (U/TH) [112]	stable metal	intact	std. can.	2	8.58E-02	9.04E-01	1.25E-03
ALUM CLAD SNF [411]	stable metal	not intact	std. can.	2	3.28E+00	4.82E+01	2.04E-03
Shippingport PWR Core II [193]	non-metal	intact	std. can.	2	2.88E+01	5.00E+02	1.67E-02
Saxton (MOX) [787]	non-metal	not intact	std. can.	2	2.26E+02	3.98E+03	1.87E-02
EBWR (U Metal) LEU [64]	other	intact	std. can.	2	5.16E+01	8.92E+02	4.00E-02
N Reactor [147]	other	not intact	std. can. MCO	2 2	8.60E+01 8.60E+01	1.46E+03 1.46E+03	9.18E-02 9.18E-02

CTS drop					HEPAs		
Bounding Fuel	Fuel Type	Fuel Condition	Can. Type	# of Cans Involved	TEDE [rem]	Highest of CDEs + DDE [rem] (a)	Skin [rem]
HWCTR (U/TH) [112]	stable metal	intact	std. can.	2	8.64E-04	1.04E-03	4.64E-04
ALUM CLAD SNF [411]	stable metal	not intact	std. can.	2	4.56E-02	5.56E-02	1.57E-03
Shippingport PWR Core II [193]	non-metal	intact	std. can.	2	2.84E-02	1.68E-01	3.20E-03
Saxton (MOX) [787]	non-metal	not intact	std. can.	2	5.70E-01	1.66E+00	1.12E-02
EBWR (U Metal) LEU [64]	other	intact	std. can.	2	3.98E-02	2.90E-01	1.24E-03
N Reactor [147]	other	not intact	std. can. MCO	2 2	1.64E-01 1.64E-01	5.64E-01 5.64E-01	3.18E-03 3.18E-03

(a) bone surface is the bounding organ

Table 6.4-7. Offsite Doses for the DC Handling System Bounding DBE (DOE SNF only)

DC drop (DOE SNF only)					No HEPAs		
Bounding Fuel	Fuel Type	Fuel Condition	Can. Type	# of Cans Involved	TEDE [rem]	Highest of CDEs + DDE [rem] (a)	Skin [rem]
HWCTR (U/TH) [112]	stable metal	intact	std. can.	9	3.86E-01	4.07E+00	5.63E-03
ALUM CLAD SNF [411]	stable metal	not intact	std. can.	9	1.48E+01	2.17E+02	9.18E-03
Shippingport PWR Core II [193]	non-metal	intact	std. can.	9	1.30E+02	2.25E+03	7.52E-02
Saxton (MOX) [787]	non-metal	not intact	std. can.	9	1.02E+03	1.79E+04	8.42E-02
EBWR (U Metal) LEU [64]	other	intact	std. can.	9	2.32E+02	4.01E+03	1.80E-01
N Reactor [147]	other	not intact	std. can. MCO	9 (b)	3.87E+02	6.57E+03	4.13E-01
				4	1.72E+02	2.92E+03	1.84E-01

DC drop (DOE SNF only)					HEPAs		
Bounding Fuel	Fuel Type	Fuel Condition	Can. type	# of Cans Involved	TEDE [rem]	Highest of CDEs + DDE [rem] (a)	Skin [rem]
HWCTR (U/TH) [112]	stable metal	intact	std. can.	9	3.89E-03	4.66E-03	2.09E-03
ALUM CLAD SNF [411]	stable metal	not intact	std. can.	9	2.05E-01	2.50E-01	7.07E-03
Shippingport PWR Core II [193]	non-metal	intact	std. can.	9	1.28E-01	7.57E-01	1.44E-02
Saxton (MOX) [787]	non-metal	not intact	std. can.	9	2.57E+00	7.46E+00	5.02E-02
EBWR (U Metal) LEU [64]	other	intact	std. can.	9	1.79E-01	1.31E+00	5.56E-03
N Reactor [147]	other	not intact	std. can. MCO	9 (b)	7.36E-01	2.54E+00	1.43E-02
				4	3.27E-01	1.13E+00	6.36E-03

(a) bone surface is the bounding organ

(b) The nine standard canisters are non-mechanistically assumed to contain the inventory of nine MCOs.

Table 6.4-8. Offsite Doses for the DC Handling System Bounding DBE (DOE SNF/HLW co-disposal)

DC drop (DOE SNF/HLW co-disposal)					No HEPAs		
Bounding Fuel	Fuel Type	Fuel Condition	Can. Type	# of Cans Involved	TEDE [rem]	Highest of CDEs + DDE [rem] (a)	Skin [rem]
HWCTR (U/TH) [112]	stable metal	intact	std. can HLW can.	1 5	3.25E+00	5.35E+01	8.82E-04
ALUM CLAD SNF [411]	stable metal	not intact	std. can HLW can.	1 5	4.85E+00	7.71E+01	1.28E-03
Shippingport PWR Core II [193]	non-metal	intact	std. can HLW can.	1 5	1.76E+01	3.03E+02	8.61E-03
Saxton (MOX) [787]	non-metal	not intact	std. can HLW can.	1 5	1.16E+02	2.04E+03	9.62E-03
EBWR (U Metal) LEU [64]	other	intact	std. can HLW can.	1 5	2.90E+01	4.99E+02	2.03E-02
N Reactor [147]	other	not intact	std. can HLW can.	1 5 (b)	4.62E+01	7.83E+02	4.62E-02

DC drop (DOE SNF/HLW co-disposal)					HEPAs		
Bounding Fuel	Fuel Type	Fuel Condition	Can. Type	# of Cans Involved	TEDE [rem]	Highest of CDEs + DDE [rem] (a)	Skin [rem]
HWCTR (U/TH) [112]	stable metal	intact	std. can HLW can.	1 5	1.40E-03	1.64E-02	2.32E-04
ALUM CLAD SNF [411]	stable metal	not intact	std. can HLW can.	1 5	2.38E-02	4.37E-02	7.86E-04
Shippingport PWR Core II [193]	non-metal	intact	std. can HLW can.	1 5	1.52E-02	1.00E-01	1.60E-03
Saxton (MOX) [787]	non-metal	not intact	std. can HLW can.	1 5	2.86E-01	8.45E-01	5.58E-03
EBWR (U Metal) LEU [64]	other	intact	std. can HLW can.	1 5	2.09E-02	1.61E-01	6.18E-04
N Reactor [147]	other	not intact	std. can HLW can.	1 5 (b)	8.28E-02	2.98E-01	1.59E-03

(a) bone surface is the bounding organ

(b) The standard canister is non-mechanistically assumed to contain the inventory of one MCO.

Category 1 events - Those natural and human-induced events that are expected to occur one or more times before permanent closure of the MGR operations area.

Category 2 events - Other natural and human-induced events that have at least one chance in 10,000 of occurring before permanent closure of the MGR.

The MGR operations area is expected to be operational for up to 40 years. However, the performance requirement for retrieval requires 100 years (Assumption 5.9) to lapse from the time of initial fuel receipt until permanent closure of the repository (CRWMS M&O 1999a). Therefore, 100 years is used as the duration for the operations area prior to permanent closure. Thus, the DBE categories applicable to the MGR are defined as follows:

Category 1 events - Those natural and human-induced events that are expected to occur one or more times in 100 years.

Category 2 events - Other natural and human-induced events that are expected to occur one or more times in 1,000,000 years and less than one time in 100 years.

For the MGR, those DBEs that occur with a frequency of less than one in 1,000,000 years are identified as Beyond Design Basis Events.

6.5.2 DBE Category Frequency Analysis Method

Specific DBE frequencies for the three bounding DBEs are calculated in the *MGR Event Tree Analysis for Cask, Canister and Container Drop Events* (CRWMS M&O 1999b). Frequency calculations included the frequency of the initiating event, the frequency of having any radioactive material release, and the frequency of having a radioactive material release which results in the maximally exposed offsite individual receiving a dose exceeding regulatory limits.

The *Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations for Yucca Mountain, Nevada* (Dyer 1999) defines the category 1 and 2 frequency limits. Since these frequencies are defined as event sequence frequencies instead of initiating event frequencies for human-induced events such as drop events, the appropriate calculation is the frequency of having any radioactive material release as a result of a specific bounding DBE. This calculation includes grouping all event sequences, with or without releases, that originate from the same initiating event (without regard to the cause of that initiating event or waste form) and includes all events in each event sequence from the initiating event, through prevention and mitigation features (if desired or necessary), to radioactive material release. This method ensures that the appropriate frequency is calculated for comparison to the category definition.

Thus, to determine the category definition frequency, events trees for each initiating event were developed in *MGR Event Tree Analysis for Cask, Canister and Container Drop Events* (CRWMS M&O 1999b) to represent identified event sequences. The frequency of each event sequence was calculated by multiplying the frequency of the initiating event by the probability of each event in that event sequence. Then, all event sequences that resulted in a radioactive material release without regard to waste form were summed to determine the overall DBE frequency of having a release.

The SC Drop DBE event tree analysis can be used as an example. First, the initiating event (i.e., SC drop) could be caused by an operator or equipment error. The estimated initiating event frequency includes both of these errors. Second, the number of cask lifts includes all casks

handled. The number of cranes used and the contents of the casks are not relevant to the calculation (i.e., using five cranes instead of one would not change the overall probability of a cask drop). Third, the drop could come from any height, including heights above the normal handling heights. The probability of having a drop from above or below the normal handling heights is included. This number only makes a difference in the final frequency if the casks or canisters contained therein are certified to the normal lift heights of the CHS. Fourth, the probability that the cask breaches is included. For each event sequence that resulted in a radioactive material release, the numbers associated with each event in that event sequence are multiplied together, summed by event sequence, and summed by fuel type (i.e., Department of Energy Spent Nuclear Fuel [DOE SNF], commercial SNF, Naval Fuel, HLW, and HLW/Pu).

6.5.3 DBE Category Frequency Analysis Results

The initial calculations in *MGR Event Tree Analysis for Cask, Canister and Container Drop Events* (CRWMS M&O 1999b) to determine the frequency of an unfiltered release are based on the input parameters described in Attachment V and identified as the Initial Case. The frequency results for the Initial Case are compared to the DBE Category 1 and 2 frequency limits in Table 6.5-1. The table shows that all Initial Case DBEs are classified as Category 1 DBEs.

In anticipation that combined frequencies from all waste forms would exceed Category 1 frequency limits, additional calculations were made in CRWMS M&O (1999b) using a variety of inputs and assumptions to determine the necessary requirements to ensure that each bounding DBE is classified as a Category 2 DBE. Based on these calculations, a set of refined inputs and assumptions (Figure 1, step 6) was selected and labeled the Baseline Case. The refined inputs and assumptions used in the Baseline Case, as taken from CRWMS M&O (1999b), are described in Attachment V. Changes from the Initial Case to the Baseline Case include: (1) reducing the two-block probability from 24% to 1% (CRWMS M&O 1999b); (2) certifying the commercial fuel SC to the normal lift height of the CHS; and (3) certifying the HLW, DOE SNF, and HLW/Pu canisters, including Multicanister Overpacks (MCOs), to the normal lift heights of the CTS. Certification means that the SC or canister is designed to not breach when dropped from below the certified height. Note that for certified SCs or canisters, potential flaws in the manufacturing or final welding process are considered. This analysis considers the likelihood of manufacturing flaws that will cause a certified cask or canister to breach when dropped from any height. A manufacturing flaw probability of 1.06×10^{-3} is used (see Attachment V). Therefore, the probability of canister or cask failure is 1 for any drop from above its certified height and 1.06×10^{-3} for any drop from its certified height or below.

The bounding DBE frequency results for the Baseline Case and a comparison of the Baseline Case event frequencies to the DBE Category 1 and 2 frequency limits are shown in Table 6.5-1. The table demonstrates that all three Baseline Case DBEs are classified as Category 2 DBEs.

Table 6.5-1: DBE Category Frequency Analysis Results and Comparison to Limits

Case	DBE	Frequency (drops resulting in an unfiltered release per year)	Category 1 Low Limit (events per year)	Category 2 Low Limit (events per year)	DBE Category Designation
Initial	Cask Drop	1.2×10^{-2}	1×10^{-2}	1×10^{-6}	Category 1
Initial	Canister Drop	2.8×10^{-2}	1×10^{-2}	1×10^{-6}	Category 1
Initial	DC/WP Drop	1.2×10^{-2}	1×10^{-2}	1×10^{-6}	Category 1
Baseline	Cask Drop	4.2×10^{-4}	1×10^{-2}	1×10^{-6}	Category 2
Baseline	Canister Drop	5.0×10^{-3}	1×10^{-2}	1×10^{-6}	Category 2
Baseline	DC/WP Drop	5.8×10^{-3}	1×10^{-2}	1×10^{-6}	Category 2

6.6 Licensing Basis Dose Limits

This section identifies the applicable regulatory dose criteria. This section performs step 7 of Figure 1.

The primary criteria applicable to this analysis are the regulatory dose limits for radiation protection of the public as specified in the *Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations for Yucca Mountain, Nevada* (Dyer 1999) and 10 CFR 20.1301. This analysis compares the regulatory criteria against calculated doses at an assumed boundary distance of 5,000 meters to determine if the MGR can be operated without exceeding the regulatory dose limits. The applicable dose criteria are listed in Table 4.2-1.

6.7 Safety Margins and DBE Frequency Analysis

Safety margins reflect the difference between the potential dose consequence of a DBE and the regulatory limit. Tables 6.4-5, 6.4-6, 6.4-7, and 6.4-8 show that mitigated doses (i.e., HEPA-filtered cases) are well below the Category 2 dose limits. The Category 2 dose limits are used for comparison because the bounding DBEs are determined to be Category 2 events (see Table 6.5-1). Therefore, if the HEPA filtration credit is taken, there are significant safety margins for all three bounding DBEs and all DOE SNF types.

Unmitigated doses (i.e., no HEPA filter cases) given in Tables 6.4-5, 6.4-6, 6.4-7, and 6.4-8 are divided by their respective Category 2 dose limits, i.e., 5-rem TEDE, 50-rem CDE+DDE, and 50-rem skin dose. The results are given in Tables 6.7-1, 6.7-2, and 6.7-3, which compare the results from the unfiltered bounding DBE offsite doses and the Category 2 dose limits. In Table 6.7-1, except for the Stable Metal, Intact Group, the unmitigated (unfiltered) consequences of radionuclide releases from bounding fuels in the remaining five DBE groups exceed the dose criteria for Category 2 events and hence no safety margin for these five DBE groups is identified.

In Table 6.7-2, except for the Stable Metal, Intact and Not Intact Groups, the unmitigated consequences of radionuclide releases from bounding fuels in the remaining four DBE groups exceed the dose criteria for Category 2 events and hence no safety margin for these four DBE groups is identified. In Table 6.7-3, the unmitigated consequences of radionuclide releases from bounding fuels in all six DBE groups exceed the dose criteria for Category 2 events and hence no safety margin is identified. Therefore, if the HEPA filtration credit is not taken, unmitigated dose consequences resulting from some DOE SNF types could exceed the Category 2 dose criteria.

The unmitigated consequences of radionuclide release from Navy fuel (see Table 6.4-1), i.e., a TEDE of 8.72×10^{-4} rem, a highest CDE plus DDE of 4.96×10^{-3} rem, and a skin dose of 7.05×10^{-6} rem, are at least three orders of magnitude lower than the Category 2 dose limits. Therefore, there are significant safety margins for all three bounding DBEs involving Navy SNF.

The decision to take credit or not take credit for HEPA filters directly impacts on the classification of the HEPA filters that are part of the WHB ventilation system. For example, if the credit for HEPA filters is taken, the HEPA filters designed to filter airborne particulate from the CTS and DC Handling System hot cells must be classified as QL-1 because the unmitigated doses exceed the Category 2 dose criteria. Such classification of HEPA filters is not being considered at this time. Since the unmitigated doses resulting from some DOE SNF types exceed the Category 2 dose criteria, the current strategy allocates performance to the canisters and handling systems. This strategy will make some events incredible (i.e., Beyond Design Basis Events) through design and/or operations changes and therefore the HEPA filters would not be required to mitigate the dose consequences if this strategy is successfully implemented.

Since for the unfiltered cases there is no safety margin for some DOE SNF types, the response to Figure 1, step 8 is "no" and a re-evaluation of the event frequencies to see whether they are below 1×10^{-6} events/year must be performed (Figure 1, step 10). A re-evaluation of frequencies is necessary, because all frequencies given in Table 6.5-1 are based on all drop events with radioactive material releases, regardless of the magnitude of dose consequences. In Figure 1, step 10, we need to calculate frequencies based on only drop events that result in dose consequences exceeding the Category 2 dose criteria. To obtain these new frequencies, a new case called "DBE Baseline Case" was analyzed by changing only one input parameter used in the Baseline Case. The input parameter called "Dose Consequences" was modified to include only those DBEs whose dose consequences exceed Category 2 dose criteria. In the Baseline Case, the dose consequence input for each waste form is "Above" the Category 2 dose criteria, resulting in a summation of all frequencies resulting from all waste forms. In the DBE Baseline Case, dose consequences from a SC, a canister, or a DC loaded with CSNF or Navy SNF, and a canister of HLW are "Below" the Category 2 dose criteria (CRWMS M&O 1999b) and therefore their respective frequencies are not included in frequency calculations, resulting in a lower DBE frequency.

The frequencies used for the Figure 1, step 10 frequency re-evaluation are obtained from the DBE Baseline Case and inputs and assumptions are shown in Attachment VII. The calculated frequencies for the DBE Baseline Case are shown in Table 6.7-4.

The results of the DBE Baseline Case indicate that the frequencies associated with all three DBEs are greater than 1×10^{-6} events per year. Therefore, the response to Figure 1, step 10 is "no" and the identification of additional consequence and frequency analysis options (Figure 1, step 11) is performed in Section 6.8.

Table 6.7-1. Comparison of Cask Drop and DC Drop (DOE SNF only) Offsite Doses to Dose Limits

Cask Drop or DC Drop (DOE SNF only)					No HEPAs		
	Fuel Type	Fuel Condition	Can. Type	# of Cans Involved	Dose/Category 2 Dose Limit		
					TEDE/5-rem	Highest of CDEs + DDE divided by 50-rem	Skin/50-rem
HWCTR (U/TH) [112]	stable metal	intact	std. can.	9	0.07	0.08	1.1E-04
ALUM CLAD SNF [411]	stable metal	not intact	std. can.	9	3.0	4.3	1.8E-04
Shippingport PWR Core II [193]	non-metal	intact	std. can.	9	26	45	1.5E-03
Saxton (MOX) [787]	non-metal	not intact	std. can.	9	204	358	1.7E-03
EBWR (U Metal) LEU [64]	other	intact	std. can.	9	46.4	80.2	3.6E-03
N Reactor [147]	other	not intact	std. can.	9	77.4	131	8.3E-03
			MCO	4	34.4	58.4	3.7E-03

Table 6.7-2. Comparison of CTS Drop Offsite Doses to Dose Limits

CTS Drop					No HEPAs		
Material-at-Risk	Fuel Type	Fuel Condition	Can. Type	# of Cans Involved	Dose/Category 2 Dose Limit		
					TEDE/5-rem	Highest of CDEs + DDE divided by 50-rem	Skin/50-rem
HWCTR (U/TH) [112]	stable metal	intact	std. can.	2	0.02	0.02	2.5E-05
ALUM CLAD SNF [411]	stable metal	not intact	std. can.	2	0.66	0.96	4.1E-05
Shippingport PWR Core II [193]	non-metal	intact	std. can.	2	5.8	10	3.3E-04
Saxton (MOX) [787]	non-metal	not intact	std. can.	2	45.2	79.6	3.7E-04
EBWR (U Metal) LEU [64]	other	intact	std. can.	2	10.3	17.8	8.0E-04
N Reactor [147]	other	not intact	std. can.	2	17.2	29.2	1.8E-03
			MCO	2	17.2	29.2	1.8E-03

Table 6.7-3. Comparison of DC Drop (DOE SNF/HLW Co-disposal) Offsite Doses to Dose Limits

DC Drop (DOE SNF/HLW co-disposal)					No HEPAs		
Material-at-Risk	Fuel Type	Fuel Condition	Can. Type	# of Cans Involved	Dose/Category 2 Dose Limit		
					TEDE/5-rem	Highest of CDEs + DDE divided by 50- rem	Skin/50-rem
HWCTR (U/TH) [112]	stable metal	intact	std. can. HLW can.	1 5	0.65	1.1	1.8E-05
ALUM CLAD SNF [411]	stable metal	not intact	std. can. HLW can.	1 5	0.97	1.5	2.6E-05
Shippingport PWR Core II [193]	non-metal	intact	std. can. HLW can.	1 5	3.5	6.1	1.7E-04
Saxton (MOX) [787]	non-metal	not intact	std. can. HLW can.	1 5	23.2	40.8	1.9E-04
EBWR (U Metal) LEU [64]	other	intact	std. can. HLW can.	1 5	5.8	10	4.1E-04
N Reactor [147]	other	not intact	MCO HLW can.	1 5	9.2	15.7	9.2E-04

Table 6.7-4: Frequencies for the DBE Baseline Case

Case	DBE	Frequency (drops resulting in doses exceeding Category 2 dose criteria per year)	Is the event credible?
DBE Baseline	Cask Drop	9.7×10^{-5}	Yes
DBE Baseline	Canister Drop	4.6×10^{-4}	Yes
DBE Baseline	DC/WP Drop	8.3×10^{-5}	Yes

In summary, the results of the consequence analyses and comparison to the Category 2 dose criteria indicate that there are significant safety margins for all three bounding DBEs involving Navy SNF. The unmitigated dose consequences resulting from some DOE SNF types exceed the offsite dose criteria for Category 2 events. However, it should be emphasized that all DOE SNF types meet the Category 2 dose criteria if the HEPA filtration credit is taken and only a fraction of DOE SNF canisters exceed the Category 2 dose criteria if the HEPA filtration credit is not taken. Additional analysis is necessary to reduce either the dose consequences below the dose limit, or to ensure that the frequency of each event with consequences exceeding the dose criteria is less than 1×10^{-6} events per year. Options for additional analysis are discussed in Section 6.8.

6.8 Additional Consequence and Frequency Analysis Options

This section summarizes the evaluation of potential design and analysis options and their expected impact on the consequence and frequency analyses. This section performs step 11 of Figure 1.

6.8.1 Additional Consequence Analysis Options

The inputs and assumptions associated with the existing consequence analysis were evaluated. As described in Section 6.4, the consequence analysis calculations are based on assumptions for the amount of radioactive material released from the Waste Handling Building (WHB), for the projected wind dispersion, and for the breathing rate of the exposed individual. The specific input parameters used in the consequence calculations are shown in Attachment IV. This section describes the impact of variations in these parameters.

The amount of material released from the WHB is the largest variable in the consequence analysis and is based on the amount of material impacted by the DBE, the amount of material made airborne and respirable, and the amount of material that escapes all containers and exits the WHB.

The amount of material impacted by the DBE is based on the material at risk (MAR), which is the total amount of material in a shipping cask, a canister, or a DC and the damage ratio (DR), which is the fraction of that material impacted by the event. The MAR in a canister is based on

the *DOE SNF DBE Offsite Dose Calculations* (CRWMS M&O 1999d, Section 6). Any variation in this parameter within a canister will directly impact the consequence analysis results since the results are directly proportional to this parameter.

Additionally, the MAR within a SC or DC/WP is up to nine DOE SNF canisters (see Section 4.1.4). Certification of the canister to the normal handling height reduces the material at risk for non-two-block drop events to one canister since it is a credible event for a manufacturing flaw to cause one canister to breach, but not two or more. Using a manufacturing flaw probability of 1.06×10^{-3} , it can be shown that only 9.54×10^{-3} canister in a SC or DC is defective. Since a partial canister (i.e., 9.54×10^{-3} canister) is not used in the consequence analysis, one canister is conservatively assumed to breach. Thus, certification of the DOE SNF canister to the normal handling height ensures that the bounding DBEs involve at most one canister for drops from normal handling heights. Note that if the certified height of the canister is higher than the CHS and DCHS two block heights, the MAR for all events including two-block events is one DOE SNF canister. Table 6.8-1 summarizes the impact of SC and canister certification on the DBE consequence analysis. Note that the consequence analysis performed in Section 6.4 does not take the certification credit (i.e., reduced number of failed canisters following a DBE) as shown in Table 6.8-1, column No. 5. Additional analyses are required to validate the assumptions used to establish this credit. If the certification credit can be established, the consequence analysis results would be decreased by a factor of up to 9 for the SC or DC drop event.

The current DBE analysis conservatively assumes that the DR in the drop event is 100% of the canister contents. Thus, the analysis assumes that the cladding of all fuel elements is damaged and breached during the DBEs. Additional analysis of the DBE may show that only a small percentage of all fuel elements in a canister are damaged during the DBE. It was conservatively assumed in the consequence analysis that for fuels in the Not Intact groups, 100% of the MAR is in powder form, which maximizes airborne releases. In order to justify a MAR in powder form that is less than 100%, more fuel characterization work is required. However, this option is not preferred by the NSNFP.

The amount of material made airborne is based on the airborne release fraction (ARF) and respirable fraction (RF) associated with the event being analyzed. For the drop event, conservative values for both parameters for six DBE groups and crud were selected (CRWMS M&O 1999d, Section 5.2). It is estimated that the combined ARF x RF value is conservative by a factor of 10 to 100 for fuel fines and crud. This combined value has a large impact on the results since the results of the consequence analysis are directly proportional to this parameter. Thus, if it can be shown that a more accurate but still conservative combined ARF x RF is 10% of the value currently used, the consequence analysis results would be decreased by a factor of 10. However, this option is not preferred by the NSNFP.

The current DBE analysis conservatively assumes that the leak path factor (LPF) is 1.0, which means that the amount of material that escapes all containers and the building following a DBE is 100% of the airborne and respirable material. Thus, the analysis assumes that 100% of the airborne and respirable material escapes the canister; the SC, DC, or WP (for those events); and the building. In reality, airborne and respirable material would deposit on the surface of each of these structures due to various physical processes, such as gravitational settling and plate-out (i.e., mass diffusion of volatile species to structural surfaces). An LPF of 0.01 or less appears to be achievable when only a small leak of the shipping cask, canister or DC is expected to develop as a result of the drop. However, additional analysis is required to validate this value. The results of the consequence analysis are directly proportional to this parameter. Therefore, the consequence analysis results could decrease by a factor of 100 or more.

Table 6.8-1: Impact of Certified SCs and Canisters on the Dose Consequence Analysis for Drops From Normal Handling Heights

Drop Event	Number of Canisters	Shipping Cask Certified	Canisters Certified	Maximum Number of Failed Canisters Following DBE	Impact on Dose Consequences
DOE SNF Shipping Cask Drop	9	No	No	9	Bounding unmitigated case, consequences shown in Table 6.4-5.
DOE SNF Shipping Cask Drop	9	Yes	No	0 to 9	Nine canisters fail, however, no release since shipping cask is certified. Failure of the shipping cask is possible due to a manufacturing flaw.
DOE SNF Shipping Cask Drop	9	No	Yes	0 or 1	One canister (see Section 6.8.1) may fail due to a manufacturing defect in the canister. Failure of more than one canister due to a manufacturing flaw is expected to be a BDBE.
DOE SNF Shipping Cask Drop	9	Yes	Yes	0 or 1	One canister (see Section 6.8.1) may fail due to a manufacturing defect. However no release is postulated since failure of a canister and the SC is expected to be a BDBE.
Canister Drop	1 DSNF Canister	N/A	No	1	Consequences bounded by the unmitigated case shown in Table 6.4-6.
Canister Drop	1 DSNF Canister	N/A	Yes	0 or 1	One canister may fail due to a manufacturing defect in the canister.
Canister Drop	2 DSNF Canisters	N/A	No	2	Bounding unmitigated case, consequences shown in Table 6.4-6.
Canister Drop	2 DSNF Canisters	N/A	Yes	0 or 1	One canister may fail due to a manufacturing defect in the canister. Failure of more than one canister due to a manufacturing flaw during the event is expected to be a BDBE.

Note: If the certified height of the canister is higher than the CHS and DCHS two-block heights, the MAR for all events including two-block events is a maximum of one DOE standard canister.

The projected wind dispersion is based on site meteorological conditions and the distance from the location of the event to the nearest site boundary. The site meteorological conditions are based on a conservative analysis of historically measured data. This is standard consequence methodology, and no variations in these data or method are analyzed or proposed.

The consequence analysis assumes that the nearest site boundary is 5,000 meters from the DBE location. Based on information from (CRWMS M&O 1998a), increasing the distance to the site boundary to 10,000 meters would reduce the dose consequences by approximately a factor of 2 (Assumption 5.8).

A breathing rate of 20 liters/min (Assumption 5.11) used for the exposed individual is based on standard consequence methodology (ICRP 1974). Thus, no variations in this parameter are analyzed or proposed.

It should be noted that the unmitigated dose consequence calculations do not take credit for HEPA filtration. The mitigation factor associated with HEPA filtration is 3.0×10^{-4} (CRWMS M&O 1999d, Section 5.2). Thus, if the HEPA filtration is credited for event sequences with operable HEPA filters, the dose consequences for the bounding DBEs would be below the dose criteria.

The option to place small-quantity high-consequence fuels, such as SAXTON (MOX) [787], in High Integrity Canisters (HICs) should be considered. The HIC is assumed to be certified to the maximum height of the disposable canister handling systems such that any credible DBE will not result in breach of a HIC and release of radionuclides. The HIC is being developed by the NSNFP to achieve this goal.

The consequence analysis conservatively assumes that all nine canisters in a SC or DC are loaded with the same fuel even though the quantities of some bounding fuels are not enough to fill all nine canisters. For example, there is only one canister of SAXTON (MOX) [787] in the DOE SNF database. However, nine SAXTON fuel canisters are assumed to be loaded into a SC or DC. The offsite dose consequences would be reduced if eight SAXTON fuel canisters in a nine-canister SC or DC were replaced with eight non-bounding fuel canisters from the Non-Metal, Not Intact Group.

In calculating the fraction of radionuclide inventory at-risk, it is assumed that all of the DOE SNF canisters of a given fuel type have the same isotopic composition (Assumption 5.16). If the isotopic data are not sufficiently skewed to adequately account for variation in the isotopic composition of a given fuel type this assumption is non-conservative. Uncertainty analysis needs to be performed to determine the effect of non-homogeneous isotopic composition on the consequence analysis results.

In summary, the results of the consequence analysis are very conservative because of the use of bounding values for many DOE SNF parameters, such as 100% material-at-risk in powder form, a DR of 1.0, and an LPF of 1.0. Additional consequence analysis based on more realistic but still bounding inputs and assumptions will result in lower DBE consequences, perhaps below the dose criteria. Some parameters recommended for further analysis (Figure 1, step 12) are summarized in Attachment VI. Based on current estimates, additional analysis using the options listed above could result in a reduction of the dose consequences by a factor of more than 358. If this achieved, all bounding DBEs would meet Category 2 dose criteria without taking credit for HEPA filters. HEPA filters could then be used for defense-in-depth.

6.8.2 Additional Frequency Analysis Options

Exploratory event tree frequency analyses were performed to evaluate various options and to determine the frequency of the DBEs with potential dose consequences exceeding the dose criteria. The additional frequency analyses were performed in the *MGR Event Tree Analysis for Cask, Canister and Container Drop Events* (CRWMS M&O 1999b) calculation. The method used is described in Section 6.5.

Numerous combinations of inputs and assumptions for MGR features that impact DBE frequency were evaluated. The parameters varied include the following: SC, canister, and DC/WP throughput; frequency of the initiating event; two-block frequency; certification requirements; manufacturing flaw probability; and the dose consequences associated with each waste form. In order to obtain frequencies below 1×10^{-6} events/year, the DBE frequencies as shown in Table 6.7-4 need to be reduced by a factor of 460 (i.e., canister drop frequency of 4.6×10^{-4} events/year is divided by 460 to obtain 1×10^{-6} events/year). The analysis of each parameter is summarized below.

The DBE Baseline Case assumes bounding throughputs (CRWMS M&O 1999b). The frequency results are directly proportional to the throughput. Thus, reducing the throughput of the waste forms that have potential consequences exceeding the dose criteria would reduce the overall DBE frequency. This option is not recommended.

The DBE Baseline Case is based on an initiating event frequency of 1.4×10^{-5} drops per lift. This value is based on data from cranes with unknown safety features and procedures. Additional analysis may result in a value of 1.0×10^{-5} to 1.0×10^{-6} drops per lift for this parameter. This value has a large impact on the results since the results of the frequency analysis are directly proportional to this value. Thus, if it can be shown that the initiating event frequency is 25% of the value currently used, the frequency analysis results would be decreased by a factor of 4.

The DBE Baseline Case input for the two-block frequency is 1% of all drop events. This value is based on an estimate of current industry data. Additional modeling of expected crane safety features and commercial nuclear power plant data should result in a probability of 0.1% to 0.0001% of all drop events for this parameter. This can be achieved by requiring rigging or making design changes to reduce the two-blocking height.

The DBE Baseline Case assumes that the commercial SNF SC and the DOE SNF, HLW, and HLW/Pu canisters are certified to the normal handling heights. In order to obtain a DBE frequency of less than 1×10^{-6} events per year, as a minimum, canisters containing waste forms that produce DBE consequences exceeding the dose criteria will need to be certified to their normal handling heights or to the two-block height (see Attachment VIII). In addition, other parameters, such as drop frequency, two-block frequency, and manufacturing flaw probability, must be equal to or reduced below the values used in the DBE Baseline Case (see Attachment VIII, Scopes 52, 56, 57, and 58). These certification requirements may require cask vendor, canister vendor, and MGR design changes.

The DBE Baseline Case assumes that the probability of a manufacturing flaw is 1.06×10^{-3} . Depending on the changes made to other parameters, this value may have to be reduced below 1×10^{-4} in order to obtain a DBE frequency of less than 1×10^{-6} events per year for events exceeding the dose criteria. This value will require the cask and canister vendors to demonstrate that their manufacturing process meets this requirement.

The DBE Baseline Case assumes that the consequences associated with the DOE SNF waste

form exceed the dose criteria for all DBEs (CRWMS M&O 1999b). If the consequence can be shown to be below the dose criteria, the frequency of all DOE SNF related events would be removed from the overall DBE frequency analysis. However, instead of trying to reduce the dose consequences, the current approach adopted by the NSNFP and the trade study being conducted by CRWMS M&O focus on reducing the DBE frequency to below 1×10^{-6} events per year for events exceeding the dose criteria.

In summary, the results of the current frequency analysis indicate that the frequencies associated with the bounding DBEs are greater than 1×10^{-6} events per year for events exceeding the dose criteria. Additional frequency analysis based on more realistic but still bounding inputs and assumptions will result in lower DBE frequencies, perhaps below 1×10^{-6} events per year for events exceeding the dose criteria. Attachment VIII summarizes some alternate inputs and assumptions for cases that result in DBE frequencies below 1×10^{-6} events per year for events exceeding the dose criteria. However, use of these alternate inputs and assumptions could result in additional waste form and facility requirements.

6.9 MGR Waste Form and Facility Requirements

MGR waste form and facility requirements are necessary to ensure compliance with all analysis assumptions. These requirements are placed on the waste form, the waste form packages, the facility, and/or the facility operations. The derivation of the waste form and facility requirements is described below, and the requirements to reduce event sequence frequencies to Category 2 are listed in Attachment IX. This section supports the performance of step 9 on Figure 1. Note that step 9 cannot be completed until the options suggested in Section 6.8 are chosen to complete Figure 1, step 12 and remaining steps (i.e., steps 13 through 16), if required.

Since the DBE analysis is not complete, the requirements identified are preliminary and are subject to change pending preparation of additional analyses and determination of the final design. Final requirements may be more or less restrictive than those identified at this time.

6.9.1 Requirements Derived from the Selection of Bounding DBEs

Requirements are derived from the selection of bounding DBEs described in Section 6.2. Section 5 lists assumptions used in this analysis. All of these assumptions are proposed as waste form or facility requirements in Attachment IX, Section 1.

6.9.2 Requirements Derived from the Selection of Bounding DOE SNF

Requirements defined in Attachment IX, Section 2 are derived from the selection of bounding DOE SNF described in Section 6.3. The assumption in this analysis that requires waste form requirements is that the fuels identified in Attachment III will result in the bounding consequences to the maximally exposed offsite individual for each fuel group.

6.9.3 Requirements Derived from the Consequence Analysis

Requirements are derived from the consequence analysis described in Section 6.4. Attachment IV lists assumptions used in the consequence analysis. Only one (i.e., distance to the site boundary) of these assumptions is proposed as a requirement in Attachment IX. The others are physical properties, such as breathing rate and do not require waste form or facility requirements.

Future consequence analysis with options discussed in Section 6.8.1 may result in additional requirements.

6.9.4 Requirements Derived from the Category Determination Analysis and DBE Baseline Case Frequency Analysis

Requirements are derived from the category determination analysis described in Section 6.5. Attachment V lists assumptions used in the category determination analysis. These assumptions are proposed as requirements in Attachment IX, Section 4.

Requirements in Attachment IX, Section 4 are also derived from the inputs and assumptions described in Attachment VII associated with the DBE Baseline Case frequency analysis.

6.9.5 Requirements Derived from the Additional Analysis

The additional analyses proposed in Section 6.8 include both consequence and frequency analyses. No requirements are derived from the proposed additional analyses.

If additional frequency analysis is performed to reduce the DBE frequency below 1×10^{-6} events per year for events exceeding the dose criteria, additional requirements may be required based on the final selection of inputs and assumptions. For example, the current Category Determination Analysis requires that the two-block probability to be less than or equal to 1×10^{-2} . Additional frequency analysis may require a lower two-block probability in order to obtain DBE frequencies below 1×10^{-6} events per year for events exceeding the dose criteria.

7. CONCLUSIONS

7.1 General Conclusions

This analysis identified and evaluated the bounding DBEs for the DOE SNF canister handling systems at the MGR. This analysis supported the DBE process through step 11 of Figure 1. The analysis is based on the VA design.

The bounding DBEs were identified as follows:

- Carrier/Cask Transport System – None (Shipping Cask with impact limiters ensures all events are BDBE)
- Cask Preparation Building – None
- Carrier/Cask Handling System – Shipping Cask Drop (no impact limiters)
- Canister Transfer System – Canister Drop onto the Floor
- Disposal Container Handling System – DC/WP Drop

The Initial Case frequency assessment associated with each DBE resulted in a Category 1 classification. Further analysis (Baseline Case) based on refined waste form and facility assumptions resulted in a DBE classification of Category 2. Thus, specific waste form and facility requirements are necessary to ensure that the bounding DBEs are not classified as Category 1 events.

Consequence analysis for each bounding DBE and each bounding DOE SNF was performed. If the HEPA filtration credit is taken, the mitigated offsite dose consequences resulting from all DOE SNF types meet the Category 2 dose criteria. If the HEPA filtration credit is not taken, the unmitigated offsite dose consequences resulting from some DOE SNF types could exceed the Category 2 dose criteria.

The offsite doses resulting from dropping Navy fuel are bounded by bounding fuels in the six DBE groups due to the robustness of the fuel and its insignificant source term. The unmitigated offsite doses from Navy fuel are at least three orders of magnitude lower than the Category 2 dose limits.

Frequency analysis was performed to determine if the associated DBE frequency is less than 1×10^{-6} events per year for events exceeding the dose criteria. The analysis (DBE Baseline Case) based on current design assumptions resulted in DBE frequencies associated with all three bounding DBEs greater than 1×10^{-6} events per year for events exceeding the dose criteria. Therefore, additional consequence analysis and frequency analysis options were identified. Additional consequence or frequency analysis is required to demonstrate that the consequences are below the dose limit, or that the DBE frequency is less than 1×10^{-6} events per year for events exceeding the dose criteria.

The current consequence analysis is based on a conservative set of bounding assumptions. Individually, the conservative assumptions were selected because they are easily defensible. Collectively, these conservative assumptions have produced large consequences and may result in some unnecessary waste form and facility requirements. The additional consequence analysis should initially focus on removing unnecessary conservatism from the inputs and assumptions through performance of additional analysis. If necessary, additional test data should be obtained as appropriate. A more accurate evaluation of these assumptions should significantly reduce the associated offsite consequences, perhaps below the dose criteria. Evaluation options were presented in Section 6.8.1. Based on current estimates, additional analysis using the options listed in Section 6.8.1 could result in a reduction of the dose consequences by a factor of 358 or more. However, instead of trying to reduce the dose consequences, the current approach adopted by the NSNFP and the trade study being conducted by CRWMS M&O focus on reducing the DBE frequency to below 1×10^{-6} events per year for events exceeding the dose criteria. Even though the additional consequence analysis can help reduce the dose consequences, work planned for this fiscal year is focused on the frequency analysis.

The option to place small-quantity high-consequence fuels, such as SAXTON (MOX) [787], in High Integrity Canisters (HICs) should be considered. The HIC is assumed to be certified to the maximum handling height of the disposable canister handling systems such that any drop of a HIC will not result in a breach and release of radionuclides.

DBE frequency analysis was performed in Section 6.8.2 to identify potential design changes that would ensure a DBE frequency of less than 1×10^{-6} events per year for events exceeding the dose criteria. Some of the cases (see Attachment VIII, scopes 52, 56, 57, and 58) yielded DBE frequencies below 1×10^{-6} events per year for events exceeding the dose criteria.

The additional frequency analysis should initially focus on removing conservatism from the inputs and assumptions through performance of additional study and analysis. The recommended additional analysis options are presented in Section 6.8.2. Additional requirements may be derived from the recommended additional frequency analyses. As part of the additional frequency analysis work, the trade study on the selection of feasible options is being performed and various facility design and operations options are being considered and evaluated. However, the on-going trade study is not considered as part of the present work scope.

The results of this analysis also include the development of preliminary facility and waste form requirements. The requirements ensure that inputs and assumptions in the analysis are assured. However, these requirements are preliminary and subject to change upon completion of the DBE analysis. Final requirements may be more or less restrictive than those identified at this time.

Assuming canister certification does not impact its design, none of the waste form related requirements defined in Section 6.9 should impact the current DOE standard canister design. However, the only option that can affect the DOE standard canister design is to reduce the DOE SNF inventory in a canister. This option is not proposed at this time and would only be considered if all analysis options recommended in Section 6.8 fail.

7.2 TBV/TBD Impact on Analysis and Conclusions

This section discusses the impact of TBVs on this analysis. Information on where and how TBVs are generated is given in Attachment I- Document Input Reference Sheets (DIRS).

TBV-3107: MFD - Carrier/Cask Transport System (DIRS, Item No. 1).

System operation information taken from DIRS, Item No. 1 is considered unqualified. This information is used in Section 6.1.1. Any change in this input would directly impact the description of system operation in Section 6.1.1.

TBV-3108: MFD - CPB Material Handling System (DIRS, Item No. 2).

System operation information taken from DIRS, Item No. 2 is considered unqualified. This information is used in Section 6.1.2. Any change in this input would directly impact the description of system operation in Section 6.1.2.

TBV-3109: MFD - Carrier/Cask Handling System (DIRS, Item No. 3).

System operation information taken from DIRS, Item No. 3 is considered unqualified. This information is used in Section 6.1.3. Any change in this input would directly impact the description of system operation in Section 6.1.3.

TBV-3110: MFD - Canister Transfer System (Large Canister) (DIRS, Item No. 4).

System operation information taken from DIRS, Item No. 4 is considered unqualified. This information is used in Section 6.1.4. Any change in this input would directly impact the description of system operation in Section 6.1.4.

TBV-3111: MFD - Canister Transfer System (Small Canister) (DIRS, Item No. 5).

System operation information taken from DIRS, Item No. 5 is considered unqualified. This information is used in Section 6.1.4. Any change in this input would directly impact the description of system operation in Section 6.1.4.

TBV-3112: MFD - DC Handling System (Welding and Staging) (DIRS, Item No. 6).

System operation information taken from DIRS, Item No. 6 is considered unqualified. This information is used in Section 6.1.5. Any change in this input would directly impact the description of system operation in Section 6.1.5.

TBV-3707: The maximum number of DOE SNF canisters in a DC is six, one, and four for the separate disposal DSNF, the co-disposal DSNF, and the DSNF MCO DCs, respectively and the maximum number of naval fuel canisters in a DC is one (DIRS, Item No. 7).

These parameters are used in the Consequence Analysis. Any change in these values would directly impact the results of the consequence analysis.

TBV-3114: Varying the distance from 5,000 m to 10,000 m, the atmospheric dispersion factor, χ/Q , decreases by a factor of 2 (DIRS, Item No. 8).

This assumption is used in the Consequence Analysis. Any change in this value would directly impact the results of the consequence analysis.

TBV-690: The preclosure period is assumed to be 100 years (DIRS, Item No. 9).

This assumption is used in the DBE Category Determination. Any change in this value would impact the frequency criteria used to evaluate the results with.

TBV-245: The MGR is designed to withstand the following subsurface DBEs: an uncontrolled transporter descent, WP horizontal drop onto sharp object, and fuel rod rupture/internal pressurization (DIRS, Item No. 9).

This TBV encompasses a set of unconfirmed technical data used in the design to withstand DBEs in the category of DBEs with no release. This TBV is used in Section 6.2.1. Any change in these values would directly impact the determination of bounding DBEs.

TBV-684: It is assumed that rockfall exceeding WP design basis is a Beyond Design Basis Event (DIRS, Item No. 9).

This assumption is used in Section 6.2.1. Any change in this assumption would directly impact the determination of bounding DBEs.

TBV-688: It is assumed that a fire in subsurface facilities is a Beyond Design Basis Event (DIRS, Item No. 9).

This assumption is used in Section 6.2.1. Any change in this assumption would directly impact the determination of bounding DBEs.

TBV-3116: It is assumed that the frequency of preclosure early failure of a WP is very low and the consequences associated with the event are negligible (DIRS, Item No. 9).

This assumption is used in Section 6.2.1. Any change in this assumption would directly impact the determination of bounding DBEs. If this assumption is false, the frequency of the early failure event would need to be included in the frequency analysis and accounted for in the DBE category determination since the DBE category determination is based on the frequency of all events that could result in an unfiltered release. The frequency of this event has not been determined, but if frequent enough, it could require the DBEs to be classified as Category 1, or result in additional facility or waste form requirements.

TBV-3708: This TBV includes all the unqualified data used in and the frequency data generated from CRWMS M&O (1999b) (DIRS, Item No. 10).

These data are used in the DBE Category Determination and the additional frequency analysis. Any change in these data could impact the DBE Category Determination and the additional frequency analysis.

TBV-1342: This assumption is used to justify a WP being certified to drop from normal handling heights in the DCHS, and not certified from the two-block height (DIRS, Item No. 10).

This assumption is used in the DBE Category Determination and the additional frequency analysis. If the WP were not certified, the frequency of a DC/WP drop resulting in a breach would increase. This increased frequency could impact the DBE Category Determination and the additional frequency analysis and result in a Category 1 classification or additional facility and waste form requirements.

TBV-3709: The HLW bounding dose consequences are used (DIRS, Item No. 11).

The bounding doses are used in the Consequence Analysis. Any change in these values would directly impact the results of the consequence analysis.

TBV-3710: DOE SNF bounding offsite doses, Navy fuel offsite dose, and the MAR in a single DOE SNF canister are used (DIRS, Item No. 12).

The offsite doses and MAR are used in the Consequence Analysis. Any change in these values would directly impact the results of the consequence analysis.

TBV-3269: A HEPA filter mitigation factor of $3.0\text{E-}04$ is used (DIRS, Item No. 12).

This parameter is used in the Consequence Analysis. Any change in this value would directly impact the results of the consequence analysis.

TBV-3235, TBV-3237, TBV-3238, TBV-3309, TBV-3238, and TBV-3475: This assumption is based on the airborne release fractions, respirable fractions, and other input parameters listed in Attachment IV for the DOE SNF waste form (DIRS, Item No. 12).

This assumption is used in the Consequence Analysis. Any change in ARF, RF and other input parameters would directly impact the results of the consequence analysis. The values currently used are extremely conservative. Potential reductions in these values could impact the requirements and conclusions developed in this analysis. These values should be further analyzed to determine if lower values are defensible.

TBV-3240: In calculating the fraction of radionuclide inventory at-risk, it is assumed that all of the DOE SNF canisters of a given fuel type have the same isotopic composition (DIRS, Item No. 12).

If the isotopic data are not sufficiently skewed to adequately account for variation in the isotopic composition of a given fuel type this assumption is non-conservative. Uncertainty analysis needs to be performed to determine the effect of non-homogeneous isotopic composition on the consequence analysis results.

TBV-3711: The data on bounding DOE SNF, DOE SNF fuel types, and bounding fuel selection taken from CRWMS M&O (1999e) are used (DIRS, Item No. 13).

The data taken from CRWMS M&O (1999e) are unqualified data. Any change in these data would directly impact the results of DOE SNF bounding fuel selection.

TBV-3122: There are no credible events that can cause a cart tipover or the shipping cask to breach as a result of a cart tipover (DIRS, Item No. 14).

This assumption is used in the Bounding DBE Determination and the DBE Category Determination. If this assumption is false, the results of the Bounding DBE Determination would not change since the Bounding DBE Determination is based on potential consequences, and the consequences associated with the current bounding DBEs are larger than the consequences associated with the cart tipover event. This is due to the fact that the current bounding DBEs are based on drops from larger heights than the heights involved in the cart tipover event. However, the frequency of the cart tipover event would need to be included in the frequency analysis and accounted for in the DBE Category Determination since the DBE Category Determination is based on the frequency of all events that could result in an unfiltered release. The frequency of this event has not been determined, but if frequent enough, it could require the DBEs to be classified as Category 1, or result in additional facility or waste form requirements.

TBV-3123: Facility controls are employed to ensure that the drop of any handling equipment cannot cause a SC, a canister, or a canister inside a disposal container (DC) to breach (DIRS, Item No. 14).

See discussion for TBV-3122.

TBV-3124: There are no credible events that can cause the lag storage rack to fail resulting in a canister breach (DIRS, Item No. 14).

See discussion for TBV-3122.

TBV-3125: Facility controls are employed to ensure that the collision of a canister with another canister cannot cause either canister to breach (DIRS, Item No. 14).

See discussion for TBV-3122.

TBV-3126: There are no credible events that can cause a cart tipover or the DC to breach as a result of a cart tipover (DIRS, Item No. 14).

See discussion for TBV-3122.

TBV-3102: 20 liters/min breathing rate for the volume intake of air for "light activity" (ICRP Publication 23) (DIRS, Item No. 19).

This assumption is used in the Consequence Analysis. Any change in this value would directly impact the results of the consequence analysis.

8. ATTACHMENTS

Attachment I	Document Input Reference Sheets
Attachment II	Specific Inputs and Assumptions Made to Select the Bounding DBEs
Attachment III	Bounding Fuel by Group and Fuel Condition

Attachment IV	Bounding Parameters Used in the DOE SNF Consequence Analysis
Attachment V	Parameters Used in the Initial Case and the Baseline Case
Attachment VI	DBE Consequence Analysis Parameters Requiring Further Analysis
Attachment VII	Parameters Used in the DBE Baseline Case
Attachment VIII	Additional Requirement Options to Ensure the DBE Frequencies Are Less than 10^{-6} Per Year
Attachment IX	Waste Form and Facility Requirements

Attachment I: Document Input Reference Sheets

Document Identifier No./Rev.:			Change:	Title: Preliminary Design Basis Event Analysis of DOE SNF					
ANL-WPS-SE-000001 REV 00			N/A						
Input Document							TBV Due To		
No.	Technical Product Input Source Title & Identifiers with Version	Section	Input Status	Section Used In	Input Description	TBV/TBD Priority	Unqual.	From Uncontrolled Source	Unconfirmed
1	CRWMS M&O 1997a. <i>MFD - Carrier/Cask Transport System. Repository Surface Design.</i> BCBD00000-01717-2700-67001, Rev. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971029.0595.	Entire	TBV-3107	6.1.1, 7.2	System operation, dimensions and distances taken from drawing	2	X	N/A	N/A
2	CRWMS M&O 1997b. <i>MFD - CPB Material Handling System. Repository Surface Design.</i> BCBD00000-01717-2700-67002, Rev. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971113.0074.	Entire	TBV-3108	6.1.2, 7.2	System operation, dimensions and distances taken from drawing	2	X	N/A	N/A
3	CRWMS M&O 1997c. <i>MFD - Carrier/Cask Handling System. Repository Surface Design.</i> BCBD00000-01717-2700-67003, Rev. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980408.0618.	Entire	TBV-3109	6.1.3, 7.2	System operation, dimensions and distances taken from drawing	2	X	N/A	N/A
4	CRWMS M&O 1997d. <i>MFD - Canister Transfer System (Large Canister). Repository Surface Design.</i> BCBD00000-01717-2700-67009, Rev. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971029.0603.	Entire	TBV-3110	6.1.4, 7.2	System operation, dimensions and distances taken from drawing	2	X	N/A	N/A

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No.	Technical Product Input Source Title & Identifiers with Version	Section	Input Status	Section Used In	Input Description	TBV/ TBD Priority	Unqual.	From Uncontrolled Source	Unconfirmed
5	CRWMS M&O 1997e. <i>MFD - Canister Transfer System (Small Canister). Repository Surface Design.</i> BCB000000-01717-2700-67010, Rev. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971029.0604.	Entire	TBV-3111	6.1.4, 7.2	System operation, dimensions and distances taken from drawing	2	X	N/A	N/A
6	CRWMS M&O 1997f. <i>MFD - DC Handling System (Welding and Staging). Repository Surface Design.</i> BCB000000-01717-2700-67011, Rev. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971029.0605.	Entire	TBV-3112	6.1.5, 7.2	System operation, dimensions and distances taken from drawing	2	X	N/A	N/A
7	CRWMS M&O 1997g. <i>Waste Quantity, Mix and Throughput Study Report.</i> B00000000-01717-5705-00059, Rev. 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971210.0628. Initial Use.	Tables F-2 and 5-9	TBV-3707	4.1.4, 7.2	The maximum number of DOE SNF canisters in a DC is six, one, and four for the separate disposal DSNF, the co-disposal DSNF, and the DSNF MCO DCs, respectively.	2	X	N/A	N/A
		Table F-2	TBV-3707	4.1.4, 7.2	The maximum number of naval fuel canisters in a DC is one.	2	X	N/A	N/A
8	CRWMS M&O 1998a. <i>Preliminary x/Q Concentration Estimates Using NRC Regulatory Guide 1.145 as Implemented by the XQ145 Software Routine.</i> Interoffice Memorandum from W. Schalk and D. Landwehr to K. Montague. LV.EAP.WWS.12/98-004. Las Vegas, Nevada. CRWMS M&O. ACC: MOL.19990222.0117.	Table 2	TBV-3114	5.8, 6.8.1, 7.2	Varying the distance from 5,000 m to 10,000 m, the atmospheric dispersion factor, x/Q, decreases by a factor of 2.	2	X	X	N/A

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Input Document							TBV Due To		
No.	Technical Product Input Source Title & Identifiers with Version	Section	Input Status	Section Used In	Input Description	TBV/ TBD Priority	Unqual.	From Uncontrolled Source	Unconfirmed
9	CRWMS M&O 1999a. <i>Preliminary Selection of MGR Design Basis Events</i> . ANL-WHS-SE-000003, Rev 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990720.0406.	Entire	N/A	4.1.1, 5.1, Att. II	List of Canister related DBEs	N/A	N/A	N/A	N/A
		Tables 6, 7, 9 and 10	N/A	6.2.1, Att. II	Source of external, internal, and no release DBEs, and Beyond Design Basis Events.	N/A	N/A	N/A	N/A
		Entire	N/A	6.2.2.3	Waste Package DBEs	N/A	N/A	N/A	N/A
		5.2	TBV-690	5.9, 6.5.1, 7.2	The preclosure period is assumed to be 100 years.	2	X	N/A	N/A
		Table 9	TBV-245	5.12, 6.2.1, 7.2	Uncontrolled transporter descent, WP horizontal drop onto sharp object, and fuel rod rupture/internal pressurization	2	X	N/A	N/A
		Table 10	TBV-684	5.13, 6.2.1, 7.2	Rockfall exceeding WP design basis	2	X	N/A	N/A
		Table 10	TBV-688	5.14, 6.2.1, 7.2	Fire in subsurface facilities	2	X	N/A	N/A
		Table 7	TBV-3116	5.15, 6.2.1, 7.2	Preclosure early failure of a WP	2	X	N/A	N/A

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Input Document							TBV Due To		
No.	Technical Product Input Source Title & Identifiers with Version	Section	Input Status	Section Used In	Input Description	TBV/ TBD Priority	Unqual.	From Uncontrolled Source	Unconfirmed
10	CRWMS M&O 1999b. <i>MGR Event Tree Analysis for Cask, Canister and Container Drop Events</i> . CAL-WPS-SE-000003, Rev. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL. 19990720.0401. Initial Use.	Entire	TBV-3708	4.1.4 4.1.5 6.5.2 6.5.3 6.8.2, 7.2	Source for all freq. related data	2	X	N/A	N/A
		Table-5.2-6	TBV-3708	6.2.2.1, 7.2	SC Lift Heights	2	X	N/A	N/A
		Table-5.2-7	TBV-3708	6.2.2.2, 7.2	Canister Lift Heights	2	X	N/A	N/A
		Table-5.2-8	TBV-3708	6.2.2.3, 7.2	DC Lift Heights	2	X	N/A	N/A
		Entire	TBV-3708	6.7, Att. V, VII & VIII, 7.2	Inputs and Assumptions for reference analysis	2	X	N/A	N/A
		3.3.1.1	TBV-1342	5.7, 6.2.1, 7.2	Used to justify a WP being certified to drop from normal handling heights in the DCHS, and not certified from the two-block height.	2	X	N/A	N/A
		3.1.7.4	TBV-3708	4.1.4, 7.2	SCs will contain up to nine canisters of DOE SNF.	2	X	N/A	N/A
		3.1.5.3	TBV-3708	4.1.4, 7.2	The maximum number of naval fuel canisters in a shipping cask is one.	2	X	N/A	N/A
11	CRWMS M&O 1999c. <i>DOE High-Level Vitrified Waste Dose Calculations</i> . CAL-WPS-SE-000002 Rev. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL. 19990720.0403. Initial Use.	6.0	TBV-3709	4.1.3, 6.4, 7.2	Bounding dose consequences	2	X	N/A	N/A

Document Identifier No./Rev.: ANL-WPS-SE-000001 REV 00			Change: N/A	Title: Preliminary Design Basis Event Analysis of DOE SNF					
Input Document							TBV Due To		
No.	Technical Product Input Source Title & Identifiers with Version	Section	Input Status	Section Used In	Input Description	TBV/ TBD Priority	Unqual.	From Uncontrolled Source	Unconfirmed
12	CRWMS M&O 1999d. <i>DOE SNF DBE Offsite Dose Calculations</i> . CAL-WPS-SE-000004, REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL. 19990720.0402. Initial Use.	6	TBV-3710	4.1.3, 6.4, 7.2	Bounding Dose Consequences	2	X	N/A	N/A
		6	TBV-3710	6.4, 7.2	Navy fuel offsite dose	2	X	N/A	N/A
		6	TBV-3710	6.8.1, 7.2	MAR in DOE SNF	2	X	N/A	N/A
		5.2	TBV-3269	6.8.1, Table 6.4-3, 7.2	HEPA Filter Mitigation Factor	2	X	N/A	N/A
		3, 5.2	TBV-3235 TBV-3237 TBV-3238 TBV-3309 TBV-3238 TBV-3475	5.10, Att. IV, Att. VI, 7.2	Airborne release fractions and respirable fractions for the DOE SNF waste form and other parameters used in consequence analysis	2	X	N/A	N/A
						2	X	N/A	N/A
						2	X	N/A	N/A
						2	X	N/A	N/A
						2	X	N/A	N/A
						2	X	N/A	N/A
						2	X	N/A	N/A
		3.2	TBV-3240	5.16, 6.8.1, 7.2	In calculating the fraction of radionuclide inventory at-risk, it is assumed that all of the DOE SNF canisters of a given fuel type have the same isotopic composition	2	X	N/A	N/A
13	CRWMS M&O 1999e. <i>DOE SNF Screening Dose Analysis</i> . BBA000000-01717-0210-00047 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL. 19990602.0176. Initial Use.	Att. II	TBV-3711	4.1.2, 7.2	Bounding DOE SNF data	2	X	N/A	N/A
		Att. II	TBV-3711	6.3.1, 7.2	DOE SNF fuel types	2	X	N/A	N/A
		Att. VI	TBV-3711	6.3.2, 7.2	Bounding fuel selection	2	X	N/A	N/A

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Input Document							TBV Due To		
No.	Technical Product Input Source Title & Identifiers with Version	Section	Input Status	Section Used In	Input Description	TBV/ TBD Priority	Unqual.	From Uncontrolled Source	Unconfirmed
14	CRWMS M&O 1999f. <i>Plutonium Can-in-Canister - Design Basis Event Analysis</i> . ANL-WPS-SE-000002 REV 00. Las Vegas, Nevada. CRWMS M&O. ACC: MOL.19990720.0407.	5.2, 7.2	TBV-3122	5.2, 7.2	There are no credible events that can cause a cart tipover or the Shipping Cask (SC) to breach as a result of a cart tipover.	2	X	N/A	N/A
		5.3, 7.2	TBV-3123	5.3, 7.2	Facility controls are employed to ensure that the drop of any handling equipment cannot cause a SC, a canister, or a canister inside a disposal canister (DC) to breach.	2	X	N/A	N/A
		5.4, 7.2	TBV-3124	5.4, 7.2	There are no credible events that can cause the lag storage rack to fail resulting in a canister breach.	2	X	N/A	N/A
		5.5, 7.2	TBV-3125	5.5, 7.2	Facility controls are employed to ensure that the collision of a canister with another canister cannot cause either canister to breach.	2	X	N/A	N/A
		5.6, 7.2	TBV-3126	5.6, 7.2	There are no credible events that can cause a cart tipover or the DC to breach as a result of a cart tipover.	2	X	N/A	N/A
15	CRWMS M&O 1999g. <i>AP-3.10Q Work Direction Document for Preliminary Design Basis Events Analysis of DOE SNF</i> . Interoffice Memorandum from D.W. Gwyn to T.D. Dunn. LV.SA.RPM.5/99-062. Las Vegas, Nevada. CRWMS M&O. ACC: MOL.19990601.0002.	Entire	N/A	1.0	General Reference	N/A	N/A	N/A	N/A

Document Identifier No./Rev.: ANL-WPS-SE-000001 REV 00			Change: N/A	Title: Preliminary Design Basis Event Analysis of DOE SNF					
Input Document							TBV Due To		
No.	Technical Product Input Source Title & Identifiers with Version	Section	Input Status	Section Used In	Input Description	TBV/ TBD Priority	Unqual.	From Uncontrolled Source	Unconfirmed
16	AP-3.15Q, Rev. 0, ICN 1. <i>Managing Technical Product Inputs</i> . Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990831.0079.	Entire	N/A	2.0, 4.0	General Reference	N/A	N/A	N/A	N/A
17	QAP-2-3, Rev. 10. <i>Classification of Permanent Items</i> . Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990316.0006.	Entire	N/A	2.0	General Reference	N/A	N/A	N/A	N/A
18	Dyer 1999. Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations for Yucca Mountain, Nevada. Letter from J. Russell Dyer (DOE) to D. R. Wilkins (YMP), September 3, 1999. ACC: MOL.19990910.0079.	111	N/A	4.2 4.3.2 6.5.2 6.6	Dose criteria	N/A	N/A	N/A	N/A
		2	N/A	6.2.1, 6.5.1	DBE categories	N/A	N/A	N/A	N/A
19	International Commission on Radiological Protection (ICRP) 1974. <i>Report of the Task Group on Reference Man</i> . ICRP Publication 23. Oxford, England: Pergamon Press. TIC: 237218.	pg 346	TBV-3102 Form from AP-SIII.2Q submitted	5.11 6.8.1, 7.2	20 liters/min breathing rate for the volume intake of air for "light activity"	2	N/A	N/A	X
20	DOE 1998a. <i>Quality Assurance Requirements and Description for the Civilian Radioactive Waste Management Program (QARD)</i> . DOE/RW/0333P Rev. 08. Vienna, Virginia: CRWMS M&O. ACC: MOL.19980601.0022.	Entire	N/A	2.0	General Reference	N/A	N/A	N/A	N/A
21	Title 10 Code of Federal Regulations Part 20. <i>Standards for Protection Against Radiation</i> . U.S. Nuclear Regulatory Commission, Washington, DC. Readily available	1301	N/A	4.2 4.3 6.6	Regulatory dose limits for radiation protection of the public	N/A	N/A	N/A	N/A
22	QAP-2-0, Rev. 05. <i>Conduct of Activities</i> . Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980826.0209	Entire	N/A	2.0	General Reference	N/A	N/A	N/A	N/A

Document Identifier No./Rev.: ANL-WPS-SE-000001 REV 00			Change: N/A	Title: Preliminary Design Basis Event Analysis of DOE SNF					
Input Document							TBV Due To		
No.	Technical Product Input Source Title & Identifiers with Version	Section	Input Status	Section Used In	Input Description	TBV/ TBD Priority	Unqual.	From Uncontrolled Source	Unconfirmed
23	64 FR 8640. <i>Disposal Of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, Nevada</i> , U.S. Nuclear Regulatory Commission, Washington, DC. Proposed Rule 10CFR63. TIC: 240520.	Entire	N/A	Page 1	General Reference	N/A	N/A	N/A	N/A

Attachment II: Specific Inputs and Assumptions Made to Select the Bounding DBEs

1. A complete list of canister related DBEs for DOE SNF are identified in the *Preliminary Selection of MGR Design Basis Events Analysis* (CRWMS M&O 1999a, Tables 6, 7, 9, and 10).
2. Only those events identified by the *Preliminary Selection of MGR Design Basis Events Analysis* (CRWMS M&O 1999a, Table 7) table labeled Internal Events with Potential Releases are credible and have the potential to result in a radioactive material release (Assumption 5.1).
3. There are no credible events that can cause the Shipping Cask to breach as a result of a cart tipover.
4. Facility controls are employed to ensure that the drop of any handling equipment can not cause a shipping cask, canister, or DC to breach.
5. There are no credible events that can cause the Lag Storage Rack to fail resulting in a canister breach.
6. Facility controls are employed to ensure that the collision of a canister with another canister can not cause either canister to breach.
7. There are no credible events that can cause the DC to breach as a result of a cart tipover.

Attachment III: Bounding Fuel by Group and Fuel Condition

GROUPS OF FUEL TYPES	FUEL CONDITION	
	INTACT FUELS	NON-INTACT (DEGRADED) FUELS
STABLE METAL	HWCTR (U/TH) [112]	Alum Clad [411]
NON-METAL	Shippingport PWR Core II [193]	SAXTON (MOX) [787]
OTHER	EBWR LEU [64]	N-Reactor [147]

Attachment IV: Bounding Parameters Used in the DOE SNF Consequence Analysis

(Data taken from CRWMS M&O 1999d, Sections 3 and 5.2)

1. The site boundary is assumed to be 5,000 meters from the location of the WHB.
2. The radioactive material release occurs during a two-hour period.
3. The adult breathing rate is assumed to be of $3.33\text{E-}04$ cubic meters per second (20 liters/min).
4. An atmospheric dispersion factor of $4.68\text{ E-}05\text{ sec/m}^3$ used in the dose calculations for the assumed 5-km dose receptor is based on 99.5% χ/Q data.
5. The following airborne release fractions and the respirable fractions for the six DBE groups are used:

Fuel Fine (particulate):

DBE Group	ARF	RF
Stable Metal, Intact	$2.0\text{E-}04$	$4.0\text{E-}03$
Stable Metal, Not Intact	$5.0\text{E-}03$	0.4
Non-Metal, Intact	$2.25\text{E-}04$	1.0
Non-Metal, Not Intact	$5.0\text{E-}03$	0.4
Other, Intact	$1.0\text{E-}03$	1.0
Other, Not Intact	$5.0\text{E-}03$	0.4

Cesium:

DBE Group	ARF	RF
Stable Metal, Intact	$2.0\text{E-}04$	1.0
Stable Metal, Not Intact	$5.0\text{E-}03$	1.0
Non-Metal, Intact	$2.25\text{E-}04$	1.0
Non-Metal, Not Intact	$5.0\text{E-}03$	1.0
Other, Intact	$1.0\text{E-}03$	1.0
Other, Not Intact	$5.0\text{E-}03$	1.0

Crud	1.0	0.3
Gas	0.3	1.0

6. The leak path factor is assumed to be 1.0.
7. The damage ratio is assumed to be 1.0.
8. The inhalation dose associated with the HLW canister is conservatively based on the maximum drop height.
9. The dose associated with HLW is bounded by the data in Table 6.4-3 of this document.
10. The dose associated with Navy fuel is bounded by the data in Tables 6.4-1 and 6.4-2 of this document.

Attachment V: Parameters Used in the Initial Case and the Baseline Case

(Data taken from CRWMS M&O 1999b)

The values of the parameters given in this Attachment are applicable to both cases, unless indicated otherwise.

1. Bounding Throughputs

The yearly throughputs for each waste form and package type are as follows:

Waste Form*	SCs	Canisters	DCs
Totals	865	1,154	570
Total Commercial	664	300	381
CSNF Bare	364	N/A	81
CSNF DPCs	0	N/A	N/A
CSNF MPC	300	300	300
Total DSNF**	101	354	89
DSNF Separate Disposal	41	195	69
Navy Fuel	15	15	15
DSNF MCO	5	20	5
DSNF with HLW	40	124	65 [†]
Total HLW	100	500	100
HLW	65	430	65
HLW/Pu	35	70	35

*Waste Forms Abbreviations-
CSNF - commercial spent nuclear fuel
Bare - bare fuel (i.e., uncanistered)
DPC - dual-purpose canister
MPC - multi-purpose canister
DSNF - DOE spent nuclear fuel
MCO - multi-canister overpack
HLW - high level waste
HLW/Pu - Pu Can-in-Canister

** Total DSNF includes fuel from all six DOE SNF Fuel Groups. There are no restrictions on specific quantities for each DOE SNF Fuel Group.

[†] This value for co-disposal DCs is not included in the total DSNF DCs.

N/A - not applicable

2. Drop Frequencies

This analysis assumed the following event probabilities:

- CHS Bridge Crane 1.4×10^{-5} drops/lift
- CTS Bridge Crane 1.4×10^{-5} drops/lift

- DCHS Bridge Crane 1.4×10^{-5} drops/lift
- probability of a two-block 24% of all drops (Initial Case)
- probability of a two-block 1% of all drops (Baseline Case)

3. Number of Lifts

This analysis assumed that the number of lifts for each package at the MGR are as follows:

- one lift per SC
- two lifts per small canister
- one lift per large canister
- one lift per DC
- two lifts per WP

Note that a fully loaded DC will contain only one large canister or more than one small canister.

4. HEPA Filter Efficiency and Availability

None required.

5. Certification Requirements

5a. Initial Case

No certification for SC, canister, or DC.

5b. Baseline Case

Certification requirements identify the height at which the SC, canister, or DC must survive a drop with no breach. The certification requirements assumed in this analysis are as follows:

Waste Form	SC	Canister	DC
CNSF	Normal	None	None
DSNF	None	Normal	None
HLW	None	Normal	None
HLW/Pu	None	Normal	None
Naval	None	None	None

Notes:

Normal - Normal Handling Heights
 Max - Maximum Possible Handling Heights
 None - No certification required

6. Manufacturing Flaws

A manufacturing flaw in a certified SC, canister, or DC will enable a drop from below the certified height to cause a breach.

For this analysis, the probability of a manufacturing flaw in a SC, canister, or DC is assumed to be 1.06×10^{-3} .

7. Dose Consequences

This value identifies whether or not a release of a specific waste form would result in dose consequences that exceed the applicable criteria. Since the purpose of this calculation is to determine the frequency of a DBE with consequences exceeding the limit, the frequencies of DBE scenarios involving waste forms in packages that produce consequences below the criteria do not contribute to the overall DBE frequency.

For this analysis, the applicable criteria are any unmitigated releases. Thus, a release involving any waste form is assumed to exceed the limit.

8. SC, Canister, and DC Handling Times

There are no restrictions on SC, canister, or DC handling times.

Attachment VI: DBE Consequence Analysis Parameters Requiring Further Analysis

(Data taken from CRWMS M&O 1999d, Sections 3 and 5.2)

Parameter	Value Used	Possible Value	Comment
Damage Ratio	100%	0% to 10%	The Baseline Case assumes that all fuels in the not-intact group are damaged by the drop event, and the fuels are 100% in powder (particulate) form, which has a much higher airborne release fraction than that of an aggregate solid. The drop event would not generate a significant amount of particulate (< 0.1%). The total amount of particulate in a canister is currently controlled by the MGR waste acceptance criteria to be much less than 1% of the total canister content.
Airborne Release Fractions times the Respirable Fraction	2.25×10^{-4} to 0.3*	5×10^{-5} to 1×10^{-4}	The value used is similar to the value appropriate for a powder material. Additional analysis or testing should result in a lower, but still bounding, value.
Leak Path Factor	1.0	Less than 1%	The value used takes no credit for any package retaining any of the airborne material. For example, no credit is taken for the cladding, the canister, the shipping cask, or the building to reduce the amount of material released out of the building. Additional analysis may identify a more realistic, but still bounding, value.

* Data are taken from Attachment IV. ARF x RF of 8×10^{-7} for the stable-metal intact group is not included because no refined value for this combined parameter is suggested.

Attachment VII: Parameters Used in the DBE Baseline Case

(Data taken from CRWMS M&O 1999b)

1. Bounding Throughputs

The yearly throughputs for each waste form and package type are as follows:

Waste Form*	SCs	Canisters	DCs
Totals	865	1,154	570
Total Commercial	664	300	381
CSNF Bare	364	N/A	81
CSNF DPCs	0	N/A	N/A
CSNF MPC	300	300	300
Total DSNF**	101	354	89
DSNF Separate Disposal	41	195	69
Navy Fuel	15	15	15
DSNF MCO	5	20	5
DSNF with HLW	40	124	65 [†]
Total HLW	100	500	100
HLW	65	430	65
HLW/Pu	35	70	35

*Waste Forms Abbreviations-
CSNF - commercial spent nuclear fuel
Bare - bare fuel (i.e., uncanistered)
DPC - dual-purpose canister
MPC - multi-purpose canister
DSNF - DOE spent nuclear fuel
MCO - multi-canister overpack
HLW - high level waste
HLW/Pu - Pu Can-in-Canister

** Total DSNF includes fuel from all six DOE SNF Fuel Groups. There are no restrictions on specific quantities for each DOE SNF Fuel Group.

[†] This value for co-disposal DCs is not included in the total DSNF DCs.

N/A - not applicable

2. Drop Frequencies

This analysis assumed the following event probabilities:

• CHS Bridge Crane	No change from the Baseline Case.
• CTS Bridge Crane	No change from the Baseline Case.
• DCHS Bridge Crane	No change from the Baseline Case.
• Probability of a two-block	No change from the Baseline Case.

3. Number of Lifts

No change from the Baseline Case.

4. HEPA Filter Efficiency and Availability

No change from the Baseline Case.

5. Certification Requirements

No change from the Baseline Case.

6. Manufacturing Flaws

No change from the Baseline Case.

7. Dose Consequences

This input parameter identifies whether a specific waste form release results in dose consequences that exceed the applicable dose criteria. This input parameter has two input values for each waste form: "above" or "below". "Above" means the calculated dose is expected to be above the dose criteria and "below" means the calculated dose is expected to be below the dose criteria. Since the purpose of this calculation is to determine the frequency of a DBE with consequences exceeding the limit, the frequencies of DBE scenarios involving waste forms in packages that produce consequences below the dose criteria do not contribute to the overall DBE frequency.

For the Category 2 DBE frequency analysis, the dose criteria are described in Table 4.2-1 (i.e., 5 rem TEDE to the maximum exposed offsite individual). The table below provides a comparison of the unmitigated doses to the dose criteria:

Waste Form	SC	Canister	DC
CNSF	Below	Below	Below
DSNF	Above	Above	Above
HLW	Above	Below	Above
HLW/Pu	Above	Above	Above
Naval	Below	Below	Below

As shown on the table, this analysis assumes that events involving all commercial SNF and Naval Fuel packages, and HLW canisters produce consequences below the dose criteria. Thus, the frequency associated with these events does not contribute to the overall frequency calculations.

8. SC, Canister, and DC Handling Times

No change from the Baseline Case.

Attachment VIII: Additional Requirement Options to Ensure the DBE Frequencies Are Less than 10^{-6} Per Year

(Data taken from CRWMS M&O 1999b)

Case*	Throughputs	Drop Freq.	Two-Block Freq.	Certification Requirements (handling height)	Manufacturing Flaw Probability	Dose Consequence	Freq -SC, Canister, DC/WP (Event/yr)
DBE Baseline Case	See Attachment V	1.4×10^{-5} drops/lift	1%	Commercial SNF SC, DOE, HLW, HLW/Pu canisters - normal height	1.06×10^{-3}	See Attachment VII	9.7×10^{-5} 4.6×10^{-4} 8.3×10^{-5}
Scope 52	No change from DBE Baseline	No change from DBE Baseline	0.001%	All SCs - normal height All canisters - normal height	DSNF, HLW/Pu and HLW canister to 1.0×10^{-5}	No change from DBE Baseline	2.7×10^{-8} 6.1×10^{-7} 4.8×10^{-7}
Scope 56	No change from DBE Baseline	1.0×10^{-6} drops/lift	0.001%	All SCs - normal height All canisters - normal height	DSNF, HLW/Pu, HLW canisters and MCO to 1.0×10^{-4}	No change from DBE Baseline	2.0×10^{-9} 1.1×10^{-7} 8.4×10^{-8}
Scope 57	No change from DBE Baseline	1.0×10^{-6} drops/lift	1%	All SCs - normal height All canisters - maximum height	DSNF, HLW/Pu, HLW canisters to 1.0×10^{-4}	No change from DBE Baseline	1.0×10^{-9} 9.9×10^{-8} 7.9×10^{-8}
Scope 58	No change from DBE Baseline	No change from DBE Baseline	1%	All SCs - normal height All canisters - maximum height	DSNF, HLW/Pu, HLW canisters to 1.0×10^{-5}	No change from DBE Baseline	1.4×10^{-9} 1.4×10^{-7} 1.1×10^{-7}

* Case name from *MGR Event Tree Analysis for Cask, Canister, and Container Drop Events* (CRWMS M&O 1999b)

Attachment IX: Waste Form and Facility Requirements

1. Requirements from the DBE Selection Analysis (Section 5)

- Cart Controls

Cart shall be designed to not tip over during a design basis earthquake. This ensures that a SC or an unsealed DC would not tip over during a design basis earthquake.

- Handling Equipment Controls

Controls are required to ensure that the drop of any handling equipment cannot cause a SC, a canister, or a canister in the DC to breach.

- Canister Handling Controls

Controls are required to ensure that the collision of a canister with another canister cannot cause either canister to breach.

- Lag Storage Rack Controls

Controls are required to ensure that a canister cannot breach as a result of failure of the lag storage rack.

2. Requirements from the Selection of Bounding DOE SNF (Attachment III)

- Bounding Waste Types

The DOE fuels listed in Attachment III are bounding types with respect to offsite dose consequences to the maximally exposed individual. Facility controls are required to ensure that DOE fuels that could result in a large offsite dose are not accepted at the MGR.

3. Requirements from the DOE SNF Consequence Analysis (Attachment IV)

- Distance to the Site Boundary

The distance from the WHB to the site boundary is at least 5,000 meters.

4. Requirements from the Category Determination Analysis (Attachment V) and the DBE Baseline Case Frequency Analysis (Attachment VII)

- Bounding Throughputs

The bounding values shown in the following table are established by selecting the minimum throughputs presented in Attachments V and VII. The bounding values given in column 4 are the maximum throughputs allowed at the MGR. Note that these values are based on the referenced frequency analyses (Attachments V and VII), and these values are subject to change should those analyses be revised.

Waste Form	Categorization Determination Analysis (Attachment V) (No. of SCs, canisters, or DCs per year)	DBE Baseline Case Frequency Analysis [†] (Attachment VII) (No. of SCs, canisters, or DCs per year)	Bounding Throughput Requirement (No. of SCs, canisters, or DCs per year)
<i>Total SCs</i>	865	NR ⁽⁶⁾	865
CSNF SCs			
Bare	NR ⁽¹⁾	NR ⁽⁵⁾	NR
DPCs	NR ⁽¹⁾	NR ⁽⁵⁾	NR
MPCs	NR ⁽¹⁾	NR ⁽⁵⁾	NR
Total	664	NR ⁽⁵⁾	664
DSNF SCs			
Separate and Co-Disposal*	NR ⁽²⁾	81 ⁽⁷⁾	81
MCOs	20 less # Naval Fuel SCs ⁽³⁾	5	5
Naval Fuel	20 less # MCO SCs ⁽³⁾	NR ⁽⁵⁾	20 less # MCO SCs
Total	101	NR ⁽⁶⁾	101
HLW SCs			
HLW	NR ⁽⁴⁾	NR ⁽⁵⁾	NR
Pu/HLW	NR ⁽⁴⁾	35	35
Total	100	NR ⁽⁶⁾	100
<i>Total Canisters</i>	1154	NR ⁽⁶⁾	1154
CSNF Canisters			
Bare	N/A	N/A	N/A
DPCs	N/A	N/A	N/A
MPCs	300	NR ⁽⁵⁾	300
Total	300	NR ⁽⁶⁾	300
DSNF Canisters			
Separate and Co-Disposal*	NR ⁽²⁾	319 ⁽⁷⁾	319
MCOs	35 less # Naval Fuel Canisters ⁽³⁾	20	20
Naval Fuel	35 less # MCOs ⁽³⁾	NR ⁽⁵⁾	35 less # MCOs
Total	354	NR ⁽⁶⁾	354
HLW Canisters			
HLW	NR ⁽⁴⁾	NR ⁽⁵⁾	NR
Pu/HLW	NR ⁽⁴⁾	70	70
Total	500	NR ⁽⁶⁾	500

Waste Form	Categorization Determination Analysis (Attachment V) (No. of SCs, canisters, or DCs per year)	DBE Baseline Case Frequency Analysis [†] (Attachment VII) (No. of SCs, canisters, or DCs per year)	Bounding Throughput Requirement (No. of SCs, canisters, or DCs per year)
Total DCs	570	NR ⁽⁶⁾	570
CSNF DCs			
Bare	NR ⁽¹⁾	NR ⁽⁵⁾	NR
DPCs	N/A	N/A	N/A
MPCs	NR ⁽¹⁾	NR ⁽⁵⁾	NR
Total	381	NR ⁽⁶⁾	381
DSNF DCs			
Separate and Co-Disposal*	NR ⁽²⁾	69 ⁽⁷⁾	69
MCOs	20 less # Naval Fuel DCs ⁽³⁾	5	5
Naval Fuel	20 less # MCO DCs ⁽³⁾	NR ⁽⁵⁾	20 less # MCO DCs
Total	89	NR ⁽⁶⁾	89
HLW DCs			
HLW	NR ⁽⁴⁾	NR ⁽⁵⁾	NR
Pu/HLW	NR ⁽⁴⁾	35	35
Total	100	NR ⁽⁶⁾	100

Notes:

NR - No Restriction
N/A - Not Applicable

[†] As necessary, additional requirements may be derived from this analysis upon its completion.

* DSNF separate disposal and co-disposal waste forms include fuel from all six DOE SNF Fuel Groups. There are no restrictions on specific quantities for each DOE SNF Fuel Group.

(1) - The handling rate of the various SCs and DCs are interchangeable in the DBE Categorization analysis, thus the results are not sensitive to their specific throughput rates. However, the total number of CNSF SCs and DCs must be satisfied.

(2) - The handling rate of the various SCs, canisters, and DCs are interchangeable in the DBE Categorization analysis, thus the results are not sensitive to their specific throughput rates. However, the total number of DSNF SCs, canisters, and DCs must be satisfied.

(3) - The DBE Categorization analysis handles these fuel types in the same manner and analyzes a combined total of 20, 35, and 20 SCs, canisters, and DCs respectively. Thus, any combination of these SCs, canisters, or DCs up to 20, 35, and 20 respectively, is acceptable.

(4) - The handling rate of the various SCs, canisters, and DCs are interchangeable in the DBE Categorization analysis, thus the results are not sensitive to their specific throughput rates. However, the total number of HLW SCs, canisters, and DCs must be satisfied.

(5) - The potential dose consequences of a bounding DBE involving this fuel type is below the dose limit. Thus, the additional frequency analysis is not sensitive to this number because the frequency of having an event with consequences exceeding the dose limit is zero for this fuel type regardless of the number of SCs, canisters, or DCs handled.

(6) - This total number of SCs, canisters, or DCs is not restricted because it includes a fuel type that is not restricted. Note that specific fuel type restrictions that are part of this total must be met where indicated.

(7) The additional frequency analysis handles these fuel types in the same manner and analyzes a combined total of 81, 319, and 69 SCs, canisters, and DCs respectively. Thus, any combination of these SCs, canisters, or DCs up to 81, 319, and 69 respectively, is acceptable.

- Drop Frequencies

The minimum frequencies and probabilities associated with the following events are as follows:

CHS Bridge Crane	1.4×10^{-5} drops/lift
CTS Bridge Crane	1.4×10^{-5} drops/lift
DCHS Bridge Crane	1.4×10^{-5} drops/lift
Probability of a two-block	1.0% of all drops

- Number of Lifts

The maximum number of lifts for each package at the MGR is as follows:

one lift per SC
two lifts per small canister
one lift per large canister
one lift per DC, two lifts per waste package with the DC handling crane

- HEPA Filter Efficiency and Availability

There are no requirements on HEPA filter efficiency or availability.

- Certification Requirements

Certification requirements identify the height at which the SC, canister, or DC must survive a drop with no breach. The minimum certification requirements are as follows:

Waste Form	SC	Canister	DC
CSNF	Normal	None	None
DSNF	None	Normal	None
HLW	None	Normal	None
HLW/Pu	None	Normal	None
Naval	None	None	None

Notes:

Normal - Normal Handling Heights
Max - Maximum Possible Handling Heights
None - No certification required

- Manufacturing Flaws

A manufacturing flaw in a certified SC, canister, or DC will enable a drop from below the certified height to cause a breach.

The minimum probability of a manufacturing flaw in an SC, canister or DC/WP is 1.06×10^{-3} .

- Dose Consequences

The unmitigated dose consequences must be below the Category 2 dose criteria for the DBEs identified as "**Below**" in the following table.

<u>Waste Form</u>	<u>SC</u>	<u>Canister</u>	<u>DC</u>
CSNF	Below	Below	Below
DSNF	Above	Above	Above
HLW	Above	Below	Above
HLW/Pu	Above	Above	Above
Naval	Below	Below	Below

- SC, Canister, and DC Handling Times

There are no restrictions on SC, canister, or DC handling times within the MGR.

5. Additional Requirements from the Additional Consequence and Frequency Analyses

In addition to the requirements already presented, additional requirements as necessary will be derived from the additional consequence and frequency analyses after they are completed.