APPENDIX A.1
INTRODUCTION AND GENERAL DESCRIPTION OF INSTALLATION
NUHOMS®-MP187 Cask System

Table of Contents

A.1. INTRODUCTION AND GENERAL DESCRIPTION OF INSTALLATION

No change or additional information required for the NUHOMS®-MP187 Cask System for Chapter 1.

APPENDIX A.2
SITE CHARACTERISTICS
NUHOMS®-MP187 Cask System

Table of Contents

A.2. SITE CHARACTERISTICS

No change or additional information required for the NUHOMS®-MP187 Cask System for Chapter 2.

APPENDIX A.3
PRINCIPAL DESIGN CRITERIA
NUHOMS®-MP187 Cask System

Table of Contents

List of Tables

A.3. PRINCIPAL DESIGN CRITERIA

The NUHOMS®-MP187 Cask System principal design criteria is documented in Section 3 of the "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report" [A.3-1]. Table A.3-1 provides a comparison of the NUHOMS®-MP187 Cask System principal design criteria and the Waste Control Specialists, LLC (WCS) Consolidated Interim Storage Facility (CISF) design criteria provided in Table 1-2 which demonstrates that the NUHOMS®-MP187 Cask System bounds the WCS CISF criteria.

A.3.1 SSCs Important to Safety

The classifications of the NUHOMS®-MP187 Cask System systems, structures and components are discussed in Section 3.4 of *Volume 1 and Section 3.2 of Appendix C of* the "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report" [A.3-1]. These classifications are summarized in Table A.3-2 for convenience.

A.3.1.1 FO-, FC-, FF- DSCs *and GTCC Canister*

The FO-, FC- and FF-dry shielded canisters (DSC) provide the fuel assembly (FA) support required to maintain the fuel geometry for criticality control. Accidental criticality inside a DSC could lead to off-site doses exceeding regulatory limits, which must be prevented. The DSCs*, including the GTCC canister,* also provide the confinement boundary for radioactive materials. Therefore, the DSCs*, including the GTCC canister,* are designed to maintain structural integrity under all accident conditions identified in Chapter 12 without losing their function to provide confinement of the spent fuel assemblies. The DSCs*, including the GTCC canister, are* important-to-safety (ITS).

A.3.1.2 Horizontal Storage Module

For the NUHOMS®-MP187 Cask System, the horizontal storage modules (HSM) used is the HSM Model 80, herein referred to as HSM. The HSMs are considered ITS since these provide physical protection and shielding for the DSC during storage. The reinforced concrete HSM is designed in accordance with American Concrete Institute (ACI) 349 [A.3-4] and constructed to the requirements of ACI-318 [A.3-5]. The level of testing, inspection, and documentation provided during construction and maintenance is in accordance with the quality assurance requirements defined in 10 CFR Part 72, Subpart G. Thermal instrumentation for monitoring HSM concrete temperatures is considered "not-important-to-safety" (NITS).

A.3.1.3 NUHOMS® Basemat and Approach Slab

The basemat and approach slabs for the HSMs are considered NITS and are designed, constructed, maintained, and tested to ACI-318 [A.3-5] as commercial-grade items.

A.3.1.4 NUHOMS® Transfer Equipment

For the NUHOMS®-MP187 Cask System, the MP187 transportation cask is qualified for transfer operations and herein referred to as a transfer cask. The MP187 transfer cask is ITS since it protects the DSC during handling and is part of the primary load path used while handling the DSCs in the Cask Handling Building. An accidental drop of a loaded transfer cask has the potential for creating conditions adverse to the public health and safety. These possible drop conditions are evaluated with respect to the impact on the DSC in Chapter 12. The MP187 is designed, constructed, and tested in accordance with a QA program incorporating a graded quality approach for ITS requirements as defined by 10 CFR Part 72, Subpart G, paragraph 72.140(b).

The remaining transfer equipment (i.e., ram, skid, transfer vehicle) is necessary for the successful loading of the DSCs into the HSM. However, these items are not required to provide reasonable assurance that the canister can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public. Therefore, these components are considered NITS and need not comply with the requirements of 10 CFR Part 72. These components are designed, constructed, and tested in accordance with good industry practices.

A.3.2 Spent Fuel to Be Stored

The authorized content for the FO-, FC- and FF-DSCs are described in site-specific license SNM-2510 [A.3-6] and the “Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report” [A.3-1].

A.3.2.1 FO-, FC-DSC

SNM-2510 Technical Specifications Section 2.1.1 [A.3-6] provides a description of the fuels stored in the FO- and FC-DSCs as referenced in Section 10.3.1.1 “FO and FC-DSC Fuel Specifications” of the “Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report” [A.3-1].

A.3.2.2 FF-DSC

SNM-2510 Technical Specifications Section 2.1.1 [A.3-6] provides a description of the fuels stored in the FF-DSC as referenced in Section 10.3.1.2 “FF-DSC Fuel Specifications” of the “Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report” [A.3-1].

A.3.3 Design Criteria for Environmental Conditions and Natural Phenomena

A.3.3.1 Tornado Wind and Tornado Missiles

The design basis tornado wind and tornado missiles for the NUHOMS®-MP187 Cask System are provided in Section 3.2.1 of Volume 1 of reference [A.3-1]. The NUHOMS®-MP187 Cask System components are designed and conservatively evaluated for the most severe tornado and missiles anywhere within the United States (Region I as defined in NRC Regulatory Guide 1.76 [A.3-8]) while the WCS CISF is in Region II, a less severe location with respect to tornado and tornado missiles.

The HSM protects the DSC from adverse environmental effects and is the principal structure exposed to tornado wind and missile loads. Furthermore, all components of the HSM (regardless of their safety classification) are designed to withstand tornadoes and tornado-based missiles. The MP187 cask protects the DSC during transit to the Storage Pad from adverse environmental effects such as tornado winds and missiles.

A.3.3.2 Water Level (Flood) Design

Although the Rancho Seco site is a dry site not subject to flooding, the DSCs and HSM are designed for an enveloping design basis flood, postulated to result from natural phenomena as specified by 10 CFR 72.122(b). The system is evaluated for a postulated flood height of 50 feet with a water velocity of 15 fps.

The DSCs are evaluated for an external hydrostatic pressure equivalent to the 50 feet head of water. The HSM is evaluated for the effects of a water current of 15 fps impinging on the sides of a submerged HSM. For the flood case that submerges the HSM, the inside of the HSM will rapidly fill with water through the HSM vents.

As documented in Sections 2.4.2.2 and 3.2.2, the WCS CISF is not in a floodplain and is above the Probable Maximum Flood elevation and, therefore, will remain dry in the event of a flood.

A.3.3.3 Seismic Design

The seismic criteria for the NUHOMS®-MP187 Cask System are provided *by the enveloping acceleration response spectra at the WCS concrete pad base and HSM center of gravity obtained by the WCS CISF soil-structure interaction (SSI) analysis. The SSI analysis is based on the WCS CISF site-specific ground motion in the form of the 10,000-year return period uniform hazard spectra as described in Section 7.6.4.*

A.3.3.4 Snow and Ice Loading

The design basis snow and ice loading for the NUHOMS®-MP187 Cask System are provided in Section 3.2.4 of Volume 1 of reference [A.3-1]. Snow and ice loads for the HSM are conservatively derived from ANSI A58.1 1982 [A.3-9]. The maximum 100 year roof snow load, specified for most areas of the continental United States for an unheated structure, of 110 psf is assumed. For the purpose of this conservative generic evaluation, a total live load of 200 psf is used in the HSM analysis to envelope all postulated live loadings, including snow and ice. Snow and ice loads for the on-site transfer cask with a loaded DSC are negligible due to the smooth curved surface of the cask, the heat rejection of the SFAs, and the infrequent short term use of the cask.

The snow and ice loads used in the evaluation of the NUHOMS®-MP187 Cask System components envelopes the maximum WCS CISF snow and ice loads of 10 psf.

A.3.3.5 Lightning

The likelihood of lightning striking the HSM Model 80 and causing an off-normal or accident condition is not considered a credible event. Simple lightning protection equipment and grounding for the HSM structures is considered a miscellaneous attachment acceptable per the HSM design.

A.3.4 Safety Protection Systems

The safety protection systems of the NUHOMS®-MP187 Cask System are discussed in Section 3.3 of the "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report" [A.3-1].

A.3.4.1 General

The NUHOMS®-MP187 Cask System is designed for safe confinement during dry storage of SFAs. The components, structures, and equipment that are designed to assure that this safety objective is met are summarized in Table A.3-2. The key elements of the NUHOMS®-MP187 Cask System and its operation at the WCS CISF that require special design consideration are:

1. Minimizing the contamination of the DSC exterior.
2. The double closure seal welds on the DSC shell to form a pressure retaining confinement boundary and to maintain a helium atmosphere.
3. Minimizing personnel radiation exposure during DSC transfer operations.
4. Design of the cask and DSC for postulated accidents.
5. Design of the HSM passive ventilation system for effective decay heat removal to ensure the integrity of the fuel cladding.
6. Design of the DSC basket assembly to ensure subcriticality.

A.3.4.2 Structural

The principal design criteria for the DSCs are presented in Section 3.2.5.2 of Volume I of the "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report" [A.3-1]. The DSCs are designed to store intact, damaged and failed PWR FAs with or without Control Components. The fuel cladding integrity is assured by limiting fuel cladding temperature and maintaining a nonoxidizing environment in the DSC cavity.

The principal design criteria for the MP187 cask when used as a transfer cask are presented in Section 3.2.5.3 of the "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report" [A.3-1]. In this mode the MP187 cask is designed for the on-site transfer of a loaded DSC from the Cask Handling Building to the HSM. The principal design criteria for the HSMs are provided in Section 3.2.5.1, Volume I of reference [A.3-1].

A.3.4.3 Thermal

The thermal performance requirements for the NUHOMS®-MP187 Cask System are described in Section 3.1.1.2 of Volume I of the "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report" [A.3-1]. The HSM relies on natural convection through the air space in the HSM to cool the DSC. This passive convective ventilation system is driven by the pressure difference due to the stack effect (ΔP_s) provided by the height difference between the bottom of the DSC and the HSM air outlet. This pressure difference is greater than the flow pressure drop (ΔP_f) at the design air inlet and outlet temperatures.

A.3.4.4 Shielding/Confinement/Radiation Protection

The shielding performance and radiation protection requirements for the NUHOMS®-MP187 Cask System are described in Section 3.3.5 of Volume I of the "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report" [A.3-1]. The confinement performance requirements for the NUHOMS®-MP187 Cask System are described in Section *3.3.2* of Volume I of the "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report" [A.3-1] *for storage conditions. In addition, bounding evaluations in WCS CISF SAR Section A.7.7 are performed to demonstrate that the confinement boundaries for the FO-, FC-, FF-DSCs do not exceed ASME B&PV Subsection NB Article NB-3200 (Level A allowables) during normal conditions of transport to provide reasonable assurance that the confinement boundary is not adversely impacted by transport to the WCS CISF.*

The HSM provides the bulk of the radiation shielding for the DSCs. The HSM design is arranged in a back-to-back arrangement. Thick concrete supplemental shield walls are used at each end of an HSM array to minimize radiation dose rates both on-site and off-site. The HSMs provide sufficient biological shielding to protect workers and the public.

The MP187 cask is designed to provide sufficient shielding to ensure dose rates are ALARA during transfer operations and off- normal and accident conditions.

There are no radioactive releases of effluents during normal and off-normal storage operations. In addition, there are no credible accidents that cause significant releases of radioactive effluents from the DSC. Therefore, there are no off-gas or monitoring systems required for the system at the WCS CISF.

A.3.4.5 Criticality

The criticality performance requirements for the NUHOMS®-MP187 Cask System are described in Section 3.3.4 of Volume I of the "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report" [A.3-1].

For the DSCs, a combination of fixed poison in the basket and geometry are relied on to maintain criticality control. The structural analysis shows that there is no deformation of the basket under accident conditions that would increase reactivity.

A.3.4.6 Material Selection

Materials are selected based on their corrosion resistance, susceptibility to stress corrosion cracking, embrittlement properties, and the environment in which they operate during normal, off normal and accident conditions. The confinement boundary for the DSC materials meet the requirements of ASME Boiler and Pressure Vessel Code, Section III, Article NB-2000 and the specification requirements of Section II, Part D [A.3-7], with the listing of ASME Code exceptions for the DSCs and the cask provided in Appendix A "ASME Code Exceptions for the MP187 cask and FO, FC, and FF DSC's" of the "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report" [A.3-1]. The DSC and cask materials are resistant to corrosion and are not susceptible to other galvanic reactions. Studies under severe marine environments have demonstrated that the shell materials used in the DSC shells are expected to demonstrate minimal corrosion during an 80-year exposure. The DSC internals are enveloped in a dry, helium-inerted environment and are designed for all postulated environmental conditions. The HSM is a reinforced concrete component with an internal DSC support structure that is fabricated to ACI and AISC Code requirements. Both have durability well beyond a design life of 80 years.

A.3.4.7 Operating Procedures

The sequence of operations are outlined for the NUHOMS®-MP187 Cask System in Chapter 5 and A.5 for receipt and transfer of the DSCs to the storage pad, insertion into the HSM, monitoring operations, and retrieval and shipping. Throughout Chapter 5, CAUTION statements are provided at the steps where special notice is needed to maintain ALARA, protect the contents of the DSC, or protect the public and/or ITS components of the NUHOMS®-MP187 Cask System.

A.3.5 References

A.3-1 "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report," NRC Docket No. 72-11, Revision 4.

A.3-2 AREVA TN Document NUH-05-151 Rev. 17, "NUHOMS®-MP187 Multi-Purpose Transportation Package Safety Analysis Report." (Basis for NRC CoC 71-9255).

A.3-3 Proposed SNM-1050, WCS *Consolidated* Interim Storage Facility Technical Specifications, Amendment 0.

A.3-4 American Concrete Institute, "Code Requirements for Nuclear Safety Related Concrete Structures" and Commentary, ACI 349-85 and ACI 349R-85, American Concrete Institute, Detroit Michigan (1985).

A.3-5 American Concrete Institute, "Building Code Requirement for Reinforced Concrete," ACI-318, American Concrete Institute, Detroit Michigan (1983).

A.3-6 U.S. Nuclear Regulatory Commission, "License for Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste," License Number SNM-2510, Docket Number 72-11, Amendment all.

A.3-7 American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Division 1, 1983 Edition with Winter 1985 Addenda.

A.3-8 Reg Guide 1.76, "Design-Basis Tornado And Tornado Missiles For Nuclear Power Plants," Revision 1, March 2007.

A.3-9 ANSI A58.1-1982, "Building Code Requirements for Minimum Design Loads In Buildings and Other Structures."

Table A.3-1
Summary of WCS CISF Principal Design Criteria
(5 pages)

Design Parameter	WCS CISF Design Criteria	Condition	NUHOMS®-MP187 Design Criteria
Type of fuel	Commercial, light water reactor spent fuel	Normal (Bounded)	*Rancho Seco FSAR Section 10.3.1.1 and 10.3.1.2 of Volume 1*
Storage Systems	Transportable canisters and storage overpacks docketed by the NRC	Normal (Bounded)	71-9255 72-11 (SNM-2510)
Fuel Characteristics	Criteria as specified in previously approved licenses for included systems	Normal (Bounded)	*Rancho Seco FSAR Section 10.3.1.1 and 10.3.1.2 of Volume 1*
Tornado (Wind Load) (HSM Model 80)	Max translational speed: 40 mph Max rotational speed: 160 mph Max tornado wind speed: 200 mph Radius of max rotational speed: 150 ft Tornado pressure drop: 0.9 psi Rate of pressure drop: 0.4 psi/sec	Accident (Bounded)	*Rancho Seco FSAR Section 3.2.1 of Volume 1* Max translational speed: 70 mph Max rotational speed: 290 mph Max tornado wind speed: 360 mph Radius of max rotational speed: 150 ft Tornado pressure drop: 3.0 psi Rate of pressure drop: 2.0 psi/sec
Tornado (Wind Load) (MP187 TC)	Max translational speed: 40 mph Max rotational speed: 160 mph Max tornado wind speed: 200 mph Radius of max rotational speed: 150 ft Tornado pressure drop: 0.9 psi Rate of pressure drop: 0.4 psi/sec	Accident (Bounded)	*Rancho Seco FSAR Section 3.2.1 of Volume 1* Max translational speed: N/A Max rotational speed: N/A Max tornado wind speed: 360 mph Radius of max rotational speed: N/A Tornado pressure drop: N/A Rate of pressure drop: N/A
Tornado (Missile)	Automobile 4000 lb, 112 ft/s Schedule 40 Pipe 287 lb, 112 ft/s Solid Steel Sphere 0.147 lb, 23 ft/s	Accident (Bounded)	*Rancho Seco FSAR Table 3-1 of Volume 2* Automobile 4000 lb, 185 ft/s 8" diameter shell 276 lb, 185 ft/s Solid Steel Sphere 0.147 lb, 23 ft/s

Table A.3-1
Summary of WCS CISF Principal Design Criteria
(5 pages)

Design Parameter	WCS CISF Design Criteria	Condition	NUHOMS®-MP187 Design Criteria
Floods	*The WCS CISF is not in a floodplain and is above the Probable Maximum Flood elevation and will remain dry in the event of a flood.*	Accident (Bounded)	*Rancho Seco FSAR Table 3-1 of Volume 2* Flood height 50 ft Water velocity 15 ft/s
Seismic (Ground Motion)	Site-specific ground-surface uniform hazard response spectra (UHRS) with 1E-4 annual frequency of exceedance (AFE) having peak ground acceleration (PGA) of 0.250 g horizontal and 0.175 g vertical. (Table 1-5 and Figure 1-5)	Accident (*Evaluated*)	*See Evaluations in Sections 7.6.4, 7.6.5 and A.7.5*
Vent Blockage	For NUHOMS® Systems: Inlet and outlet vents blocked 40 hrs	Accident (Same)	*Rancho Seco FSAR Section 8.3.5 of Volume 2* Inlet and outlet vents blocked 40 hrs
Fire/Explosion	For NUHOMS® Systems: Equivalent fire 300 gallons of diesel fuel	Accident (Same)	*Rancho Seco FSAR Section 8.2.1 of Volume 1 and Appendix B* Equivalent fire 300 gallons of diesel fuel
Cask Drop	For NUHOMS® Systems: Transfer Cask Horizontal side drop or slap down 80 inches(3)	Accident (Same)	*Rancho Seco FSAR Section 8.2.1 of Volume 1 and Appendix B* Transfer Cask Horizontal side drop or slap down 80 inches(3)
Transfer Load	For NUHOMS® Systems only: Normal insertion load 60 kips Normal extraction load 60 kips	Normal (Same)	*Rancho Seco FSAR Appendix B page 8.1-26* Normal insertion load 60 kips Normal extraction load 60 kips
Transfer Load	For NUHOMS® Systems only: Maximum insertion load 80 kips Maximum extraction load 80 kips	Off-Normal/ Accident (Same)	*Rancho Seco FSAR Appendix B page 8.1-29* Maximum insertion load 80 kips Maximum extraction load 80 kips

Table A.3-1
Summary of WCS CISF Principal Design Criteria
(*5* pages)

Design Parameter	WCS CISF Design Criteria	Condition	NUHOMS®-MP187 Design Criteria
Ambient Temperatures	Normal temperature 44.1 – 81.5°F	Normal (Bounded)	*Rancho Seco FSAR Section 8.1.1.3 of Volume 1* Normal temperature 0 - *101*°F(1)
Off-Normal Temperature	Minimum temperature 30.1°F Maximum temperature *113*°F	Off-Normal (Bounded)	*Rancho Seco FSAR Section 8.1.1.3 of Volume 1* Minimum temperature -20.0°F Maximum temperature 120°F(2)
Extreme Temperature	Maximum temperature 113°F	Accident (Bounded)	*Rancho Seco FSAR Section 8.1.1.3 of Volume 1* Maximum temperature 120°F(2)
Solar Load (Insolation)	Horizontal flat surface insolation 2949.4 BTU/day-ft^2 Curved surface solar insolation 1474.7 BTU/day-ft^2	Normal (*No Impact*)	*Rancho Seco FSAR Table 8-1 of Volume 2* Horizontal flat surface insolation*(5)* *2112* BTU/day-ft^2 Curved surface solar insolation Not Specified
Snow and Ice	Snow Load 10 psf	Normal (Bounded)	*Rancho Seco FSAR Section 3.2.4 of Volume 1* Snow Load 110 psf
Dead Weight	Per design basis for systems listed in Table 1-1	Normal (Same)	*Rancho Seco FSAR Section 8.1.1.1 of Volume 1* [A.3-1]
Internal and External Pressure Loads	Per design basis for systems listed in Table 1-1	Normal (Same)	*Rancho Seco FSAR Sections 3.2.2 and 8.1.1.2 of Volume 1* [A.3-1]
Design Basis Thermal Loads	Per design basis for systems listed in Table 1-1	Normal (Same)	*Rancho Seco FSAR Sections 8.1.1.3 and 8.1.1.9 of Volume 1*

Table A.3-1
Summary of WCS CISF Principal Design Criteria
(5 pages)

Design Parameter	WCS CISF Design Criteria	Condition	NUHOMS®-MP187 Design Criteria
Operating Loads	Per design basis for systems listed in Table 1-1	Normal (Same)	*Rancho Seco FSAR Table 3-3 and Table 3-4 of Volume 1 and Table 3-1 of Volume 2 provide the Operating Loads applicable to the Canisters, Transfer Cask and HSM.* [A.3-1]
Live Loads	Per design basis for systems listed in Table 1-1	Normal (Same)	*Rancho Seco FSAR Section 3.2.4 of Volume 1* Design Load (including snow and ice) 200psf
Radiological Protection	Public wholebody ≤ 5 Rem Public deep dose plus individual organ or tissue ≤ 50 Rem Public shallow dose to skin or extremities ≤ 50 mrem Public lens of eye ≤ 15 mrem	Accident (Same)	*Chapter 9 demonstrates these limits are met* Public wholebody ≤ 5 Rem Public deep dose plus individual organ or tissue ≤ 50 Rem Public shallow dose to skin or extremities ≤ 50 Rem Public lens of eye ≤ 15 Rem
Radiological Protection	Public wholebody ≤ 25 mrem/yr(4) Public thyroid ≤ 75 mrem/yr(4) Public critical organ ≤ 25 mrem/yr(4)	Normal (Same)	*Chapter 9 demonstrates these limits are met* Public wholebody ≤ 25 mrem/yr(4) Public thyroid ≤ 75 mrem/yr(4) Public critical organ ≤ 25 mrem/yr(4)
Confinement	Per design basis for systems listed in Table 1-1	N/A	*Rancho Seco FSAR Section 3.3.2.1 of Volume 1 and Appendix B pages 3.3-1 to 3.3-2 of* Reference [A.3-1]
Nuclear Criticality	Per design basis for systems listed in Table 1-1	N/A	*Rancho Seco FSAR Section 3.3.4 of Volume 1 of* Reference [A.3-1]
Decommissioning	Minimize potential contamination	Normal (Same)	*Rancho Seco FSAR Section 3.5 and 9.6 of Volume 1* Minimize potential contamination

Table A.3-1
Summary of WCS CISF Principal Design Criteria
(*5* pages)

Design Parameter	WCS CISF Design Criteria	Condition	NUHOMS®-MP187 Design Criteria
Materials Handling and Retrieval Capability	Cask/canister handling system prevent breach of confinement boundary under all conditions Storage system allows ready retrieval of canister for shipment off-site	Normal (Same)	*Rancho Seco FSAR Section 3.2.5.2 of Volume 1* Cask/canister handling system prevent breach of confinement boundary under all conditions *Rancho Seco FSAR Section 5.1 of Volume 2* Storage system allows ready retrieval of canister for shipment off-site

Notes

1. *Not used*
2. *Not used*
3. 75g Vertical 75g Horizontal and 25g corner is equivalent to 80 inch drop.
4. In accordance with 10 CFR 72.104*(a)*(3) limits include any other radiation from uranium fuel cycle operations within the region.
5. *Rancho Seco FSAR Section 8.1.1.1, Item 6 of Volume 2 demonstrates that variations in isolation have little impact on system temperatures, therefore use of the lower values in the evaluations is acceptable.*

Table A.3-2
NUHOMS®-MP187 Cask Major Components and Safety Classifications

Component	10CFR72 Classification
Dry Shielded Canister (DSC)	Important to Safety[(1)]
Horizontal Storage Module (HSM)	Important to Safety[(1)]
Basemat and Approach Slabs	Not Important to Safety
Transfer Equipment	
Cask	Important to Safety
Transport Trailer/Skid	Not Important to Safety
Ram Assembly	Not Important to Safety
Lubricant	Not Important to Safety
Auxiliary Equipment	
HSM Temperature Monitoring	Not Important to Safety

Notes

1. Graded Quality

APPENDIX A.4
OPERATING SYSTEMS
NUHOMS®-MP187 Cask System

Table of Contents

List of Tables

A.4. OPERATING SYSTEMS

This Appendix provides information on the operating systems applicable to the NUHOMS®-MP187 Cask System identified in Chapter 4 of the SAR. Those systems include the concrete pad structures, cask storage system, cask transporter system and the optional HSM thermal monitoring system.

A.4.1 Concrete Pad Structures

This section is applicable to the basemat and approach slabs for the NUHOMS® HSM Model 80. The following discussion provides guidance for these structures; but as noted in Section A.4.1.3, the basemat and approach slabs are not-important-to-safety (NITS).

A.4.1.1 Operating Functions

The NUHOMS® System basemat and approach slabs are cast-in-place reinforced concrete foundation structures that support the HSMs (the basemat) and provide for access and support of the transfer system (the approach slabs). The thickness of the basemat and the approach slab will be determined by Storage Area foundation analysis.

A.4.1.2 Design Description

The following provides a description of the design considerations that will be taken into account when designing the basemat and approach slabs.

The basemat and approach slab loads consist of both dead and live loads, seismic loads, and tornado wind loads imposed on the HSM array and transferred to the basemat.

The dead load consists of the weight of the basemat or approach slab.

Live loads for the basemat include the weight of the loaded DSC, the weight of the modules and shield walls plus an additional 200 psf applied over the surface area of the HSM base to account for snow and ice loads, safety railings on the roofs of the HSM, etc. These loads are provided in Table A.4-1. The values shown in Table A.4-1 are based on nominal material density; however, the as-built weight can vary ±5%, therefore; the storage pad is designed to accommodate 105% of the nominal weight shown in the table.

Live loads for the approach slab include the MP187 cask and transfer vehicle design payload which is 300,000 lb. Additional live loads of 200 psf are applied over the surface area of the approach slabs.

Localized front (furthest from HSM) jack loads of 85,000 lb and rear jack loads of 109,000 lb are considered in designing the approach slab (this conservatively assumes the load of the DSC is carried only by the two rear jacks as the DSC is inserted into the HSM). These loads are spread as necessary by use of spreading plates or other suitable means.

The site-specific soil conditions at the Waste Control Specialists, LLC (WCS) Consolidated Interim Storage Facility (CISF) are considered in the basemat design based on basemat and HSM acceleration resulting from seismic activity.

Tornado wind loads acting on the HSM array are transferred to the basemat as friction and pressure loads. Generic design pressure loads acting on the NUHOMS® system due to tornado wind loading are described in the Standardized NUHOMS® UFSAR, Section 3.2.1 [A.4-1]. These may be replaced by the site-specific tornado loads which are significantly lower.

The basemat for the NUHOMS® HSMs will be level and constructed with a "Class B" surface flatness finish as specified in ACI 301-89 [A.4-2], or FF 25 per ASTM E 1155. Specifically, finishes with Class B tolerances shall be true planes within 1/4" in 10 feet, as determined by a ten foot straightedge placed anywhere on the slab in any direction. Although Class B surface finish is required, for modules with mating surfaces Class A surface flatness or FF 50 per ASTM E 1155 is recommended in order to provide better fit up and minimize gaps.

The surface finish for the basemat may be broomed, troweled or ground surface. Laser guided finishers and certified personnel may be utilized for construction of the basemat to assure proper finish, levelness and flatness. Alternatively, when grouted installation of HSMs is used, a reduced flatness may be targeted. The grouted installation consists of setting the modules on approximately one-inch thick stainless steel shims and grouting between the module and the pad using cement-based grouts.

The slope of the approach slabs shall not exceed 7% which is the adjustable limit of brake for the transfer vehicle.

The overall dimensions of the HSM modules are listed in Table A.4-2. When determining the length of the basemat, 1/2" should be added to the width of each module to account for as-built conditions in the modules and basemat. The basemat typically extends one foot beyond the front face of the module and matches the elevation of the approach slab. Thus, the width of a basemat for the double array is typically two feet wider than the modules. Similarly, the basemat typically extends one foot beyond the end walls.

To maintain levelness and stability of the module array, the joints intersecting the basemat should be minimized. Joints with expansion and sealant material must be compatible with expected basemat temperatures.

Two methods of HSM array expansion are permitted. One involves the temporary removal of end walls, installation of new modules, and then re-installation of the end walls. This method requires that the existing modules adjacent to the end walls be empty (unloaded) during array expansion. The other method of array expansion effectively buries the existing end walls by placing new modules directly adjacent to the end walls with new end walls placed at the end of the expanded array. The length of the basemat should be designed to accommodate the planned method of array expansion, as applicable. The basemat shall be designed to a maximum differential settlement of 1/4 inch, front to back and side-to-side (HSM array).

Finally, approach roads and aprons should be designed or repaired to eliminate features such as speed bumps, drains or potholes that would result in a difference of more than 5 inches in surface flatness over any 10-foot wide by 20-foot long area.

A.4.1.3 Safety Considerations

The foundation is not relied upon to provide safety functions. There are no structural connections or means to transfer shear between the HSM base unit module and the foundation slab. Therefore, the basemat and approach slabs for the HSMs are considered NITS and are designed, constructed, maintained, and tested as commercial-grade items.

A.4.2 Cask Storage System

This section is applicable to the *FO-, FC-and FF-DSC and Greater than Class C (GTCC) waste canisters;* NUHOMS® HSM Model 80*; and MP187 cask configured for transfer operations*.

A.4.2.1 Operating Function

The overall function of the HSM Model 80 used at the WCS CISF is to safely provide interim storage of spent nuclear fuel (SNF) *and GTCC waste* canisters. These canisters provide a convenient means to place set quantities of spent nuclear fuel (SNF) and GTCC into dry storage in a way that allows easy retrieval of the canisters for off-site shipment.

The FO-, FC- and FF-DSC canisters containing SNF assemblies and GTCC waste canisters are designed for storage in accordance with 10 CFR 72, and for transportation in accordance with 10 CFR 71. The main function of sealed canisters is to accommodate SNF assemblies and GTCC waste, and provide confinement and criticality control during normal operation and postulated design-basis accident conditions for on-site storage. *The FC-and FO-DSCs are shown in drawing NUH-05-4004 Revision 16 and the FF-DSC is shown in drawing NUH-05-4005 Revision 14, included in Section A.4.6. The GTCC canister is shown in drawings 13302-1005 Revision 0 and 13302-10007 Revision 0 included in Section A.4.6.*

The HSM Model 80 is designed in accordance with 10 CFR 72, and provides horizontal on-site storage of the sealed SNF and GTCC waste canisters. The main function of the HSM Model 80 is to provide safe, long-term storage of FO-, FC- and FF-DSCs containing SNF assemblies and GTCC waste canisters containing solid reactor waste.

The HSM Model 80 design function is to passively cool the canisters by air convection. The HSM Model 80 also provides the capability for canister transfer from their associated transportation/transfer casks. *The drawings for the HSM Model 80 are not included in Reference [A.4-4] as the HSM was incorporated by reference into the the "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report." The applicable drawings for the HSM Model 80 are NUH-03-6008-SAR Revision 10, NUH-03-6009-SAR Revision 9, NUH-03-6010-SAR Revision 5, NUH-03-6014-SAR Revision 9, NUH-03-6015-SAR Revision 8, NUH-03-6016-SAR Revision 10, NUH-03-6017-01-SAR Revision 7, NUH-03-6018-SAR Revision 7 and NUH-03-6024-SAR Revision 5 included in Section A.4.6.*

The MP187 cask, in the transfer configuration, design function is to protect the canisters and provide shielding from the radiation sources inside the canisters during transfer operations. The MP187 cask in the transfer configuration is shown in drawings NUH-05-4001 Revision 15 and NUH-05-4003 Revision 10, included in Section A.4.6.

A.4.2.2 Design Description

The FO-, FC- and FF-DSCs and GTCC waste canister are stainless steel flat head pressure vessels that provides confinement that is designed to withstand all normal condition loads as well as the off-normal and accident condition loads created by earthquakes, tornadoes, flooding, and other natural phenomena.

The HSM Model 80 is a low profile, reinforced concrete structure designed to withstand all normal condition loads as well as the off-normal and accident condition loads created by earthquakes, tornadoes, flooding, and other natural phenomena. The HSM is also designed to withstand off-normal and accident condition loadings postulated to occur during design basis accident conditions such as a complete loss of ventilation. *The MP187 cask, in the transfer configuration, is used to transfer the canisters from the CHB to the storage pad where the cask is mated to the HSM Model 80. The cask is designed to withstand all normal condition loads as well as the off-normal and accident condition loads created by earthquakes, tornadoes, flooding, and other natural phenomena.*

A.4.2.3 Safety Considerations

The FO-, FC- and FF- DSCs are important-to-safety (ITS), Quality Category A components. The GTCC waste canister is an ITS, Quality Category B component. The HSM Model 80 is an ITS, Quality Category B component. *The MP-187 Cask is an ITS, Quality Category B component.*

A.4.3 Cask Transporter System

This section is applicable to the cask transporter system for the MP187 cask. This following provides a general description of the cask transporter system, however as noted Section A.4.3.3, this equipment is NITS.

A.4.3.1 Operating Function

The cask transporter system for the MP187 cask is designed to move the loaded MP187 cask in the on-site transfer configuration between the Cask Handling Building and the Storage Area and transfer the canister from the MP187 cask to the HSM Model 80.

A.4.3.2 Design Description

The transfer vehicle includes a transfer skid which cradles the top and bottom lifting trunnions of the cask, and is designed to be moved with the skid and cask. The transfer vehicle is also used in the Storage Area to transfer the canister from an MP187 cask to an HSM. It features a transfer skid, a skid positioner, a hydraulic ram system and hydraulic jacks for stabilization. The system utilizes a self-contained hydraulic ram to hydraulically push the canister out of the MP187 cask and into the HSM. The alignment of the MP187 cask and the HSM is verified by an alignment system.

A.4.3.3 Safety Considerations

All transfer equipment is designed to limit the height of the MP187 cask to less than 80” above the surrounding surface; therefore, it is NITS and is designed, constructed, maintained, and tested as commercial-grade items.

A.4.4 Storage Module Thermal Monitoring System

Instrumentation is provided for monitoring HSM temperatures as described in Section 5.1.3 HSM Thermal Monitoring Program of the Technical Specifications [A.4-3] that may be used as one of two options provided to prevent conditions that could lead to exceeding the concrete and SNF clad temperature criteria.

A.4.5 References

A.4-1 AREVA TN Document NUH-003, Revision 14, "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel." (Basis for NRC CoC 72-1004).

A.4-2 American Concrete Institute, "Specifications for Structural Concrete for Buildings," ACI 301, 1989.

A.4-3 Proposed SNM-1050, WCS *Consolidated* Interim Storage Facility Technical Specifications, Amendment 0.

A.4-4 "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report," NRC Docket No. 72-11, Revision 4.

A.4.6 Supplemental Data Drawings

The following drawings are incorporated by reference or enclosed as noted below:

1. *"NUHOMS FO-DSC and FC-DSC for PWR Fuel Main Assembly (four sheets)," NUH-05-4004, Revision 16 (See Volume 4 of the "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report" [A.4-4]).*
2. *"NUHOMS FF-DSC for PWR Fuel Main Assembly (four sheets)," NUH-05-4005, Revision 14 (See Volume 4 of the "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report" [A.4-4]).*
3. *Not Used.*
4. *Not Used.*
5. *"Standardized NUHOMS® ISFSI Horizontal Storage Module ISFSI General Arrangement (three sheets)," NUH-03-6008-SAR, Revision 10 (See Section E.2 of Appendix E of the "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel" [A.4-1]).*
6. *"Standardized NUHOMS® ISFSI Horizontal Storage Module Main Assembly (two sheets)," NUH-03-6009-SAR, Revision 9 (See Section E.2 of Appendix E of the "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel" [A.4-1]).*
7. *"Standardized NUHOMS® ISFSI Horizontal Storage Module Base Unit Assembly (two sheets)," NUH-03-6010-SAR, Revision 5 (See Section E.2 of Appendix E of the "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel" [A.4-1]).*
8. *"Standardized NUHOMS® ISFSI Horizontal Storage Module Base Unit (three sheets)," NUH-03-6014-SAR, Revision 9 (See Section E.2 of Appendix E of the "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel" [A.4-1]).*
9. *"Standardized NUHOMS® ISFSI Horizontal Storage Module Roof Slab Assembly (two sheets)," NUH-03-6015-SAR, Revision 8 (See Section E.2 of Appendix E of the "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel" [A.4-1]).*
10. *"Standardized NUHOMS® ISFSI Horizontal Storage Module DSC Support Structure (two sheets)," NUH-03-6016-SAR, Revision 10 (See Section E.2 of Appendix E of the "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel" [A.4-1]).*

11. *"Standardized NUHOMS® ISFSI Horizontal Storage Module, Module Accessories (five sheets)," NUH-03-6017-01-SAR, Revision 7 (See Section E.2 of Appendix E of the "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel" [A.4-1]).*

12. *"Standardized NUHOMS® ISFSI Horizontal Storage Module Shield Wall Plans and Details (two sheets)," NUH-03-6018-SAR, Revision 7 (See Section E.2 of Appendix E of the "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel" [A.4-1]).*

13. *"Standardized NUHOMS® ISFSI Horizontal Storage Module, Module Erection Hardware (two sheets)," NUH-03-6024-SAR, Revision 5 (See Section E.2 of Appendix E of the "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel" [A.4-1]).*

14. *"NUHOMS MP-187 Multi-purpose Cask Main Assembly (six sheets)," NUH-05-4001 Revision 15 (See Volume 4 of the "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report" [A.4-4]).*

15. *"NUHOMS MP-187 Multi-purpose Cask Onsite Transfer Arrangement (two sheets)," NUH-05-4003 Revision 10 (See Volume 4 of the "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report" [A.4-4]).*

Table A.4-1
Weight of HSM Model 80

Component	Nominal Weight kips(1)	105% weight kips
HSM Model 80	239.4	251.4
End Walls	48	50.4

Notes

1. Values reported in this table are for the purposes of designing the basemat and may differ from other SAR values.

Table A.4-2
HSM Model 80 Overall Dimensions

Width	Depth	Height
122”	228”	180”

APPENDIX A.5
OPERATING PROCEDURES
NUHOMS®-MP187 Cask System

Table of Contents

List of Figures

A.5. OPERATING PROCEDURES

This chapter presents the operating procedures for the NUHOMS®-MP187 System containing FO-, FC-, FF-DSCs and GTCC waste canisters originally loaded and stored under Materials License SNM-2510. The procedures include receipt of the NUHOMS®-MP187 Cask (TC); placing the TC onto the transfer skid on the transfer vehicle, transfer to the Storage Area, DSC transfer into the horizontal storage module (HSM), monitoring operations, and DSC retrieval from the HSM. The NUHOMS®-MP187 transfer equipment, and the Cask Handling Building systems and equipment are used to accomplish these operations. Procedures are delineated here to describe how these operations may be performed and are not intended to be limiting. Temporary shielding may be used throughout as appropriate to maintain doses as low as reasonably achievable (ALARA).

The following sections outline the typical operating procedures for the NUHOMS®-MP187 System. These procedures have been developed to minimize the amount of time required to complete the subject operations, to minimize personnel exposure, and to assure that all operations required for transfer, and storage are performed safely. Operations may be performed in a different order if desired to better utilize personnel and minimize dose as conditions dictate.

Pictograms of the NUHOMS®-MP187 System operations are presented in Figure A.5-1.

The generic terms used throughout this section are as follows.

- TC, or transfer cask is used for the NUHOMS®-MP187 transport/transfer cask.
- DSC is used for the FO-DSC, FC-DSC, FF-DSC and GTCC waste canisters.
- HSM is used for the HSM Model 80.

A.5.1 Procedures for Receiving the Transport Cask and Transfer to the HSM

A pictorial representation of key phases of this process is provided in Figure A.5-1.

A.5.1.1 Receipt of the Loaded NUHOMS®-MP187 Cask

Procedures for receiving the loaded TC after shipment are described in this section. These procedures are taken from reference [A.5-1] *and must remain consistent with* [A.5-1].

1. Verify that the tamperproof seals are intact.
2. Remove the tamperproof seals.
3. Remove the impact limiter attachment bolts from each impact limiter and remove the impact limiters from the TC.
4. Remove the transportation skid personnel barrier and skid support structure (closure assembly).
5. Take contamination smears on the outside surfaces of the TC. If necessary, decontaminate the TC until smearable contamination is at an acceptable level.
6. Attach *the WCS Lift Beam Assembly* to TC top and bottom ends.
7. Using the overhead crane, lift the TC from the railcar.

CAUTION: Verify that the TC is not lifted more than 80" above the adjacent surface in accordance with the limits specified in Section 5.2.1 of the Technical Specifications [A.5-2].

   a. Remove upper and lower trunnion plugs.
   b. Inspect the trunnion sockets for excessive wear, galling, or distortion in accordance with the transport license requirements [A.5-1].
   c. Install the upper and lower trunnions. Torque trunnion attachment bolts to at least 200 ft-lbs in accordance with the transport license requirements [A.5-1].

8. Place the TC onto the transfer cask skid trunnion towers.
9. Inspect the trunnions to ensure that they are properly seated onto the skid.
10. Remove the *WCS Lift Beam Assembly*.
11. Install the cask shear key plug assembly.
12. Install the on-site support skid pillow block covers.

13. Any time prior to removing the TC top cover plate or the bottom ram access cover plate, sample the TC cavity atmosphere through the vent port. Flush the TC interior gases to the radwaste system if necessary.

14. Draw a vacuum on the TC cavity and helium leak test the DSC in accordance with reference [A.5-3] requirements.

A.5.1.2 Transfer to the HSM

1. Prior to the TC arrival at the HSM, remove the HSM door, inspect the cavity of the HSM, removing any debris and ready the HSM to receive a DSC. The doors on adjacent HSMs must remain in place.

CAUTION: The inside of empty modules have the potential for high *dose* rates due to adjacent loaded modules. Proper ALARA practices should be followed for operations inside these modules and in the areas outside these modules whenever the door from an empty HSM has been removed.

2. Inspect the HSM air inlets and outlets to ensure that they are clear of debris. Inspect the screens on the air inlets and outlets for damage.

3. Verify specified lubrication of the DSC support structure rails.

4. Move the TC from the Cask Handling Building to the storage pad along the designated transfer route.

5. Once at the storage pad, position the transfer vehicle to within a few feet of the HSM.

   Note: If performing inspection of the DSC surface per reference [A.5-3] requirement, install inspection apparatus between the TC and the HSM.

6. Check the position of the transfer vehicle to ensure the centerline of the HSM and TC approximately coincide. If the transfer vehicle is not properly oriented, reposition the transfer vehicle, as necessary.

7. Unbolt and remove the TC top cover plate.

8. Verify the DSC serial number against appropriate records.

CAUTION: High dose rates are expected after removal of the TC top cover plate. Proper ALARA practices should be followed.

9. Back the transfer vehicle to within a few inches of the HSM/inspection apparatus, set the transfer vehicle brakes and disengage the tractor, if applicable. Extend the transfer vehicle vertical jacks.

10. Use the skid positioning system to bring the TC into approximate vertical and horizontal alignment with the HSM. Using alignment equipment and the alignment marks on the TC and the HSM, adjust the position of the TC until it is properly aligned with the HSM.

11. Using the skid positioning system, fully insert the TC into the HSM/inspection apparatus access opening docking collar.

12. Secure the TC to the front wall embedments of the HSM using the cask restraints.

13. After the TC is docked with the HSM/inspection apparatus, verify the alignment of the TC using the alignment equipment.

14. Remove the bottom ram access cover plate. Position the ram behind the TC in approximate horizontal alignment with the TC and level the ram. Extend the ram through the bottom TC opening into the DSC grapple ring.

15. Operate the ram grapple and engage the grapple arms with the DSC grapple ring.

16. Recheck all alignment marks and ready all systems for DSC transfer.

17. Activate the ram to initiate insertion of the DSC into the HSM. Stop the ram when the DSC reaches the support rail stops at the back of the module.

    Note: Performing inspection of the DSC surface, as required, by the aging management program while the DSC is being transferred from the TC to the HSM.

18. Disengage the ram grapple mechanism so that the grapple is retracted away from the DSC grapple ring.

19. Retract and disengage the ram system from the TC and move it clear of the TC. Remove the cask restraints from the HSM.

20. Using the skid positioning system, disengage the TC from the HSM/inspection apparatus access opening.

21. Remove the inspection apparatus if used.

22. Install the DSC axial restraint through the HSM door opening.

CAUTION: High dose rates are expected in the HSM cavity after removal of the HSM door. Proper ALARA practices should be followed.

23. The transfer vehicle can be moved, as necessary, to install the HSM door. Install the HSM door and secure it in place. The door may be welded for security.

24. Replace the TC top cover plate and ram access cover plate. Secure the skid to the transfer vehicle.

25. Move the transfer vehicle and TC to the designated area. Return the remaining transfer equipment to the Storage Area.

A.5.1.3 Monitoring Operations

1. Perform routine security surveillance in accordance with the security plan.

2. Perform a daily visual surveillance of the HSM air inlets and outlets (bird screens) to verify that no debris is obstructing the HSM vents in accordance with Section 5.1.3(a) of the Technical Specification [A.5-2] requirements, or, perform a temperature measurement for each HSM in accordance with Section 5.1.3(b) of the Technical Specifications [A.5-2] requirements.

A.5.2 Procedures for Retrieval and Off-Site Shipment

The following section outlines the procedures for retrieving the DSC from the HSM for shipment off-site.

A.5.2.1 DSC Retrieval from the HSM

1. Ready the TC, transfer vehicle, and support skid for service. Remove the top cover and ram access plates from the TC. Move the transfer vehicle to the HSM.

2. Remove the HSM door and the DSC axial restraint. Position the transfer vehicle to within a few feet of the HSM.

3. Check the position of the transfer vehicle to ensure the centerline of the HSM and TC approximately coincide. If the transfer vehicle is not properly oriented, reposition the transfer vehicle as necessary.

CAUTION: High dose rates are expected in the HSM cavity after removal of the HSM door. Proper ALARA practices should be followed.

4. Back the TC to within a few inches of the HSM, set the transfer vehicle brakes and disengage the tractor, if applicable. Extend the transfer transfer vehicle vertical jacks.

5. Use the skid positioning system to bring the TC into approximate vertical and horizontal alignment with the HSM. Using alignment equipment and the alignment marks on the TC and the HSM, adjust the position of the TC until it is properly aligned with the HSM.

6. Using the skid positioning system, fully insert the TC into the HSM access opening docking collar.

7. Secure the TC to the front wall embedments of the HSM using the cask restraints.

8. After the TC is docked with the HSM, verify the alignment of the TC using the alignment equipment.

9. Position the ram behind the TC in approximate horizontal alignment with the TC and level the ram. Extend the ram through the TC into the HSM until it is inserted in the DSC grapple ring.

10. Operate the ram grapple and engage the grapple arms with the DSC grapple ring.

11. Recheck all alignment marks and ready all systems for DSC transfer.

12. Activate the ram to pull the DSC into the TC.

13. Once the DSC is seated in the TC, disengage the ram grapple mechanism so that the grapple is retracted away from the DSC grapple ring.

14. Retract and disengage the ram system from the TC and move it clear of the TC. Remove the cask restraints from the HSM.

15. Using the skid positioning system, disengage the TC from the HSM access opening.

CAUTION: The inside of empty modules have the potential for high *dose* rates due to adjacent loaded modules. Proper ALARA practices should be followed for operations inside these modules and in the areas outside these modules whenever the door from the empty HSM has been removed.

16. Bolt the TC top cover plate and the ram access cover plate into place, tightening the bolts to the required torque in a star pattern.

17. Retract the vertical jacks and disconnect the skid positioning system.

18. Ready the transfer vehicle for transfer.

19. Replace the HSM door and DSC axial restraint on the HSM.

20. Move the TC from the storage pad to the Cask Handling Building along the designated transfer route.

21. Prepare the transportation cask for transport in accordance with *Certificate of Compliance No. 9255*.

A.5.3 References

A.5-1 Certificate of Compliance for Radioactive Material Packages, No. 9255, current Revision , including the TN drawings incorporated by Condition 5.(a)(3) of the CoC and SAR Chapters 7 and 8 incorporated by Condition 7 of the CoC.

A.5-2 Proposed SNM-1050, WCS *Consolidated* Interim Storage Facility Technical Specifications, Amendment 0.

A.5-3 "Post Transport Package Evaluation," QP-10.02, Revision *1*.

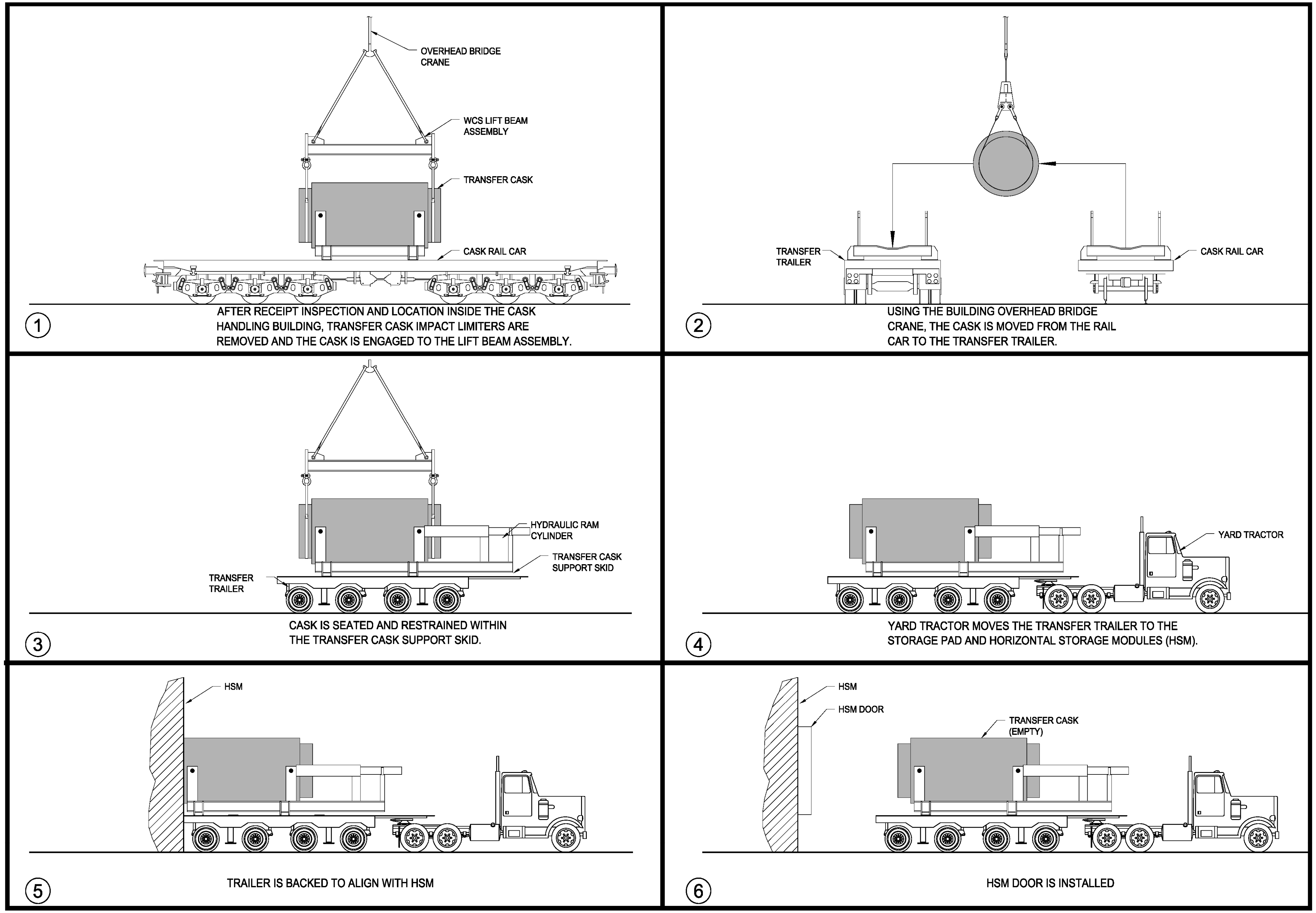


Figure A.5-1
NUHOMS®-MP187 System Operations

APPENDIX A.6
WASTE CONFINEMENT AND MANAGEMENT
NUHOMS®-MP187 Cask System

Table of Contents

A.6. WASTE CONFINEMENT AND MANAGEMENT

No change or additional information required for the NUHOMS®-MP187 Cask System for Chapter 6.

APPENDIX A.7
STRUCTURAL EVALUATION
NUHOMS®-MP187 Cask System

Table of Contents

List of Tables

List of Figures

A.7. STRUCTURAL EVALUATION

This Appendix describes the structural evaluation of the NUHOMS®-MP187 Cask System components utilized for transfer and storage of canisterized spent nuclear fuel (SNF) and Greater Than Class C (GTCC) waste at the Waste Control Specialists, LLC (WCS) Consolidated Interim Storage Facility (CISF). As presented in Chapter 1, Table 1-1, the NUHOMS®-MP187 Cask System includes the FO-, FC-, FF- Dry Shielded Canisters (DSCs or canisters); GTCC waste canisters; and the HSM Model 80 storage overpack as the storage components, and the MP187 cask as the on-site cask for handling and transfer operations. The canisters and the MP187 cask are described in detail in Section 4.2, Volume I of the Rancho Seco Independent Spent Fuel Storage Installation Final Safety Analysis Report (ISFSI FSAR) [A.7-4]. The HSM Model 80 is described in detail in Section 4.2.3.2 of the Standardized NUHOMS® Updated Final Safety Analysis Report (UFSAR) [A.7-3]. All three components are NRC-approved [A.7-1] [A.7-6] for SNF and GTCC waste canister transfer and storage under the requirements of 10 CFR Part 72. This appendix is prepared to demonstrate that these licensed NUHOMS®-MP187 Cask System components are also qualified to safely transfer and store canisterized SNF and GTCC waste that is currently in storage at the Rancho Seco ISFSI at the WCS CISF in accordance with the requirements of 10 CFR Part 72.

The evaluation of the MP187 cask as the on-site transfer cask is contained in Volume I and Volume III of [A.7-4]. The evaluation of the canisters is contained in Volume I and Volume II of [A.7-4]. The evaluation of the HSM Model 80 is contained in Chapter 8 of [A.7-3].

Except for the seismic reconciliation evaluation presented in Section A.7.5, *and the qualification of the canister confinement boundaries during Normal Conditions of Transport in Section A.7.7,* no new structural analyses are presented in this appendix. This appendix demonstrates that (with the exception of the seismic reconciliation evaluation) the structural evaluations contained in [A.7-4] and, as applicable, in [A.7-3] are bounding for the WCS CISF.

A.7.1 Discussion

As discussed in Chapter 1.0, the canisters from the Rancho Seco ISFSI will be transported to the WCS CISF in the NUHOMS®-MP187 Multi-Purpose Cask, licensed under NRC Certificate of Compliance 9255 [A.7-2]. At the WCS CISF, the canisters are to be stored inside the Standardized NUHOMS® HSM Model 80. The canisters, licensed for storage at the Rancho Seco ISFSI under NRC SNM-2510 [A.7-1], are described in Section 4.2.5.2 of Volume I of [A.7-4]. The HSM Model 80, licensed under NRC Certificate of Compliance 1004 [A.7-6], is described in Section 4.2.3.2 of [A.7-3]. The MP187 cask is to be used for on-site transfer and handling operations at the WCS CISF. The MP187 cask, licensed for on-site transfer at the Rancho Seco ISFSI under NRC SNM-2510 [A.7-1], is described in Section 4.2.5.3 of Volume I of [A.7-4].

As stated in Section 1.2 of Volume I of [A.7-4], the canisters are stored within the HSMs installed at the Rancho Seco ISFSI. The HSM design for the Rancho Seco ISFSI is based on the HSM design as described in the Standardized NUHOMS® UFSAR, Revision 4A. *Appendix B of [A.7-4] contains the applicable page from the Standardized NUHOMS® UFSAR Revision 4A, as listed on the Appendix B list of pages. Appendix B of [A.7-4] is henceforth cited as [A.7-5].* A subsequent revision of the Standardized NUHOMS® UFSAR implemented certain design modifications to the HSM; and the revised HSM configuration was eventually designated as the HSM Model 80. See Section 1.3.1.2 of [A.7-3]. The main design modifications implemented in included:

1) the steel cask docking ring flange is eliminated so that the cask docking flange is formed in concrete during casting of the base unit,
2) the support rail extension plate anchorage is modified to eliminate field welding, and,
3) a drop-in tube steel is used as the axial retainer, so that the door is no longer in the load path for axial restraint of the canister.

These modifications were shown not to have an adverse effect on the intended safety functions of the HSM. Therefore, the Rancho Seco ISFSI HSMs and the HSM Model 80 are equivalent and can be substituted at the WCS CISF without affecting the licensing basis of the canisters as contained in [A.7-4].

The MP187 cask is a multi-purpose cask designed and evaluated as a transfer cask for use in loading HSMs under 10 CFR Part 72 [A.7-1] [A.7-4] and as a transportation cask for off-site shipments under the provisions of 10 CFR Part 71 [A.7-2] [A.7-7]. The evaluation of the MP187 cask as a transfer cask is based on Revision 13 of drawing NUH-05-4001 (Cask Main Assembly) and Revision 8 of NUH-05-4003 (Cask On-Site Transfer Arrangement), as shown in Volume IV of [A.7-4]. The current revision of NUH-05-4001 is Revision 15 as shown in Section 1.3.2 of [A.7-7]. There are no significant design differences in the cask main assembly configuration between these two revisions.

Furthermore, as described in Chapter 3 the design criteria for the Rancho Seco ISFSI envelops the design criteria for the WCS CISF, except for the site-specific seismic criteria, which are reconciled in Section A.7.5. Therefore, the 10CFR Part 72 evaluations of the MP187 cask performed in [A.7-4] are applicable and the current configuration of the MP187 cask is acceptable for use as a transfer cask at the WCS CISF.

Finally, bounding evaluations in Section A.7.7 are performed to demonstrate that the confinement boundaries for the FO-, FC-, FF-DSCs do not exceed ASME B&PV Subsection NB Article NB-3200 (Level A allowables) during normal conditions of transport to provide reasonable assurance that the confinement boundary is not adversely impacted by transport to the WCS CISF.

A.7.2 Summary of Mechanical Properties of Materials

As described in Sections 1.2.1 and 1.2.2 of Volume I of [A.7-4], the Rancho Seco canisters and HSM designs are based on the Standardized NUHOMS® design for the 24P DSC*, which is discussed in Appendix B of the Rancho Seco FSAR* [A.7-5], with modifications made to the basket design to qualify the Rancho Seco canisters for off-site transport. Per Section 8.1.1.3 of Volume I of [A.7-4], the mechanical properties of materials of construction for the canisters and the HSMs at the Rancho Seco ISFSI are the same as those presented in Table 8.1-3 of *Appendix B of the Rancho Seco FSAR* [A.7-5]. Mechanical properties for the MP187 cask are provided in Section 2.3 of [A.7-7].

The material specifications for the canisters and the MP187 cask are provided in the drawings contained in Volume IV of [A.7-4]. Material properties of the Standardized NUHOMS® HSM Model 80 are presented in Table 8.1-3 of [A.7-3]. Material specifications for the HSM Model 80 are provided in the HSM drawings contained in Appendix E.2 of [A.7-3].

A.7.3 Structural Analysis of MP187 Cask with a Canister (Transfer Configuration)

Section 3.2 of Volume I of [A.7-4] presents the structural design criteria for the canisters and the MP187 cask. Table 3-3 and Table 3-4 of Volume I of [A.7-4] summarize the design loading criteria for the canisters and the MP187 cask, respectively. As described in Section 3.2.5.2 of Volume I of [A.7-4], the canisters are designed to meet the stress intensity allowables of the ASME Boiler and Pressure Vessel Code (1992 Code, 1993 Addendum) Section III, Division I, Subsections NB, NF, and NG for Class I components and supports. As described in Section 3.2.5.3 of Volume I, the MP187 cask is designed to meet the stress intensity allowables of the ASME Code, Subsection NB for structural or shell components and Subsection NF for the neutron shield jacket assembly.

Table 3-6 of Volume I of [A.7-4] presents the load combinations for the canisters according to the ASME B&PV Code Service Levels A, B, C, and D, while Table 3-7 of Volume I of [A.7-4] presents pertinent ASME Code stress allowables criteria.

Table 3-8 of Volume I of [A.7-4] presents the load combinations for the MP187 cask according to the ASME B&PV Code Service Levels A, B, C, and D, while Table 3-9 of Volume I of [A.7-4] presents pertinent ASME Code stress allowables criteria.

The following sections are a summary of the structural analyses.

A.7.3.1 Normal and Off-Normal Conditions

The structural analysis of the MP187 cask and the canisters for normal and off-normal operating conditions during transfer operations are discussed in Section 8.1 of Volume I of [A.7-4]. Table 8-1 of Volume I of [A.7-4] presents a summary of the normal and off-normal load types applicable to each component.

Normal loads include: (1) dead weight loads (Section 8.1.1.1), (2) design basis internal pressure loads (Section 8.1.1.2), (3) design basis thermal loads (Section 8.1.1.3), (4) normal operational handling loads (Section 8.1.1.4) and (5) design basis live loads (Section 8.1.1.6). Off-normal loads include off-normal handling (Section 8.1.1.5), and off-normal temperature and pressure loads. Normal and off-normal loads that are unique to the HSM storage mode of operations are addressed in Volume II, Chapter 8. (All section references in this paragraph are to [A.7-4]).

Linear elastic static analysis of the MP187 cask and the canisters are performed using finite element models using the ANSYS program. Stresses for the critical lift loads of the MP187 cask trunnions, trunnion sleeves, trunnion attachment bolts and trunnion sleeve/cask outer shell welds are determined using hand calculations. Stress results for normal and off-normal conditions are summarized in Volume I of [A.7-4], Table 8-3 for the MP187 cask and in Table 8-4, Table 8-5, and Table 8-6 for the canisters, respectively. The stresses in the MP187 cask and the canister components are shown to meet the stress allowables criteria of the ASME Code.

A.7.3.2 Accident Conditions

The structural analysis of the MP187 cask and the canisters for postulated accidents during transfer operations are discussed in Section 8.2 of Volume I of [A.7-4]. Table 8-7 of Volume I of [A.7-4] presents a summary of the accident load types applicable to each component.

Postulated accident loads include: (1) accidental cask drop, (2) canister leakage, (3) accident pressurization, (4) earthquake, and (5) fire. In addition, Section 3.2 of Volume I of [A.7-4] discusses natural phenomena type loads, e.g. tornado wind loads and tornado-generated missiles, and flood loading.

Linear elastic or elastic-plastic equivalent static analyses are performed using finite element models using the ANSYS program. Accident condition stresses for the MP187 cask are summarized in Table 8-8 and for the canisters in Table 8-9, Table 8-10, and Table 8-11, respectively, of Volume I of [A.7-4].

Section 8.3 of Volume III of [A.7-4] presents results for the MP187 cask stability and stress analysis for tornado wind and tornado generated missiles. The stability analyses correspond to a hypothetical storage configuration of the cask (cask in vertical configuration). Section 8.2.4.3 of Volume I of [A.7-4] addresses the seismic stability of the MP187 cask during on-site transfer operations (the loaded cask is secured to the on-site transfer skid and trailer in the horizontal configuration) and determines that the results for the cask in the hypothetical storage mode (vertical configuration), as documented in Volume III, are bounding. Section B.7.8 presents an alternate evaluation of the MP187 cask in the transfer configuration at the WCS CISF.

A.7.3.3 Load Combinations (Volume I of [A.7-4])

MP187 Cask enveloping load combination results are summarized in Table 8-12, Table 8-13, and Table 8-14 for Service Level A and B (normal/off-normal conditions), Service Level C (accident conditions), and Service Level D (accident conditions), respectively.

FO- DSC enveloping load combination results are summarized in Table 8-15, Table 8-16, and Table 8-17 for Service Level A and B (normal/off-normal conditions), Service Level C (accident conditions), and Service Level D (accident conditions) of [A.7-4], respectively.

FC- DSC enveloping load combination results are summarized in Table 8-18, Table 8-19, and Table 8-20 for Service Level A and B (normal/off-normal conditions), Service Level C (accident conditions), and Service Level D (accident conditions) of [A.7-4], respectively.

FF- DSC enveloping load combination results are summarized in Table 8-21, Table 8-22, and Table 8-23 for Service Level A and B (normal/off-normal conditions), Service Level C (accident conditions), and Service Level D (accident conditions) of [A.7-4], respectively.

The GTCC waste canisters are bounded by the FO-DSC.

The results of the analyses show that adequate safety margins exist for all postulated accidents and natural phenomena events and that the stress criteria of the ASME Code are satisfied.

A.7.4 Structural Analysis of HSM Model 80 with a Canister (Storage Configuration)

As described in Section 3.2 of Volume I of [A.7-4], the canisters are designed by analysis to meet the stress intensity allowables of the ASME Boiler and Pressure Vessel Code (1992 Code, 1993 Addendum) Section III, Division I, Subsection NB, NF, and NG for Class I components and supports.

The canisters' design approach, design criteria and load combinations for storage in the HSM are discussed in Section 3.2.5.2 of Volume II of [A.7-4]. Table 3-5 of [A.7-4] summarizes the storage load combinations and ASME Code Service Levels for the canisters.

As stated in Volume II of [A.7-4], the Rancho Seco HSM design is similar to the Standardized NUHOMS® HSM design. As discussed in Section A.7.1 the Standardized NUHOMS® HSM design that formed the basis for the licensing of the Rancho Seco HSM*, which is discussed in Appendix B of the Rancho Seco FSAR* [A.7-5] was subsequently designated as the HSM Model 80 in [A.7-3]. The loads for the HSM concrete and DSC steel support structure shown in Table 3.2-1 of [A.7-3] are the same or bound the loads in Table 3-1 and Table 3-2 of Volume II of [A.7-4]. The HSM Model 80 is evaluated in [A.7-3] for canister weights that bound the bounding weight of 81.2 kips for the canisters. (e.g. the evaluation of the HSM Model 80 loaded with a 61BT DSC (weight of 88.39 kips, per Table K.3.2-1 of [A.7-3]) is presented in Sections K.3.7.3.4 and K.3.7.3.5 of [A.7-3]).

The design approach, design criteria, and loading combinations for the reinforced concrete HSM Model 80 and its DSC steel support structure are discussed in Section 3.2.5 of [A.7-3]. Table 3.2-5 and Table 3.2-8 of [A.7-3] provide the loads and load combinations for the HSM concrete and DSC steel support structure, respectively. These are the same as those shown in Volume II of [A.7-4], Table 3-4 and Table 3-6 and discussed in Section 3.2.5.1. Both the Rancho Seco HSM and the HSM Model 80 are designed in accordance with the requirements of the ACI "Code Requirements for Nuclear Safety Related Concrete Structures" ACI 349-85 (concrete) and the AISC "Specification for Structural Steel Buildings", Ninth Edition, 1989 (DSC steel support structure). Table 3.2-10 of [A.7-3] summarizes the design criteria for the DSC steel support steel structure. This is the same as presented in Table 3-8 of Volume II of [A.7-4].

The discussion above establishes that the HSM as described in Volume II of [A.7-4] and the HSM Model 80 as described in [A.7-3] have the same geometry and are based on the same design criteria. Furthermore, as discussed in Chapter 3, (with the exception of seismic loading criteria), the loading and structural design criteria for the Rancho Seco ISFSI and the Standardized NUHOMS® components bound the WCS CISF design requirements. The seismic load is reconciled in Section A.7.5.2 and Section A.7.5.3 for the canisters and the HSM Model 80, respectively. Therefore, the HSM Model 80 as described in [A.7-3] is acceptable for storage of the canisters at the WCS CISF.

The structural analyses of the canisters for normal, off-normal, and accident conditions during storage are presented in Sections 8.1.4, 8.2 and 8.3 of Volume II of [A.7-4], respectively. The structural analyses of the HSM Model 80 for normal and off-normal conditions are presented in Section 8.1, and for accident conditions in Section 8.2, of [A.7-3].

The following Sections are a summary of the structural analyses.

A.7.4.1 Normal and Off-Normal Conditions

Normal and off-normal loads that are unique to the HSM storage mode of operations are addressed in Volume II, Chapter 8 of [A.7-4]. Table 8-6 and Table 8-7 of Volume II of [A.7-4] present the normal and off-normal loads applicable to each component. For the HSM Model 80, similar tables are presented (Table 8.1-1 and Table 8.1-2) in [A.7-3].

Normal loads analyzed for the storage mode of operation include: (1) dead weight loads (Section 8.1.4.1), (2) design basis internal pressure loads (Section 8.1.4.2), (3) design basis thermal loads (Section 8.1.4.3), (4) operational handling loads (Section 8.1.4.4), and (5) design basis live loads (Section 8.1.4.5). Off-normal loads include off-normal handling, and off-normal temperature and pressure loads. (All section references in this paragraph are to [A.7-4]).

The structural analyses of the canisters for normal and off-normal operating conditions during storage operations are discussed in Sections 8.1.4 and 8.2 of Volume II of [A.7-4]. Results for normal and off-normal HSM storage conditions loads applicable to the canisters are summarized in Table 8-9, Table 8-10, and Table 8-11, respectively in Volume II of [A.7-4].

The structural analyses of the HSM Model 80 for normal and off-normal operating conditions are presented in Sections 8.1.1.4 through 8.1.1.7 and 8.1.2 (as applicable to the HSM Model 80) of [A.7-3]. Table 8.1-14 thru Table 8.1-19 of [A.7-3] present the structural analyses results for the HSM Model 80 for normal and off-normal conditions.

A.7.4.2 Accident Conditions

The structural analyses of the canisters for postulated accidents during storage operations are discussed in Section 8.3 of Volume II of [A.7-4]. Table 8-8 of Volume II of [A.7-4] presents the accident load types during storage applicable to each storage system component. The loads identification Table 8.2-1 in [A.7-3] identifies storage condition loadings applicable for the HSM Model 80.

Postulated accident loads include: (1) tornado winds and tornado generated missiles, (2) design basis earthquake, (3) design basis flood, (4) lightning effects, (5) debris blockage of HSM air inlet and outlet openings, (6) reduced HSM air inlet and outlet shielding, (7) snow and ice loads, and (8) fire and explosion.

Volume II, Section 8.3 of [A.7-4] states that the accident condition loadings for the canisters loaded in the Rancho Seco HSM are the same or bounded by the 24P DSC in the HSM*, as discussed in Appendix B of the Rancho Seco FSAR* [A.7-5].

The structural analyses of the HSM Model 80 for accident conditions are presented in Section 8.2 of [A.7-3]. Table 8.2-3 presents the structural analyses results for the HSM Model 80 for accident conditions.

The original HSM in *Appendix B of the Rancho Seco FSAR* [A.7-5] was subsequently designated as the HSM Model 80 in [A.7-3]. Thus, the results for the canisters in [A.7-4] and the HSM Model 80 in [A.7-3] are applicable, except for the seismic load evaluations. Seismic reconciliation evaluations as described in Section A.7.5 address the site-specific ground motion at WCS CISF.

A.7.4.3 Load Combinations

HSM Model 80 enveloping load combination results are summarized in Table 8.2-18, Table 8.2-19, and Table 8.2-20 of [A.7-3]. The stress results for the HSM Model 80 presented in Table 8.2-18, Table 8.2-19, and Table 8.2-20 are bounding when the HSM Model 80 is loaded with a canister.

The enveloping load combination results summarized in Table 8-15, Table 8-16, and Table 8-17 of Volume I of [A.7-4] bound the storage specific loads for the FO DSC and GTCC waste canister.

The enveloping load combination results summarized in Table 8-18, Table 8-19, and Table 8-20 of Volume I of [A.7-4] bound the storage specific loads for the FC DSC.

The enveloping load combination results summarized in Table 8-21, Table 8-22, and Table 8-23 of Volume I of [A.7-4] bound the storage specific loads for the FF DSC.

A.7.5 Seismic Reconciliation of the MP187 Cask, Canisters, and HSM Model 80

The site-specific seismic ground motion developed for the WCS CISF in the form of the 10,000-year return period uniform hazard response spectra for the horizontal and vertical directions are described in Chapter 2. A comparison of the site-specific response spectra for the WCS CISF ground motion and the Regulatory Guide 1.60 design-basis ground motions' response spectra are shown in Figure A.7-1 for 3%, 5%, and 7% damping values. This comparison indicates that for system frequencies above about 10 Hz (horizontal direction) and 9 Hz (vertical direction), the WCS CISF spectral accelerations are higher than the design basis spectral accelerations. The ZPA values of 0.25g (horizontal) and 0.175g (vertical) for the WCS CISF ground motion are essentially the same as those for the Rancho Seco IFSFI and the Standardized NUHOMS® System.

This section summarizes the stress reconciliation of the MP187 cask, the canisters, and the HSM Model 80 *using the enveloped acceleration spectra at the HSMs center of gravity (CG) and base derived from the WCS concrete pad soil-structure interaction (SSI) analysis.*

A.7.5.1 MP187 Cask

The MP187 cask is a multi-purpose cask, designed as a transfer cask for use in loading HSMs under the provisions of 10 CFR 72, and as a transportation cask for off-site shipment under the provisions of 10 CFR 71. Due to the cask's design to meet off-site shipping requirements, large factors of safety are afforded for on-site transfer operations.

As noted in Volume I, Section 1.2 and Volume III, Section 8 of [A.7-4], the MP187 cask was intended to be licensed under 10 CFR 72 for storage of a canister if required to recover from an off-normal event at the ISFSI. Although ultimately not licensed as a storage component, the fact that it was designed to meet the storage requirements under 10 CFR Part 72 provides the MP187 cask with additional uncredited safety margins.

As noted in Section 3.2.3 of Volume I of [A.7-4], based on the calculated cask structural frequencies of 17.9 (ovalling mode) and 83 Hz (beam mode), an amplification factor of 2.5 and a multimode factor of 1.5 are applied to the R.G. 1.60 ZPA acceleration of 0.25g (horizontal) and 0.17g (vertical). This resulted in equivalent static accelerations for the horizontal and vertical directions of 0.95g and 0.65g. The R.G. 1.60 response spectrum amplification for 2% damping at 17.9 Hz is 1.8 (a higher amplification factor of 2.5 was conservatively used in the design basis evaluation). Thus, the 0.95g used for the MP187 cask design basis seismic evaluation has margin to accommodate the increased spectral amplifications for the WCS CISF.

This factor is applied to the governing seismic stress in Table 8-8 of Volume I of [A.7-4]. As reported in Table 8-8 of Volume I of [A.7-4] the maximum seismic stress is 3.4 ksi. The load combination results are shown in Table 8-13 of Volume I. Per Note 2 of Table 8-13 the seismic load combinations C1 and C2 are enveloped into a bounding load combination C1/C2. The enveloping bounding load combination C1/C2 consists of deadweight stress (2.4 ksi from Table 8-3), normal handling (3.7 ksi from Table 8-3), accident pressure (0.5 ksi from Table 8-8), and seismic (3.4 ksi from Table 8-8). Table 8-13 shows that the controlling stress ratio is 0.42 and corresponds to the cask outer shell primary stress of 10 ksi. Using the above-calculated factor the seismic stress of 3.4 ksi is increased to *3.4x2.17 = 7.38 ksi.* Moreover, per Volume I, Section 8.2.3, accident pressure loads apply only for a hypothetical storage condition. When used as a transfer cask the MP187 cask is not required to hold pressure. Therefore, in this evaluation the 0.5 ksi accident pressure is removed from the load combination. The updated C1/C2 load combination now renders a total stress of *13.5* ksi, or a stress ratio of 0.*56*.

Furthermore, the maximum stress ratio in Table 8-13 is 0.81 and corresponds to a non-seismic load combination (C4). It is concluded that seismic load is not the controlling load at the WCS CISF and the bounding load stress margins for the MP187 cask, as documented in [A.7-4], remain unchanged.

A.7.5.2 Canisters

SSI analyses were performed for the pad with high level waste storage units at the Andrews, TX waste storage facility site. These analyses are presented in Section 7.6.4. One of the purposes of the analyses was to determine the envelope of the acceleration response spectra at the HSM center of gravity. The +/-15% peak-broadened HSM CG response spectra for damping values of 7%, 3%, and 2% are shown in Figures D.7-7 through D.7-9.

Based on NRC Reg. Guide 1.61 [A.7-8], a damping value of three percent is used for the DSC seismic analysis. The resulting stresses in the DSC shell due to the vertical and horizontal seismic loads are determined and reconciled with the original seismic analysis for the individual DSCs.

DSC Natural Frequency Calculation

ANSYS [A.7-9] finite element analyses are used to determine the natural frequencies of the DSCs. Since the FC and FF DSCs have ASTM B29 Lead in the shield plug assemblies a bounding model is developed to envelop the critical dimensions of the DSCs. Similarly FO, 61BT, and 61BTH Type 1 DSCs have steel shield plugs a bounding model is developed to envelop the critical dimensions of the DSCs. These critical dimensions and the dimensions used in the bounding model are summarized in Table A.7-1 and Table A.7-2.

Since a half symmetry model is used, symmetry boundary conditions were applied on the symmetry surface. Furthermore, the DSC was restrained radially along two lines of nodes at the outer diameter; at plane of symmetry and at 0.61 inch, which is less than the half-rail width. All nodes on the outer surface of outer top cover plate and DSC shell within the axial retainer area (3 inch x 2.44 inch) are also restrained in the axial direction. The boundary conditions are shown in Figure A.7-2.

Two different analyses are performed to encompass the directional loading of the basket and spent fuel assemblies. The first analysis is performed where the basket and spent fuel assemblies mass is lumped on the bottom of the top shield plug. This analysis simulates the axial direction seismic load. In the second analysis, the basket and spent fuel assemblies mass is lumped on the DSC shell inner surface. This analysis simulates the vertical and lateral direction seismic load.

The lowest mode for each model is shown in Figure A.7-3 and Figure A.7-4.

As shown in the modal analyses, the differences between all of the DSCs are minimal from the stiffness perspective. The 61BT and 61BTH Type 1 DSCs were shown to be stable when loaded in the HSM-HS [A.7-3]. The stability was shown by performing non-linear time-history analysis [Section U.3.7.2.1 of A.7-3]. The angle of the rail is at 30 degrees for both HSM-HS and HSM-80/102. Due to the same rail angle and a bounding spectra analysis, it is concluded that the DSCs will remain stable on the HSM rails.

Per Section 8.2.4.3 in Volume I and Section 8.3.2.2 in Volume II of [A.7-4] the canister shell components are evaluated for seismic loading of 3.0g and 1.0g for the horizontal and vertical directions, respectively. The basket components (spacer disc, support rods) are evaluated for 1.5g and 1.0g for the horizontal and vertical directions, respectively.

The seismic evaluation shows that the seismic accelerations used in the original seismic evaluations of the DSCs bound the seismic demand accelerations from the WCS CISF site-specific loading.

A.7.5.3 HSM Model 80

The seismic reconciliation of the HSM Model 80 is described in D.7.3.1.

A.7.6 Thermal Stress Reconciliation of the MP187 Cask System Components

From Chapter 1, the maximum ambient temperatures at the WCS CISF are *81.5*°F, *113*°F and *113*°F for normal, off-normal, and accident conditions. Based on the discussion in Chapter 8, the corresponding 24-hour daily average temperatures of 95°F and 105°F for normal and off-normal conditions, respectively are justified for use in the structural reconciliation evaluations for the WCS CISF.

The lowest off-normal ambient temperature at the WCS CISF is *30.1*°F. This is *above* the -20°F minimum temperature used in [A.7-4] and is bounded by the -40°F in [A.7-3].

A.7.6.1 Reconciliation of WCS CISF Environmental Ambient Conditions with Environmental Ambient Conditions in the Standardized NUHOMS® UFSAR

The HSM Model 80 structural analysis is performed for normal ambient temperature of 100°F and off-normal maximum temperature of 125°F, respectively in Section 8.1.1.5 of [A.7-3]. These temperatures bound the daily average ambient temperatures of *81.5*°F and 105°F used for normal and off-normal conditions, respectively at the WCS CISF. The lowest off-normal ambient temperature at the WCS CISF is *30.1*°F, which is bounded by the -40°F used in [A.7-3].

Table 8.1-17 of [A.7-3] show the temperatures in the HSM Model 80 resulting from the heat transfer analysis of the HSM Model 80 loaded with a 24kW heat load canister for the various design basis ambient thermal conditions. These temperatures are used for the thermal stress analyses.

Therefore, the maximum temperatures and thermal stress evaluation results reported in [A.7-3] for the HSM Model 80 remain bounding for the WCS CISF.

A.7.6.2 Reconciliation of WCS CISF Environmental Ambient Conditions with Environmental Ambient Conditions in the Rancho Seco ISFSI FSAR

As documented in Section 8.1.1.1 of Volume II of [A.7-4], a maximum ambient temperature of 101°F, 117°F and 117°F are used for normal, off-normal and accident conditions, respectively. These temperatures bound the daily average ambient temperatures of 95°F, 105°F and 105°F for normal, off-normal and accident conditions, respectively used at the WCS CISF. The lowest off-normal ambient temperature at the WCS CISF is *30.1*°F, which is the same as that at the Rancho Seco ISFSI site.

Therefore, the maximum temperatures and thermal stress evaluation results reported in [A.7-4] for the MP187 cask loaded with a canister remain bounding for the WCS CISF.

Section A.8.4 and A.8.5 present additional discussions on the thermal analysis basis for the transfer and storage of canisters at the WCS CISF using the MP187 cask and the HSM Model 80.

A.7.7 Structural Evaluation of Canister Confinement Boundary under Normal Conditions of Transport

The FO-, FC- and FF- DSCs shell assemblies each consist of a cylindrical shell, top outer/inner cover plates, bottom inner/outer cover plates and bottom and top shield plugs. Each canister consists of a shell which is a welded, stainless steel cylinder with a stainless steel bottom closure assembly, and a stainless steel top closure assembly. Additional details, geometry and shell and plate thicknesses are provided on the drawings in Section A.4.6. The confinement boundaries are addressed in Section A.11.1. The FC- and FF-DSC shells are evaluated for Normal Conditions of Transport in the MP187 Transport cask in Section A.7.7.1 and the FO-DSC and 24PT1 DSC of the Standardized Advanced NUHOMS® System shells are evaluated in Section A.7.7.2.

A.7.7.1 Evaluation of FC- and FF-DSC Shells

A.7.7.1.1 Assumptions

1. *Smaller components of the DSC, such as the siphon and vent block, keyways, and tapped holes in the shield plugs and in the inner top and bottom cover plates are not modeled due to negligible impact on the stiffness of the assembly and stresses.*

2. *A Single FE Model is used for analyzing both FC- and FF- DSCs with enveloping dimensions and loads.*

3. *The primary stresses evaluation assumes a uniform 400 °F temperature for all material components which conservatively bounds the actual temperatures, per reference [A.7-12].*

4. *Thermal Stress evaluation is not evaluated separately and the stress results presented in [A.7-13] are also applicable for this evaluation.*

5. *The guide sleeve evaluation performed in references [A.7-12] and [A.7-13] is still applicable for this calculation.*

6. *Enveloping DSC internal weight = 52,580 lbs per reference [A.7-14] is considered for the evaluation.*

7. *The NCT drop loads (25g) bound vibration loads which are on the order of a factor of 5 lower.*

A.7.7.1.2 Material Properties

Material properties are based on reference [A.7-11] for the material at 400 °F. Table A.7-5 provides material properties for SA-240 Type 304 Steel (18CR-8Ni). Table A.7-6 provides a summary of stress criteria for subsection NB pressure boundary components in the DSC shell and cover plates. Table A.7-8 provides allowable weld stresses for pressure boundary partial penetration welds, material Type 304. Table A.7-9 provides Level A/B allowable membrane, membrane plus bending, and combined membrane, bending and secondary stresses for the FC- and FF- DSCs.

A.7.7.1.3 Design Criteria

Structural design criteria for the FC- and FF-DSCs are based on ASME B&PV Code, Section III, Division 1, Subsection NB, 1992, including 1993 addenda and Appendix F.

A.7.7.1.4 Methodology

A single Finite Element Model (FEM) is used for analyzing both FC- and FF-DSCs with enveloping dimensions and loads. The DSC shell assembly is analyzed for the postulated load conditions using a three-dimensional (3D) 180° half-symmetric FEM. The most limiting dimensional properties between the FC- and FF-DSCs were modeled using reference [A.7-17]. References [A.7-15] and [A.7-16] provide the different dimensions of the DSCs along with the model dimensions used.

The resulting stresses in the DSC structural components are compared with the allowable stresses set forth by ASME B&PV Code, Section III, Subsection NB [A.7-11] for normal (Level A) conditions.

The stress due to each load is differentiated by the type of stress induced, e.g. membrane, bending, etc., and the classification of stress, e.g. primary, etc. In some locations, stresses are also differentiated based upon their proximity to a gross structural discontinuity, boundary condition, or their proximity to the confinement boundary.

There are two welds in the DSC confinement boundary. The first joins the DSC shell and the OTCP and the second joins the ITCP with the DSC shell. An allowable load/stress reduction factor of 0.6 (joint efficiency factor is used for the weld evaluation in this calculation. The allowable weld stresses are listed in Table A.7-8.

A.7.7.1.5 Design and Input Loads & Data

Load Combinations for the Canisters include vertical (top and bottom end) drops and side drops. Three load cases are performed for top end drop including: top end drop, top end drop with internal pressure (8 psi), and top end drop with external pressure (8 psi). The bottom end drop has the same pressure applied internally and externally to the DSC with loads applied the opposite end of the DSC. Side drop loads have both toward and away-from-rail load conditions with 8psi internal or external pressure applied to the DSC.

The following sections are a summary of the structural analyses.

A.7.7.1.5.1 Vertical Drop

A.7.7.1.5.1.1 Bottom End Drop

In addition to pressure representing the payload inertia load, conservative internal pressure of 8 psig and external pressure of 8 psig are added.

Three load cases are performed for bottom end drop:

1. *Bottom end drop*
2. *Bottom end drop with internal pressure (8 psi)*
3. *Bottom end drop with external pressure (8 psi)*

A.7.7.1.5.1.2 Top End Drop

Three load cases are performed for top end drop:

1. *Top end drop*
2. *Top end drop with internal pressure (8 psi)*
3. *Top end drop with external pressure (8 psi)*

A.7.7.1.5.2 Side Drop on Cask Rails

Three load cases are analyzed for the side drop onto the cask rail:

1. *Side drop onto the cask rail*
2. *Side drop onto the cask rail with internal pressure (8 psi)*
3. *Side drop onto the cask rail with external pressure (8 psi)*

A uniform pressure load is applied to the DSC inner surface at rail location. The inner nodes of the DSC are selected at 30° rail and a uniform pressure is applied.

For side drop load cases onto the two transfer cask rails, inertia loads for canister internals is accounted for by applying equivalent pressure onto the rail. The total load on first rail is calculated as shown below:

Cavity Length, $L = 160.0$ *in*

Total weight of canister internal to be used $W = 52580$ *lb (For 360° Model) (Assumption 6)*

Total Load on Rail:

Width of Rail = 4.00 in

*Area of first rail over which uniform pressure is applied = 4.0 in * 160 in = 640 in2*

*Uniform pressure over the first rail for 25g = 25*52580 / 2*640 = 1026.95 psi.*

A.7.7.1.5.3 Side Drop Away from Cask Rails

Three load cases are analyzed for side drop away from the cask rail

1. *Side drop away from the cask rail*
2. *Side drop away from the cask rail with internal pressure (8 psi)*
3. *Side drop away from the cask rail with external pressure (8 psi)*

For side drop load cases away from rails, inertia loads for canister internals is accounted for by applying a cosine varying pressure on the inside surface of the canister shell. Assuming that the canister internals react upon 90° arc of the inside surface, then the inertial load of the internals, P(θ), which varies with angle, θ, (θ = 0 is at the impact point), is governed by the following expression

$$P_{(\theta)} = P_{max}\cos(2\theta) \quad (0° < \theta < 45°)$$

Where P_{max} is the maximum pressure at the impact point (θ = 0). Assuming the axial length of the applied load is L, the inside radius of the canister shell is R, and the load distribution, P(θ) above, then the total inertial load generated by the internals, F, is the following:

$$F = \int_{\frac{-\pi}{4}}^{\frac{\pi}{4}} P_{\max}\cos(2\theta)\cos(\theta)LRd\theta$$

$$\Rightarrow \quad F = \frac{P_{\max}LR}{2}\int_{\frac{-\pi}{4}}^{\frac{\pi}{4}}[\cos((2+1)\theta)+\cos((2-1)\theta)]d\theta$$

By integrating the equation above, we get the following:

$$F = \left[\frac{P_{\max}LR}{2}\right]\left[\frac{\sin(3\theta)}{3}+\sin(\theta)\right]\Bigg|_{\frac{-\pi}{4}}^{\frac{\pi}{4}}$$

Therefore,

$$F = \left[\frac{P_{\max} LR}{2}\right]\left[\frac{\sin\left(\frac{3\pi}{4}\right)}{3} + \sin\left(\frac{\pi}{4}\right) - \frac{\sin\left(\frac{-3\pi}{4}\right)}{3} - \sin\left(\frac{-\pi}{4}\right)\right]$$

$$F = P_{\max} LR\left[\frac{\sin\left(\frac{3\pi}{4}\right)}{3} + \sin\left(\frac{\pi}{4}\right)\right]$$

The canister shell inner radius, R = 32.965 in. The axial length of the applied load (basket length), L = 160.0 in. Weight of canister internals (Basket Assembly + Fuel) is 52580 lb. (Assumption 6).

Side Drop NCT G Load = 25g.

$$F = 52{,}580 \times 25g = 1{,}314{,}500 \qquad [\text{for NCT}]$$

Therefore, Pmax for Normal Condition of Transport (NCT) is:

$$P_{\max} = \frac{1314500}{(160)(32.965)}\left[\frac{\sin\left(\frac{3\pi}{4}\right)}{3} + \sin\left(\frac{\pi}{4}\right)\right]^{-1} = 264.37\ \text{psi}$$

The equivalent pressure applied on the canister inside shell surface for load cases away from transfer cask rails is

$$P_{(\theta)} = 264.37\cos(2\theta)$$

θ = angle from the bottom (θ = 0) of the horizontal canister shell to the center of the shell element, up to 45°.

A.7.7.1.5.4 Load Combinations

A summary of load combinations examined for NCT conditions for the FC- and FF-DSCs is presented in Table A.7-3.

A.7.7.1.6 Stress Evaluation Results

Tables A.7-3 through A.7-9 and Figures A.7-7 through A.7-9 represent stress evaluations from the Vertical and Side Drop Cases for the FF and FC Canisters. Figure A.7-7 presents stress intensity plot for the FF and FC Canisters based on the most critical load case. For these canisters, the most critical load case for normal conditions of transport (NCT) is represented by the side drop away from rails with internal pressure shown in Figure A.7-7.

Figures A.7-8 and A.7-9 present the limiting weld stress intensities for the FF and FC Canisters. The limiting weld stress for the FF and FC Canisters for the Outer Top Cover Plate (Figure A.7-9) and the limiting weld stress for FF and FC Canisters for the Internal top cover plate (Figure A.7-8) is based on the side drop away-from-cask rails with internal pressure evaluation. For all analyzed load combinations, the worst-case stress results for each component of the DSC shell assembly along with the weld stresses are summarized in Table A.7-4.

The maximum component stress ratio is equal to 0.88 and occurs in the Cylindrical Shell for Side Drop away from the cask rails.

Results from the FC- and FF-DSCs structural analysis are acceptable for the loads and combinations described in Section A.7.7.1.5 and hence structurally adequate for normal conditions of transport loading conditions.

A.7.7.2 Structural Analysis of MP187 FO- and 24PT1 DSCs (Transport Configuration)

A.7.7.2.1 Assumptions

1. *Smaller components of the DSC, such as the siphon and vent block, keyways, and tapped holes in the shield plugs and in the inner top and bottom cover plates are not modeled due to negligible impact on the stiffness of the assembly and stresses.*

2. *The primary stresses evaluation assumes a uniform 400 °F temperature for all material components which conservatively bounds the actual temperatures, per reference [A.7-19].*

3. *Thermal Stress evaluation is not evaluated separately and the stress results presented in reference [A.7-19] are also applicable for this calculation.*

4. *The guide sleeve evaluation performed in references [A.7-18] and [A.7-19] is still applicable for this calculation.*

5. *Other assumptions pertaining to specific sections have been provided as and when required.*

6. *Enveloping DSC internal weight = 52,580 lbs per reference [A.7-14] is considered for the evaluation.*

7. The NCT drop loads (25g) bound vibration loads which are on the order of a factor of 5 lower.

A.7.7.2.2 Material Properties

Material properties are based on reference [A.7-11] for the material at 400 °F. Tables A.7-12 and A.7-13 provide properties for ASTM A-240 Type 316 and SA-36, respectively. Table A.7-7 provides a summary of the stress criteria used to determine stress allowables for pressure boundary components including the DSC shell and cover plates, while Table A.7-8 gives allowable weld stresses for pressure boundary partial penetration welds in the FO- and 24PT1 DSCs.

A.7.7.2.3 Design Criteria

Structural design criteria for the FO-DSC is based on ASME B&PV Code, Section III, Division 1, Subsection NB, 1992, including 1993 addenda and Appendix F. Structural design criteria for the 24PT1 DSC is based on ASME B&PV Code, Section III, Division 1, Subsection NB, 1992, including 1994 addenda and Appendix F. For the purposes of the evaluation of the DSC shells for Normal Conditions of Transport, the information taken from the 1992 and either addenda are identical, therefore only the N 1992, including 1993 addenda code years are referenced throughout this evaluation.

A.7.7.2.4 Methodology

A single Finite Element Model (FEM) is used for analyzing both FO- and 24PT1 DSCs with enveloping dimensions and loads. The WCS DSC shell assembly is analyzed for the postulated load conditions using a three-dimensional (3D) 180° half-symmetric FEM. The FEM is developed using the nominal dimensions from Table A.7-10.The most limiting dimensional properties between the FO and 24PT1 DSCs were modeled using reference [A.7-17]. Table A.7-10 and references [A.7-15] and [A.7-21] provide the different dimensions of the DSCs along with the model dimensions used.

The resulting stresses in the DSC structural components are compared with the allowable stresses set forth by ASME B&PV Code, Section III, Subsection NB [A.7-11] for normal (Level A) conditions.

The stress due to each load is differentiated by the type of stress induced, e.g. membrane, bending, etc., and the classification of stress, e.g. primary, etc. In some locations, stresses are also differentiated based upon their proximity to a gross structural discontinuity, boundary condition, or their proximity to the confinement boundary.

There are two welds in the DSC confinement boundary. The first joins the DSC shell and the OTCP and the second joins the ITCP with the DSC shell. An allowable load/stress reduction factor of 0.6 (joint efficiency factor is used for the weld evaluation in this calculation. The allowable weld stresses are listed in Table A.7-8.

A.7.7.2.5 Design and Input Loads & Data

The following represent design and input loads for the FO- and 24PT1 DSCs:

A.7.7.2.5.1 Vertical Drop

Load Combinations for the Canisters include Vertical drops. Three load cases are performed for bottom end, top, and side drop.

In addition to pressure representing the payload inertia load, conservative internal pressure of 10.5 psig or external pressure of 8 psig are added

A.7.7.2.5.1.1 Bottom End Drop

Three load cases are performed for bottom end drop:

1. *Bottom end drop*
2. *Bottom end drop with internal pressure (10.5 psi)*
3. *Bottom end drop with external pressure (8 psi)*

A.7.7.2.5.1.2 Top End Drop

Three load cases are performed for top end drop:

1. *Top end drop*
2. *Top end drop with internal pressure (10.5 psi)*
3. *Top end drop with external pressure (8 psi)*

A.7.7.2.5.2 Side Drop on Cask Rails

Three load cases are analyzed for the side drop onto the cask rail:

1. *Side drop onto the cask rail*
2. *Side drop onto the cask rail with internal pressure (10.5 psi)*
3. *Side drop onto the cask rail with external pressure (8 psi)*

For side drop load cases onto the cask rail, inertia loads for canister internals is accounted for by applying equivalent pressure onto the rail only. The total load on rail is calculated as shown below:

Width of Rail w = 4 in [A.7-20]

Cavity Length, l = 160 in

Total weight of canister internal to be used *W = 52,580 lb (For 360° Model)*

*Area of rail over which uniform pressure is applied = 4 in * 160 in = 640 in*^{2}

*Uniform pressure over the rail P = W / (2*640) = 41.078 psi.*

P= 41.078 x 25g = 1026.95 psi *[For NCT at 25g]*

A.7.7.2.5.3 Side Drop Away from Cask Rails

Three load cases are analyzed for side drop away from the cask rail

1. *Side drop away from the cask rail*
2. *Side drop away from the cask rail with internal pressure (10.5 psi)*
3. *Side drop away from the cask rail with external pressure (8 psi)*

For side drop load cases away from transfer cask rails, inertia loads for canister internals is accounted for by applying a cosine varying pressure on the inside surface of the canister shell. Assuming that the canister internals react upon 90° arc of the inside surface, then the inertial load of the internals, P(θ), which varies with angle, θ, (θ = 0 is at the impact point), is governed by the following expression:

$$P_{(\theta)} = P_{max} \cos(2\theta) \quad (0° < \theta < 45°)$$

Where P_{max} *is the maximum pressure at the impact point (θ = 0). Assuming the axial length of the applied load is L, the inside radius of the canister shell is R, and the load distribution, P(θ) above, then the total inertial load generated by the internals, F, is the following:*

$$F = \int_{\frac{-\pi}{4}}^{\frac{\pi}{4}} P_{\max} \cos(2\theta)\cos(\theta) LR d\theta$$

$$\Rightarrow \quad F = \frac{P_{\max} LR}{2} \int_{\frac{-\pi}{4}}^{\frac{\pi}{4}} [\cos((2+1)\theta) + \cos((2-1)\theta)] d\theta$$

By integrating the equation above we get the following.

$$F = \left[\frac{P_{\max} LR}{2}\right]\left[\frac{\sin(3\theta)}{3} + \sin(\theta)\right]\Bigg|_{\frac{-\pi}{4}}^{\frac{\pi}{4}}$$

Therefore,

$$F = \left[\frac{P_{\max} LR}{2}\right]\left[\frac{\sin\left(\frac{3\pi}{4}\right)}{3} + \sin\left(\frac{\pi}{4}\right) - \frac{\sin\left(\frac{-3\pi}{4}\right)}{3} - \sin\left(\frac{-\pi}{4}\right)\right]$$

$$F = P_{\max} LR\left[\frac{\sin\left(\frac{3\pi}{4}\right)}{3} + \sin\left(\frac{\pi}{4}\right)\right]$$

The canister shell inner radius, R = 32.97 in. The axial length of the applied load (basket length), L = 160 in.

Weight of canister internals (Basket Assembly + Fuel) for 24 PT1 Canister with long cavity is 52,580 lb. [A.7-14].

Side Drop NCT G Load = 25g.

$$F = 52{,}580 \times 25g = 1{,}314{,}500 \qquad [\text{for NCT}]$$

Therefore, P_{max} for Normal Condition of Transport (NCT) is:

$$P_{\max} = \frac{1314500}{(160)(32.97)}\left[\frac{\sin\left(\frac{3\pi}{4}\right)}{3} + \sin\left(\frac{\pi}{4}\right)\right]^{-1} = 264.26 \text{ psi}$$

The equivalent pressure applied on the canister inside shell surface for load cases away from transfer cask rails is:

$$P_{(\theta)} = 264.26 \cos(2\theta)$$

θ = angle from the bottom (θ = 0) of the horizontal canister shell to the center of the shell element, up to 45°.

A.7.7.2.5.4 Load Combinations

A summary of load combinations examined for NCT conditions for the FO- and 24PT1 DSCs is presented in Table A.7-3.

A.7.7.2.6 Stress Evaluation Results

Table A.7-3, A.7-4, A.7-7, A.7-8, A.7-10 through A.7-13 and Figures A.7-10 through A.7-12 represent stress evaluations from the Vertical and Side Drop Cases for the FO and 24PT1 Canisters. Figure A.7-10 presents stress intensity plot for the FO and 24PT1 Canisters based on the most critical load case. For these canisters, the most critical load case for normal conditions of transport (NCT) is represented by the side drop away from rails with internal pressure shown in Figure A.7-10.

Figures A.7-11 and A.7-12 show that the limiting weld stress for FO- and 24PT1 DSCs is at the Outer top cover plate based on the side drop away-from-cask rails with internal pressure. The limiting weld stress for the FO- and 24PT1 DSCs for the Outer Top cover Plate is shown in Figure A.7-11 and the limiting weld stress for the FO- and 24PT1 DSCsfor the inner top cover plate is shown in Figure A.7-12. The limiting weld stress is based on side drop away-from –cask rails evaluation with internal pressure. . For all analyzed load combinations, stress results for each component of the DSC shell assembly along with the weld stresses are summarized in Table A.7-11.

The maximum component stress ratio is equal to 0.78 and occurs in the Cylindrical Shell for Side Drop away from rails. The maximum weld stress ratio is 0.96 for all conditions.

Result from the FO- and 24PT1 DSCs structural analysis are acceptable for the loads and combinations described in Table A.7-3 and hence structurally adequate for normal conditions of transport loading conditions.

A.7.8 Conclusions of the Structural Analysis

This appendix demonstrates that the HSM as described in Volume II of [A.7-4] and the HSM Model 80 as described in [A.7-3] have the same geometry and are based on the same design criteria; i.e. they are essentially identical.

Furthermore, the design requirements and environmental conditions that form the design basis upon which the MP187 cask, the canisters, and the HSM Model 80 were licensed by the NRC bound the design requirements and environmental conditions at the WCS CISF. Therefore, the HSM Model 80 as described in [A.7-3] is acceptable for storage of the canisters at the WCS CISF.

The structural performance of the MP187 cask with canisters *(Conditions of Storage)* at the WCS CISF, evaluated under normal, off-normal, and accident conditions of operation, satisfies all of the 10 CFR Part 72 stress limits and criteria.

Finally, the structural performance of the canister confinement boundaries were evaluated for Normal Conditions of Transport against ASME B&PV Code Subsection NB Article NB-3200 (Level A allowables) and were found to satisfy all of the stress limits and criteria demonstrating that the confinement boundaries are not adversely impacted by transportation of the canisters to the WCS CISF in the MP187 transport cask.

A.7.9 References

A.7-1 U.S. Nuclear Regulatory Commission, "License for Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste," License Number SNM-2510, Docket Number 72-11.

A.7-2 U.S. Nuclear Regulatory Commission, "Certificate of Compliance No. 9255, Revision 12 for the Model No. NUHOMS®-MP187 Multi-Purpose Cask (Docket 71-9255).

A.7-3 AREVA TN Document NUH-003, Revision 14, "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel." (Basis for NRC CoC 72-1004).

A.7-4 "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report," NRC Docket No. 72-11, Revision 4.

A.7-5 *Appendix B to "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report," NRC Docket No. 72-11, Revision 4.*

A.7-6 U.S. Nuclear Regulatory Commission, "Certificate of Compliance for Spent Fuel Storage Casks," Certificate No. 1004, Docket 72-1004, Amendment 13 for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel.

A.7-7 AREVA TN Document NUH-05-151 Rev. 17, "NUHOMS®-MP187 Multi-Purpose Transportation Package Safety Analysis Report." (Basis for NRC CoC 71-9255).

A.7-8 *Regulatory Guide 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," U.S. Nuclear Regulatory Commission, Revision 1, March 2007.*

A.7-9 ANSYS Computer Code and User's Manual, Version 14.

A.7-10 Not Used.

A.7-11 ASME B&PV Code, Section III, Division 1, Subsection NB, 1992, including 1993 Addenda.

A.7-12 AREVA TN Document 2069.0201, Revision 0, "NUHOMS®-MP187 FC-DSC 10CFR72 Structural Analysis."

A.7-13 AREVA TN Document 2069.0205, Revision 0, "NUHOMS®-MP187 FF-DSC 10CFR72 Structural Analysis."

A.7-14 AREVA TN Document NUH005.0350, Revision 8, "Rancho Seco NUHOMS(R) Mass Properties Calculation."

A.7-15 AREVA TN Document NUH-05-4004, Revision 16, "NUHOMS FO-DSC and FC-DSC for PWR Fuel Main Assembly."

A.7-16 AREVA TN Document NUH-05-4005, Revision 14, "NUHOMS FF-DSC for PWR Fuel Main Assembly."

A.7-17 ANSYS Computer Code and Users Manual, Release 14.0.

A.7-18 AREVA TN Document, ANUH-01.0150, Revision 6, "Updated Final Safety Analysis Report for the Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, NRC Docket No. 72-1029.

A.7-19 AREVA TN Document 2069.0200, Revision 0, "*NUHOMS®-MP187 FO-DSC 10CFR72 Structural Analysis.*"

A.7-20 AREVA TN Document NUH-05-4001, Revision 15, "*NUHOMS MP-187 Multi-purpose Cask Main Assembly.*"

A.7-21 AREVA TN Document NUH-05-4010, Revision 5, "General License NUHOMS® 24PT1-DSC Main Assembly."

Table A.7-1
Summary of FC and FF DSC Dimensions

	FC	***FF***	***ANSYS Model***
Outer Top Cover Plate (in)	*1.25*	*1.25*	*1.25*
Inner Top Cover Plate (in)	*0.75*	*0.75*	*0.75*
Top Shield Plug Assembly (in)	*5.13*	*5.00*	*5.00*
Inner Bottom Cover Plate (in)	*0.75*	*0.75*	*0.75*
Bottom Shield Plug Assembly (in)	*5.25*	*5.25*	*5.25*
DSC Shell Outer Diameter (in)	*67.19*	*67.19*	*67.19*
DSC Shell Thickness (in)	*0.63*	*0.63*	*0.63*
Total Length (except grapple ring) (in)	*186.2*	*186.5*	*186.2*
Basket + Spent fuel assemblies weight (kips)	*58.31*	*52.10*	*60.00*

Table A.7-2
Summary of FO, 61BT, and 61BTH Type 1 Dimensions

	FO	***61BT***	***61BTH Type 1***	***ANSYS Model***
Outer Top Cover Plate (in)	*1.25*	*1.25*	*1.25*	*1.25*
Inner Top Cover Plate (in)	*0.75*	*0.75*	*0.75*	*0.75*
Top Shield Plug (in)	*8.25*	*7.00*	*7.00*	*7.00*
Inner Bottom Cover Plate (in)	*0.75*	*0.75*	*1.69*	*0.75*
Outer Bottom Cover Plate (in)	*1.75*	*1.75*	*1.70*	*1.75*
Bottom Shield Plug (in)	*6.25*	*5.00*	*4.00*	*5.00*
DSC Shell Outer Diameter (in)	*67.19*	*67.25*	*67.25*	*67.25*
DSC Shell Thickness (in)	*0.63*	*0.5*	*0.5*	*0.5*
Total Length (except grapple ring) (in)	*186.2*	*196.04*	*196.04*	*196.04*
Basket + Spent fuel assemblies weight (kips)	*55.20*	*65.9*	*66.4*	*70.00*

Table A.7-3
Load Cases for End/Side Drop Normal Condition of Transport (NCT)

Load Case Number	*Loading Condition*	*Service Level*	*Case Description*
1	*25g Lateral Load (Side Drop Away From Rails)*	*A*	*Horizontal cask, supported on side, 25g transverse acceleration. Impact away from transport cask rails.*
2	*25g Lateral Load + 8psi Internal Pressure (Side Drop Away From Rails with Internal Pressure)*	*A*	*Horizontal cask, supported on side, 25g transverse acceleration + 8 psi Internal Pressure. Impact away from transport cask rails.*
3	*25g Lateral Load + 8psi External Pressure (Side Drop Away From Rails with External Pressure)*	*A*	*Horizontal cask supported on side, 25g transverse acceleration + 8 psi External Pressure. Impact away from transport cask rails.*
4	*25g Lateral Load (Side Drop on Rails)*	*A*	*Horizontal cask, supported on side, 25g transverse acceleration. Impact onto the cask rails.*
5	*25g Lateral Load + 8psi Internal Pressure (Side Drop on Rails with Internal Pressure)*	*A*	*Horizontal cask supported on side, 25g transverse acceleration + 8 psi Internal Pressure. Impact onto the cask rails.*
6	*25g Lateral Load + 8psi External Pressure (Side Drop on Rails with External Pressure)*	*A*	*Horizontal cask supported on side, 25g transverse acceleration + 8 psi External Pressure. Impact onto the cask rails.*
7	*30g Vertical Load on Top End (Top End Drop)*	*A*	*Vertical cask, supported on top end, 30g axial acceleration. Impact onto the OTCP*
8	*30g Vertical Load on Top End + 8psi Internal Pressure (Top End Drop with Internal Pressure)*	*A*	*Vertical cask supported on top end, 30g axial acceleration + 8 psi Internal Pressure. Impact onto the OTCP*
9	*30g Vertical Load on Top End + 8psi External Pressure (Top End Drop with External Pressure)*	*A*	*Vertical cask supported on top end, 30g axial acceleration + 8 psi External Pressure. Impact onto the OTCP*
10	*30g Vertical Load on Bottom End (Bottom End Drop)*	*A*	*Vertical cask, supported on top end, 30g axial acceleration. Impact onto the BSP Assembly*
11	*30g Vertical Load on Bottom End + 8psi Internal Pressure (Bottom End Drop with Internal Pressure)*	*A*	*Vertical cask supported on top end, 30g axial acceleration + 8 psi Internal Pressure. Impact onto the BSP Assembly*
12	*30g Vertical Load on Bottom End + 8psi External Pressure (Bottom End Drop with External Pressure)*	*A*	*Vertical cask supported on top end, 30g axial acceleration + 8 psi External Pressure. Impact onto the BSP Assembly*

Table A.7-4
Stress Results FC- and FF-DSC – Stress Results Summary

Part. No	Component	Stress Category	BED (ksi)	TED (ksi)	SD (ksi)	Allowable Stress (ksi)	Max Stress Ratio
1	Cylindrical Shell	Pm	5.07	4.40	13.60	18.60	0.73
		PL + Pb	9.17	9.71	24.68	27.90	0.88
2	Outer Top Cover Plate	Pm	0.59	1.08	7.97	18.60	0.43
		PL + Pb	2.05	1.15	11.14	27.90	0.40
3	Inner Top Cover Plate	Pm	1.71	1.78	8.52	18.60	0.46
		PL + Pb	2.30	2.30	10.32	27.90	0.37
4	Inner Bottom Cover Plate	Pm	7.47	2.30	10.49	18.60	0.56
		PL + Pb	8.76	3.65	18.70	27.90	0.67
5	Cylindrical Shell - OTCP Weld	PL	3.01	1.16	15.70	16.74	0.94
		PL (Impact Zone)			19.95	33.48	0.60
6	Cylindrical Shell - ITCP Weld	PL	3.40	2.79	12.37	16.74	0.74
		PL (Impact Zone)			18.19	33.48	0.54

Table A.7-5
SA-240-304 Steel (18CR-8Ni) Material Properties

Temp. (°F)	*E Modulus of Elasticity (ksi)*	*S_m Allow. Stress Intensity (ksi)*	*S_y Yield Stress (ksi)*	*S_u Ultimate Tensile Strength (ksi)*	*α_{AVG} Coeff. of Thermal Expansion ($x\ 10^{-6}\ °F^{-1}$)*
70	28,300	20.0	30.0	75.0	8.5
100	----	20.0	30.0	75.0	8.6
200	27,600	20.0	25.0	71.0	8.9
300	27,000	20.0	22.4	66.2	9.2
400	26,500	18.6	20.7	64.0	9.5
500	25,800	17.5	19.4	63.4	9.7
600	25,300	16.6	18.4	63.4	9.8
700	24,800	15.8	17.6	63.4	10.0

Table A.7-6
SA-36 Carbon Steel Material Properties

Temp. (°F)	E Modulus of Elasticity (ksi)	S_m Allow. Stress Intensity (ksi)	S_y Yield Stress (ksi)	S_u Ultimate Tensile Strength (ksi)	α_{AVG} Coeff. of Thermal Expansion ($x\ 10^{-6}\ °F^{-1}$)
-100	30,200	----	----	----	----
-20	----	19.3	36.0	58.0	----
70	29,400	19.3	36.0	58.0	6.4
100	----	19.3	36.0	58.0	6.5
200	28,800	19.3	33.0	58.0	6.7
300	28,300	19.3	31.8	58.0	6.9
400	27,900	19.3	30.8	58.0	7.1
500	27,300	19.3	29.3	58.0	7.3
600	26,500	18.4	27.6	53.3	7.4
700	25,500	17.3	25.8	53.3	7.6

Table A.7-7
Summary of Stress Criteria for Subsection NB Pressure Boundary Components
DSC Shell and Cover Plates

Service Level	*Stress Category*	*References*	*Notes*
Design [NB-3221]	$P_m \leq 1.0S_m$ $P_L \leq 1.5S_m$ $P_m(or\ P_L) + P_b \leq 1.5S_m$ $F_p \leq 1.0S_y\ or\ 1.5S_y$ $\sigma_1 + \sigma_2 + \sigma_3 \leq 4S_m$ *External Pressure: NB-3133*	*NB-3221.1, NB-3221.2, NB-3221.3, NB-3227.1 and NB-3227.4*	*Note 2*
Level A [NB-3222]	$P_m \leq 1.0S_m$ $P_L \leq 1.5S_m$ $P_m(or\ P_L) + P_b \leq 1.5S_m$ $P_m(or\ P_L) + P_b + Q \leq 3.0S_m$ $F_p \leq 1.0S_y\ or\ 1.5S_y$ $\sigma_1 + \sigma_2 + \sigma_3 \leq 4S_m$ *External Pressure: NB-3133*	*NB-3222, NB-3227.1, & NB-3227.4*	*Notes 1 & 2*

Notes:

1. *The Level A limit of NB-3222.2 may be exceeded provided the criteria of NB-3228.5 are satisfied.*
2. *There are no specific limits on primary stresses for Level A events. However, the stresses due to primary loads during normal service must be computed and combined with the effects of other loadings in satisfying other limits. See NB-3222.1. The Code Design limits on primary stresses shall be used for Service Level A.*

Table A.7-8
Allowable Weld Stresses for Pressure Boundary Partial Penetration Welds, Material Type 304

Service Level	***Stress Region / Category***	***Stress Criteria***	***Allowable Stress Value at 400 °F (ksi)***
Pressure Boundary Partial Penetration Welds			
Level A / Level B	*Weld Stress away from Impact Zone*	*0.6 [1.5 Sm]*	*16.83*
	Weld Stress in local area near Impact Zone	*0.6 [3 Sm]*	*33.66*
Non-Pressure Boundary Partial Penetration and Fillet Welds			
Service Level	***Allowable Stress***		***Basis***
Level A	F_w=0.30S_u *(weld metal)* F_w=0.40S_y *(base metal)*		*Table NF-3324.5(a)-1*

Table A.7-9
SA-240 Type 304 - Stress Allowables

Temp (^oF)	*S_m (ksi)*	*S_y (ksi)*	*S_u (ksi)*	*Level A/B*		
				P_m	*$P_m + P_b$*	*$P_m + P_b + Q$*
70	*20.0*	*30.0*	*75.0*	*20.0*	*30.0*	*60.0*
200	*20.0*	*25.0*	*71.0*	*20.0*	*30.0*	*60.0*
300	*20.0*	*22.4*	*66.2*	*20.0*	*30.0*	*60.0*
400	*18.6*	*20.7*	*64.0*	*18.7*	*27.9*	*55.8*
500	*17.5*	*19.4*	*63.4*	*17.5*	*26.25*	*52.5*
600	*16.6*	*18.4*	*63.4*	*16.4*	*24.9*	*49.8*
700	*15.8*	*17.6*	*63.4*	*16.0*	*23.7*	*47.4*

Table A.7-10
Summary of FO- and 24PT1 DSC Dimensions

	FO	***24PT1***	***ANSYS Model***
Outer Top Cover Plate (in)	*1.25*	*1.37*	*1.25*
Inner Top Cover Plate (in)	*0.75*	*1.24*	*0.75*
Top Shield Plug (in)	*8.00*	*7.55*	*7.61*
Outer Bottom Cover Plate (in)	*1.75*	*1.87*	*1.75*
Inner Bottom Cover Plate (in)	*0.75*	*1.63*	*0.75*
Bottom Shield Plug (in)	*6.25*	*5.17*	*5.29*
DSC Shell Outer Diameter (in)	*67.19*	*67.19*	*67.19*
Cylindrical Shell Thickness (in)	*0.625*	*0.61*	*0.625*
Total Length (except grapple ring) (in)	*186.17*	*186.40*	*186.40*

Table A.7-11
Stress Results FO- and 24PT1 DSCs – Stress Results Summary

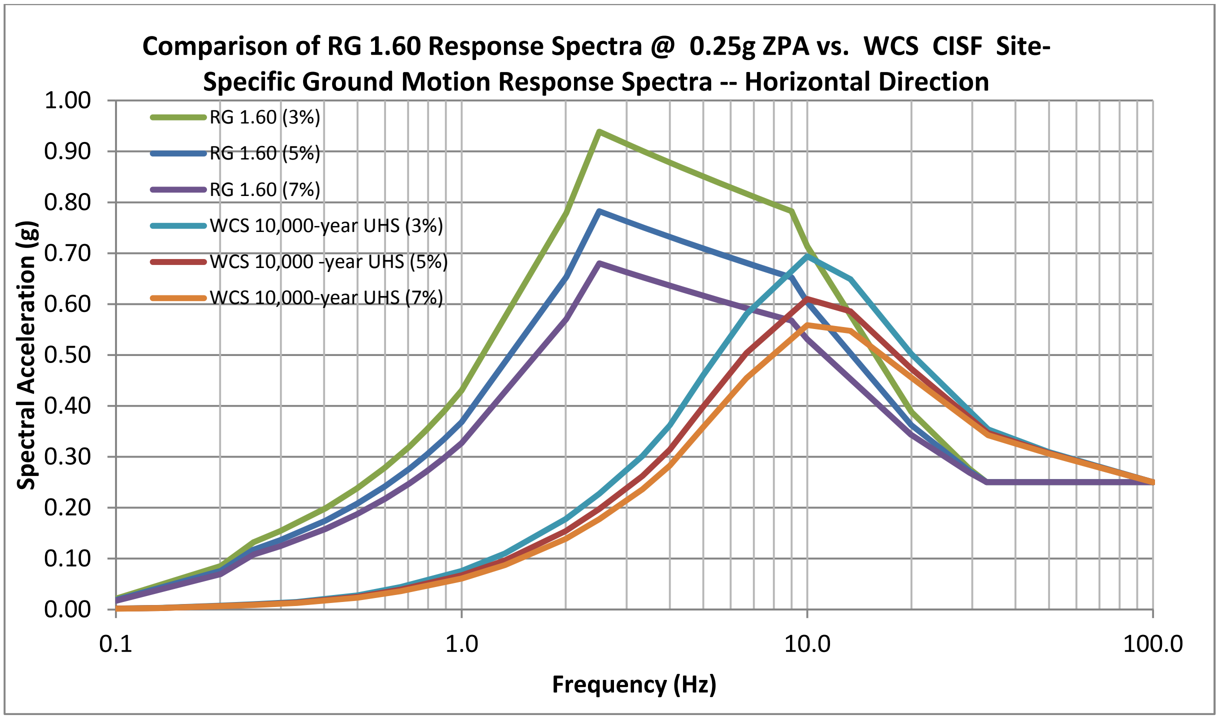
Sl. No	***Component***	***Stress Category***	***BED (ksi)***	***TED (ksi)***	***SD (ksi)***	***Allowable Stress (ksi)***	***Max Stress Ratio***
1	*Cylindrical Shell*	*Pm*	*4.10*	*4.04*	*13.09*	*19.3*	*0.68*
		PL	*NA*	*NA*	*19.83*	*28.95*	*0.68*
		Pm + Pb	*6.53*	*10.78*	*22.05*	*28.95*	*0.76*
2	*Outer Top Cover Plate*	*Pm*	*0.15*	*0.68*	*7.81*	*19.3*	*0.40*
		Pm + Pb	*0.49*	*0.69*	*12.79*	*28.95*	*0.44*
3	*Inner Top Cover Plate*	*Pm*	*0.18*	*0.72*	*8.32*	*19.3*	*0.43*
		Pm + Pb	*0.42*	*0.72*	*11.27*	*28.95*	*0.39*
4	*Outer Bottom Cover Plate*	*Pm*	*2.16*	*0.31*	*8.52*	*19.3*	*0.44*
		Pm + Pb	*2.63*	*1.32*	*14.46*	*28.95*	*0.50*
5	*Inner Bottom Cover Plate*	*Pm*	*0.78*	*1.37*	*14.39*	*19.3*	*0.75*
		Pm + Pb	*1.99*	*8.57*	*15.98*	*28.95*	*0.55*
6	*Grapple Support Plate*	*Pm*	*0.57*	*0.79*	*1.18*	*19.3*	*0.06*
		Pm + Pb	*1.31*	*1.79*	*1.90*	*28.95*	*0.07*
7	*Grapple Ring*	*Pm*	*0.07*	*0.10*	*1.27*	*19.3*	*0.07*
		Pm + Pb	*0.17*	*0.26*	*1.40*	*28.95*	*0.05*
8	*Support Ring*	*Pm*	*2.43*	*1.98*	*12.79*	*19.3*	*0.66*
		Pm + Pb	*4.20*	*3.57*	*22.63*	*28.95*	*0.78*
9	*Cylindrical Shell - OTCP Weld*	*PL (Away Impact Zone)*	*0.26*	*1.10*	*16.63*	*17.37*	*0.96*
		PL (Near Impact Zone)	*NA*	*NA*	*21.13*	*34.74*	*0.61*
10	*Cylindrical Shell - ITCP Weld*	*PL (Away Impact Zone)*	*0.94*	*0.63*	*11.53*	*17.37*	*0.66*
		PL (Near Impact Zone)	*NA*	*NA*	*18.15*	*34.74*	*0.52*
11	*Cylindrical Shell - OBCP Weld*	*PL (Away Impact Zone)*	*1.33*	*0.73*	*8.07*	*17.37*	*0.46*
		PL (Near Impact Zone)	*NA*	*NA*	*14.49*	*34.74*	*0.42*
12	*Cylindrical Shell - Support Ring Weld*	*PL*	*4.74*	*3.98*	*12.86*	*17.37*	*0.74*

Table A.7-12
SA-240/ SA-479/ ASTM A-240 Type 316 Steel (18Cr-8Ni) Material Properties

Temp. (°F)	***E Modulus of Elasticity (ksi)***	***S_m Allow. Stress Intensity (ksi)***	***S_y Yield Stress (ksi)***	***S_u Ultimate Tensile Strength (ksi)***	***α_{AVG} Coeff. of Thermal Expansion ($x\ 10^{-6}\ °F^{-1}$)***
-100	*29,100*	*----*	*----*	*----*	*----*
-20	*----*	*20.0*	*30.0*	*75.0*	*----*
70	*28,300*	*----*	*----*	*----*	*----*
100	*----*	*20.0*	*30.0*	*75.0*	*8.54*
200	*27,600*	*20.0*	*25.8*	*75.0*	*8.76*
300	*27,000*	*20.0*	*23.3*	*73.4*	*8.97*
400	*26,500*	*19.3*	*21.4*	*71.8*	*9.21*
500	*25,800*	*18.0*	*19.9*	*71.8*	*9.42*
600	*25,300*	*17.0*	*18.8*	*71.8*	*9.60*
700	*24,800*	*16.3*	*18.1*	*71.8*	*9.76*

Table A.7-13
SA-36 Carbon Steel Material Properties

Temp. (°F)	***E Modulus of Elasticity (ksi)***	***S_m Allow. Stress Intensity (ksi)***	***S_y Yield Stress (ksi)***	***S_u Ultimate Tensile Strength (ksi)***	***α_{AVG} Coeff. of Thermal Expansion ($x 10^{-6}$ °F^{-1})***
-100	*30,200*	*----*	*----*	*----*	*----*
-20	*----*	*19.3*	*36.0*	*58.0*	*----*
70	*29,400*	*19.3*	*36.0*	*58.0*	*6.4*
100	*----*	*19.3*	*36.0*	*58.0*	*6.5*
200	*28,800*	*19.3*	*33.0*	*58.0*	*6.7*
300	*28,300*	*19.3*	*31.8*	*58.0*	*6.9*
400	*27,900*	*19.3*	*30.8*	*58.0*	*7.1*
500	*27,300*	*19.3*	*29.3*	*58.0*	*7.3*
600	*26,500*	*18.4*	*27.6*	*53.3*	*7.4*
700	*25,500*	*17.3*	*25.8*	*53.3*	*7.6*



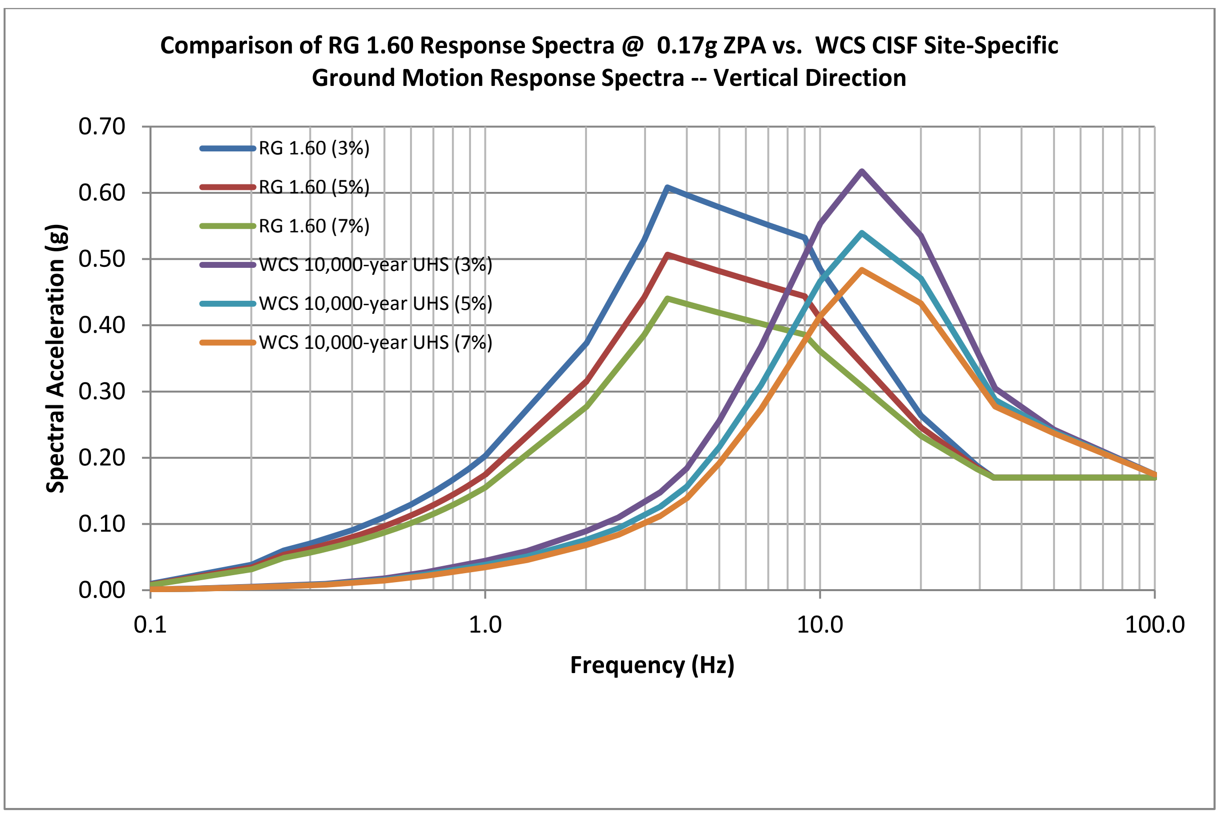


Figure A.7-1
Rancho Seco ISFSI FSAR and Standardized NUHOMS® UFSAR Design Basis Response Spectra (R.G. 1.60) vs. WCS CISF Site-Specific 10,000-year UHS

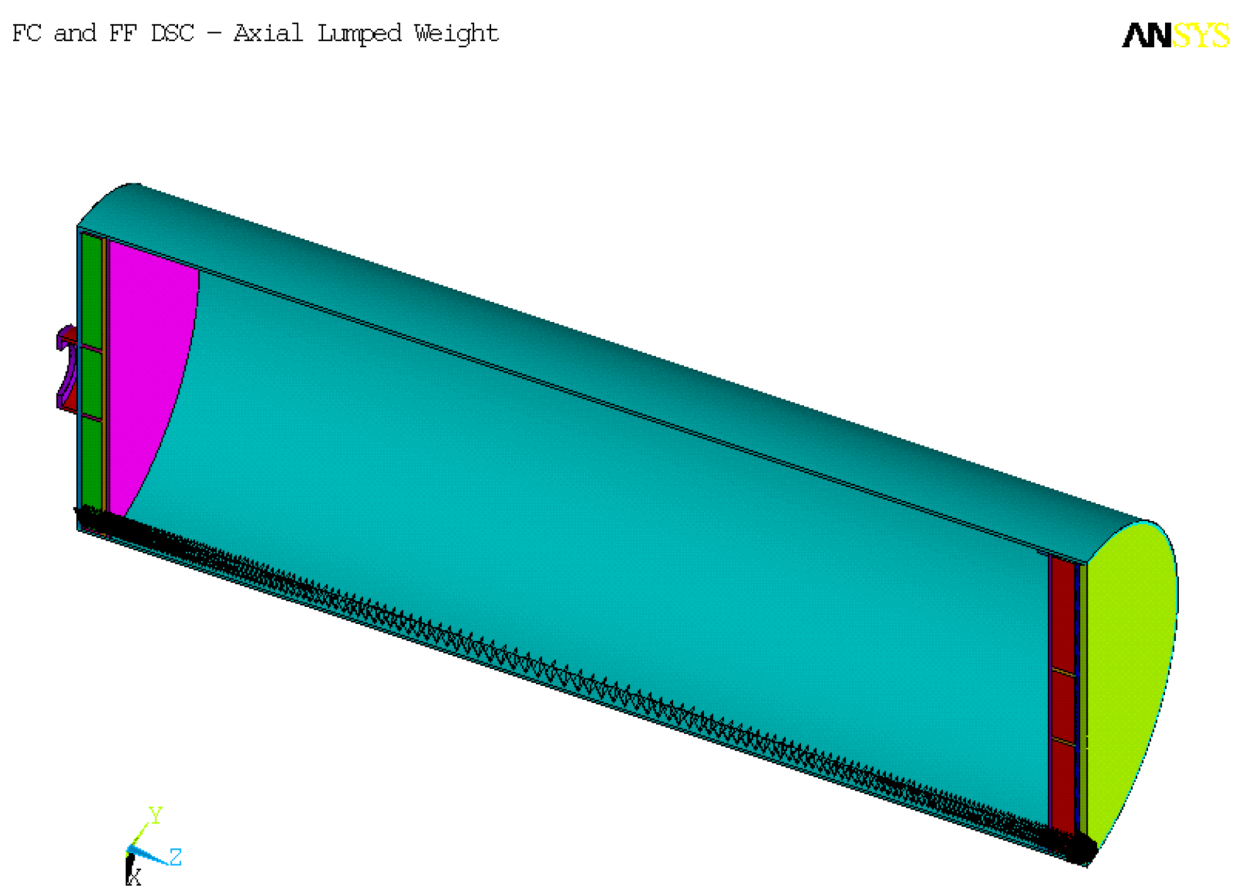


Figure A.7-2
DSC Models Boundary Conditions

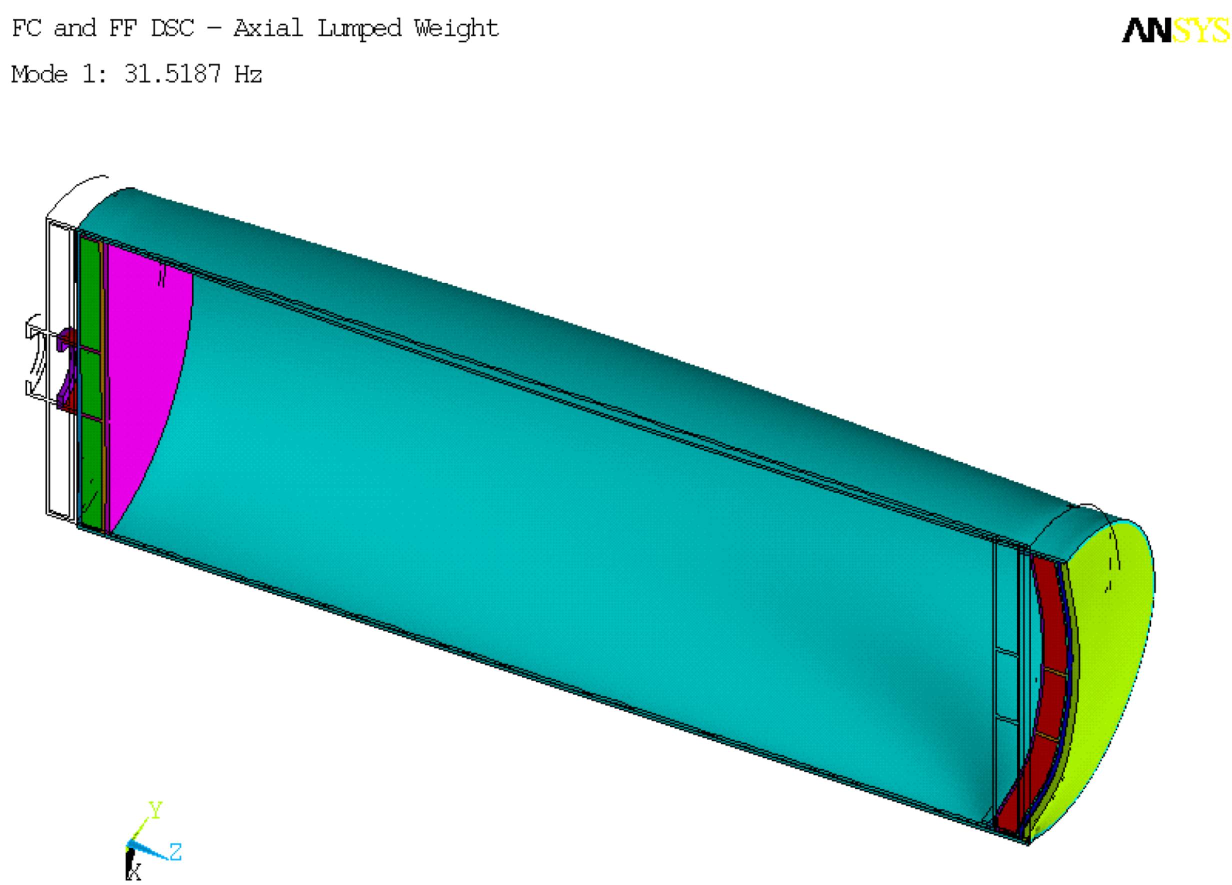


Figure A.7-3
FC and FF Axial Direction DSC Model – First Mode Shape

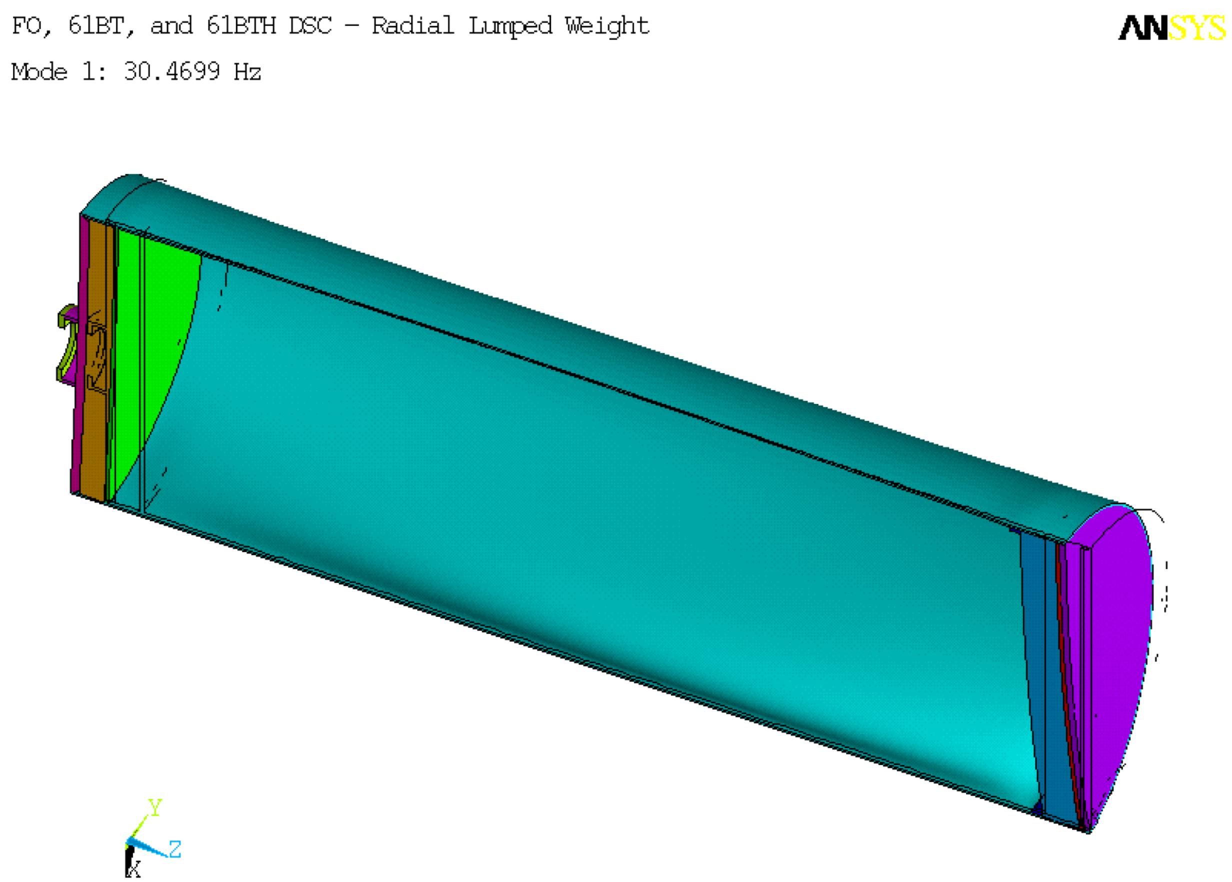


Figure A.7-4
FO, 61BT, and 61BTH Type 1 Radial Direction DSC Model – First Mode Shape

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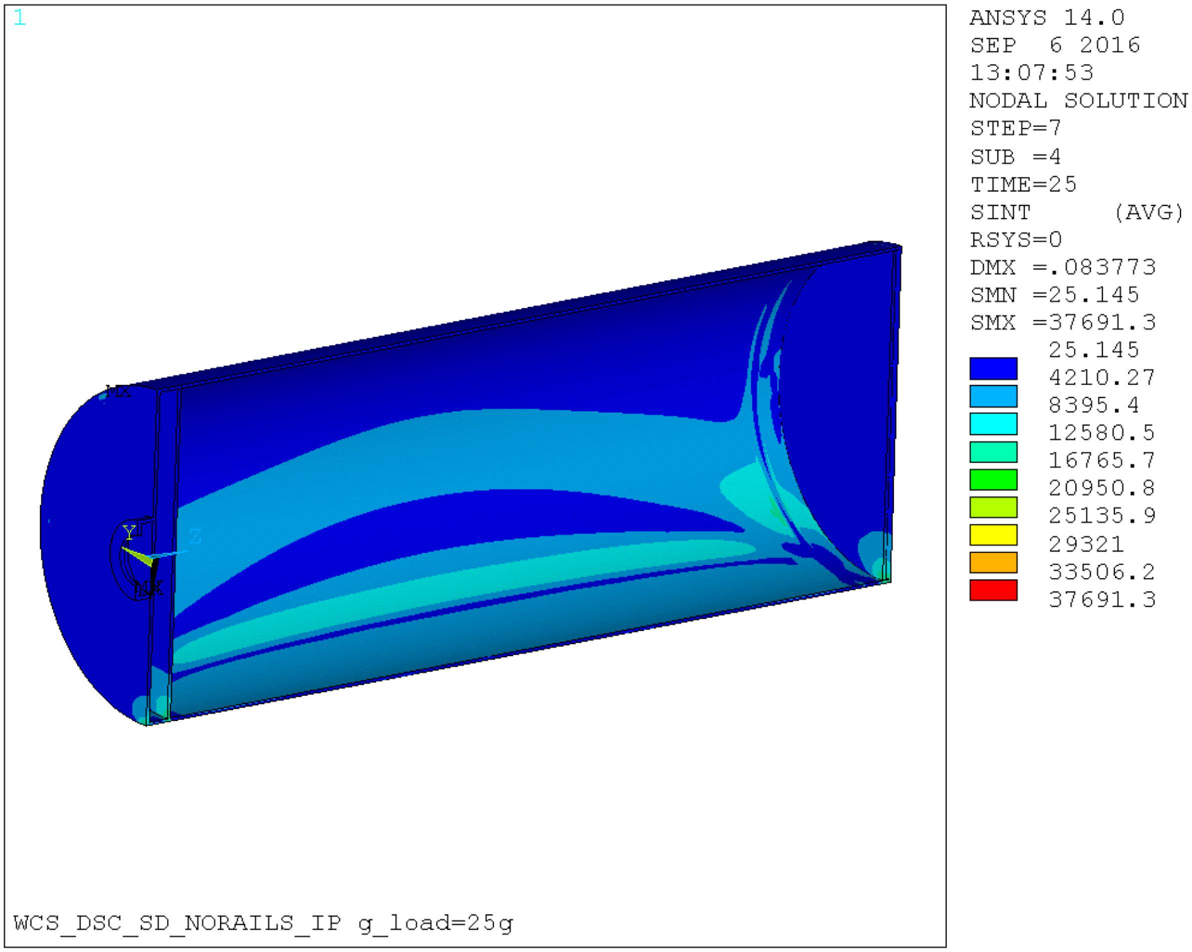


Figure A.7-7
Stress Intensity Plot for Most Critical Load Case (Side Drop Away from Rails with Internal Pressure) FC- and FF-DSCs

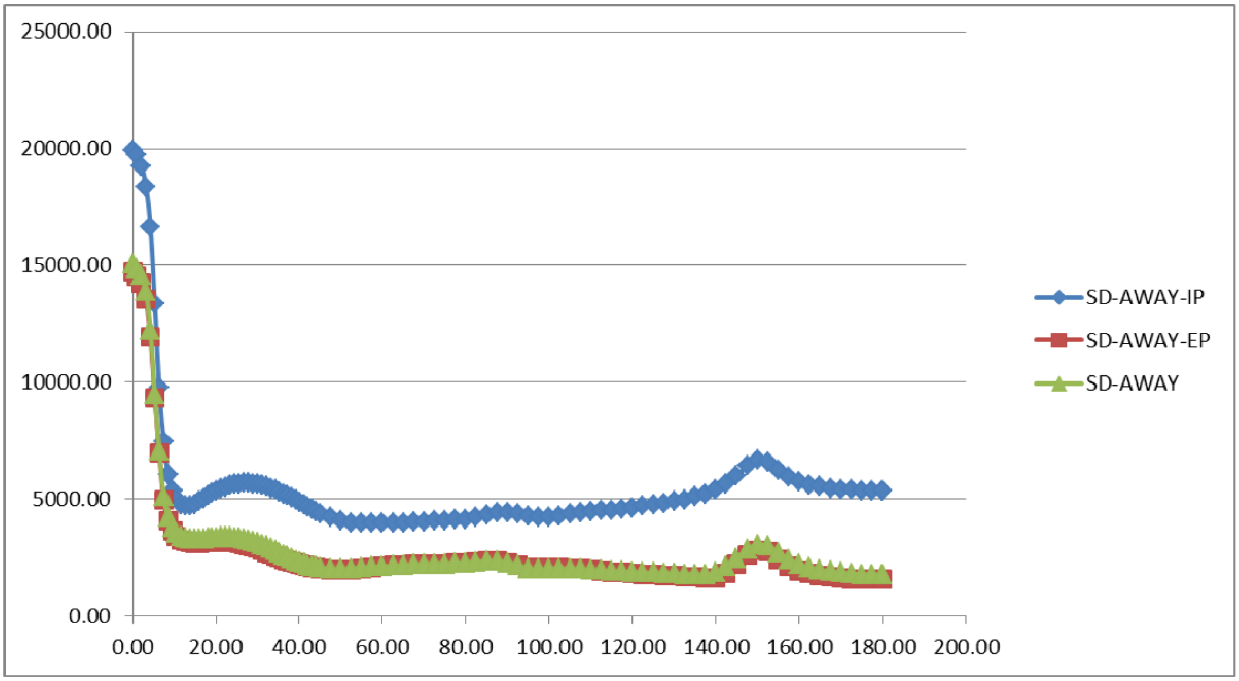


Figure A.7-8
Variation of OTCP – DSC Shell Weld Stress Intensity with Angle (ɵ) FC- ad FF-DSCs

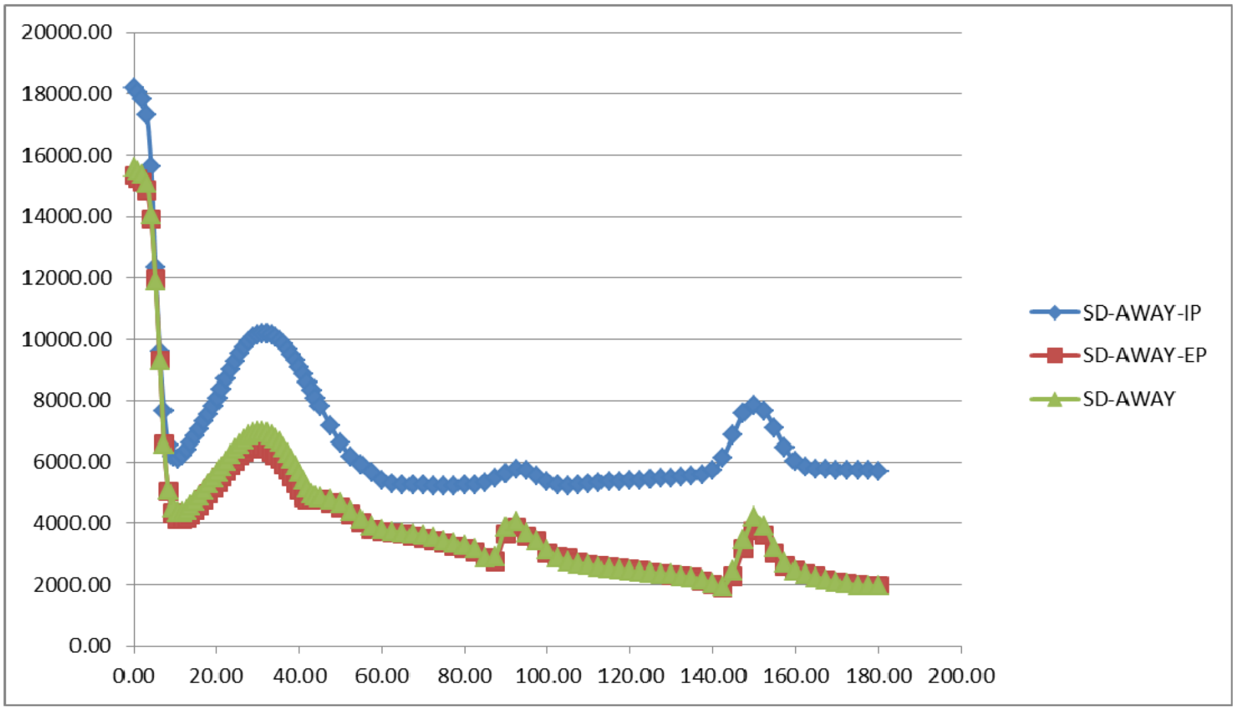


Figure A.7-9
Variation of ITCP – DSC Shell Weld Stress Intensity with Angle (θ) FC- ad FF-DSCs

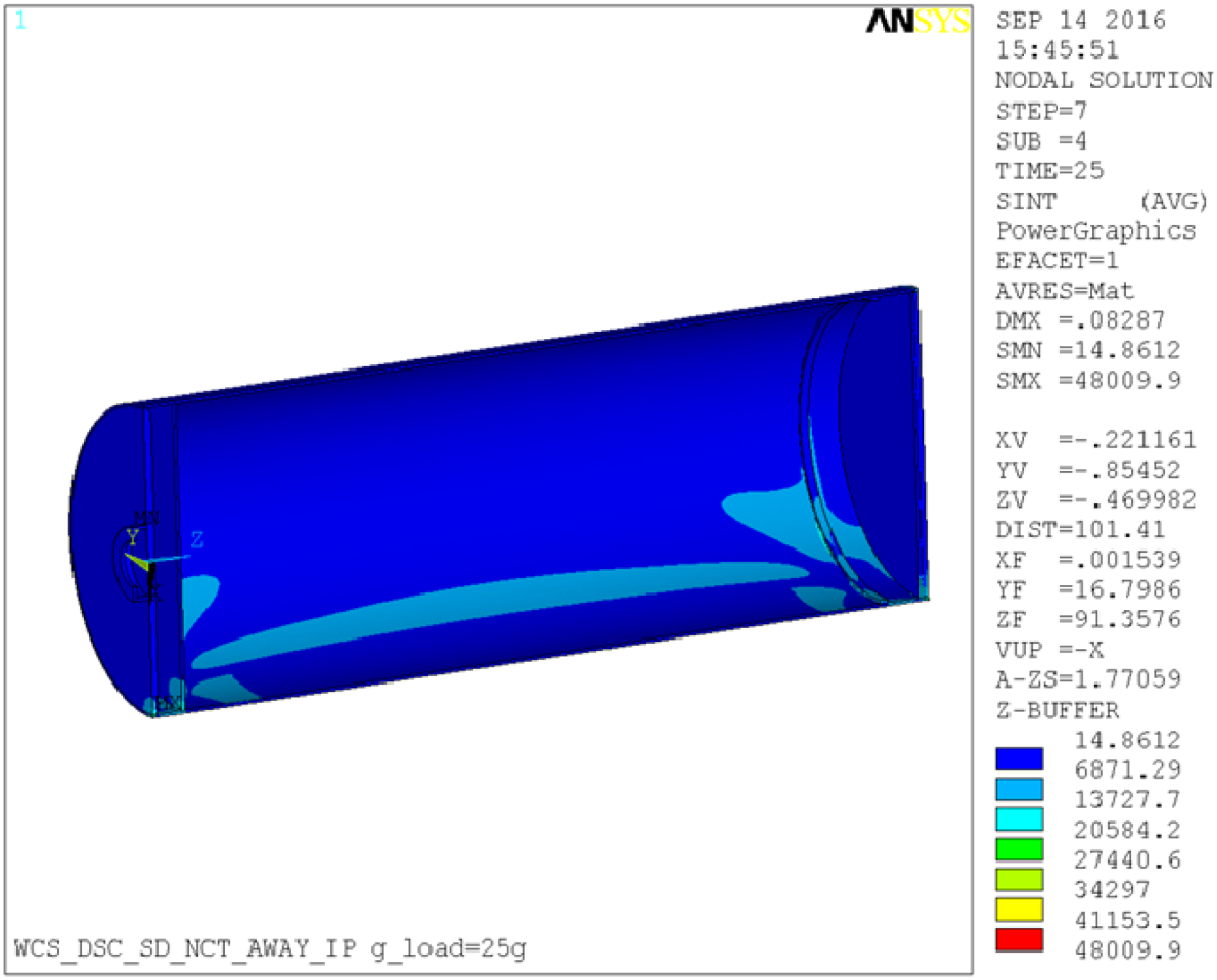


Figure A.7-10
Stress Intensity Plot for Most Critical Load Case (Side Drop Away from Rails with Internal Pressure) FO- and 24PT1 DSCs

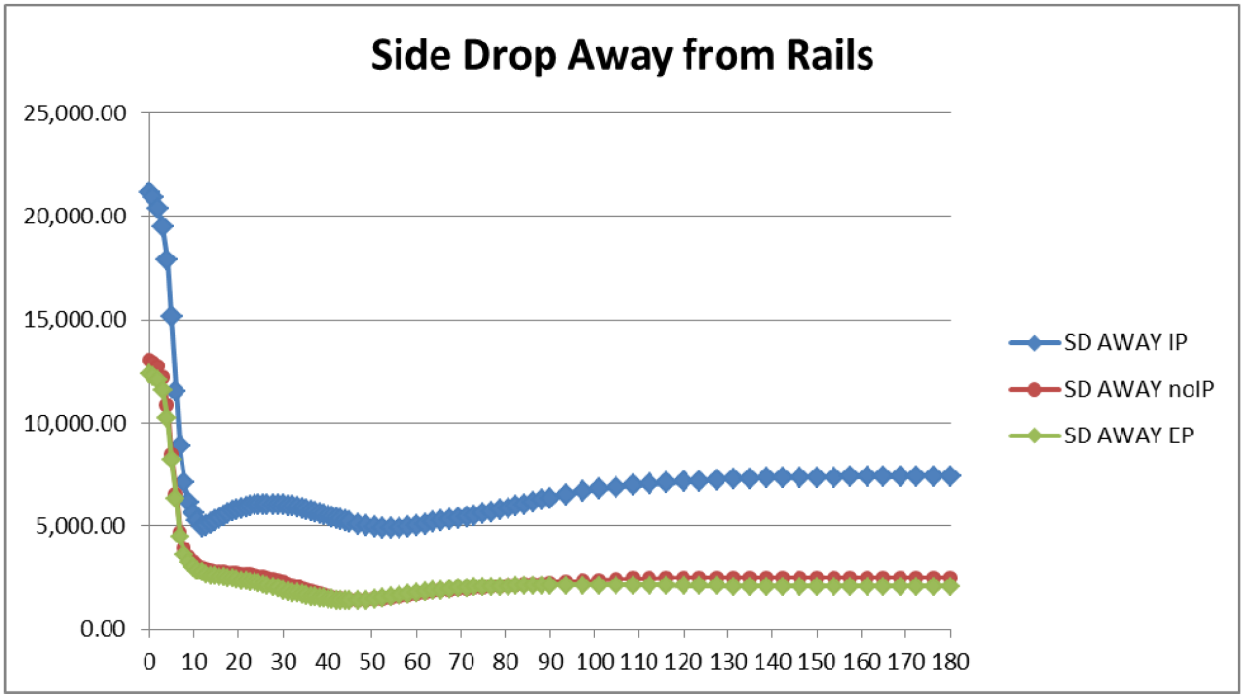


Figure A.7-11
Variation of OTCP – DSC Shell Weld Stress Intensity with Angle (θ) FO- and 24PT1 DSCs

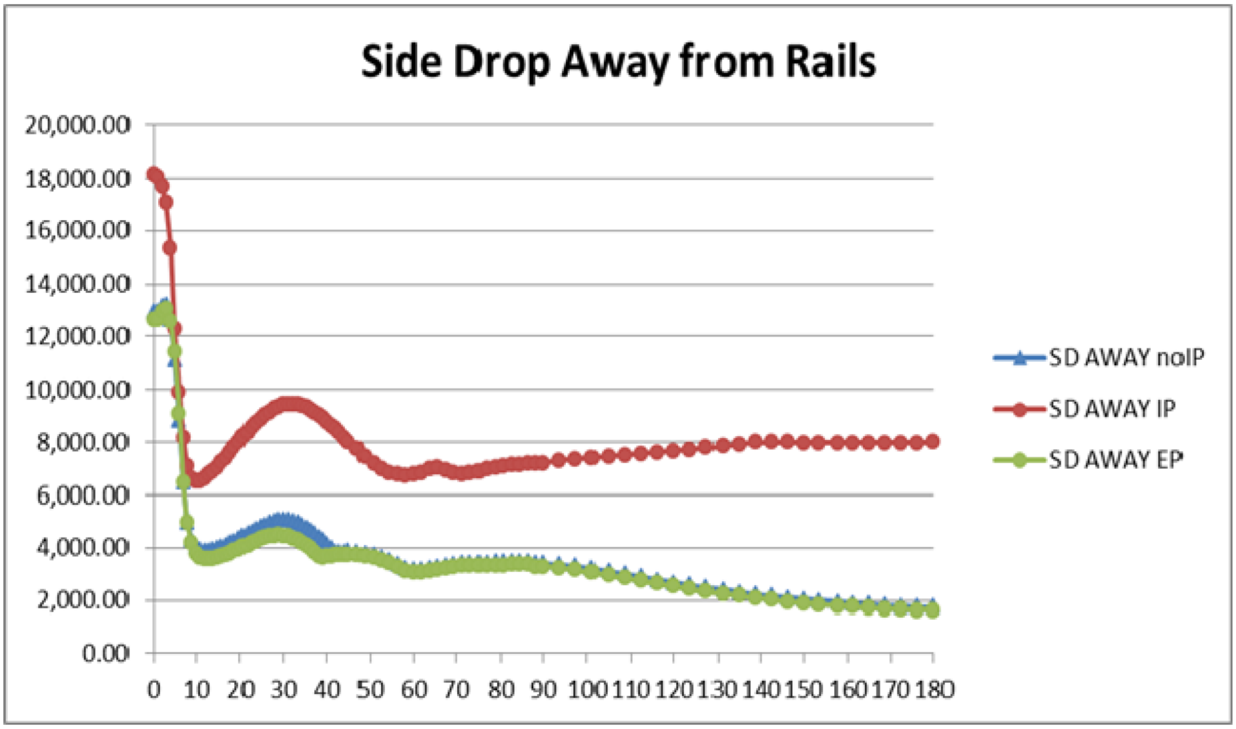


Figure A.7-12
Variation of ITCP – DSC Shell Weld Stress Intensity with Angle (ɵ) FO- and 24PT1 DSCs

APPENDIX A.8
THERMAL EVALUATION
NUHOMS®-MP187 Cask System

Table of Contents

A.8. THERMAL EVALUATION

This Appendix qualifies the NUHOMS®-MP187 Cask System for storage and transfer at the Waste Control Specialists, LLC (WCS) Consolidated Interim Storage Facility (CISF) with the same heat load of 13.5 kW under the WCS CISF environmental conditions. No new thermal analysis is performed in this Appendix. This qualification demonstrates that all the 10 CFR Part 72 thermal requirements for storage and transfer of the FO-, FC-, and FF- Dry Shielded Canisters (DSCs) (hereafter canisters) *and GTCC canister* at the WCS CISF are met.

A.8.1 Discussion

As discussed in Chapter 1, the canisters from the Rancho Seco Nuclear Generating Station Independent Spent Fuel Storage Installation (ISFSI) will be transported to the WCS CISF in the NUHOMS® MP187 Transportation Cask (MP187 cask) under NRC Certificate of Compliance 9255 [A.8-1]. At the WCS CISF, the canisters, described in Section 4.2.5.2, Volume I of the Rancho Seco SAR [A.8-3], are to be stored inside the HSM Model 80 described in Chapter 4 of the Standardized NUHOMS® UFSAR [A.8-2]. The use of the HSM Model 80 for storing the canisters is justified in Section A.8.4.1.

The canisters at the Rancho Seco site are licensed for storage in the Rancho Seco HSM modules and on-site transfer in the MP187 cask with a design basis heat load of 13.5 kW [A.8-3]. The thermal analysis for storage of the canisters is presented in Sections 8.1.1.2, Volume II of [A.8-3] while the thermal analysis for the transfer of these DSCs is presented in Section 8.1.1.1, Volume III of [A.8-3]. *As documented in Section 3.1.1.2. of Appendix C of [A.8-3] the GTCC canister is bounded by the evaluations for the FO-. FC- and FF-DSCs; therefore, no additional discussion of the GTCC canister is required in this chapter.*

This Appendix qualifies the canisters for storage in HSM Model 80s and transfer operations with the MP187 cask at the WCS CISF with the same heat load of 13.5 kW under the WCS CISF environmental conditions. No new thermal analysis is performed in this Appendix. This demonstrates that all the 10 CFR Part 72 thermal requirements for storage and transfer of the canisters at the WCS CISF are met.

A.8.2 Summary of Thermal Properties of Materials

The canister designs are based on the Standardized NUHOMS®-24P DSC design from [A.8-2] and as described in Section 1.2.2, Volume I of [A.8-3]. The material properties of the HSM Model 80 storage module and the 24P DSC are presented in Table 8.1-8 and Table 8.1-9 of [A.8-2].

The properties of the materials used in the thermal analysis of the MP187 cask are defined in Section 8.1.1.1, Volume III of [A.8-3].

A.8.3 Ambient Conditions at the WCS CISF

A.8.3.1 Ambient Temperature Specification at WCS CISF

As specified in Table 1-2 the normal ambient temperature is considered in the range of *44.1*°F to *81.5*°F. Off-normal ambient temperature is considered in the range of *30.1*°F to *113*°F. *Accident ambient temperature is considered as 113°F.*

A.8.3.2 Comparison of WCS CISF Ambient Conditions with Ambient Conditions Used in the Rancho Seco ISFSI *F*SAR [A.8-3]

A review of the thermal evaluation presented in Section 8.1.1.1, Volume II of [A.8-3] shows that average daily ambient temperatures of 101°F and 117°F are used for normal and off-normal hot storage conditions, respectively. These temperatures bound the temperatures for normal*,* off-normal conditions*, and accident conditions* at the WCS CISF. *T*he lowest off-normal ambient temperature evaluated is *the* -20°F cold conditions considered in [A.8-3].

Based on this discussion, the ambient conditions used for the thermal evaluations for storage and transfer operations in [A.8-3] are bounding for the WCS CISF.

A.8.4 Thermal Analysis of HSM Model 80 with FO/FC/FF DSCs

A.8.4.1 Qualification of the HSM Model 80 for Storage of Canisters

As discussed in Section A.8.1, the canisters will be stored inside the HSM Model 80 at the WCS CISF and not in the Rancho Seco HSMs as licensed under site specific license [A.8-3].

However, a review of the thermal evaluation presented in Section 8.1.1, Volume II of [A.8-3] indicates that the Rancho Seco HSMs are similar to HSM Model 80. As described in Item 4 Section 8.1.1, Volume II of [A.8-3], the geometries and thermophysical properties of the materials used for the two HSMs are identical as it relates to the thermal performance. In addition, based on the discussion in Item 5 of Section 8.1.1, Volume II of [A.8-3], the thermal evaluation performed for the HSM Model 80 in [A.8-2] is bounding for the Rancho Seco HSM due to the lower maximum heat load of 13.5 kW versus the 24 kW analyzed in the for the HSM Model 80.

Based on the above discussion, the use of a HSM Model 80 in place of the Rancho Seco HSM will not alter the thermal performance. Therefore, the maximum temperatures for the canisters with a maximum heat load of 13.5 kW during storage in HSM Model 80 are bounded by the results presented in [A.8-3].

Sections A.8.4.2 through A.8.4.4 summarize the thermal evaluation of canisters during storage in HSM based on [A.8-3].

A.8.4.2 Thermal Model of Rancho Seco HSM and Canisters

The HEATING7 thermal model of the Rancho Seco HSM with a canister is the same as the HSM Model 80 with 24P DSC described in Section 8.1.3 of [A.8-2]. This is appropriate based on the justification provided in Section 8.1.1.1 Item 4, Volume II of [A.8-3] that “the geometries of the DSC and HSM at Rancho Seco ISFSI are similar to the NUHOMS®-24P design” of [A.8-2]. The HEATING7 thermal model of the canister basket assemblies is described in Volume II, Section 8.1.1.2 of [A.8-3].

A.8.4.3 Rancho Seco HSM Thermal Model Results

Section 8.1.1.1, Volume II of [A.8-3] presents the HSM thermal analysis with the canisters. The Rancho Seco HSM thermal model results for the canisters for normal, off-normal and accident conditions are presented in Table 8-4, Volume II of [A.8-3]. These results are based on a design basis heat load of 24 kW for a NUHOMS®-24P DSC in a HSM Model 80 [A.8-2].

As discussed in Section A.8.3, the normal, off-normal and accident ambient conditions at the WCS CISF are bounded by the Rancho Seco site ambient conditions. Also, the Rancho Seco HSM design is similar to the HSM Model 80 based on the discussion in Section A.8.4.1. Hence, the thermal analysis results of the canister with a design basis heat load of 13.5 kW, when stored in the HSM Model 80 at the WCS CISF, are bounded by the results presented in Table 8-4, Volume II of [A.8-3].

The maximum fuel cladding temperature for the canisters for long term storage and accident conditions is presented in Table 8-5, Volume II of [A.8-3]. Table 8-2a and Table 8-2b, Volume 1 of [A.8-3] present the maximum internal pressure for canisters with and without the control components, respectively for both transfer and storage conditions. Based on the discussion in Section A.8.3, the normal, off-normal and accident ambient conditions at the WCS CISF are bounded by the Rancho Seco site ambient conditions. Therefore, the maximum fuel cladding temperature and internal pressures determined in [A.8-3] are also applicable to the WCS CISF.

A.8.4.4 Evaluation of HSM Model 80 Performance with a Canister

The thermal performance of the HSM Model 80 with a canister at the WCS CISF under normal, off-normal, and accident conditions of operation is bounded by the evaluation documented in [A.8-3]. The bounding evaluation demonstrates that all the 10 CFR Part 72 thermal limits and criteria for the WCS CISF are met.

A.8.5 Thermal Analysis of MP187 Cask with FO/FC/FF DSCs

As discussed in Section A.8.1, on-site transfer operations of the canisters will be performed using MP187 cask at the WCS CISF. This configuration is licensed as described in [A.8-3]. Based on the discussion in Section A.8.3, the ambient conditions at the WCS CISF are bounded by those considered in [A.8-3]. Therefore, no further evaluations are performed and the thermal evaluations performed for the Rancho Seco ISFSI bound are applicable for the WCS CISF. Sections A.8.5.1 through A.8.5.3 present an overview of the thermal evaluations performed for transfer conditions from [A.8-3].

A.8.5.1 Thermal Model MP187 Cask with FO/FC/FF DSCs

The MP187 cask thermal model is described in Section 8.1.1.1, Volume III of [A.8-3].

A.8.5.2 MP187 Cask Thermal Model Results

Normal and Off-Normal Conditions:

The results of the thermal evaluation for on-site transfer operations of canisters in MP187 cask described in Section 8.1.1.1, Volume III of [A.8-3] and Table 8-1, Volume III of [A.8-3]. The resulting canister shell temperature is used as a boundary condition to calculate maximum fuel cladding temperature, which is presented in Table 8-2, Volume III of [A.8-3].

A.8.5.3 Accident Conditions

The ISFSI at the Rancho Seco site is analyzed for a design basis fire accident during transfer as described in Section 8.2.5, Volume I of [A.8-3]. The results of this evaluation are also applicable to the WCS CISF.

A.8.5.4 Evaluation of MP187 Cask Performance

The thermal performance of the MP187 cask with the canisters at the WCS CISF, evaluated under normal, off-normal, and accident conditions of operation, satisfy all the 10 CFR Part 72 thermal limits and criteria.

A.8.6 References

A.8-1 U.S. Nuclear Regulatory Commission, "Certificate of Compliance No. 9255, Revision 12 for the Model No. NUHOMS®-MP187 Multi-Purpose Cask (Docket 71-9255).

A.8-2 AREVA TN, "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel," NUH-003, Revision 14, September 2014.

A.8-3 "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report," NRC Docket No. 72-11, Revision 4.

APPENDIX A.9
RADIATION PROTECTION
NUHOMS®-MP187 Cask System

Table of Contents

List of Tables

List of Figures

A.9. RADIATION PROTECTION

The NUHOMS®-MP187 Cask System radiation protection evaluations are documented in Section 7 of the "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report" (FSAR) [A.9-1].

A.9.1 Radiation Protection Design Features

Details of the Storage Area shielding design features for the NUHOMS®-MP187 Cask System which includes the FO-, FC-, FF- Dry Shielded Canisters (DSCs) and Greater Than Class C (GTCC) waste canisters stored in an HSM Model 80 are documented in Section 7.3.2.1 *and Appendix C, Section 7.3.1.1* of reference [A.9-1]. *Drawings showing the shield thicknesses for the canisters, HSM Model 80 and MP 187 cask are listed in Section A.4.6.*

A.9.2 Occupational Exposure Evaluation

A.9.2.1 Analysis Methodology

Dose rates are known in the vicinity of the HSM Model 80 and MP187 cask based upon the existing FSAR[A.9-1] and SAR[A.9-2]. The operational sequence is determined for each system, as well as the associated number of workers, their location, and duration per operation. The collective dose per step is then computed as:

$$C = D*N*T,$$

where

C is the collective dose (person-mrem),

D is the dose rate for each operation (mrem/hr),

N is the number of workers for that operation, and

T is the duration of the operation (hr)

Once the collective dose is determined for each step, the collective doses are summed to create the total collective dose. The total collective dose is determined for a single receipt/transfer operation.

A.9.2.2 Dose Assessment

A dose assessment is performed for receipt and transfer of an FO-, FC-, or FF-DSC to HSM Model 80 using the MP187 cask. GTCC waste canisters are bounded by the spent nuclear fuel (SNF) canisters with respect to dose rates on the surface of the cask and storage overpack.

Seven general locations around the cask are defined, as shown in the top half of Figure A.9-1: top, top edge, top corner, side, bottom corner, bottom edge, and bottom. These seven general locations are reduced to only three locations for which dose rate information is available, as shown in the bottom half of Figure A.9-1: top, side, and bottom.

A loading operation is divided into receipt and transfer operations. Dose rates for receipt operations are obtained from *Table 5.1-1 of* the transportation SAR for the MP187 cask *[A.9-2]*. Dose rates for the transfer operations are obtained from *Table 7-1 of Volume II of* the storage FSAR *[A.9-1]* for the HSM Model 80.

The configurations used in the dose rate analysis are summarized in Table A.9-1. Results for the various loading scenarios are provided in Table A.9-2 and Table A.9-3. Separate tables are developed for receipt and transfer operations. These tables provide the process steps, number of workers, occupancy time, distance, dose rate, and collective dose for all operations.

The total collective dose for an operation is the sum of the receipt and transfer collective doses. The total collective dose for receipt and transfer of FO-, FC-, or FF-DSC or GTCC waste canister to an HSM Model 80 using the MP187 cask: 1057 person-mrem.

The total collective dose for unloading, an FO-, FC-, or FF-DSC or reactor related GTCC waste canister from an HSM Model 80 and preparing it for transport off-site is bounded by the loading operations (1057 person-mrem). Operations for removing these canisters from the HSM Model 80 and off-site shipment are identical to loading operations, except in reverse order. The collective dose for unloading is bounded because during storage at the WCS CISF the source terms will have decayed reducing surface dose rates. The total collective dose is the sum of the receipt, transfer, retrieval, and shipment is 2114 person-mrem.

A.9.3 References

A.9-1 "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report," NRC Docket No. 72-11, Revision 4.

A.9-2 AREVA TN Document NUH-05-151 Rev. 17, "NUHOMS®-MP187 Multi-Purpose Transportation Package Safety Analysis Report." (Basis for NRC CoC 71-9255).

Table A.9-1
Receipt and Transfer Configurations

Actual Configuration	Receipt Analysis Configuration	Transfer Analysis Configuration
FO-, FC-, or FF-DSC transferred from the MP187 cask into an HSM Model 80	FC-DSC (bounds FO- and FF-DSC and GTCC waste canister) inside MP187 cask [A.9-2]	FC-DSC (bounds FO- and FF-DSC) inside MP187 cask [A.9-1]

Table A.9-2
Occupational Collective Dose for Receipt of MP187 Cask Loaded with FO-, FC-, or FF-DSC

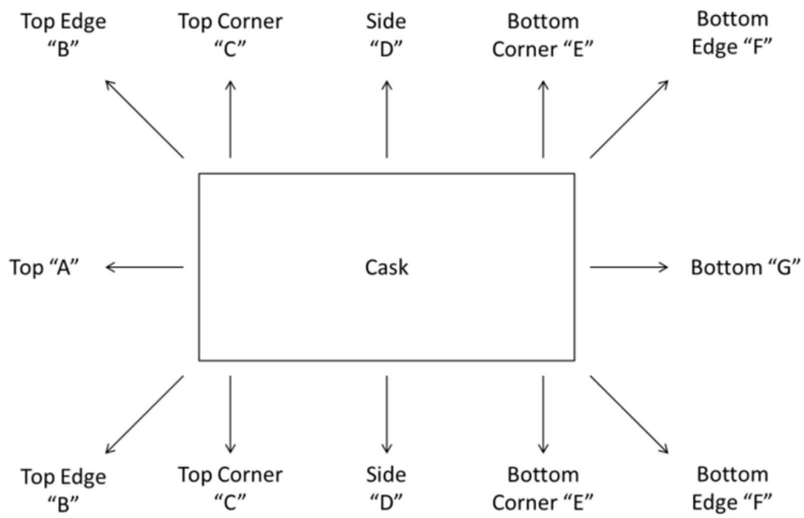
Process Step	Number of Workers	Occupancy Time (hours)	Worker Location Around Cask	Worker Distance (m)	Total Dose Rate (mrem/hr)	Total Dose (person-mrem)*
Verify that the tamperproof seals are intact.	1	0.07	Top	1	0.847	1
	1	0.07	Bottom	1	1.62	
Remove the tamperproof seals.	1	0.07	Top	1	0.847	1
	1	0.07	Bottom	1	1.62	
Remove personnel barrier	3	0.5	Side	1	55.6	84
Remove the impact limiter attachment bolts from each impact limiter and remove the impact limiters from the cask.	2	0.5	Top Edge	1	0.847	3
	2	0.5	Bottom Edge	1	1.62	
Remove the transportation skid closure assembly.	2	0.25	Top Corner	1	55.6	56
	2	0.25	Bottom Corner	1	55.6	
Take contamination smears on the outside surfaces of the cask. If necessary, decontaminate the cask until smearable contamination is at an acceptable level.	2	0.17	Top	1	36	52
	2	0.17	Side	1	55.6	
	2	0.17	Bottom	1	59	
Place suitable slings around the cask top and bottom ends.	2	0.5	Top Corner	1	55.6	112
	2	0.5	Bottom Corner	1	55.6	
Using a suitable crane lift the cask from the railcar	2	0.1	Side	1	55.6	12
Remove the cask trunnion plugs.	2	0.5	Top Corner	1	55.6	112
	2	0.5	Bottom Corner	1	55.6	
Inspect the trunnion sockets and install the upper and lower trunnions. Torque the trunnion attachment screws for each of the four trunnions.	2	0.5	Top Corner	1	55.6	112
	2	0.5	Bottom Corner	1	55.6	
Place cask onto the on-site transfer vehicle.	2	0.5	Side	2	55.6	56
Remove the slings from the cask.	2	0.5	Top Corner	1	55.6	112
	2	0.5	Bottom Corner	1	55.6	
Install the on-site support skid pillow block covers.	1	0.2	Side	2	55.6	12
Transfer the cask to a staging module.	1	0.2	Side	2	55.6	12
					Total (person-mrem)	737

*Rounded up to nearest whole number

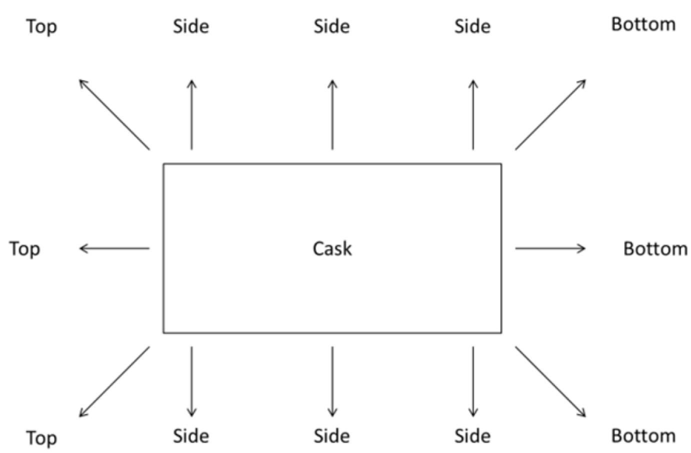
Table A.9-3
Occupational Collective Dose for Transfer of FO-, FC-, or FF-DSC from MP187 Cask to HSM Model 80

Process Step	Number of Workers	Occupancy Time (hours)	Worker Location Around Cask	Worker Distance (m)	Total Dose Rate (mrem/hr)	Total Dose (person-mrem)*
Position the Cask Close to the HSM.	---	---	---	Far	Background	0
Remove the Cask Lid	3	1	Top	1	28	84
Align and Dock the Cask with the HSM	2	0.25	Top/Half Front HSM	1	126.55	64
Lift the Ram into Position and Align with Cask	2	0.5	Bottom	1	58.3	59
Transfer the DSC to the HSM	---	---	---	Far	Background	0
Lift the Ram Onto transfer vehicle and Un-Dock the Cask	2	0.25	Top/Front Vent HSM	1	136.5	69
Install the HSM Access Door	2	0.5	Top/Front HSM	1	43.9	44
					Total (person-mrem)	320

*Rounded up to nearest whole number



Detailed Cask Locations



Simplified Cask Locations

Figure A.9-1
Worker Locations Around Cask

APPENDIX A.10
CRITICALITY EVALUATION
NUHOMS®-MP187 Cask System

Table of Contents

A.10. CRITICALITY EVALUATION

The design criteria for the NUHOMS® MP187 Cask System requires that the canisters be designed to remain subcritical under normal, off-normal, and accident conditions. The design of the canister is such that, under all credible conditions, the highest effective neutron multiplication factor (k_{eff}) remains less than 0.95 including uncertainties and bias.

A.10.1 Discussion and Results

The NUHOMS®-MP187 Cask System criticality analysis is documented in Section 3.3.4, Volume I of the “Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report” [A.10-1] and in Chapter 6 of the “Safety Analysis Report for the NUHOMS®-MP187 Multi-purpose Cask” [A.10-2]. This criticality analysis bounds the conditions for transfer and on-site storage at the Waste Control Specialist, LLC (WCS) Consolidated Interim Storage Facility (CISF) because there is no credible event which would result in the flooding of a canister in HSM storage which would result in k_{eff} exceeding the worst case 10 CFR 71 transportation conditions evaluated in [A.10-1] and [A.10-2]. Specific information on the criticality safety analysis which bounds the WCS CISF is discussed in this section.

The FO- and FC-DSCs consist of a shell assembly and an internal basket assembly. The basket assemblies are composed of four axially oriented support rods and twenty-six spacer discs. This basket assembly provides positive location for twenty-four spent nuclear fuel (SNF) assemblies under normal operating conditions, off-normal operating conditions and accident conditions. The basket assembly uses fixed neutron absorbers that isolate each SNF assembly. Guide sleeves are designed to permit unrestricted flooding and draining of SNF cells. The FC-DSC is designed with a longer internal cavity length to accommodate SNF assemblies with control components. No credit is taken for the presence of control hardware, thus the FC-DSC is identical to the FO-DSC for the purpose of criticality analysis.

The FF-DSC is different from the FO-DSC in its capacity, function, and design. The FF-DSC's capacity is thirteen SNF assemblies and is intended to package SNF with cladding defects. SNF assemblies cladding damage is limited to no more than 15 SNF pins with known or suspected cladding damage greater than hairline cracks and pinhole leaks. Missing cladding and/or crack size in the SNF pins is limited such that a SNF pellet is not able to pass through the gap created by the cladding opening during normal handling. Each assembly is placed in a separate, removable can with a fixed mesh screen on the bottom and similarly screened lid on top. These cans have slightly larger interior dimensions than the FO-DSCs (9.00 in. vs. 8.90 in.) to accommodate bowed or twisted SNF. Due to its smaller payload and the relatively massive nature of the FF-DSC cans, the FF-DSC does not require borated neutron absorbers. The SNF cans are designed to permit unrestricted flooding and draining of SNF cells.

The continued efficacy of the neutron absorbers is assured when the canister arrives as the WCS CISF because the basket, including poison material, is designed and analyzed to maintain its configuration for all normal, off-normal and accident conditions of storage and for normal and hypothetical accidents during transport in the MP187 cask as documented in Section 6.1.2, 6.1.3, 6.1.4 and 6.3 of [A.10-2].

The design basis criticality analysis performed for the NUHOMS®-MP187 Cask System assumes the most reactive configuration of the canister and contents in an infinite array of casks bounding all conditions of receipt transfer and storage at the WCS CISF where the canisters will remain dry under all conditions of transfer and storage including normal, off-normal and accident conditions as demonstrated in Chapter 12.

The results of the evaluations demonstrate that the maximum calculated k_{eff}, including statistical uncertainty and bias, are less than less than 0.95.

A.10.2 Package Fuel Loading

Section 2.1 of the Technical Specifications [A.10-3] lists the *SNF* canisters authorized for storage at the WCS CISF. Section 3.3.4.2, Volume I Spent Fuel Loading of [A.10-1] provides the Package Fuel Loading.

A.10.3 Model Specification

Section 3.3.4.3, Volume I Model Specification of [A.10-1] provides a discussion of the criticality model cask regional densities used to calculate the bounding k_{eff} for the NUHOMS®-MP187 Cask System.

A.10.4 Criticality Calculation

Section 3.3.4.4 Criticality Calculation and 3.3.4.5 Error Contingency Criteria, Volume I of [A.10-1] provides a discussion of the criticality calculations that demonstrate that the maximum calculated k_{eff} for the NUHOMS®-MP187 Cask System is less than 0.95.

A.10.5 Critical Benchmark Experiments

Section 3.3.4.6 Verification Analysis, Volume I of [A.10-1] provides a discussion of the benchmark experiments and applicability, details of benchmark calculations, and the results of benchmark calculations.

A.10.6 References

A.10-1 "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report," NRC Docket No. 72-11, Revision 4.

A.10-2 AREVA TN Document NUH-05-151 Rev. 17, "NUHOMS®-MP187 Multi-Purpose Transportation Package Safety Analysis Report." (Basis for NRC CoC 71-9255).

A.10-3 Proposed SNM-1050, WCS *Consolidated* Interim Storage Facility Technical Specifications, Amendment 0.

APPENDIX A.11
CONFINEMENT EVALUATION
NUHOMS®-MP187 Cask System

Table of Contents

List of Tables

A.11. CONFINEMENT EVALUATION

The design criteria for the NUHOMS® MP187 Cask System requires that the FO-, FC, FF- Dry Shielded Canisters (DSCs or canisters) *and GTCC Canister* are designed to ensure confinement of stored materials under normal, off-normal, and accident conditions during all operations, transfers, and storage. This chapter summarizes the system design features that ensure radiological releases are within limits and will remain As Low As Reasonably Achievable (ALARA), and that spent nuclear fuel (SNF) cladding and SNF assemblies are protected from degradation during storage. *As documented in Section 8.2.2 of Appendix C of [A.11-1] the confinement evaluation for the FO-, FC- and FF- DSCs bound the GTCC canister; therefore, no additional discussion for the GTCC canister is required in this chapter.*

A.11.1 Confinement Boundary

The confinement boundary for the FO-, FC- and FF-DSCs is documented in Section 3.3.2.1 of [A.11-1]. *Reference [A.11-1] does not include a figure showing the confinement boundary for the FO-, FC- and FF-DSCs. However, Figure 7.1-1 of reference [A.11-12] provides a figures that shows the component and welds that make up the confinement boundary for the 24PT1-DSC which is also applicable to the FO-, FC-, and FF-DSCs with one exception, the FO-, FC-, and FF-DSCs do not have a "helium Leak Test Plug" in the Outer Top Cover Plate. Drawings for the canisters, including the confinement boundary are referenced in Section A.4.6.*

The canisters will not release radioactive contents under all normal, off-normal, and accident conditions; see Section 3.3.2 and Section 8.2.2 of [A.11-1]. However, during fabrication and closure operations the confinement boundary was leak tested to 10^{-5} std cm^3/sec in accordance with ANSI N14.5 [A.11-2]. Therefore, for these canister designs, a non-mechanistic release is postulated based on a leakage rate of 10^{-5} std cm^3/sec. *In addition, bounding evaluations in Section A.7.7 are performed to demonstrate that the confinement boundaries for the FO-, FC-, FF-DSCs do not exceed ASME B&PV Subsection NB Article NB-3200 (Level A allowables) during normal conditions of transport to provide reasonable assurance that the confinement boundary is not adversely impacted by transport to the WCS CISF.*

Section 4.3, Codes and Standards, of the Technical Specifications for the Rancho Seco ISFSI [A.11-11] cites the applicable ASME Code for the MP187 FO-, FC-, and FF-DSCs.

Section 3.1, "DSC Integrity," of the Technical Specifications for the Rancho Seco ISFSI; [A.11-11] includes limiting condition for operation (LCO) 3.1.1 for DSC vacuum pressure, LCO 3.1.2 for DSC helium leakage rate, and LCO 3.1.3 for DSC helium backfill pressure. These LCOs create dry, inert, leak tight atmosphere, which contributes to preventing the leakage of radioactive material.

A.11.2 Potential Release Source Term

As noted in Section A.11.1 the FO-, FC-, FF- DSCs, a non-mechanistic leakage rate of 10^{-5} std cm^3/sec is postulated. The actinides and fission products for a B&W 15x15 fuel assembly are computed using SCALE6/ORIGEN-ARP. Two isotopic sets are considered, based on the design basis neutron and gamma sources. The design basis neutron source has a burnup of 38,268 MWd/MTU, enrichment of 3.18% U-235, and was discharged in 1983. The design basis gamma source has a burnup of 34,143 MWd/MTHM, enrichment of 3.21% U-235, and was discharged in 1989. The two source terms considered are decayed until June 2020, which corresponds to the placement of the first canisters at the Waste Control Specialists, LLC (WCS) Consolidated Interim Storage Facility (CISF). The reported source term in Table A.11-1 is the maximum value of the two isotopic sets considered. *The design basis radioactive inventory for the confinement evaluation included in reference [A.11-1] was determined using these same bounding fuel assemblies as documented in Section 7.2.1 of Volume I of [A.11-1] (See also calculation 2069-0507, Revision 0 included in Volume IV of [A.11-1]).*

The crud source is determined based on 140 µCi/cm^2 Co-60 on the surfaces of the SNF rods at the time of discharge [A.11-3]. The design basis gamma assembly was discharged in 1989, or 31 years decay until loading. Therefore, the crud source term in Table A.11-1 is decayed 31 years.

A.11.3 Confinement Analysis

Per Section A.11.1 the FO-, FC-, FF- DSCs, a non-mechanistic leakage rate of 10^{-5} std cm^3/sec is postulated. A confinement analysis is performed for normal, off-normal, and accident conditions to determine the dose to an individual due to inhalation and ingestion. There is no credible mechanism that would produce a leak of this magnitude through the confinement boundary of the canister. All welds in the canister shell are volumetrically examined, as is the weld between the inner bottom cover plate and the shell. Because it is not feasible to volumetrically examine the inner top cover plate weld, this weld is leak tested in accordance with the stated criteria. However, no credit is taken for the presence of the outer top cover plate, which is welded to the canister shell with a 0.5 inch weld that receives no fewer than three levels of dye-penetrant testing. The releases postulated in this analysis, therefore, are several orders of magnitude greater than any expected release.

A.11.3.1 Methodology

1. Calculate the specific activity (Ci/cm^3) in the canister cavity for each radioactive isotope based on the rod breakage fractions, release fractions, isotopic inventory, and cavity free volume. It is conservatively assumed that every SNF assembly in every canister has the same radiological source as the design basis SNF assembly. This assumption is conservative because many SNF assemblies will have less activity than the design basis source. Two sets of release fractions are considered: fuel-to-canister release fractions and Canister-to-Environment release fractions. The fuel-to-canister release fractions are the fraction of isotopes released from the interior of the SNF rod to the internal void region of the canister upon failure of the SNF rods. The fuel-to-canister release fractions used in this analysis are those specified in NUREG-1536 [A.11-4, Table 5-2] or NUREG-1567 [A.11-5, Table 9.2] and are summarized in Table A.11-2. The Canister-to-Environment release fractions are the fraction of isotopes released from the canister to the environment. As the radioactive materials from the SNF assembly will not be released directly to the environment, there will be some release retention in the canister. The fraction of radioactive materials released from the canister to the environment is justified and provided in [A.11-6, Table 3-5] and reproduced in Table A.11-3. These additional factors account for material that may condense, plate out or be filtered out before escaping the canister due to leakage hole size. This accounting of canister retention is also documented in other NRC documents [A.11-7, Section 7.3.8]. The two sets of release fractions are combined to create the fuel-to-environment release fractions in Table A.11-4. No credit is taken for retention of material released from the canister and potentially retained in the Horizontal Storage Module (HSM).

2. Using the as-tested leak rate and adjusting for normal, off-normal, and accident conditions in the canister cavity, determine the adjusted maximum canister leak rate for each set of conditions. The guidance of ANSI N14.5 [A.11-2] is used to calculate the adjusted leak rates.

3. Calculate the isotope specific leak rates by multiplying the specific activities by the seal leak rate for each condition.

4. Determine the dose to the whole body, thyroid, lens of the eye, skin, and other critical organs from inhalation and immersion exposures at the controlled area boundary. Atmospheric dispersion factors are determined using Regulatory Guide 1.145 [A.11-8] and dose conversion factors are taken from EPA Guidance Reports No. 11 [A.11-9] and No. 12 [A.11-10].

A.11.3.2 Specific Activities for Release

Specific activities for release are computed for the canister based on SNF assembly activities in Table A.11-1 and normal, off-normal, and accident release fractions in Table A.11-4. The specific activities are based on 24 SNF *design basis* assemblies per canister and a cavity free volume of 5,592,315 cm^3. The specific activities for release are provided in Table A.11-5. *The maximum number of fuel assemblies in any canister is 24 SNF assemblies; therefore, this assumption bounds all of the loaded FO-, FC- and FF-DSCs.*

A.11.3.3 Leakage Rates

A leak rate in the units std·cm^3/sec corresponds to a leak of dry air at a temperature of 25°C from a pressure of 1 atm (absolute) to a pressure of 0.01 atm (absolute). Because the canister contains an atmosphere that is primarily helium at various temperatures and pressures, the specified standard leak rate must be adjusted for the change in gas, temperature, and pressure. The design basis conditions for the canisters are provided in Table 8-2a of [A.11-1]. Using the method from ANSI N14.5 [A.11-2] and a leakage hole length assumed to be the size of the weld length (3/16 inches), the hole diameter is computed to be 4.7611×10^{-4} cm for a leakage rate of 10^{-5} std·cm^3/sec.

Based on ANSI N14.5, the computed leakage rates for the three operating conditions are:

- Normal condition leakage rate = 4.4914×10^{-6} cm^3/sec
- Off-normal condition leakage rate = 7.5892×10^{-6} cm^3/sec
- Accident condition leakage rate = 2.5413×10^{-5} cm^3/sec

The isotope specific leak rates (Q_i - Ci/sec) used in the exposure calculations are equal to the number of canisters, multiplied by the specific activity, multiplied by the leakage rate, or:

$$Q_i = N \cdot S_i \cdot L$$

where: N is the number of canisters

S_i is the specific activity of nuclide i (Ci/cm^3)

L is the leakage rate (cm^3/sec)

For normal operation, all 21 canisters are assumed to leak at the maximum normal condition leak rate. The presence of the 13 potentially damaged SNF assemblies in the FF-DSC is not expected to significantly affect the results of this calculation. For off-normal and accident conditions only a single canister is assumed to contribute. This assumption is consistent with the guidance of NUREG-1536 [A.11-4] and NUREG-1567 [A.11-5]. The isotope specific leak rates are shown in Table A.11-6.

A.11.3.4 Atmospheric Dispersion Coefficients

For normal and off-normal conditions, an atmospheric dispersion coefficient is calculated using D-stability and a wind speed of 5 m/sec and a 100 m distance to the controlled area boundary. The controlled area boundary is farther than 100 m from the WCS CISF so use of 100 m is conservative. For accident conditions, a dispersion coefficient is calculated using F-stability and a wind speed of 1 m/sec. These atmospheric conditions are consistent with the guidance of NUREG-1536 [A.11-4] and NUREG-1567 [A.11-5]. The smallest vertical plane cross-sectional area of one HSM is conservatively used as the vertical plane cross-sectional area of the building: area = HSM Width * HSM Height = 9’8” x 15’ = 20,880 in^2 = 13.47 m^2.

The atmospheric dispersion coefficients can be determined through selective use of Equations 1, 2, and 3 of Regulatory Guide 1.145 [A.11-8] for ground-level relative concentrations at the plume centerline. For D-stability, 5 m/sec wind speed and a distance of 100 m, the horizontal dispersion coefficient, σ_y, is 8 m per Figure 1 of [A.11-8]. The vertical dispersion coefficient, σ_z, is 4.6 m per Figure 2 of [A.11-8]. The correction factor at these conditions is determined to be 1.122 per Figure 3 of [A.11-8].

For F-stability, 1 m/sec wind speed and a distance of 100 m, the horizontal dispersion coefficient, σ_y, is 4 m per Figure 1 of [A.11-8]. The vertical dispersion coefficient, σ_z, is 2.3 m per Figure 2 of [A.11-8]. The correction factor at these conditions is 4 per Figure 3 of [A.11-8].

With the three values of χ/Q determined, the higher χ/Q value of the first two (Equation 1 and Equation 2) is compared with the last one (Equation 3) and the lower of those two is evaluated as the appropriate atmospheric dispersion coefficient per guidance of Regulatory Guide 1.145 [A.11-8].

The parameters used and the calculated atmospheric dispersion coefficients are summarized in Table A.11-7.

A.11.3.5 Dose Computations

Dose Conversion Factors (DCFs) for air submersion are taken from Table III.1 of Federal Guidance Report No. 12 [A.11-10], as specified in NUREG-1536 [A.11-4] and NUREG-1567 [A.11-5].

DCFs for inhalation are taken from Table 2.1 of Federal Guidance Report No. 11 [A.11-9] as specified in NUREG-1536 [A.11-4] and NUREG-1567 [A.11-5]. The worst case clearance class is conservatively used for each organ/nuclide combination. Note that because inhalation does not contribute to the shallow dose equivalent, the DCFs for skin are set equal to zero.

The Deep Dose Equivalent (DDE) due to air submersion for the whole body and each individual organ is given by:

$$DDE_{i,o} = Q_i \left({}^{Ci}\!/_{\sec} \right) \cdot DCF_{i,o} \left({}^{Sv \cdot m^3}\!/_{Bq \cdot \sec} \right) \cdot {}^{\chi}\!/_{Q} \left({}^{\sec}\!/_{m^3} \right) \cdot t(hr) \cdot C$$

where: $DDE_{i,o}$ is the deep dose equivalent contribution from nuclide i to organ o, mrem (this is the shallow dose equivalent (SDE) when used for the skin)

Q_i is the isotope specific leak rate per Table A.11-6, Ci/sec

$DCF_{i,o}$ is the dose *conversion* factor for nuclide i to organ o

χ/Q is the *atmospheric* dispersion factor per Table A.11-7.

t is the duration of the exposure, 8760 hours (1 year) for normal and off-normal conditions, 720 hours (30 days) for accident condition per [A.11-4]

C is a conversion factor equal to 1.332×10^{19} mrem-Bq-sec/(Sv-Ci-hr)

The Committed Dose Equivalent (CDE) for internal organ doses (Committed Effective Dose Equivalent, CEDE, for the internal whole body dose) due to inhalation is given by:

$$CDE_{i,o} = Q_i \left({}^{Ci}\!/_{\sec} \right) \cdot DCF_{i,o} \left({}^{Sv}\!/_{Bq} \right) \cdot {}^{\chi}\!/_{Q} \left({}^{\sec}\!/_{m^3} \right) \cdot R \left({}^{m^3}\!/_{\sec} \right) \cdot t(hr) \cdot C$$

where: $CDE_{i,o}$ is the committed dose equivalent contribution from nuclide i to organ o, mrem (this is the committed effective dose equivalent (CEDE) when used for the whole body)

Q_i is the isotope specific leak rate per Table A.11-6, Ci/sec

$DCF_{i,o}$ is the dose conversion factor for nuclide i to organ o

χ/Q is the atmospheric dispersion factor per Table A.11-7.

R is the respiration rate, a normal worker breathing rate, 3.3×10^{-4} m^3/sec [A.11-9]

t is the duration of the exposure, 8760 hours (1 year) for normal and off-normal conditions, 720 hours (30 days) for accident condition per [A.11-4]

C is a conversion factor equal to $1.332x10^{19}$ mrem-Bq-sec/(Sv-Ci-hr)

The Total Effective Dose Equivalent (TEDE) to the whole body is equal to the sum of DDE and CDE effective doses. The Total Organ Dose Equivalent (TODE) for a given organ is equal to the sum of the DDE and CDE for that organ. TODE for the lens of the eye is the sum of the SDE and TEDE.

The limiting results for normal, off-normal, and accident conditions are summarized in Table A.11-8. The limiting organ for all conditions is the bone surface. Calculated exposures for normal operation bound those for off-normal conditions due to the larger number of canisters (21) included in the normal condition calculation.

The maximum normal-operation TEDE due to the release is 7.77E-3 mrem, which satisfies the NUREG-1536 [A.11-4] and NUREG-1567 [A.11-5] criteria of "a small fraction of the limits prescribed in 10CFR72.104(a)". This result must be added to the direct and air-scattered radiation from the WCS CISF at all distances at or beyond 100 meters to demonstrate final compliance with 10CFR72.104(a). As shown in Table A.11-8, normal operation doses to the thyroid and other organs are also within the 10CFR72.104(a) limits. All calculated accident doses are well below the applicable 10CFR72.106(b) limits. It is therefore concluded that the NUHOMS® system at the WCS CISF satisfies the confinement criteria.

A.11.4 References

A.11-1 "Rancho Seco Independent Spent Fuel Storage Installation, Final Safety Analysis Report, Volume 1, ISFSI System," NRC Docket No. 72-11, Revision 4.

A.11-2 ANSI N14.5, "Leakage Tests on Packages for Shipment of Radioactive Materials," 1997.

A.11-3 NRC Spent Fuel Project Office, Interim Staff Guidance, ISG-5, Rev. 1, "Confinement Evaluation."

A.11-4 NUREG-1536, Revision 1, "Standard Review Plan for Spent Fuel Dry Cask Storage Systems at a General License Facility," U.S. 200 Regulatory Commission, Office of Nuclear Material Safety and Safeguards.

A.11-5 NUREG-1567, "Standard Review Plan for Spent Fuel Dry Storage Facilities," Revision 0, U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards, March 2000.

A.11-6 Calvert Cliffs Nuclear Power Plant Calculation CA07718, "2011 Update of ISFSI USAR DSC Leakage Dose Analysis," NRC Ascension Number ML11364A025.

A.11-7 NUREG/CR-6672, Sandia National Laboratories, "Reexamination of Spent Fuel Shipment Risk Estimates," Volume 1, NRC Ascension Number ML003698324.

A.11-8 U.S. NRC Regulatory Guide 1.145, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants," Revision 1, November 1982.

A.11-9 Federal Guidance Report No. 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion," EPA-520/1-88-020, September 1988.

A.11-10 Federal Guidance Report No. 12, "External Exposure to Radionuclides in Air, Water, and Soil," EPA 402-R-93-081, September 1993.

A.11-11 "Technical Specifications for the Rancho Seco Independent Spent Fuel Installation," Amendment 3, U.S. NRC Docket Number 72-0011.

A.11-12 AREVA TN document, ANUH-01.0150, Revision 6, "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated nuclear Fuel," U.S. NRC Docket 72-1029.

Table A.11-1
SNF Assembly Activities

Nuclide	Type	Activity as of June 2020 (Ci/FA)	Activity Fraction
Cs-137	Volatile	2.324E+04	24.82%
Ba-137m	Volatile	2.195E+04	23.44%
Y-90	Volatile	1.498E+04	16.00%
Sr-90	Volatile	1.497E+04	15.99%
Pu-241	Fine	1.414E+04	15.10%
Am-241	Fine	2.050E+03	2.19%
Pu-238	Fine	1.488E+03	1.59%
Cm-244	Fine	5.221E+02	0.56%
Kr-85	Gas	4.816E+02	0.51%
Pu-240	Fine	2.807E+02	0.30%
Eu-154	Fine	2.442E+02	0.26%
Pu-239	Fine	1.711E+02	0.18%
Ni-63	Fine	1.592E+02	0.17%
Sm-151	Fine	1.544E+02	0.16%
H-3	Gas	6.704E+01	0.07%
Np-239	Fine	1.559E+01	0.02%
Am-243	Fine	1.559E+01	0.02%
Am-242m	Fine	1.400E+01	0.01%
Am-242	Fine	1.394E+01	0.01%
Cm-242	Fine	1.155E+01	0.01%
Cm-243	Fine	9.250E+00	0.01%
I-129	Gas	1.493E-02	0.00%
Co-60	Crud	7.158E-01	-
TOTAL	-	9.364E+04	-

Table A.11-2
Fuel-to-Canister Release Fractions

Group	Normal/ Off-Normal	Accident
Rod Breakage Percentage	0.01/0.1	1
Fraction of Gases Released	0.3	0.3
Fraction of Volatiles Released	2×10^{-4}	2×10^{-4}
Fraction of Fuel Fines Released	3×10^{-5}	3×10^{-5}
Fraction of Crud Released	0.15	1.0

Table A.11-3
Canister-to-Environment Release Fractions [A.11-6, Table 3-5]

Group	Normal/ Off-Normal	Accident
Gases	1	1
Volatiles	7E-05	8E-04
Fines	2E-03	2E-02
Crud	2E-03	2E-02

Table A.11-4
Fuel-to-Environment Release Fractions

Group	Normal/ Off-Normal	Accident
Rod Breakage Percentage	0.01/0.1	1
Fraction of Gases Released	0.3	0.3
Fraction of Volatiles Released	1.40E-08	1.60E-07
Fraction of Fuel Fines Released	6.00E-08	6.00E-07
Fraction of Crud Released	3.00E-04	2.00E-02

Table A.11-5
Specific Activities for Release per Canister

Nuclide	Type	Normal (Ci/cm^3)	Off-Normal (Ci/cm^3)	Accident (Ci/cm^3)
Cs-137	Volatile	1.396E-11	1.396E-10	1.596E-08
Ba-137m	Volatile	1.396E-11	1.396E-10	1.596E-08
Y-90	Volatile	9.000E-12	9.000E-11	1.029E-08
Sr-90	Volatile	9.000E-12	9.000E-11	1.029E-08
Pu-241	Fine	3.641E-11	3.641E-10	3.641E-08
Am-241	Fine	5.279E-12	5.279E-11	5.279E-09
Pu-238	Fine	3.832E-12	3.832E-11	3.832E-09
Cm-244	Fine	1.344E-12	1.344E-11	1.344E-09
Kr-85	Gas	6.201E-06	6.201E-05	6.201E-04
Pu-240	Fine	7.228E-13	7.228E-12	7.228E-10
Eu-154	Fine	6.288E-13	6.288E-12	6.288E-10
Pu-239	Fine	4.406E-13	4.406E-12	4.406E-10
Ni-63	Fine	4.099E-13	4.099E-12	4.099E-10
Sm-151	Fine	3.976E-13	3.976E-12	3.976E-10
H-3	Gas	8.631E-07	8.631E-06	8.631E-05
Np-239	Fine	4.014E-14	4.014E-13	4.014E-11
Am-243	Fine	4.014E-14	4.014E-13	4.014E-11
Am-242m	Fine	3.605E-14	3.605E-13	3.605E-11
Am-242	Fine	3.589E-14	3.589E-13	3.589E-11
Cm-242	Fine	2.974E-14	2.974E-13	2.974E-11
Cm-243	Fine	2.382E-14	2.382E-13	2.382E-11
I-129	Gas	1.922E-10	1.922E-09	1.922E-08
Co-60	Crud	9.216E-12	9.216E-11	6.144E-08

Table A.11-6
Isotope Specific Release Rates, Q_i

Nuclide	Type	Normal (Ci/sec)	Off-Normal (Ci/sec)	Accident (Ci/sec)
Cs-137	Volatile	1.317E-15	1.060E-15	4.055E-13
Ba-137m	Volatile	1.317E-15	1.060E-15	4.055E-13
Y-90	Volatile	8.489E-16	6.831E-16	2.614E-13
Sr-90	Volatile	8.489E-16	6.831E-16	2.614E-13
Pu-241	Fine	3.434E-15	2.763E-15	9.253E-13
Am-241	Fine	4.979E-16	4.006E-16	1.341E-13
Pu-238	Fine	3.614E-16	2.908E-16	9.737E-14
Cm-244	Fine	1.268E-16	1.020E-16	3.416E-14
Kr-85	Gas	5.848E-10	4.706E-10	1.576E-08
Pu-240	Fine	6.817E-17	5.485E-17	1.837E-14
Eu-154	Fine	5.931E-17	4.772E-17	1.598E-14
Pu-239	Fine	4.155E-17	3.344E-17	1.120E-14
Ni-63	Fine	3.866E-17	3.111E-17	1.042E-14
Sm-151	Fine	3.750E-17	3.017E-17	1.010E-14
H-3	Gas	8.141E-11	6.550E-11	2.193E-09
Np-239	Fine	3.786E-18	3.047E-18	1.020E-15
Am-243	Fine	3.786E-18	3.047E-18	1.020E-15
Am-242m	Fine	3.400E-18	2.736E-18	9.161E-16
Am-242	Fine	3.386E-18	2.724E-18	9.122E-16
Cm-242	Fine	2.805E-18	2.257E-18	7.558E-16
Cm-243	Fine	2.247E-18	1.808E-18	6.053E-16
I-129	Gas	1.813E-14	1.459E-14	4.885E-13
Co-60	Crud	8.692E-16	6.994E-16	1.561E-12

Note: Normal conditions based on 21 canpoisters, while off-normal and accident conditions based on a single canister.

Table A.11-7
Atmospheric Dispersion Coefficients

Parameter	Normal/Off-Normal	Accident
Stability	D	F
$\overline{U_{10}}$ (m/sec)	5	1
A (m^2)	13.47	13.47
σ_y (m)	8	4
σ_z (m)	4.6	2.3
M	1.122	4
Equation 1 of [A.11-8] (sec/m^3)	1.635E-03	2.806E-02
Equation 2 of [A.11-8] (sec/m^3)	5.766E-04	1.153E-02
Equation 3 of [A.11-8] (sec/m^3)	1.542E-03	8.650E-03
χ/Q (sec/m^3)	1.542E-03	8.650E-03

Table A.11-8
Summary of Dose Results

Normal Conditions		
Organ	**10CFR72.104(a) Limit (mrem)**	**Dose (mrem)**
Whole Body (TEDE)	25	7.77E-03
Thyroid (TODE)	75	1.78E-03
Other Critical Organ (TODE) (bone surface)	25	1.37E-01
Off-Normal Conditions		
Organ	**10CFR72.104(a) Limit (mrem)**	**Dose (mrem)**
Whole Body (TEDE)	25	6.25E-03
Thyroid (TODE)	75	1.43E-03
Other Critical Organ (TODE) (bone surface)	25	1.10E-01
Accident Conditions		
Organ	**10CFR72.106(b) Limit (mrem)**	**Dose (mrem)**
Whole Body (TEDE)	5.00E+03	9.51E-01
Organ (TODE) (bone surface)	5.00E+04	1.70E+01
Lens of Eye (LDE) (TEDE+SDE)	1.50E+04	9.68E-01
Skin (SDE)	5.00E+04	1.73E-02

Note: Normal conditions based on 21 canisters, while off-normal and accident conditions based on a single canister.

APPENDIX A.12
ACCIDENT ANALYSIS
NUHOMS®-MP187 Cask System

Table of Contents

A.12. ACCIDENT ANALYSIS

This section describes the postulated off-normal and accident events that could occur during transfer and storage for the NUHOMS® MP187 Cask System. Detailed analysis are provided in the "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report" [A.12-1] are referenced herein. *As documented in Section 8.2 and associated subsections in Appendix C of [A.12-1] the evaluations for the FO-, FC- and FF-DSCs bound the GTCC Canister, therefore no additional discussion for the GTCC canister is required in this chapter.*

A.12.1 Off-Normal Operations

The off-normal conditions considered for the NUHOMS® MP187 Cask System are off-normal transfer loads, extreme temperatures and a postulated release of radionuclides.

A.12.1.1 Off-Normal Transfer Loads

The causes of, detection of, evaluation and corrective actions of off-normal transfer loads are addressed in Section 8.1.1.5 of Volume I of [A.12-1].

A.12.1.2 Off-Normal HSM Storage Events (Extreme Temperatures)

Postulated Cause of Event

The postulated cause of extreme temperatures is documented in Section 8.1.1.1 Item 2 of Volume II of [A.12-1].

Analysis of Effects and Consequences

Section A.8.4 demonstrates that the evaluations presented in Section 8.2 of Volume II of [A.12-1] bound the Waste Control Specialists, LLC (WCS) Consolidated Interim Storage Facility (CISF) conditions in the HSM Model 80. Section A.8.5 demonstrates that the evaluations presented in Section 8.2 of Volume III of [A.12-1] bound the WCS CISF conditions in the MP187 cask.

A.12.1.3 Off-Normal Release of Radionuclides

Postulated Cause of Event

In accordance with NUREG-1536 [A.12-2], for off-normal conditions, it is conservatively assumed that 10% of the fuel rods fail.

Analysis of Effects and Consequences

Section A.11.3 provides the bounding confinement analysis for the NUHOMS® MP187 Cask System canisters. Table A.11-8 shows that the off-site doses are very small at 100 meters from the storage pad. The actual boundary is approximately 0.75 miles from the storage pads. Therefore, dose from off-normal condition leakage is significantly less than the regulatory limits.

Corrective Actions

None Required.

A.12.2 Postulated Accident

The postulated accident conditions for the NUHOMS® MP187 Cask System addressed in this SAR section are:

- Blockage of Air Inlets/Outlets
- Drop Accidents
- Earthquakes
- Lightning
- Fire/Explosion
- Flood
- Tornado Wind and Missiles

A.12.2.1 Blockage of Air Inlets/Outlets

Cause of Accident

Section 8.3.5 of Volume II of [A.12-1] provides the potential for blocked air vents for the HSM Model 80.

Accident Analysis

The structural, thermal, and radiological consequences and the recovery measures required to mitigate the blocking of the air inlets and outlets are addressed in Section 8.3.5 of Volume II of [A.12-1]. In addition, Chapter A.8 demonstrates that the thermal analysis performed for the NUHOMS® MP187 Cask System in [A.12-1] is bounding for WCS CISF conditions.

A.12.2.2 Drop Accidents

Cause of Accident

Section 8.2.1.1 of Volume I of [A.12-1] discusses the cask drop for the MP187 cask in the transfer configuration.

Accident Analysis

The structural, thermal, and radiological consequences and the recovery measures required to mitigate the effects of a drop accident are addressed in Section 8.2.1.3 of Volume I of [A.12-1]. In addition, Chapter A.8 demonstrates that the thermal analysis performed for the NUHOMS® MP187 Cask System in [A.12-1] is bounding for WCS CISF conditions.

A.12.2.3 Earthquakes

Cause of Accident

Site-specific ground-surface uniform hazard response spectra (UHRS) with 1E-4 annual frequency of exceedance (AFE) having peak ground acceleration (PGA) of 0.250 g horizontal and 0.175 g vertical are shown in Table 1-2, Table 1-5 and Figure 1-5. *The site-specific response spectra are used in the WCS CISF SSI analysis to obtain the enveloped acceleration spectra at the HSM CG and base.* Section A.7.5 demonstrates that the enveloping *WCS CISF site-specific* seismic forces remain below their applicable capacities for the NUHOMS® MP187 Cask System components.

Accident Analysis

The structural, thermal, and radiological consequences and the recovery measures required to mitigate an earthquake are addressed in Sections 8.3.2.2, 8.3.2.1 of Volume II and 8.3.2.1 of Volume III of [A.12-1]. In addition, Chapter A.8 demonstrates that the thermal analysis performed for the NUHOMS® MP187 Cask System in [A.12-1] is bounding for WCS CISF conditions.

A.12.2.4 Lightning

Cause of Accident

The likelihood of lightning striking the HSM Model 80 and causing an off-normal or accident condition is not considered a credible event. Simple lightning protection equipment for the HSM structures is considered a miscellaneous attachment acceptable per the HSM design.

Accident Analysis

Should lightning strike in the vicinity of the HSM the normal storage operations of the HSM will not be affected. The current discharged by the lightning will follow the low impedance path offered by the surrounding structures or the grounding system installed around each block of HSMs. The heat or mechanical forces generated by current passing through the higher impedance concrete will not damage the HSM. Since the HSM requires no equipment for its continued operation, the resulting current surge from the lightning will not affect the normal operation of the HSM.

Since no accident conditions will develop as the result of a lightning strike near the HSM, no corrective action would be necessary. In addition, there would be no radiological consequences

A.12.2.5 Fire and Explosion

Cause of Accident

Sections 3.3.6 and 8.2.5 of Volume I of [A.12-1] provide the potential sources of fire and explosion that may occur at the WCS CISF.

Accident Analysis

The structural, thermal, and radiological consequences and the recovery measures required to mitigate a fire accident are addressed in Section 8.2.5 of Volume I of [A.12-1]. Per Section 8.2.5.3 of Volume I of [A.12-1] the maximum flammable fuel either during the transfer operation or inside the WCS CISF is 300 gallons of diesel fuel.

A.12.2.6 Flood

Cause of Accident

The Probable Maximum flood elevation is considered to occur as a severe natural phenomenon.

Accident Analysis

As documented in Sections 2.4.2.2 and 3.2.2, the WCS CISF is not in a floodplain and is above the Probable Maximum Flood elevation and, therefore, will remain dry in the event of a flood.

A.12.2.7 Tornado Wind and Missiles

Cause of Accident

In accordance with ANSI-57.9 [A.12-4] and 10 CFR 72.122, the NUHOMS® MP187 Cask System components are designed for tornado effects including tornado wind effects. In addition, the HSM and MP187 cask in the transfer configuration are also design for tornado missile effects. The NUHOMS® MP187 Cask System components are designed and conservatively evaluated for the most severe tornado and missiles anywhere within the United States (Region I as defined in NRC Regulatory Guide 1.76 [A.12-5]) while the WCS CISF is in Region II, a less severe location with respect to tornado and tornado missiles.

Accident Analysis

The structural, thermal, and radiological consequences and the recovery measures required to mitigate the effects of tornado wind and missile loads are addressed in Section 8.3.1 of Volume II and Table 8-13 and Section 8.3.1.3 of Volume III of [A.12-1].

A.12.3 References

A.12-1 “Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report,” NRC Docket No. 72-11, Revision 4.

A.12-2 NUREG-1536, Revision 1, "Standard Review Plan for Spent Fuel Dry Cask Storage Systems at a General License Facility," U.S. 200 Regulatory Commission, Office of Nuclear Material Safety and Safeguards.

A.12-3 NRC Regulatory Guide 1.60, Rev. 1, “Design Response Spectra for Seismic Design of Nuclear Power Plants,” Dec 1973.

A.12-4 American National Standards Institute, American Nuclear Society, ANSI/ANS 57.9 1984, Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type).

A.12-5 NRC Regulatory Guide 1.76, “Design Basis Tornado and Tornado Missiles for Nuclear Power Plants,” 1974.

APPENDIX B.1
INTRODUCTION AND GENERAL DESCRIPTION OF INSTALLATION
Standardized Advanced NUHOMS® System

Table of Contents

B.1. INTRODUCTION AND GENERAL DESCRIPTION OF INSTALLATION

No change or additional information required for the Advanced NUHOMS® System containing the NUHOMS® 24PT1-DSCs for Chapter 1.

APPENDIX B.2
SITE CHARACTERISTICS
Standardized Advanced NUHOMS® System

Table of Contents

B.2. SITE CHARACTERISTICS

No change or additional information required for the Advanced NUHOMS® System containing the NUHOMS® 24PT1-DSCs for Chapter 2.

APPENDIX B.3
PRINCIPAL DESIGN CRITERIA
Standardized Advanced NUHOMS® System

Table of Contents

List of Tables

B.3. PRINCIPAL DESIGN CRITERIA

The Standardized Advanced NUHOMS® System principal design criteria is documented in Chapter 2 of the "Advanced NUHOMS® Horizontal Modular Storage System Safety Analysis Report" [B.3-1]. Table B.3-1 provides a comparison of the Standardized Advanced NUHOMS® System principal design criteria and the Waste Control Specialists, LLC (WCS) Consolidated Interim Storage Facility (CISF) design criteria provided in Table 1-2 which demonstrates that the Standardized Advanced NUHOMS® System bounds the WCS CISF criteria.

B.3.1 SSCs Important to Safety

The classifications of the Standardized Advanced NUHOMS® System systems, structures and components, are discussed in Section 2.5 of the of the "Advanced NUHOMS® Horizontal Modular Storage System Safety Analysis Report" [B.3-1] for the canister and AHSM and Section 3.4 of the "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report" [B.3-2] for the MP187 cask in the transfer configuration. These classifications are summarized in Table B.3-2 for convenience.

B.3.1.1 24PT1 DSC

The 24PT1-DSC provides fuel assembly support required to maintain the fuel geometry for criticality control. Accidental criticality inside a 24PT1-DSC could lead to off-site doses comparable with the limits in 10 CFR Part 100, which must be prevented. The 24PT1-DSC also provides the confinement boundary for radioactive materials. The DSCs are designed to maintain structural integrity under all accident conditions identified in Chapter 12 without losing their function to provide confinement of the spent fuel assemblies. The DSCs are important-to-safety (ITS).

B.3.1.2 Horizontal Storage Module

For the Standardized Advanced NUHOMS® System, the horizontal storage modules (HSM) used is the advance horizontal storage module, herein referred to as AHSM. The AHSM is considered ITS since it provides physical protection and shielding for the spent fuel container (24PT1-DSC) during storage. The reinforced concrete AHSM is designed in accordance with ACI 349-97 [B.3-5] and built to ACI-318 [B.3-6]. The level of testing, inspection, and documentation provided during construction and maintenance is in accordance with the quality assurance requirements as defined in 10 CFR 72, Subpart G. Thermal instrumentation for monitoring AHSM concrete temperatures is considered "not-important-to-safety" (NITS).

B.3.1.3 NUHOMS® Basemat and Approach Slab

The basemat and approach slabs for the AHSMs are considered NITS and are designed, constructed, maintained, and tested to ACI-318 [B.3-5] as commercial-grade items.

B.3.1.4 NUHOMS® Transfer Equipment

The MP187 transportation cask is qualified for transfer operations for the Standardized Advanced NUHOMS® System in this application and herein is referred to as a transfer cask. The MP187 cask is ITS since it protects the DSC during handling and is part of the primary load path used while handling the DSCs in the Transfer Facility. An accidental drop of a loaded transfer cask has the potential for creating conditions adverse to the public health and safety. These possible drop conditions are evaluated with respect to the impact on the DSC in Chapter 12. Therefore, the MP187 is designed, constructed, and tested in accordance with a QA program incorporating a graded quality approach for ITS requirements as defined by 10 CFR Part 72, Subpart G, paragraph 72.140(b).

The remaining transfer equipment (i.e., ram, skid, transfer vehicle) is necessary for the successful loading of the DSCs into the AHSMs. However, these items are not required to provide reasonable assurance that the canister can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public. Therefore, these components are considered NITS and need not comply with the requirements of 10 CFR Part 72. These components are designed, constructed, and tested in accordance with good industry practices.

B.3.2 Spent Fuel to Be Stored

The authorized contents for the 24PT1-DSCs are described in Certificate of Compliance 72-1029 [B.3-7] and the "Advanced NUHOMS® Horizontal Modular Storage System Safety Analysis Report" [B.3-1].

Certificate of Compliance 72-1029 Technical Specifications Section 2.1 [B.3-7] provides a description of the fuels stored in the 24PT1 DSCs as referenced in Section 2.1 "Spent Fuel to be Stored" of the "Advanced NUHOMS® Horizontal Modular Storage System Safety Analysis Report" [B.3-1].

B.3.3 Design Criteria for Environmental Conditions and Natural Phenomena

B.3.3.1 Tornado Wind and Tornado Missiles

The design basis tornado wind and tornado missiles for the Standardized Advanced NUHOMS® Horizontal Modular Storage System AHSM are provided in Section 2.2.1 of reference [B.3-1] and for the NUHOMS®-MP187 cask in Section 3.2.1 of Volume 1 of reference [B.3-2]. The Standardized Advanced NUHOMS® Horizontal Modular Storage System components are designed and conservatively evaluated for the most severe tornado and missiles anywhere within the United States (Region I as defined in NRC Regulatory Guide 1.76 [B.3-9]) while the WCS CISF is in Region II, a less severe location with respect to tornado and tornado missiles.

The AHSM protects the DSC from adverse environmental effects and is the principal structure exposed to tornado wind and missile loads. Furthermore, all components of the AHSM (regardless of their safety classification) are designed to withstand tornadoes and tornado-based missiles. The MP187 cask protects the DSC during transit to the Storage Pad from adverse environmental effects such as tornado winds and missiles.

B.3.3.2 Water Level (Flood) Design

The 24PT1 DSCs and AHSMs are designed for an enveloping design basis flood, postulated to result from natural phenomena as specified by 10 CFR 72.122(b). The system is evaluated for a flood height of 50 feet with a water velocity of 15 fps.

The DSCs are subjected to an external hydrostatic pressure equivalent to the 50 feet head of water. The AHSM is evaluated for the effects of a water current of 15 fps impinging on the sides of a submerged AHSM. For the flood case that submerges the AHSM, the inside of the AHSM will rapidly fill with water through the AHSM vents.

As documented in Sections 2.4.2.2 and 3.2.2, the WCS CISF is not in a floodplain and is above the Probable Maximum Flood elevation and, therefore, will remain dry in the event of a flood.

B.3.3.3 Seismic Design

The seismic criteria for the Standardized Advanced NUHOMS® Horizontal Modular Storage System AHSM are provided in Section 2.2.3 of reference [B.3-1]. This system was designed for very high seismic regions, such as the west coast, and as such the design basis earthquake shown in Figures 2.2-1 and 2.2-2 of reference [B.3-1] for the AHSM easily envelops *the enveloping acceleration response spectra at the WCS concrete pad base and HSM center of gravity obtained by the WCS CISF soil-structure interaction (SSI) analysis* at all frequencies as demonstrated in Sections B.7.5 and B.7.8. Due to the very low accelerations, the ties between the individual modules and the shear keys used to transfer vertical motions are not required at the WCS CISF.

B.3.3.4 Snow and Ice Loading

The design basis snow and ice loading for the Standardized Advanced NUHOMS® Horizontal Modular Storage System are provided in Section 2.2.4 of reference [B.3-1]. Snow and ice loads for the AHSM are conservatively derived from ASCE 7 [B.3-10]. The maximum 100-year roof snow load, specified for most areas of the continental United States for an unheated structure, of 110 psf is assumed. Snow and ice loads for the on-site transfer cask with a loaded DSC are negligible due to the smooth curved surface of the cask, the heat rejection of the SFAs, and the infrequent short term use of the cask.

The snow and ice loads used in the evaluation of the Standardized Advanced NUHOMS® Horizontal Modular Storage System components envelope the maximum WCS CISF snow and ice loads of 10 psf.

B.3.3.5 Lightning

The likelihood of lightning striking the AHSM and causing an off-normal or accident condition is not considered a credible event. Simple lightning protection equipment and grounding for the AHSM structures is considered a miscellaneous attachment acceptable per the AHSM design.

B.3.4 Safety Protection Systems

The safety protection systems of the Standardized Advanced NUHOMS® Horizontal Modular Storage System are discussed in Section 2.3 of the "Advanced NUHOMS® Horizontal Modular Storage System Safety Analysis Report" [B.3-1].

B.3.4.1 General

The Standardized Advanced NUHOMS® Horizontal Modular Storage System is designed for safe confinement during dry storage of SFAs. The components, structures, and equipment that are designed to assure that this safety objective is met are summarized in Table B.3-2. The key elements of the Standardized Advanced NUHOMS® Horizontal Modular Storage System and its operation at the WCS CISF that require special design consideration are:

1. Minimizing the contamination of the DSC exterior.
2. The double closure seal welds on the DSC shell to form a pressure retaining confinement boundary and to maintain a helium atmosphere.
3. Minimizing personnel radiation exposure during DSC transfer operations.
4. Design of the cask and DSC for postulated accidents.
5. Design of the AHSM passive ventilation system for effective decay heat removal to ensure the integrity of the fuel cladding.
6. Design of the DSC basket assembly to ensure subcriticality.

B.3.4.2 Structural

The principal design criteria for the 24PT1 DSCs are presented in Section 2.3.2 of the "Advanced NUHOMS® Horizontal Modular Storage System Safety Analysis Report" [B.3-1]. The DSCs are designed to store intact, damaged and failed PWR FAs with or without Control Components. The fuel cladding integrity is assured by limiting fuel cladding temperature and maintaining a nonoxidizing environment in the DSC cavity.

The principal design criteria for the MP187 cask when used as a transfer cask are presented in Section 3.2.5.3 of the "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report" [B.3-2]. In this mode, the MP187 cask is designed for the on-site transfer of a loaded DSC from the Cask Handling Building to the AHSM.

B.3.4.3 Thermal

The thermal performance requirements for the Standardized Advanced NUHOMS® Horizontal Modular Storage System are described in Section 2.3.2 of the “Advanced NUHOMS® Horizontal Modular Storage System Safety Analysis Report” [B.3-1]. The AHSM relies on natural convection through the air space in the AHSM to cool the DSC. This passive convective ventilation system is driven by the pressure difference due to the stack effect (ΔP_s) provided by the height difference between the bottom of the DSC and the AHSM air outlet. This pressure difference is greater than the flow pressure drop (ΔP_f) at the design air inlet and outlet temperatures.

B.3.4.4 Shielding/Confinement/Radiation Protection

The shielding performance and radiation protection requirements for the Standardized Advanced NUHOMS® Horizontal Modular Storage System are described in Sections 2.3.2.5 and 2.3.5 of the “Advanced NUHOMS® Horizontal Modular Storage System Safety Analysis Report” [B.3-1]. The confinement performance requirements for the Standardized NUHOMS® Horizontal Modular Storage System are described in Section 2.3.2 of the “Advanced NUHOMS® Horizontal Modular Storage System Safety Analysis Report” [B.3-1] *for storage conditions. In addition, a bounding evaluation in WCS CISF SAR Section A.7.7 (also referenced in Section B.7.9) is performed to demonstrate that the confinement boundary for the 24PT1-DSC does not exceed ASME B&PV Subsection NB Article NB-3200 (Level A allowables) during normal conditions of transport to provide reasonable assurance that the confinement boundary is not adversely impacted by transport to the WCS CISF*.

The AHSM provides the bulk of the radiation shielding for the DSCs. The AHSM design is arranged in a back-to-back arrangement. Thick concrete supplemental shield walls are used at either end of an AHSM array to minimize radiation dose rates both on-site and off-site. The AHSMs provide sufficient biological shielding to protect workers and the public.

The MP187 cask is designed to provide sufficient shielding to ensure dose rates are ALARA during transfer operations and off-normal and accident conditions.

There are no radioactive releases of effluents during normal and off-normal storage operations. In addition, there are no credible accidents that cause significant releases of radioactive effluents from the DSC. Therefore, there are no off-gas or monitoring systems required for the system at the WCS CISF.

B.3.4.5 Criticality

The criticality performance requirements for the Standardized Advanced NUHOMS® Horizontal Modular Storage System are described in Section 2.3.4 of the “Advanced NUHOMS® Horizontal Modular Storage System Safety Analysis Report” [B.3-1].

For the DSCs, a combination of fixed poison in the basket and geometry are relied on to maintain criticality control. The structural analysis shows that there is no deformation of the basket under accident conditions that would increase reactivity.

B.3.4.6 Material Selection

Materials are selected based on their corrosion resistance, susceptibility to stress corrosion cracking, embrittlement properties, and the environment in which they operate during normal, off normal and accident conditions. The confinement boundary for the DSC materials meet the requirements of ASME Boiler and Pressure Vessel Code, Section III, Article NB-2000 and the specification requirements of Section II, Part D [B.3-8]. The DSC and cask materials are resistant to corrosion and are not susceptible to other galvanic reactions. Studies under severe marine environments have demonstrated that the shell materials used in the DSC shells are expected to demonstrate minimal corrosion during an 80-year exposure. The DSC internals are enveloped in a dry, helium-inerted environment and are designed for all postulated environmental conditions. The AHSM is a reinforced concrete component with an internal DSC support structure that is fabricated to ACI and AISC Code requirements. Both have durability well beyond a design life of 80 years.

B.3.4.7 Operating Procedures

The sequence of operations are outlined for the Standardized Advanced NUHOMS® System in Chapter 5 and B.5 for receipt and transfer of the DSCs to the storage pad, insertion into the AHSM, monitoring operations, and retrieval and shipping. Throughout Chapter 5, CAUTION statements are provided at the steps where special notice is needed to maintain ALARA, protect the contents of the DSC, or protect the public and/or ITS components of the Standardized Advanced NUHOMS® System.

B.3.5 References

B.3-1 AREVA TN Document, ANUH-01.0150, Revision 6, "Updated Final Safety Analysis Report for the Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, NRC Docket No. 72-1029.

B.3-2 "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report," NRC Docket No. 72-11, Revision 4.

B.3-3 AREVA TN Document NUH-05-151 Rev. 17, "NUHOMS®-MP187 Multi-Purpose Transportation Package Safety Analysis Report." (Basis for NRC CoC 71-9255).

B.3-4 Proposed SNM-1050, WCS *Consolidated* Interim Storage Facility Technical Specifications, Amendment 0.

B.3-5 American Concrete Institute, American Concrete Institute, Code Requirements for Nuclear Safety Related Concrete Structures, ACI 349-97, American Concrete Institute, Detroit Michigan.

B.3-6 American Concrete Institute, "Building Code Requirements for Reinforced Concrete," ACI-318, 1989 (92).

B.3-7 U.S. Nuclear Regulatory Commission, Certificate of Compliance for the Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, Certificate No. 1029, Amendment all.

B.3-8 American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NB, 1992 Edition with Addenda through 1994 with Code Case N-595-1.

B.3-9 Reg Guide 1.76, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants," Revision 1, March 2007.

B.3-10 American Society of Civil Engineers Standard ASCE 7-95, "Minimum Design Loads for Buildings and Other Structures," (Formerly ANSI A58.1).

Table B.3-1
Summary of WCS CISF Principal Design Criteria
(*5* pages)

Design Parameter	WCS CISF Design Criteria	Condition	Standardized Advanced NUHOMS® System Design Criteria
Type of fuel	Commercial, light water reactor spent fuel	Normal (Bounded)	*Advanced NUHOMS® FSAR Section 2.1*
Storage Systems	Transportable canisters and storage overpacks docketed by the NRC	Normal (Bounded)	71-9255 72-1029
Fuel Characteristics	Criteria as specified in previously approved licenses for included systems	Normal (Bounded)	*Advanced NUHOMS® FSAR Section 2.1*
Tornado (Wind Load) (AHSM)	Max translational speed: 40 mph Max rotational speed: 160 mph Max tornado wind speed: 200 mph Radius of max rotational speed: 150 ft Tornado pressure drop: 0.9 psi Rate of pressure drop: 0.4 psi/sec	Accident (Bounded)	*Advanced NUHOMS® FSAR Section 2.2.1 and Table 3.6-10* Max translational speed: 70 mph Max rotational speed: 290 mph Max tornado wind speed: 360 mph Radius of max rotational speed: 150 ft Tornado pressure drop: 3.0 psi Rate of pressure drop: 2.0 psi/sec
Tornado (Wind Load) (MP187 Cask)	Max translational speed: 40 mph Max rotational speed: 160 mph Max tornado wind speed: 200 mph Radius of max rotational speed: 150 ft Tornado pressure drop: 0.9 psi Rate of pressure drop: 0.4 psi/sec	Accident (*Bounded*)	*Rancho Seco FSAR Section 3.2.1 of Volume 1* Max translational speed: *NA* Max rotational speed: *NA* Max tornado wind speed: *360* mph Radius of max rotational speed: *NA* Tornado pressure drop: *NA* Rate of pressure drop: *NA*

Table B.3-1
Summary of WCS CISF Principal Design Criteria
(*5* pages)

Design Parameter	WCS CISF Design Criteria	Condition	Standardized Advanced NUHOMS® System Design Criteria
Tornado (Missile)	Automobile 4000 lb, 112 ft/s Schedule 40 Pipe 287 lb, 112 ft/s Solid Steel Sphere 0.147 lb, 23 ft/s	Accident (Bounded)	*Advanced NUHOMS® FSAR Section 2.2.1* Automobile 4000 lb, 195 ft/s 8” diameter *artillery* shell 276 lb, 185 ft/s Solid Steel Sphere *NA* 12” OD Steel Pipe 1500 lb, *205* fps Wood pole 1500 lb, 294 ft/s
Floods	*The WCS CISF is not in a floodplain and is above the Probable Maximum Flood elevation and will remain dry in the event of a flood.*	Accident (Bounded)	*Advanced NUHOMS® FSAR Section 2.2.2 and Table 3.6-10* Flood height 50 ft Water velocity 15 ft/s
Seismic (Ground Motion)	Site-specific ground-surface uniform hazard response spectra (UHRS) with 1E-4 annual frequency of exceedance (AFE) having peak ground acceleration (PGA) of 0.250 g horizontal and 0.175 g vertical. (Table 1-5 and Figure 1-5)	Accident (Bounded)	*Advanced NUHOMS® FSAR Section 2.2.3* Reg Guide 1.60 Response Spectra anchored at 1.5 g horizontal and 1.0 g vertical peak accelerations
Vent Blockage	For NUHOMS® Systems: Inlet and outlet vents blocked 40 hrs	Accident (Same)	*Advanced NUHOMS® FSAR Section 4.6.2 and Table 3.6-10* Inlet and outlet vents blocked 40 hrs
Fire/Explosion	For NUHOMS® Systems: Equivalent fire 300 gallons of diesel fuel	Accident (Same)	*Advanced NUHOMS® FSAR Section 4.6.4* Equivalent fire 300 gallons of diesel fuel
Cask Drop	For NUHOMS® Systems: Transfer Cask Horizontal side drop or slap down 80 inches(3)	Accident (Same)	*Section B.7.3 (New Evaluation)* Transfer Cask Horizontal side drop or slap down 80 inches(3)

Table B.3-1
Summary of WCS CISF Principal Design Criteria
(*5* pages)

Design Parameter	WCS CISF Design Criteria	Condition	Standardized Advanced NUHOMS® System Design Criteria
Transfer Load	For NUHOMS® Systems only: Normal insertion load 60 kips Normal extraction load 60 kips	*Normal* (Same)	*Section B.7.3 (New Evaluation) and Advanced NUHOMS® FSAR Section 3.6.2.2.5 and Table 3.6-10* Normal insertion load 60 kips Normal extraction load 60 kips
Transfer Load	For NUHOMS® Systems only: Maximum insertion load 80 kips Maximum extraction load 80 kips	Off-Normal/ Accident (Same)	*Section B.7.3 (New Evaluation) and Advanced NUHOMS® FSAR Section 3.6.2.2.7* Maximum insertion load 80 kips Maximum extraction load 80 kips
Ambient Temperatures	Normal temperature 44.1 – 81.5°F	Normal (Bounded)	*Advanced NUHOMS® FSAR Table 4.1-1* Normal temperature 0 - *104*°F(1)
Off-Normal Temperature	Minimum temperature 30.1°F Maximum temperature *113*°F	Off-Normal (Bounded)	*Advanced NUHOMS® FSAR Table 4.1-1* Minimum temperature -40.0°F Maximum temperature *117*°F(2)
Extreme Temperature	Maximum temperature 113°F	Accident (Bounded)	*Advanced NUHOMS® FSAR Table 4.1-1* Maximum temperature 120°F
Solar Load (Insolation)	Horizontal flat surface insolation 2949.4 BTU/day-ft^2 Curved surface solar insolation 1474.7 BTU/day-ft^2	Normal (Same)	*Advanced NUHOMS® FSAR Section 4.4.2.2* Horizontal flat surface insolation 2952 BTU/day-ft^2 Curved surface solar insolation *Not Specified*
Snow and Ice	Snow Load 10 psf	Normal (Bounded)	*Advanced NUHOMS® FSAR Section 2.2.4* Snow Load 110 psf
Dead Weight	Per design basis for systems listed in Table 1-1	Normal (Same)	*Advanced NUHOMS® FSAR Sections 3.1.2.1.3.1, 3.6.1.1.3, and 3.6.2.2.1 and Table 3.6-10*

Table B.3-1
Summary of WCS CISF Principal Design Criteria
(*5* pages)

Design Parameter	WCS CISF Design Criteria	Condition	Standardized Advanced NUHOMS® System Design Criteria
Internal and External Pressure Loads	Per design basis for systems listed in Table 1-1	Normal (Same)	*Advanced NUHOMS® FSAR* Section 3.1.2.1.3.2
Design Basis Thermal Loads	Per design basis for systems listed in Table 1-1	Normal (Same)	*Advanced NUHOMS® FSAR* Section 3.1.2.1.3.3
Operating Loads	Per design basis for systems listed in Table 1-1	Normal (Same)	*Advanced NUHOMS® FSAR Section* 3.1.2.2.2 *and Table 3.6-10*
Live Loads	Per design basis for systems listed in Table 1-1	Normal (Same)	*Advanced NUHOMS® FSAR Table 3.6-10* Design Load (including snow and ice) 200psf
Radiological Protection	Public wholebody ≤ 5 Rem Public deep dose plus individual organ or tissue ≤ 50 Rem Public shallow dose to skin or extremities ≤ 50 Rem Public lens of eye ≤ 15 Rem	Accident (Same)	*Chapter 9 demonstrates these limits are met* Public wholebody ≤ 5 Rem Public deep dose plus individual organ or tissue ≤ 50 Rem Public shallow dose to skin or extremities ≤ 50 Rem Public lens of eye ≤ 15 Rem
Radiological Protection	Public wholebody ≤ 25 mrem/yr(4) Public thyroid ≤ 75 mrem/yr(4) Public critical organ ≤ 25 mrem/yr(4)	Normal (Same)	*Chapter 9 demonstrates these limits are met* Public wholebody ≤ 25 mrem/yr(4) Public thyroid ≤ 75 mrem/yr(4) Public critical organ ≤ 25 mrem/yr(4)
Confinement	Per design basis for systems listed in Table 1-1	N/A	*Advanced NUHOMS® FSAR Section 7* [B.3-1] (leaktight)
Nuclear Criticality	Per design basis for systems listed in Table 1-1	N/A	*Advanced NUHOMS® FSAR Section 6*
Decommissioning	Minimize potential contamination	Normal (Same)	*Advanced NUHOMS® FSAR Section 14* Minimize potential contamination

Table B.3-1
Summary of WCS CISF Principal Design Criteria
(*5* pages)

Design Parameter	WCS CISF Design Criteria	Condition	Standardized Advanced NUHOMS® System Design Criteria
Materials Handling and Retrieval Capability	Cask/canister handling system prevent breach of confinement boundary under all conditions Storage system allows ready retrieval of canister for shipment off-site	Normal (Same)	*Advanced NUHOMS® FSAR Section 2.5.1* Cask/canister handling system prevent breach of confinement boundary under all conditions Storage system allows ready retrieval of canister for shipment off-site

Notes

1. *Not Used*
2. *Not Used*
3. 75g Side drop and 25g corner is equivalent to 80 inch drop.
4. In accordance with 10 CFR 72.104*(a)*(3) limits include any other radiation from uranium fuel cycle operations within the region.

Table B.3-2
Standardized Advanced NUHOMS® Horizontal Modular Storage System
Major Components and Safety Classifications

Component	10CFR72 Classification
Dry Shielded Canister (DSC)	Important to Safety(1)
Advanced Horizontal Storage Module (AHSM)	Important to Safety(1)
Basemat and Approach Slabs	Not Important to Safety
Transfer Equipment	
Cask	Important to Safety
Transport Trailer/Skid	Not Important to Safety
Ram Assembly	Not Important to Safety
Lubricant	Not Important to Safety
Auxiliary Equipment	
AHSM Temperature Monitoring	Not Important to Safety

Notes

1. Graded Quality

APPENDIX B.4
OPERATING SYSTEMS
Standardized Advanced NUHOMS® System

Table of Contents

List of Tables

B.4. OPERATING SYSTEMS

This Appendix provides information on the operating systems applicable to the Standardized Advanced NUHOMS® System Cask System identified in Chapter 4 of the SAR. Those systems include the concrete pad structures, cask storage system, cask transporter system and the optional AHSM thermal monitoring system.

B.4.1 Concrete Pad Structures

This section is applicable to the basemat and approach slabs for the NUHOMS® AHSM. The following discussion provides guidance for these structures; but as noted in Section B.4.1.3, the basemat and approach slabs are not-important-to-safety (NITS).

B.4.1.1 Operating Functions

The NUHOMS® System basemat and approach slabs are cast-in-place reinforced concrete foundation structures that support the AHSMs (the basemat) and provide for access and support of the transfer system (the approach slabs). The thickness of the basemat and the approach slab will be determined by Storage Area foundation analysis.

B.4.1.2 Design Description

The following provides a description of the design considerations that will be taken into account when designing the basemat and approach slabs.

The basemat and approach slab loads consist of both dead and live loads, seismic loads, and tornado wind loads imposed on the AHSM array and transferred to the basemat.

The dead load consists of the weight of the basemat or approach slab.

Live loads for the basemat include the weight of the loaded DSC, the weight of the modules and shield walls plus an additional 200 psf applied over the area of the AHSM base to account for snow and ice loads, safety railings on the roofs of the AHSM, etc. These loads are provided in Table B.4-1. The values shown in Table B.4-1 are based on nominal material density; however, the as-built weight can vary ±5%, therefore; the storage pad is designed to accommodate 105% of the nominal weight shown in the table.

Live loads for the approach slab include the MP187 cask and transfer vehicle design payload which is 300,000 lb. Additional live loads of 200 psf are applied over the surface area of the approach slabs.

Localized front (furthest from AHSM) jack loads of 85,000 lb and rear jack loads of 109,000 lb are considered in designing the approach slab (this conservatively assumes the load of the DSC is carried only by the two rear jacks as the DSC is inserted into the AHSM). These loads are spread as necessary by use of spreading plates or other suitable means.

The site-specific soil conditions at the Waste Control Specialists, LLC (WCS) Consolidated Interim Storage Facility (CISF) are considered in the basemat design based on basemat and AHSM acceleration resulting from seismic activity.

Tornado wind loads acting on the AHSM array are transferred to the basemat as friction and pressure loads. Generic design pressure loads acting on the NUHOMS® system due to tornado wind loading are described in the Standardized Advanced NUHOMS® UFSAR, Section 3.6.2.2.4 [B.4-1]. These may be replaced by the site-specific tornado loads which are significantly lower.

The basemat for the NUHOMS® AHSMs will be level and constructed with a "Class B" surface flatness finish as specified in ACI 301-89 [B.4-2], or FF 25 per ASTM E 1155. Specifically, finishes with Class B tolerances shall be true planes within 1/4" in 10 feet, as determined by a ten foot straightedge placed anywhere on the slab in any direction. Although Class B surface finish is required, for modules with mating surfaces Class A surface flatness or FF 50 per ASTM E 1155 is recommended in order to provide better fit up and minimize gaps.

The surface finish for the basemat may be broomed, troweled or ground surface. Laser guided finishers and certified personnel may be utilized for construction of the basemat to assure proper finish, levelness and flatness. Alternatively, when grouted installation of AHSMs is used, a reduced flatness may be targeted. The grouted installation consists of setting the modules on approximately one-inch thick stainless steel shims and grouting between the module and the pad using cement-based grouts.

The slope of the approach slabs shall not exceed 7% which is the adjustable limit of brake of the transfer vehicle.

The overall dimensions of the AHSM modules are listed in Table B.4-2. When determining the length of the basemat, 1/2" should be added to the width of each module to account for as-built conditions in the modules and basemat. The basemat typically extends one foot beyond the front face of the module and matches the elevation of the approach slab. Thus, the width of a basemat for the double array is typically two feet wider than the modules. Similarly, the basemat typically extends one foot beyond the end walls.

To maintain levelness and stability of the module array, the joints intersecting the basemat should be minimized. Joints with expansion and sealant material must be compatible with expected basemat temperatures.

Two methods of AHSM array expansion are permitted. One involves the temporary removal of end walls, installation of new modules, and then re-installation of the end walls. This method requires that the existing modules adjacent to the end walls be empty (unloaded) during array expansion. The other method of array expansion effectively buries the existing end walls by placing new modules directly adjacent to the end walls with new end walls placed at the end of the expanded array. The length of the basemat should be designed to accommodate the planned method of array expansion, as applicable. The basemat shall be designed to a maximum differential settlement of 1/4 inch, front to back and side-to-side (AHSM array).

Finally, approach roads and aprons should be designed or repaired to eliminate features such as speed bumps, drains or potholes that would result in a difference of more than 5 inches in surface flatness over any 10-foot wide by 20-foot long area.

B.4.1.3 Safety Considerations

The foundation is not relied upon to provide safety functions. There are no structural connections or means to transfer shear between the AHSM base unit module and the foundation slab. Therefore, the basemat and approach slabs for the AHSMs are considered NITS and are designed, constructed, maintained, and tested as commercial-grade items.

B.4.2 Cask Storage System

This section is applicable to the *NUHOMS®-24PT1 canisters;* NUHOMS® AHSM*; and MP187 cask configured for transfer operations*.

B.4.2.1 Operating Function

The overall function of the AHSM used at the WCS CISF is to safely provide interim storage of spent nuclear fuel (SNF) canisters. These canisters provide a convenient means to place set quantities of SNF into dry storage in a way that allows easy retrieval of the canisters for off-site shipment.

The NUHOMS®-24PT1 canisters containing SNF assemblies are designed for storage in accordance with 10 CFR 72, and for transportation in accordance with 10 CFR 71. The main function of sealed canisters is to accommodate SNF assemblies, and provide confinement and criticality control during normal operation and postulated design-basis accident conditions for on-site storage. *The NUHOMS®-24PT1 canister is shown in drawing NUH-05-4010 Revision 5, included in Section B.4.6.*

The AHSM is designed in accordance with 10 CFR 72, and provides horizontal on-site storage of the sealed SNF canisters. The main function of the AHSM is to provide safe, long-term storage of NUHOMS®-24PT1 canisters containing SNF assemblies.

The AHSM design function is to passively cool the canisters by air convection. The AHSM also provides the capability for canister transfer from their associated transportation/transfer casks. *The AHSM is shown in drawing NUH-03-4011 Revision 7, included in Section B.4.6.*

The MP187 cask, in the transfer configuration, design function is to protect the canisters and provide shielding from the radiation sources inside the canisters during transfer operations. The MP187 cask in the transfer configuration is shown in drawings NUH-05-4001 Revision 15 and NUH-05-4003 Revision 10, included in Section A.4.6.

B.4.2.2 Design Description

The NUHOMS®-24PT1 canister is a stainless steel flat head pressure vessel that provides confinement and is designed to withstand all normal condition loads as well as the off-normal and accident condition loads created by earthquakes, tornadoes, flooding, and other natural phenomena.

The AHSM is a low profile, reinforced concrete structure designed to withstand all normal condition loads as well as the off-normal and accident condition loads created by earthquakes, tornadoes, flooding, and other natural phenomena. The AHSM is also designed to withstand off-normal and accident condition loadings postulated to occur during design basis accident conditions such as a complete loss of ventilation.

The MP187 cask, in the transfer configuration, is used to transfer the canisters from the CHB to the storage pad where the cask is mated to the AHSM. The cask is designed to withstand all normal condition loads as well as the off-normal and accident condition loads created by earthquakes, tornadoes, flooding, and other natural phenomena.

B.4.2.3 Safety Considerations

The NUHOMS®-24PT1 canisters are Important- to-Safety (ITS), Quality Category A components.

The AHSM is an important-to-safety (ITS), Quality Category B component. *The MP187 cask is an ITS, Quality Category B component.*

B.4.3 Cask Transporter System

This section is applicable to the cask transporter system for the MP187 cask. This following provides a general description of the cask transporter system, however as noted Section B.4.3.3, this equipment is NITS.

B.4.3.1 Operating Function

The cask transporter system for the MP187 cask is designed to move the loaded MP187 cask in the on-site transfer configuration between the Cask Handling Building and the Storage Area and transfer the canister from the MP187 cask to the AHSM.

B.4.3.2 Design Description

The transfer vehicle includes a transfer skid which cradles the top and bottom lifting trunnions of the cask, and is designed to be moved with the skid and cask. The transfer vehicle is also used in the Storage Area to transfer the canister from an MP187 cask to an AHSM. It features a transfer skid, a skid positioner, a hydraulic ram system and hydraulic jacks for stabilization. The system utilizes a self-contained hydraulic ram to hydraulically push the canister out of the MP187 cask and into the AHSM. The alignment of the MP187 cask and the AHSM is verified by an alignment system.

B.4.3.3 Safety Considerations

All transfer equipment is designed to limit the height of the MP187 cask to less than 80” above the surrounding surface; therefore, it is NITS and is designed, constructed, maintained, and tested as commercial-grade items.

B.4.4 Storage Module Thermal Monitoring System

Instrumentation is provided for monitoring AHSM temperatures as described in Section 5.1.3 AHSM Thermal Monitoring Program of the Technical Specifications [B.4-3] that may be used as one of two options provided to prevent conditions that could lead to exceeding the concrete and fuel clad temperature criteria.

B.4.5 References

B.4-1 AREVA TN Document, ANUH-01.0150, Revision 6, "Updated Final Safety Analysis Report for the Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, NRC Docket No. 72-1029.

B.4-2 American Concrete Institute, "Specifications for Structural Concrete for Buildings," ACI 301, 1989.

B.4-3 Proposed SNM-1050, WCS *Consolidated* Interim Storage Facility Technical Specifications, Amendment 0.

B.4.6 Supplemental Data Drawings

The following drawings are located as noted below:

1. *"General License NUHOMS® 24PT1-DSC Main Assembly (six sheets)," NUH-05-4010, Revision 5 (See Section 1.5.2 of the Standardized Advanced NUHOMS® UFSAR [B.4-1]).*

2. *"General License NUHOMS® Advanced Horizontal Storage Module Main Assembly (nine sheets)," NUH-003-4011, Revision 7 (See Section 1.5.2 of the Standardized Advanced NUHOMS® UFSAR [B.4-1]).*

Table B.4-1
Weight of AHSM

Component	Nominal Weight kips(1)	105% weight kips
AHSM	318.3	334.3
End Walls	188	197.4

Notes

1. Values reported in this table are for the purposes of designing the basemat and may differ from other SAR values.

Table B.4-2
AHSM Overall Dimensions

Width	Depth	Height w/o vent covers	Height w/ vent covers
101”	235”	222”	247”

APPENDIX B.5
OPERATING PROCEDURES
Standardized Advanced NUHOMS® System

Table of Contents

List of Figures

B.5. OPERATING PROCEDURES

This chapter presents the operating procedures for the Standardized Advanced NUHOMS® System containing the NUHOMS® 24PT1-DSCs originally loaded and stored under Certificate of Compliance (CoC) 1029 with the addition of the NUHOMS®-MP187 transport/transfer cask (TC) qualified for transfer operations with the 24PT1 DSC. The procedures include receipt of the NUHOMS®-MP187 Cask; placing the TC onto the transfer skid on the transfer vehicle, transfer to the Storage Area, DSC transfer into the Standardized Advanced Horizontal Storage Module (AHSM), monitoring operations, and DSC retrieval from the AHSM. The NUHOMS®-MP187 cask transfer equipment, and the Cask Handling Building systems and equipment are used to accomplish these operations. Procedures are delineated here to describe how these operations may be performed and are not intended to be limiting. Temporary shielding may be used throughout as appropriate to maintain doses as low as reasonably achievable (ALARA).

The following sections outline the typical operating procedures for the Standardized Advanced NUHOMS® System. These procedures have been developed to minimize the amount of time required to complete the subject operations, to minimize personnel exposure, and to assure that all operations required for transfer, and storage are performed safely. Operations may be performed in a different order if desired to better utilize personnel and minimize dose as conditions dictate.

Pictograms of the Standardized Advanced NUHOMS® System operations are presented in Figure B.5-1.

The generic terms used throughout this section are as follows.

- TC, or transfer cask is used for the NUHOMS®-MP187 transportation/transfer cask.
- DSC is used for the NUHOMS® 24PT1-DSC.
- AHSM is used for the Standardized Advanced Horizontal Storage Module.

B.5.1 Procedures for Loading the DSC and Transfer to the AHSM

A pictorial representation of key phases of this process is provided in Figure B.5-1.

B.5.1.1 Receipt of the Loaded NUHOMS®-MP187 Cask

Procedures for receiving the loaded TC after shipment are described in this section. These procedures are taken from reference [B.5-1]*, and must remain consistent with* [B.5-1].

1. Verify that the tamperproof seals are intact.
2. Remove the tamperproof seals.
3. Remove the impact limiter attachment bolts from each impact limiter and remove the impact limiters from the TC.
4. Remove the transportation skid personnel barrier and skid support structure (closure assembly).
5. Take contamination smears on the outside surfaces of the TC. If necessary, decontaminate the TC until smearable contamination is at an acceptable level.
6. Attach *the WCS Lift Beam Assembly* to TC top and bottom ends.
7. Using the overhead crane, lift the TC from the railcar.

CAUTION: Verify that the TC is not lifted more than 80" above the adjacent surface in accordance with the limits specified in Section 5.2.1 of the Technical Specifications [A.5-2].

   a. Remove upper and lower trunnion plugs.
   b. Inspect the trunnion sockets for excessive wear, galling, or distortion in accordance with the transport license requirements [B.5-1].
   c. Install the upper and lower trunnions. Torque trunnion attachment bolts to at least 200 ft-lbs in accordance with the transport license requirements [B.5-1].

8. Place the TC onto the transfer cask skid trunnion towers.
9. Inspect the trunnions to ensure that they are properly seated onto the skid.
10. Remove the *WCS Lift Beam Assembly*.
11. Install the cask shear key plug assembly.
12. Install the on-site support skid pillow block covers.

13. Any time prior to removing the TC top cover plate or the bottom ram access cover plate, sample the TC cavity atmosphere through the vent port. Flush the TC interior gases to the radwaste system if necessary.

14. Draw a vacuum on the TC cavity and helium leak test the DSC in accordance with reference [B.5-3] requirements.

B.5.1.2 Transfer to the AHSM

CAUTION: Verify that the requirements of Section 5.2.1 of the Technical Specifications [B.5-2] are met prior to the next step. The maximum lifting height and ambient temperature requirements must be met during transfer from the Cask Handling Building to the AHSM.

1. Move the TC from the Cask Handling Building to the storage pad along the designated transfer route.

2. Prior to the TC arrival at the AHSM, remove the AHSM door, inspect the cavity of the AHSM, removing any debris and ready the AHSM to receive a DSC. The doors on adjacent AHSMs must remain in place.

CAUTION: The inside of empty modules have the potential for high *dose* rates due to adjacent loaded modules. Proper ALARA practices should be followed for operations inside these modules and in the areas outside these modules whenever the door from an empty AHSM has been removed.

3. Inspect the AHSM air inlet and outlet to ensure that they are clear of debris. Inspect the screens on the air inlet and outlet for damage.

4. Verify specified lubrication of the DSC support structure rails.

5. Once at the storage pad, position the transfer vehicle to within a few feet of the AHSM.

   Note: If performing inspection of the DSC surface per reference [B.5-3] requirement, install inspection apparatus between the TC and the AHSM.

6. Check the position of the transfer vehicle to ensure the centerline of the AHSM and TC approximately coincide. If the transfer vehicle is not properly oriented, reposition the transfer vehicle, as necessary.

7. Unbolt and remove the TC top cover plate.

8. Verify the DSC serial number against appropriate records.

CAUTION: High dose rates are expected after removal of the TC top cover plate. Proper ALARA practices should be followed.

9. Back the transfer vehicle to within a few inches of the AHSM/inspection apparatus, set the transfer vehicle brakes and disengage the tractor, if applicable. Extend the transfer vehicle vertical jacks.

10. Use the skid positioning system to bring the TC into approximate vertical and horizontal alignment with the AHSM. Using alignment equipment and the alignment marks on the TC and the AHSM, adjust the position of the TC until it is properly aligned with the AHSM.

11. Using the skid positioning system, fully insert the TC into the AHSM/inspection apparatus access opening docking collar.

12. Secure the TC to the front wall embedments of the AHSM using the cask restraints.

13. After the TC is docked with the AHSM/inspection apparatus, verify the alignment of the TC using the alignment equipment.

14. Remove the bottom ram access cover plate. Position the ram behind the TC in approximate horizontal alignment with the TC and level the ram. Extend the ram through the bottom TC opening into the DSC grapple ring.

15. Operate the ram grapple and engage the grapple arms with the DSC grapple ring.

16. Recheck all alignment marks and ready all systems for DSC transfer.

17. Activate the ram to initiate insertion of the DSC into the AHSM. Stop the ram when the DSC reaches the support rail stops at the back of the module.

    Note: Performing inspection of the DSC surface, as required, by the aging management program while the DSC is being transferred from the TC to the AHSM.

18. Disengage the ram grapple mechanism so that the grapple is retracted away from the DSC grapple ring.

19. Retract and disengage the ram system from the TC and move it clear of the TC. Remove the cask restraints from the AHSM.

20. Using the skid positioning system, disengage the TC from the AHSM/inspection apparatus access opening.

21. Remove the inspection apparatus if used.

22. Install the DSC seismic restraints through the AHSM door opening.

CAUTION: High dose rates are expected in the AHSM cavity after removal of the AHSM door. Proper ALARA practices should be followed.

23. The transfer vehicle can be moved, as necessary, to install the AHSM door. Install the AHSM door and secure it in place.

24. Replace the TC top cover plate and ram access cover plate. Secure the skid to the transfer vehicle.

25. Move the transfer vehicle and TC to the designated area. Return the remaining transfer equipment to the Storage Area.

26. Remove the AHSM Door and adjust the seismic restraints on the DSC one week following initial placement.

B.5.1.3 Monitoring Operations

27. Perform routine security surveillance in accordance with the security plan.

28. Perform a daily visual surveillance of the AHSM air inlet and outlet (bird screens) to verify that no debris is obstructing the AHSM vents in accordance with Section 5.1.3(a) of the Technical Specification [B.5-2] requirements, or, perform a temperature measurement for each AHSM in accordance with Section 5.1.3(b) of the Technical Specifications [B.5-2] requirements.

B.5.2 Procedures for Retrieval and Off-Site Shipment

The following section outlines the procedures for retrieving the DSC from the AHSM for shipment off-site.

B.5.2.1 DSC Retrieval from the AHSM

CAUTION: Verify that the requirements of Section 5.2.1 of the Technical Specifications [B.5-2] are met prior to the next step. The maximum lifting height and ambient temperature requirements must be met during transfer from the AHSM to the Cask Handling Building.

1. Ready the TC, transfer vehicle, and support skid for service. Remove the top cover and ram access plates from the TC. Move the transfer vehicle to the AHSM.

2. Remove the AHSM door and the DSC seismic restraints. Position the transfer vehicle to within a few feet of the AHSM.

3. Check the position of the transfer vehicle to ensure the centerline of the AHSM and TC approximately coincide. If the transfer vehicle is not properly oriented, reposition the transfer vehicle as necessary.

CAUTION: High dose rates are expected in the AHSM cavity after removal of the AHSM door. Proper ALARA practices should be followed.

4. Back the TC to within a few inches of the AHSM, set the transfer vehicle brakes and disengage the tractor, if applicable. Extend the transfer vehicle vertical jacks.

5. Use the skid positioning system to bring the TC into approximate vertical and horizontal alignment with the AHSM. Using alignment equipment and the alignment marks on the TC and the AHSM, adjust the position of the TC until it is properly aligned with the AHSM.

6. Using the skid positioning system, fully insert the TC into the AHSM access opening docking collar.

7. Secure the TC to the front wall embedments of the AHSM using the cask restraints.

8. After the TC is docked with the AHSM, verify the alignment of the TC using the alignment equipment.

9. Position the ram behind the TC in approximate horizontal alignment with the TC and level the ram. Extend the ram through the TC into the AHSM until it is inserted in the DSC grapple ring.

10. Operate the ram grapple and engage the grapple arms with the DSC grapple ring.

11. Recheck all alignment marks and ready all systems for DSC transfer.

12. Activate the ram to pull the DSC into the TC.

13. Once the DSC is seated in the TC, disengage the ram grapple mechanism so that the grapple is retracted away from the DSC grapple ring.

14. Retract and disengage the ram system from the TC and move it clear of the TC. Remove the cask restraints from the AHSM.

15. Using the skid positioning system, disengage the TC from the AHSM access opening.

CAUTION: The inside of empty modules have the potential for high *dose* rates due to adjacent loaded modules. Proper ALARA practices should be followed for operations inside these modules and in the areas outside these modules whenever the door from the empty AHSM has been removed.

16. Bolt the TC top cover plate and the ram access cover plate into place, tightening the bolts to the required torque in a star pattern.

17. Retract the vertical jacks and disconnect the skid positioning system.

18. Ready the transfer vehicle for transfer.

19. Replace the AHSM door and DSC seismic restraints on the AHSM.

20. Move the TC from the storage pad to the Cask Handling Building along the designated transfer route.

21. Prepare the transportation cask for transport in accordance with *Certificate of Compliance No. 9255*.

B.5.3 References

B.5-1 U.S. Nuclear Regulatory Commission, "Certificate of Compliance No. 9255, Revision 12 for the Model No. NUHOMS®-MP187 Multi-Purpose Cask (Docket 71-9255).

B.5-2 Proposed SNM-1050, WCS *Consolidated* Interim Storage Facility Technical Specifications, Amendment 0.

B.5-3 "Post Transport Package Evaluation," QP-10.02, Revision *1*.

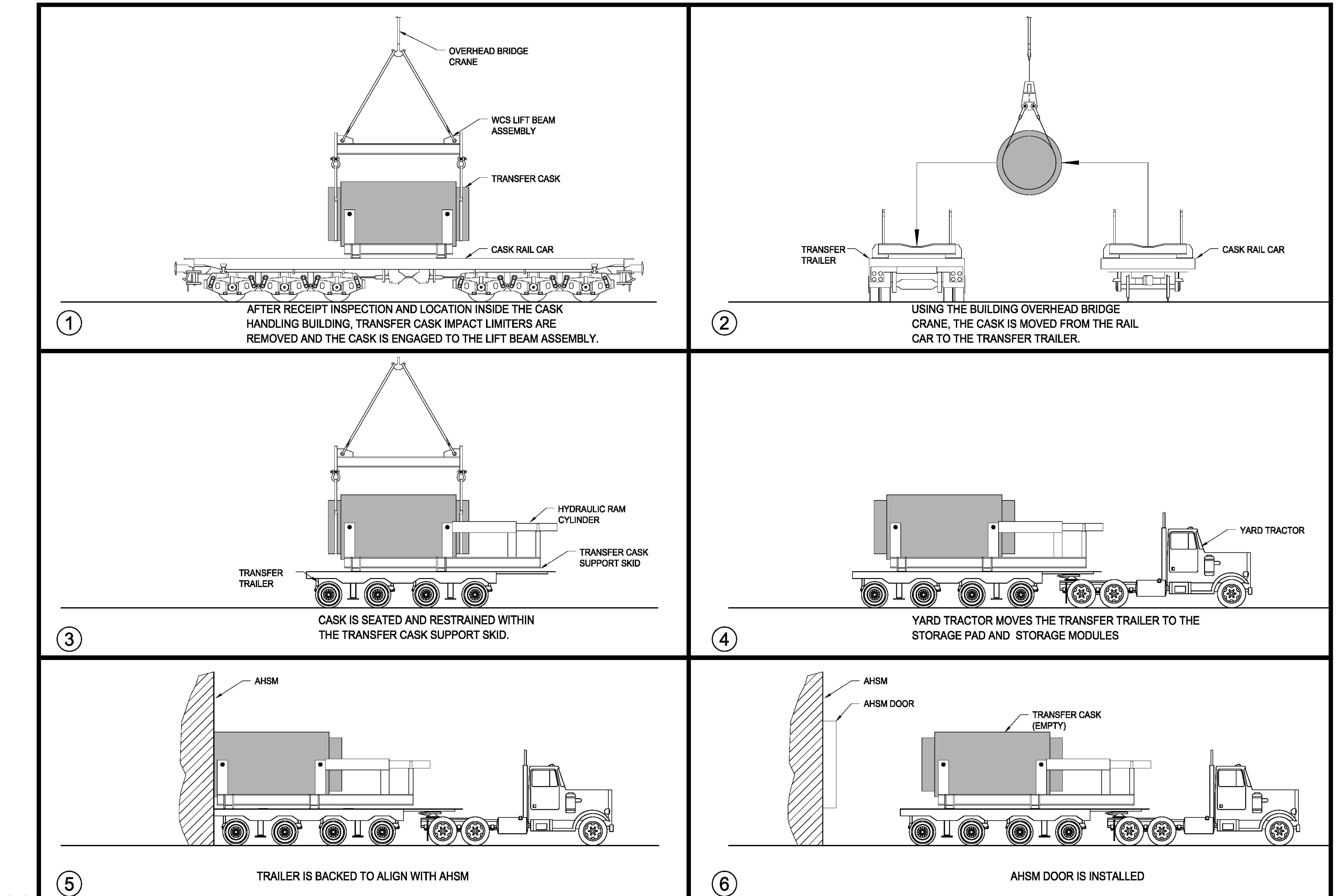


Figure B.5-1
Standardized Advanced NUHOMS® System Loading Operations

APPENDIX B.6
WASTE CONFINEMENT AND MANAGEMENT
Standardized Advanced NUHOMS® System

Table of Contents

B.6. WASTE CONFINEMENT AND MANAGEMENT

No change or additional information required for the Advanced NUHOMS® System containing the NUHOMS® 24PT1-DSCs for Chapter 6.

APPENDIX B.7
STRUCTURAL EVALUATION
Standardized Advanced NUHOMS® System

Table of Contents

List of Tables

List of Figures

B.7. STRUCTURAL EVALUATION

This Appendix describes the structural evaluation of the Standardized Advanced NUHOMS® System components utilized for storage of canisterized spent nuclear fuel (SNF) at the Waste Control Specialists, LLC (WCS) Consolidated Interim Storage Facility (CISF). As presented in Chapter 1, Table 1-1, the Standardized Advanced NUHOMS® System storage components include the 24PT1 Dry Shielded Canister (DSC or canister) and the AHSM concrete overpack.

The 24PT1 DSC is described in Section 3.1.1.1 of the Standardized Advanced NUHOMS® Updated Final Safety Analysis Report (UFSAR) [B.7-1]. The AHSM is described in Section 3.1.1.2 of [B.7-1]. Both of these components are approved by the NRC [B.7-6] for storage of SNF under the requirements of 10 CFR Part 72.

At the WCS CISF, the NUHOMS®-MP187 cask will be used for on-site transfer operations. The MP187 cask is a multi-purpose cask approved by the NRC for on-site transfer of the FO-, FC-, and FF- DSCs and Greater Than Class C (GTCC) waste canisters [B.7-2], and as a transportation cask for off-site shipments of the FO-, FC-, FF-, 24PT1 DSCs [B.7-3]. Volume I and Volume III of the Rancho Seco Independent Spent Fuel Storage Installation Final Safety Analysis Report (ISFSI FSAR) [B.7-4] describe the MP187 cask when used as on-site transfer cask under 10 CFR Part 72. Section 1.2 of the NUHOMS®-MP187 Multi-Purpose Transportation Package Safety Analysis Report (SAR) [B.7-5] describes the MP187 cask when used as a transportation cask under 10 CFR Part 71.

This appendix is prepared to demonstrate that the licensed canisters and AHSM storage components are qualified to safely transfer and store SNF and GTCC waste at the WCS CISF. Additionally, this appendix provides the justification to allow use of the MP187 cask for on-site transfer of the canister, consistent with the cask's allowable payloads in the MP187 cask's transportation license.

The structural evaluations presented herein are based on existing analyses as documented in [B.7-1] for the 24PT1 DSC and the AHSM and [B.7-4] for the MP187 cask *except for the qualification of the 24PT1-DSC confinement boundary during Normal Conditions of Transport in Section B.7.9 which points to the evaluation documented in Section A.7.7.2.*

<u>MP187 Cask</u>

The design basis design criteria for the MP187 cask as an on-site transfer cask for the canisters is provided in [B.7-4] Volume I Table 3-4, Table 3-8, Table 3-9, and Table 3-10. The loading criteria summary shown in [B.7-4] Table 3-4 bounds the loading criteria for the WCS CISF as specified in Appendix B.3, Table B.3-1 (with the exception of seismic loading which is addressed in Section B.7.5).

Canister

The 24PT1 DSC design approach, design criteria and load combinations for transfer and storage conditions are summarized in Section 2.2, Section 3.1.2, and Table 3.1-2 through Table 3.1-7 of [B.7-1]. The codes and standards used for design and fabrication of the canister are provided in Table 3.1-1 of [B.7-1]. Section 3.6.1 discusses the results of the analyses for the canister.

Advanced Horizontal Storage Module (AHSM)

The design approach, design criteria and loading combinations for the reinforced concrete AHSM and its DSC support structure are discussed in Section 2.2, Section 3.1.2, and Table 3.1-9 through Table 3.1-13 of [B.7-1]. The codes and standards used for design and fabrication of the AHSM are provided in Table 3.1-1 of [B.7-1]. Section 3.6.2 discusses the results of the analyses for the AHSM.

B.7.1 Discussion

As discussed in Chapter 1, the 24PT1 DSCs, currently stored inside AHSMs at the San Onofre Nuclear Generating Station (SONGS) ISFSI, will be transported to the WCS CISF utilizing the NUHOMS®-MP187 Transportation Cask. The canisters and the AHSM are Standardized Advanced NUHOMS® System components for the storage of SNF under NRC Certificate of Compliance No. 1029 [B.7-6] and are described in Chapter 1 of [B.7-1]. The MP187 transportation cask is licensed under NRC Certificate of Compliance (CoC) No. 9255 [B.7-3].

At the WCS CISF, the canisters will be stored inside newly fabricated AHSMs utilizing the MP187 cask for on-site transfer operations. The MP187 cask is a multi-purpose cask licensed as an on-site transfer cask [B.7-2] under 10 CFR Part 72 as described in [B.7-4].

As described in [B.7-1] the canister and the AHSM utilize the OS197 transfer cask for on-site transfer operations. The OS197 transfer cask is licensed under CoC No. 1004 and is described in the Standardized NUHOMS® UFSAR [B.7-7]. This appendix reconciles the design basis analyses of the 24PT1 DSC in the OS197 transfer cask *(that will not be used at the WCS CISF)* to justify use of the MP187 cask for transfer of the 24PT1 DSC at the WCS CISF.

The design basis seismic criteria for the canister and AHSM significantly exceed the seismic criteria for the WCS CISF (see Figure B.7-2). Hence, no reconciliation for seismic loads for the canister and AHSM need to be performed in this appendix.

The qualification of the MP187 cask for use as the on-site transfer cask at WCS CISF is based on the design basis analysis as documented in [B.7-4]. The cask stability evaluations in [B.7-4] use the hypothetical case of the cask as a storage component, and hence in the vertical configuration, as bounding the horizontal configuration in the transfer mode.

Finally, a bounding evaluation in Section B.7.9 is performed to demonstrate that the confinement boundaries for the 24PT1-DSC does not exceed ASME B&PV Subsection NB Article NB-3200 (Level A allowables) during normal conditions of transport to provide reasonable assurance that the confinement boundary is not adversely impacted by transport to the WCS CISF.

B.7.2 Summary of Mechanical Properties of Materials

The material properties for the canister and the AHSM are provided in Section 3.3 of [B.7-1].

The material properties for the MP187 cask are provided in Section 2.3 of [B.7-5].

B.7.3 Structural Evaluation of MP187 Transfer Cask with Canister (Transfer Configuration at WCS CISF)

This section reconciles the use of the MP187 cask for transfer of the canister at the WCS CISF. This section also evaluates the 24PT1 DSC as a payload in the MP187 cask.

B.7.3.1 Evaluation of MP187 Cask Loaded with a Canister

The 10 CFR Part 71 evaluation of the canister in the MP187 cask is contained in Appendix A of the NUHOMS®-MP187 Multi-Purpose Transportation Package Safety Analysis Report (SAR) [B.7-5]. This section presents the evaluation of the canister in the MP187 cask for transfer operations under 10CFR Part 72. As in the 10 CFR Part 71 evaluations in Appendix A of [B.7-5], the evaluation presented herein is based on the design similarities between the FO- and FC- DSCs and the 24PT1 DSC.

As shown in Table A2.1-1 of [B.7-5], reproduced here as Table B.7-1, the 24PT1 DSC in [B.7-1] is the same as the FO DSC in [B.7-4], except that the 24PT1 DSC has a modified spacer disc spacing and support rod configuration. Sections A2.6.11.A and A2.6.11.B of [B.7-5] addressed these differences and concluded that the FO- and FC- DSCs configuration bounds the 24PT1 DSC configuration.

Table A2.2-1 of [B.7-5], reproduced here as Table B.7-2, shows that the 24PT1 DSC weight, center of gravity (cg) and weight moment of inertia (MOI) are bounded by those of the FO-, FC-, and FF- DSCs. As shown in this table, the 24PT1 DSC weight (78,400 lbs) is between the weight of the heaviest DSC (the FC- DSC with a weight of 81,120 lbs) and the lightest DSC (the FF- DSC with a weight of 74,900 lbs). This ensures that the effect of the lighter canister (increasing g-loads during postulated drop) and a heavier canister (higher stresses for non-drop loading conditions) envelop the 24PT1 DSC.

The total weight of the loaded MP187 cask (on-site transfer configuration) ranges from 239,700 lbs (with FC- DSC) to 233,500 lbs (with FF- DSC). This range bounds the total weight of 237,200 lbs (with 24PT1 DSC). Thus, the MP187 cask loaded with a FO- and FC- DSC configuration bounds the MP187 loaded with a 24PT1 DSC configuration [B.7-5, Table A2.2-2].

Section B.7.8 presents an alternate evaluation of the MP187 cask in the transfer configuration at the WCS CISF.

Based on the evaluation above, the structural evaluation of the MP187 cask documented in [B.7-4] for the MP187 cask loaded with the FO- and FC- DSCs is applicable to the MP187 cask loaded with a 24PT DSC.

B.7.3.2 Evaluation of the Canister in the MP187 Transfer Cask

The structural analysis of the canister for normal, off-normal, and accident loads is presented in Section 3.6.1, Section 11.1, and Section 11.2, respectively, of [B.7-1]. Pertinent transfer and handling loads and load combinations applicable to the canister are described in Table 3.6-1 of [B.7-1]. Results for normal and off-normal conditions for the canister shell assembly are summarized in Table 3.6-2, and for accident conditions in Table 3.6-3 of [B.7-1]. Controlling load combination results for the canister shell assembly subcomponents for normal, off-normal, and accident conditions are presented in Table 3.6-4 through Table 3.6-6 of [B.7-1]. Results for normal, off-normal, and accident conditions for the basket assembly subcomponents are summarized in Table 3.6-7 through Table 3.6-9 of [B.7-1].

The above design basis structural evaluations involved transfer operations of the canister in the OS197 transfer cask. The OS197 transfer cask is described in Section 4.2.3.3 of [B.7-7]. The discussion below provides the basis for acceptance of the MP187 cask for transfer operations of the canister.

Table B.7-3 presents a comparison of the OS197 transfer cask and the MP187 cask. In the canister design basis analysis the transfer cask is conservatively assumed to be rigid. Therefore, differences in stiffness due to different cask dimensions (shell thickness, cask length, etc.) between the OS197 transfer cask and MP187 cask have no impact on the canister analyses. Only the interface dimensions (cask cavity diameter, cask rail thickness and cask rail locations) may have an effect on the analyses only when the cask is in the horizontal orientation (e.g., side drop is the controlling case). As shown in Table B.7-3 the interface dimensions are the same between the two casks, except for the cask rail locations, where the rails are located at ±18.5º in the OS197 transfer cask and at ±30º in the MP187 cask. However, as shown in Figure B.7-1 the rails in the MP187 cask are located in the thickened region of the spacer disc, whereas in the OS197 transfer cask the rails are located in the thin region of the spacer disc perimeter. The side drop analyses are performed at multiple drop orientations of 0º, 18.5º and 45º. The 18.5º case corresponds to a drop on a single rail and represents the worst drop case. Thus, basket spacer disc stresses in the OS197 transfer cask are considered bounding.

Based on the evaluation above, the structural evaluation of the canister documented in Section 3.6 and Section 11.0 of [B.7-1] is applicable to the canister loaded in the MP187 cask for transfer operations at the WCS CISF.

B.7.4 Structural Analysis of AHSM with a Canister (Storage Configuration)

This section evaluates the AHSM loaded with the canister for service at the WCS CISF. The evaluation is based on the design basis stress analyses of these components documented in [B.7-1].

The structural analysis of the canister in the storage configuration and the AHSM (reinforced concrete and DSC steel support structure) for normal, off-normal, and accident conditions is presented in Section 3.6, Section 11.1 and Section 11.2, respectively, of [B.7-1]. Pertinent storage loads and load combinations applicable to the canister are described in Table 3.6-1 of [B.7-1]. AHSM loading summary descriptions are provided in Table 3.6-10. Load combinations applicable to the AHSM and DSC steel support structure are described in Table 3.6-12, and Table 3.6-13 of [B.7-1], respectively.

Results for normal and off-normal conditions for the canister shell assembly are summarized in Table 3.6-2, and for accident conditions in Table 3.6-3 of [B.7-1] as applicable. Controlling load combination results for the canister shell assembly subcomponents for normal, off-normal, and accident conditions are presented in Table 3.6-4 through Table 3.6-6, as applicable. Results for normal, off-normal, and accident conditions for the basket assembly subcomponents are summarized in Table 3.6-7 through Table 3.6-9 of [B.7-1], as applicable.

Calculated ultimate capacities of the AHSM concrete components are tabulated in Table 3.6-14 of [B.7-1], and the comparison with the resulting forces and moments is summarized in Table 3.6-15 of [B.7-1]. Stress analysis results for the DSC steel support structure are summarized in Table 3.6-16 (for the rail components), Table 3.6-17 (for the rail extension plates), and Table 3.6-18 (for the support structure cross members) of [B.7-1]. The stress qualification for these components is provided in Table 3.6-19 and Table 3.6-20 of [B.7-1]. The stress qualification for the AHSM ties and concrete keys is provided in Table 3.6-21 of [B.7-1].

B.7.5 Seismic Reconciliation of the Advanced NUHOMS® 24PT1 DSC and AHSM Storage Components and the MP187 Transfer Cask

The site-specific seismic ground motion developed for the WCS CISF in the form of the 10,000-year return period uniform hazard response spectra for the horizontal and vertical directions are described in Chapter 2.

As described in Section 2.2.3.1 of [B.7-1] the design basis seismic design criteria for the canister and AHSM components consists of the standard NRC Regulatory Guide 1.60 response spectrum shape anchored at a ZPA of 1.5g for the horizontal direction. The vertical spectrum is set at two-thirds of the horizontal direction over the entire frequency range. The horizontal and vertical spectra are specified at the top of the basemat. The horizontal and vertical components of the design response spectra, at 4% damping, are shown in Figure 2.2-1 and Figure 2.2-2 of [B.7-1].

A comparison of the seismic design basis for the Standardized Advanced NUHOMS® components and the *±15% peak broadened response spectra obtained at the center of gravity (CG) level from the soil structure interaction analysis of the WCS pad* are shown in Figure B.7-2 for the horizontal and vertical directions.

As shown in Figure B.7-2, the design basis seismic criteria for the canister and AHSM significantly exceed the seismic criteria for the *AHSMs and 24PT1s on the WCS pad*. Hence, the canister and the AHSM designs have significant margins and no reconciliation for seismic loads needs to be performed for these components.

As discussed in Appendix A.7, the design basis response spectra for the MP187 cask is the standard NRC Regulatory Guide 1.60 spectrum shape anchored at 0.25g for the horizontal direction and 0.17g for the vertical direction. These spectra are compared to the WCS CISF site-specific spectra in Figure A.7-1, for damping values of 3%, 5%, and 7%. *The WCS CISF site-specific spectra are compared to the ±15% peak broadened response spectra at the HSM base, which are obtained from the soil-structure interaction analysis of the WCS pad, in Figure A.7-5 and A.7-6 for a damping value of 3%.*

The discussion in Section B.7.3 demonstrates the similarity of the canister, described in [B.7-1], and the FO- DSC, described in [B.7-4]. Therefore, the seismic reconciliation of the MP187 cask loaded with a bounding FO-, FC- and FF- DSC presented in Section A.7.5.1 is applicable to the MP187 cask loaded with a 24PT1 DSC.

B.7.6 Thermal Stress Reconciliation of the Standardized Advanced NUHOMS® System Components

From Chapter 3, the maximum ambient temperatures at the WCS CISF are *81.5*°F, *113*°F and *113*°F for normal, off-normal, and accident conditions. Based on the discussion in Chapter 8, the corresponding 24-hour daily average temperatures of 95°F and 105°F for normal and off-normal conditions, respectively, are justified for use in the structural reconciliation evaluations for the WCS CISF.

The lowest off-normal ambient temperature at the WCS CISF is *30.1*°F. This is *above* the -20°F minimum temperature used in [B.7-4] (for use of the MP187) and is bounded by the -40°F in [B.7-1] (for use of the canister and AHSM).

B.7.6.1 Reconciliation of WCS CISF Environmental Ambient Conditions with Environmental Ambient Conditions used for the AHSM Analyses in the Standardized Advanced NUHOMS® UFSAR

The AHSM structural analysis is performed for normal ambient temperature range of 0 °F to 104 °F and off-normal maximum temperature range of -40 °F to 117°F, respectively, in Section 3.6.2 of [B.7-1]. These temperatures bound the daily average ambient temperatures of 95°F and 105°F used for normal and off-normal conditions, respectively at the WCS CISF. The lowest off-normal ambient temperature at the WCS CISF is *30.1*°F, which is bounded by the -40°F used in [B.7-1]. Therefore, the maximum temperatures and thermal stress evaluation results reported in [B.7-1] for the AHSM remain bounding for the WCS CISF.

B.7.6.2 Reconciliation of WCS CISF Environmental Ambient Conditions with Environmental Ambient Conditions used for the Canister Analysis in the Standardized Advanced NUHOMS® UFSAR

As documented in Table 4.1-1 (See also Table 3.1-8) of [B.7-1], the ambient temperature range for normal conditions is 0 °F to 104 °F. The ambient temperature range for off-normal and accident conditions is -40 °F to 117 °F. These temperatures bound the daily average ambient temperatures of 95°F, 105°F and 105°F for normal, off-normal and accident conditions, respectively used at the WCS CISF. Therefore, the maximum temperatures and thermal stress evaluation results reported in [B.7-1] for the canister in the AHSM remain bounding for the WCS CISF.

B.7.7 Conclusions of the Structural Analysis

This appendix demonstrates that the AHSM and the canister as described in [B.7-1] are suitable for storage at the WCS CISF. This appendix also demonstrates that the MP187 cask as described in [B.7-4] is suitable for transfer of the canister at the WCS CISF.

Furthermore, the design requirements and environmental conditions that form the design basis upon which the MP187 cask, the canister, and the AHSM components were licensed by the NRC bound the requirements and environmental conditions at the WCS CISF (with the exception of the seismic loading on the MP187 cask which is addressed in Section A.7.5.1). Therefore, the AHSM as described in [B.7-1] is acceptable for storage of the canister at the WCS CISF.

The structural performance of the MP187 cask with a canister *(Conditions of Storage)* at the WCS CISF, evaluated under normal, off-normal, and accident conditions of operation, satisfies all the 10 CFR Part 72 stress limits and criteria.

Finally, the structural performance of the canister confinement boundary was evaluated for Normal Conditions of Transport (See Section B.7.9) against ASME B&PC Code Subsection NB Article NB-3200 (Level A allowables) and were found to satisfy all of the stress limits and criteria demonstrating that the confinement boundaries are not adversely impacted by transportation of the canisters to the WCS CISF in the MP187 transport cask.

B.7.8 Alternate Cask Stability and Missile Penetration Evaluation of the MP187 Cask (On-Site Transfer Configuration)

This section presents an alternate structural evaluation of the MP187 cask for tornado, seismic, and missile impact loads. The evaluation encompasses stability, stress, and missile penetration effects, as applicable.

The following evaluation considers the MP187 cask loaded with an FO-, FC-, FF-DSC. The MP187 cask with 24PT1 DSC configuration is bounded by the MP187 cask with an FO-, FC-, or FF-DSC (Section B.7.3).

B.7.8.1 Assumptions

1. The gust factor, G, value for wind loading of 0.85 is taken from Section 6.5.8.1 of ASCE 7-05 standard [B.7-8].

2. The stability calculations use a weight of the MP187 cask with transfer skid and transfer trailer of W_c = 270 kips. Per Table B.7-6, the minimum weight of the loaded cask for the analyzed configurations is 221.98 kips. The weight for the MP187 cask transfer trailer is 40 kips, and for the transfer skid is 21 kips. Therefore, the total weight of the cask with transfer trailer and skid is expected to be at minimum 221.98+40+21 = 282.98 kips. Thus, assuming a minimum weight of 270 kips to calculate the resisting moment is conservative.

3. The MP187 transfer trailer length, width, and height dimensions are 264 inches, 10.5 feet and 42 inches, respectively. The length, width, and height of the transfer skid are 186 inches, 10.5 feet, and 15 inches, respectively (refer to Figure B.7-3). These dimensions are representative dimensions for NUHOMS® Systems' transfer equipment.

B.7.8.2 Material Properties

Material properties of the cask outer shell, top cover plate, and ram access cover plate at 400 °F are taken from [B.7-5]. The material properties for the analyzed components are summarized in Table B.7-7.

B.7.8.3 Design Criteria

For stability analyses, the permissible angle of rotation is considered to be equal to one third of the critical angle of rotation – i.e. the angle of tilt at which the center of gravity of the configuration is directly over the configuration's edge (tip-over angle).

Stress allowables are based on ASME Code, Section III, Division 1, Appendix F, [B.7-9].

For missile penetration analyses, the required material thickness is calculated using Nelms' formula from [B.7-10] and the Ballistic Research Laboratory methodology contained in [B.7-11].

B.7.8.4 Methodology

The following analyses are performed for the MP187 cask and components using hand calculations:

- stability analysis
- stress analysis
- penetration analysis

Methodology assumptions used in the evaluations are discussed below:

Stability Analysis Methodology

The stability evaluation for the overturning force caused by the DBT wind pressure is performed in Section B.7.8.6.1 by comparing the overturning moment acting on the cask-skid-trailer configuration (presented in Figure B.7-3) with the restoring moment of the assembly due to its self-weight. The analyses consider the lightest weights of the MP187 cask/canister configurations since they produce the smallest restoring moment.

The stability evaluation for the effects of seismic ground motion is performed in Section B.7.8.6.2 by comparing the overturning moment acting on the cask-skid-trailer configuration with the restoring moment of the assembly due its self weight. The seismic loads are conservatively assumed to act as constant (static) loads and the vertical acceleration is considered to act concurrently with the horizontal acceleration.

The stability evaluation for the tornado missile impact is conducted in Section B.7.8.6.3 using the equations of conservation of energy and conservation of angular momentum.

The stability evaluation for the combined tornado wind and missile load is performed in Section B.7.8.6.4 using the approximate force time-history of the missile impact from [B.7-11] and the standard equations of motion.

In the DBT wind effect evaluations, it is assumed that the combined geometry of the cask-skid-trailer system has a solid vertical projected area. The reduction in total wind pressure due to the open areas and shape factor is conservatively ignored.

Case B of Table B.7-5 (the massive high kinetic energy missile) is used for overturning stability of the cask since it produces the maximum force and the highest overturning moment. Conservatively, the impact is assumed as perfectly inelastic.

The tornado loads are generated for three separate loading phenomena. These phenomena are considered individually and then are considered in combination in accordance with Section 3.3.2 of NUREG-0800 [B.7-12] as follows:

1. Pressure or suction forces created by drag as air impinges and flows past the casks with a maximum tornado wind speed of 200 mph

2. Suction forces due to a tornado generated pressure drop or differential pressure load of 0.9 psi

3. Impact forces created by tornado-generated missiles impinging on the casks

Per [B.7-12], the total tornado load on a structure needs to be combined in accordance with formula:

$W_t = W_w + 0.5W_p + W_m$

where,

W_t = Total tornado load

W_w = Load from tornado wind effect

W_p = Load from tornado atmospheric pressure change

W_m = Load from tornado missile impact effect

Load from tornado atmospheric pressure change effect, Wp, in the above formula is ignored since temporary differential pressure load does not cause unbalanced loads on the symmetric design of the cask leading to overturning of the cask.

<u>Stress Analysis Methodology</u>

The stresses in the Cask Shell, Top Cover Plate (Lid) and Ram Closure Plate components due to DBT wind load and DBT missile load are calculated using the applicable analytic formulas for thin walled cylindrical vessels and flat circular plates, documented in [B.7-13].

The stresses evaluated in the analyzed components are:

- Primary Membrane Stress (P_M)
- Primary Membrane plus Bending Stress ($P_M + P_B$)

Stress allowables are based on the ASME Code, Section III, Division 1, Appendix F, [B.7-9].

The loads are specified in Sections B.7.8.5.1 and B.7.8.5.2 and are summarized in Table B.7-4 and Table B.7-5. Specific formulas used in the stress evaluations are presented in Section B.7.8.7.

Penetration Analysis Methodology

The critical thickness of plates that results in penetration by missile load is calculated by using Nelms' formula from [B.7-10] and the Ballistic Research Laboratory formula from [B.7-11]. These magnitudes are compared with the thickness of the Cask Shell, Top Cover Plate and Ram Closure Plate.

For this evaluation, the Case A missile (6" NPS Schedule 40 pipe, 15 ft. long) from Table B.7-5 is used. Missile Case B is judged less severe for penetration effects due to the large area of impact. Case C is judged less severe for penetration effects due to the much lower kinetic energy. The calculation evaluates missile impacts in the normal direction to the cask shell or plate to maximize penetration effect.

B.7.8.5 Design Input Loads & Data

DBT Velocity Pressure Load

The cask is evaluated for stress and overturning due to the Design Basis Tornado (DBT) loads specified in Table B.7-4. The DBT load characteristics correspond to those in Regulatory Guide 1.76 Region II parameters from [B.7-14] and ASCE 7-05 standard [B.7-8]. The MP187 cask dimensions and weight data are based on the design described in [B.7-5]. Load specifications are consistent with requirements of Section 3.3.2 of NUREG-0800 [B.7-12].

Per Table B.7-4 and per Section 6.5.10 of [B.7-8] (for the MP187 cask-skid-trailer assembly dimensions), the maximum velocity pressure load q_z at the height of the centroid of the analyzed assembly is

$$q_z = 0.00256\ K_z K_{dt} K_d I(v)^2$$
$$= 0.00256 \times 0.87 \times 1.0 \times 1.0 \times 1.15 \times 200^2 = 102.45\ \text{lb/ft}^2$$

Per Section 6.5.15 of [B.7-8], the design wind force, F, is calculated as:

$$F = q_z G C_f A_f = 102.45 \times 0.85 \times 0.82 \times 226 = 16.14\ kips.$$

In the above equation, the gust factor G=0.85 (per assumption 1 of Section B.7.8.1), the force coefficient C_f=0.82 (for cask-skid-trailer configuration dimensions), and the projected area normal to the wind for the analyzed assembly, A_f=226 ft^2. (for cask-skid-trailer dimensions).

DBT Generated Missile Impact Forces

The tornado-generated missile impact evaluation is performed for the missiles specified in Table B.7-5.

Automobile Missile (Table B.7-5 – Case B)

The impact force acting on the cask due to this missile is based on the Bechtel topical report ([B.7-11] equation D-6):

$$F = 0.625 \times V_i \times W_m \times \sin(20t) = 0.625 \times 134.81 \times 4000 \times \sin(20 \times 0.0785) \approx 340 kip$$

In above equation:

t = time from the instant of initial impact (sec) = 0.0785 sec for maximum impact force to occur, [B.7-11]

V_i = total striking velocity of the missile
= $\sqrt{112^2 + (0.67 \times 112)^2} = 134.81$ fps (Table B.7-5)

W_m = weight of missile =4000 lb. (Table B.7-5)

Schedule 40 Pipe Missile (Table B.7-5 – Case A)

The impact force is calculated using the principle of conservation of momentum and the relation

$$F \Delta T = G_f - G_i$$

$$F = \frac{M_m (V_i - V_f)}{(T_f - T_i)} = \frac{M_m (V_i - V_f)}{(\Delta T)} = \frac{287 \times (134.81 - 0)}{32.2 \times 0.05 \times 1000} = 24.03\, kips$$

where:

ΔT = the time of contact = 0.05 sec (conservatively shorter than impact time 0.075 seconds, from [B.7-11])

G_f $= M_m V_f = 0$ the linear momentum after impact at time $T = T_f$

G_i = $M_m V_i$ the linear momentum at time $T = T_i$

V_i = total striking velocity of the missile
= $\sqrt{112^2 + (0.67 \times 112)^2} = 134.81$ fps (Table B.7-5)

M_m = the mass of the missile

B.7.8.6 Tornado & *Missile Impact* Loads Analysis - Stability Evaluations

Cask Stability for Design Basis Tornado Wind Pressure Load

The restoring moment will be the smallest for the assembly with minimum weight. Conservatively, the total weight of the loaded cask and transfer trailer and skid, W_c, is taken as 270 kips (refer to Section B.7.8.1, Assumption 2). The restoring moment, M_{st} = (Total Weight) × (Half Width of the Trailer) = 270 × 5.25 = 1,417.50 kips-ft.

The maximum overturning moment (M_{ot}) for the cask-skid-trailer due to DBT wind pressure is calculated by taking both the windward force and the leeward force into account. Conservatively, it is assumed that the wind loads on the windward side and leeward side are the same and are equal to the design wind load, F = 16.14 kips (calculated in Section B.7.8.5.1)

Per Figure B.7-3, the height corresponding to the centerline of the MP187 Cask is taken as the point of load application: H=(42+15+83.5/2) = 98.75 inches = 8.23 ft.

Therefore, the overturning moment, M_{ot} = 2×F×H = 2× 16.14 x (8.23) = 265.66 kip-ft

Factor of safety against overturning $\frac{M_{st}}{M_{ot}} = \frac{1417.50}{265.66} = 5.34$

Cask Stability for Massive Missile Impact Load

A stability analysis is performed to analyze the most critical impact, when the missile hits the cask on the side. However, it is conservatively assumed that the missile hits the top most point of the cask as shown in Figure B.7-4.

The Case B missile from Table B.7-5, i.e. the massive high kinetic energy automobile missile, is used since it produces the maximum force and the highest overturning moment. Conservatively, the impact is assumed as perfectly inelastic

Using the geometrical relations of Figure B.7-4 and the missile characteristics from Table B.7-5, the evaluation is based on conservation of momentum at impact and the conservation of energy to estimate the angle of rotation, θ, due to the impact (cask stops rotating when the angular velocity after impact becomes zero).

The resultant formula for the angle of rotation due to impact, θ, for the analyzed geometry has the following form:

$$\sin(\phi + \theta) = \frac{(R_1 V_i M_m)^2}{2W_c R_2[(I_c)_o + R_1^2 M_m]} + \sin\phi$$

with:

$\phi = \tan^{-1}(L_1/R) = \tan^{-1}(\frac{42+15+83.5/2}{5.25\times12})$

= 57.46° (refer to Figure B.7-3 and Figure B.7-4),

$(H_i)_o$ = the angular momentum about point O before impact $= R_1 V_i M_m$ (Figure B.7-4),

$(H_a)_o$ = the angular momentum about point O after impact $= R_1^2 \omega_i M_m + (I_c)_o \omega_i$ (Figure B.7-4),

R_1 $= \sqrt{L^2 + R^2} = \sqrt{11.71^2 + 5.25^2} = 12.83\ ft$ is the distance from point O to the impact point (Figure B.7-4),

R_2 $= \sqrt{L_1{}^2 + R^2} = \sqrt{8.23^2 + 5.25^2} = 9.76\ ft$ is the distance from point O to the center of the cask. (Figure B.7-4),

V_i = total striking velocity of the missile = $\sqrt{112^2 + (0.67\times112)^2} = 134.81$ fps (Table B.7-5),

M_m = the mass of the missile (4000/32.2 = 124.22 lbm, per Table B.7-5),

W_c = the minimum weight of the cask assembly (270 kips),

$(I_c)_o$ = the mass moment of inertia of the cask about an axis through point O,

$(I_c)_o = (I_c)_{CG} + M_c R_2^2$ (from the parallel axis theorem),

M_c = the mass of the cask assembly (270×1000)/32.2=8385.09 lbm,

$(I_c)_{CG}$ = the mass moment of inertia of the cask about center of gravity of MP187 cask.

Conservatively, $(I_c)_{CG} = \frac{M_c R_c^2}{2} = \frac{8385.09\times3.48^2}{2} = 50{,}773.40\ ft^2 lbm$

Ultimately, angle of rotation due to impact can be determined as:

$$\theta = sin^{-1}(0.8531) - \emptyset = 58.55° - 57.46° = 1.09°$$

Tip over occurs when the C.G. is directly above the point of rotation, therefore the tip over angle is $\theta_{tip} = 90.0° - 57.46° = 32.54°$, and $1/3\,\theta_{tip} = 1/3 \times 32.54° = 10.85°$. Since $\theta < 1/3 \times \theta_{tip}$, the tip over of the cask will not occur.

Cask Stability for Design Basis Tornado Wind and Missile Load Combination

A time-dependent analysis is performed to determine the maximum angle of rotation attained by the cask-skid-trailer assembly due to concurrent DBT wind and missile loading. The input loading is the summation of the wind pressure loading from Section B.7.8.5.1 and the massive missile impact force from Section B.7.8.5.2. The standard equations of rotational motion are solved with an approximate step-wise linear procedure to determine the rotational motion of the assembly subjected to the combined wind and missile loading.

The overturning moment causing rotational acceleration is:

$$M_{acc} = M_{ot} - M_{st}$$

The angular velocity is:

$$\omega_i = \frac{\left[\frac{M_{acc,i} + M_{acc,i-1}}{2} * (t_i - t_{i-1})\right]}{(I_c)_o} + \omega_{i-1}$$

The angle of rotation is:

$$\theta_i = \left[\frac{\omega_i + \omega_{i-1}}{2} * (t_i - t_{i-1})\right] + \theta_{i-1}$$

where,

i = index for the current time step

$i-1$ = index for the previous time step

In the above equations the overturning moment and stabilizing moments are, respectively:

$$M_{ot} = F_{missile} * \mathrm{L} + q_z * L_\theta^2 * \mathrm{L}_T$$

$$M_{st} = W_c * R_2 * \cos(\emptyset + \theta)$$

where:

L_θ = height to the top of cask system which is dependent on rotation angle θ,

L = 42+15+83.5=140.5 inch, initial total height of the cask system (Figure B.7-3),

L_T = 264 inch, length of trailer (Section B.7.8.1)

$F_{missile}$ $= 0.625 V_i W_m sin(20t)$, missile force, refer to Section B.7.8.5.2, per Ref. [B.7-11], equation D-6

W_c = 270 kips, is the minimum weight of the cask assembly (Section B.7.8.1),

R_2 = 9.76 ft, is the distance from point O to the center of the cask. (Figure B.7-4).

The solution to the equation of motion is documented in Figure B.7-5. The governing angle of rotation is θ=3.0°.

As indicated in Section B.7.8.6.3, the tip over angle $\theta_{tip} = 32.54°$ and $1/3 \times \theta_{tip} = 10.85°$. Since $\theta < 1/3 \times \theta_{tip}$, the tip over of the cask will not occur.

B.7.8.7 Tornado Wind and Missile Analysis - Stress Evaluations

Stress evaluations for cask components exposed to tornado loads are discussed below. The evaluations consider the cask as a thin walled vessel and the cover plates as simply supported thin circular plates, and use stress formulas from [B.7-13] appropriate for the analyzed load characteristics. Specifications of the stress formulas and basic assumptions employed in the analyses are summarized below. Stress results are listed in Table B.7-8 and Table B.7-9.

Stress Formulas Used in Tornado Loads Evaluations

Load Description	Component Analyzed	Stress Formula Reference & Assumptions
Wind Pressure Load	Outer Shell	[B.7-13], case 8c from Table 13.3, page 650; Simply supported thin cylindrical shell, subjected to a uniform pressure load over the entire length
	Top Cover Plate	[B.7-13], case 10a from Table 11.2, page 509; Simply supported thin circular plate, subjected to a uniform pressure load over the entire area
	RAM Closure Plate	[B.7-13], case 10a from Table 11.2, page 509; Simply supported thin circular plate, subjected to a uniform pressure load over the entire area
Massive Missile Load	Outer Shell	[B.7-13], case 8b from Table 13.3, page 650; Simply supported thin cylindrical shell, subjected to a concentrated load over the short length
	Top Cover Plate	[B.7-13], case 10a from Table 11.2, page 509; Simply supported thin circular plate, subjected to a uniform load over the entire area
	RAM Closure Plate	[B.7-13], case 10a from Table 11.2, page 509; Simply supported thin circular plate, subjected to a uniform load over the entire area
Local	Outer Shell	[B.7-13], case 8a from Table 13.3, page 649; Simply supported thin cylindrical shell, subjected to load P distributed over a

Load		small area at midspan
	Top Cover Plate	[B.7-13], case 16 from Table 11.2, page 514; Simply supported thin circular plate, subjected to a load over the small central area
	RAM Closure Plate	[B.7-13], case 16 from Table 11.2, page 514; Simply supported thin circular plate, subjected to a load over the small central area

B.7.8.8 Tornado Missile Analysis - Penetration Evaluations

Nelms' Formula Evaluation

Nelms' formula [B.7-10] is used to determine the thickness value due to incipient puncture energy, which is directly proportional to the mass and velocity of the missile and inversely proportional to the diameter of the missile.

$$E_F = \frac{1}{2} M_m V_m^{\ 2}$$

$$E_F / S = 2.4 d^{1.6} t^{1.4}$$

where:

M_m = the mass of the missile (287 lbs)/(32.2 ft/sec^2) = 8.91 lbm,

V_m = the total velocity of the striking missile normal to target surface (=134.81 fps),

S = the ultimate tensile strength of the jacket material (refer to Table B.7-7),

t = the maximum thickness of plate material leading to onset of plate puncture (inch),

d = the diameter of the punch/missile (6.625 inch, refer to Table B.7-7),

E_F = the incipient puncture energy of the prismatic cask jacket (inch - lb).

The threshold thickness values causing perforation for the Outer Shell, Top Cover Plate and RAM Closure Plate according to Nelms' correlation are 0.43 inch, 0.43 inch, and 0.43 inch, respectively.

Ballistic Research Laboratory Formula Evaluation

In the Ballistic Research Laboratory report, the relation for the determination of the thickness is also directly proportional to mass and velocity and inversely proportional to diameter of the missile.

$$t = \frac{\left(\frac{M_m V_m^2}{2}\right)^{2/3}}{672d} = 0.42 \text{ inch}$$

In the above relation:

t = the maximum thickness of plate material leading to onset of plate puncture (inch),

d = the diameter of the punch/missile (= 6.625 inch),

M_m = the mass of the striking missile, (=287/32.2 = 8.91 lbm),

V_m = the velocity of the striking missile normal to target surface (=134.81 fps).

Reference [B.7-11] recommends increasing the thickness, t, by 25 percent to prevent perforation. Therefore, the minimum thickness required to prevent perforation of the MP187 cask is 0.53 inch.

B.7.8.9 Summary of Results

The factor of safety on overturning from DBT tornado wind pressure load is 5.34.

The resultant stresses for the bounding individual DBT, missile impact and combined tornado load are summarized in Table B.7-8 and Table B.7-9, respectively. The primary membrane stress and combined membrane plus bending stresses due to DBT and missile impact are below the allowable stresses.

The minimum thickness of the steel components required to prevent perforation by tornado missiles is found to be 0.53 inch, which is less than the thickness of the MP187 cask Outer Shell, Top Cover Plate, and RAM Closure Plate of 2.49 inches, 6.50 inches, and 3.18 inches, respectively.

The maximum rotation angle of the MP187 cask transfer configuration due to combined tornado wind plus massive missile impact load is θ=3.0°, which is significantly below the permissible angle of rotation, 10.85°.

B.7.9 Structural Evaluation of 24PT1-DSC Confinement Boundary under Normal Conditions of Transport

The 24PT1-DSC shell assembly consists of a cylindrical shell, top outer/inner cover plates, bottom inner/outer cover plates and bottom and top shield plugs. The 24PT1-DSC consists of a shell, which is a welded, stainless steel cylinder with a stainless steel bottom closure assembly, and a stainless steel top closure assembly. Additional details, geometry and shell and plate thicknesses are provided on the drawings in Section B.4.6. The confinement boundary is addressed in Section B.11.1. The 24PT1-DSC shell is evaluated for Normal Conditions of Transport in the MP187 Transport cask in Section A.7.7.2 with the FO-DSC of the NUHOMS® MP187 Cask System.

Result of the FO- and 24PT1 DSCs structural analysis are acceptable for the loads and combinations described in Table A.7-3 and hence structurally adequate for normal conditions of transport loading conditions.

B.7.10 References

B.7-1 AREVA TN Document, ANUH-01.0150, Revision 6, "Updated Final Safety Analysis Report for the Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, NRC Docket No. 72-1029.

B.7-2 U.S. Nuclear Regulatory Commission, "License for Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste," License Number SNM-2510, Docket Number 72-11.

B.7-3 U.S. Nuclear Regulatory Commission, "Certificate of Compliance No. 9255, Revision 12 for the Model No. NUHOMS®-MP187 Multi-Purpose Cask (Docket 71-9255).

B.7-4 "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report," NRC Docket No. 72-11, Revision 4.

B.7-5 AREVA TN Document NUH-05-151 Rev. 17, "NUHOMS®-MP187 Multi-Purpose Transportation Package Safety Analysis Report." (Basis for NRC CoC 71-9255).

B.7-6 U.S. Nuclear Regulatory Commission, Certificate of Compliance for the Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, Certificate No. 1029.

B.7-7 AREVA TN Document NUH-003, Revision 14, "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel." (Basis for NRC CoC 72-1004).

B.7-8 American Society of Civil Engineers Standard ASCE 7-05, "Minimum Design Loads for Buildings and Other Structures," (Formerly ANSI A58.1).

B.7-9 ASME Boiler and Pressure Vessel Code, Section III, Appendix F, 2004 Edition with 2006 Addenda.

B.7-10 H.A. Nelms, "Structural Analysis of Shipping Casks, Effects of Jacket Physical Properties and Curvature on Puncture Resistance," Vol. 3, ORNL TM-1312, Oak Ridge National Laboratory, Oak Ridge Tennessee, June 1968.

B.7-11 R.B. Linderman, J.V. Rotz and G.C.K. Yek "Design of Structures for Missile Impact," Topical Report BC-TOP-9A, Bechtel Power Corporation, Revision 2, September 1974.

B.7-12 U.S. NRC Document, NUREG-0800, Section 3.3.2, Revision 3, "Tornado Loads," Standard Review Plan (Formerly NUREG-76/087), 2007.

B.7-13 R.G Budynas and W.C Young, "Roark's Formula for Stress and Strain," Eighth Edition, McGraw-Hill Book Company.

B.7-14 Reg Guide 1.76, "Design-Basis Tornado And Tornado Missiles For Nuclear Power Plants," Revision 1, March 2007.

Table B.7-1
Configuration of the FO-DSC Compared to the 24PT1 DSC (from Table A2.1-1 of [B.7-5])

Characteristic	FO-DSC Configuration	24PT1-DSC Configuration
Shell Outside Diameter x Length	67.19 “ x 186.5”	67.19” x 186.5”
DSC Internal Cavity Length	167.0”	167.0”
Shell (SA240)	5/8” thick, Type 304	5/8” thick, Type 316
Support Rod Diameter/Preload	2”/80 +/- 5 kips	1.25”/40 +/- 15 kips
Support Rod Spacer Sleeves, Outside Dia./Inside Dia.	3” / 2.08”	3” / 1.33”
Spacer Discs (Number-Material)	26 – SA537, Cl 2	26 – SA537, Cl 2
Spacer Disc Spacing	See Section 1.3.2 of [B.7-5] for spacing	See Section A1.3.2 of [B.7-5] for spacing
Guidesleeves (inside width x length)	8.9” x 161.8”	8.9” x 165.25”
Top and Bottom Fuel Spacers	Not Required	See Section A1.3.2 of [B.7-5]
Failed Fuel Cans	Not Permitted	Up to four, symmetrically loaded (similar to FF-DSC)

Table B.7-2
Comparison of Canister Weights, Centers of Gravity and Moments of Inertia
(from Table A2.2-1 of [B.7-5])

Parameter	FO-DSC	FC-DSC	FF-DSC	24PT1-DSC
Total Canister weight (lbs)	80,710	81,120	74,900	78,400[1,2]
Canister cg location, along center line of canister, with respect to the outer surface of the MP187 Cask bottom cover plate (inches)	100.4	98.7	102.4	99.3
Canister MOI (lbm-in^2), relative to cg	3.36E+08	2.88E+08	3.03E+08	3.29E+08

[1] This weight is increased by 1,000 lbs. when four failed fuel cans are included in the canister.

[2] This weight is made up of (rounded to nearest 100 lbs.):

Shell Assembly	15,600 lbs.
Basket Assembly	18,500 lbs.
Shield Plug	8,000 lbs.
Inner Cover Plate	700 lbs.
Outer Cover Plate	1,200 lbs.
Fuel Spacers	2,700 lbs.
WE 14x14 fuel/including NFAH	31,700 lbs.

Table B.7-3
MP187 and OS197 Casks – Comparison of Basic Design Parameters

Parameter	MP187 Cask	OS197 Cask
Outer Shell Thickness (*in*)	2.49	1.50(1)
Inner Shell Thickness *(in)*	1.24	0.50
Bottom End Closure Thickness *(in)*	8.00	5.00
Top Lid Thickness (*in*)	6.50	5.25
Lead Gamma Shield Thickness *(in)*	4.00	3.56
Cask Body Outer Diameter (*in*)	83.50	79.12
Cask Cavity Diameter *(in)*	68.00	68.00
Cask Rails Locations (from bottom centerline)	±30.0º	±18.5º
Cask Rail Thickness (*in*)	0.12	0.12
Overall Length of Cask Body (*in*)	201.50	207.22
Cavity Length (*in*)	187.00	196.75
Cask Weight (Dry, Empty) (*kips*)	158.58	111.25
Cask Weight (Dry, Loaded) (*kips*) w/ bounding FC-DSC	239.70	N/A
Cask Weight (Dry, Loaded) (*kips*) w/ 24PT1 DSC	237.20	189.65

Note: (1) Thickened to 2.00 inches at upper trunnion regions

Table B.7-4
DBT Wind Load Characteristics for WCS CISF

Design Parameter	Design Criteria
Maximum wind speed	200 miles per hour
Maximum rotational speed	160 miles per hour
Translational speed	40 miles per hour
Radius of the maximum rotational speed	150 feet
Pressure drop across the tornado	0.9 psi
Rate of pressure drop	0.4 psi per second

Table B.7-5
Design-Basis Tornado Missile Spectrum and Maximum Horizontal Speeds

Case #	Missile	Weight (lb)	Horizontal Impact Velocity V_{MH}^{max} (fps)
A	Schedule 40 Pipe (ϕ 6.625 inch x 15 ft long)	287	112
B	Automobile (16.4 ft x 6.6 ft x 4.3 ft)	4,000	112
C	Solid Steel Sphere (ϕ 1 inch)	0.147	23

Note: V_{MH}^{max} = Horizontal velocity of missile, vertical velocity of missile = 0.67 V_{MH}^{max}

Table B.7-6
NUHOMS®-MP187 Cask and Canister Weights for Analyzed Configurations

	Configuration of Cask/DSC for MP187 Cask			
	Configuration	**(Ref. [B.7-5, Table 2.1.2-1])**	**(Ref. [B.7-5, Table A2.2-1])**	
Case No.	**Cask/Canister**	**Weight of Cask without NSP Assembly (lb)**	**DSC Weight (lb)**	**Total Weight (lb)**
1	MP187/FC-DSC	147,080	81,120	228,200
2	MP187/FO-DSC	147,080	80,710	227,790
3	MP187/FF-DSC	147,080	74,900	221,980
4	MP187/24PT1 DSC (14x14 Fuel Assembly)	147,080	78,400	225,475

Table B.7-7
Materials, Properties and Allowable Stresses for MP187 Cask at 400 ºF

Material Properties for MP187 at 400°F							
Component	**Material**	**S_m (ksi)**	**S_y (ksi)**	**S_u (ksi)**	**E (10^3 ksi)**	**Primary Membrane (ksi)**	**Primary Membrane plus Bending (ksi)**
Top Structural Shell (4)	SA-240 Type 304	18.7	20.7	64.4	26.5	44.90	64.40
Bottom Structural Shell (4)	SA-240 Type XM-19	30.2	40.8	90.7	26.5	63.50	90.70
Ram Access Closure Plate	SA-240 Type XM-19	30.2	40.8	90.7	26.5	63.50	90.70
Top Closure Plate	SA-240 Type 304	18.7	20.7	64.4	26.5	44.90	64.40

Note:

1. Primary Membrane stress for Service Level D, $P_m \leq$ min ($2.4S_m$, $0.7S_u$) (Ref. [B.7-9])
2. Membrane plus Bending stress for Service Level D, $P_m + P_b \leq$ min ($3.6S_m$, S_u) (Ref. [B.7-9])
3. Material properties are taken from Ref. [B.7-5].
4. Conservatively, material properties of the top structural shell are used in the evaluation as the allowables are less and will bound bottom structural shell as well.

Table B.7-8
Stress Results for MP187 Cask due to Tornado Wind and Missile Loads

MP187 Cask Results						
Load Description	Stress Category	Calculated Stress (ksi)			Allowable Stress (ksi)	Impact Force
		Structural Shell	Top Cover Plate	Ram Access Closure Plate		
Wind Pressure Load	Primary Membrane	0.19	0.00		44.9	16.14 kips
	Primary Membrane plus Bending	0.72	0.04		64.4	
	Primary Membrane			0.00	63.5	
	Primary Membrane plus Bending			0.15	90.7	
Massive Missile Loads	Primary Membrane	15.37	0.07		44.9	340 kips
	Primary Membrane plus Bending	55.21	3.24		64.4	
	Primary Membrane			1.50	63.5	
	Primary Membrane plus Bending			14.74	90.7	
Local Load	Primary Membrane	1.24	0.70		44.9	24.03 kips
	Primary Membrane plus Bending	3.88	1.87		64.4	
	Primary Membrane			0.70	63.5	
	Primary Membrane plus Bending			5.57	90.7	

Table B.7-9
Combined Tornado Effect on MP187 Cask – Stress Results

Load Description	Stress Category	Combined Stress (ksi)			Allowable Stress (ksi)
		Structural Shell	Top Closure Plate	Ram Access Closure Plate	
Wind Pressure Load + Missile Load	Primary Membrane	15.56	0.07		44.9
	Primary Membrane plus Bending	55.93	3.28		64.4
	Primary Membrane			1.50	63.5
	Primary Membrane plus Bending			14.90	90.7

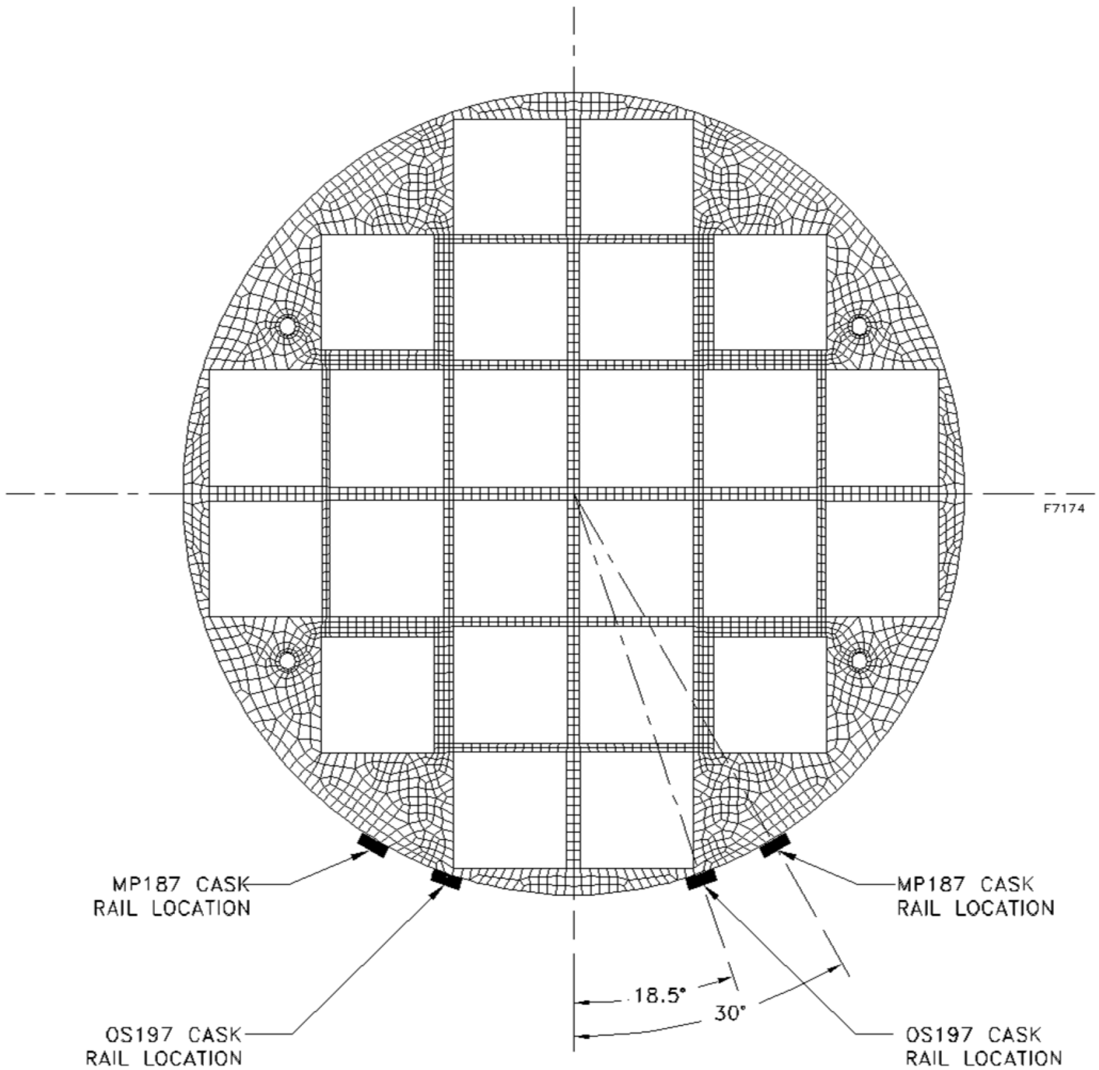


Figure B.7-1
Location of Cask Rails in the MP187 and OS197 Casks

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Withheld Pursuant to 10 CFR 2.390

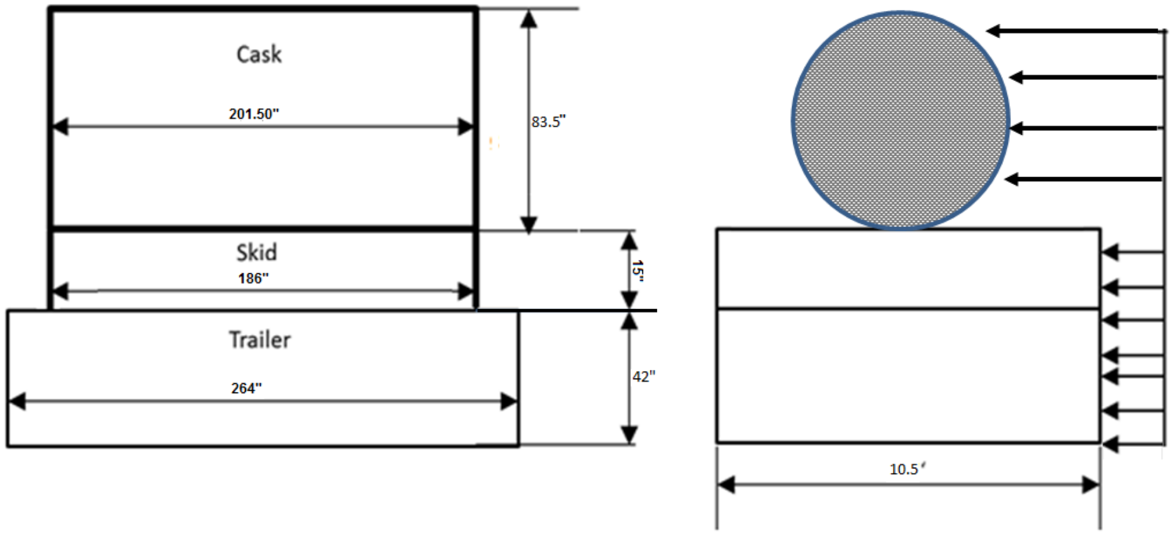


Figure B.7-3
Arrangement of MP187 Cask Shell, Skid and Trailer at Rest

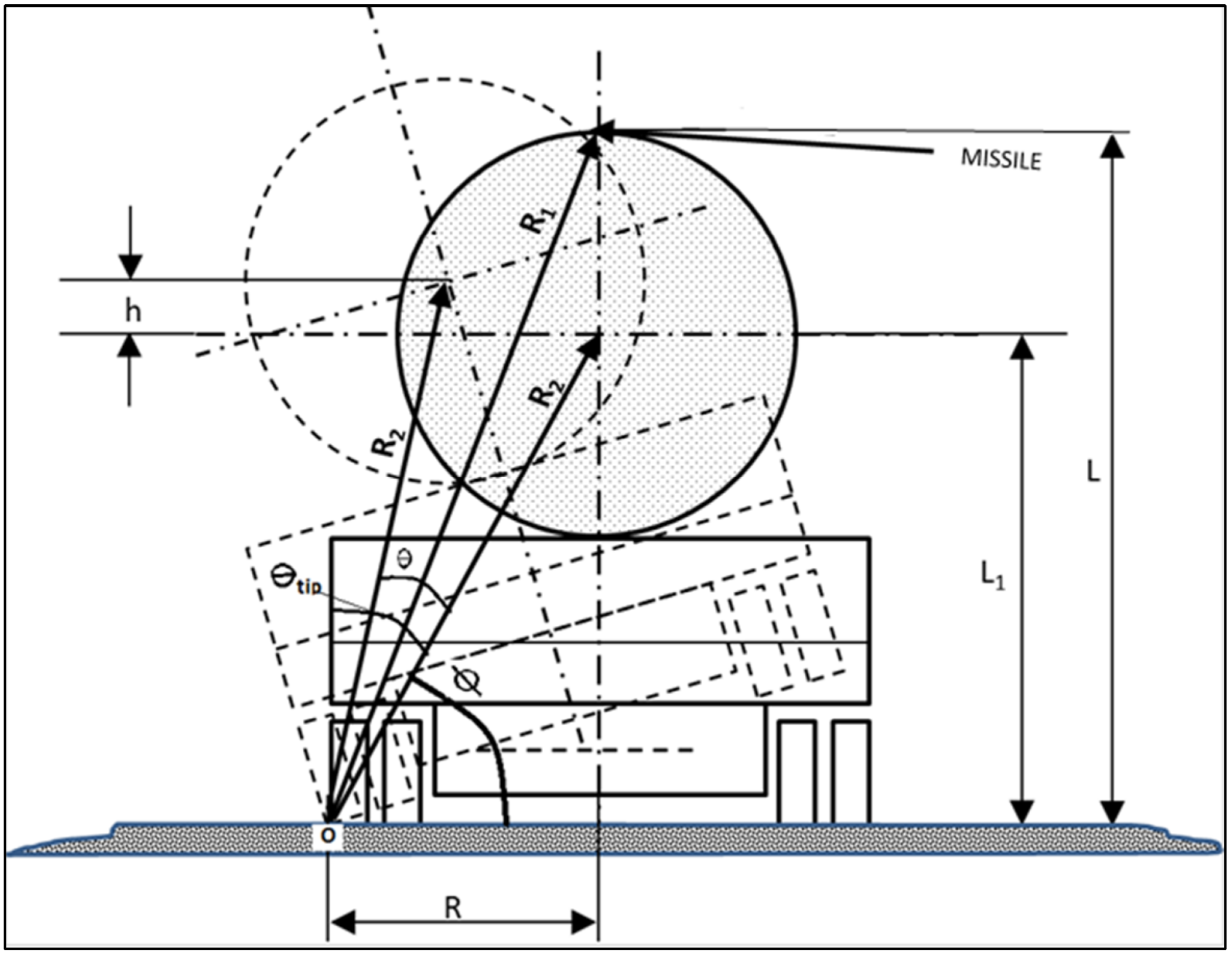


Figure B.7-4
Geometry Utilized in Cask Stability Assessments

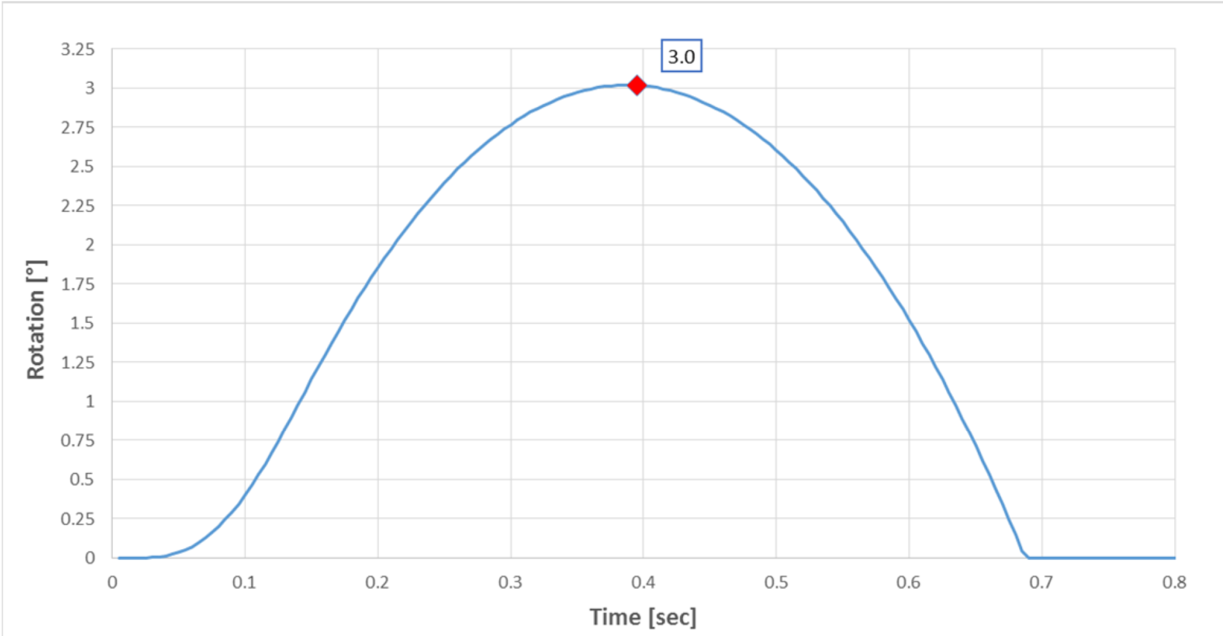


Figure B.7-5
Angle of Rotation due to Wind and Massive Missile Loading Combination

APPENDIX B.7
STRUCTURAL EVALUATION
Standardized Advanced NUHOMS® System

Table of Contents

List of Tables

List of Figures

B.7. STRUCTURAL EVALUATION

This Appendix describes the structural evaluation of the Standardized Advanced NUHOMS® System components utilized for storage of canisterized spent nuclear fuel (SNF) at the Waste Control Specialists, LLC (WCS) Consolidated Interim Storage Facility (CISF). As presented in Chapter 1, Table 1-1, the Standardized Advanced NUHOMS® System storage components include the 24PT1 Dry Shielded Canister (DSC or canister) and the AHSM concrete overpack.

The 24PT1 DSC is described in Section 3.1.1.1 of the Standardized Advanced NUHOMS® Updated Final Safety Analysis Report (UFSAR) [B.7-1]. The AHSM is described in Section 3.1.1.2 of [B.7-1]. Both of these components are approved by the NRC [B.7-6] for storage of SNF under the requirements of 10 CFR Part 72.

At the WCS CISF, the NUHOMS®-MP187 cask will be used for on-site transfer operations. The MP187 cask is a multi-purpose cask approved by the NRC for on-site transfer of the FO-, FC-, and FF- DSCs and Greater Than Class C (GTCC) waste canisters [B.7-2], and as a transportation cask for off-site shipments of the FO-, FC-, FF-, 24PT1 DSCs [B.7-3]. Volume I and Volume III of the Rancho Seco Independent Spent Fuel Storage Installation Final Safety Analysis Report (ISFSI FSAR) [B.7-4] describe the MP187 cask when used as on-site transfer cask under 10 CFR Part 72. Section 1.2 of the NUHOMS®-MP187 Multi-Purpose Transportation Package Safety Analysis Report (SAR) [B.7-5] describes the MP187 cask when used as a transportation cask under 10 CFR Part 71.

This appendix is prepared to demonstrate that the licensed canisters and AHSM storage components are qualified to safely transfer and store SNF and GTCC waste at the WCS CISF. Additionally, this appendix provides the justification to allow use of the MP187 cask for on-site transfer of the canister, consistent with the cask's allowable payloads in the MP187 cask's transportation license.

The structural evaluations presented herein are based on existing analyses as documented in [B.7-1] for the 24PT1 DSC and the AHSM and [B.7-4] for the MP187 cask *except for the qualification of the 24PT1-DSC confinement boundary during Normal Conditions of Transport in Section B.7.9 which points to the evaluation documented in Section A.7.7.2*.

MP187 Cask

The design basis design criteria for the MP187 cask as an on-site transfer cask for the canisters is provided in [B.7-4] Volume I Table 3-4, Table 3-8, Table 3-9, and Table 3-10. The loading criteria summary shown in [B.7-4] Table 3-4 bounds the loading criteria for the WCS CISF as specified in Appendix B.3, Table B.3-1 (with the exception of seismic loading which is addressed in Section B.7.5).

Canister

The 24PT1 DSC design approach, design criteria and load combinations for transfer and storage conditions are summarized in Section 2.2, Section 3.1.2, and Table 3.1-2 through Table 3.1-7 of [B.7-1]. The codes and standards used for design and fabrication of the canister are provided in Table 3.1-1 of [B.7-1]. Section 3.6.1 discusses the results of the analyses for the canister.

Advanced Horizontal Storage Module (AHSM)

The design approach, design criteria and loading combinations for the reinforced concrete AHSM and its DSC support structure are discussed in Section 2.2, Section 3.1.2, and Table 3.1-9 through Table 3.1-13 of [B.7-1]. The codes and standards used for design and fabrication of the AHSM are provided in Table 3.1-1 of [B.7-1]. Section 3.6.2 discusses the results of the analyses for the AHSM.

B.7.1 Discussion

As discussed in Chapter 1, the 24PT1 DSCs, currently stored inside AHSMs at the San Onofre Nuclear Generating Station (SONGS) ISFSI, will be transported to the WCS CISF utilizing the NUHOMS®-MP187 Transportation Cask. The canisters and the AHSM are Standardized Advanced NUHOMS® System components for the storage of SNF under NRC Certificate of Compliance No. 1029 [B.7-6] and are described in Chapter 1 of [B.7-1]. The MP187 transportation cask is licensed under NRC Certificate of Compliance (CoC) No. 9255 [B.7-3].

At the WCS CISF, the canisters will be stored inside newly fabricated AHSMs utilizing the MP187 cask for on-site transfer operations. The MP187 cask is a multi-purpose cask licensed as an on-site transfer cask [B.7-2] under 10 CFR Part 72 as described in [B.7-4].

As described in [B.7-1] the canister and the AHSM utilize the OS197 transfer cask for on-site transfer operations. The OS197 transfer cask is licensed under CoC No. 1004 and is described in the Standardized NUHOMS® UFSAR [B.7-7]. This appendix reconciles the design basis analyses of the 24PT1 DSC in the OS197 transfer cask *(that will not be used at the WCS CISF)* to justify use of the MP187 cask for transfer of the 24PT1 DSC at the WCS CISF.

The design basis seismic criteria for the canister and AHSM significantly exceed the seismic criteria for the WCS CISF (see Figure B.7-2). Hence, no reconciliation for seismic loads for the canister and AHSM need to be performed in this appendix.

The qualification of the MP187 cask for use as the on-site transfer cask at WCS CISF is based on the design basis analysis as documented in [B.7-4]. The cask stability evaluations in [B.7-4] use the hypothetical case of the cask as a storage component, and hence in the vertical configuration, as bounding the horizontal configuration in the transfer mode.

Finally, a bounding evaluation in Section B.7.9 is performed to demonstrate that the confinement boundaries for the 24PT1-DSC does not exceed ASME B&PV Subsection NB Article NB-3200 (Level A allowables) during normal conditions of transport to provide reasonable assurance that the confinement boundary is not adversely impacted by transport to the WCS CISF.

B.7.2 Summary of Mechanical Properties of Materials

The material properties for the canister and the AHSM are provided in Section 3.3 of [B.7-1].

The material properties for the MP187 cask are provided in Section 2.3 of [B.7-5].

B.7.3 Structural Evaluation of MP187 Transfer Cask with Canister (Transfer Configuration at WCS CISF)

This section reconciles the use of the MP187 cask for transfer of the canister at the WCS CISF. This section also evaluates the 24PT1 DSC as a payload in the MP187 cask.

B.7.3.1 Evaluation of MP187 Cask Loaded with a Canister

The 10 CFR Part 71 evaluation of the canister in the MP187 cask is contained in Appendix A of the NUHOMS®-MP187 Multi-Purpose Transportation Package Safety Analysis Report (SAR) [B.7-5]. This section presents the evaluation of the canister in the MP187 cask for transfer operations under 10CFR Part 72. As in the 10 CFR Part 71 evaluations in Appendix A of [B.7-5], the evaluation presented herein is based on the design similarities between the FO- and FC- DSCs and the 24PT1 DSC.

As shown in Table A2.1-1 of [B.7-5], reproduced here as Table B.7-1, the 24PT1 DSC in [B.7-1] is the same as the FO DSC in [B.7-4], except that the 24PT1 DSC has a modified spacer disc spacing and support rod configuration. Sections A2.6.11.A and A2.6.11.B of [B.7-5] addressed these differences and concluded that the FO- and FC-DSCs configuration bounds the 24PT1 DSC configuration.

Table A2.2-1 of [B.7-5], reproduced here as Table B.7-2, shows that the 24PT1 DSC weight, center of gravity (cg) and weight moment of inertia (MOI) are bounded by those of the FO-, FC-, and FF- DSCs. As shown in this table, the 24PT1 DSC weight (78,400 lbs) is between the weight of the heaviest DSC (the FC- DSC with a weight of 81,120 lbs) and the lightest DSC (the FF- DSC with a weight of 74,900 lbs). This ensures that the effect of the lighter canister (increasing g-loads during postulated drop) and a heavier canister (higher stresses for non-drop loading conditions) envelop the 24PT1 DSC.

The total weight of the loaded MP187 cask (on-site transfer configuration) ranges from 239,700 lbs (with FC- DSC) to 233,500 lbs (with FF- DSC). This range bounds the total weight of 237,200 lbs (with 24PT1 DSC). Thus, the MP187 cask loaded with a FO- and FC- DSC configuration bounds the MP187 loaded with a 24PT1 DSC configuration [B.7-5, Table A2.2-2].

Section B.7.8 presents an alternate evaluation of the MP187 cask in the transfer configuration at the WCS CISF.

Based on the evaluation above, the structural evaluation of the MP187 cask documented in [B.7-4] for the MP187 cask loaded with the FO- and FC- DSCs is applicable to the MP187 cask loaded with a 24PT DSC.

B.7.3.2 Evaluation of the Canister in the MP187 Transfer Cask

The structural analysis of the canister for normal, off-normal, and accident loads is presented in Section 3.6.1, Section 11.1, and Section 11.2, respectively, of [B.7-1]. Pertinent transfer and handling loads and load combinations applicable to the canister are described in Table 3.6-1 of [B.7-1]. Results for normal and off-normal conditions for the canister shell assembly are summarized in Table 3.6-2, and for accident conditions in Table 3.6-3 of [B.7-1]. Controlling load combination results for the canister shell assembly subcomponents for normal, off-normal, and accident conditions are presented in Table 3.6-4 through Table 3.6-6 of [B.7-1]. Results for normal, off-normal, and accident conditions for the basket assembly subcomponents are summarized in Table 3.6-7 through Table 3.6-9 of [B.7-1].

The above design basis structural evaluations involved transfer operations of the canister in the OS197 transfer cask. The OS197 transfer cask is described in Section 4.2.3.3 of [B.7-7]. The discussion below provides the basis for acceptance of the MP187 cask for transfer operations of the canister.

Table B.7-3 presents a comparison of the OS197 transfer cask and the MP187 cask. In the canister design basis analysis the transfer cask is conservatively assumed to be rigid. Therefore, differences in stiffness due to different cask dimensions (shell thickness, cask length, etc.) between the OS197 transfer cask and MP187 cask have no impact on the canister analyses. Only the interface dimensions (cask cavity diameter, cask rail thickness and cask rail locations) may have an effect on the analyses only when the cask is in the horizontal orientation (e.g., side drop is the controlling case). As shown in Table B.7-3 the interface dimensions are the same between the two casks, except for the cask rail locations, where the rails are located at ±18.5º in the OS197 transfer cask and at ±30º in the MP187 cask. However, as shown in Figure B.7-1 the rails in the MP187 cask are located in the thickened region of the spacer disc, whereas in the OS197 transfer cask the rails are located in the thin region of the spacer disc perimeter. The side drop analyses are performed at multiple drop orientations of 0º, 18.5º and 45º. The 18.5º case corresponds to a drop on a single rail and represents the worst drop case. Thus, basket spacer disc stresses in the OS197 transfer cask are considered bounding.

Based on the evaluation above, the structural evaluation of the canister documented in Section 3.6 and Section 11.0 of [B.7-1] is applicable to the canister loaded in the MP187 cask for transfer operations at the WCS CISF.

B.7.4 Structural Analysis of AHSM with a Canister (Storage Configuration)

This section evaluates the AHSM loaded with the canister for service at the WCS CISF. The evaluation is based on the design basis stress analyses of these components documented in [B.7-1].

The structural analysis of the canister in the storage configuration and the AHSM (reinforced concrete and DSC steel support structure) for normal, off-normal, and accident conditions is presented in Section 3.6, Section 11.1 and Section 11.2, respectively, of [B.7-1]. Pertinent storage loads and load combinations applicable to the canister are described in Table 3.6-1 of [B.7-1]. AHSM loading summary descriptions are provided in Table 3.6-10. Load combinations applicable to the AHSM and DSC steel support structure are described in Table 3.6-12, and Table 3.6-13 of [B.7-1], respectively.

Results for normal and off-normal conditions for the canister shell assembly are summarized in Table 3.6-2, and for accident conditions in Table 3.6-3 of [B.7-1] as applicable. Controlling load combination results for the canister shell assembly subcomponents for normal, off-normal, and accident conditions are presented in Table 3.6-4 through Table 3.6-6, as applicable. Results for normal, off-normal, and accident conditions for the basket assembly subcomponents are summarized in Table 3.6-7 through Table 3.6-9 of [B.7-1], as applicable.

Calculated ultimate capacities of the AHSM concrete components are tabulated in Table 3.6-14 of [B.7-1], and the comparison with the resulting forces and moments is summarized in Table 3.6-15 of [B.7-1]. Stress analysis results for the DSC steel support structure are summarized in Table 3.6-16 (for the rail components), Table 3.6-17 (for the rail extension plates), and Table 3.6-18 (for the support structure cross members) of [B.7-1]. The stress qualification for these components is provided in Table 3.6-19 and Table 3.6-20 of [B.7-1]. The stress qualification for the AHSM ties and concrete keys is provided in Table 3.6-21 of [B.7-1].

B.7.5 Seismic Reconciliation of the Advanced NUHOMS® 24PT1 DSC and AHSM Storage Components and the MP187 Transfer Cask

The site-specific seismic ground motion developed for the WCS CISF in the form of the 10,000-year return period uniform hazard response spectra for the horizontal and vertical directions are described in Chapter 2.

As described in Section 2.2.3.1 of [B.7-1] the design basis seismic design criteria for the canister and AHSM components consists of the standard NRC Regulatory Guide 1.60 response spectrum shape anchored at a ZPA of 1.5g for the horizontal direction. The vertical spectrum is set at two-thirds of the horizontal direction over the entire frequency range. The horizontal and vertical spectra are specified at the top of the basemat. The horizontal and vertical components of the design response spectra, at 4% damping, are shown in Figure 2.2-1 and Figure 2.2-2 of [B.7-1].

A comparison of the seismic design basis for the Standardized Advanced NUHOMS® components and the *±15% peak broadened response spectra obtained at the center of gravity (CG) level from the soil structure interaction analysis of the WCS pad* are shown in Figure B.7-2 for the horizontal and vertical directions.

As shown in Figure B.7-2, the design basis seismic criteria for the canister and AHSM significantly exceed the seismic criteria for the *AHSMs and 24PT1s on the WCS pad*. Hence, the canister and the AHSM designs have significant margins and no reconciliation for seismic loads needs to be performed for these components.

As discussed in Appendix A.7, the design basis response spectra for the MP187 cask is the standard NRC Regulatory Guide 1.60 spectrum shape anchored at 0.25g for the horizontal direction and 0.17g for the vertical direction. These spectra are compared to the WCS CISF site-specific spectra in Figure A.7-1, for damping values of 3%, 5%, and 7%. *The WCS CISF site-specific spectra are compared to the ±15% peak broadened response spectra at the HSM base, which are obtained from the soil-structure interaction analysis of the WCS pad, in Figure A.7-5 and A.7-6 for a damping value of 3%.*

The discussion in Section B.7.3 demonstrates the similarity of the canister, described in [B.7-1], and the FO- DSC, described in [B.7-4]. Therefore, the seismic reconciliation of the MP187 cask loaded with a bounding FO-, FC- and FF- DSC presented in Section A.7.5.1 is applicable to the MP187 cask loaded with a 24PT1 DSC.

B.7.6 Thermal Stress Reconciliation of the Standardized Advanced NUHOMS® System Components

From Chapter 3, the maximum ambient temperatures at the WCS CISF are *81.5*°F, *113*°F and *113*°F for normal, off-normal, and accident conditions. Based on the discussion in Chapter 8, the corresponding 24-hour daily average temperatures of 95°F and 105°F for normal and off-normal conditions, respectively, are justified for use in the structural reconciliation evaluations for the WCS CISF.

The lowest off-normal ambient temperature at the WCS CISF is *30.1*°F. This is *above* the -20°F minimum temperature used in [B.7-4] (for use of the MP187) and is bounded by the -40°F in [B.7-1] (for use of the canister and AHSM).

B.7.6.1 Reconciliation of WCS CISF Environmental Ambient Conditions with Environmental Ambient Conditions used for the AHSM Analyses in the Standardized Advanced NUHOMS® UFSAR

The AHSM structural analysis is performed for normal ambient temperature range of 0 °F to 104 °F and off-normal maximum temperature range of -40 °F to 117°F, respectively, in Section 3.6.2 of [B.7-1]. These temperatures bound the daily average ambient temperatures of 95°F and 105°F used for normal and off-normal conditions, respectively at the WCS CISF. The lowest off-normal ambient temperature at the WCS CISF is *30.1*°F, which is bounded by the -40°F used in [B.7-1]. Therefore, the maximum temperatures and thermal stress evaluation results reported in [B.7-1] for the AHSM remain bounding for the WCS CISF.

B.7.6.2 Reconciliation of WCS CISF Environmental Ambient Conditions with Environmental Ambient Conditions used for the Canister Analysis in the Standardized Advanced NUHOMS® UFSAR

As documented in Table 4.1-1 (See also Table 3.1-8) of [B.7-1], the ambient temperature range for normal conditions is 0 °F to 104 °F. The ambient temperature range for off-normal and accident conditions is -40 °F to 117 °F. These temperatures bound the daily average ambient temperatures of 95°F, 105°F and 105°F for normal, off-normal and accident conditions, respectively used at the WCS CISF. Therefore, the maximum temperatures and thermal stress evaluation results reported in [B.7-1] for the canister in the AHSM remain bounding for the WCS CISF.

B.7.7 Conclusions of the Structural Analysis

This appendix demonstrates that the AHSM and the canister as described in [B.7-1] are suitable for storage at the WCS CISF. This appendix also demonstrates that the MP187 cask as described in [B.7-4] is suitable for transfer of the canister at the WCS CISF.

Furthermore, the design requirements and environmental conditions that form the design basis upon which the MP187 cask, the canister, and the AHSM components were licensed by the NRC bound the requirements and environmental conditions at the WCS CISF (with the exception of the seismic loading on the MP187 cask which is addressed in Section A.7.5.1). Therefore, the AHSM as described in [B.7-1] is acceptable for storage of the canister at the WCS CISF.

The structural performance of the MP187 cask with a canister *(Conditions of Storage)* at the WCS CISF, evaluated under normal, off-normal, and accident conditions of operation, satisfies all the 10 CFR Part 72 stress limits and criteria.

Finally, the structural performance of the canister confinement boundary was evaluated for Normal Conditions of Transport (See Section B.7.9) against ASME B&PC Code Subsection NB Article NB-3200 (Level A allowables) and were found to satisfy all of the stress limits and criteria demonstrating that the confinement boundaries are not adversely impacted by transportation of the canisters to the WCS CISF in the MP187 transport cask.

B.7.8 Alternate Cask Stability and Missile Penetration Evaluation of the MP187 Cask (On-Site Transfer Configuration)

This section presents an alternate structural evaluation of the MP187 cask for tornado, seismic, and missile impact loads. The evaluation encompasses stability, stress, and missile penetration effects, as applicable.

The following evaluation considers the MP187 cask loaded with an FO-, FC-, FF-DSC. The MP187 cask with 24PT1 DSC configuration is bounded by the MP187 cask with an FO-, FC-, or FF-DSC (Section B.7.3).

B.7.8.1 Assumptions

1. The gust factor, G, value for wind loading of 0.85 is taken from Section 6.5.8.1 of ASCE 7-05 standard [B.7-8].

2. The stability calculations use a weight of the MP187 cask with transfer skid and transfer trailer of W_c = 270 kips. Per Table B.7-6, the minimum weight of the loaded cask for the analyzed configurations is 221.98 kips. The weight for the MP187 cask transfer trailer is 40 kips, and for the transfer skid is 21 kips. Therefore, the total weight of the cask with transfer trailer and skid is expected to be at minimum 221.98+40+21 = 282.98 kips. Thus, assuming a minimum weight of 270 kips to calculate the resisting moment is conservative.

3. The MP187 transfer trailer length, width, and height dimensions are 264 inches, 10.5 feet and 42 inches, respectively. The length, width, and height of the transfer skid are 186 inches, 10.5 feet, and 15 inches, respectively (refer to Figure B.7-3). These dimensions are representative dimensions for NUHOMS® Systems' transfer equipment.

B.7.8.2 Material Properties

Material properties of the cask outer shell, top cover plate, and ram access cover plate at 400 °F are taken from [B.7-5]. The material properties for the analyzed components are summarized in Table B.7-7.

B.7.8.3 Design Criteria

For stability analyses, the permissible angle of rotation is considered to be equal to one third of the critical angle of rotation – i.e. the angle of tilt at which the center of gravity of the configuration is directly over the configuration's edge (tip-over angle).

Stress allowables are based on ASME Code, Section III, Division 1, Appendix F, [B.7-9].

For missile penetration analyses, the required material thickness is calculated using Nelms' formula from [B.7-10] and the Ballistic Research Laboratory methodology contained in [B.7-11].

B.7.8.4 Methodology

The following analyses are performed for the MP187 cask and components using hand calculations:

- stability analysis
- stress analysis
- penetration analysis

Methodology assumptions used in the evaluations are discussed below:

Stability Analysis Methodology

The stability evaluation for the overturning force caused by the DBT wind pressure is performed in Section B.7.8.6.1 by comparing the overturning moment acting on the cask-skid-trailer configuration (presented in Figure B.7-3) with the restoring moment of the assembly due to its self-weight. The analyses consider the lightest weights of the MP187 cask/canister configurations since they produce the smallest restoring moment.

The stability evaluation for the effects of seismic ground motion is performed in Section B.7.8.6.2 by comparing the overturning moment acting on the cask-skid-trailer configuration with the restoring moment of the assembly due its self weight. The seismic loads are conservatively assumed to act as constant (static) loads and the vertical acceleration is considered to act concurrently with the horizontal acceleration.

The stability evaluation for the tornado missile impact is conducted in Section B.7.8.6.3 using the equations of conservation of energy and conservation of angular momentum.

The stability evaluation for the combined tornado wind and missile load is performed in Section B.7.8.6.4 using the approximate force time-history of the missile impact from [B.7-11] and the standard equations of motion.

In the DBT wind effect evaluations, it is assumed that the combined geometry of the cask-skid-trailer system has a solid vertical projected area. The reduction in total wind pressure due to the open areas and shape factor is conservatively ignored.

Case B of Table B.7-5 (the massive high kinetic energy missile) is used for overturning stability of the cask since it produces the maximum force and the highest overturning moment. Conservatively, the impact is assumed as perfectly inelastic.

The tornado loads are generated for three separate loading phenomena. These phenomena are considered individually and then are considered in combination in accordance with Section 3.3.2 of NUREG-0800 [B.7-12] as follows:

1. Pressure or suction forces created by drag as air impinges and flows past the casks with a maximum tornado wind speed of 200 mph

2. Suction forces due to a tornado generated pressure drop or differential pressure load of 0.9 psi

3. Impact forces created by tornado-generated missiles impinging on the casks

Per [B.7-12], the total tornado load on a structure needs to be combined in accordance with formula:

$W_t = W_w + 0.5W_p + W_m$

where,

W_t = Total tornado load

W_w = Load from tornado wind effect

W_p = Load from tornado atmospheric pressure change

W_m = Load from tornado missile impact effect

Load from tornado atmospheric pressure change effect, Wp, in the above formula is ignored since temporary differential pressure load does not cause unbalanced loads on the symmetric design of the cask leading to overturning of the cask.

Stress Analysis Methodology

The stresses in the Cask Shell, Top Cover Plate (Lid) and Ram Closure Plate components due to DBT wind load and DBT missile load are calculated using the applicable analytic formulas for thin walled cylindrical vessels and flat circular plates, documented in [B.7-13].

The stresses evaluated in the analyzed components are:

- Primary Membrane Stress (P_M)
- Primary Membrane plus Bending Stress ($P_M + P_B$)

Stress allowables are based on the ASME Code, Section III, Division 1, Appendix F, [B.7-9].

The loads are specified in Sections B.7.8.5.1 and B.7.8.5.2 and are summarized in Table B.7-4 and Table B.7-5. Specific formulas used in the stress evaluations are presented in Section B.7.8.7.

Penetration Analysis Methodology

The critical thickness of plates that results in penetration by missile load is calculated by using Nelms' formula from [B.7-10] and the Ballistic Research Laboratory formula from [B.7-11]. These magnitudes are compared with the thickness of the Cask Shell, Top Cover Plate and Ram Closure Plate.

For this evaluation, the Case A missile (6" NPS Schedule 40 pipe, 15 ft. long) from Table B.7-5 is used. Missile Case B is judged less severe for penetration effects due to the large area of impact. Case C is judged less severe for penetration effects due to the much lower kinetic energy. The calculation evaluates missile impacts in the normal direction to the cask shell or plate to maximize penetration effect.

B.7.8.5 Design Input Loads & Data

DBT Velocity Pressure Load

The cask is evaluated for stress and overturning due to the Design Basis Tornado (DBT) loads specified in Table B.7-4. The DBT load characteristics correspond to those in Regulatory Guide 1.76 Region II parameters from [B.7-14] and ASCE 7-05 standard [B.7-8]. The MP187 cask dimensions and weight data are based on the design described in [B.7-5]. Load specifications are consistent with requirements of Section 3.3.2 of NUREG-0800 [B.7-12].

Per Table B.7-4 and per Section 6.5.10 of [B.7-8] (for the MP187 cask-skid-trailer assembly dimensions), the maximum velocity pressure load q_z at the height of the centroid of the analyzed assembly is

$$q_z = 0.00256\ K_z\, K_{dt}\, K_d\, I(v)^2$$
$$= 0.00256 \times 0.87 \times 1.0 \times 1.0 \times 1.15 \times 200^2 = 102.45\ \text{lb/ft}^2$$

Per Section 6.5.15 of [B.7-8], the design wind force, F, is calculated as:

$$F = q_z G C_f A_f = 102.45 \times 0.85 \times 0.82 \times 226 = 16.14\ kips.$$

In the above equation, the gust factor G=0.85 (per assumption 1 of Section B.7.8.1), the force coefficient C_f=0.82 (for cask-skid-trailer configuration dimensions), and the projected area normal to the wind for the analyzed assembly, A_f=226 ft^2. (for cask-skid-trailer dimensions).

DBT Generated Missile Impact Forces

The tornado-generated missile impact evaluation is performed for the missiles specified in Table B.7-5.

Automobile Missile (Table B.7-5 – Case B)

The impact force acting on the cask due to this missile is based on the Bechtel topical report ([B.7-11] equation D-6):

$$F = 0.625 \times V_i \times W_m \times \sin(20t) = 0.625 \times 134.81 \times 4000 \times \sin(20 \times 0.0785) \approx 340\,kip$$

In above equation:

t = time from the instant of initial impact (sec) = 0.0785 sec for maximum impact force to occur, [B.7-11]

V_i = total striking velocity of the missile
= $\sqrt{112^2 + (0.67 \times 112)^2} = 134.81$ fps (Table B.7-5)

W_m = weight of missile =4000 lb. (Table B.7-5)

Schedule 40 Pipe Missile (Table B.7-5 – Case A)

The impact force is calculated using the principle of conservation of momentum and the relation

$$F \Delta T = G_f - G_i$$

$$F = \frac{M_m (V_i - V_f)}{(T_f - T_i)} = \frac{M_m (V_i - V_f)}{(\Delta T)} = \frac{287 \times (134.81 - 0)}{32.2 \times 0.05 \times 1000} = 24.03\,kips$$

where:

ΔT = the time of contact = 0.05 sec (conservatively shorter than impact time 0.075 seconds, from [B.7-11])

G_f $= M_m V_f = 0$ the linear momentum after impact at time $T = T_f$

G_i = $M_m V_i$ the linear momentum at time $T = T_i$

V_i = total striking velocity of the missile
= $\sqrt{112^2 + (0.67 \times 112)^2} = 134.81$ fps (Table B.7-5)

M_m = the mass of the missile

B.7.8.6 Tornado & *Missile Impact* Loads Analysis - Stability Evaluations

Cask Stability for Design Basis Tornado Wind Pressure Load

The restoring moment will be the smallest for the assembly with minimum weight. Conservatively, the total weight of the loaded cask and transfer trailer and skid, W_c, is taken as 270 kips (refer to Section B.7.8.1, Assumption 2). The restoring moment, M_{st} = (Total Weight) × (Half Width of the Trailer) = 270 × 5.25 = 1,417.50 kips-ft.

The maximum overturning moment (M_{ot}) for the cask-skid-trailer due to DBT wind pressure is calculated by taking both the windward force and the leeward force into account. Conservatively, it is assumed that the wind loads on the windward side and leeward side are the same and are equal to the design wind load, F = 16.14 kips (calculated in Section B.7.8.5.1)

Per Figure B.7-3, the height corresponding to the centerline of the MP187 Cask is taken as the point of load application: H=(42+15+83.5/2) = 98.75 inches = 8.23 ft.

Therefore, the overturning moment, M_{ot} = 2×F×H = 2× 16.14 x (8.23) = 265.66 kip-ft

Factor of safety against overturning $\frac{M_{st}}{M_{ot}} = \frac{1417.50}{265.66} = 5.34$

Cask Stability for Massive Missile Impact Load

A stability analysis is performed to analyze the most critical impact, when the missile hits the cask on the side. However, it is conservatively assumed that the missile hits the top most point of the cask as shown in Figure B.7-4.

The Case B missile from Table B.7-5, i.e. the massive high kinetic energy automobile missile, is used since it produces the maximum force and the highest overturning moment. Conservatively, the impact is assumed as perfectly inelastic

Using the geometrical relations of Figure B.7-4 and the missile characteristics from Table B.7-5, the evaluation is based on conservation of momentum at impact and the conservation of energy to estimate the angle of rotation, θ, due to the impact (cask stops rotating when the angular velocity after impact becomes zero).

The resultant formula for the angle of rotation due to impact, θ, for the analyzed geometry has the following form:

$$\sin(\phi + \theta) = \frac{(R_1 V_i M_m)^2}{2W_c R_2[(I_c)_o + R_1^2 M_m]} + \sin\phi$$

with:

$\phi = \tan^{-1}({}^{L_1}/_{R}) = \tan^{-1}(\frac{42+15+83.5/2}{5.25\times 12})$

= 57.46° (refer to Figure B.7-3 and Figure B.7-4),

$(H_i)_o$ = the angular momentum about point O before impact $= R_1 \mathrm{V}_i M_m$ (Figure B.7-4),

$(H_a)_o$ = the angular momentum about point O after impact $= R_1^2 \omega_i M_m + (I_c)_o \omega_i$ (Figure B.7-4),

R_1 $= \sqrt{L^2 + R^2} = \sqrt{11.71^2 + 5.25^2} = 12.83\ ft$ is the distance from point O to the impact point (Figure B.7-4),

R_2 $= \sqrt{{L_1}^2 + R^2} = \sqrt{8.23^2 + 5.25^2} = 9.76\ ft$ is the distance from point O to the center of the cask. (Figure B.7-4),

V_i = total striking velocity of the missile = $\sqrt{112^2 + (0.67\times 112)^2} = 134.81$ fps (Table B.7-5),

M_m = the mass of the missile (4000/32.2 = 124.22 lbm, per Table B.7-5),

W_c = the minimum weight of the cask assembly (270 kips),

$(I_c)_o$ = the mass moment of inertia of the cask about an axis through point O,

$(I_c)_o = (I_c)_{CG} + M_c R_2^2$ (from the parallel axis theorem),

M_c = the mass of the cask assembly (270×1000)/32.2=8385.09 lbm,

$(I_c)_{CG}$ = the mass moment of inertia of the cask about center of gravity of MP187 cask.

Conservatively, $(I_c)_{CG} = \frac{M_c {R_c}^2}{2} = \frac{8385.09\times 3.48^2}{2} = 50{,}773.40\ ft^2 lbm$

Ultimately, angle of rotation due to impact can be determined as:

$$\theta = sin^{-1}(0.8531) - \emptyset = 58.55° - 57.46° = 1.09°$$

Tip over occurs when the C.G. is directly above the point of rotation, therefore the tip over angle is $\theta_{tip} = 90.0° - 57.46° = 32.54°$, and $1/3\,\theta_{tip} = 1/3 \times 32.54° = 10.85°$. Since $\theta < 1/3 \times \theta_{tip}$, the tip over of the cask will not occur.

Cask Stability for Design Basis Tornado Wind and Missile Load Combination

A time-dependent analysis is performed to determine the maximum angle of rotation attained by the cask-skid-trailer assembly due to concurrent DBT wind and missile loading. The input loading is the summation of the wind pressure loading from Section B.7.8.5.1 and the massive missile impact force from Section B.7.8.5.2. The standard equations of rotational motion are solved with an approximate step-wise linear procedure to determine the rotational motion of the assembly subjected to the combined wind and missile loading.

The overturning moment causing rotational acceleration is:

$$M_{acc} = M_{ot} - M_{st}$$

The angular velocity is:

$$\omega_i = \frac{\left[\frac{M_{acc,i} + M_{acc,i-1}}{2} * (t_i - t_{i-1})\right]}{(I_c)_o} + \omega_{i-1}$$

The angle of rotation is:

$$\theta_i = \left[\frac{\omega_i + \omega_{i-1}}{2} * (t_i - t_{i-1})\right] + \theta_{i-1}$$

where,

i = index for the current time step

$i-1$ = index for the previous time step

In the above equations the overturning moment and stabilizing moments are, respectively:

$$M_{ot} = F_{missile} * L + q_z * L_\theta^2 * L_T$$

$$M_{st} = W_c * R_2 * \cos(\emptyset + \theta)$$

where:

L_θ = height to the top of cask system which is dependent on rotation angle θ,

L = 42+15+83.5=140.5 inch, initial total height of the cask system (Figure B.7-3),

L_T = 264 inch, length of trailer (Section B.7.8.1)

$F_{missile}$ $= 0.625 V_i W_m sin(20t)$, missile force, refer to Section B.7.8.5.2, per Ref. [B.7-11], equation D-6

W_c = 270 kips, is the minimum weight of the cask assembly (Section B.7.8.1),

R_2 = 9.76 ft, is the distance from point O to the center of the cask. (Figure B.7-4).

The solution to the equation of motion is documented in Figure B.7-5. The governing angle of rotation is θ=3.0°.

As indicated in Section B.7.8.6.3, the tip over angle $\theta_{tip} = 32.54°$ and $1/3 \times \theta_{tip} = 10.85°$. Since $\theta < 1/3 \times \theta_{tip}$, the tip over of the cask will not occur.

B.7.8.7 Tornado Wind and Missile Analysis - Stress Evaluations

Stress evaluations for cask components exposed to tornado loads are discussed below. The evaluations consider the cask as a thin walled vessel and the cover plates as simply supported thin circular plates, and use stress formulas from [B.7-13] appropriate for the analyzed load characteristics. Specifications of the stress formulas and basic assumptions employed in the analyses are summarized below. Stress results are listed in Table B.7-8 and Table B.7-9.

Stress Formulas Used in Tornado Loads Evaluations		
Load Description	**Component Analyzed**	**Stress Formula Reference & Assumptions**
Wind Pressure Load	Outer Shell	[B.7-13], case 8c from Table 13.3, page 650; Simply supported thin cylindrical shell, subjected to a uniform pressure load over the entire length
	Top Cover Plate	[B.7-13], case 10a from Table 11.2, page 509; Simply supported thin circular plate, subjected to a uniform pressure load over the entire area
	RAM Closure Plate	[B.7-13], case 10a from Table 11.2, page 509; Simply supported thin circular plate, subjected to a uniform pressure load over the entire area
Massive Missile Load	Outer Shell	[B.7-13], case 8b from Table 13.3, page 650; Simply supported thin cylindrical shell, subjected to a concentrated load over the short length
	Top Cover Plate	[B.7-13], case 10a from Table 11.2, page 509; Simply supported thin circular plate, subjected to a uniform load over the entire area
	RAM Closure Plate	[B.7-13], case 10a from Table 11.2, page 509; Simply supported thin circular plate, subjected to a uniform load over the entire area
Local	Outer Shell	[B.7-13], case 8a from Table 13.3, page 649; Simply supported thin cylindrical shell, subjected to load P distributed over a

Load		small area at midspan
	Top Cover Plate	[B.7-13], case 16 from Table 11.2, page 514; Simply supported thin circular plate, subjected to a load over the small central area
	RAM Closure Plate	[B.7-13], case 16 from Table 11.2, page 514; Simply supported thin circular plate, subjected to a load over the small central area

B.7.8.8 Tornado Missile Analysis - Penetration Evaluations

Nelms' Formula Evaluation

Nelms' formula [B.7-10] is used to determine the thickness value due to incipient puncture energy, which is directly proportional to the mass and velocity of the missile and inversely proportional to the diameter of the missile.

$$E_F = \frac{1}{2} M_m V_m^{\ 2}$$

$$E_F / S = 2.4 d^{1.6} t^{1.4}$$

where:

M_m = the mass of the missile (287 lbs)/(32.2 ft/sec^2) = 8.91 lbm,

V_m = the total velocity of the striking missile normal to target surface (=134.81 fps),

S = the ultimate tensile strength of the jacket material (refer to Table B.7-7),

t = the maximum thickness of plate material leading to onset of plate puncture (inch),

d = the diameter of the punch/missile (6.625 inch, refer to Table B.7-7),

E_F = the incipient puncture energy of the prismatic cask jacket (inch - lb).

The threshold thickness values causing perforation for the Outer Shell, Top Cover Plate and RAM Closure Plate according to Nelms' correlation are 0.43 inch, 0.43 inch, and 0.43 inch, respectively.

Ballistic Research Laboratory Formula Evaluation

In the Ballistic Research Laboratory report, the relation for the determination of the thickness is also directly proportional to mass and velocity and inversely proportional to diameter of the missile.

$$t = \frac{\left(\frac{M_m V_m^2}{2}\right)^{2/3}}{672d} = 0.42 \text{ inch}$$

In the above relation:

t = the maximum thickness of plate material leading to onset of plate puncture (inch),

d = the diameter of the punch/missile (= 6.625 inch),

M_m = the mass of the striking missile, (=287/32.2 = 8.91 lbm),

V_m = the velocity of the striking missile normal to target surface (=134.81 fps).

Reference [B.7-11] recommends increasing the thickness, t, by 25 percent to prevent perforation. Therefore, the minimum thickness required to prevent perforation of the MP187 cask is 0.53 inch.

B.7.8.9 Summary of Results

The factor of safety on overturning from DBT tornado wind pressure load is 5.34.

The resultant stresses for the bounding individual DBT, missile impact and combined tornado load are summarized in Table B.7-8 and Table B.7-9, respectively. The primary membrane stress and combined membrane plus bending stresses due to DBT and missile impact are below the allowable stresses.

The minimum thickness of the steel components required to prevent perforation by tornado missiles is found to be 0.53 inch, which is less than the thickness of the MP187 cask Outer Shell, Top Cover Plate, and RAM Closure Plate of 2.49 inches, 6.50 inches, and 3.18 inches, respectively.

The maximum rotation angle of the MP187 cask transfer configuration due to combined tornado wind plus massive missile impact load is θ=3.0°, which is significantly below the permissible angle of rotation, 10.85°.

B.7.9 Structural Evaluation of 24PT1-DSC Confinement Boundary under Normal Conditions of Transport

The 24PT1-DSC shell assembly consists of a cylindrical shell, top outer/inner cover plates, bottom inner/outer cover plates and bottom and top shield plugs. The 24PT1-DSC consists of a shell, which is a welded, stainless steel cylinder with a stainless steel bottom closure assembly, and a stainless steel top closure assembly. Additional details, geometry and shell and plate thicknesses are provided on the drawings in Section B.4.6. The confinement boundary is addressed in Section B.11.1. The 24PT1-DSC shell is evaluated for Normal Conditions of Transport in the MP187 Transport cask in Section A.7.7.2 with the FO-DSC of the NUHOMS® MP187 Cask System.

Result of the FO- and 24PT1 DSCs structural analysis are acceptable for the loads and combinations described in Table A.7-3 and hence structurally adequate for normal conditions of transport loading conditions.

B.7.10 References

B.7-1 AREVA TN Document, ANUH-01.0150, Revision 6, "Updated Final Safety Analysis Report for the Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, NRC Docket No. 72-1029.

B.7-2 U.S. Nuclear Regulatory Commission, "License for Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste," License Number SNM-2510, Docket Number 72-11.

B.7-3 U.S. Nuclear Regulatory Commission, "Certificate of Compliance No. 9255, Revision 12 for the Model No. NUHOMS®-MP187 Multi-Purpose Cask (Docket 71-9255).

B.7-4 "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report," NRC Docket No. 72-11, Revision 4.

B.7-5 AREVA TN Document NUH-05-151 Rev. 17, "NUHOMS®-MP187 Multi-Purpose Transportation Package Safety Analysis Report." (Basis for NRC CoC 71-9255).

B.7-6 U.S. Nuclear Regulatory Commission, Certificate of Compliance for the Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, Certificate No. 1029.

B.7-7 AREVA TN Document NUH-003, Revision 14, "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel." (Basis for NRC CoC 72-1004).

B.7-8 American Society of Civil Engineers Standard ASCE 7-05, "Minimum Design Loads for Buildings and Other Structures," (Formerly ANSI A58.1).

B.7-9 ASME Boiler and Pressure Vessel Code, Section III, Appendix F, 2004 Edition with 2006 Addenda.

B.7-10 H.A. Nelms, "Structural Analysis of Shipping Casks, Effects of Jacket Physical Properties and Curvature on Puncture Resistance," Vol. 3, ORNL TM-1312, Oak Ridge National Laboratory, Oak Ridge Tennessee, June 1968.

B.7-11 R.B. Linderman, J.V. Rotz and G.C.K. Yek "Design of Structures for Missile Impact," Topical Report BC-TOP-9A, Bechtel Power Corporation, Revision 2, September 1974.

B.7-12 U.S. NRC Document, NUREG-0800, Section 3.3.2, Revision 3, "Tornado Loads," Standard Review Plan (Formerly NUREG-76/087), 2007.

B.7-13 R.G Budynas and W.C Young, "Roark's Formula for Stress and Strain," Eighth Edition, McGraw-Hill Book Company.

B.7-14 Reg Guide 1.76, "Design-Basis Tornado And Tornado Missiles For Nuclear Power Plants," Revision 1, March 2007.

Table B.7-1
Configuration of the FO-DSC Compared to the 24PT1 DSC (from Table A2.1-1 of [B.7-5])

Characteristic	FO-DSC Configuration	24PT1-DSC Configuration
Shell Outside Diameter x Length	67.19 “ x 186.5”	67.19” x 186.5”
DSC Internal Cavity Length	167.0”	167.0”
Shell (SA240)	5/8” thick, Type 304	5/8” thick, Type 316
Support Rod Diameter/Preload	2”/80 +/- 5 kips	1.25”/40 +/- 15 kips
Support Rod Spacer Sleeves, Outside Dia./Inside Dia.	3” / 2.08”	3” / 1.33”
Spacer Discs (Number-Material)	26 – SA537, Cl 2	26 – SA537, Cl 2
Spacer Disc Spacing	See Section 1.3.2 of [B.7-5] for spacing	See Section A1.3.2 of [B.7-5] for spacing
Guidesleeves (inside width x length)	8.9” x 161.8”	8.9” x 165.25”
Top and Bottom Fuel Spacers	Not Required	See Section A1.3.2 of [B.7-5]
Failed Fuel Cans	Not Permitted	Up to four, symmetrically loaded (similar to FF-DSC)

Table B.7-2
Comparison of Canister Weights, Centers of Gravity and Moments of Inertia (from Table A2.2-1 of [B.7-5])

Parameter	FO-DSC	FC-DSC	FF-DSC	24PT1-DSC
Total Canister weight (lbs)	80,710	81,120	74,900	78,400[1,2]
Canister cg location, along center line of canister, with respect to the outer surface of the MP187 Cask bottom cover plate (inches)	100.4	98.7	102.4	99.3
Canister MOI ($lbm\text{-}in^2$), relative to cg	3.36E+08	2.88E+08	3.03E+08	3.29E+08

1 This weight is increased by 1,000 lbs. when four failed fuel cans are included in the canister.

2 This weight is made up of (rounded to nearest 100 lbs.):

Shell Assembly	15,600 lbs.
Basket Assembly	18,500 lbs.
Shield Plug	8,000 lbs.
Inner Cover Plate	700 lbs.
Outer Cover Plate	1,200 lbs.
Fuel Spacers	2,700 lbs.
WE 14x14 fuel/including NFAH	31,700 lbs.

Table B.7-3
MP187 and OS197 Casks – Comparison of Basic Design Parameters

Parameter	MP187 Cask	OS197 Cask
Outer Shell Thickness (*in*)	2.49	1.50(1)
Inner Shell Thickness *(in)*	1.24	0.50
Bottom End Closure Thickness *(in)*	8.00	5.00
Top Lid Thickness (*in*)	6.50	5.25
Lead Gamma Shield Thickness *(in)*	4.00	3.56
Cask Body Outer Diameter (*in*)	83.50	79.12
Cask Cavity Diameter *(in)*	68.00	68.00
Cask Rails Locations (from bottom centerline)	±30.0º	±18.5º
Cask Rail Thickness (*in*)	0.12	0.12
Overall Length of Cask Body (*in*)	201.50	207.22
Cavity Length (*in*)	187.00	196.75
Cask Weight (Dry, Empty) (*kips*)	158.58	111.25
Cask Weight (Dry, Loaded) (*kips*) w/ bounding FC-DSC	239.70	N/A
Cask Weight (Dry, Loaded) (*kips*) w/ 24PT1 DSC	237.20	189.65

Note: (1) Thickened to 2.00 inches at upper trunnion regions

Table B.7-4
DBT Wind Load Characteristics for WCS CISF

Design Parameter	Design Criteria
Maximum wind speed	200 miles per hour
Maximum rotational speed	160 miles per hour
Translational speed	40 miles per hour
Radius of the maximum rotational speed	150 feet
Pressure drop across the tornado	0.9 psi
Rate of pressure drop	0.4 psi per second

Table B.7-5
Design-Basis Tornado Missile Spectrum and Maximum Horizontal Speeds

Case #	Missile	Weight (lb)	Horizontal Impact Velocity V_{MH}^{max} (fps)
A	Schedule 40 Pipe (ϕ 6.625 inch x 15 ft long)	287	112
B	Automobile (16.4 ft x 6.6 ft x 4.3 ft)	4,000	112
C	Solid Steel Sphere (ϕ 1 inch)	0.147	23

Note: V_{MH}^{max} = Horizontal velocity of missile, vertical velocity of missile = 0.67 V_{MH}^{max}

Table B.7-6
NUHOMS®-MP187 Cask and Canister Weights for Analyzed Configurations

	Configuration of Cask/DSC for MP187 Cask			
	Configuration	(Ref. [B.7-5, Table 2.1.2-1])	(Ref. [B.7-5, Table A2.2-1])	
Case No.	Cask/Canister	Weight of Cask without NSP Assembly (lb)	DSC Weight (lb)	Total Weight (lb)
1	MP187/FC-DSC	147,080	81,120	228,200
2	MP187/FO-DSC	147,080	80,710	227,790
3	MP187/FF-DSC	147,080	74,900	221,980
4	MP187/24PT1 DSC (14x14 Fuel Assembly)	147,080	78,400	225,475

Table B.7-7
Materials, Properties and Allowable Stresses for MP187 Cask at 400 ºF

Material Properties for MP187 at 400°F							
Component	**Material**	**S_m (ksi)**	**S_y (ksi)**	**S_u (ksi)**	**E (10^3 ksi)**	**Primary Membrane (ksi)**	**Primary Membrane plus Bending (ksi)**
Top Structural Shell (4)	SA-240 Type 304	18.7	20.7	64.4	26.5	44.90	64.40
Bottom Structural Shell (4)	SA-240 Type XM-19	30.2	40.8	90.7	26.5	63.50	90.70
Ram Access Closure Plate	SA-240 Type XM-19	30.2	40.8	90.7	26.5	63.50	90.70
Top Closure Plate	SA-240 Type 304	18.7	20.7	64.4	26.5	44.90	64.40

Note:

1. Primary Membrane stress for Service Level D, $P_m \leq$ min ($2.4S_m$, $0.7S_u$) (Ref. [B.7-9])
2. Membrane plus Bending stress for Service Level D, $P_m + P_b \leq$ min ($3.6S_m$, S_u) (Ref. [B.7-9])
3. Material properties are taken from Ref. [B.7-5].
4. Conservatively, material properties of the top structural shell are used in the evaluation as the allowables are less and will bound bottom structural shell as well.

Table B.7-8
Stress Results for MP187 Cask due to Tornado Wind and Missile Loads

MP187 Cask Results						
Load Description	**Stress Category**	**Calculated Stress (ksi)**			**Allowable Stress (ksi)**	**Impact Force**
		Structural Shell	**Top Cover Plate**	**Ram Access Closure Plate**		
Wind Pressure Load	Primary Membrane	0.19	0.00		44.9	16.14 kips
	Primary Membrane plus Bending	0.72	0.04		64.4	
	Primary Membrane			0.00	63.5	
	Primary Membrane plus Bending			0.15	90.7	
Massive Missile Loads	Primary Membrane	15.37	0.07		44.9	340 kips
	Primary Membrane plus Bending	55.21	3.24		64.4	
	Primary Membrane			1.50	63.5	
	Primary Membrane plus Bending			14.74	90.7	
Local Load	Primary Membrane	1.24	0.70		44.9	24.03 kips
	Primary Membrane plus Bending	3.88	1.87		64.4	
	Primary Membrane			0.70	63.5	
	Primary Membrane plus Bending			5.57	90.7	

Table B.7-9
Combined Tornado Effect on MP187 Cask – Stress Results

Load Description	Stress Category	Combined Stress (ksi)			Allowable Stress (ksi)
		Structural Shell	Top Closure Plate	Ram Access Closure Plate	
Wind Pressure Load + Missile Load	Primary Membrane	15.56	0.07		44.9
	Primary Membrane plus Bending	55.93	3.28		64.4
	Primary Membrane			1.50	63.5
	Primary Membrane plus Bending			14.90	90.7

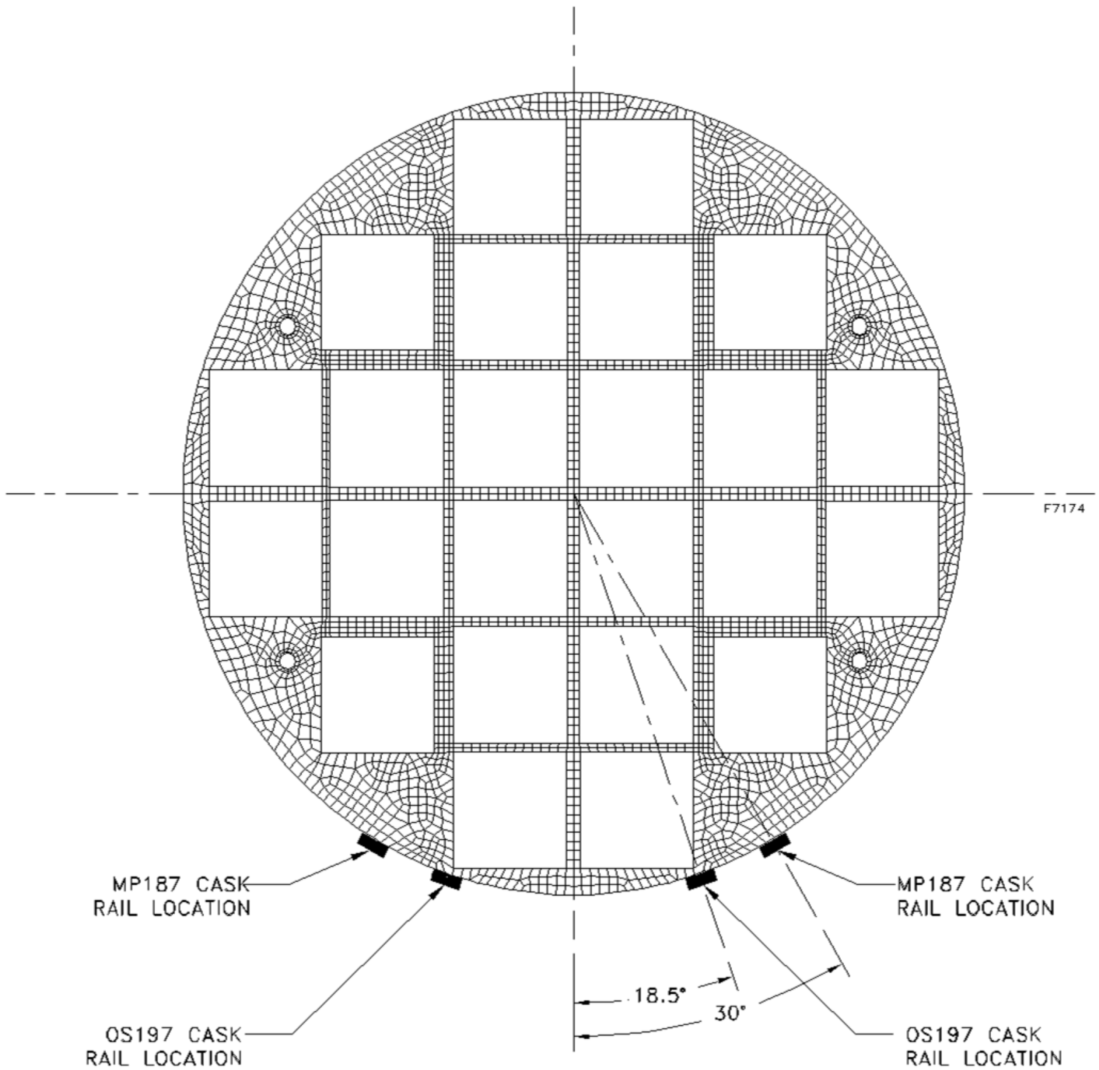


Figure B.7-1
Location of Cask Rails in the MP187 and OS197 Casks

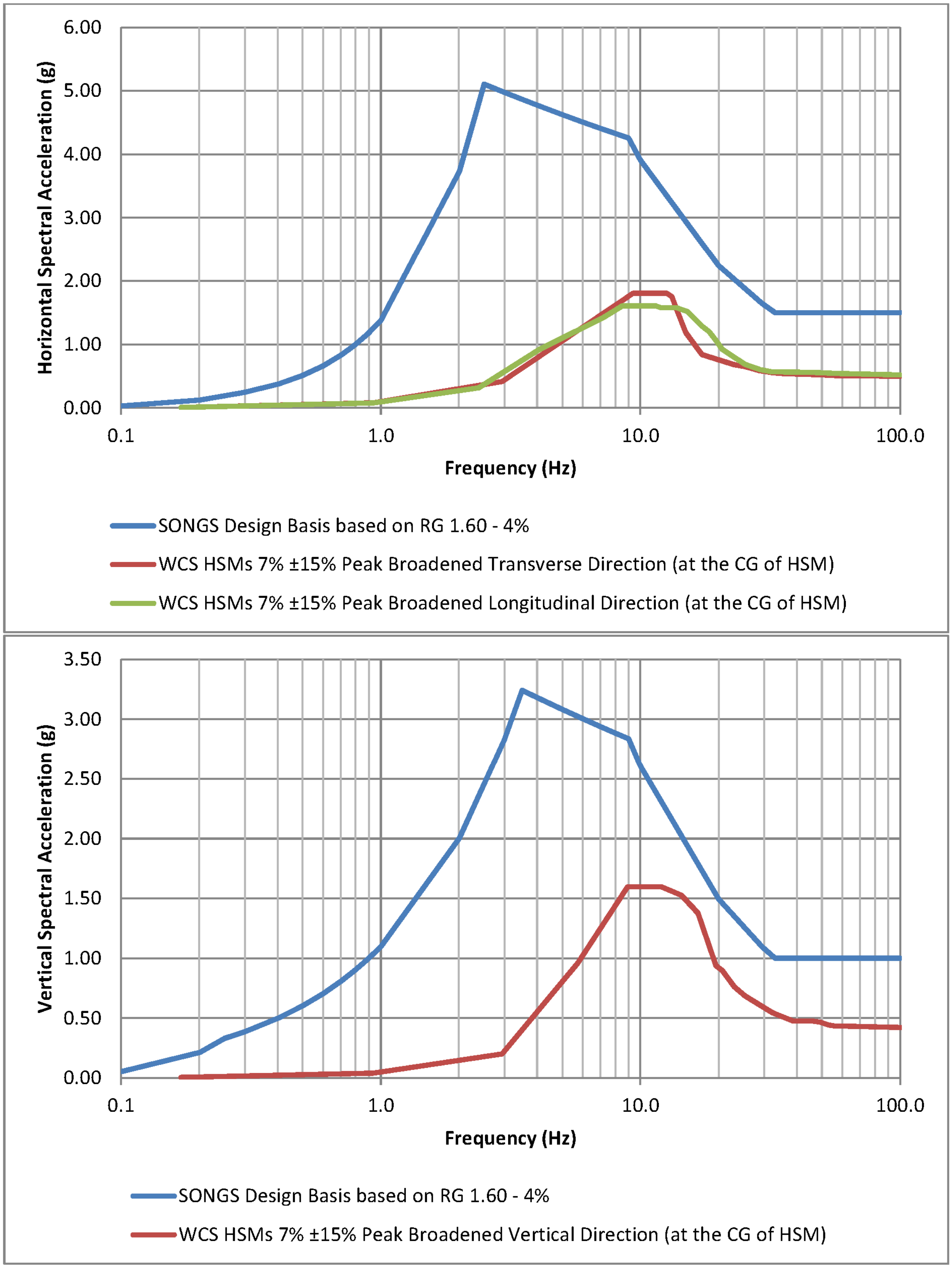


Figure B.7-2

Design Basis Response Spectra for Canister, and AHSM compared to the Spectra at the C.G. of the HSM from WCS Soil Structure Interaction Analysis

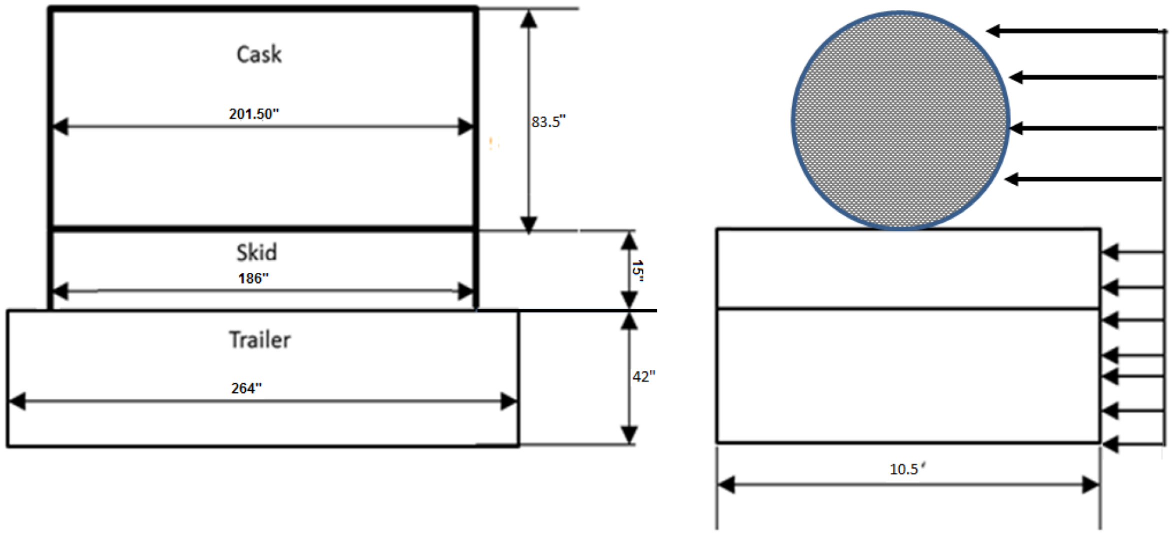


Figure B.7-3
Arrangement of MP187 Cask Shell, Skid and Trailer at Rest

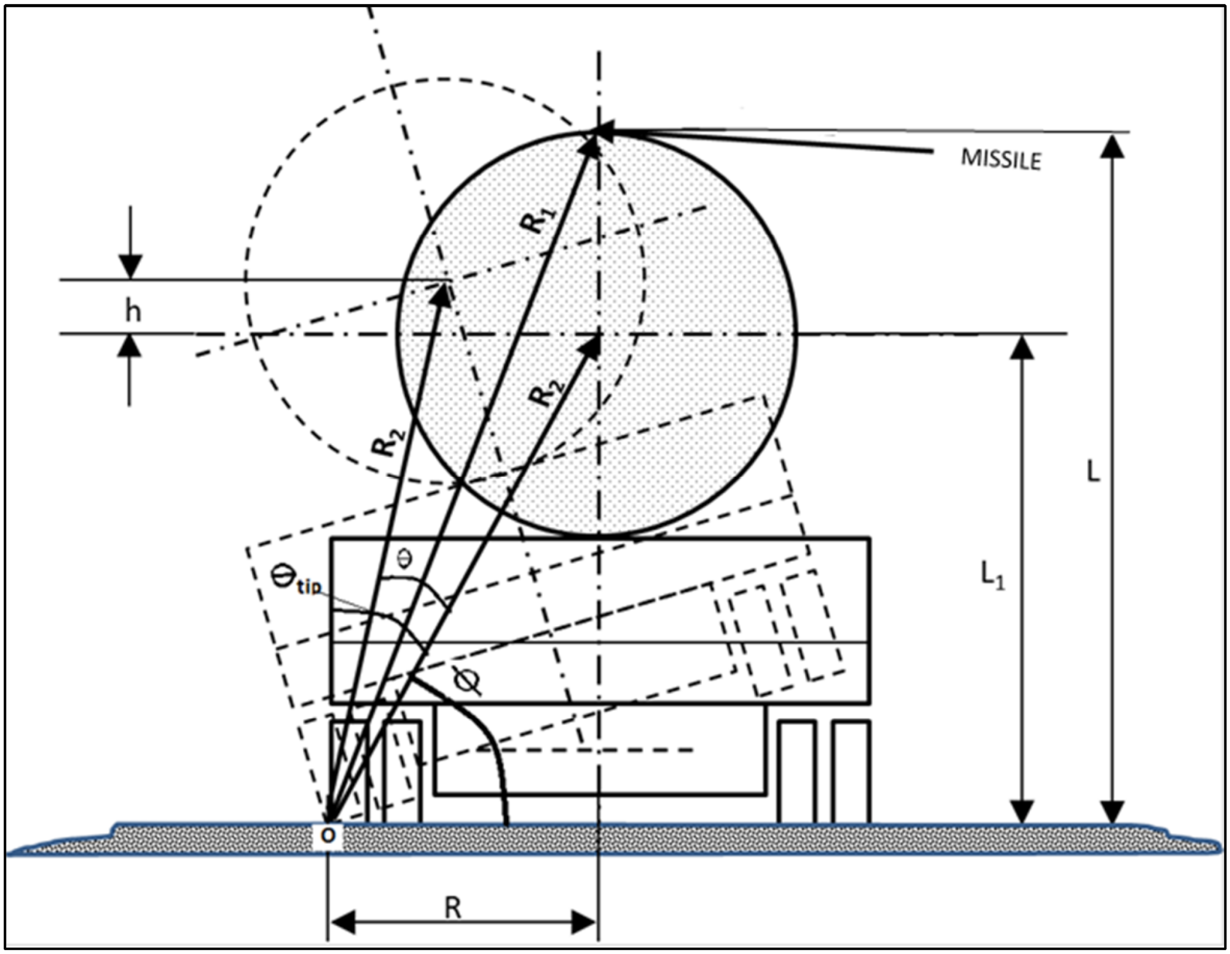


Figure B.7-4
Geometry Utilized in Cask Stability Assessments

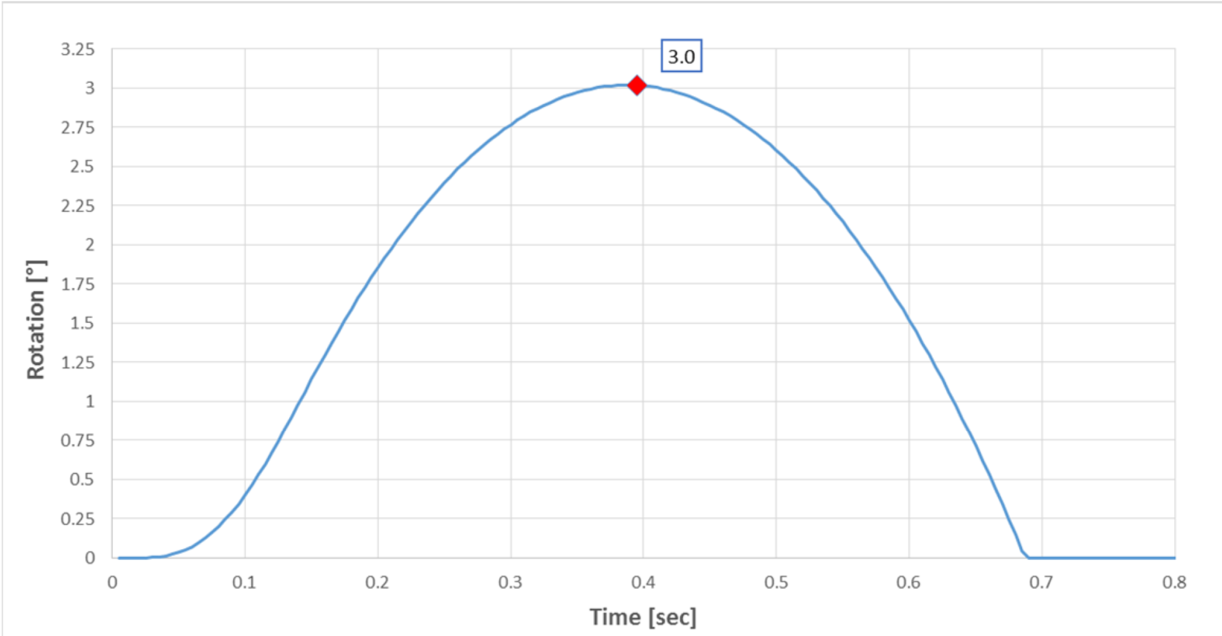


Figure B.7-5
Angle of Rotation due to Wind and Massive Missile Loading Combination

APPENDIX B.8
THERMAL EVALUATION
Standardized Advanced NUHOMS® System

Table of Contents

B.8. THERMAL EVALUATION

This Appendix qualifies the Standardized Advanced NUHOMS® System for storage and transfer at the Waste Control Specialist, LLC (WCS) Consolidated Interim Storage Facility (CISF) with the same heat load of 14 kW under the WCS CISF environmental conditions. No new thermal analysis is performed in this Appendix. This qualification demonstrates that all the 10 CFR Part 72 thermal requirements for storage and transfer of the 24PT1 Dry Shielded Canisters (DSCs or canisters) at the WCS CISF are met.

As presented in Chapter 1, Table 1-1, the Standardized Advanced NUHOMS® System storage components include the 24PT1 DSC and the AHSM concrete overpack.

The 24PT1 DSC is described in Section 3.1.1.1 of the Standardized Advanced NUHOMS® Updated Final Safety Analysis Report (UFSAR) [B.8-1]. The AHSM is described in Section 3.1.1.2 of the UFSAR [B.8-1].

At the WCS CISF, the NUHOMS®-MP187 cask will be used for on-site transfer operations. The MP187 cask is a multi-purpose cask approved by the NRC as a transportation cask for off-site shipments of the 24PT1 DSC [B.8-2]. This Appendix qualifies the thermal design of the MP187 cask for transfer operations with the 24PT1 DSC.

B.8.1 Discussion

As discussed in Chapter 1, loaded 24PT1 DSCs from an existing ISFSI site are to be transported to the WCS CISF inside a NUHOMS®-MP187 Multi-Purpose Cask [B.8-2] under NRC Certificate of Compliance 9255 [B.8-3]. At the WCS CISF, the 24PT1 DSCs are to be stored inside AHSM modules described in the Standardized Advanced NUHOMS® Updated Final Safety Analysis Report [B.8-1]. The MP187 cask is also to be used for on-site transfer of loaded 24PT1 DSCs.

A description of the 24PT1 DSC and AHSM design features is presented in Section 3.1.1.1 and 3.1.1.2, respectively of [B.8-1]. The thermal analysis for storage of the 24PT1 DSC inside the AHSM module is presented in Chapter 4 of [B.8-1]. This Appendix reconciles the thermal evaluation performed in [B.8-1] for the storage of the 24PT1 DSC in the AHSM for normal, off-normal and accident conditions at the WCS CISF.

A description of the MP187 Cask is presented in Volume 1, Section 4.2.5.3 of the Rancho Seco SAR [B.8-4] and is licensed at that site for on-site transfer of FO- FC- FF- DSCs and GTCC waste canisters. The use of the NUHOMS® MP187 Cask for the on-site transfer of the 24PT1 DSC at the WCS CISF under 10 CFR Part 72 is qualified in this Appendix.

B.8.2 Summary of Thermal Properties of Materials

The thermal properties of the materials used in the analysis of the AHSM storage module and the 24PT1 DSC are described in Section 4.2 of [B.8-1]. The thermal properties of the materials used in the analysis of the MP187 Cask are discussed in Volume III, Section 8.1.1.1 of the Rancho Seco SAR [B.8-4].

B.8.3 Specification for Components

Allowable temperature ranges for the structural materials used in the design are given in Table 4.1-3, Table 4.1-4, and Table 4.1-5 of [B.8-1].

B.8.4 Ambient Conditions at the WCS CISF

B.8.4.1 Ambient Temperature Specification at WCS CISF

As specified in Table 1-2, normal ambient temperature is considered in the range of *44.1*°F to *81.5*°F. Off-normal ambient temperature is considered in the range of -*30.1*°F to *113*°F. *Accident ambient temperature is considered as 113°F.*

B.8.4.2 Comparison of WCS CISF Ambient Conditions with Ambient Conditions Used in the AHSM Thermal Evaluation from ANUH UFSAR [B.8-1] for Storage Conditions

A review of the ambient temperatures used in the thermal evaluation of AHSM in Section 4.1.2 of [B.8-1] shows that average daily ambient temperatures of 97°F and 107°F *corresponding to a maximum ambient temperatures of 101°F and 117°F* are used for normal and off-normal hot storage conditions, respectively. These temperatures bound the ambient temperatures for normal and off-normal conditions at the WCS CISF. *In addition, the accident ambient temperature of 113°F listed in Table 1-2 for the WCS CISF is the daily maximum ambient temperature. This is bounded by the daily maximum temperature of 117°F considered for the off-normal conditions. The* lowest off-normal ambient temperature *evaluated is* the -40°F considered for the off-normal conditions as noted in Table 4.1-1 of [B.8-1].

Based on this discussion, the ambient conditions used for the thermal evaluations for storage operations in the thermal evaluation of AHSM in [B.8-1] are bounding for the WCS CISF.

B.8.4.3 Comparison of WCS CISF Ambient Conditions with Ambient Conditions Used in the Rancho Seco ISFSI SAR [B.8-4] for Transfer Conditions

A review of the thermal evaluation presented in Section 8.1.1.1, Volume II of [B.8-4] shows that average daily ambient temperatures of 101°F and 117°F are used for normal and off-normal hot storage conditions, respectively. These temperatures bound the ambient temperatures for normal*,* off-normal*, and accident* conditions, respectively at the WCS CISF. Similarly, the lowest off-normal ambient temperature at the WCS CISF is *30.1°F and is bounded by the* -20°F, cold conditions considered in [B.8-4].

Based on this discussion, the ambient conditions used for the thermal evaluations for transfer operations in [B.8-4] are bounding for the WCS CISF.

B.8.5 Thermal Analysis of AHSM with 24PT1 DSC for Storage Conditions

As discussed in Section B.8.1, 24PT1 DSCs will be stored inside the AHSM storage modules at the WCS CISF. This configuration for storage operations is approved under CoC 1029 and a discussion on the thermal evaluation for this configuration is presented in Chapter 4 of [B.8-1]. Because this configuration is previously approved, this section only presents a reconciliation of the ambient temperatures between the thermal evaluation in [B.8-1] and the WCS CISF.

Based on this discussion in Section B.8.4.2, the ambient conditions used for the thermal evaluations of AHSM in [B.8-1] are bounding for the WCS CISF and therefore, no additional evaluations are performed. Sections B.8.5.2 through B.8.5.4 present the references to the appropriate section within [B.8-1] as it relates to the thermal evaluations performed for 24PT1 DSC during storage in AHSM.

B.8.5.1 Thermal Model of the AHSM with 24PT1 DSC

The HEATING7 thermal model of the AHSM used for evaluation of normal and off-normal conditions of the AHSM components is described in Section 4.4.2.2 of [B.8-1].

The thermal model used for the evaluation of the AHSM components for a 40-hour AHSM blocked vent accident is essentially the same as that described in Section 4.4.2.2 of [B.8-1] with minor modifications as described in Section 4.6.2.2 of [B.8-1]. The thermal model of the 24PT1 DSC basket is described in Section 4.4.4.1 of [B.8-1].

B.8.5.2 AHSM Thermal Model Results

Normal and Off-Normal Conditions:

As documented in Section 4.4.2.2 of [B.8-1], the AHSM is qualified for a heat load of 24 kW. The design basis heat load for the AHSM at the WCS CISF for storage of the 24PT1 DSC is 14 kW.

The AHSM thermal model results presented in Table 4.4-3 and Table 4.4-5 of [B.8-1] are evaluated for a heat load of 24 kW. These tables present the maximum temperatures of the AHSM concrete, heat shields, DSC steel support structure, DSC shell and the DSC shell assembly subcomponents for normal and off-normal conditions. The calculated maximum temperatures of the AHSM and the 24PT1 DSC subcomponents are below their respective allowable material limits listed in Table 4.1-3 and Table 4.1-4 of [B.8-1]. These results bound the results of a 24PT1 DSC/AHSM with a 14 kW heat load stored at the WCS CISF for normal and off-normal conditions.

AHSM Blocked Vent Accident

The AHSM thermal model results for a 40-hour blocked vent accident are presented in Table 4.4-3 and Table 4.4-5 of [B.8-1]. Theses tables present the maximum temperatures of the AHSM and 24PT1 DSC shell assembly subcomponents based on a design basis heat load of 24 kW. The calculated maximum temperatures are below the allowable material limits listed in Table 4.1-5 of [B.8-1]. These results bound the results for AHSM/24PT1 DSC with a 14 kW heat load at the WCS CISF for accident conditions.

The bounding internal pressure for the 24PT1 DSC for normal, off-normal and accident conditions of storage are listed in Table 4.4-11 of [B.8-1].

B.8.5.3 Evaluation of AHSM Performance with 24PT1 DSC

The thermal performance of the AHSM module with a 24PT1 DSC at the WCS CISF under normal, off-normal, and accident conditions of operation is bounded by the evaluation documented in [B.8-1]. The bounding evaluation demonstrates that all the 10 CFR Part 72 thermal limits and criteria for the WCS CISF are met.

B.8.5.4 NUHOMS®-24PT1 DSC Basket Model Results

Normal, Off-Normal and Accident Conditions

The AHSM model is used to calculate the maximum 24PT1 DSC shell temperatures for a decay heat load of 16 kW and 14 kW in [B.8-1] for normal, off-normal and AHSM blocked vent accident conditions. The DSC shell temperatures, presented in Table 4.4-4 of [B.8-1], are used as boundary conditions in the 24PT1 DSC basket model for calculating basket component temperatures and fuel cladding temperatures. The calculated basket component temperatures and fuel cladding temperatures are presented in Table 4.4-6 and 4.4-7, respectively of [B.8-1]. These calculated temperatures are below their respective allowable material temperature limits listed in Tables 4.1-3, 4.1-4 and 4.1-5 of [B.8-1].

B.8.6 Thermal Analysis of MP187 Transfer Cask with 24PT1 DSC for Transfer Conditions

As discussed in Section B.8.1, the 24PT1 DSC will be transported to the WCS CISF under the NRC Certificate of Compliance No. 9255 [B.8-3]. The use of 24PT1 DSC in MP187 cask is approved for 10CFR Part 71 off-site transportation with a maximum heat load of 14 kW [B.8-3]. Within the WCS CISF, the transfer operations i.e. movement of the DSC from the transfer cask into the storage module will be performed under 10CFR Part 72. This section presents the thermal evaluation for this on-site transfer operation with the MP187 cask.

A review of the thermal evaluation presented for 24PT1 in the MP187 cask during off-site transportation in Chapter A.3 of the [B.8-2, B.8-3] indicates that the thermal evaluation for 24PT1 is bounded by the thermal evaluation presented for FO- and FC-DSCs in Chapter 3 of [B.8-2, B.8-3]. This is because the 24PT1 DSC is nearly identical to the FO- DSC as noted in Section A2.1, Section A.3.2 of [B.8-2, B.8-3]. The similarities are also described in the Executive Summary Section of [B.8-1].

A similar approach is presented in this section, wherein the thermal evaluation performed for on-site transfer of FO- DSCs in MP187 cask at the Rancho Seco Independent Spent Fuel Storage Installation (ISFSI) [B.8-4] bounds the maximum temperatures for transfer of 24PT1 in MP187 cask at the WCS CISF.

<u>Comparison of Heat Loads between the FO- DSC and 24PT1 DSC</u>

a. Heat Loads within the MP187 cask

Bounding axial peaking factors for the different burnup ranges are shown for pressurized water reactor (PWR) spent nuclear fuel (SNF) assemblies in Table 2 of NUREG/CR-6801 [B.8-5]. As seen from the table, the axial peaking profile of a PWR fuel assembly causes a slight increase in the heat generation rate at the middle of the fuel assembly while reducing the heat generation at the ends. However, the axial peaking profile does not increase the total heat load.

In the thermal evaluation presented in Section 8.1.1.1, Volume III of [B.8-4], a peaking factor of 1.08 is used over the total heat load of 13.5 kW in evaluating the MP187 cask component and DSC Shell temperatures. Because of this the total heat load considered in the MP187 cask model is 14.58 kW (13.5 kW x 1.08 = 14.58 kW). This exceeds the maximum heat load of 14 kW for the 24PT1 DSC and based on the discussion for the axial peaking profile, this evaluation remains bounding.

b. Heat Loads within the DSC

The DSC shell temperature profile determined from the MP187 cask model is used as boundary condition in determining the maximum fuel cladding and spacer disc temperature in Section 8.1.1.2, Volume II of [B.8-4]. As discussed in Section 8.1.1.2, Volume II of [B.8-4], the maximum decay heat per fuel assembly of 0.764 kW allowed for the FC- DSC is used in determining the maximum fuel cladding temperature. This increases the total heat load used in the DSC model to 18.34 kW.

In comparison, the maximum decay heat per fuel assembly allowed within the 24PT1 DSC is 0.583 kW as noted in Section 1.2.3 of [B.8-1] while the maximum allowable heat load for the DSC is limited to 14 kW. This indicates that the heat load used in the evaluation of FO- and FC- DSC in Section 8.1.1.2, Volume II of [B.8-4] bounds the maximum decay heat per fuel assembly (0.583 kW in 24PT1 vs. 0.764 kW for FO- and FC- DSC) and the total heat load of the DSC (14 kW for 24PT1 vs 18.34 kW used in thermal evaluation of FO- and FC- DSC).

Based on the discussion presented in Item “a” and “b”, the maximum heat load used in the thermal evaluation of the FO- and FC- DSCs during transfer in MP187 cask at Rancho Seco ISFSI bounds the transfer at the WCS CISF and no further evaluations are presented. The results of thermal evaluation for FO- and FC- DSCs during transfer in MP187 cask at Rancho Seco ISFSI are presented in Section A.8.5 of this application.

B.8.6.1 Evaluation of MP187 Cask Performance

The thermal performance of the MP187 cask is evaluated under normal, off-normal and accident conditions of operation, and all the temperature limits and criteria are satisfied.

B.8.7 References

B.8-1 AREVA TN, "Updated Final Safety Analysis Report for the Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel," ANUH-01.0150, Revision 6.

B.8-2 AREVA TN Document NUH-05-151 Rev. 17, "NUHOMS®-MP187 Multi-Purpose Transportation Package Safety Analysis Report." (Basis for NRC CoC 71-9255).

B.8-3 U.S. Nuclear Regulatory Commission, "Certificate of Compliance No. 9255, Revision 12 for the Model No. NUHOMS®-MP187 Multi-Purpose Cask (Docket 71-9255).

B.8-4 "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report," NRC Docket No. 72-11, Revision 4.

B.8-5 Office of Nuclear Regulator Research, USNRC, "Recommendations for Addressing Axial Burnup in PWR Burnup Credit Analysis," NUREG/CR-6801, Published March 2003.

APPENDIX B.9
RADIATION PROTECTION
Standardized Advanced NUHOMS® System

Table of Contents

List of Tables

List of Figures

B.9. RADIATION PROTECTION

The Standardized Advanced NUHOMS® System Cask System radiation protection evaluations are documented in Section 10 of the "Standardized Advanced NUHOMS® Horizontal Modular Storage System Safety Analysis Report" [B.9-1].

B.9.1 Radiation Protection Design Features

Details of the Storage Area shielding design features for the Standardized Advanced NUHOMS® System Cask System which includes the NUHOMS®-24PT1 Dry Shielded Canister (DSC) stored in an AHSM are documented in Section 10.2.1 of reference [B.9-1]. *Drawings showing the shield thicknesses for the MP187 cask are included in Section A.4.6 and drawings showing the shield thicknesses for the NUHOMS®-24PT1 DSC and AHSM are included in Section B.4.6.*

B.9.2 Occupational Exposure Evaluation

B.9.2.1 Analysis Methodology

Dose rates are known in the vicinity of the AHSM and MP187 cask based upon the existing FSAR[B.9-1] and SAR[B.9-2]. The operational sequence is determined for each system, as well as the associated number of workers, their location, and duration per operation. The collective dose per step is then computed as:

$$C = D*N*T,$$

where

C is the collective dose (person-mrem),

D is the dose rate for each operation (mrem/hr),

N is the number of workers for that operation, and

T is the duration of the operation (hr)

Once the collective dose is determined for each step, the collective doses are summed to create the total collective dose. The total collective dose is determined for a single receipt/transfer operation.

B.9.2.2 Dose Assessment

A dose assessment is performed for receipt and transfer of an NUHOMS®-24PT1 DSC to AHSM using the MP187 cask.

Seven general locations around the cask are defined, as shown in the top half of Figure B.9-1: top, top edge, top corner, side, bottom corner, bottom edge, and bottom. These seven general locations are reduced to only three locations for which dose rate information is available, as shown in the bottom half of Figure B.9-1: top, side, and bottom.

A loading operation is divided into receipt and transfer operations. Dose rates for receipt operations are obtained from *Table 5.1-1 of* the transportation SAR for the MP187 cask *[B.9-2]*. Dose rates for the transfer operations are obtained from *Table 5.1-2 of* the storage FSAR *[B.9-1]* for the AHSM.

For some configurations, dose rates are not available in the reference transportation SAR or storage FSAR. In these instances, bounding dose rates are obtained for similar systems:

- For transfer of the 24PT1 DSC inside the MP187 cask, bounding dose rates for transfer of the 24PT1 DSC inside the OS197 transfer cask *from Tables 5.1-3, 5.1-4 and 5.1-5 of reference [B.9-1]* are utilized. This approach is conservative because the OS197 transfer cask contains less shielding than the MP187 cask.

The configurations used in the dose rate analysis are summarized in Table B.9-1. Results for the various loading scenarios are provided in Table B.9-2 and Table B.9-3. Separate tables are developed for receipt and transfer operations. These tables provide the process steps, number of workers, occupancy time, distance, dose rate, and collective dose for all operations.

The total collective dose for an operation is the sum of the receipt and transfer collective doses. The total collective dose for receipt and transfer of NUHOMS®-24PT1 DSC to an AHSM using the MP187 cask: 1097 person-mrem.

The total collective dose for unloading a 24PT1 DSC or reactor related GTCC waste canister from an AHSM and preparing it for transport off-site is bounded by the loading operations (1097 person-mrem). Operations for removing the canister from the AHSM and off-site shipment are identical to loading operations, except in reverse order. The collective dose for unloading is bounded because during storage at the WCS CISF the source terms will have decayed reducing surface dose rates. The total collective dose is the sum of the receipt, transfer, retrieval, and shipment is 2194 person-mrem.

B.9.3 References

B.9-1 AREVA TN Document, ANUH-01.0150, Revision 6, "Updated Final Safety Analysis Report for the Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, NRC Docket No. 72-1029.

B.9-2 AREVA TN Document NUH-05-151 Rev. 17, "NUHOMS®-MP187 Multi-Purpose Transportation Package Safety Analysis Report." (Basis for NRC CoC 71-9255).

Table B.9-1
***Analyses Used for* Receipt and Transfer Configurations**

Actual Configuration	Receipt Analysis Configuration	Transfer Analysis Configuration
24PT1 DSC transferred from the MP187 cask into an AHSM	24PT1 inside MP187 cask [B.9-2]	24PT1 inside OS197 transfer cask (bounds MP187 cask) [B.9-1]

Table B.9-2
Occupational Collective Dose for Receipt of MP187 Cask Loaded with 24PT1 DSC

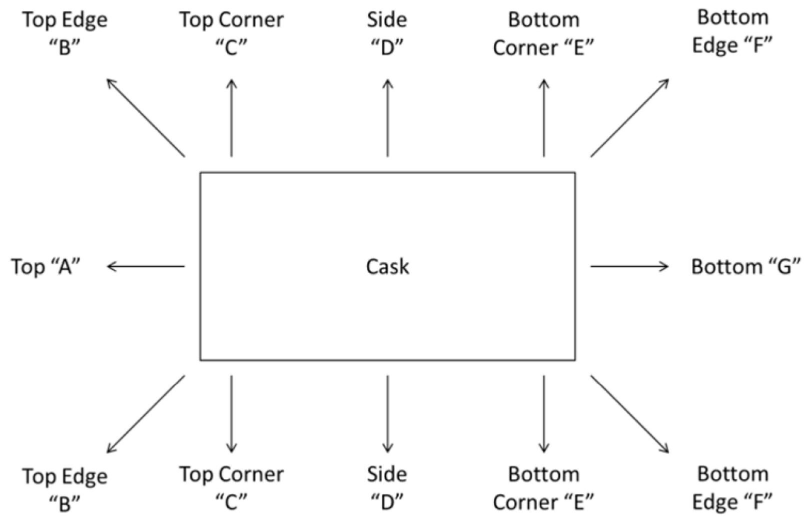
Process Step	Number of Workers	Occupancy Time (hours)	Worker Location Around Cask	Worker Distance (m)	Total Dose Rate (mrem/hr)	Total Dose (person-mrem)*
Verify that the tamperproof seals are intact.	1	0.07	Top	1	1.19	1
	1	0.07	Bottom	1	1.63	
Remove the tamperproof seals.	1	0.07	Top	1	1.19	1
	1	0.07	Bottom	1	1.63	
Remove personnel barrier	3	0.5	Side	1	57.5	87
Remove the impact limiter attachment bolts from each impact limiter and remove the impact limiters from the cask.	2	0.5	Top Edge	1	1.19	3
	2	0.5	Bottom Edge	1	1.63	
Remove the transportation skid closure assembly.	2	0.25	Top Corner	1	57.5	58
	2	0.25	Bottom Corner	1	57.5	
Take contamination smears on the outside surfaces of the cask. If necessary, decontaminate the cask until smearable contamination is at an acceptable level.	2	0.17	Top	1	20	48
	2	0.17	Side	1	57.5	
	2	0.17	Bottom	1	62	
Place suitable slings around the cask top and bottom ends.	2	0.5	Top Corner	1	57.5	115
	2	0.5	Bottom Corner	1	57.5	
Using a suitable crane lift the cask from the railcar	2	0.1	Side	1	57.5	12
Remove the cask trunnion plugs.	2	0.5	Top Corner	1	57.5	115
	2	0.5	Bottom Corner	1	57.5	
Inspect the trunnion sockets and install the upper and lower trunnions. Torque the trunnion attachment screws for each of the four trunnions.	2	0.5	Top Corner	1	57.5	115
	2	0.5	Bottom Corner	1	57.5	
Place cask onto the on-site transfer vehicle.	2	0.5	Side	2	57.5	58
Remove the slings from the cask.	2	0.5	Top Corner	1	57.5	115
	2	0.5	Bottom Corner	1	57.5	
Install the on-site support skid pillow block covers.	1	0.2	Side	2	57.5	12
Transfer the cask to a staging module.	1	0.2	Side	2	57.5	12
					Total (person-mrem)	752

*Rounded up to nearest whole number

Table B.9-3
Occupational Collective Dose for Transfer of 24PT1 DSC from MP187 Cask to AHSM

<table>
<tr><th>Process Step</th><th>Number of Workers</th><th>Occupancy Time (hours)</th><th>Worker Location Around Cask</th><th>Worker Distance (m)</th><th>Total Dose Rate (mrem/hr)</th><th>Total Dose (person-mrem)*</th></tr>
<tr><td>Remove the Cask Lid</td><td>2</td><td>0.5</td><td>Top</td><td>1</td><td>7.14</td><td>8</td></tr>
<tr><td>Align and Dock the Cask with the AHSM</td><td>2</td><td>0.25</td><td>Top/Front Half HSM Vent</td><td>1</td><td>113.17</td><td>57</td></tr>
<tr><td>Insert 24PT1-DSC into the AHSM</td><td>4</td><td>0.5</td><td>Bottom</td><td>1</td><td>18.9</td><td>38</td></tr>
<tr><td>Transfer the 24PT1-DSC to the AHSM</td><td>---</td><td>---</td><td>---</td><td>Far</td><td>Background</td><td>0</td></tr>
<tr><td>Lift the Ram Onto Transfer Vehicle and Un-Dock the Cask</td><td>2</td><td>0.25</td><td>HSM Front Vent</td><td>1</td><td>45.28</td><td>23</td></tr>
<tr><td>Install the AHSM Access Door</td><td>2</td><td>0.5</td><td>HSM Front Surface</td><td>1</td><td>1.93</td><td>2</td></tr>
<tr><td rowspan="3">Adjust 24PT1-DSC seismic restraint</td><td>2</td><td>0.5</td><td>HSM Front Surface</td><td>1</td><td>1.93</td><td rowspan="3">217</td></tr>
<tr><td>2</td><td>0.5</td><td>HSM Front Surface</td><td>1</td><td>1.93</td></tr>
<tr><td>2</td><td>0.08</td><td>Bottom</td><td>1</td><td>1326</td></tr>
<tr><td colspan="6">Total (person-mrem)</td><td>345</td></tr>
</table>

*Rounded up to nearest whole number



Detailed Cask Locations

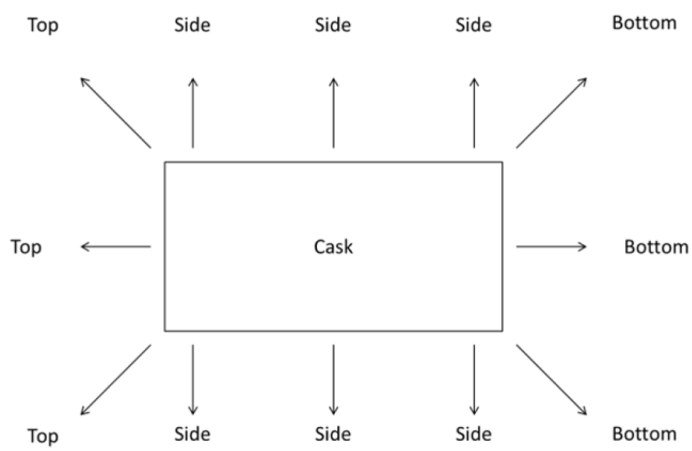


Figure B.9-1
Worker Locations Around Cask

APPENDIX B.10
CRITICALITY EVALUATION
Standardized Advanced NUHOMS® System

Table of Contents

B.10. CRITICALITY EVALUATION

The design criteria for the Standardized Advanced NUHOMS® 24PT1 DSC require that the canister is designed to remain subcritical under normal, off-normal, and accident conditions associated with spent nuclear fuel (SNF) handling, storage and off-site transportation. The design of the canister is such that, under all credible conditions, the highest effective neutron multiplication factor (k_{eff}) remains less than the upper safety limit (USL) of 0.9401 including an administrative margin of 0.05, code bias and bias uncertainties.

B.10.1 Discussion and Results

The 24PT1 DSC criticality analysis is documented in Chapter 6 of the "Standardized Advanced NUHOMS® System Updated Final Safety Analysis Report" [B.10-1]. This criticality analysis bounds the conditions for transfer and on-site storage at the Waste Control Specialists, LLC (WCS) Consolidated Interim Storage Facility (CISF) because there is no credible event which would result in the flooding of a canister in HSM storage which would result in k_{eff} exceeding the worst case 10 CFR 72 storage conditions evaluated in [B.10-1]. Specific information on the criticality safety analysis which bounds the WCS CISF is discussed in this section.

The 24PT1 DSC consists of a shell assembly and an internal basket assembly. The basket assemblies are composed of four axially oriented support rods and twenty-six spacer discs. This basket assembly provides positive location for twenty-four SNF assemblies under normal operating conditions, off-normal operating conditions and accident conditions. The basket assembly uses fixed neutron absorbers that isolate each SNF assembly. Guide sleeves are designed to permit unrestricted flooding and draining of SNF cells. The canister system is designed to be resistant to corrosion in marine environments and to permit storage of control components integral with the SNF and/or damaged SNF assemblies. The 24PT1 DSC accommodates up to 24 PWR SNF assemblies with stainless steel or Zircaloy cladding, uranium dioxide (UO_2) or U-Pu mixed-oxide (MOX) fuel pellets, Integral Fuel Burnable Absorber (IFBA) assemblies, and control components. It can also store up to four stainless steel clad damaged SNF assemblies in lieu of an equal number of undamaged SNF assemblies or one failed MOX assembly with no other failed assemblies. The criticality analysis credits the fixed borated neutron absorbing material Boral™, placed between the SNF assemblies and does not credit the presence of soluble boron during loading and unloading operations. Subcriticality during wet loading or unloading, drying, sealing, transfer, and storage operations is maintained through the geometric separation of the SNF assemblies by the basket assembly and the neutron absorbing capability of the 24PT1 DSC materials.

The continued efficacy of the neutron absorbers is assured when the canister arrives as the WCS CISF because the basket, including poison material, is designed and analyzed to maintain its configuration for all normal, off-normal and accident conditions of storage and for normal and hypothetical accidents during transport in the MP187 cask as documented in Section A.6.1.2 and A.6.3 of the "Safety Analysis Report for the NUHOMS®-MP187 Multi-purpose Cask" [B.10-4].

The design basis criticality analysis performed for the 24PT1 DSC assumes the most reactive configuration of the canister and contents in an infinite array of casks bounding all conditions of receipt, transfer and storage at the WCS CISF where the canisters will remain dry under all conditions of transfer and storage including normal, off-normal and accident conditions as demonstrated in Chapter 12 of this SAR.

The results of the evaluations demonstrate that the maximum calculated k_{eff}, including statistical uncertainty and bias, are less than 0.9401.

B.10.2 Package Fuel Loading

Section 2.1 of the Technical Specifications [B.10-3] lists the SNF assemblies authorized for storage at the WCS CISF. Section 6.2 Spent Fuel Loading of [B.10-1] provides the Package Fuel Loading.

B.10.3 Model Specification

Section 6.3 Model Specification of [B.10-1] provides a discussion of the criticality model canister regional densities used to calculate the bounding k_{eff} for the 24PT1 DSC.

B.10.4 Criticality Calculation

Section 6.4 Criticality Calculation of [B.10-1] provides a discussion of the criticality calculations that demonstrate that the maximum calculated k_{eff} for the 24PT1 DSC is less than 0.9401.

B.10.5 Critical Benchmark Experiments

Section 6.5 Critical Benchmark Experiments of [B.10-1] provides a discussion of the benchmark experiments and applicability, details of benchmark calculations, and the results of benchmark calculations, including calculation of the USL.

B.10.6 References

B.10-1 AREVA TN Document, ANUH-01.0150, Revision 6, "Updated Final Safety Analysis Report for the Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, NRC Docket No. 72-1029.

B.10-2 AREVA TN, "Technical Specifications for the Standardized Advanced NUHOMS® System Operating Controls and Limits," USNRC Docket Number 72-1029.

B.10-3 Proposed SNM-1050, WCS *Consolidated* Interim Storage Facility Technical Specifications, Amendment 0.

B.10-4 AREVA TN Document NUH-05-151 Rev. 17, "NUHOMS®-MP187 Multi-Purpose Transportation Package Safety Analysis Report." (Basis for NRC CoC 71-9255).

APPENDIX B.11
CONFINEMENT EVALUATION
Standardized Advanced NUHOMS® System

Table of Contents

B.11 CONFINEMENT EVALUATION

The design criteria for the Standardized Advanced NUHOMS® 24PT1 Dry Shielded Canister (DSC or canister) require that the canister is designed to maintain confinement of radioactive material under normal, off-normal, and accident conditions associated with spent nuclear fuel (SNF) handling, storage and off-site transportation.

B.11.1 Confinement Boundary

The 24PT1 DSC confinement is documented in Chapter 7 of the "Standardized Advanced NUHOMS® System Updated Final Safety Analysis Report" [B.11-1]. Section 7.1 of [B.11-1] details the requirements of the confinement boundary. *Figure 7.1-1 of reference [B.11-1] provides a figure that shows the components and welds that make up the confinement boundary for the 24PT1-DSC. Drawings for the canisters, including the confinement boundary are referenced in Section B.4.6. In addition, a bounding evaluation in Section A.7.7 (also referenced in Section B.7.9) is performed to demonstrate that the confinement boundary for the 24PT1-DSC does not exceed ASME B&PV Subsection NB Article NB-3200 (Level A allowables) during normal conditions of transport to provide reasonable assurance that the confinement boundary is not adversely impacted by transport to the WCS CISF.*

The Technical Specifications for Standardized Advanced NUHOMS® [B.11-2] outline the requirements for preventing the leakage of radioactive materials in the 24PT1 DSC. Section 4.3, "Codes and Standards," lists the codes and standards for design, fabrication, and inspection of the 24PT1 DSC, including alternatives to the ASME Code for the 24PT1 DSC shell assembly and basket.

Section 3.1, "DSC Integrity," of the Technical Specifications for the Standardized Advanced NUHOMS® [B.11-2] includes limiting condition for operation (LCO) 3.1.1.a for DSC vacuum drying time and pressure and LCO 3.1.2.a for DSC helium backfill pressure. These LCOs create a dry, inert atmosphere, which contributes to preventing the leakage of radioactive material.

B.11.2 Requirements for Normal Conditions of Storage

Section 7.2 of [B.11-1] describes how the 24PT1 DSC is designed, fabricated and tested to be "leaktight" to prevent the leakage of radioactive materials. *The Technical Specifications for Standardized Advanced NUHOMS® [B.11-2] outline the requirements for preventing the leakage of radioactive materials in the 24PT1 DSC. Section 4.3, "Codes and Standards," lists the codes and standards for design, fabrication, and inspection of the 24PT1 DSC, including alternatives to the ASME Code for the 24PT1 DSC shell assembly and basket.*

Section 3.1, "DSC Integrity," of the Technical Specifications for the Standardized Advanced NUHOMS® [B.11-2] includes limiting condition for operations (LCO) 3.1.1.a for DSC vacuum drying time and pressure and LCO 3.1.2.a for DSC helium backfill pressure. These LCOs create a dry, inert atmosphere, which contributes to preventing the leakage of radioactive material.

B.11.3 Confinement Requirements for Hypothetical Accident Conditions

Section 7.3 of [B.11-1] provides a discussion on how the 24PT1 DSC is designed, fabricated and tested to be "leak tight" to prevent the leakage of radioactive materials following hypothetical accident conditions. *The Technical Specifications for Standardized Advanced NUHOMS® [B.11-2] outline the requirements for preventing the leakage of radioactive materials in the 24PT1 DSC. Section 4.3, "Codes and Standards," lists the codes and standards for design, fabrication, and inspection of the 24PT1 DSC, including alternatives to the ASME Code for the 24PT1 DSC shell assembly and basket.*

Section 3.1, "DSC Integrity," of the Technical Specifications for the Standardized Advanced NUHOMS® [B.11-2] includes limiting condition for operation (LCO) 3.1.1.a for DSC vacuum drying time and pressure and LCO 3.1.2.a for DSC helium backfill pressure. These LCOs create a dry, inert atmosphere, which contributes to preventing the leakage of radioactive material.

B.11.4 References

B.11-1 AREVA TN Document, ANUH-01.0150, Revision 6, "Updated Final Safety Analysis Report for the Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel," NRC Docket No. 72-1029.

B.11-2 AREVA TN, "Technical Specifications for the Standardized Advanced NUHOMS® System Operating Controls and Limits," *Amendment 3,* USNRC Docket Number 72-1029.

APPENDIX B.12
ACCIDENT ANALYSIS
Standardized Advanced NUHOMS® System

Table of Contents

B.12. ACCIDENT ANALYSIS

This section describes the postulated off-normal and accident events that could occur during transfer and storage for the Standardized Advanced NUHOMS® System. Detailed analyses are provided in the "Standardized Advanced NUHOMS® Horizontal Modular Storage System Safety Analysis Report" [B.12-1] for the NUHOMS® 24PT1 canister and AHSM are referenced herein. Qualification for use of the NUHOMS® MP187 cask as a transfer cask for off-normal and accident conditions is also addressed.

B.12.1 Off-Normal Operations

The off-normal conditions considered for the Standardized Advanced NUHOMS® System are off-normal transfer loads, extreme temperatures and a postulated release of radionuclides.

B.12.1.1 Off-Normal Transfer Loads

Off-Normal transfer loads are addressed in Section 11.1.1 of [B.12-1] which is a “jammed” canister during loading or unloading from the AHSM.

Postulated Cause of the Event

The postulated cause of the event is described in Section 11.1.1.1 of [B.12-1]

Detection of the Event

Detection of the event is described in Section 11.1.1.2 of [B.12-1].

Analysis of Effects and Consequences

Section 11.1.1.3 of [B.12-1] provides a discussion of the analysis performed and effects and consequences of the event. There is no breach of the confinement pressure boundary and, therefore, no potential for release of radioactive materials.

Corrective Actions

Consistent with Section 11.1.1.4 of [B.12-1], the required corrective action is to reverse the direction of the force being applied to the canister by the ram, and return the canister to its previous position. Since no permanent deformation of the canister occurs, the sliding transfer of the canister to its previous position is unimpeded. The transfer cask alignment is then rechecked, and the transfer cask repositioned as necessary before attempts at transfer are renewed.

B.12.1.2 Extreme Ambient Temperatures

The design of the Standardized Advanced NUHOMS® System envelopes the extreme temperatures at the Waste Control Specialists, LLC (WCS) Consolidated Interim Storage Facility (CISF) as demonstrated in Section B.8.4.

Postulated Cause of the Event

The postulated cause of the event is described in Section 11.1.2.1 of [B.12-1]

Detection of the Event

Detection of the event is described in Section 11.1.2.2 of [B.12-1].

Analysis of Effects and Consequences

Section 11.1.2.3 of [B.12-1] provides a discussion of the analysis performed and effects and consequences of the event. There is no breach of the confinement pressure boundary and, therefore, no potential for release of radioactive materials.

Corrective Actions

Consistent with Section 11.1.2.4 of [B.12-1], the corrective action is to install a transfer cask solar shield if the ambient temperature exceeds 100°F. The extreme ambient temperatures analyzed do not adversely impact operation of the Standardized Advanced NUHOMS® System.

B.12.1.3 Off-Normal Release of Radionuclides

As described in Section 11.1.3 of [B.12-1], the canister is designed, fabricated and tested to be leak-tight, therefore, there is no possibility for release of radionuclides from the canister under normal, off-normal and accident conditions.

B.12.2 Postulated Accident

The postulated accident conditions for the Standardized Advanced NUHOMS® System addressed in this SAR section are:

- Blockage of Air Inlets/Outlets
- Drop Accidents
- Earthquakes
- Lightning
- Fire/Explosion
- Flood
- Tornado Wind and Missiles

B.12.2.1 Blockage of Air Inlet/Outlets

Cause of Accident

Section 11.2.7.1 of [B.12-1] provides the causes of blocked air vents for the AHSM.

Accident Analysis

The structural and thermal consequences of blocking the air inlet and outlets are addressed in Section 11.2.7.2 of [B.12-1]. In addition, Chapter B.8 demonstrates that the thermal analysis performed for the Standardized Advanced NUHOMS® System in [B.12-1] is bounding for WCS CISF conditions.

Accident Dose Calculations

As documented in Section 11.2.7.3 of [B.12-1], there are no radiological consequences for this accident condition.

Corrective Actions

Consistent with Section 11.2.7.4 of [B.12-1], blockage of the AHSM vents is to be cleared within the 40-hour time frame analyzed to restore AHSM ventilation.

B.12.2.2 Drop Accidents

Cause of Accident

Section 11.2.5.1 of [B.12-1] discusses the cask drop for the MP187 cask in the transfer configuration when it contains the canister.

Accident Analysis

The structural, thermal, and radiological consequences and the recovery measures required to mitigate the effects of a drop accident are addressed in Section 8.2.1.3 of Volume I of [B.12-5] for the MP187 cask in the transfer configuration. Section 3.6 of [B.12-1] demonstrates that the canister remains leak tight and the basket maintains its configuration following the drop event. In addition, Chapter B.8 demonstrates that the thermal analysis performed for the NUHOMS® MP187 Cask System in [B.12-1] is bounding for WCS CISF conditions.

Corrective Action

Consistent with Section 11.2.5.4 of [B.12-1], the canister will be inspected for damage, as necessary. Removal of the transfer cask top cover plate may require cutting of the bolts in the event of a corner drop onto the top end. These operations will take place in the Cask Handling Building.

Following recovery of the transfer cask and transfer of the canister in the AHSM, the transfer cask will be inspected, repaired and tested as appropriate prior to reuse.

For recovery of the cask and contents, it may be necessary to develop a special sling/lifting apparatus to move the transfer cask from the drop site to the Cask Handling Building. This may require several weeks of planning to ensure all steps are correctly organized. During this time, temporary shielding may be added to the transfer cask to minimize on-site exposure to WCS CISF operations personnel. The transfer cask would be roped off to ensure the safety of personnel.

B.12.2.3 Earthquakes

Cause of Accident

Site-specific ground-surface uniform hazard response spectra (UHRS) with 1E-4 annual frequency of exceedance (AFE) having peak ground acceleration (PGA) of 0.250 g horizontal and 0.175 g vertical are shown in Table 1-2, Table 1-5 and Figure 1-5. *The site-specific response spectra are used in the WCS CISF SSI analysis to obtain the enveloped acceleration spectra at the HSM CG and base.* Section B.7.5 demonstrates that the enveloping *WCS CISF site-specific* seismic forces remain below their applicable capacities for the MP187 cask and Standardized Advanced NUHOMS® System components.

Accident Analysis

The structural and thermal consequences of an earthquake are addressed in Section 11.2.1.2 of [B.12-1]. The MP187 cask, when mounted on the transfer vehicle during an earthquake is subjected to stresses which are bounded by the 80-inch cask drop analysis. In addition, Chapter B.8 demonstrates that the thermal analysis performed for the Standardized Advanced NUHOMS® System in [B.12-1] is bounding for WCS CISF conditions.

Accident Dose Calculations

As documented in Section 11.2.1.3 of [B.12-1], there are no radiological consequences as a result of a seismic event.

Corrective Actions

Consistent with Section 11.2.1.4 of [B.12-1], inspection of AHSMs subsequent to a significant earthquake is required to identify potential damage or change in AHSM configuration. Repair of damage to AHSM concrete components, including shield walls may be necessary. Movement of AHSMs as a result of the seismic event will require evaluation and possible repositioning of AHSMs and shielding to preseismic event configuration.

B.12.2.4 Lightning

Cause of Accident

As stated in Section 11.2.6.1 of [B.12-1], the likelihood of lightning striking the AHSM and causing an off-normal or accident condition is not considered a credible event. Simple lightning protection equipment for the AHSM structures is considered a miscellaneous attachment acceptable per the AHSM design.

Accident Analysis

Should lightning strike in the vicinity of the AHSM the normal storage operations of the AHSM will not be affected. The current discharged by the lightning will follow the low impedance path offered by the surrounding structures or the grounding system installed around each block of AHSMs. The heat or mechanical forces generated by current passing through the higher impedance concrete will not damage the AHSM. Since the AHSM requires no equipment for its continued operation, the resulting current surge from the lightning will not affect the normal operation of the AHSM.

Since no accident conditions will develop as the result of a lightning strike near the AHSM, no corrective action would be necessary. In addition, there would be no radiological consequences

B.12.2.5 Fire and Explosion

Cause of Accident

As described in Section 11.2.4.1 of [B.12-1] combustible materials will not normally be stored at the storage pad. Therefore, a credible fire would be very small and of short duration such as that due to a fire or explosion from a vehicle or portable crane.

However, a hypothetical fire accident is evaluated for the Standardized Advanced NUHOMS® System based on a diesel fuel fire. The source of fuel is postulated to be from a ruptured fuel tank of the transfer vehicle or portable crane. The bounding capacity of the fuel tank is 300 gallons and the bounding hypothetical fire is an engulfing fire around the transfer cask. Direct engulfment of the AHSM is highly unlikely. Any fire within the WCS CISF boundary while the canister is in the AHSM would be bounded by the fire during transfer cask movement. The AHSM concrete acts as a significant insulating firewall to protect the canister from the high temperatures of the fire.

Accident Analysis

The structural and thermal consequences of a fire accident are addressed in Section 12.2.4.2 of [B.12-1]. Appendix B.8 demonstrates that the MP187 cask performs its safety functions during and after the postulated fire/explosion accident. As stated above, the maximum flammable fuel either during the transfer operation or inside the WCS CISF is 300 gallons of diesel fuel.

Accident Dose Calculations

As documented in Section 11.2.4.3 of [B.12-1], there are minimal radiological consequences for this accident condition.

Corrective Actions

Consistent with Section 11.2.4.4 of [B.12-1], evaluation of AHSM or cask neutron shield damage as a result of a fire is to be performed to assess the need for temporary shielding (for AHSM or cask, if fire occurs during transfer operations) and repairs to restore the transfer cask and AHSM to pre-fire design conditions.

B.12.2.6 Flood

Cause of Accident

The Probable Maximum flood is considered to occur as a severe natural phenomenon.

Accident Analysis

As documented in Sections 2.4.2.2 and 3.2.2, the WCS CISF is not in a floodplain and is above the Probable Maximum Flood elevation and, therefore, will remain dry in the event of a flood.

B.12.2.7 Tornado Wind and Missiles

Cause of Accident

In accordance with ANSI-57.9 [B.12-3] and 10 CFR 72.122, the Standardized Advanced NUHOMS® System components are designed for tornado effects including tornado wind effects. In addition, the AHSM and MP187 cask in the transfer configuration are also design for tornado missile effects. The Standardized Advanced NUHOMS® System components are designed and conservatively evaluated for the most severe tornado and missiles anywhere within the United States (Region I as defined in NRC Regulatory Guide 1.76 [B.12-4]) while the WCS CISF is in Region II, a less severe location with respect to tornado and tornado missiles.

Accident Analysis

The structural and thermal consequences of the effect of tornado wind and missile loads on the AHSM are addressed in Section 11.2.2.2 of [B.12-1]. Similarly, the structural and thermal consequences of tornado wind and missile loads for the NUHOMS® MP187 cask are addressed in Section 8.3.1.3 of Volume III of [B.12-5].

Accident Dose Calculations

As documented in Section 11.2.2.3 of [B.12-1], there are no radiological consequences for this accident condition.

Corrective Actions

Consistent with Section 11.2.2.4 of [B.12-1], evaluation of AHSM damage as a result of a Tornado is to be performed to assess the need for temporary shielding and AHSM repairs to return the AHSMs to pre-tornado design conditions.

B.12.3 References

B.12-1 AREVA TN Document, ANUH-01.0150, Revision 6, “Updated Final Safety Analysis Report for the Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, NRC Docket No. 72-1029.

B.12-2 NRC Regulatory Guide 1.60, Rev. 1, "Design Response Spectra for Seismic Design of Nuclear Power Plants." Dec 1973.

B.12-3 American National Standards Institute, American Nuclear Society, ANSI/ANS 57.9 1984, Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type).

B.12-4 NRC Regulatory Guide 1.76, “Design Basis Tornado and Tornado Missiles for Nuclear Power Plants,” 1974.

B.12-5 “Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report,” NRC Docket No. 72-11, Revision 4.

APPENDIX C.1
INTRODUCTION AND GENERAL DESCRIPTION OF INSTALLATION
Standardized NUHOMS®-61BT System

Table of Contents

C.1. INTRODUCTION AND GENERAL DESCRIPTION OF INSTALLATION

No change or additional information required for the Standardized NUHOMS® System containing the NUHOMS® 61BT DSCs for Chapter 1.

APPENDIX C.2
SITE CHARACTERISTICS
Standardized NUHOMS®-61BT System

Table of Contents

C.2. SITE CHARACTERISTICS

No change or additional information required for the Standardized NUHOMS® System containing the NUHOMS® 61BT DSCs for Chapter 2.

APPENDIX C.3
PRINCIPAL DESIGN CRITERIA
Standardized NUHOMS®-61BT System

Table of Contents

List of Tables

C.3. PRINCIPAL DESIGN CRITERIA

The Standardized NUHOMS®-61BT System principal design criteria is documented in Chapter K.2 of the "Standardized NUHOMS® Horizontal Modular Storage System Safety Analysis Report" [C.3-1]. Table C.3-1 provides a comparison of the Standardized NUHOMS®-61BT System principal design criteria and the Waste Control Specialists, LLC (WCS) Consolidated Interim Storage Facility (CISF) design criteria provided in Table 1-2 which demonstrates that the Standardized NUHOMS®-61BT System bounds the WCS CISF criteria.

C.3.1 SSCs Important to Safety

The classifications of the NUHOMS®-61BT System systems, structures and components, are discussed in Section K.2.3.1 of the "Standardized NUHOMS® Horizontal Modular Storage System Safety Analysis Report" [C.3-1]. These classifications are summarized in Table C.3-2 for convenience.

C.3.1.1 61BT-DSCs

The 61BT-DSC provides fuel assembly support required to maintain the fuel geometry for criticality control. Accidental criticality inside a 61BT-DSC could lead to off-site doses comparable with the limits in 10 CFR Part 100 which must be prevented. The 61BT-DSC also provides the confinement boundary for radioactive materials.

The 61BT-DSC is designed to maintain structural integrity under all accident conditions identified in Chapter 12 without losing its function to provide confinement of the spent fuel assemblies. The DSCs are important-to-safety (ITS).

C.3.1.2 Horizontal Storage Module

For the Standardized NUHOMS®-61BT System the horizontal storage modules (HSM) used is the HSM Model 102, herein referred to as HSM. The HSMs are considered ITS since these provide physical protection and shielding for the DSC during storage. The reinforced concrete HSM is designed in accordance with American Concrete Institute (ACI) 349 [C.3-4] and constructed to ACI-318 [C.3-5]. The level of testing, inspection, and documentation provided during construction and maintenance is in accordance with the quality assurance requirements as defined in 10 CFR Part 72, Subpart G. Thermal instrumentation for monitoring HSM concrete temperatures is considered "not important-to-safety" (NITS).

C.3.1.3 NUHOMS® Basemat and Approach Slab

The basemat and approach slabs for the HSMs are considered NITS and are designed, constructed, maintained, and tested as commercial-grade items.

C.3.1.4 NUHOMS® Transfer Equipment

The MP197HB transportation cask is qualified for transfer operations for Standardized NUHOMS®-61BT System in this application and herein is referred to as a transfer cask. The MP197HB cask is ITS since it protects the DSC during handling and is part of the primary load path used while handling the DSCs in the Cask Handling Building. An accidental drop of a loaded transfer cask has the potential for creating conditions adverse to the public health and safety. These possible drop conditions are evaluated with respect to the impact on the DSC in Chapter 12. Therefore, the MP197HB is designed, constructed, and tested in accordance with a QA program incorporating a graded quality approach for ITS requirements as defined by 10 CFR Part 72, Subpart G, paragraph 72.140(b).

The remaining transfer equipment (i.e., ram, skid, transfer vehicle) is necessary for the successful loading of the DSCs into the HSM. However, these items are not required to provide reasonable assurance that the canister can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public. Therefore, these components are considered NITS and need not comply with the requirements of 10 CFR Part 72. These components are designed, constructed, and tested in accordance with good industry practices.

C.3.2 Spent Fuel to Be Stored

The authorized content for the 61BT-DSCs are described in Certificate of Compliance 72-1004 [C.3-6] and Section K.2.1 of the “Standardized NUHOMS® Horizontal Modular Storage System Safety Analysis Report” [C.3-1].

Certificate of Compliance 72-1004 Technical Specifications Table 1-1c or Table 1-1j [C.3-6] provides a description of the fuels stored in the 61BT-DSCs as referenced in Section K.2.1 “Spent Fuel to be Stored” of the “Standardized NUHOMS® Horizontal Modular Storage System Safety Analysis Report” [C.3-1].

C.3.3 Design Criteria for Environmental Conditions and Natural Phenomena

C.3.3.1 Tornado Wind and Tornado Missiles

The design basis tornado wind and tornado missiles for the Standardized NUHOMS® Horizontal Modular Storage System HSM Model 102 are provided in Section K.2.2.1 and Section 3.2.1 of reference [C.3-1] and in Table C.3-1 for the NUHOMS®-MP197HB cask. The 61BT-DSC and HSM Model 102 components are designed and conservatively evaluated for the most severe tornado winds and missiles postulated to occur anywhere within the United States (Region I as defined in NRC Regulatory Guide 1.76 [C.3-8]) while the WCS CISF is in Region II, a less severe location with respect to tornado and tornado missiles. The MP197HB cask is evaluated against the Region II tornado and tornado missiles as described in Appendix C.7.

The HSM protects the DSC from adverse environmental effects and is the principal structure exposed to tornado wind and missile loads. Furthermore, all components of the HSM (regardless of their safety classification) are designed to withstand tornado winds and tornado-based missiles. The MP197HB cask protects the DSC during transit to the Storage Pad from adverse environmental effects such as tornado winds and missiles.

C.3.3.2 Water Level (Flood) Design

The DSCs and HSM are designed for an enveloping design basis flood, postulated to result from natural phenomena as specified by 10 CFR 72.122(b). The system is evaluated for a flood height of 50 feet with a water velocity of 15 fps.

The DSCs are subjected to an external hydrostatic pressure equivalent to the 50 feet head of water. The HSM is evaluated for the effects of a water current of 15 fps impinging on the sides of a submerged HSM. For the flood case that submerges the HSM, the inside of the HSM will rapidly fill with water through the HSM vents.

As documented in Sections 2.4.2.2 and 3.2.2, the WCS CISF is not in a floodplain and is above the Probable Maximum Flood elevation and, therefore, will remain dry in the event of a flood.

C.3.3.3 Seismic Design

The seismic criteria for the Standardized NUHOMS® System HSM Model 102 are provided in Section K.2.2.3 and Section 3.2.3 of reference [C.3-1]. *The site-specific seismic ground motion developed for the WCS CISF in the form of the 10,000-year return period uniform hazard response spectrum for the horizontal and vertical directions are described in Chapter 2. Those spectra are used to derive the enveloped acceleration spectra at the WCS concrete pad base and HSM center of gravity. These enveloped spectra are the design seismic basis for the NUHOMS®-61BT System components.*

C.3.3.4 Snow and Ice Loading

The design basis snow and ice loading for the Standardized NUHOMS® -61BT System are provided in Section K.2.2.4 and Section 3.2.4 of reference [C.3-1]. Snow and ice loads for the HSM are conservatively derived from ANSI A58.1 1982 [C.3-9]. The maximum 100 year roof snow load, specified for most areas of the continental United States for an unheated structure, of 110 psf is assumed. For the purpose of this conservative generic evaluation, a total live load of 200 psf is used in the HSM analysis to envelope all postulated live loadings, including snow and ice. Snow and ice loads for the on-site transfer cask with a loaded DSC are negligible due to the smooth curved surface of the cask, the heat rejection of the SFAs, and the infrequent short term use of the cask.

The snow and ice loads used in the evaluation of the Standardized NUHOMS®-61BT System components envelopes the maximum WCS CISF snow and ice loads of 10 psf.

C.3.3.5 Lightning

The likelihood of lightning striking the HSM Model 102 and causing an off-normal or accident condition is not considered a credible event. Simple lightning protection equipment and grounding for the HSM structures is considered a miscellaneous attachment acceptable per the HSM design.

C.3.4 Safety Protection Systems

The safety protection systems of the NUHOMS®-61BT System are discussed in Section K.2.3 of the "Standardized NUHOMS® Horizontal Modular Storage System Safety Analysis Report" [C.3-1].

C.3.4.1 General

The NUHOMS®-61BT System is designed for safe confinement during dry storage of SFAs. The components, structures, and equipment that are designed to assure that this safety objective is met are summarized in Table C.3-2. The key elements of the NUHOMS®-61BT System and its operation at the WCS CISF that require special design consideration are:

1. Minimizing the contamination of the DSC exterior.

2. The double closure seal welds on the DSC shell to form a pressure retaining confinement boundary and to maintain a helium atmosphere.

3. Minimizing personnel radiation exposure during DSC transfer operations.

4. Design of the cask and DSC for postulated accidents.

5. Design of the HSM passive ventilation system for effective decay heat removal to ensure the integrity of the fuel cladding.

6. Design of the DSC basket assembly to ensure subcriticality.

C.3.4.2 Structural

The principal design criteria for the DSCs are presented in Section K.2.3.2 of the "Standardized NUHOMS® Horizontal Modular Storage System Safety Analysis Report" [C.3-1]. The DSCs are designed to store intact and failed PWR FAs with or without channels. The fuel cladding integrity is assured by limiting fuel cladding temperature and maintaining a nonoxidizing environment in the DSC cavity.

The principal design criteria for the MP197HB cask are presented in Section 3.2.5.3 of the "NUHOMS®-MP197 Transportation Package Safety Analysis Report" [C.3-10]. The cask is designed to transfer the loaded DSCs to the HSM.

C.3.4.3 Thermal

The HSM relies on natural convection through the air space in the HSM to cool the DSC. This passive convective ventilation system is driven by the pressure difference due to the stack effect (ΔP_s) provided by the height difference between the bottom of the DSC and the HSM air outlet. This pressure difference is greater than the flow pressure drop (ΔP_f) at the design air inlet and outlet temperatures.

C.3.4.4 Shielding/Confinement/Radiation Protection

The shielding performance and radiation protection requirements for the Standardized NUHOMS®-61BT System are described in Sections K.2.3.5 and 3.3.5 of Reference [C.3-1]. The confinement performance requirements for the Standardized NUHOMS®-61BT System are described in Section K.2.3.2 of Reference [C.3-1] for storage conditions. In addition, a bounding evaluation in WCS CISF SAR Section C.7.8 is presented to demonstrate that the confinement boundary for the 61BT DSC does not exceed ASME B&PV Subsection NB Article NB-3200 (Level A allowables) during normal conditions of transport to provide reasonable assurance that the confinement boundary is not adversely impacted by transport to the WCS CISF.

The HSM provides the bulk of the radiation shielding for the DSCs. The HSM design is arranged in a back-to-back arrangement. Thick concrete supplemental shield walls are used at either end of an HSM array to minimize radiation dose rates both on-site and off-site. The HSM provide sufficient biological shielding to protect workers and the public.

The MP197HB cask is designed to provide sufficient shielding to ensure dose rates are ALARA during transfer operations and off-normal and accident conditions.

There are no radioactive releases of effluents during normal and off-normal storage operations. In addition, there are no credible accidents that cause significant releases of radioactive effluents from the DSC. Therefore, there are no off-gas or monitoring systems required for the system at the WCS CISF.

C.3.4.5 Criticality

For the DSCs, a combination of fixed poison in the basket and geometry are relied on to maintain criticality control. The structural analysis shows that there is no deformation of the basket under accident conditions that would increase reactivity.

C.3.4.6 Material Selection

Materials are selected based on their corrosion resistance, susceptibility to stress corrosion cracking, embrittlement properties, and the environment in which they operate during normal, off normal and accident conditions. The confinement boundary for the DSC materials meet the requirements of ASME Boiler and Pressure Vessel Code, Section III, Article NB-2000 and the specification requirements of Section II, Part D [C.3-7], with the listing of ASME Code alternatives for the DSCs provided in Tables K.3.1-2 and K.3.1-3 of the "Standardized NUHOMS® Horizontal Modular Storage System Safety Analysis Report" [C.3-1]. The code alternatives applicable to the MP197HB Cask are provided in Appendix A.2.13.13 of reference [C.3-10]. The DSC and cask materials are resistant to corrosion and are not susceptible to other galvanic reactions. Studies under severe marine environments have demonstrated that the shell materials used in the DSC shells are expected to demonstrate minimal corrosion during an 80-year exposure. The DSC internals are enveloped in a dry, helium-inerted environment and are designed for all postulated environmental conditions. The HSM is a reinforced concrete component with an internal DSC support structure that is fabricated to ACI and AISC Code requirements. Both have durability well beyond a design life of 80 years.

C.3.4.7 Operating Procedures

The sequence of operations are outlined for the NUHOMS®-61BT System in Chapter 5 and C.5 for receipt and transfer of the DSCs to the storage pad, insertion into the HSM, monitoring operations, and retrieval and shipping. Throughout Chapter 5, CAUTION statements are provided at the steps where special notice is needed to maintain ALARA, protect the contents of the DSC, or protect the public and/or ITS components of the NUHOMS®-61BT System.

C.3.5 References

C.3-1 AREVA TN Document NUH-003, Revision 14, "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel." (Basis for NRC CoC 72-1004).

C.3-2 U.S. Nuclear Regulatory Commission, "Certificate of Compliance No. 9302, Revision 7 for the Model No. NUHOMS®-MP197 and NUHOMS®-MP197HB Packages (Docket 71-9302).

C.3-3 Proposed SNM-1050, WCS *Consolidated* Interim Storage Facility Technical Specifications, Amendment 0.

C.3-4 American Concrete Institute, "Code Requirements for Nuclear Safety Related Concrete Structures" and Commentary, ACI 349-85 and ACI 349R-85, American Concrete Institute, Detroit Michigan (1985).

C.3-5 American Concrete Institute, "Building Code Requirement for Reinforced Concrete," ACI-318, American Concrete Institute, Detroit Michigan (1983).

C.3-6 Certificate of Compliance 72-1004, Amendment all.

C.3-7 American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NB, 1998 Edition including 1999 Addenda.

C.3-8 Reg Guide 1.76, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants," Revision 1, March 2007.

C.3-9 ANSI A58.1-1982, "Building Code Requirements for Minimum Design Loads In Buildings and Other Structures."

C.3-10 AREVA TN Document, NUH09.101 Rev. 17, "NUHOMS® -MP197 Transportation Package Safety Analysis Report." (Basis for NRC CoC 71-9302).

Table C.3-1
Summary of WCS CISF Principal Design Criteria
(*5* pages)

Design Parameter	WCS CISF Design Criteria	Condition	NUHOMS®-61BT Design Criteria
Type of fuel	Commercial, light water reactor spent fuel	Normal (Bounded)	*Standardized NUHOMS® SAR Section K.2.1*
Storage Systems	Transportable canisters and storage overpacks docketed by the NRC	Normal (Bounded)	71-9302 72-1004
Fuel Characteristics	Criteria as specified in previously approved licenses for included systems	Normal (Bounded)	*Standardized NUHOMS® SAR Section K.2.1*
Tornado (Wind Load) (HSM Model 102)	Max translational speed: 40 mph Max rotational speed: 160 mph Max tornado wind speed: 200 mph Radius of max rotational speed: 150 ft Tornado pressure drop: 0.9 psi Rate of pressure drop: 0.4 psi/sec	Accident (Bounded)	*Standardized NUHOMS® SAR Section 3.2.1 and Section K.2.2.1* Max translational speed: 70 mph Max rotational speed: 290 mph Max tornado wind speed: 360 mph Radius of max rotational speed: 150 ft Tornado pressure drop: 3.0 psi Rate of pressure drop: 2.0 psi/sec
Tornado (Wind Load) (MP197HB TC)	Max translational speed: 40 mph Max rotational speed: 160 mph Max tornado wind speed: 200 mph Radius of max rotational speed: 150 ft Tornado pressure drop: 0.9 psi Rate of pressure drop: 0.4 psi/sec	Accident (Bounded)	*Sections C.7.7.4 (New Evaluation)* Max translational speed: N/A Max rotational speed: N/A Max tornado wind speed: 360 mph Radius of max rotational speed: N/A Tornado pressure drop: N/A Rate of pressure drop: N/A

Table C.3-1
Summary of WCS CISF Principal Design Criteria
(*5* pages)

Design Parameter	WCS CISF Design Criteria	Condition	NUHOMS®-61BT Design Criteria
Tornado (HSM Missile)	Automobile 4000 lb, 112 ft/s Schedule 40 Pipe 287 lb, 112 ft/s Solid Steel Sphere 0.147 lb, 23 ft/s	Accident (Bounded)	*Standardized NUHOMS® SAR Section 3.2.1 and Section K.2.2.1* Automobile 4000 lb, 195 ft/s 8" diameter shell 276 lb, 185 ft/s Solid Steel Sphere 0.147 lb, 23 ft/s Wood plank missile 1500 lb, 440 ft/s
Tornado (MP197HB Missile)	Automobile 4000 lb, 112 ft/s Schedule 40 Pipe 287 lb, 112 ft/s Solid Steel Sphere 0.147 lb, 23 ft/s	Accident (Same)	*Section C.7.7.1 (New Evaluation)* Automobile 4000 lb, 112 ft/s Schedule 40 Pipe 287 lb, 112 ft/s Solid Steel Sphere 0.147 lb, 23 ft/s
Floods	*The WCS CISF is not in a floodplain and is above the Probable Maximum Flood elevation and will remain dry in the event of a flood.*	Accident (Bounded)	*Standardized NUHOMS® SAR Sections 3.2.2 and Section K.2.2.2* Flood height 50 ft Water velocity 15 ft/s
Seismic (Ground Motion)	Site-specific ground-surface uniform hazard response spectra (UHRS) with 1E-4 annual frequency of exceedance (AFE) having peak ground acceleration (PGA) of 0.250 g horizontal and 0.175 g vertical. (Table 1-5 and Figure 1-5)	Accident (*Evaluated*)	*See Evaluations in Section 7.6.4, 7.6.5, C.7.3 and C.7.5.3.*
Vent Blockage	For NUHOMS® Systems: Inlet and outlet vents blocked 40 hrs	Accident (Same)	*Standardized NUHOMS® SAR Section K.4.6.1* Inlet and outlet vents blocked 40 hrs
Fire/Explosion	For NUHOMS® Systems: Equivalent fire 300 gallons of diesel fuel	Accident (Same)	*Section C.8.5 (New Evaluation) Standardized NUHOMS® SAR Section K.4.6.5* Equivalent fire 300 gallons of diesel fuel

Table C.3-1
Summary of WCS CISF Principal Design Criteria
(*5* pages)

Design Parameter	WCS CISF Design Criteria	Condition	NUHOMS®-61BT Design Criteria
Cask Drop	For NUHOMS® Systems: Transfer Cask Horizontal side drop or slap down 80 inches(2)	Accident (Same)	*Section C.7.7 (New Evaluation)* Transfer Cask Horizontal side drop or slap down 80 inches(2)
Transfer Load	For NUHOMS® Systems only: Normal insertion load 60 kips Normal extraction load 60 kips	Normal (*Bounded*)	*Sections C.7.7 (New Evaluation) and Standardized NUHOMS® SAR Section K.3.6.1.1* Normal insertion load *80* kips Normal extraction load 60 kips
Transfer Load	For NUHOMS® Systems only: Maximum insertion load 80 kips Maximum extraction load 80 kips	Off-Normal/ Accident (Same)	*Sections C.7.7 (New Evaluation) and Standardized NUHOMS® SAR Section K.3.6.2.1* Maximum insertion load 80 kips Maximum extraction load 80 kips
Ambient Temperatures	Normal temperature 44.1 – 81.5°F	Normal (Bounded)	*Sections C.8.5 (New Evaluation) and Standardized NUHOMS® SAR Section K.4.4.1* Normal temperature 0 - 100°F(1)
Off-Normal Temperature	Minimum temperature 30.1°F Maximum temperature *113*°F	Off-Normal (Bounded)	*Sections C.8.5 (New Evaluation) and Standardized NUHOMS® SAR Section K.4.5.2* Minimum temperature -40.0°F Maximum temperature 125°F
Extreme Temperature	Maximum temperature 113°F	Accident (Bounded)	*Sections C.8.5 (New Evaluation) and Standardized NUHOMS® SAR Section K.4.6.1* Maximum temperature 125°F

Table C.3-1
Summary of WCS CISF Principal Design Criteria
(*5* pages)

Design Parameter	WCS CISF Design Criteria	Condition	NUHOMS®-61BT Design Criteria
Solar Load (Insolation)	Horizontal flat surface insolation 2949.4 BTU/day-ft^2 Curved surface solar insolation 1474.7 BTU/day-ft^2	Normal (Same)	*Sections C.8.5 (New Evaluation) and Standardized NUHOMS® FSAR Table 8.1-17* Horizontal flat surface insolation 2949.4 BTU/day-ft^2 Curved surface solar insolation 1474.7 BTU/day-ft^2
Snow and Ice	Snow Load 10 psf	Normal (Bounded)	*Standardized NUHOMS® FSAR Sections 3.2.4 and K.2.2.4* Snow Load 110 psf
Dead Weight	Per design basis for systems listed in Table 1-1	Normal (Same)	*Standardized NUHOMS® FSAR Sections 8.1.1.4, K.3.2, K.3.6.1.1 and Tables K.2-10 and K.3.2-1*
Internal and External Pressure Loads	Per design basis for systems listed in Table 1-1	Normal (Same)	*Standardized NUHOMS® FSAR Section K.3.6.1.1 and Tables K.2-10, K.3.4-5 and K.3.2-1*
Design Basis Thermal Loads	Per design basis for systems listed in Table 1-1	Normal (Same)	*Standardized NUHOMS® FSAR Sections K.3.6.1.2 and K.3.6.1.3 of Reference* [C.3-1]
Operating Loads	Per design basis for systems listed in Table 1-1	Normal (Same)	*Standardized NUHOMS® FSAR Sections K.3.6.1.1, K.3.6.1.2, K.3.6.1.4, K.3.6.2.1 and Tables K.2-5 and K.2-10*
Live Loads	Per design basis for systems listed in Table 1-1	Normal (Same)	*Standardized NUHOMS® FSAR Section K.3.6.1.1* Design Load (including snow and ice) 200psf

Table C.3-1
Summary of WCS CISF Principal Design Criteria
(*5* pages)

Design Parameter	WCS CISF Design Criteria	Condition	NUHOMS®-61BT Design Criteria
Radiological Protection	Public wholebody ≤ 5 Rem Public deep dose plus individual organ or tissue ≤ 50 Rem Public shallow dose to skin or extremities ≤ 50 Rem Public lens of eye ≤ 15Rem	Accident (Same)	*Chapter 9 demonstrates these limits are met* Public wholebody ≤ 5 Rem Public deep dose plus individual organ or tissue ≤ 50 Rem Public shallow dose to skin or extremities ≤ 50 Rem Public lens of eye ≤ 15 Rem
Radiological Protection	Public wholebody ≤ 25 mrem/yr(3) Public thyroid ≤ 75 mrem/yr(3) Public critical organ ≤ 25 mrem/yr(3)	Normal (Same)	*Chapter 9 demonstrates these limits are met* Public wholebody ≤ 25 mrem/yr(3) Public thyroid ≤ 75 mrem/yr(3) Public critical organ ≤ 25 mrem/yr(3)
Confinement	Per design basis for systems listed in Table 1-1	N/A	*Standardized NUHOMS® FSAR Section K.7 including K.7.3.2*
Nuclear Criticality	Per design basis for systems listed in Table 1-1	N/A	*Standardized NUHOMS® FSAR Section K.6 and Table K.6-10*
Decommissioning	Minimize potential contamination	Normal (Same)	*Standardized NUHOMS® FSAR Sections 9.6 and K.14* Minimize potential contamination
Materials Handling and Retrieval Capability	Cask/canister handling system prevent breach of confinement boundary under all conditions Storage system allows ready retrieval of canister for shipment off-site	Normal (Same)	*Standardized NUHOMS® FSAR Section K.2.3.2* Cask/canister handling system prevent breach of confinement boundary under all conditions Storage system allows ready retrieval of canister for shipment off-site

Notes

1. "Standardized NUHOMS® Horizontal Modular Storage System Safety Analysis Report" [C.3-1] normal ambient temperature range is 0 - 100°F. Section 8 of this SAR evaluates a normal ambient temperature range of 0° - 110°F.
2. 75g Vertical, 75g Horizontal and 25g corner is equivalent to 80 inch drop.
3. In accordance with 10 CFR 72.104*(a)*(3) limits include any other radiation from uranium fuel cycle operations within the region.

Table C.3-2
NUHOMS®-61BT System Major Components and Safety Classifications

Component	10CFR72 Classification
Dry Shielded Canister (DSC)	Important to Safety(1)
Horizontal Storage Module (HSM)	Important to Safety(1)
Basemat and Approach Slabs	Not Important to Safety
Transfer Equipment	
Cask	Important to Safety
Transport Trailer/Skid	Not Important to Safety
Ram Assembly	Not Important to Safety
Lubricant	Not Important to Safety
Auxiliary Equipment	
HSM Temperature Monitoring	Not Important to Safety

Notes

1. Graded Quality

APPENDIX C.4
OPERATING SYSTEMS
Standardized NUHOMS®-61BT System

Table of Contents

List of Tables

C.4. OPERATING SYSTEMS

This Appendix provides information on the operating systems applicable to the Standardized NUHOMS® System with the NUHOMS® 61BT DSC identified in Chapter 4 of the SAR. Those systems include the concrete pad structures, cask storage system, cask transporter system and the optional HSM thermal monitoring system.

C.4.1 Concrete Pad Structures

This section is applicable to the basemat and approach slabs for the NUHOMS® HSM Model 102. The following discussion provides guidance for these structures; but as noted in Section C.4.1.3, the basemat and approach slabs are not-important-to-safety (NITS).

C.4.1.1 Operating Functions

The NUHOMS® System basemat and approach slabs are cast-in-place reinforced concrete foundation structures that support the HSMs (the basemat) and provide for access and support of the transfer system (the approach slabs). The thickness of the basemat and the approach slab will be determined by site foundation analysis.

C.4.1.2 Design Description

The following provides a description of the design considerations that will be taken into account when designing the basemat and approach slabs.

The basemat and approach slab loads consist of both dead and live loads, seismic loads, and tornado wind loads imposed on the HSM array and transferred to the basemat.

The dead load consists of the weight of the basemat or approach slab.

Live loads for the basemat include the weight of the loaded DSC, the weight of the modules and shield walls plus an additional 200 psf applied over the surface area of the HSM base to account for snow and ice loads, safety railings on the roofs of the HSM, etc. These loads are provided in Table C.4-1. The values shown in Table C.4-1 are based on nominal material density; however, the as-built weight can vary ±5%, therefore; the storage pad is designed to accommodate 105% of the nominal weight shown in the table.

Live loads for the approach slab include the MP197HB cask and transfer vehicle design payload which is 300,000 lb. Additional live loads of 200 psf are applied over the surface area of the approach slabs.

Localized front (furthest from HSM) jack loads of 85,000 lb and rear jack loads of 109,000 lb are considered in designing the approach slab (this conservatively assumes the load of the DSC is carried only by the two rear jacks as the DSC is inserted into the HSM). These loads are spread as necessary by use of spreading plates or other suitable means.

The site-specific soil conditions at the Waste Control Specialist, LLC (WCS) Consolidated Interim Storage Facility (CISF) are considered in the basemat design based on basemat and HSM acceleration resulting from seismic activity.

Tornado wind loads acting on the HSM array are transferred to the basemat as friction and pressure loads. Generic design pressure loads acting on the NUHOMS® system due to tornado wind loading are described in the Standardized NUHOMS® UFSAR, Section 3.2.1 [C.4-1]. These may be replaced by the site-specific tornado loads which are significantly lower.

The basemat for the NUHOMS® HSMs will be level and constructed with a "Class B" surface flatness finish as specified in ACI 301-89 [C.4-2], or FF 25 per ASTM E 1155. Specifically, finishes with Class B tolerances shall be true planes within 1/4" in 10 feet, as determined by a ten foot straightedge placed anywhere on the slab in any direction. Although Class B surface finish is required, for modules with mating surfaces Class A surface flatness or FF 50 per ASTM E 1155 is recommended in order to provide better fit up and minimize gaps.

The surface finish for the basemat may be broomed, troweled or ground surface. Laser guided finishers and certified personnel may be utilized for construction of the basemat to assure proper finish, levelness and flatness. Alternatively, when grouted installation of HSMs is used, a reduced flatness may be targeted. The grouted installation consists of setting the modules on approximately one-inch thick stainless steel shims and grouting between the module and the pad using cement-based grouts.

The slope of the approach slabs shall not exceed 7% which is the adjustable limit of brake of the transfer vehicle.

The overall dimensions of the HSM modules are listed in Table C.4-2. When determining the length of the basemat, 1/2" should be added to the width of each module to account for as-built conditions in the modules and basemat. The basemat typically extends one foot beyond the front face of the module and matches the elevation of the approach slab. Thus, the width of a basemat for the double array is typically two feet wider than the modules. Similarly, the basemat typically extends one foot beyond the end walls.

To maintain levelness and stability of the module array, the joints intersecting the basemat should be minimized. Joints with expansion and sealant material must be compatible with expected basemat temperatures.

Two methods of HSM array expansion are permitted. One involves the temporary removal of end walls, installation of new modules, and then re-installation of the end walls. This method requires that the existing modules adjacent to the end walls be empty (unloaded) during array expansion. The other method of array expansion effectively buries the existing end walls by placing new modules directly adjacent to the end walls with new end walls placed at the end of the expanded array. The length of the basemat should be designed to accommodate the planned method of array expansion, as applicable. The basemat shall be designed to a maximum differential settlement of 1/4 inch, front to back and side-to-side (HSM array).

Finally, approach roads and aprons should be designed or repaired to eliminate features such as speed bumps, drains or potholes that would result in a difference of more than 5 inches in surface flatness over any 10-foot wide by 20-foot long area.

C.4.1.3 Safety Considerations

The foundation is not relied upon to provide safety functions. There are no structural connections or means to transfer shear between the HSM base unit module and the foundation slab. Therefore, the basemat and approach slabs for the HSMs are considered NITS and are designed, constructed, maintained, and tested as commercial-grade items.

C.4.2 Cask Storage System

This section is applicable to the NUHOMS® *61BT DSC;* HSM Model 102*; and MP197HB cask configured for transfer operations*.

C.4.2.1 Operating Function

The overall function of the HSM Model 102 used at the WCS CISF is to safely provide interim storage of spent nuclear fuel (SNF) *NUHOMS® 61BT* DSCs (canisters). These canisters provide a convenient means to place set quantities of SNF into dry storage in a way that allows easy retrieval of the canisters for off-site shipment.

The NUHOMS® 61BT DSCs containing SNF assemblies and are designed for storage in accordance with 10 CFR 72, and for transportation in accordance with 10 CFR 71. The main function of sealed canisters is to accommodate SNF assemblies and provide confinement and criticality control during normal operation and postulated design-basis accident conditions for on-site storage. *The NUHOMS® 61BT DSCs are shown in drawings NUH-61B-1060-SAR Revision 6, NUH-61B-1063-SAR Revision 4, NUH-61B-1064-SAR Rev.6, NUH-61B-1065-SAR Rev.6, NUH-61B-1061-SAR Revision 5, NUH-61B-1062-SAR Revision 6, and NUH-61B-1066-SAR Revision 6 included in Section C.4.6.*

The HSM Model 102 is designed in accordance with 10 CFR 72, and provides horizontal on-site storage of the sealed SNF and GTCC waste canisters. The main function of the HSM Model 102 is to provide safe, long-term storage of NUHOMS® 61BT DSCs containing SNF assemblies.

The HSM Model 102 design function is to passively cool the canisters by air convection. The HSM Model 102 also provides the capability for canister transfer from their associated transportation/transfer casks. *The drawings for the HSM model 102 are NUH-03-6008-SAR Revision 10, NUH-03-6009-SAR Revision 9, NUH-03-6010-SAR Revision 5, NUH-03-6014-SAR Revision 9, NUH-03-6015 SAR Revision 8, NUH-03-6016-SAR Revision 10, NUH-03-6017-01-SAR Revision 7, NUH-03-6018-SAR Revision 7 and NUH-03-6024-SAR Revision 5 included in Section A.4.6.*

The MP197HB cask, in the transfer configuration, design function is to protect the canisters and provide shielding from the radiation sources inside the canisters during transfer operations. The MP197HB cask in the transfer configuration is shown in drawings MP197HB-71-1002 Revision 6, MP197HB-71-1004 Revision 4, MP197HB-71-1005 Revision 4, MP197HB-71-1006 Revision 2 and MP197-HB-71-1014 Revision 1, included in Section C.4.6.

C.4.2.2 Design Description

The NUHOMS® 61BT DSCs are stainless steel flat head pressure vessels that provide confinement that is designed to withstand all normal condition loads as well as the off-normal and accident condition loads created by earthquakes, tornadoes, flooding, and other natural phenomena.

The HSM Model 102 is a low profile, reinforced concrete structure designed to withstand all normal condition loads as well as the off-normal and accident condition loads created by earthquakes, tornadoes, flooding, and other natural phenomena. The HSM is also designed to withstand off-normal and accident condition loadings postulated to occur during design basis accident conditions such as a complete loss of ventilation.

The MP197HB cask, in the transfer configuration, is used to transfer the canisters from the Cask Handling Building to the storage pad where the cask is mated to the HSM Model 102. The cask is designed to withstand all normal condition loads as well as the off-normal and accident condition loads created by earthquakes, tornadoes, flooding, and other natural phenomena.

C.4.2.3 Safety Considerations

The NUHOMS® 61BT DSCs are important-to-safety (ITS), Quality Category A components.

The HSM Model 102 is an important-to-safety (ITS), Quality Category B component. *The MP197HB cask is an ITS, Quality Category C component.*

C.4.3 Cask Transporter System

This section is applicable to the cask transporter system for the Standardized NUHOMS® System. This following provides a general description of the cask transporter system, however as noted Section C.4.3.3, this equipment is NITS.

C.4.3.1 Operating Function

The cask transporter system for the MP197HB cask is designed to move the loaded MP197HB cask in the on-site transfer configuration between the transfer facility and the Storage Area and transfer the canister from the MP197HB cask to the HSM Model 102.

C.4.3.2 Design Description

The transfer vehicle includes a transfer skid which cradles the top and bottom lifting trunnions of the cask, and is designed to be moved the skid and cask. The transfer vehicle is also used in the Storage Area to transfer the canister from an MP197HB cask to an HSM. It features a transfer skid, a skid positioner, a hydraulic ram system and hydraulic jacks for stabilization. The system utilizes a self-contained hydraulic ram to hydraulically push the canister out of the MP197HB cask and into the HSM. The alignment of the MP197HB and the HSM is verified by an alignment system.

C.4.3.3 Safety Considerations

All transfer equipment is designed to limit the height of the MP197HB cask to less than 80” above the surrounding surface; therefore, it is NITS and is designed, constructed, maintained, and tested as commercial-grade items.

C.4.4 Storage Module Thermal Monitoring System

Instrumentation is provided for monitoring HSM temperatures as described in Section 5.1.3 HSM Thermal Monitoring Program of the Technical Specifications [C.4-3] that may be used as one of two options provided to prevent conditions that could lead to exceeding the concrete and fuel clad temperature criteria.

C.4.5 References

C.4-1 AREVA TN Document NUH-003, Revision 14, "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel." (Basis for NRC CoC 72-1004).

C.4-2 American Concrete Institute, "Specifications for Structural Concrete for Buildings," ACI 301, 1989.

C.4-3 Proposed SNM-1050, WCS *Consolidated* Interim Storage Facility Technical Specifications, Amendment 0.

C.4-4 "NUHOMS® MP197 Transport Packaging Safety Analysis Report" Revision 17, USNRC Docket Number 71-9302.

C.4.6 Supplemental Data Drawings

The following drawings are located as noted below:

1. *"NUHOMS® 61BT Transportable canister for BWR Fuel General Arrangement (two sheets)," NUH-61B-1060-SAR, Revision 6 (See Section K.1.5 of Appendix K of the "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel" [C.4-1]).*

2. *"NUHOMS® 61BT Transportable canister for BWR Fuel Shell Assembly (two sheets)," NUH-61B-1061-SAR, Revision 5 (See Section K.1.5 of Appendix K of the "Updated final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel" [C.4-1]).*

3. *"NUHOMS® 61BT Transportable Canister for BWR Fuel Canister Details (two sheets)," NUH-61B-1062-SAR Revision 6 (See Section K.1.5 of Appendix K of the "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel" [C.4-1]).*

4. *"NUHOMS® 61BT Transportable Canister for BWR Fuel Basket Assembly (one sheet)," NUH-61B-1063-SAR, Revision 4 (See Section K.1.5 of Appendix K of the "Update Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel" [C.4-1]).*

5. *"NUHOMS® 61BT Transportable Canister for BWR Fuel Basket Details (two sheets)," NUH-61B-1064-SAR, Revision 6 (See Section K.1.5 of Appendix K of the "Updated Final Safety Analysis Report for the standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel" [C.4-1]).*

6. *"NUHOMS® 61BT Transportable Canister for BWR Fuel Parts List (one sheet)," NUH-61B-11065-SAR, Revision 6 (See Section K.1.5 of Appendix K of the "Updated Final Safety Analysis Report for the standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel" [C.4-1]).*

7. *"NUHOMS® 61BT Transportable Canister Basket Details for Damaged BWR fuel (three sheets),"NUH-61B-1066-SAR, Revision 6 (See Section K.1.5 of Appendix K of the "Updated Final Safety Analysis Report for the standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel" [C.4-1]).*

8. *"NUHOMS®-MP197HB Packaging Parts List (two sheets)," MP197HB-71-1002 Revision 6 (See Section A.1.4.10.1 of the "NUHOMS®-MP197 Transport Packaging Safety Analysis Report" [C.4-4]).*

9. *"NUHOMS® MP197HB Packaging Cask Body Assembly (one Sheet)," MP197HB-71-1004 Revision 4 (See Section A.1.4.10.1 of the "NUHOMS®-MP197 Transport Packaging Safety Analysis Report" [C.4-4]).*

10. *"NUHOMS® MP197HB Packaging Cask Body Details (three sheets)," MP197HB-71-1005 Revision 4 (See Section A.1.4.10.1 of the "NUHOMS®-MP197 Transport Packaging Safety Analysis Report" [C.4-4]).*

11. *"NUHOMS® MP197HB Packaging Lid Assembly and Details (one sheet)," MP-197HB-71-1006 Revision 2 (See Section A.1.4.10.1 of the "NUHOMS®-MP197 Transport Packaging Safety Analysis Report" [C.4-4]).*

12. *"NUHOMS® MP197HB Packaging Internal Sleeve Design (two sheets)," MP197HB-71-1014 revision1 (See Section A.1.4.10.1 of the "NUHOMS®-MP197 Transport Packaging Safety Analysis Report" [C.4-4]).*

Table C.4-1
Weight of HSM Model 102

Component	Nominal Weight kips(1)	105% weight kips
HSM Model 102	258.3	271.2
End Walls	48	50.4

Notes

1. Values reported in this table are for the purposes of designing the basemat and may differ from other SAR values.

Table C.4-2
HSM Model 102 Overall Dimensions

Width	Depth	Height
122”	228”	180”

APPENDIX C.5
OPERATING PROCEDURES
Standardized NUHOMS®-61BT System

Table of Contents

List of Figures

C.5. OPERATING PROCEDURES

This chapter presents the operating procedures for the Standardized NUHOMS® System containing the NUHOMS®-61BT DSCs originally loaded and stored under Certificate of Compliance (CoC) 1004 with the addition of the NUHOMS®-MP197HB transport/transfer cask (TC) qualified for transfer operations with the 61BT DSC. The procedures include receipt of the TC; placing the TC onto the transfer skid on the transfer vehicle, transfer to the Storage Area, DSC transfer into the Horizontal Storage Module (HSM), monitoring operations, and DSC retrieval from the HSM. The NUHOMS®-MP197HB transfer equipment, and the Cask Handling Building systems and equipment are used to accomplish these operations. Procedures are delineated here to describe how these operations may be performed and are not intended to be limiting. Temporary shielding may be used throughout as appropriate to maintain doses as low as reasonably achievable (ALARA).

The following sections outline the typical operating procedures for the Standardized NUHOMS®-61BT System. These procedures have been developed to minimize the amount of time required to complete the subject operations, to minimize personnel exposure, and to assure that all operations required for transfer, and storage are performed safely. Operations may be performed in a different order if desired to better utilize personnel and minimize dose as conditions dictate.

Pictograms of the Standardized NUHOMS®-61BT System operations are presented in Figure C.5-1.

The generic terms used throughout this section are as follows.

- TC, or transfer cask is used for the NUHOMS®-MP197HB transport/transfer cask.
- DSC is used for the NUHOMS®-61BT DSC.
- HSM is used for the HSM Model 102.

C.5.1 Procedures for Loading the DSC and Transfer to the HSM

A pictorial representation of key phases of this process is provided in Figure C.5-1.

C.5.1.1 Receipt of the Loaded NUHOMS®-MP197HB Cask

Procedures for receiving the loaded TC after shipment are described in this section. These procedures are taken from reference [C.5-1]*, and must remain consistent with* [C.5-1].

1. Verify that the tamperproof seals are intact.
2. Remove the tamperproof seals.
3. Remove the holddown bolts from the impact limiters and install the impact limiter hoist rings provided.
4. Remove the impact limiters from the TC.
5. Remove the transportation skid personnel barrier and tie-down straps.
6. Take contamination smears on the outside surfaces of the TC. If necessary, decontaminate the TC until smearable contamination is at an acceptable level.
7. Install the front and rear trunnions and torque the bolts to 1000-1100 ft-lbs for double shoulder trunnions and 800-900 ft-lbs for single shoulder trunnions following the torqueing sequence in accordance with the transport license requirements [C.5-1].
8. Attach *the WCS Lift Beam Assembly* to TC top and bottom ends.
9. Using the overhead crane, lift the TC from the conveyance. Place the TC onto the transfer cask skid trunnion towers.

CAUTION: Verify that the TC is not lifted more than 80” above the adjacent surface in accordance with the limits specified in Section 5.2.1 of the Technical Specifications [C.5-2].

10. Inspect the trunnions to ensure that they are properly seated onto the skid.
11. Remove the *WCS Lift Beam Assembly*.
12. Install the TC shear key plug assembly.
13. Install the on-site support skid pillow block covers.
14. Any time prior to removing the TC top cover plate or the bottom ram access cover plate, sample the TC cavity atmosphere through the vent port. Flush the TC interior gases to the radwaste system if necessary.

15. Draw a vacuum on the TC cavity and helium leak test the DSC in accordance with reference [C.5-3] requirements.

C.5.1.2 Transfer to the HSM

1. Prior to the TC arrival at the HSM or prior to positioning the TC at the HSM, remove the HSM door, inspect the cavity of the HSM, removing any debris and ready the HSM to receive a DSC. The doors on adjacent HSMs should remain in place.

CAUTION: The inside of empty modules have the potential for high *dose* rates due to adjacent loaded modules. Proper ALARA practices should be followed for operations inside these modules and in the areas outside these modules whenever the door from an empty HSM has been removed.

2. Inspect the HSM air inlets and outlets to ensure that they are clear of debris. Inspect the screens on the air inlets and outlets for damage.
3. Verify specified lubrication of the DSC support structure rails.
4. Move the TC from the Cask Handling Building to the storage pad along the designated transfer route.
5. Once at the storage pad, position the transfer vehicle to within a few feet of the HSM.

   Note: If performing inspection of the DSC surface, install inspection apparatus between TC and HSM.

6. Check the position of the transfer vehicle to ensure the centerline of the HSM and TC approximately coincide. If the transfer vehicle is not properly oriented, reposition the transfer vehicle, as necessary.
7. Unbolt and remove the TC top cover plate.
8. Verify the DSC serial number against appropriate records.

CAUTION: High dose rates are expected after removal of the TC top cover plate. Proper ALARA practices should be followed.

9. Remove the cask spacer ring and install the unloading flange.
10. Back the transfer vehicle to within a few inches of the HSM/inspection apparatus, set the transfer vehicle brakes and disengage the tractor, if applicable. Extend the transfer vehicle vertical jacks.

11. Use the skid positioning system to bring the TC into approximate vertical and horizontal alignment with the HSM. Using alignment equipment and the alignment marks on the TC and the HSM, adjust the position of the TC until it is properly aligned with the HSM.

12. Using the skid positioning system, fully insert the TC into the HSM/inspection apparatus access opening docking collar.

13. Secure the TC to the front wall embedments of the HSM using the cask restraints.

14. After the TC is docked with the HSM/inspection apparatus, verify the alignment of the TC using the alignment equipment.

15. Remove the bottom ram access cover plate. Position the ram behind the TC in approximate horizontal alignment with the TC and level the ram. Extend the ram through the bottom TC opening into the DSC grapple ring.

16. Operate the ram grapple and engage the grapple arms with the DSC grapple ring.

17. Recheck all alignment marks and ready all systems for DSC transfer.

18. Activate the ram to initiate insertion of the DSC into the HSM. Stop the ram when the DSC reaches the support rail stops at the back of the module.

    Note: If performing inspection of the DSC surface per reference [C.5-3] requirement, install inspection apparatus between the TC and the HSM.

19. Disengage the ram grapple mechanism so that the grapple is retracted away from the DSC grapple ring.

20. Retract and disengage the ram system from the TC and move it clear of the TC. Remove the cask restraints from the HSM.

21. Using the skid positioning system, disengage the TC from the HSM/inspection apparatus access opening.

22. Remove the inspection apparatus, if used.

23. Install the DSC axial restraint through the HSM door opening.

CAUTION: High dose rates are expected in the HSM cavity after removal of the HSM door. Proper ALARA practices should be followed.

24. The transfer vehicle can be moved, as necessary, to install the HSM door. Install the HSM door and secure it in place. The door may be welded for security.

25. Remove the unloading flange and replace the cask spacer ring.

26. Replace the TC top cover plate and ram access cover plate. Secure the skid to the transfer vehicle.

27. Move the transfer vehicle and TC to the designated area. Return the remaining transfer equipment to the Storage Area.

C.5.1.3 Monitoring Operations

1. Perform routine security surveillance in accordance with the security plan.

2. Perform a daily visual surveillance of the EOS-HSM air inlets and outlets (bird screens) to verify that no debris is obstructing the HSM vents in accordance with Section 5.1.3(a) of the Technical Specification [C.5-2] requirements, or, perform a temperature measurement for each EOS-HSM in accordance with Section 5.1.3(b) of the Technical Specifications [C.5-2] requirements.

C.5.2 Procedures for Unloading the DSC

The following section outlines the procedures for retrieving the DSC from the HSM for shipment off-site.

C.5.2.1 DSC Retrieval from the HSM

1. Ready the TC, transfer vehicle, and support skid for service. Remove the top cover and ram access plates from the TC. Move the transfer vehicle to the HSM.

2. Remove the HSM door and the DSC axial restraint. Position the transfer vehicle to within a few feet of the HSM.

3. Check the position of the transfer vehicle to ensure the centerline of the HSM and TC approximately coincide. If the transfer vehicle is not properly oriented, reposition the transfer vehicle as necessary.

CAUTION: High dose rates are expected in the HSM cavity after removal of the HSM door. Proper ALARA practices should be followed.

4. Back the TC to within a few inches of the HSM, set the transfer vehicle brakes and disengage the transfer vehicle, if applicable. Extend the transfer vehicle vertical jacks.

5. Use the skid positioning system to bring the TC into approximate vertical and horizontal alignment with the HSM. Using alignment equipment and the alignment marks on the TC and the HSM, adjust the position of the TC until it is properly aligned with the HSM.

6. Using the skid positioning system, fully insert the TC into the HSM access opening docking collar.

7. Secure the TC to the front wall embedments of the HSM using the cask restraints.

8. After the TC is docked with the HSM, verify the alignment of the TC using the alignment equipment.

9. Position the ram behind the TC in approximate horizontal alignment with the TC and level the ram. Extend the ram through the TC into the HSM until it is inserted in the DSC grapple ring.

10. Operate the ram grapple and engage the grapple arms with the DSC grapple ring.

11. Recheck all alignment marks and ready all systems for DSC transfer.

12. Activate the ram to pull the DSC into the TC.

13. Once the DSC is seated in the TC, disengage the ram grapple mechanism so that the grapple is retracted away from the DSC grapple ring.

14. Retract and disengage the ram system from the TC and move it clear of the TC. Remove the cask restraints from the HSM.

15. Using the skid positioning system, disengage the TC from the HSM access opening.

CAUTION: The inside of empty modules have the potential for high *dose* rates due to adjacent loaded modules. Proper ALARA practices should be followed for operations inside these modules and in the areas outside these modules whenever the door from the empty HSM has been removed.

16. Bolt the TC top cover plate and the ram access cover plate into place, tightening the bolts to the required torque in a star pattern.

17. Retract the vertical jacks and disconnect the skid positioning system.

18. Ready the transfer vehicle for transfer.

19. Replace the HSM door and DSC axial restraint on the HSM.

20. Move the TC from the storage pad to the Cask Handling Building along the designated transfer route.

21. Prepare the transportation cask for transport in accordance with *Certificate of Compliance No. 9302.*

C.5.3 References

C.5-1 U.S. Nuclear Regulatory Commission, “Certificate of Compliance No. 9302, Revision 7 for the Model No. NUHOMS®-MP197 and NUHOMS®-MP197HB Packages (Docket 71-9302).

C.5-2 Proposed SNM-1050, WCS *Consolidated* Interim Storage Facility Technical Specifications, Amendment 0.

C.5-3 “Post Transport Package Evaluation,” QP-10.02, Revision *1*.

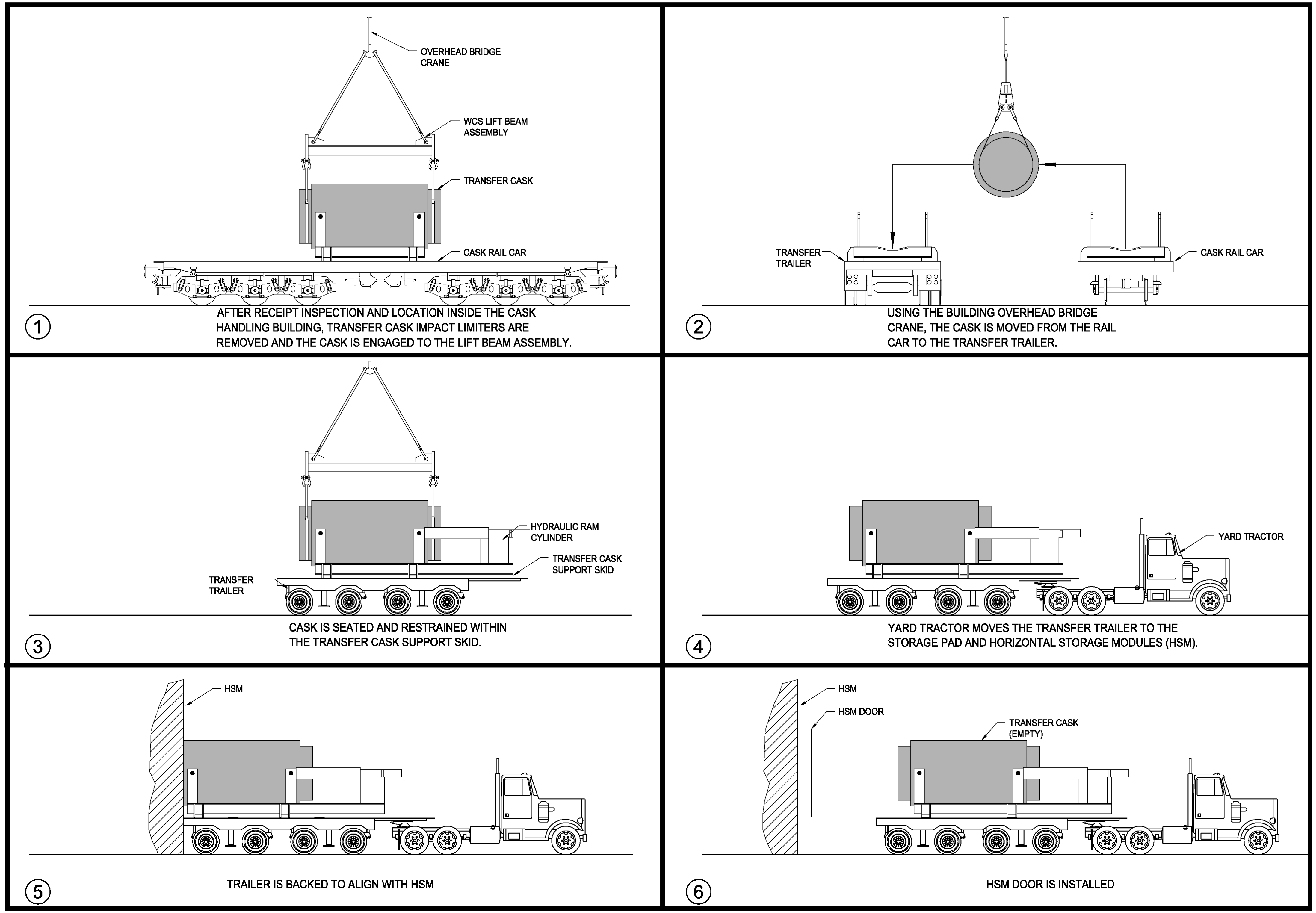


Figure C.5-1
Standardized NUHOMS®-61BT System Loading Operations

APPENDIX C.6
WASTE CONFINEMENT AND MANAGEMENT
Standardized NUHOMS®-61BT System

Table of Contents

C.6. WASTE CONFINEMENT AND MANAGEMENT

No change or additional information required for the Standardized NUHOMS® System containing the NUHOMS® 61BT DSCs for Chapter 6.

APPENDIX C.7
STRUCTURAL EVALUATION
Standardized NUHOMS®-61BT System

Table of Contents

List of Tables

List of Figures

C.7. STRUCTURAL EVALUATION

This Appendix describes the structural evaluation of the Standardized NUHOMS®-61BT System components utilized for transfer and storage of canisterized spent nuclear fuel (SNF) at the Waste Control Specialists, LLC (WCS) Consolidated Interim Storage Facility (CISF). As presented in Chapter 1, Table 1-1, the Standardized NUHOMS®-61BT System storage components include the 61BT Dry Shielded Canister (DSC or canister) and the HSM Model 102 concrete overpack. At the WCS CISF, the MP197HB transportation cask is used for on-site transfer activities.

The HSM Model 102 is described in detail in Section 4.2.3.2 of the Standardized NUHOMS® Updated Final Safety Analysis Report (UFSAR) [C.7-13]. The 61BT DSC is described in detail in Section K.1.2 of [C.7-13]. Both of these components are approved by the NRC [C.7-13] for transfer and storage of SNF under the requirements of 10 CFR Part 72.

The MP197HB cask is described in detail in Section A.1.2 of the NUHOMS®-MP197 Transportation Package Safety Analysis Report (SAR) [C.7-1]. The MP197HB cask is approved by the NRC for off-site transport of canisters under the requirements of 10 CFR Part 71. This SAR presents the analyses required for approval of the MP197HB cask as the on-site transfer cask at the WCS CISF under the requirements of 10 CFR Part 72. The structural evaluation of the MP197HB cask as the on-site transfer cask is contained in this appendix. The evaluation of the canisters for transfer and storage is contained in Appendix K of [C.7-13] for the Standardized NUHOMS®-61BT System [C.7-13]. The evaluation of the HSM Model 102 is contained in Chapter 8 of [C.7-13].

This appendix is prepared to demonstrate that these licensed Standardized NUHOMS®-61BT System components are also qualified to safely transfer and store SNF at the WCS CISF. In addition to the seismic reconciliation evaluation presented in Section C.7.3, this appendix presents the analyses required to qualify the MP197HB cask for on-site transfer activities per 10 CFR Part 72 for the 61BT and 61BTH Type 1 canisters. These analyses, in combination with existing evaluations in [C.7-13], demonstrate that the MP197HB / Canisters / HSM Model 102 transfer and storage system satisfies all of the 10 CFR Part 72 requirements for storage at the WCS CISF. *Qualification of the 61BT DSC confinement boundary during Normal Conditions of Transport is addressed in Section C.7.8.*

MP197HB Cask

The principal design criteria for the MP197HB cask for service at the WCS CISF are described in Table C.7-1 and below in Section C.7.7.1. The design approach, design criteria and loading combinations for the MP197HB cask are also described in Section C.7.7.1.

Horizontal Storage Module

The design approach, design criteria and loading combinations for the reinforced concrete HSM Model 102 and its DSC steel support structure are discussed in Section 3.2.5.1 of [C.7-13].

Canister

The 61BT DSC design approach, design criteria and load combinations for transfer and storage are summarized in Appendix K Sections K.2.5 and K.3 of [C.7-13].

C.7.1 Discussion

As discussed in Chapter 1, the canisters from an ISFSI site will be transported to the WCS CISF in the NUHOMS®-MP197HB Cask under NRC Certificate of Compliance (CoC) 9302 [C.7-1]. At the WCS CISF, the 61BT DSCs, described in Appendix K of [C.7-13], are to be stored inside the Standardized NUHOMS® HSM Model 102 described in Chapter 4 of [C.7-13].

The 61BT DSC is licensed under NRC Certificate of Compliance 1004 [C.7-13] for storage in the HSM Model 102 and for transfer operations in the OS197 cask. This appendix will reconcile the analyses of the canister for transfer operations in the OS197 cask with the transfer operations in the MP197HB cask specified for the WCS CISF. Additionally, this appendix provides the structural analysis required to support the licensing of the MP197HB cask under 10 CFR Part 72 for on-site transfer operations at the WCS CISF.

As described in Chapter 3, with the exception of seismic loading, the design criteria for the Standardized NUHOMS® components used in [C.7-13] envelops the design criteria for the WCS CISF.

Finally, bounding evaluations in Section C.7.8 are referenced to demonstrate that the confinement boundaries for the 61BT DSC does not exceed ASME B&PV Subsection NB Article NB-3200 (Level A allowables) during normal conditions of transport to provide reasonable assurance that the confinement boundary is not adversely impacted by transport to the WCS CISF.

C.7.2 Summary of Mechanical Properties of Materials

The material properties for the 61BT DSC are given in Appendix K Section K.3.3 of [C.7-13].

The material properties for the HSM Model 102 are given in Table 8.1-3 of [C.7-13].

The material properties for the MP197HB cask are given in Chapter A.2.2 of [C.7-1].

C.7.3 Seismic Reconciliation of the 61BT DSC, HSM Model 102, and MP197HB Cask

The site-specific seismic ground motion developed for the WCS CISF in the form of the 10,000-year return period uniform hazard response spectrum for the horizontal and vertical directions are described in Chapter 2. A comparison of the site-specific response spectra for the WCS CISF ground motion and the Regulatory Guide 1.60 design-basis ground motions' response spectra are shown in Figure C.7-25 for 3%, 5%, and 7% damping values. This comparison indicates that for system frequencies above about 10 Hz (horizontal direction) and 9 Hz (vertical direction), the WCS CISF spectral accelerations are higher than the design basis spectral accelerations. The ZPA values of 0.25g (horizontal) and 0.17g (vertical) for the WCS CISF ground motion are the same as those for the Standardized NUHOMS® System.

This section describes the reconciliation evaluations of the 61BT DSC, HSM Model 102, and MP197HB cask *using the enveloping response spectra at the HSM CG and base, which are obtained from the soil-structure interaction (SSI) analysis of the WCS CISF. Comparisons of the 3%-damped WCS CISF 10,000-year return period uniform hazard response spectra and +/-15% peak-broadened HSM base response spectra from the WCS CISF SSI analysis in the HSM's transverse, longitudinal, and vertical directions are shown in Figure C.7-26 and Figure C.7-27. The +/-15% peak-broadened HSM Base response spectra for damping values of 7%, 3%, and 2% are shown in Figure C.7-28 through Figure C.7-30.*

C.7.3.1 HSM Model 102

The reconciliation of the seismic loading on the HSM Model 102 is contained in Section D.7.3.1. Section D.7.3.1 considers the WCS CISF site-specific seismic loading on the HSM Model 102 loaded with a 61BTH Type 1 DSC, the weight of which bounds the 61BT DSC.

C.7.3.2 MP197HB Transfer Cask

The MP197HB Cask is designed as a transportation cask for off-site shipment under the provisions of 10 CFR 71. Due to the cask's design to meet off-site shipping requirements, large factors of safety are afforded for on-site transfer operations.

The MP197HB cask consists of a 2.75″ thick steel outer shell, a 3.0″ thick layer of lead, and a 1.25″ thick steel inner shell. *Soil-structure interaction (SSI) analyses were performed for the pad with high level waste storage units at the Andrews, TX waste storage facility site. These analyses are presented in Section 7.6.4. One of the purposes of the analyses was to determine the envelope of the acceleration response spectra at the HSM base, at the pad level. The +/-15% broadened envelope of the acceleration response spectra at the base of the HSM modules are shown in Figure C.7-26 and Figure C.7-27, for the cask transverse, longitudinal and vertical directions.*

Therefore, it is concluded that the MP197HB cask is acceptable for the WCS CISF site-specific seismic loading.

C.7.3.3 61BT DSC

Per Section K.3.7.3 of Reference [C.7-13], the canister shell components are evaluated for seismic loading of 3.0g and 1.0g for the horizontal and vertical directions, respectively. The basket components are evaluated for a bounding acceleration of 2g in each of the axial, transverse, and vertical direction [Section K.3.6.1.3.4 of C.7-13].

C.7.4 Reconciliation of Thermal Loads for the 61BT DSC in the HSM Model 102 and MP197HB Cask

As noted in Section C.8.4.4 the thermal performance of the HSM Model 102 with the 61BT DSC at the WCS CISF for normal, off-normal, and accident conditions is bounded by the original design basis evaluations as described in Appendix K.4 of [C.7-13]. Since the temperatures of the canister components during storage at the WCS CISF are bounded by the analyses in [C.7-13], the analyses for design basis internal pressure and normal thermal loads, as well as the allowable stress criteria, are also bounded.

The thermal analyses of the 61BT DSC for transfer conditions at the WCS CISF for normal, off-normal, and accident conditions in the MP197HB cask are detailed in Section C.8.5. Comparison of the maximum canister component temperatures shown in Table C.8-2 for transfer conditions at the WCS CISF and Table K.4-2 of [C.7-13] indicate that the maximum canister component temperatures increase by between 2% and 5% for transfer in the MP197HB cask versus the OS197 transfer cask. This small increase is inconsequential for the thermal stress evaluations as the temperatures used to determine the component material properties and allowable stresses (500 ºF for the canister shell and 650 ºF for the basket [C.7-13 Table K.3.7-11]) bound the maximum temperatures during transfer in the MP197HB cask (387 ºF for the canister shell and 637 ºF for the basket [Table C.8-2]).

Therefore, it is concluded that the temperature distributions and thermal stresses for normal, off-normal, and accident conditions in [C.7-13] are applicable for transfer of the canister in the MP197HB cask.

C.7.5 Structural Analysis of 61BT DSC (Storage and Transfer)

The structural analysis of the 61BT DSC for normal, off-normal, and accident loads is presented in Sections K.3.6.1, K.3.6.2, and K3.7 respectively, of [C.7-13]. Loading types applicable to each affected component are summarized in Table K.3.6-1, Table K.3.6-2, and Table K.3.7-1 for normal, off-normal, and accident conditions, respectively, of [C.7-13]. Results for normal and off-normal loads are summarized in Table K.3.7-11 of [C.7-13]. Results for accident loads are presented in Table K.3.7-12 and K.3.7-13 of [C.7-13].

The evaluations of the 61BT DSC for transfer loads performed in [C.7-13] Appendix K and summarized below in Sections C.7.5.1 through C.7.5.3 were performed for transfer in the OS197 transfer cask. The geometric parameters of the transfer cask that may affect the structural analyses are the cask cavity inner diameter, cask rail locations, cask rail width, and cask rail thickness. Transport (and transfer) of the 61BT DSC in the MP197HB cask requires the use of a sleeve installed inside the MP197HB cask. The dimensions of the above-mentioned geometric parameters for the MP197HB cask with the internal spacer sleeve are compared to the dimensions of the same parameters for OS197 transfer cask, as follows:

♦ Cavity Diameter:	OS197:	68.00”
	MP197HB with sleeve:	68.00”
♦ Rail Locations:	OS197:	±18.5°
	MP197HB with sleeve:	±18.5° and ±38°
♦ Rail Width:	OS197:	3.00”
	MP197HB with sleeve:	3.00”
♦ Rail Thickness:	OS197:	0.12”
	MP197HB with sleeve:	(0.62”-0.50” inset=) 0.12”

As shown above, all of the subject dimensions are identical. The MP197HB cask has an additional set of rails which will have a beneficial effect due to the additional support offered to the canister shell and basket assembly. The transfer cask shell is conservatively assumed to be rigid for analyses of the canister shell and basket. Therefore, any difference in stiffness of the OS197 transfer cask and MP197HB cask has no impact on the canister analyses as only the interface dimensions would have an effect on the analyses. Since the interface dimensions are the same, the analyses of the 61BT DSC shell and basket assemblies for on-site transfer in the OS197 transfer cask are applicable and equivalent for on-site transfer in the MP197HB cask.

The MP197HB cask including the internal spacer sleeve contain the same features as the OS197 transfer cask designed to minimize the possibility of a jammed or binding canister during loading and unloading operations. The calculations performed for the postulated off-normal condition of a jammed or binding canister are based only on the maximum hydraulic ram force and the diameter of the canister.

Based on the reconciliations presented above, the 61BT DSC calculations performed in [C.7-13] and discussed below in Section C.7.5.1, Section C.7.5.2, and Section C.7.5.3 involving use of the OS197 transfer cask are applicable for loading and unloading of the 61BT DSC with the MP197HB cask.

The following is a summary of the structural analyses of the 61BT DSC shell and basket assemblies.

C.7.5.1 Normal Loads (Storage in HSM Model 102 and Transfer in MP197HB Cask)

The structural analysis of the 61BT DSC for normal loads is presented in Section K.3.6.1 of [C.7-13].

61BT DSC Shell Assembly

Section K.3.6.1.2 of [C.7-13] describes the 61BT DSC shell analyses for Normal Operating Loads. The analyses are performed using 3-dimensional ANSYS finite element models. The load cases considered include deadweight, design basis normal operating internal and external pressure, normal operating thermal loads, and normal operation handling loads.

The maximum calculated stress results for the individual load cases are shown in Table K.3.6-4 of [C.7-13]. The calculated stresses for each load case are combined in accordance with the load combinations presented in Table K.3.7-15 of [C.7-13]. The resulting stresses for the controlling load combinations are reported in Section K.3.7.10 of [C.7-13]. All stresses are within the ASME Code allowable stresses.

61BT DSC Basket Assembly

Section K.3.6.1.3 of [C.7-13] describes the 61BT DSC basket analyses for Normal Operating Loads. The analyses are performed using a 3-dimensional ANSYS finite element model. The basket is evaluated separately for Handling/Transfer Loads and for Operation/Storage loads in Sections K.3.6.1.3.3 and K.3.6.1.3.4 of [C.7-13], respectively. The basket thermal stress analysis is contained in Section K.3.4.4.3 of [C.7-13]. The load cases considered include thermal stress, deadweight, handling/transfer loads, and seismic loads. The seismic loading case is considered a Service Level C event; however, it has been used to bound the Horizontal Dead Weight case and is, therefore, presented in the section for Normal Operation/Storage Loads.

Section K.3.6.1.3.3-C of [C.7-13] presents a table of results for the Handling/Transfer Loads analyses of the 61BT basket. All stresses are within the allowable limits

Section K.3.6.1.3.4-E of [C.7-13] presents a table of results for the Operating/Storage Loads analyses of the 61BT basket. All stresses are within the allowable limits.

C.7.5.2 Off-Normal Loads

The structural analyses for off-normal loads is contained in Section K.3.6.2 of [C.7-13]. Two limiting off-normal events are defined which envelope the range of expected off-normal structural loads:

- Jammed Canister During Transfer:
  The analysis of the jammed 61BT canister during transfer is identical to the analysis of the 52B canister contained in Section 8.1.2 of [C.7-13]. All stresses are within the ASME code limits. As discussed in Section C.7.5, the analysis of this condition for transfer in the OS197 transfer cask is equivalent and applicable for transfer in the MP197HB cask.

- Off-Normal Thermal Loads:
  Off-Normal ambient temperatures are defined as -40 °F and 125 °F for the 61BT DSC. The stress results presented in Table K.3.6-4 of [C.7-13] show that the canister stress limits are satisfied for the off-normal thermal loads. The thermal stress analyses in Section K.3.4.4.3 of [C.7-13] show that the stress limits for the basket are satisfied for the off-normal thermal loads. As discussed in Section C.7.4, the thermal stress analyses of the 61BT DSC for transfer in the OS197 transfer cask are applicable for transfer in the MP197HB cask.

C.7.5.3 Accident Loads

The structural analysis of the 61BT DSC for accident loads is presented in Section K.3.7 of [C.7-13]. The following accident conditions affect the canister and are evaluated:

<u>Earthquake</u>

The seismic load is reconciled in Section C.7.3. As concluded in Section C.7.3, the 61BT DSC is acceptable for storage at the WCS CISF.

<u>Flood</u>

Evaluation of the canister for flood loads is contained in Section K.3.7.4.2 of [C.7-13]. The ASME Code methodology in NB-3133.3 is used to show that there is a safety margin of at least 1.8 against buckling of the canister shell. The shell stresses are calculated using an ANSYS finite element model and are shown to be much less than the ASME Service Level C allowable values.

<u>Accidental Cask Drop</u>

The 61BT DSC evaluations for the accident drop cases are presented in Section K.3.7.5 of [C.7-13]. Equivalent static loading of 75g is used to evaluate the effects of the drops.

The canister shell assembly accidental drop analysis results are summarized in Table K.3.7-3 of [C.7-13]. The controlling load combination results are shown in Table K.3.7-13 of [C.7-13]. All applicable ASME stress criteria are satisfied. Stability of the canister shell against buckling is also evaluated and shown to satisfy the acceptance criteria of ASME Appendix F.

Basket Assembly results for the side-drop and end-drop are summarized in Table K.3.7-5 and Table K.3.7-6, respectively, of [C.7-13]. The controlling load combination results are shown in Table K.3.7-13 of [C.7-13]. All applicable stress limits were met. Stability analyses are performed using both finite element analyses and hand calculations to evaluate the basket and transition rail plates for stability. The results indicated that the fuel compartment plates and transition rails have sufficient margin against failure.

C.7.6 Structural Analysis of HSM Model 102 with 61BT DSC (Storage Configuration)

The structural analysis of the HSM Model 102 reinforced concrete and DSC steel support structure for normal, off-normal, and accident conditions is presented in Sections 8.1.1, 8.1.2 and 8.2, respectively, of [C.7-13]. Loading types applicable to each affected component are summarized in Table 8.1-1, Table 8.1-2, and Table 8.2-1 for normal, off-normal, and accident conditions, respectively, of [C.7-13]. Results for normal and off-normal loads are summarized in Table 8.1-14 and Table 8.1-19 of [C.7-13]. Results for accident loads are presented in Table 8.2-18, Table 8.2-19, and Table 8.2-20 of [C.7-13].

The analyses and results listed above were originally performed for a bounding canister weigh of 80,000 lbs. As discussed in [C.7-13] Section K.3.7.10.5, the maximum weight of the 61BT DSC is 88,390 lbs. The bounding stress results for the HSM reinforced concrete and DSC steel support structure are adjusted for the increased weight. As shown in Table K.3.7-2 of [C.7-13], all of the limiting HSM structural components are acceptable for the 61BT DSC weight.

In this section, reference made to the HSM indicates the HSM Model 80 or HSM Model 102.

The following is a summary of the structural analyses.

C.7.6.1 Normal Loads

DSC Steel Support Structure

Section 8.1.1.4 of [C.7-13] describes the evaluations of the DSC steel support structure for normal condition loads. The structure is evaluated using a linear elastic beam model for the following loads: deadweight, operational handling loads, and thermal stress.

The results of the analyses for Normal Loads are shown in Table 8.1-14, Table 8.1-15, and Table 8.1-16 of [C.7-13].

HSM Reinforced Concrete

Section 8.1.1.5 of [C.7-13] describes the evaluations of the HSM reinforced concrete structure for normal condition loads. The structure is evaluated per ACI 349-85 considering frame and shear wall behavior using a finite element model. The following normal loads are considered: deadweight, live loads, creep and shrinkage, thermal stress, and radiation effects.

The results are shown in Table 8.1-19 of [C.7-13].

HSM Door and Anchorage

Section 8.1.1.6 of [C.7-13] describes the evaluations of the HSM door for normal condition loads. The door is evaluated for deadweight and a uniform pressure of 10 psi which envelopes the equivalent pressure load due to seismic and tornado wind pressure.

HSM Heat Shield

Section 8.1.1.7 of [C.7-13] describes the evaluations of the HSM heat shield for normal condition loads. The only load during normal operation is selfweight since the design of the heat shields allows for free thermal expansion.

C.7.6.2 Off-Normal Loads

DSC Steel Support Structure

Section 8.1.2 of [C.7-13] describes the evaluations of the DSC steel support structure for the following off-normal condition loads: jammed canister and off-normal thermal loads. The results of the DSC steel support structure analyses for off-normal loads are shown in Table 8.1-14, Table 8.1-15, and Table 8.1-16 of [C.7-13].

HSM Reinforced Concrete

Section 8.1.2 of [C.7-13] describes the evaluations of the HSM for off-normal thermal condition loads. The results of the HSM analyses for Off-Normal Loads are shown in Table 8.1-19 of [C.7-13].

C.7.6.3 Accident Loads

DSC Steel Support Structure

Section 8.2 of [C.7-13] describes the evaluations of the DSC steel support structure for accident condition loads.

- Earthquake
  As described in Section 8.2.3.2 of [C.7-13], the HSM and DSC steel support structure are evaluated for accident level seismic loads using the Reg. Guide 1.60 response spectra anchored at 0.25g and 0.17g in the horizontal and vertical directions, respectively. A damping value of 7% is used. The analysis is performed with an ANSYS finite element model. All stress are shown to be within allowable limits.
- Blocked Vent Thermal Loads
  As described in Section 8.2.7 of [C.7-13], the DSC steel support structure is analyzed for thermal stresses due to growth differential between the steel and concrete structure.

HSM Reinforced Concrete

- Tornado Winds and Tornado Generated Missiles
  Evaluation of the HSM for tornado wind and missile effects is presented in Section 8.2.2 of [C.7-13]. The safety margins against overturning and sliding of the HSM are determined using hand calculations. The resistance of the HSM concrete to tornado-generated missile perforation and scabbing is determined using the National Defense Research Committee formula with additional margin added based on the requirements of ACI 349-85. The HSM door is also shown to be adequate to protect against missile impact. Table 8.2-3 of [C.7-13] provides the results of the analyses for tornado wind and tornado missile loads.

  Additional evaluations are performed for the massive missile. The maximum sliding distance of the HSM due to massive missile impact is found to be 0.58" and the maximum tipping angle of rotation is found to be 1.12° which is much less than the critical angle leading to tip-over of the HSM. The global structural effects of the massive missile impact are also evaluated and found to be acceptable.

- Earthquake
  As described in Section 8.2.3.2 of [C.7-13], the HSM is evaluated for accident level seismic loads using the Reg. Guide 1.60 response spectra anchored at 0.25g and 0.17g in the horizontal and vertical directions, respectively. A damping value of 7% is used. The resulting forces and moments in the HSM components are shown in Table 8.2-3 of [C.7-13].

  A factor of safety of 1.17 against overturning and 1.24 against sliding due to seismic load is calculated.

  A seismic reconciliation for the WCS CISF site-specific *seismic loading* is performed in Section C.7.3.1.

- Flood
  Section 8.2.4 of [C.7-13] evaluates the HSM for the effects of flood loading. The safety factors against overturning and sliding are 1.55 and 1.13, respectively. Table 8.2-3 of [C.7-13] provides the results of the analyses for flood loading.

- Lightening
  As discussed in Section 8.2.6 of [C.7-13], lightening is found not to affect the normal operation of the HSM.

- Blocked Vent Thermal Loads
  As described in Section 8.2.7 of [C.7-13], the HSM is analyzed for thermal stresses due to the blocked vent condition. Table 8.2-3 of [C.7-13] provides the results of the analyses for the blocked vent thermal load case.

DSC Axial Retainer

Section 8.2.3.2(C)(iii) of [C.7-13] evaluates the DSC axial retainer for a seismic load of 0.40g using a canister weight of 102 kips and an impact factor of 1.5. The seismic reconciliation of the HSM Model 102 in Section D.7.3.1 *evaluates the axial retainer considering* the WCS CISF site-specific load.

C.7.6.4 Load Combinations

Section 8.2.10 of [C.7-13] describes the combination of the applicable normal, off-normal, and accident load cases.

- HSM Reinforced Concrete
  The governing calculated bending moments and shear forces for each applicable load combination are shown in Table 8.2-18 of [C.7-13]. The same table also lists the ultimate capacities of each section and shows that the design strength of the HSM is greater than the strength required for the most critical load combinations.
- DSC Steel Support Structure
  The applicable loads on the DSC steel support structure are combined into three governing load cases. The resulting maximum stresses are compared to the AISC code allowables in Table 8.2-19 of [C.7-13]. The same load combinations are used for the DSC steel support structure connecting elements. The maximum connection loads are shown in Table 8.2-20 of [C.7-13]. The structural steel design is based on the requirements of the AISC specification for structural steel buildings, 1989 version, and the embedments are designed in accordance with the requirements of ACI 349-85.

C.7.7 Structural Analysis of MP197HB Cask as On-Site Transfer Cask

C.7.7.1 General Information

This section presents the structural evaluations of the MP197HB cask for on-site transfer operations at the WCS CISF loaded with either the 61BT or 61BTH Type 1 DSC. The evaluations consist of *finite element* analyses and hand calculations to demonstrate that the MP197HB cask meets the requirements of 10 CFR Part 72.

Section C.7.7.2 discusses the evaluations and results for Normal and Off-Normal Conditions. Section C.7.7.3 discusses the analyses for Accident Conditions. The stability, stresses, and penetration resistance of the MP197HB cask due to design basis tornado, seismic loads, and missile impact are presented in Section C.7.7.4.

Key structural dimensions and weights of the MP197HB cask are summarized in Table C.7-9 and compared with the MP187 cask and the OS197 transfer cask licensed for on-site transfer operations in [C.7-12] and [C.7-13], respectively.

Figure C.7-1 identifies key components of the MP197HB cask body ANSYS finite element model. This model is the same as the model used in [C.7-1], which was reviewed and approved by the NRC for the MP197HB transportation license CoC 71-9302. Cask body stresses are examined for the following seven structural components: Outer Shell, Inner Shell, Top Cover Plate (Lid), Top Flange, Bottom Flange, Bottom Plate, and RAM (Access) Closure Plate. Individual design elements of the MP197HB cask, such as lid bolts and neutron shield shell, are structurally qualified by reference to analyses conducted for the cask for bounding loads documented in [C.7-1].

C.7.7.1.1 Finite Element Analysis Models

The ANSYS code Release 14.0, [C.7-14], is used for the evaluations of normal, off-Normal, and accident condition events. The FEA models employed in [C.7-1] and described in [C.7-1] Appendix A.2.13.1.2 (3D models) and [C.7-1] Appendix A.2.13.3.2 (axisymmetric model) are utilized to the maximum possible extent and adapted to fit the requirements of analyses for the WCS CISF. The original models were generated by means of the ANSYS code, Release 10.0. The ANSYS model features specific to Normal and Off-Normal Condition evaluations are delineated in Section C.7.7.2.2. Section C.7.7.3.2 presents model features specific to Accident Condition evaluations. Key common features for all employed models are outlined below.

The mesh, mesh refinement and element types are the same as in the original [C.7-1] evaluations. The MP197HB cask components are modeled by means of ANSYS SOLID45 elements for the 3D models and PLANE42 elements for the 2D models. Boundaries between components are modeled by means of the same surface-to-surface or node-to-surface contact elements. Control parameters for these contact elements have been adjusted to match the requirements of ANSYS 14.0 release. Confirmatory tests were carried out to verify consistency of the ANSYS results between ANSYS 14.0 release and ANSYS 10.0 release used in [C.7-1] calculations.

In the 3D models, boundaries between the steel and lead Gamma Shielding, between the Lid and Top Flange, and between the RAM Closure Plate and Bottom Plate are modeled with surface-to-surface contact elements CONTA173 and TARGE170. In 2D models, boundaries between the steel and lead Gamma Shielding, between the Lid and Top Flange, and between the RAM Closure Plate and Bottom Plate are modeled with surface-to-surface contact elements CONTA171 and TARGE169.

For the Lid and RAM Closure Plate interfaces no credit is taken for steel-to-steel friction (parameter MU=0). At the steel and Gamma Shielding interfaces, the steel to lead friction factor is taken as MU=0.25. The effects of the Neutron Shield weight on the cask response is modeled by means of SURF154 surface elements (SURF153 in 2D model).

All evaluations, except for the end drop calculations, consider the cask in the horizontal position.

C.7.7.1.2 Loads

Applicable loads for on-site transfer operations in the WCS CISF are summarized in Table C.7-1. Normal and off-normal conditions are addressed in detail in Section C.7.7.2. Accident loads are discussed in detail in Section C.7.7.3. Since transfer-handling loads bound seismic loads (See Section C.7.3.2) and HSM Loading/canister Transfer loads, these loads are not evaluated. Although the Top Cover Plate bolts do not need to be preloaded in the transfer configuration of the MP197HB cask, analyses account for the bolt-preload load magnitude specified for the transportation operations in [C.7-1]. The bolt preload effect is included so that the preload need not be relieved upon arrival of the cask at the WCS CISF and commencement of transfer operations.

C.7.7.1.3 Materials

Material properties of the MP197HB cask are taken from [C.7-1]. All material properties are listed in [C.7-1], Table A.2-4. The properties are based on the ASME code, [C.7-15]. Mechanical properties of cask components are evaluated at a temperature of 400 °F that conservatively exceeds the maximum temperature of the cask body at the WCS CISF, documented in Table C.8-1 and D.8-1 for the 61BT and 61BTH Type 1 DSCs, respectively. This temperature also bounds the MP197HB cask temperature for all canisters licensed for the transport in the MP197HB cask in [C.7-1].

C.7.7.1.4 Weights

In the transfer configuration, the MP197HB cask body weighs approximately 163.3 kips. The 61BT DSC weight is 88.4 kips. The 61BTH Type 1 DSC weighs 88.8 kips. The maximum total bounding weight of the MP197HB cask loaded with a 61BT or 61BTH Type 1 DSC is therefore 163.3+88.4 = 252.1 kips.

All ANSYS evaluations use a bounding canister weight of 118.5 kips. This weight represents the bounding canister weight used in [C.7-1] for all canisters licensed for transport in the MP197HB cask ([C.7-1], Section A.2.13.1.2). The weight also accounts for the presence of sleeves or spacers within the cask. The MP197HB cask body weight is modeled to closely represent the actual weight of the cask design.

For the MP197HB cask in the horizontal position, the canister weight load is simulated as a pressure load distributed uniformly in the axial direction and as a cosine pressure function laterally with the maximum pressure load, P_{max}, at the bottom part of the load and an angle span of 90° for lateral distribution (±45° from location of P_{max}). The load extends axially over the entire cavity length of the MP197HB cask. The peak pressure load, P_{max}, is determined by setting the integral of the pressure components to be equal to the magnitude of the net acting force. An example of the cosine distribution of the pressure load for 75g side drop is presented in Figure C.7-14.

For the vertical loads (e.g. side drop load), the peak pressure P_{max} takes place at the Inner Shell bottom position. When the resultant lateral component of acceleration departs from the vertical direction, then the canister pressure load is modeled as tilted by the same angle. Such scenario arises for asymmetric transfer handling loads analyzed for normal and off-normal Conditions in Section C.7.7.2.

Table C.7-4 identifies the tilt angles of canister loads. For example, in the case of unit acceleration loads for the vertical and transverse directions (Table C.7-3, case TR3) the tilt angle is 45° (Table C.7-4). Individual load components and corresponding coordinate systems employed in Normal and Off-Normal Conditions are presented in Table C.7-3.

Simulation of the canister weight by means of a cosine pressure distribution is the same method employed in other NUHOMS® system license evaluations (e.g. Refs. [C.7-1] & [C.7-13]).

C.7.7.1.5 Trunnions and Trunnion Attachment Blocks

Per [C.7-1], the MP197HB cask can be equipped with two types of trunnions: double shoulder trunnions and single shoulder trunnions. The MP197HB cask with double shoulder trunnions (non-single failure proof) will be used for transfer operations at the WCS CISF. These trunnions are designed and fabricated to meet the requirements of American National Standards Institute (ANSI) N14.6 [C.7-18].

Reference [C.7-1], Section A.2.13.5.2 documents evaluations of the MP197HB cask double shoulder trunnions, trunnion flanges and trunnion attachment blocks as well as evaluations of the MP197HB cask Outer Shell local stresses at the attachment block location. These components have been qualified for a minimum factor of safety of three against yield stress or five against ultimate stress (whichever is the most restrictive) for 290 kip lifting load. Those evaluations constitute the design basis for these components for the MP197HB cask operations projected for the WCS CISF. The (ANSI) N14.6 loads and associated stress criteria envelope transfer loads and associated stress criteria.

The trunnions, trunnion flanges and trunnion attachment blocks are included in the model used for normal and off-normal conditions in Section C.7.7.2. The sole purpose of their modeling is to ensure appropriate transition of loads from the skid supports to the cask body.

C.7.7.1.6 Bolts

Evaluations of the MP197HB cask Top Cover Plate bolts and RAM Closure Plate bolts documented in [C.7-1] remain applicable for the MP197HB cask functioning as the on-site transfer cask at the WCS CISF. Top Cover Plate bolt evaluations are documented in [C.7-1], Section A.2.13.2.2. RAM Closure Plate bolt evaluations are documented in [C.7-1], Section A.2.13.2.9. Bolt stresses meet the acceptance criteria of [C.7-17].

The evaluations of the MP197HB cask trunnion bolts documented in [C.7-1] Section A.2.13.5.2 remain applicable for the MP197HB cask functioning as the on-site transfer cask at the WCS CISF. The bolts have been qualified for a minimum factor of safety of three against yield stress or five against ultimate stress (whichever is the most restrictive) for 290 kips lifting load and the thermal load assessed for the operating temperature of 300 °F.

C.7.7.1.7 Neutron Shield

The evaluations of the structural integrity for the MP197HB cask Neutron Shield shell documented in [C.7-1] Appendix A.2.13.4 remain applicable for the MP197HB cask on-site operations at the WCS CISF.

The neutron Shield shell is designed to meet the requirements of ASME Code, Section III, Subsection NF documented in [C.7-1], Appendix A.2.13.4 and Table A.12.13.4-1 for 25g side drop and 25g end drop Normal Condition design loads. These loads are bounding for the MP197HB cask on-site operations at the WCS CISF. Therefore, the Neutron Shield shell is structurally adequate for the MP197HB cask on-site operation at the WCS CISF.

C.7.7.1.8 Welds

Per [C.7-1], Section A.1.4.10.1, the MP197HB cask shell closure welds are full penetration groove welds with a weld material qualified by NDE per ASME Code, Subsection NB requirements. Since the base metal at weld locations satisfies the stress criteria imposed by Table C.7-2, the cask shell closure welds are structurally adequate for the MP197HB cask operations at the WCS CISF.

The neutron shield welds are designed to meet the requirements of ASME code Section III, Subsection NF documented in [C.7-1], Appendix A.2.13.4 and Table A.12.13.4-1 for 25g side drop and 25g end drop Normal Condition design loads. These loads are bounding for the MP197HB cask operations projected for the WCS CISF. Therefore, the Neutron Shield welds are structurally adequate for the MP197HB cask operation projected for the WCS CISF.

The grove welds connecting the trunnion attachment blocks and the Outer Shell component of the cask are evaluated in [C.7-1], Section A.2.13.5.2. These evaluations constitute the design basis for these welds for the MP197HB cask operations projected for the WCS CISF. The welds have been qualified for a minimum factor of safety of three against yield stress or five against ultimate stress (whichever is the most restrictive) for 290 kip lifting load.

C.7.7.1.9 Structural Design Criteria

In order to meet the requirements of on-site transfer operations at the WCS CISF the MP197HB cask is designed to meet the requirements of 10CFR72 for normal, off-normal and accident conditions.

The MP197HB cask structure is designed to meet the requirements of ASME Code, Section III, Subsection NC, [C.7-16], stress limits for normal and off-normal condition loads and ASME Code, Section III, Appendix F stress limits for accident conditions, [C.7-8]. Specific criteria used in the evaluations are summarized in Table C.7-2.

The reporting method for MP197HB cask body stresses for Normal and Off-Normal Conditions is described in Section C.7.7.2.4. The reporting method for MP197HB cask body stresses for Accident conditions is described in Section C.7.7.3.4.

C.7.7.2 Normal and Off-Normal Conditions

C.7.7.2.1 Loads

The applicable loads for normal and off-normal conditions are presented in Table C.7-1. Normal condition loads are classified as ASME Code Service Level A events. Off-normal condition loads are classified as ASME Code Service Level B events.

Detailed specifications of mechanical load components and a list of analyzed cases are presented in Table C.7-3 and Table C.7-4. Evaluations also account for the presence of additional stresses in the upper part of the MP197HB cask created by the bolt preload. This assessment takes advantage of [C.7-1] evaluations of the MP197HB cask lid bolt preload. The HSM Loading/canister transfer loads present in Table C.7-1 are bounded by Transfer-Handling loads.

Two cases for thermal loads were selected as bounding and analyzed in thermal stress evaluations of the MP197HB cask:

1. Temperature load distributions for canister payload with heat load 18.3 kW.

2. Temperature load distributions for canister payload with heat load 22.0 kW.

Temperature distributions from thermal runs were mapped to the structural model to evaluate thermal stresses. The comparison of stresses for the two cases listed above is presented in Table C.7-5. Temperature distributions for the bounding case (22 kW heat load) are presented in Figure C.7-7 (thermal model) and Figure C.7-8 (structural model).

The lifting load case (case LFT3G) considers the MP197HB cask lifted by slings attached to a lifting beam of the crane. The lifted arrangement uses Twin-Path SLINGMAX brand slings made of high strength synthetic material. Each sling wraps up around the bottom part of the horizontal MP197HB cask, forming a 60° basket hitch type support and connects at its top end to the lifting beam by means of shackles.

C.7.7.2.2 Finite Element Analysis Models

Evaluations use the ANSYS model MOD20TI developed for the MP197HB cask transportation evaluations for normal conditions of transport, discussed in detail in [C.7-1], Appendix A.2.13.1.2 B. The ANSYS model is modified to match the boundary conditions and loads associated with on-site transfer operations at the WCS CISF. The ANSYS model mesh, its refinement and element types are the same as in the original evaluations [C.7-1]. The MP197HB cask components are modeled by means of ANSYS SOLID45 elements. The mesh is illustrated in Figure C.7-2 through Figure C.7-4. The boundary conditions are described in Section C.7.7.2.3.

The original model, a 180° representation of the MP197HB cask, has been expanded to represent the whole body of the cask design. The MP197HB cask support elements present in the cask transportation configuration have been deleted from the model. The revised model (WCSTI) has added representation of the upper and the lower trunnions and trunnion attachment blocks, and the neutron shield shell assembly. The FEA model also includes simplified skid trunnion tower representations and their interfaces with the trunnions. For the lifting load evaluations (case LFT3G) the model includes sling representations and their interfaces with the cask body.

The trunnion and trunnion attachment blocks stresses are not analyzed. They are included in the model solely to simulate the distribution of reaction forces from the skid trunnion towers to the analyzed cask body components. Structural qualification of the trunnions, trunnion bolting, trunnion attachment blocks, and attachment welds are provided in Sections C.7.7.1.5, C.7.7.1.6, and C.7.7.1.8. The trunnions and trunnion attachment blocks are joined with the cask body by using the permanent bonding feature of the ANSYS contact elements.

For the lifting load (case LFT3G), the slings are modeled using LINK180 elements, set as uniaxial (tension only) cable elements assembled into bands in a fabric like design with the longitudinal threads of the fabric bands resisting the cask loads and the transverse threads keeping their longitudinal parts together. The modeled width of the band is marginally less than the lower bound of the actual sling width. Contact interfaces between the MP197HB cask and the slings are modeled by means of node-to-node contact elements CONTA178. The contact elements are set to have no friction. The illustration of the model is presented in Figure C.7-6.

The material models and mesh originally used in the MOD20TI ANSYS database ([C.7-1] Appendix A.2.13.1.2) are unchanged. Steel materials are modeled by means of linear, elastic stress-strain relation. Lead material is represented by the bilinear kinematic hardening material model (TB, BKIN), with 1% tangent modulus.

C.7.7.2.3 Boundary Conditions

In transfer-handling operations the MP197HB cask is supported by means of the trunnions. The transfer skid supports for the trunnions are modeled as boundary solid entities in the form of semi-cylinder rings with the inner surface of the cylinder representing the curvature of the skid tower at the trunnion location and with the outer surface of the cylinder constrained. The boundary element configuration for the lower trunnion is illustrated in Figure C.7-5.

Contact interfaces between the boundary elements and the trunnions are modeled by means of surface contact elements CONTA173 and TARGE170.

For the lifting load (case LFT3G), two sling bands embrace the bottom part of the Outer Shell component of the MP197HB cask at the cask bottom and top. The bands are fixed in all directions at their projected connection with lifting beam. Rotational and translational stabilization of cask body is achieved by applying minimal constraint of translation degrees of freedom of three nodes of the cask body. The illustration of the model and boundary conditions is presented in Figure C.7-6.

C.7.7.2.4 Stress Analysis Methodology

The individual mechanical load cases analyzed are listed Table C.7-3. The thermal load cases analyzed are listed in Table C.7-5. Component stresses due to Top Cover Plate Bolt preload are taken from [C.7-1], Table A.2.13.1-1.

For purposes of reporting stress results, the cask body is divided into the following seven components: Outer Shell, Inner Shell, Top Cover Plate (Lid), Top Flange, Bottom Flange, Bottom Plate, and Ram Closure Plate. For each component, the stresses are categorized according to the rules of the ASME Code, Section III, Subsection NC for Class 2 components, [C.7-16].

The methods of extraction and interpretation of stress results from the ANSYS model (e.g. stress classification path selection, stress component qualification, and stress linearization method) are the same as described in [C.7-1], Appendix A.2.13.1.10, for elastic analysis methodology.

For the elastic analysis methodology, stress path evaluation in ANSYS brings the information about average stress intensity across the path, P_M, as well as maximum linearized stress at classification path surface, P_L+P_B. Conservatively no distinction is made between paths located at gross or local discontinuities and areas remote from these discontinuities and all path averaged stresses (including general primary stress intensities, P_M, and local primary stress intensities, P_L) are classified and reported as the P_M stresses and assessed against P_M stress allowable.

Also, in order to simplify P_M+P_B stress assessment, all membrane plus bending stresses reported from ANSYS model paths are classified as primary membrane and bending stresses, P_M+P_B, and assessed against P_M+P_B stress allowables.

Stress envelopes have been created for each separate load category: lifting, transfer handling, and thermal as described in Table C.7-6. Thermal load stresses from Table C.7-5 have been added to the primary stresses $P_M/P_L + P_B$ to obtain P+Q stresses. Results are summarized in Table C.7-7 and Table C.7-8.

C.7.7.2.5 Summary of Results

Load specifications for seven mechanical load cases are identified in Table C.7-3 and Table C.7-4. Thermal loads and thermal stress results are provided in Table C.7-5. The maximum stress intensity and the deformation plots for the load cases TR3 and LFT3G are shown in Figure C.7-9 through Figure C.7-12 as sample cases.

All load cases are grouped into load categories as shown in Table C.7-6 and stress envelopes are generated for each load category. The description of the method used to generate the stress envelopes and specification of analysis cases included in the envelopes is provided in Table C.7-6.

Resultant stresses are provided in Table C.7-7 and Table C.7-8. These tables show the general primary membrane stresses, P_M, primary membrane plus bending stresses, $P_M + P_B$, and primary plus secondary stresses, P + Q. The stress ratios listed in the table are the calculated stresses divided by the allowable stresses. All of the analyzed load cases meet the applicable ASME Code stress criteria.

C.7.7.3 Accident Conditions

C.7.7.3.1 Loads

Structural integrity of the MP197HB cask for accident conditions is established by addressing the following events:

a. Horizontal side drop from a height of 80 inches (via 75g static evaluation of horizontal drop).

b. Vertical end drops onto top or bottom of the cask with a deceleration of 75g. These end drops are not postulated or credible events for the on-site transfer operations in the WCS CISF since the cask remains in the horizontal position during all anticipated operations at the facility. However, 75g vertical end drop analyses are conducted (in conjunction with the 75g horizontal drop) to obtain the stress envelope for the postulated 25g corner drop.

c. An oblique corner drop from a height of 80 inches onto the top or bottom corner of the cask, occurring at an angle of 30° to the horizontal. This case is not specifically evaluated since the side drop and the end drop evaluations are deemed to bound the consequences of the corner drop.

The 75g cask decelerations have been approved as a conservative basis for the accident drop evaluations of site-specific (MP187 cask) and general license (OS197 and OS200) transfer casks to verify the structural integrity of NUHOMS® system casks ([C.7-12] and [C.7-13]).

The key design parameters for the MP197HB cask, OS197 transfer cask and MP187 cask are compared in Table C.7-9. The comparison includes the outer shell length, diameter and thickness, cask length, cask weight and cask cavity length, and other crucial design parameters. The comparison of the NUHOMS® System casks confirms the similarity of the cask designs and components. It is also noted that the MP197HB cask is heavier than MP187 cask and OS197 transfer casks. Based on the similarity of the cask designs, the 75g inertia acceleration criteria are considered to be bounding for the accident drop stress evaluations for the MP197HB cask design.

C.7.7.3.2 Finite Element Analysis Models

The accident conditions are evaluated using a 3D half-symmetry model for side drop evaluations and a 2D axis-symmetric model for end drop evaluations. The models are taken from [C.7-1] and adapted to match the boundary conditions and load specifications for the on-site drop evaluations. The FEA model mesh, its refinement and ANSYS element types are the same as in the original evaluations. The MP197HB cask components are modeled by means of ANSYS SOLID45 elements in 3D models and PLANE42 elements in the 2D model. The schematic of the 3D half-symmetry cask model is presented in Figure C.7-1. The mesh of the 3D half-symmetry model is illustrated in Figure C.7-2.

The source ANSYS model for the 3D half-symmetry analyses is the model MOD20 described in [C.7-1], Appendix A.2.13.1.2.

Steel material is modeled by means of the bilinear kinematic hardening method (TB, BKIN). The initial slope of the curve is taken as the elastic modulus of the material. At the specified yield stress, the curve continues along the second slope defined by the tangent modulus. The tangent modulus is taken as 5% of the elastic modulus.

The lead is modeled using the ANSYS multi-linear kinematic hardening material model (TB, KINH). The slope of the first segment of the curve corresponds to the elastic modulus of the material and no segment slope is larger than the slope of the first segment. The slope of the stress-strain curve is assumed to be zero beyond the last user-defined stress-strain data point. The material properties are the same as those used in [C.7-1] Appendix A.2.13.1.2.

For the side drop, the canister inertial load onto the cask inner shell is modeled using the cosine varying pressure as described in Section C.7.7.1.4 and shown in Figure C.7-14. For the end drops, the canister load is applied as a uniform pressure on the top or bottom plates, as shown in Figure C.7-17 and Figure C.7-18.

C.7.7.3.3 Boundary Conditions

For the side drop, the cask is assumed to be supported over a 30° arc (15° in the ANSYS half-model of the cask). The constraints apply only to the radial direction along the arc. In addition, symmetry boundary conditions are applied on the cut plane of the half-symmetric model and minimum boundary conditions are applied in the axial direction to avoid rigid body motion. Boundary conditions for the side drop analysis are illustrated in Figure C.7-13.

For the end drop, interaction between the cask and the ground is modeled by means of contact elements. The outside nodes (representing the ground) of the node-node contact elements are fixed in all degrees of freedom. In addition, symmetry boundary conditions are applied in the radial direction at the symmetry axis line of the 2D model. Boundary conditions for the top and bottom end drop analyses are illustrated Figure C.7-17 and Figure C.7-18, respectively.

C.7.7.3.4 Stress Analysis Methodology

For purposes of reporting stress results, the cask body is divided into the following seven components: Outer Shell, Inner Shell, Top Cover Plate (Lid), Top Flange, Bottom Flange, Bottom Plate, and Ram (Access) Closure Plate. For each component, the stresses are categorized according to the rules of the ASME Code Section III, Appendix F, [C.7-8].

The methods of extraction and interpretation of stress results from the ANSYS model (e.g. stress classification path selection, stress component qualification, and stress linearization method) remain the same as described in [C.7-1], Appendix A.2.13.1.10, for plastic analysis methodology.

For the plastic analysis methodology, stress path evaluation in ANSYS brings the information about average stress intensity across the path, P_M, as well as maximum stress intensity at the path surface, labeled as $P_M + P_B$. Conservatively no distinction is made between paths located at gross or local discontinuities and areas remote from these discontinuities and all path averaged stresses (including general primary stress intensities, P_M, and local primary stress intensities, P_L) are classified and reported as P_M stresses and assessed against the P_M stress allowable.

Table C.7-10 lists the maximum values of reported results for the side drop load, while Table C.7-11 lists the maximum values of reported results for both the top and bottom end drop load.

The extent of lead slump in the MP197HB cask is assessed only for the vertical end drop scenario. The side drop induces only negligible amounts of slump in the lead shielding.

C.7.7.3.5 Summary of Results

The maximum stress intensity and the deformation plots for the 75g side drop are shown in Figure C.7-15 and Figure C.7-16, respectively. As shown in Table C.7-10 all stresses are within allowable limits for the side drop load.

The maximum stress intensity for the 75g top and bottom end drop are shown in Figure C.7-19 and Figure C.7-20, respectively. As shown in Table C.7-11 all stresses are within allowable limits for both the top and bottom end drop load.

The buckling analysis reveals commencement of buckling for the inner shell at 230g loads for both the bottom and top end drops. The buckling load for the MP197HB cask is well above the ASME Code required 3/2×75g = 112.5g load. An illustration of the top end drop buckling deformation and radial displacement curve at the buckling location is presented in Figure C.7-21.

At 75g there is a lead slump of 0.545 inches and 0.543 inches for the bottom and top end drops, respectively.

C.7.7.4 MP197HB Cask Stability and Missile Penetration Analyses

The MP197HB cask loaded with the 61BT or 61BTH DSCs is evaluated in this section for the effects of design basis tornado (DBT) wind pressure, tornado-generated missile impact, and seismic loads.

C.7.7.4.1 Assumptions

1. The gust factor, G, value for wind loading of 0.85 is taken from Section 6.5.8.1 of ASCE 7-05 standard [C.7-3].

2. The calculations use a weight of the MP197HB cask with transfer skid and transfer vehicle of Wc = 245 kips. Per Table C.7-14, the minimum weight of the loaded cask for the analyzed configurations is 223.97 kips. For Standardized NUHOMS® Systems, the weight for the transfer vehicle is 20 kips, and for the transfer skid is 6 kips. Therefore, the total weight of the cask with transfer vehicle and skid is expected to be at minimum 223.97+20+6 = 249.97 kips.

3. The following dimensional requirements are considered for the transfer vehicle and transfer skid designs: the maximum length, width and height of the transfer vehicle are 240 inches, 11 feet and 43 inches, respectively. The maximum length and height of the transfer skid are 208 inches, and 17 inches, respectively (refer to Figure C.7-22). These dimensions are representative dimensions for NUHOMS® Systems' transfer equipment.

C.7.7.4.2 Material Properties

Material properties of the cask outer shell, top cover plate, and ram access cover plate at 400 °F are taken from [C.7-1]. The properties for analyzed components are summarized in Table C.7-15.

C.7.7.4.3 Design Criteria

For stability analyses, the permissible angle of rotation is considered to be equal to one third of the critical angle of rotation – i.e. the angle of tilt at which the center of gravity of the stack-up configuration is directly over the stack-up configuration's edge (tip-over angle).

Stress allowables are based on ASME Code, Section III, Division 1, Appendix F, [C.7-8].

For missile penetration analyses, the required material thickness is calculated using Nelms' formula from [C.7-6] and the Ballistic Research Laboratory methodology contained in [C.7-7].

C.7.7.4.4 Methodology

The following analyses are performed for the cask and components using hand calculations:

- stability analysis
- stress analysis
- penetration analysis

Methodology assumptions used in the evaluations are discussed below:

Stability Analysis Methodology

The stability evaluation for the overturning force caused by the DBT wind pressure is performed in Section C.7.7.4.6.1 by comparing the overturning moment acting on the cask-skid-and-transfer vehicle configuration (presented in Figure C.7-22) with the restoring moment of the assembly due to its self-weight. The analyses consider the lightest weights of the Cask/canister configurations since they produce the smallest restoring moment.

The stability evaluation for the effects of seismic ground motion is performed in Section C.7.7.4.6.2 by comparing the overturning moment acting on the cask-skid-transfer vehicle configuration with the restoring moment of the assembly due its selfweight. The seismic loads are conservatively assumed to act as constant (static) loads and the vertical acceleration is considered to act concurrently with the horizontal acceleration.

The stability evaluation for the tornado missile impact is conducted in Section C.7.7.4.6.3 using the equations of conservation of energy and conservation of angular momentum.

The stability evaluation for the combined tornado wind and missile load is performed in Section C.7.7.4.6.4 using the approximate force time-history of the missile impact from [C.7-7] and the standard equations of motion.

In the DBT wind effect evaluations, it is assumed that the combined geometry of the cask/skid/transfer vehicle system has a solid vertical projected area. The reduction in total wind pressure due to the open areas and shape factor is conservatively ignored.

Case B of Table C.7-13 (the massive high kinetic energy missile) is used for overturning stability of the cask since it produces the maximum force and the highest overturning moment. Conservatively, the impact is assumed as perfectly inelastic.

The tornado loads are generated for three separate loading phenomena. These phenomena are considered individually and then are considered in combination in accordance with Section 3.3.2 of NUREG-0800 [C.7-4] as follows:

1. Pressure or suction forces created by drag as air impinges and flows past the casks with a maximum tornado wind speed of 200 mph
2. Suction forces due to a tornado generated pressure drop or differential pressure load of 0.9 psi
3. Impact forces created by tornado-generated missiles impinging on the casks

Per [C.7-4], the total tornado load on a structure needs to be combined in accordance with formula:

$$W_t = W_w + 0.5W_p + W_m$$

where,

W_t = Total tornado load

W_w = Load from tornado wind effect

W_p = Load from tornado atmospheric pressure change

W_m = Load from tornado missile impact effect

Load from tornado atmospheric pressure change effect, W_p, in the above formula is ignored since temporary differential pressure load does not cause unbalanced loads on the symmetric design of the cask leading to overturning of the cask.

Stress Analysis Methodology

The stresses in the Cask Shell, Top Cover Plate (Lid) and Ram Closure Plate components due to DBT wind load and DBT missile load are calculated using the applicable analytic formulas for thin walled cylindrical vessels and flat circular plates, documented in [C.7-5].

The stresses evaluated in the analyzed components are:

- Primary Membrane Stress (P_M)
- Primary Membrane plus Bending Stress ($P_M + P_B$)

Stress allowables are based on the ASME Code, Section III, Division 1, Appendix F, [C.7-8].

The loads are specified in Sections C.7.7.4.5.1 and C.7.7.4.5.2 and are summarized in Table C.7-12 and Table C.7-13. Specific formulas used in the stress evaluations are presented in Section C.7.7.4.7.

Penetration Analysis Methodology

The critical thickness of plates that results in penetration by missile load is calculated by using Nelms' formula from [C.7-6] and the Ballistic Research Laboratory formula from [C.7-7]. These magnitudes are compared with the thickness of the Cask Shell, Top Cover Plate and Ram Closure Plate.

For this evaluation, the Case A missile (6" NPS Schedule 40 pipe, 15 ft. long) from Table C.7-13 is used. Missile Case B is judged less severe for penetration effects due to the large area of impact. Case C is judged less severe for penetration effects due to the much lower kinetic energy. The calculation evaluates missile impacts in the normal direction to the cask shell or plate to maximize penetration effect.

C.7.7.4.5 Design Input Loads & Data

C.7.7.4.5.1 DBT Velocity Pressure Load

The cask is evaluated for stress and overturning due to the Design Basis Tornado (DBT) loads specified in Table C.7-12. The DBT load characteristics correspond to those in Regulatory Guide 1.76 Region II parameters from [C.7-2] and ASCE 7-05 standard [C.7-3]. The MP197HB cask dimensions and weight data are based on the design described in [C.7-1]. Load specifications are consistent with requirements of Section 3.3.2 of NUREG-0800 [C.7-4].

Per Table C.7-12 and per Section 6.5.10 of [C.7-3] (for the MP197HB cask/skid/transfer vehicle assembly dimensions), the maximum velocity pressure load q_z at the height of the centroid of the analyzed assembly is

$$q_z = 0.00256\ K_z\ K_{dt}\ K_d\ I(v)^2$$
$$= 0.00256 \times 0.87 \times 1.0 \times 1.0 \times 1.15 \times 200^2 = 102.45\ \text{lb/ft}^2$$

Per Section 6.5.15 of [C.7-3], the design wind force, F, is calculated as:

$$F = q_z G C_f A_f = 102.45 \times 0.85 \times 0.82 \times 240 = 17.14\ kips.$$

In the above equation, the gust factor G=0.85 (per assumption 1 of Section C.7.7.4.1), the force coefficient C_f=0.82 (for cask-skid-transfer vehicle configuration dimensions), and the projected area normal to the wind for the analyzed assembly, A_f=240 ft$^{2.}$ (for cask/skid and transfer vehicle dimensions).

C.7.7.4.5.2 DBT Generated Missile Impact Forces

The tornado-generated missile impact evaluation is performed for the missiles specified in Table C.7-13.

<u>Automobile Missile (Table C.7-13 – Case B)</u>

The impact force acting on the cask due to this missile is based on the Bechtel topical report ([C.7-7] equation D-6):

$$F = 0.625 \times V_i \times W_m \times \sin(20t) = 0.625 \times 134.81 \times 4000 \times \sin(20 \times 0.0785) \approx 340 kip$$

In above equation:

t = time from the instant of initial impact (sec) = 0.0785 sec for maximum impact force to occur, [C.7-7]

V_i = total striking velocity of the missile = $\sqrt{112^2 + (0.67 \times 112)^2} = 134.81$ fps (Table C.7-13)

W_m = weight of missile =4000 lb. (Table C.7-13)

Schedule 40 Pipe Missile (Table C.7-13 – Case A)

The impact force is calculated using the principle of conservation of momentum and the relation $F\Delta T = G_f - G_i$:

$$F = \frac{M_m(V_i - V_f)}{(T_f - T_i)} = \frac{M_m(V_i - V_f)}{(\Delta T)} = \frac{287 \times (134.81 - 0)}{32.2 \times 0.05 \times 1000} = 24.03\ kips$$

where:

ΔT = the time of contact
= 0.05 sec (conservatively shorter than impact time 0.075 sec from [C.7-7])

G_f $= M_m V_f = 0$ the linear momentum after impact at time $T = T_f$

G_i = $M_m V_i$ the linear momentum at time $T = T_i$

V_i = total striking velocity of the missile = $\sqrt{112^2 + (0.67 \times 112)^2} = 134.81$ fps (Table C.7-13)

M_m = the mass of the missile

C.7.7.4.6 Tornado & *Missile Impact* Loads Analysis - Stability Evaluations

C.7.7.4.6.1 Cask Stability for Design Basis Tornado Wind Pressure Load

The restoring moment will be the smallest for the assembly with minimum weight. Conservatively, the total weight of the loaded cask and transfer vehicle and skid - W_c is taken as 245 kips (refer Section C.7.7.4.1, Assumption 2). The restoring moment, M_{st} = (Total Weight) × (Half Width of the transfer vehicle) = 245 × 5.5 = 1,347.5 kips-ft.

The maximum overturning moment (M_{ot}) for the cask/skid/transfer vehicle due to DBT wind pressure is calculated by taking windward force and leeward force into account. Conservatively, it is assumed that the wind load in windward side and leeward side is same and is equal to the design wind load, F = 17.14 kips (calculated in Section C.7.7.4.5.1)

Per Figure C.7-22, the height corresponding to the centerline of the MP197HB cask is taken as the point of load application: H=43+17+84.5/2 = 102.25 inches = 8.52 ft.

Therefore, the overturning moment, M_{ot} = 2×F×H = 2× 17.14 x (8.52) = 292.1 kips-ft

Factor of safety against overturning

$$\frac{M_{st}}{M_{ot}} = \frac{1347.5}{292.1} = 4.61$$

C.7.7.4.6.2 Cask Stability for Massive Missile Impact Load

A stability analysis is performed to analyze the most critical impact, when the missile hits the cask on the side. However, it is conservatively assumed that the missile hits the top most point of the cask as shown in Figure C.7-23.

The Case B missile from Table C.7-13, i.e. the massive high kinetic energy automobile missile, is used since it produces the maximum force and the highest overturning moment. Conservatively, the impact is assumed as perfectly inelastic

Using the geometrical relations of Figure C.7-23 and the missile characteristics from Table C.7-13, the evaluation is based on conservation of momentum at impact and the conservation of energy to estimate the angle of rotation θ due to the impact (cask stops rotating when the angular velocity after impact becomes zero).

The resultant formula for angle of rotation due to impact θ for the analyzed geometry has the following form:

$$\sin(\phi + \theta) = \frac{(R_1 V_i M_m)^2}{2W_c R_2[(I_c)_o + R_1^2 M_m]} + \sin\phi$$

with:

$$\phi = \tan^{-1}(L_1/R) = \tan^{-1}\left(\frac{43+17+84.5/2}{5.5\times12}\right) = 57.16°$$

(refer to Figure C.7-22 and Figure C.7-23),

$(H_i)_o$ = the angular momentum about point O before impact $= R_1 V_i M_m$ (Figure C.7-23),

$(H_a)_o$ = the angular momentum about point O after impact $= R_1^2 \omega_i M_m + (I_c)_o \omega_i$ (Figure C.7-23),

R_1 $= \sqrt{L^2 + R^2} = \sqrt{12.04^2 + 5.5^2} = 13.24\ ft$ is the distance from point O to the impact point (Figure C.7-23),

R_2 $= \sqrt{L_1^2 + R^2} = \sqrt{8.52^2 + 5.5^2} = 10.14\ ft$ is the distance from point O to the center of the cask. (Figure C.7-23),

V_i = total striking velocity of the missile = $\sqrt{112^2 + (0.67 \times 112)^2} = 134.81$ fps (Table C.7-13),

M_m = the mass of the missile (4000/32.2 = 124.22 lbm, per Table C.7-13),

W_c = the minimum weight of the cask assembly (245 kips),

$(I_c)_o$ = the mass moment of inertia of the cask about an axis through point O,

$(I_c)_o = (I_c)_{CG} + M_c R_2^2$ (from the parallel axis theorem),

M_c = the mass of the cask assembly in (245×1000)/32.2=7608.70 lbm),

$(I_c)_{CG}$ = the mass moment of inertia of the cask about center of gravity of MP197HB cask.

Conservatively, $(I_c)_{CG} = \dfrac{M_c R_c^2}{2} = \dfrac{7{,}608.70 \times 3.52^2}{2} = 47{,}137.42\ ft^2 lbm$

Ultimately, angle of rotation due to impact can be determined as:

$$\theta = sin^{-1}(0.8518) - \emptyset = 58.41° - 57.16° = 1.25°$$

Tip over occurs when the C.G. is directly above the point of rotation, therefore the tip over angle, θ_{tip}, is $\theta_{tip} = 90.0° - 57.16° = 32.84°$, and $1/3\,\theta_{tip} = 1/3 \times 32.84° = 10.95°$. Since $\theta < 1/3 \times \theta_{tip}$, the tip over of the cask will not occur.

C.7.7.4.6.3 Cask Stability for Design Basis Tornado Wind and Missile Load Combination

A time-dependent analysis is performed to determine the maximum angle of rotation attained by the cask/skid/transfer vehicle assembly due to concurrent DBT wind and missile loading. The input loading is the summation of the wind pressure loading from Section C.7.7.4.1 and the massive missile impact force from Section C.7.7.4.2. The standard equations of rotational motion are solved with an approximate step-wise linear procedure to determine the rotational motion of the assembly subjected to the combined wind and missile loading.

The overturning moment causing rotational acceleration is:

$$M_{acc} = M_{ot} - M_{st}$$

The angular velocity is:

$$\omega_i = \frac{\left[\frac{M_{acc,i} + M_{acc,i-1}}{2} * (t_i - t_{i-1}) \right]}{(I_c)_o} + \omega_{i-1}$$

The angle of rotation is:

$$\theta_i = \left[\frac{\omega_i + \omega_{i-1}}{2} * (t_i - t_{i-1}) \right] + \theta_{i-1}$$

where,

i = index for the current time step

$i-1$ = index for the previous time step

In the above equations the overturning moment and stabilization moments are, respectively:

$$M_{ot} = F_{\text{missile}} * \text{L} + \text{q}_\text{z} * L_\theta^2 * \text{L}_\text{T}$$

$$M_{st} = W_c * R_2 * \cos(\emptyset + \theta)$$

where:

L_θ = height to the top of cask system which is dependent on rotation angle θ,

L = 43+17+84.5=144.5 inch, initial total height of the cask system (Figure C.7-22),

L_T = 240 inch, length of transfer vehicle (Section C.7.7.4.1)

$F_{missile}$ = $0.625 V_\text{i} W_m sin(20t)$, missile force, refer to Section C.7.7.4.5.2, per Ref. [C.7-7], equation D-6

W_c = 245 kips, is the minimum weight of the cask assembly (Section C.7.7.4.1),

R_2 = 10.14 ft, is the distance from point O to the center of the cask. (Figure C.7-23).

The solution to the equation of motion is documented in Figure C.7-24. The governing angle of rotation is $\theta = 3.7°$.

As indicated in Section C.7.7.4.6.3, the tip over angle $\theta_{tip} = 32.84°$ and $1/3 \times \theta_{tip} = 10.95°$. Since $\theta < 1/3 \times \theta_{tip}$, the tip over of the cask will not occur.

C.7.7.4.7 Tornado Wind and Missile Analysis - Stress Evaluations

Stress evaluations for cask components exposed to tornado loads are discussed below. The evaluations consider the cask as a thin walled vessel and the cover plates as simply supported thin circular plates, and use stress formulas from [C.7-5] appropriate for the analyzed load characteristics. Specifications of the stress formulas and basic assumptions employed in the analyses are summarized below. Stress results are listed in Table C.7-16 and Table C.7-17.

<table>
<tr><th colspan="3">Stress Formulas Used in Tornado Loads Evaluations</th></tr>
<tr><th>Load Description</th><th>Component Analyzed</th><th>Stress Formula Reference & Assumptions</th></tr>
<tr><td rowspan="3">Wind Pressure Load</td><td>Outer Shell</td><td>[C.7-5], case 8c from Table 13.3, page 650; Simply supported thin cylindrical shell, subjected to a uniform pressure load over the entire length</td></tr>
<tr><td>Top Cover Plate</td><td>[C.7-5], case 10a from Table 11.2, page 509; Simply supported thin circular plate, subjected to a uniform pressure load over the entire area</td></tr>
<tr><td>RAM Closure Plate</td><td>[C.7-5], case 10a from Table 11.2, page 509; Simply supported thin circular plate, subjected to a uniform pressure load over the entire area</td></tr>
<tr><td rowspan="3">Massive Missile Load</td><td>Outer Shell</td><td>[C.7-5], case 8b from Table 13.3, page 650; Simply supported thin cylindrical shell, subjected to a concentrated load over the short length</td></tr>
<tr><td>Top Cover Plate</td><td>[C.7-5], case 10a from Table 11.2, page 509; Simply supported thin circular plate, subjected to a uniform load over the entire area</td></tr>
<tr><td>RAM Closure Plate</td><td>[C.7-5], case 10a from Table 11.2, page 509; Simply supported thin circular plate, subjected to a uniform load over the entire area</td></tr>
<tr><td rowspan="3">Local Load</td><td>Outer Shell</td><td>[C.7-5], case 8a from Table 13.3, page 649; Simply supported thin cylindrical shell, subjected to load P distributed over a small area at midspan</td></tr>
<tr><td>Top Cover Plate</td><td>[C.7-5], case 16 from Table 11.2, page 514; Simply supported thin circular plate, subjected to a load over the small central area</td></tr>
<tr><td>RAM Closure Plate</td><td>[C.7-5], case 16 from Table 11.2, page 514; Simply supported thin circular plate, subjected to a load over the small central area</td></tr>
</table>

C.7.7.4.8 Tornado Missile Analysis - Penetration Evaluations

C.7.7.4.8.1 Nelms' Formula Evaluation

Nelms' formula ([C.7-6]) is used to determine the thickness value due to incipient puncture energy, which is directly proportional to the mass and velocity of the missile and inversely proportional to the diameter of the missile.

$$E_F = \frac{1}{2} M_m V_m^{\ 2}$$

$$E_F / S = 2.4 d^{1.6} t^{1.4}$$

where:

M_m = the mass of the missile (287 lbs)/(32.2 ft/sec^2) = 8.91 lbm),

V_m = the total velocity of the striking missile normal to target surface (=134.81 fps),

S = the ultimate tensile strength of the jacket material (refer Table C.7-15),

t = the maximum thickness of plate material leading to an onset of the plate puncture (inch),

d = the diameter of the punch/missile (6.625 inch, refer Table C.7-13),

E_F = the incipient puncture energy of the prismatic cask jacket (inch - lb).

The threshold thickness values causing perforation for the Outer Shell, Top Cover Plate and RAM Closure Plate according to Nelms' correlation are 0.43 inch, 0.43 inch, and 0.43 inch, respectively.

C.7.7.4.8.2 Ballistic Research Laboratory Formula Evaluation

In the Ballistic Research Laboratory report, the relation for the determination of the thickness is also directly proportional to mass and velocity and inversely proportional to diameter of the missile.

$$t = \frac{\left(\frac{M_m V_m^2}{2}\right)^{2/3}}{672d} = 0.42 \text{ inch}$$

In above relation:

t = the maximum thickness of plate material leading to an onset of plate puncture (inch),

d = the diameter of the punch/missile (= 6.625 inch),

M_m = the mass of the striking missile, (=287/32.2 = 8.91 lbm),

V_m = the velocity of the striking missile normal to target surface (=134.81 fps).

Reference [C.7-7] recommends increasing the thickness, t, by 25 percent to prevent perforation. Therefore, the minimum thickness required to prevent perforation of the MP197HB cask is 0.53 inch.

C.7.7.4.9 Summary of Results

Factor of safety on overturning from DBT tornado load is 4.61, which is greater than the required safety factor of 1.1.

The resultant stresses for the bounding individual DBT, missile impact and combined tornado load are summarized in Table C.7-16 and Table C.7-17, respectively. The primary membrane stress intensity and combined membrane plus bending stresses due to DBT and missile impact are below the allowable stresses.

The minimum thickness of the steel components required to prevent perforation by tornado missiles is found to be 0.53 inch, which is less than the thickness of the MP197HB cask outer shell, Top Cover Plate, and RAM Closure Plate of 2.75 inches, 4.5 inches, and 2.5 inches, respectively.

The maximum rotation angle of the MP197HB cask stack-up configuration due to combined tornado wind plus massive missile impact load is $\theta=3.7°$, which is significantly below the permissible angle of rotation, 10.95°.

C.7.8 Structural Evaluation of 61BT DSC Confinement Boundary under Normal Conditions of Transport

The 61BT DSC shell assembly consists of a cylindrical shell, top outer/inner cover plates, bottom inner/outer cover plates and bottom and top shield plugs. The 61BT DSC consists of a shell, which is a welded, stainless steel cylinder with a stainless steel bottom closure assembly, and a stainless steel top closure assembly. Additional details, geometry and shell and plate thicknesses are provided on the drawings in Section C.4.6. The confinement boundary is addressed in Section C.11.1. The 61BT DSC shell is evaluated for Normal Conditions of Transport in the MP197HB Transport cask in Sections A.2.6.15.2 and A.2.13.7 of [C.7-1]. As described in Section A.2.13.7.1 of [C.7-1], the 61TH DSC is categorized as a Group 2 DSC. The analysis of the Group 2 DSCs (which include the 61BT DSC) are documented Sections A.2.13.7.2 and A.2.13.7.3 of [C.7-1] and the results are reported in Sections A.2.13.7.4.2 A.1 – A.3 of [C.7-1] for Normal Conditions of Transport.

The result of the 61BT DSCs structural analysis is acceptable for the loads and combinations described in Section A.2.13.7.3 of [C.7-1] and hence structurally adequate for normal conditions of transport loading conditions.

C.7.9 References

C.7-1 AREVA TN Document, NUH09.101 Rev. 17. “NUHOMS® -MP197 Transportation Package Safety Analysis Report.” (Basis for NRC CoC 71-9302).

C.7-2 Reg Guide 1.76, “Design-Basis Tornado And Tornado Missiles For Nuclear Power Plants,” Revision 1, March 2007.

C.7-3 American Society of Civil Engineers Standard ASCE 7-05, “Minimum Design Loads for Buildings and Other Structures,” (Formerly ANSI A58.1).

C.7-4 U.S. NRC Document, NUREG-0800, Section 3.3.2, Revision 3, "Tornado Loads," Standard Review Plan (Formerly NUREG-76/087), 2007.

C.7-5 R.G Budynas and W.C Young, “Roark’s Formula for Stress and Strain,” Eighth Edition, McGraw-Hill Book Company.

C.7-6 H.A. Nelms, "Structural Analysis of Shipping Casks, Effects of Jacket Physical Properties and Curvature and Puncture Resistance," Vol. 3, ORNL TM-1312, Oak Ridge National Laboratory, Oak Ridge Tennessee, June 1968.

C.7-7 R.B. Linderman, J.V. Rotz and G.C.K. Yek “Design of Structures for Missile Impact,” Topical Report BC-TOP-9-A, Bechtel Power Corporation, Revision 2, September 1974.

C.7-8 ASME Boiler and Pressure Vessel Code, Section III, Appendix F, 2004 Edition with 2006 Addenda.

C.7-9 U.S. NRC Document, Safety Evaluation Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards, December, 1994, ML053410448.

C.7-10 Sandia National Laboratories Report GEND-INF-091, “Test Data Report for Quarter Scale NUPAC 125-B Rail Cask Model," M. W. Warrant and B. J. Joseph, Sandia National Laboratories, February, 1988.

C.7-11 AREVA TN Document, ANUH-01.0150, Revision 6, “Updated Final Safety Analysis Report for the Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, NRC Docket No. 72-1029.

C.7-12 “Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report,” NRC Docket No. 72-11, Revision 4.

C.7-13 AREVA TN Document NUH-003, Revision 14, “Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel.” (Basis for NRC CoC 72-1004).

C.7-14 ANSYS Computer Code and User’s Manual, Version 14.0.

C.7-15 ASME Boiler and Pressure Vessel Code, Section II, Part D, 2004 Edition with 2006 Addenda.

C.7-16 ASME Boiler and Pressure Vessel Code, Section III, Division1, Subsection NC, 2004 Edition with 2006 Addenda.

C.7-17 US NRC Document NUREG/CR-6007 "Stress Analysis of Closure Bolts for Shipping Casks."

C.7-18 ANSI N14.6-1993 American National Standard for Radioactive Materials – "Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4500 kg) or More," 1993.

C.7-19 Blevins, Robert D. Formulas for Natural Frequency and Mode Shape. 2001.

C.7-20 Regulatory Guide 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," U.S. Nuclear Regulatory Commission, Revision 1, March 2007.

Table C.7-1
Load Combination and Service Levels for MP197HB Cask

Load Case (3)		**Normal Conditions**			**Off-Normal Conditions**		**Accident Conditions**					
Dead Load I Live Load			X			X	X					
Thermal w/canister	0° to 110 °F Ambient	X	X									
	-20° to 120 °F Ambient				X	X						
Cask Lift	2g Vertical + DW			X								
Transfer Handling Loads(1)	± 1g Vertical + DW	X			X							
	± 1g Axial + DW	X			X							
	± 1g Transverse + DW	X			X							
	± 1/2g Axial ±1/2g Transverse ±1/2g Vertical + DW	X			X							
HSM Loading/ Canister Transfer	Normal (110k) Insertion		X			X						
	Normal (80k) Retrieval		X			X						
	"Accident" (110k) Insertion						X					
	"Accident" (110k) Retrieval						X					
Seismic (2)	± *0.36g* Axial ± *0.53g* Transverse ± *0.44g* Vertical + DW							X				
Drop Loads	75g Vertical (End) Drop									X		
	25g (30°) Corner Drop										X	
	75g Side Drop											X
ASME Code Service Level		A	A	A	B	B	C	C	D	D	D	D

Notes:
1. Cases with transfer handling loads are subdivided into four (4) separate cases as follows:
   Subcase a: ± 1g Vertical + DW
   Subcase b: ± 1g Axial + DW
   Subcase c: ± 1g Transverse + DW
   Subcase d: ± 1/2g Axial ± 1/2g Transverse ± 1/2g Vertical + DW
2. Seismic Level C load is bounded by transfer load, Subcase d
3. Normal and Off-Normal Conditions evaluations account additionally for the Top Cover Plate bolt preload load

Table C.7-2
Acceptance Stress Criteria for Steel Components

Item	Stress Type	Service Levels A & B	Service Level C	Service Level D (Elastic Analysis)	Service Level D (Plastic Analysis)
Transfer Cask Structural Shell	Primary Membrane	S_m	1.2 S_m	Smaller of 2.4 S_m or 0.7 S_u	Larger of 0.7 Su or S_y+(S_u-S_y)/3
	Primary Membrane + Bending	1.5 S_m	1.8 S_m	Smaller of 3.6 S_m or S_u	0.9 S_u
	Primary + Secondary	3.0 S_m	N/A	N/A	N/A
	Average Bearing	S_y	N/A	N/A	N/A
	Pure Shear (2)	0.6 S_m	0.72 S_m	0.42 S_u	0.42 S_u
	Compression	N/A	N/A	N/A	2/3 F_a (1)

Notes 1: Components subjected to compressive loads evaluated against buckling limits. Maximum compressive load (or stress) limited to two/thirds of the value of buckling load determined by the comprehensive analysis per ASME Code, Appendix F requirement F-1331.5(a).

2: Average primary shear stress across the section under design loading in pure shear (special stress limit)

Table C.7-3
Mechanical Load Cases – Load Magnitudes

Load Category	Load ID	Dead Weight Lateral X-Direction	Inertia Load Lateral X-Direction	Inertia Load Lateral Y-Direction	Inertia Load Axial Z-Direction	Canister Weight Load Axial Z-Direction	Canister Weight Load Lateral Direction	Temperature Uniform Distribution
Lifting	LFT3G	1.0g	2.0g	-	-	-	361.3 kip	400
Transfer Handling	TR1A	1.0g	-	-	1.0g	118.5 kip	120.4 kip	400
	TR1B	1.0g	-	-	-1.0g	118.5 kip	120.4 kip	400
	TR2	1.0g	1.0g	-	-	-	240.9 kip	400
	TR3	1.0g	-	1.0g	-	-	170.3 kip	400
	MAX0A	1.0g	0.5g	0.5g	0.5g	59.3 kip	190.4 kip	400
	MAX0B	1.0g	0.5g	0.5g	-0.5g	59.3 kip	190.4 kip	400

Note: X, Y, and Z coordinates are illustrated in Figure C.7-3.

Table C.7-4
Mechanical Load Cases – Pressure Load Magnitudes

Load Category	Load ID	Inertia Total Load Lateral Orientation	Inertia Total Load Axial Orientation	Canister Load Lateral Tilt Angle Zero Angle @ Bottom	Canister Weight Load Lateral Direction	Canister Weight Load Axial Z-Direction	Top or Bottom Pressure Axial Z-Direction	Cosine Pressure Peak Lateral Direction
Lifting	LFT3G	3.000g	-	0.0º	361.3 kip	-	-	54.6 psi
Transfer Handling	TR1A	1.000g	1.000g	0.0º	120.4 kip	118.5 kip	37.4 psi	18.2 psi
	TR1B	1.000 g	-1.000g	0.0º	120.4 kip	118.5 kip	33.4 psi	18.2 psi
	TR2	2.000 g	-	0.0º	240.9 kip	-	-	36.4 psi
	TR3	1.414g	-	45.0º	120.4 kip	-	-	25.7 psi
	MAX0A	1.581g	0.500g	18.4º	190.4 kip	59.3 kip	18.7 psi	28.8 psi
	MAX0B	1.581g	- 0.500g	18.4º	190.4 kip	59.3 kip	16.7 psi	28.8 psi

Table C.7-5
Thermal Stress Results – Normal and Off-Normal Conditions

Component	Secondary Membrane plus Bending Stress 'Q' (ksi)		
Name	**61BT DSC (18.3 kW Heat Load)**	**61BTH Type 1 DSC (22 kW Heat Load)**	**Envelope**
Outer Shell	15.169	17.992	17.992
Inner Shell	14.848	17.321	17.321
Top Cover Plate	4.984	5.401	5.401
Top Flange	16.601	19.080	19.080
Bottom Flange	19.191	22.182	22.182
Bottom Plate	8.348	9.421	9.421
Ram Closure Plate	6.418	6.908	6.908

Table C.7-6
Load Envelopes

Load Category	Result Envelope Description
Lifting	Stress envelope consists of maximum component stresses P_M and P_M+P_B for case LFT3G plus Top Cover Plate bolt preload stresses from [C.7-1] Table A.2.13.1-1
Transfer Handling	Stress envelope consists of maximum component stresses P_M and P_M+P_B for cases TR1A ,TR1B, TR2, TR3, MAX0A, MAX0B plus Top Cover Plate bolt preload stresses from [C.7-1] Table A.2.13.1-1
Thermal	Thermal Stress Envelope of Component Maximum Linearized Stress for Normal and Off-Normal Conditions (refer to Table C.7-5)

Table C.7-7
Stress Results Envelope for Transfer Handling Loads

Component	Material Specification	Max Stress (ksi) Stress Ratio			Allowable Stress (ksi)			Material Properties (ksi)		
		P_M	P_M+P_B	P+Q	P_M	P_M+P_B	P+Q	S_y	S_u	S_m
Outer Shell	SA-203 Gr. E	2.3 10.0%	5.6 16.3%	23.6 34.4%	22.9	34.4	68.7	34.2	70	22.9
Inner Shell	SA-203 Gr. E	2.2 9.6%	3.4 9.6%	20.7 30.1%	22.9	34.4	68.7	34.2	70	22.9
Top Cover	SA-350 LF3	6.4 29.9%	15.5 48.3%	20.9 32.6%	21.4	32.1	64.2	32	70	21.4
Top Flange	SA-350 LF3	6.6 30.8%	14.5 45.2%	33.5 52.2%	21.4	32.1	64.2	32	70	21.4
Bottom Flange	SA-350 LF3	1.0 4.7%	2.7 8.4%	24.9 38.8%	21.4	32.1	64.2	32	70	21.4
Bottom Plate	SA-350 LF3	2.3 10.7%	6.3 19.6%	15.7 24.5%	21.4	32.1	64.2	32	70	21.4
Ram Closure Plate	SA-240 Type 304	0.5 2.7%	1.0 3.6%	7.9 14.2%	18.6	27.9	55.8	20.7	64	18.6

Table C.7-8
Stress Results Envelope for Lifting Loads

Component	Material Specification	Max Stress (ksi) Stress Ratio			Allowable Stress (ksi)			Material Properties (ksi)		
		P_M	P_M+P_B	P+Q	P_M	P_M+P_B	P+Q	S_y	S_u	S_m
Outer Shell	SA-203 Gr. E	4.7 20.5%	8.3 24.2%	26.3 38.3%	22.9	34.4	68.7	34.2	70	22.9
Inner Shell	SA-203 Gr. E	7.3 31.9%	9.8 28.5%	27.1 39.4%	22.9	34.4	68.7	34.2	70	22.9
Top Cover	SA-350 LF3	6.4 29.9%	14.5 45.2%	19.9 31.0%	21.4	32.1	64.2	32	70	21.4
Top Flange	SA-350 LF3	11.1 51.9%	19.7 61.4%	38.8 60.4%	21.4	32.1	64.2	32	70	21.4
Bottom Flange	SA-350 LF3	3.4 15.9%	6.2 19.3%	28.4 44.2%	21.4	32.1	64.2	32	70	21.4
Bottom Plate	SA-350 LF3	4.8 22.4%	8.8 27.4%	18.2 28.3%	21.4	32.1	64.2	32	70	21.4
Ram Closure Plate	SA-240 Type 304	0.5 2.7%	1.0 3.6%	7.9 14.2%	18.6	27.9	55.8	20.7	64	18.6

Table C.7-9
MP197HB, MP187 and OS187 Casks – Comparison of Basic Design Parameter

Parameter	MP197HB Cask	MP187 Cask	OS197 Cask
Outer Shell Thickness (*in*)	2.75	2.49	1.50
Inner Shell Thickness *(in)*	1.25	1.25	0.50
Bottom End Closure Thickness *(in)*	6.50	8.00	2.00
Top Lid Thickness (*in*)	4.50	6.50	5.25
Lead Gamma Shield Thickness *(in)*	3.00	4.00	3.56
Cask Body Outer Diameter (*in*)	84.50	83.50	79.12
Cask Cavity Diameter *(in)*	70.50	68.00	68.00
Overall Length of Cask Body (*in*)	210.25	201.50	207.20
Overall Length of Outer Shell *(in)*	190.25	183.50	183.35
Overall Length of Inner Shell *(in)*	185.25	173.75	191.25
Overall Length of Lead *(in)*	194.50	182.44	189.25
Cavity Length (*in*)	199.25	187.00	196.75
Cask Weight (Dry, Empty) (*kips*)	163.31	158.58	111.25
Cask Loaded (Dry, Loaded) (*kips*)	251.70	239.70	204.37

Table C.7-10
Side Drop – Summary of Results

Cask Component	Material Specification	Stress Category	Allowable Stress (ksi)	Maximum Stress (ksi)	Stress Ratio
Outer Shell	SA-203 Gr. E	P_M	49.00	27.60	0.56
		P_M+P_B	63.00	43.82	0.70
Inner Shell	SA-203 Gr. E	P_M	49.00	28.28	0.58
		P_M+P_B	63.00	40.49	0.64
Top Cover Plate	SA-350 LF3	P_M	49.00	33.77	0.69
		P_M+P_B	63.00	36.56	0.58
Top Flange	SA-350 LF3	P_M	49.00	34.08	0.70
		P_M+P_B	63.00	42.64	0.68
Bottom Flange	SA-350 LF3	P_M	49.00	33.06	0.67
		P_M+P_B	63.00	36.97	0.59
Bottom Plate	SA-350 LF3	P_M	49.00	33.18	0.68
		P_M+P_B	63.00	36.44	0.58
Ram Closure Plate	SA-240 Type 304	P_M	44.80	2.82	0.06
		P_M+P_B	57.60	6.63	0.12

Table C.7-11
End Drop – Summary of Results

Cask Component	Material Specification	Stress Category	Allowable Stress (ksi)	Maximum Stress (ksi)	Stress Ratio
Bottom End Drop					
Outer Shell	SA-203 Gr. E	P_M	49.00	12.35	0.25
		P_M+P_B	63.00	13.45	0.21
Inner Shell	SA-203 Gr. E	P_M	49.00	11.24	0.23
		P_M+P_B	63.00	14.96	0.24
Top Cover Plate	SA-350 LF3	P_M	49.00	0.72	0.01
		P_M+P_B	63.00	7.50	0.12
Top Flange	SA-350 LF3	P_M	49.00	2.47	0.05
		P_M+P_B	63.00	3.55	0.06
Bottom Flange	SA-350 LF3	P_M	49.00	11.41	0.23
		P_M+P_B	63.00	14.03	0.22
Bottom Plate	SA-350 LF3	P_M	49.00	9.74	0.20
		P_M+P_B	63.00	16.54	0.26
Ram Closure Plate	SA-240 Type 304	P_M	44.80	0.42	0.01
		P_M+P_B	57.60	2.27	0.04
Top End Drop					
Cask Component	**Material Specification**	**Stress Category**	**Allowable Stress (ksi)**	**Maximum Stress (ksi)**	**Stress Ratio**
Outer Shell	SA-203 Gr. E	P_M	49.00	12.48	0.25
		P_M+P_B	63.00	13.55	0.22
Inner Shell	SA-203 Gr. E	P_M	49.00	11.58	0.24
		P_M+P_B	63.00	16.11	0.26
Top Cover Plate	SA-350 LF3	P_M	49.00	8.04	0.16
		P_M+P_B	63.00	9.77	0.16
Top Flange	SA-350 LF3	P_M	49.00	11.18	0.23
		P_M+P_B	63.00	15.69	0.25
Bottom Flange	SA-350 LF3	P_M	49.00	3.31	0.07
		P_M+P_B	63.00	5.39	0.09
Bottom Plate	SA-350 LF3	P_M	49.00	1.43	0.03
		P_M+P_B	63.00	4.80	0.08
Ram Closure Plate	SA-240 Type 304	P_M	44.80	0.79	0.02
		P_M+P_B	57.60	2.73	0.05

Table C.7-12
DBT Wind Load Characteristics for WCS CISF

Design Parameter	Design Criteria
Maximum wind speed	200 miles per hour
Maximum rotational speed	160 miles per hour
Translational speed	40 miles per hour
Radius of the maximum rotational speed	150 feet
Pressure drop across the tornado	0.9 psi
Rate of pressure drop	0.4 psi per second

Table C.7-13
Design-Basis Tornado Missile Spectrum and Maximum Horizontal Speeds

Case #	Missile	Weight (lb)	Horizontal Impact Velocity V_{MH}^{max} (fps)
A	Schedule 40 Pipe (ϕ 6.625 inch x 15 ft long)	287	112
B	Automobile (16.4 ft x 6.6 ft x 4.3 ft)	4,000	112
C	Solid Steel Sphere (ϕ 1 inch)	0.147	23

Note: V_{MH}^{max} = Horizontal velocity of missile, vertical velocity of missile = 0.67 V_{MH}^{max}

Table C.7-14
NUHOMS® MP197HB Cask and Canister Weights for Analyzed Configurations

Configuration of Cask/Canister for MP197HB			
Cask/Cansiter	**Weight of Cask without NSP Assembly (lb)**	**Canister Weight (lb)**	**Total Weight (lb)**
MP197HB/61BT DSC	135,584	88,390	223,974
MP197HB/61BTH Type 1 DSC	135,584	88,770	224,354

Table C.7-15
Materials, Properties and Allowable Stresses for MP197HB Cask at 400 ºF

Material Properties for MP197HB Cask at 400 °F							
Cask Component	**Material**	**S_m (ksi)**	**S_y (ksi)**	**S_u (ksi)**	**E (10^3 ksi)**	**Allowable Primary Membrane (ksi)**	**Allowable Primary Membrane + Bending (ksi)**
Outer Shell	SA-203 Grade E	22.9	34.2	70.0	26.2	49.00	70.00
Ram Closure Plate	SA-203 Grade E	22.9	34.2	70.0	26.2	49.00	70.00
	SA-240 Type 304	18.6	20.7	64.0	26.4	44.60	64.00
	SA-182 Type F304	18.6	20.7	64.0	26.4	44.60	64.00
Top Cover Plate	SA 350 Grade LF3	21.4	32.0	70.0	26.2	49.00	70.00
	SA-203 Grade E	22.9	34.2	70.0	26.2	49.00	70.00

Table C.7-16
Stress Results for MP197HB Cask due to Tornado Wind and Missile Loads

MP197HB Cask Results						
Load Description	**Stress Category**	**Calculated Stress (ksi)**			**Allowable Stress (ksi)**	**Impact Force (kip)**
		Outer Shell	**Lid**	**Ram Closure Plate**		
Wind Pressure Load	Primary Membrane	0.17	0.00		49.0	17.14
	Primary Membrane plus Bending	0.62	0.08		70.0	
	Primary Membrane			0.00	44.6	
	Primary Membrane plus Bending			0.25	64.0	
Massive Missile Load	Primary Membrane	13.07	0.09		49.0	340
	Primary Membrane plus Bending	46.65	6.70		70.0	
	Primary Membrane			0.89	44.6	
	Primary Membrane plus Bending			22.32	64.0	
Local Load	Primary Membrane	1.15	0.70		49.0	24.03
	Primary Membrane plus Bending	3.21	3.14		70.0	
	Primary Membrane			0.70	44.6	
	Primary Membrane plus Bending			8.62	64.0	

Table C.7-17
Combined Tornado Effect on MP197HB Cask – Stress Results

Load Description	Stress Category	Combined Stress (ksi)			Allowable Stress (ksi)
		Structural Shell	Lid	Ram Closure Plate	
Wind Pressure Load + Missile Load	Primary Membrane	13.24	0.09		49.0
	Primary Membrane plus Bending	47.27	6.78		70.0
	Primary Membrane			0.89	44.6
	Primary Membrane plus Bending			22.57	64.0

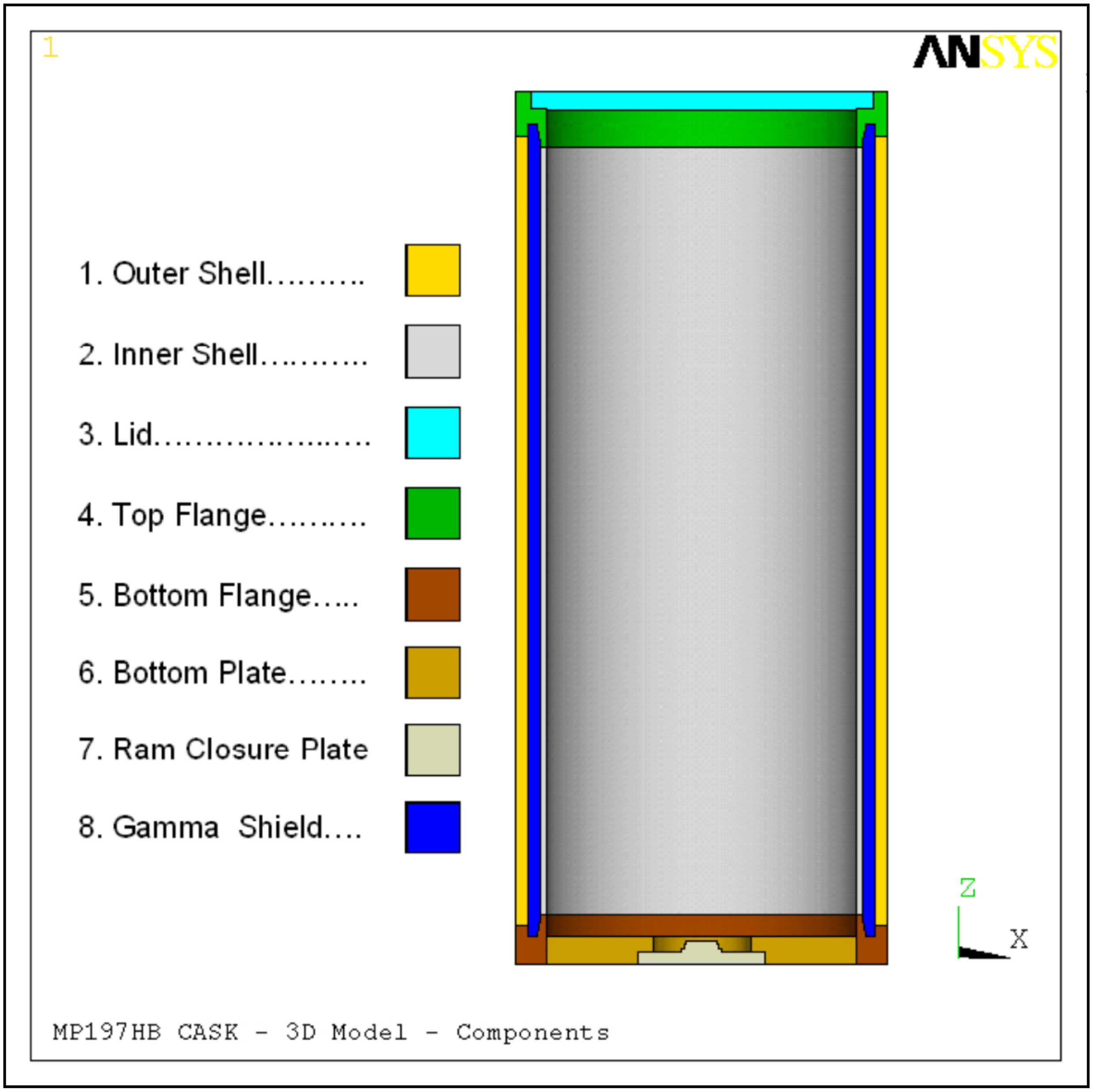


Figure C.7-1
Schematic of the MP197HB Cask - 3D FEA Model

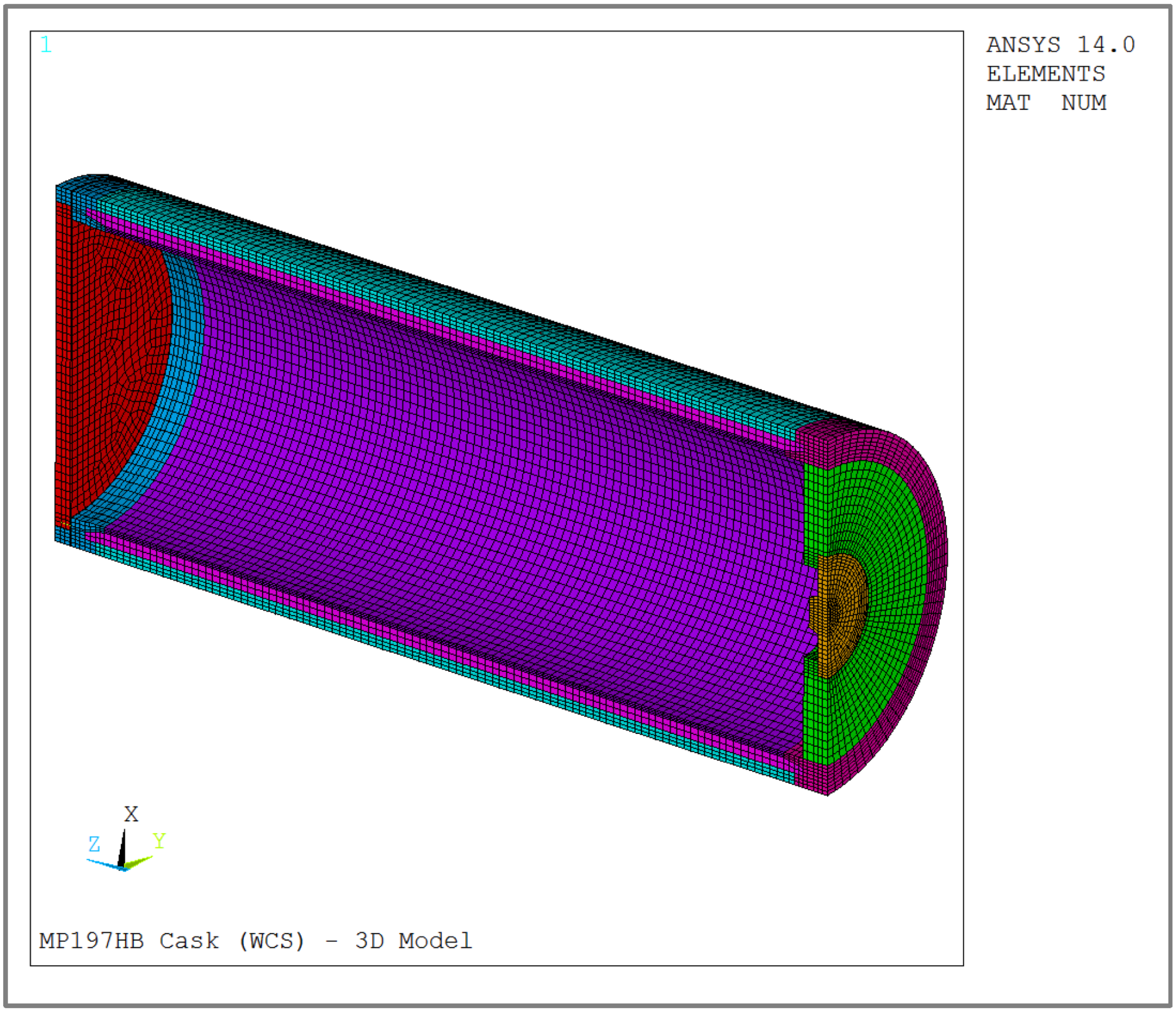


Figure C.7-2
3D FEA Half-Symmetry Model for Accident Conditions – Mesh

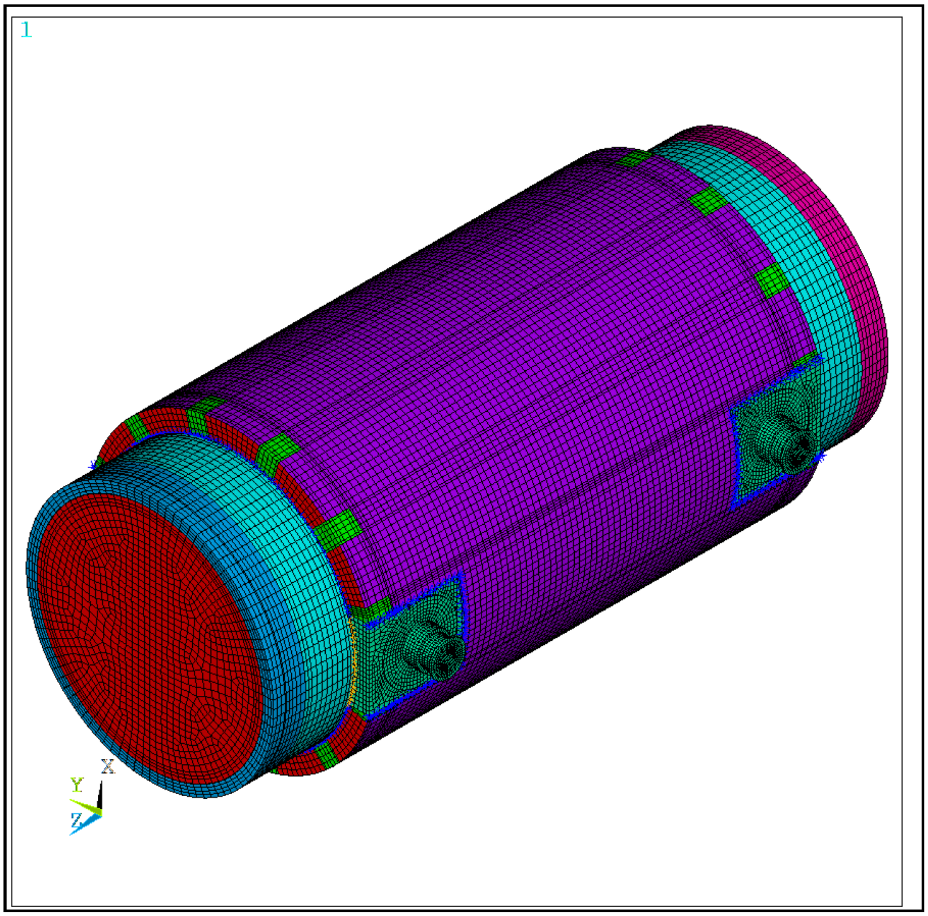


Figure C.7-3
3D FEA Model for Normal & Off-Normal Conditions – Mesh - General View

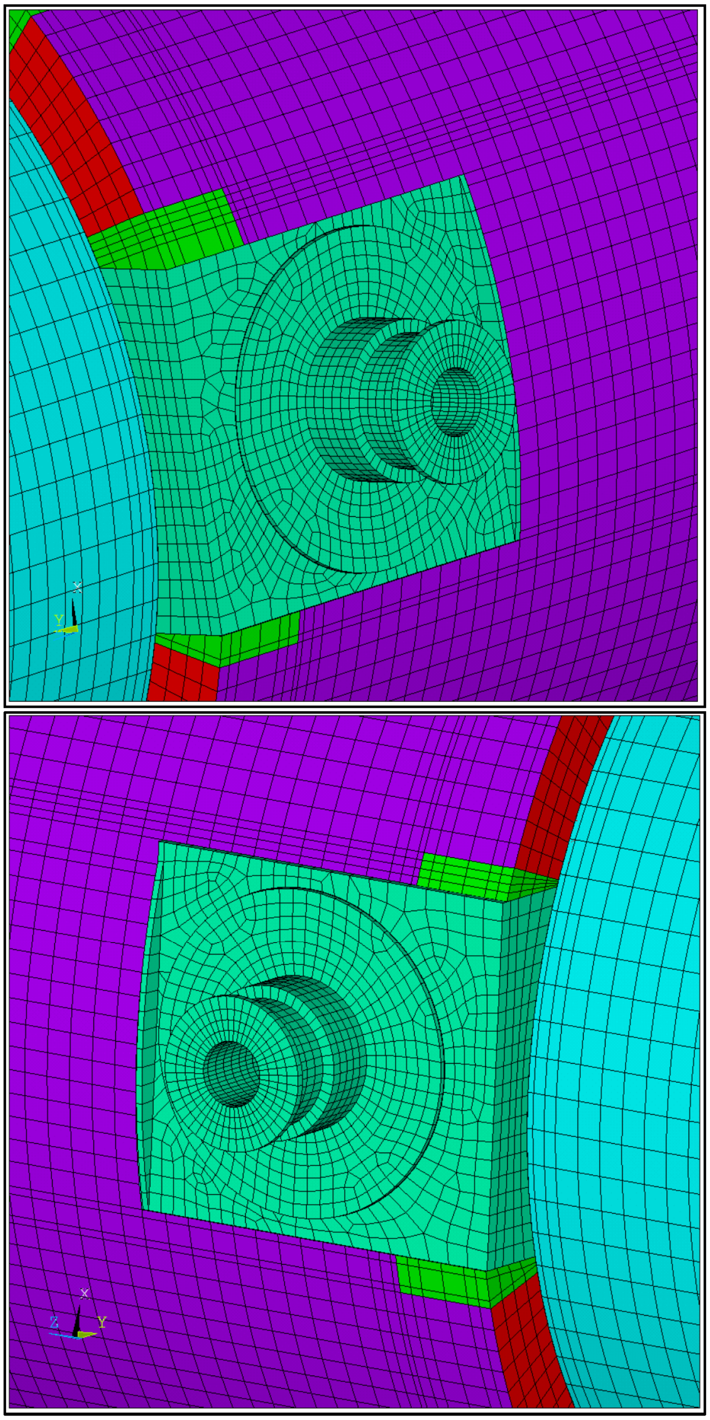


Figure C.7-4
3D FEA Model for Normal & Off-Normal Conditions – Mesh – Upper & Lower Trunnions

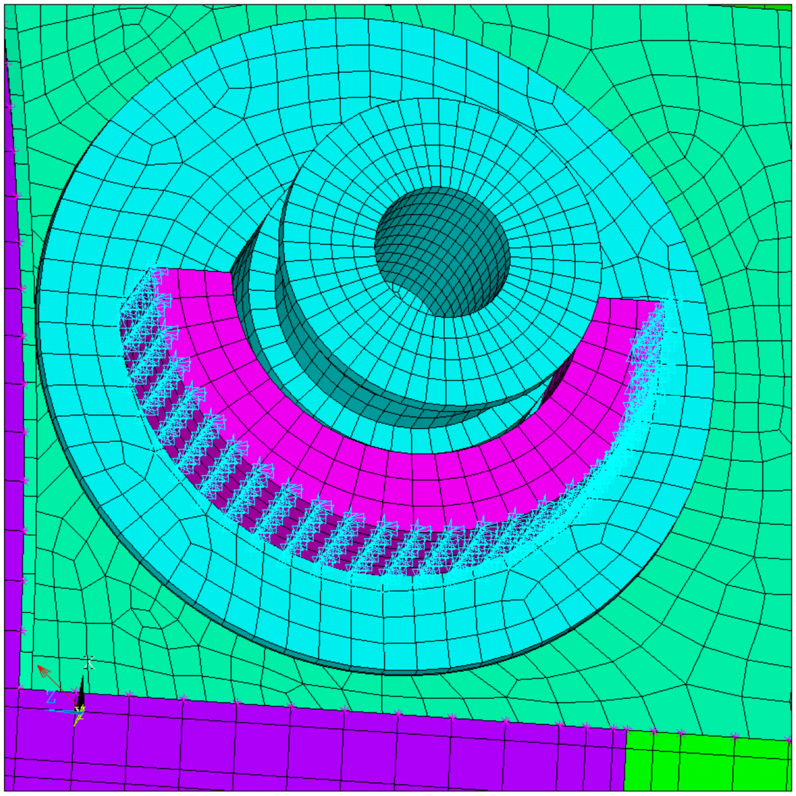


Figure C.7-5
3D MP197HB Cask -Trunnion Support Model – Lower Trunnion Example

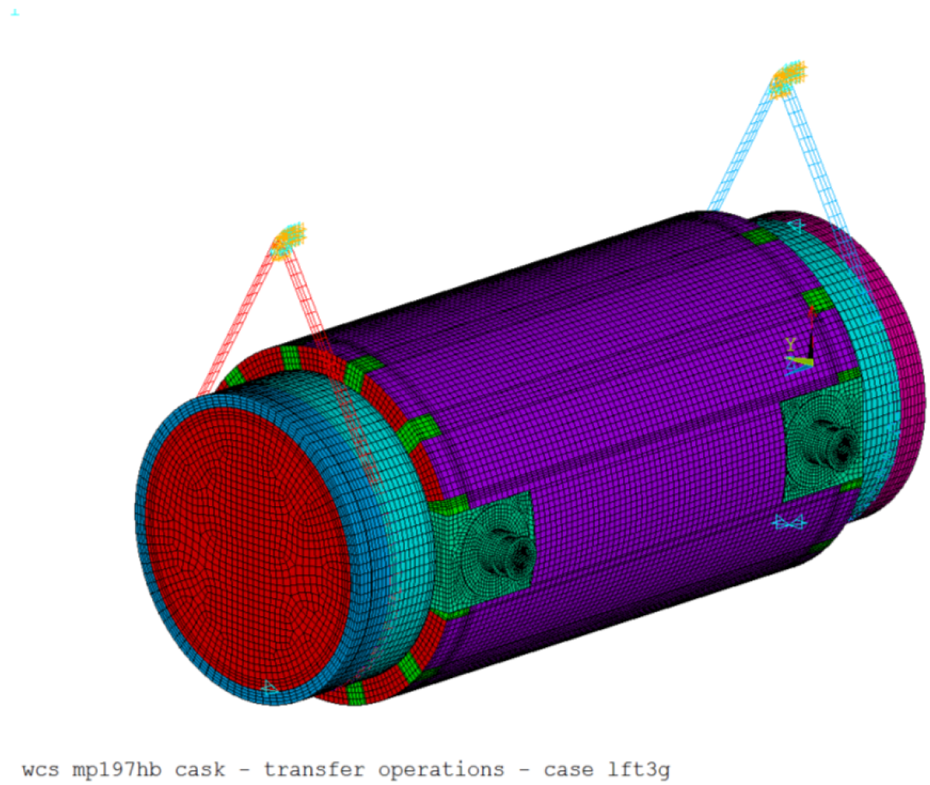


Figure C.7-6
3D MP197HB Cask – Lifting Support Model

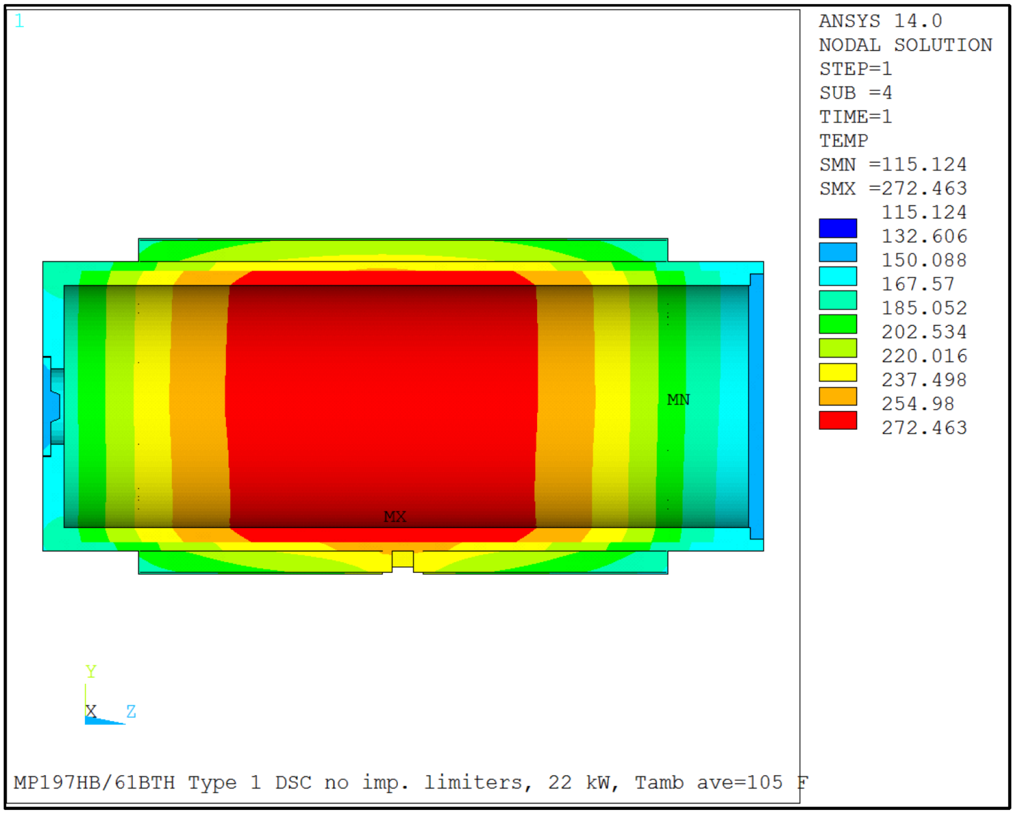


Figure C.7-7
Bounding Case with 61BTH Type 1 DSC (22 KW) – Thermal Model

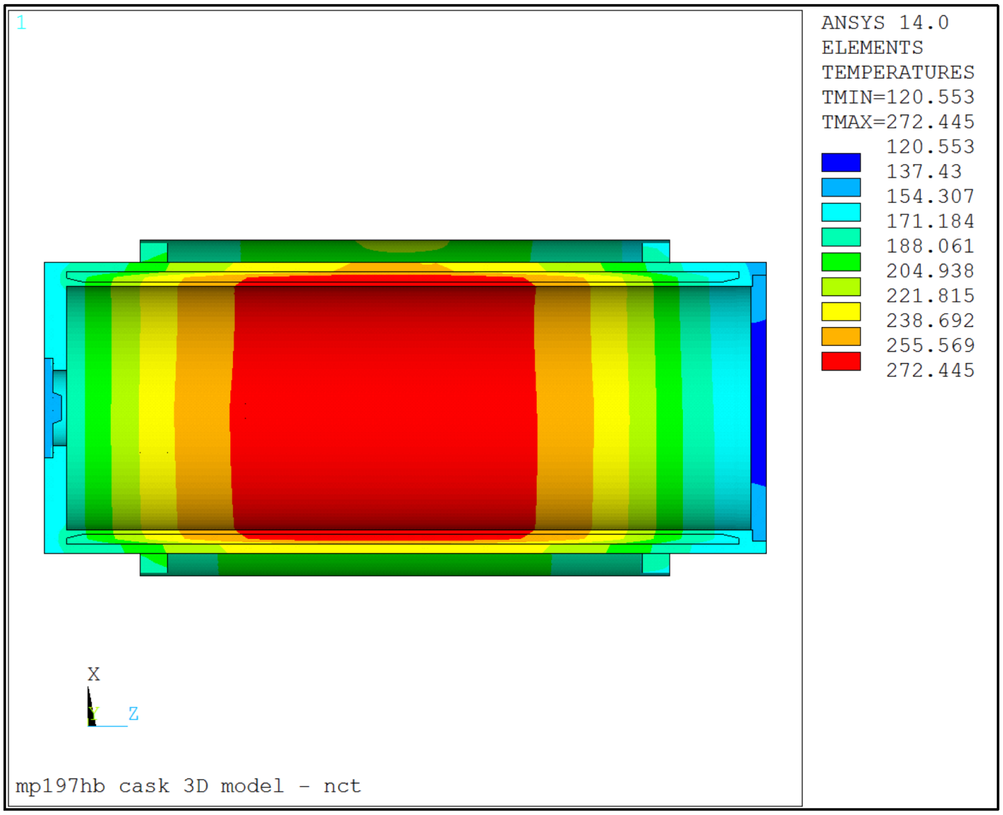


Figure C.7-8
Mapped Temperature for Bounding Case 61 BTH Type 1 DSC –Structural Model

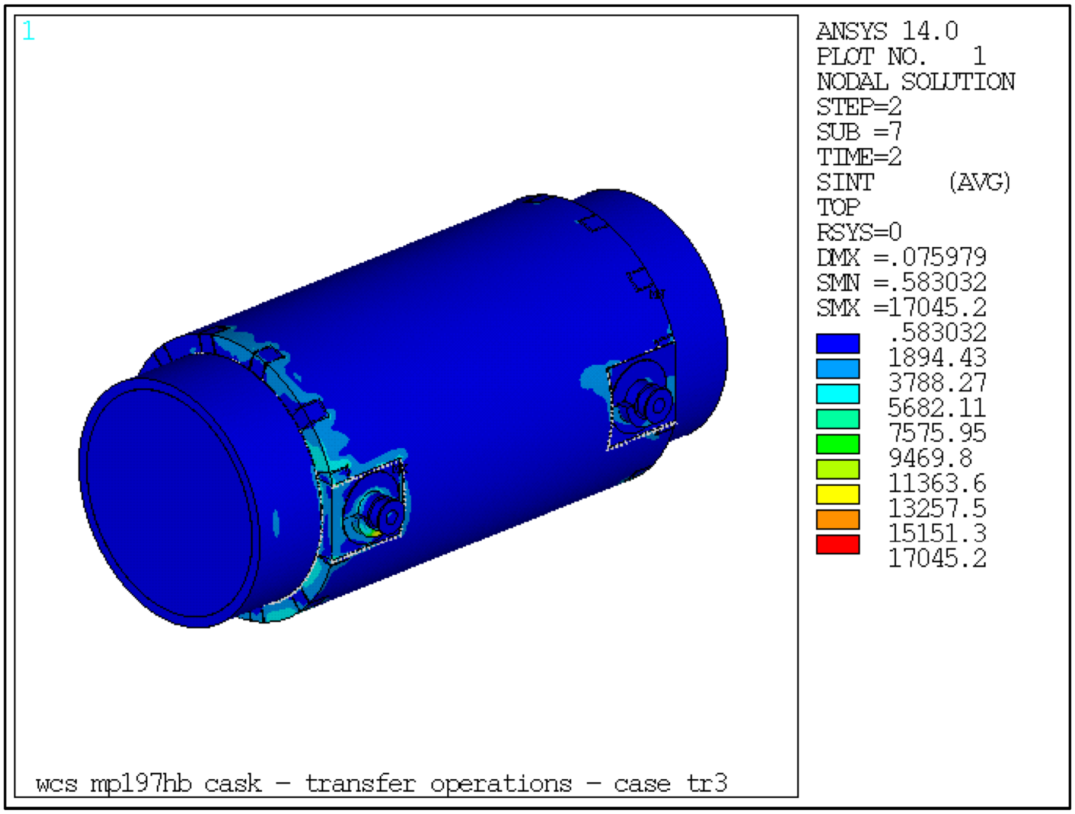


Figure C.7-9
MP197HB Cask – Stress Intensity (psi) – Load Case TR3

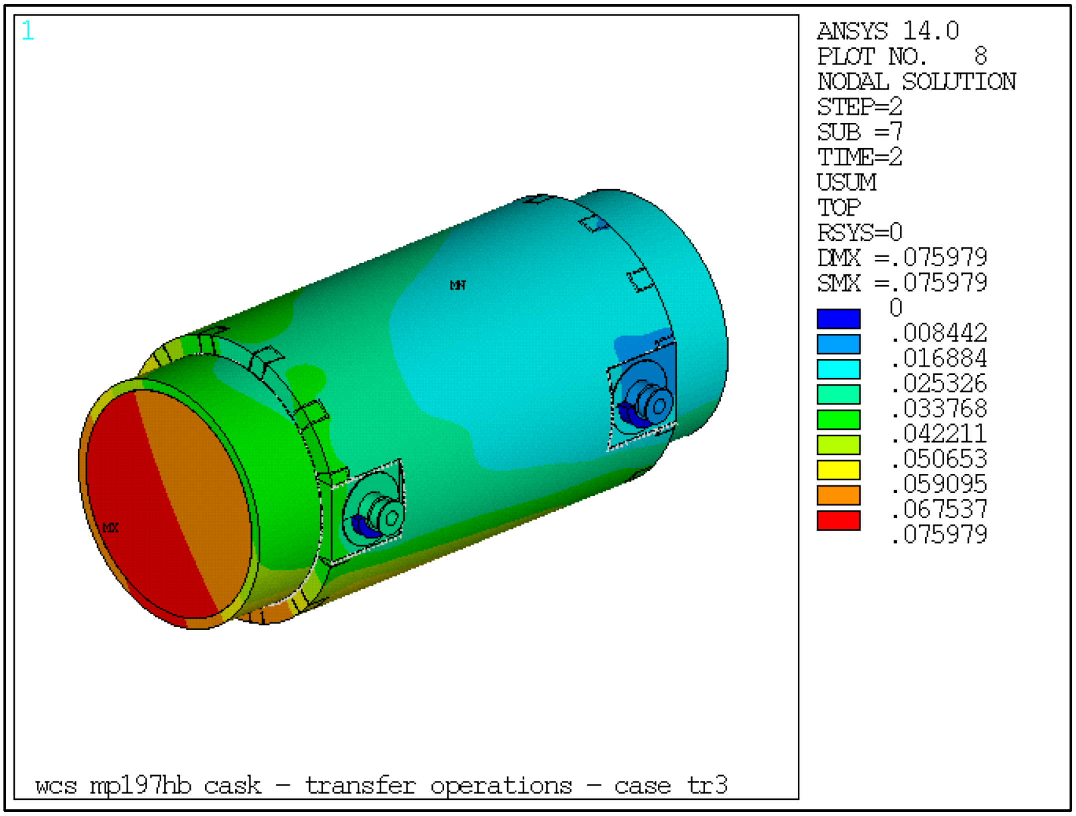


Figure C.7-10
MP197HB Cask –Displacements (inch) – Load Case TR3

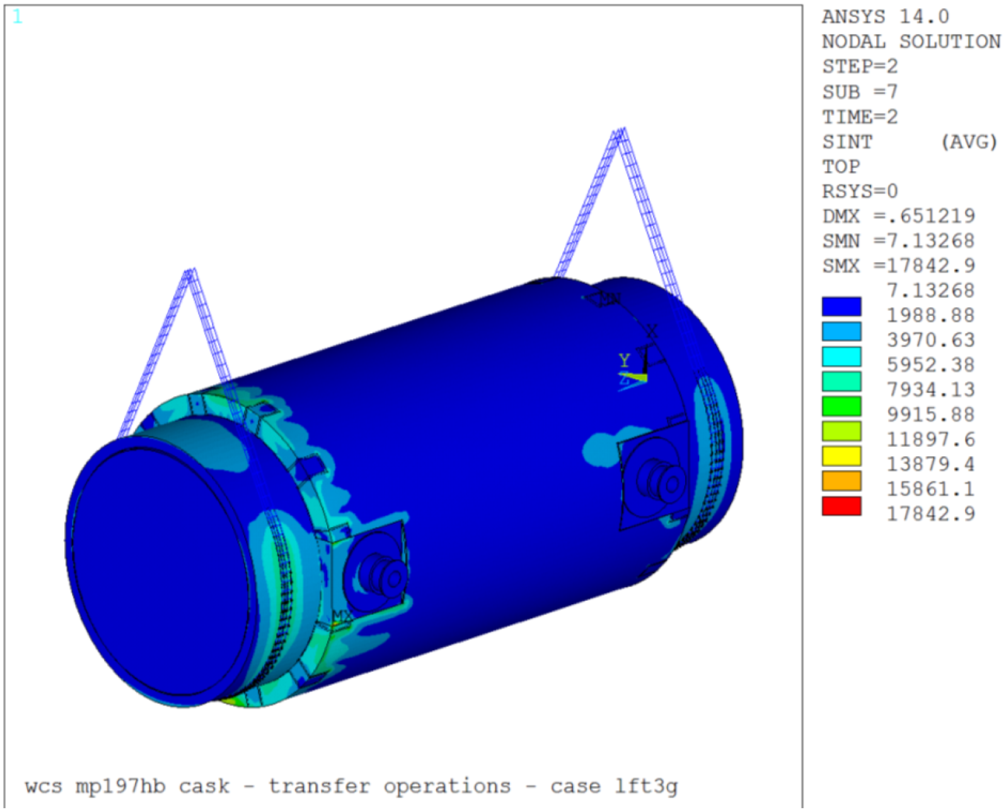


Figure C.7-11
MP197HB Cask – Stress Intensity (psi) – Load Case LFT3G

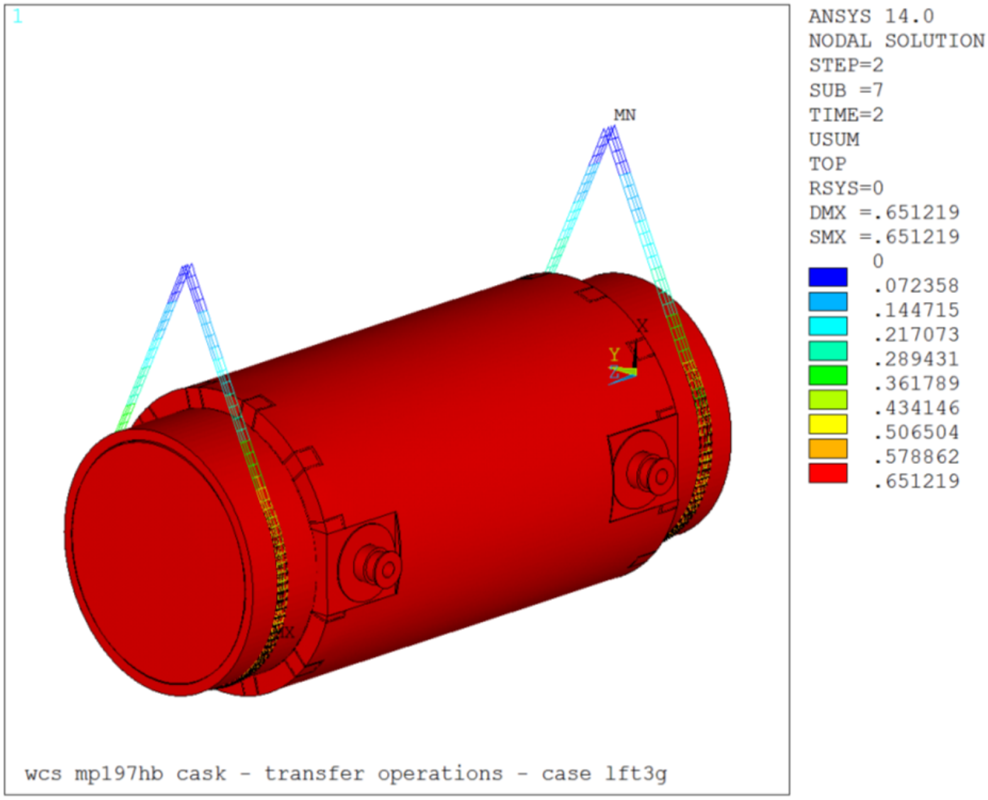


Figure C.7-12
MP197HB Cask –Displacements (inch) – Load Case LFT3G

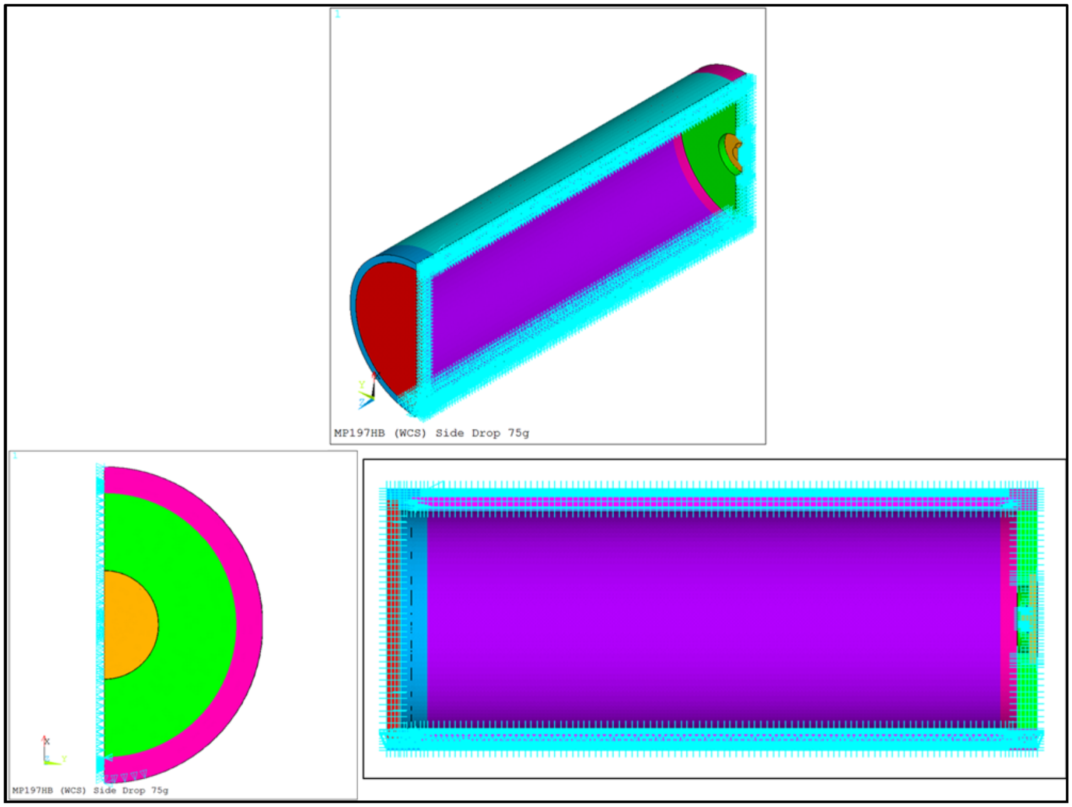


Figure C.7-13
Boundary conditions for 75g Side Drop

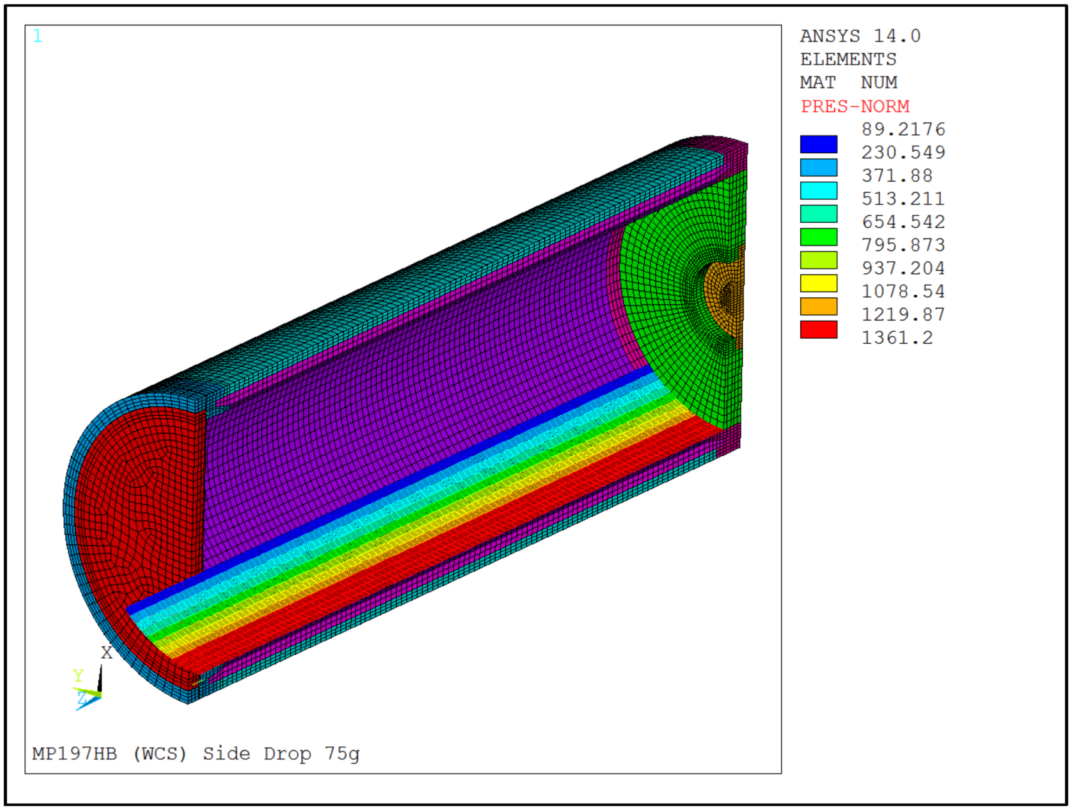


Figure C.7-14
Pressure Load Distribution for the 75g Side Drop

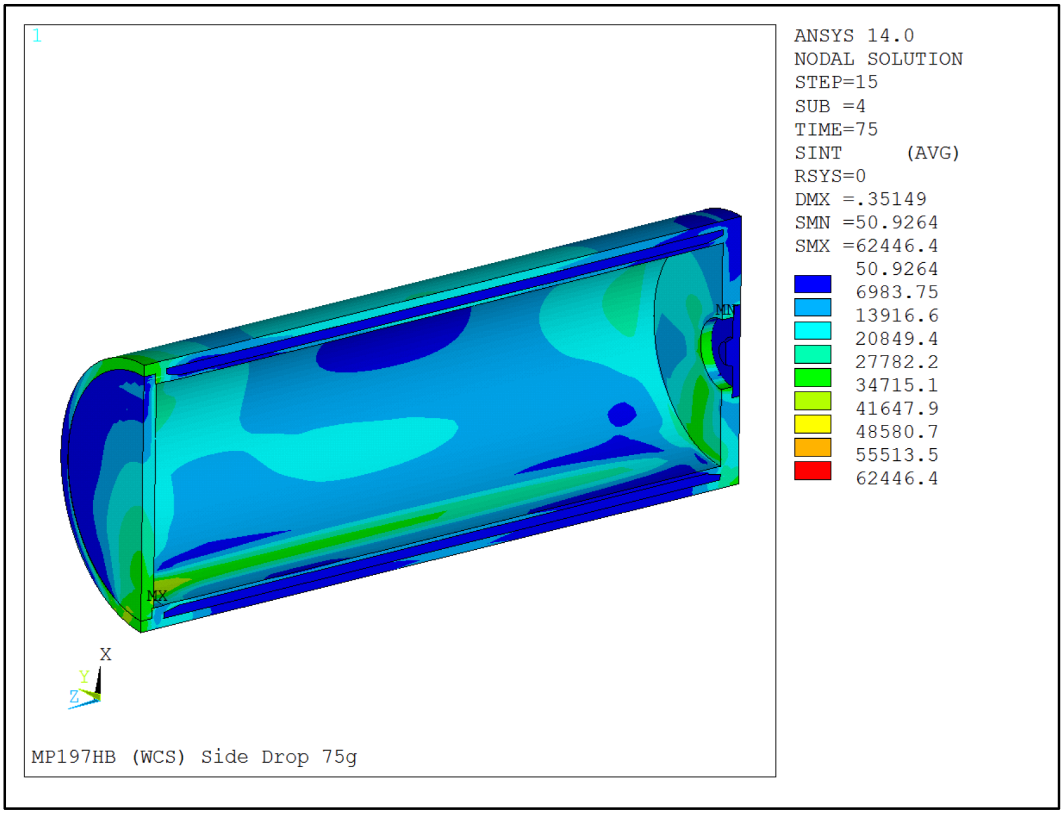


Figure C.7-15
MP197HB Cask –Stress Intensity (psi) - the 75g Side Drop

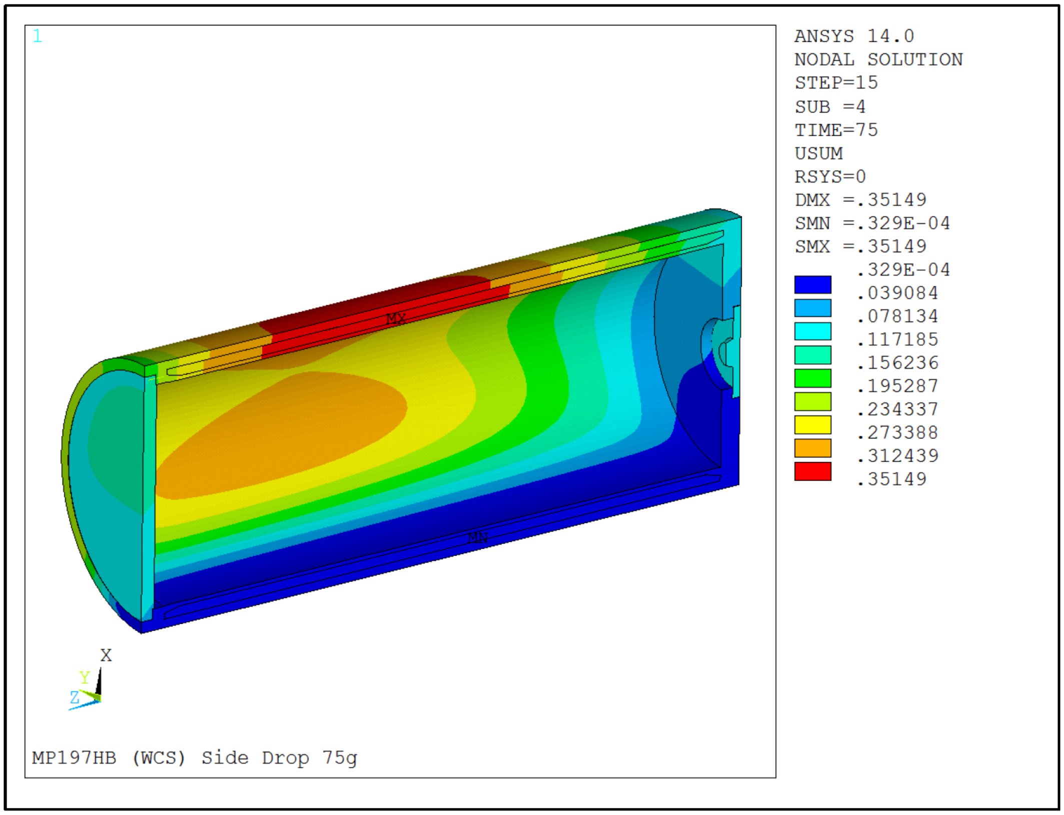


Figure C.7-16
MP197HB Cask –Deformation (inch) - 75g Side Drop

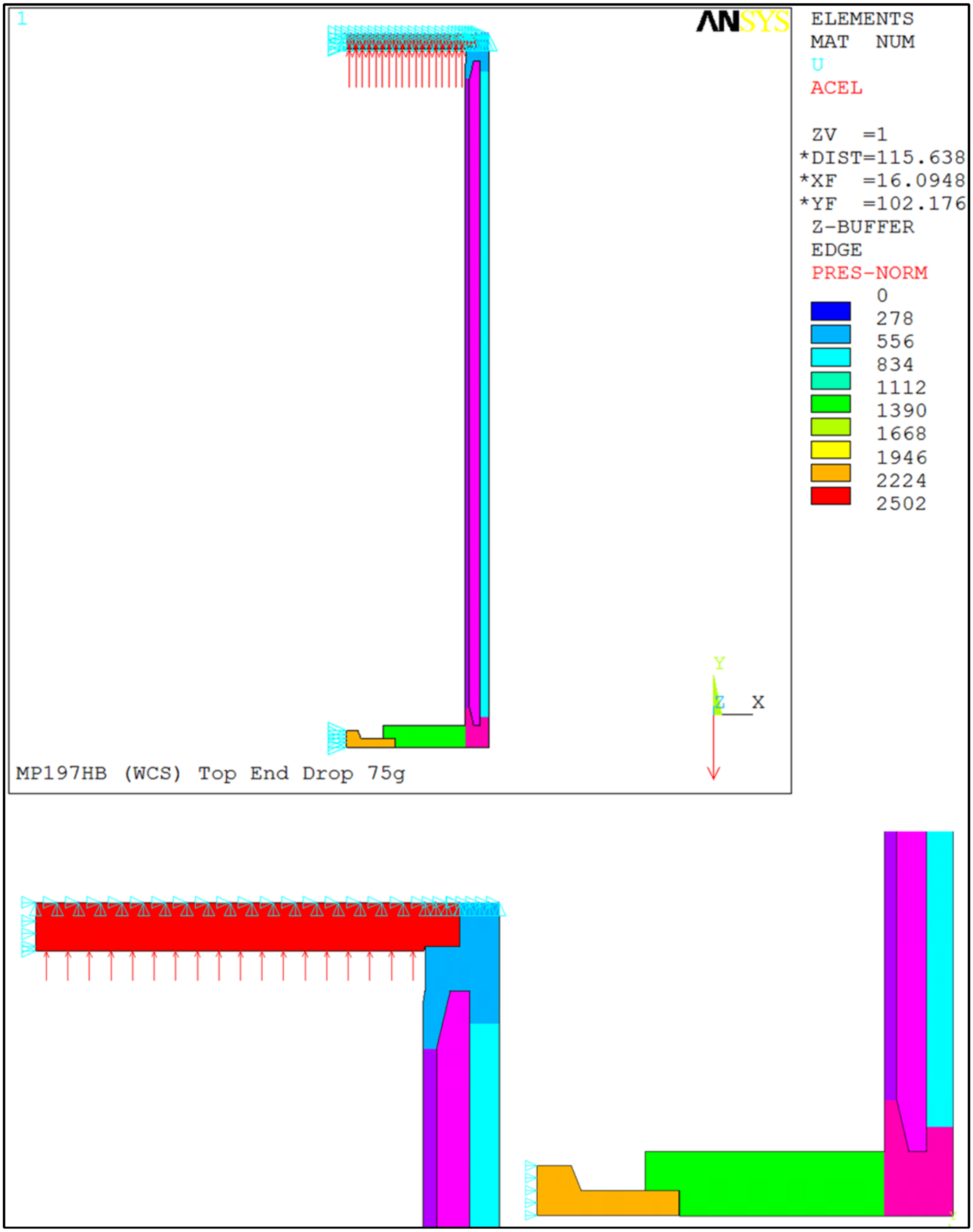


Figure C.7-17
Boundary conditions for 75g Top End Drop

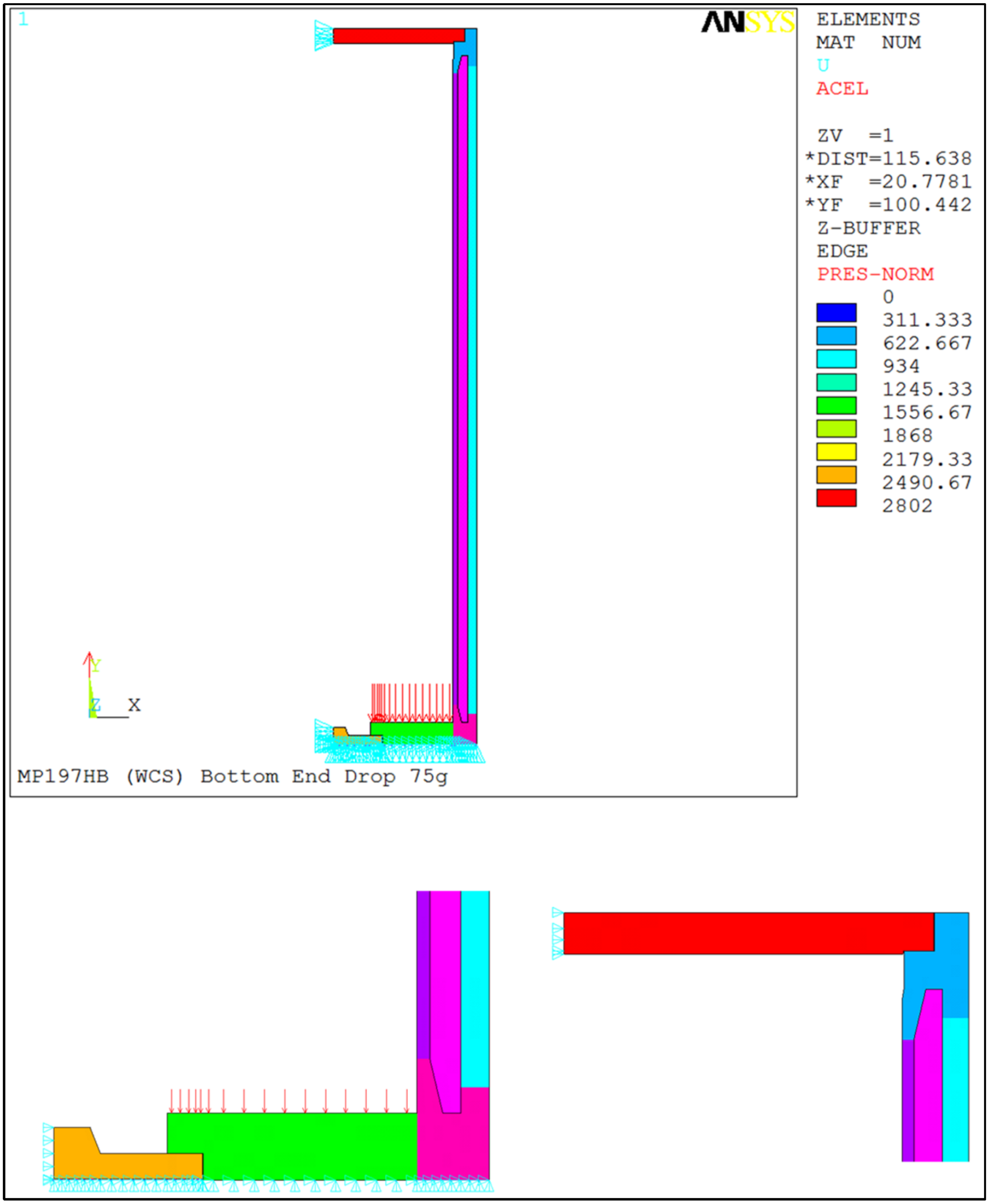


Figure C.7-18
Boundary conditions for 75g Bottom End Drop

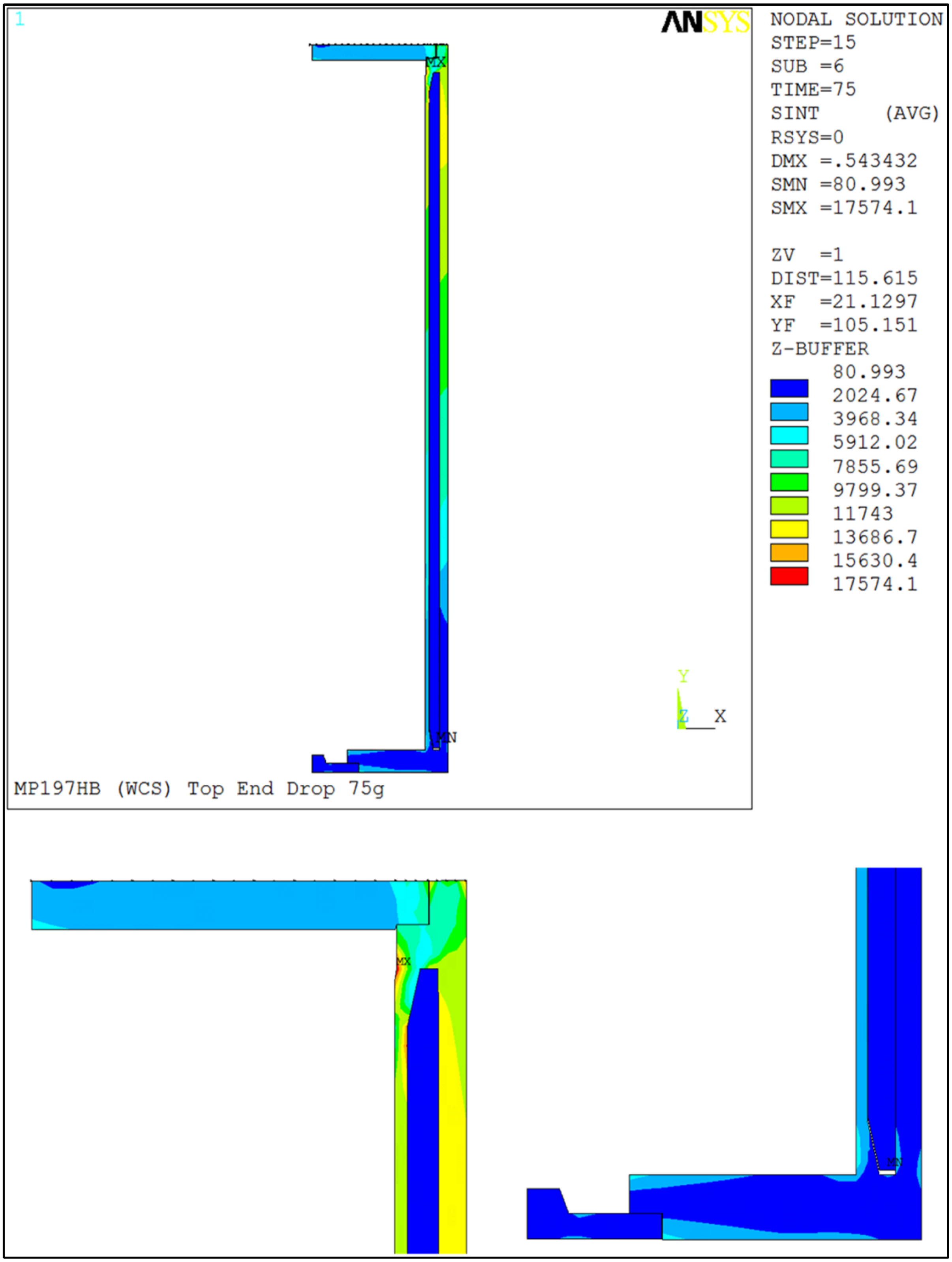


Figure C.7-19
Stress Distribution (psi) for 75g Top End Drop

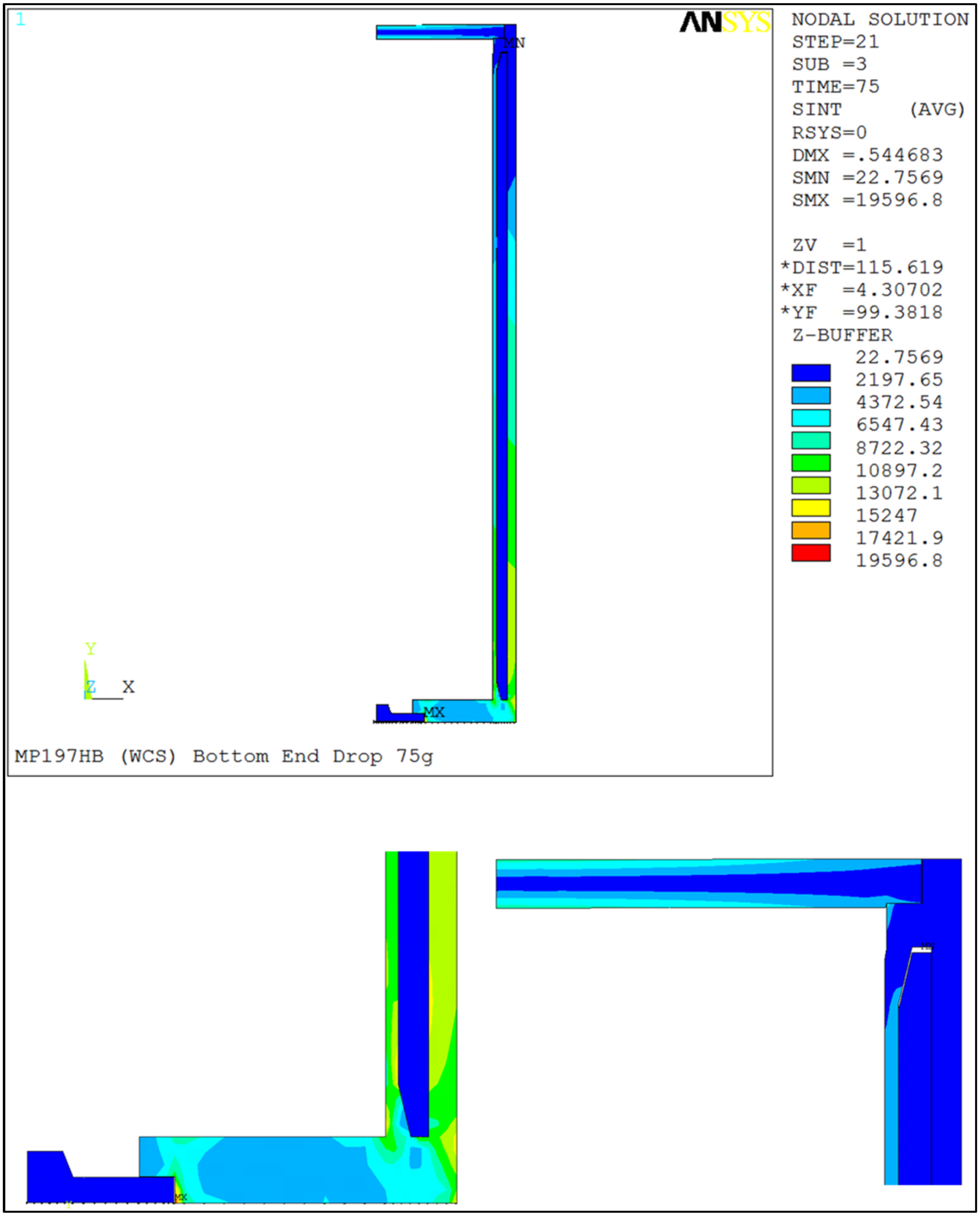


Figure C.7-20
Stress Distribution (psi) for 75g Bottom End Drop

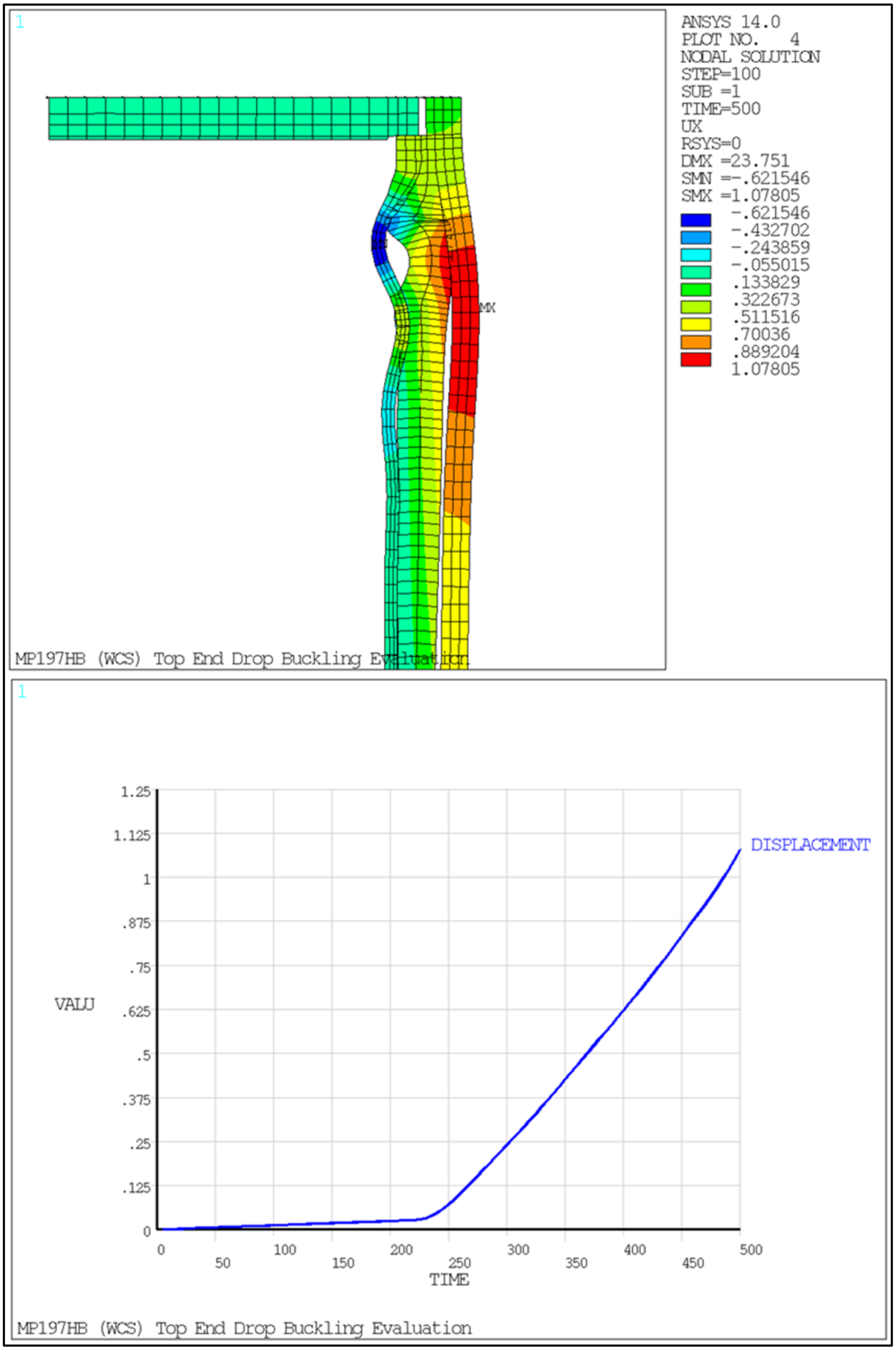


Figure C.7-21
Top End Drop Buckling

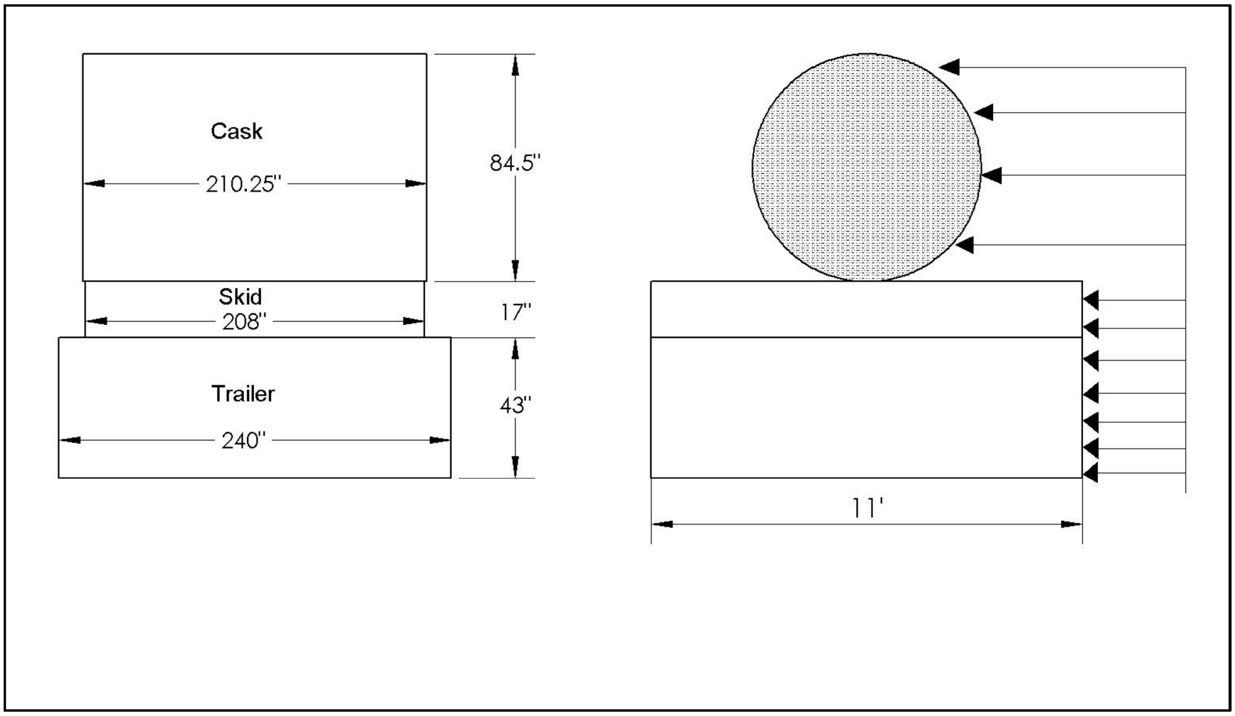


Figure C.7-22
Arrangement of MP197HB Cask Shell, Skid and Transfer Vehicle at Rest

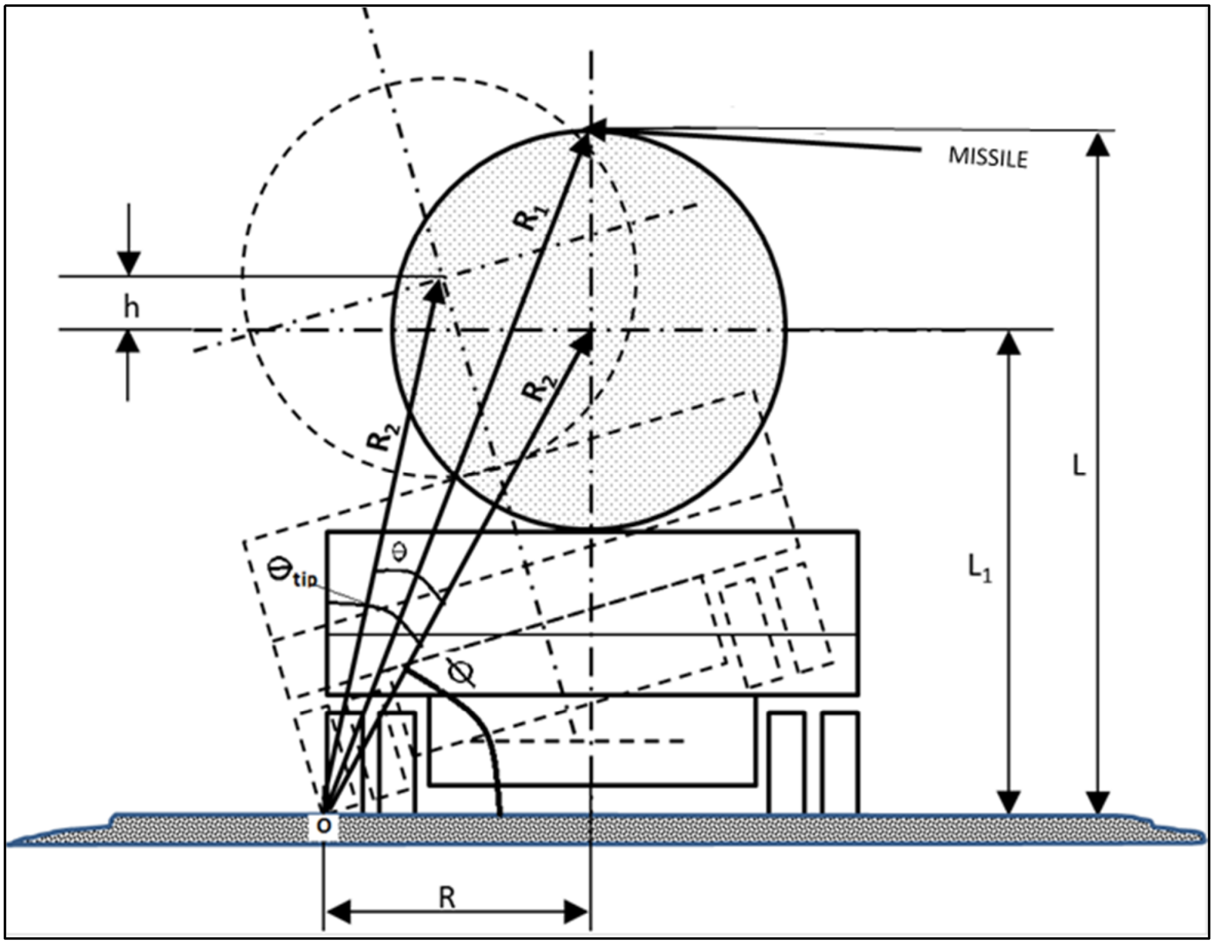


Figure C.7-23
Geometry Utilized in Cask Stability Assessments

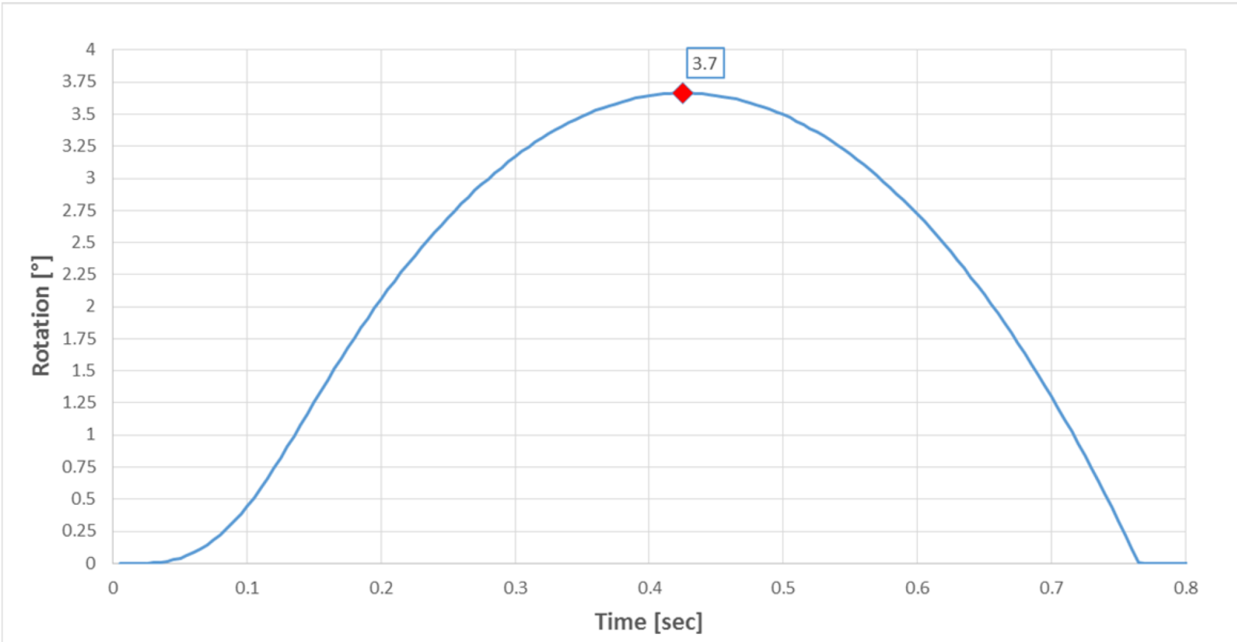
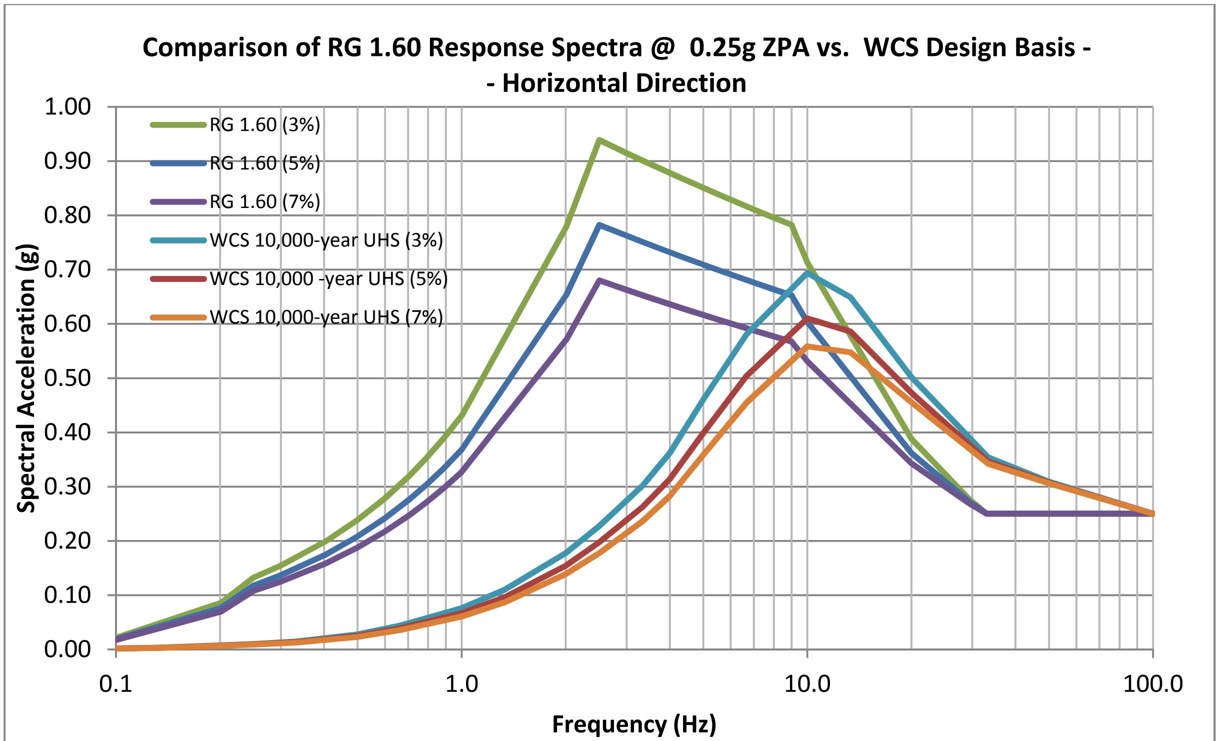


Figure C.7-24
Angle of Rotation due to Wind and Massive Missile Loading Combination



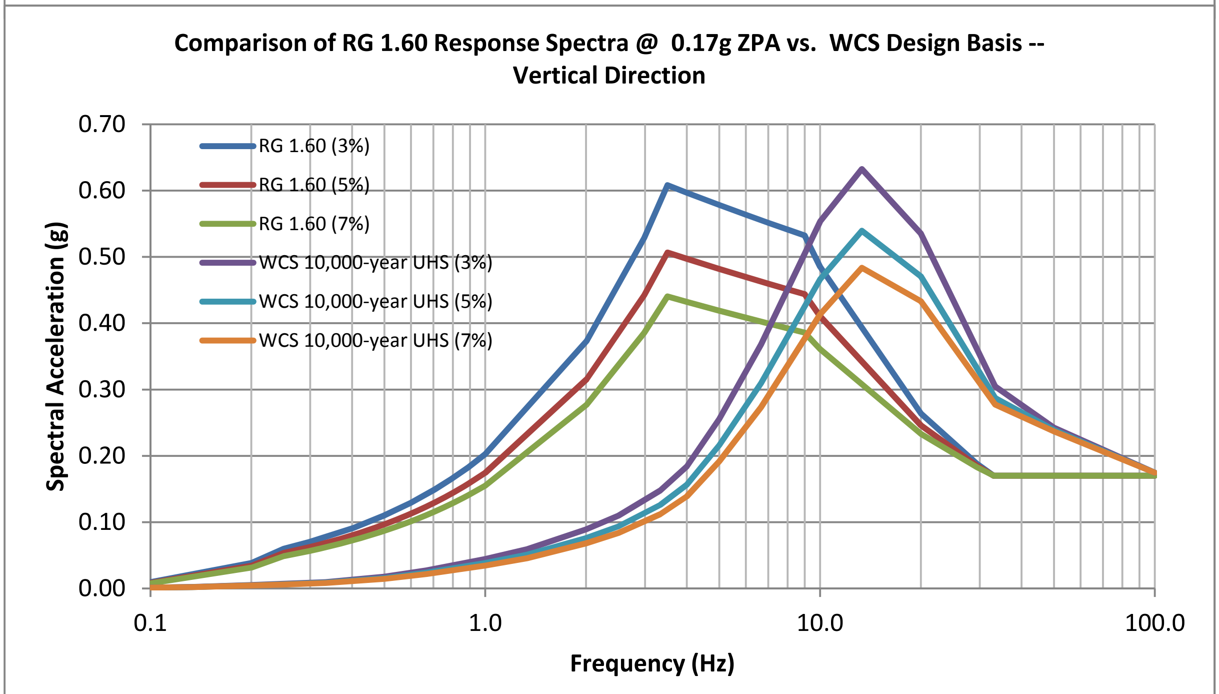


Figure C.7-25
Design Basis Response Spectra for the 61BT DSC, HSM Model 102 and MP197HB Cask compared to the WCS CISF 10,000-year UHS

Proprietary Information on Pages C.7-84 through C.7-88
Withheld Pursuant to 10 CFR 2.390

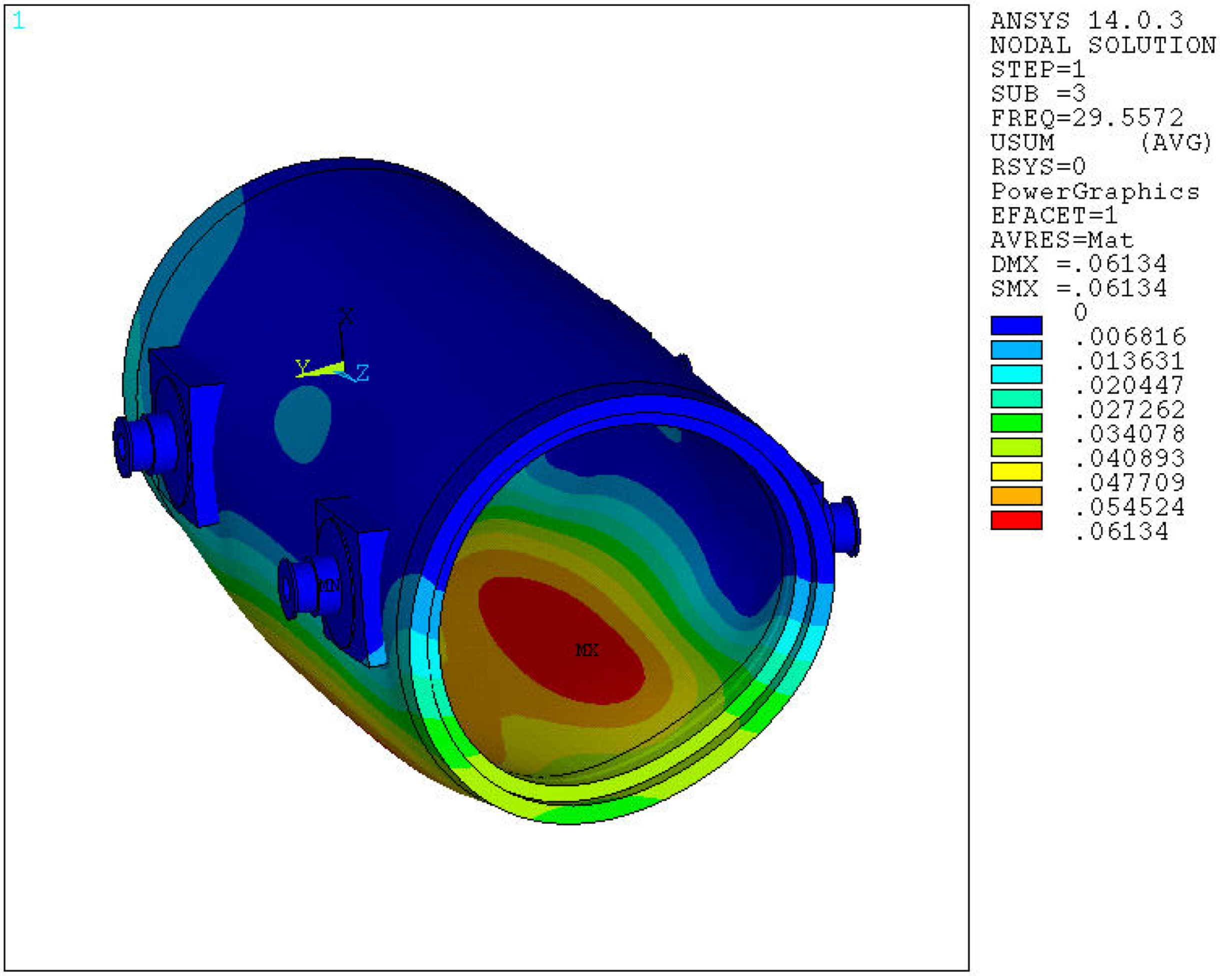


Figure C.7-31
Dominant frequency (29.6Hz) for transverse direction

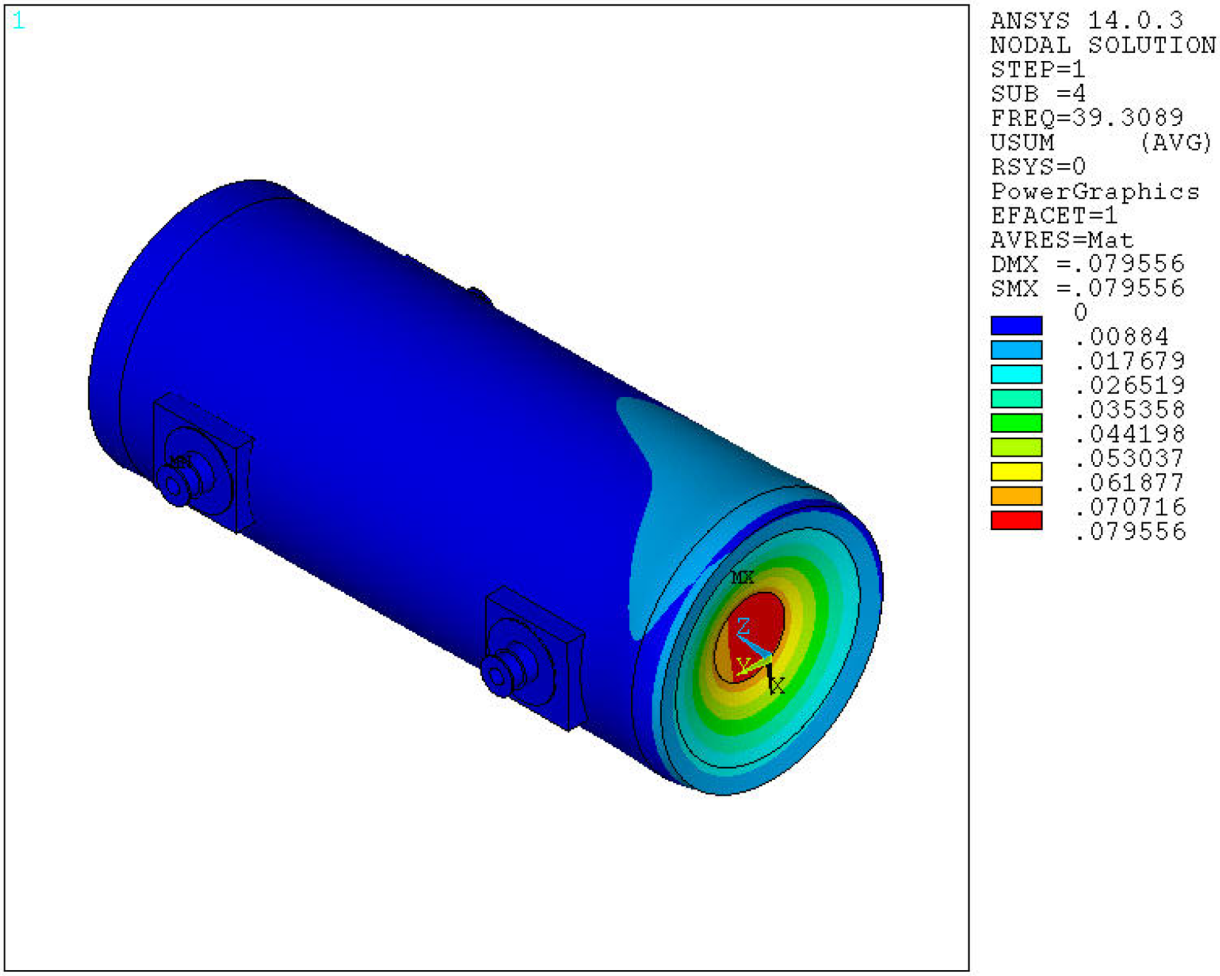


Figure C.7-32
Dominant frequency (39.3Hz) for longitudinal direction

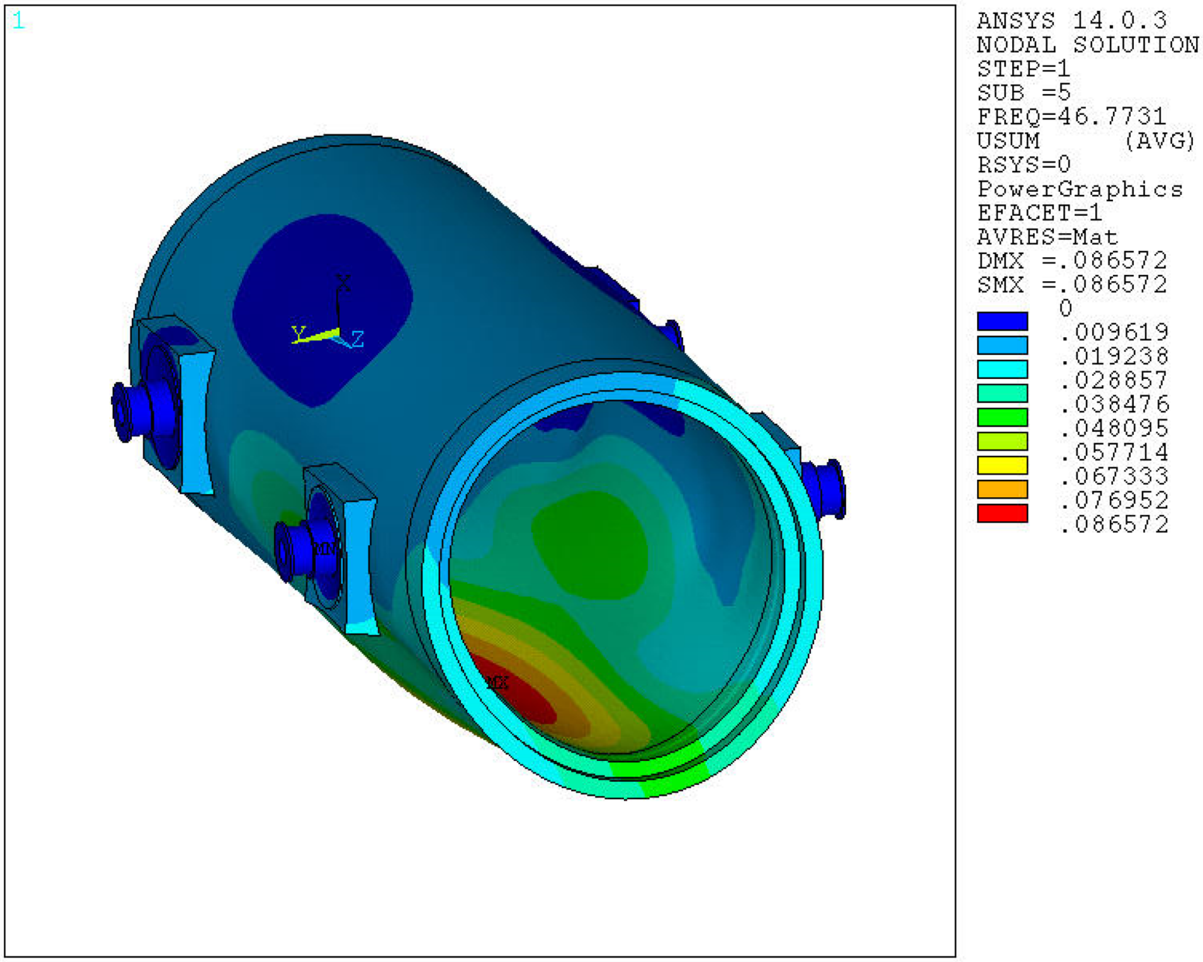


Figure C.7-33
Dominant frequency (46.8Hz) for vertical direction

APPENDIX C.8
THERMAL EVALUATION
Standardized NUHOMS®-61BT System

Table of Contents

List of Tables

C.8. THERMAL EVALUATION

This chapter presents the thermal evaluations which demonstrate that the NUHOMS®-61BT Dry Shielded Canister (DSC or canister), stored in the NUHOMS® HSM Model 102 storage module and transferred to the Waste Control Specialists, LLC (WCS) Consolidated Interim Storage Facility (CISF) in the MP197HB cask configured as a transfer cask, meets the thermal requirements of 10 CFR 72 for the dry storage of spent nuclear fuel (SNF). The NUHOMS®-61BT System is designed to passively reject decay heat during storage and transfer for normal, off-normal and accident conditions while maintaining temperatures and pressures within specified regulatory limits.

C.8.1 Discussion

As discussed in Chapter 1.0, the 61BT DSCs from an Independent Spent Fuel Storage Installation (ISFSI) site will be transported to the WCS CISF in the MP197HB cask under NRC Certificate of Compliance No. 9302 [C.8-2]. At the WCS CISF, the 61BT DSCs, described in Section K.1, Appendix K of [C.8-3], are to be stored inside the Standardized NUHOMS® HSM Model 102 described in Chapter 4 of [C.8-3]. For on-site transfer of the 61BT DSCs, the MP197HB cask, described in Section A.1.2, Appendix A of the MP197 SAR [C.8-4], is to be used.

The 61BT DSC is certified for storage in the HSM Model 102 and on-site transfer in the OS197 transfer cask with a design basis heat load of 18.3 kW [C.8-3]. The thermal analysis for storage and transfer of the 61BT DSC is presented in Appendix K.4 of [C.8-3].

This Appendix qualifies the 61BT DSC for storage at the WCS CISF with the same heat load of 18.3 kW under the WCS CISF environmental conditions. No new thermal analysis is performed for storage of the 61BT DSC in this Appendix. Although no new thermal evaluation is performed for storage conditions, the material properties, thermal models and results from Appendix K.4 of [C.8-3] are referenced in this section for completeness.

The MP197HB cask has previously been certified for transportation of the 61BT DSC [C.8-2]. Upon arrival of the MP197HB cask, it is reconfigured from its transportation arrangement to its transfer arrangement. A new thermal analysis for transfer of the 61BT DSC in the MP197HB cask with a heat load of 18.3 kW is also performed. During transfer operations, the MP197HB cask does not provide any confinement function. Therefore, the thermal performance of the various seals within the MP197HB cask is not evaluated in this application.

The thermal design criteria for storage and transfer of 61BT DSC are listed in Section K.4.1, Appendix K.4 of [C.8-3]. For the new thermal analysis presented in Section C.8.6 of this Appendix, the only change to these criteria is that the 61BT DSC SNF assemblies meet the SNF cladding temperature limits of the NRC Interim Staff Guidance (ISG)-11, Revision 3 [C.8-6] during transfer conditions.

This Appendix demonstrates that all the 10 CFR Part 72 thermal requirements for storage and transfer of the 61BT DSC at the WCS CISF are met.

C.8.2 Summary of Thermal Properties of Materials

The material properties of the HSM Model 102 module, are listed in Table 8.1-8 and Table 8.1-9 of [C.8-3]. The material properties of the 61BT DSC are listed in Section K.4.2 of [C.8-3] and the material properties of the MP197HB cask are listed in Section A.3.2.1 of [C.8-4].

Helium gas within the MP197HB cask/canister annulus is replaced with air during transfer operations. Because of these changes, the effective properties for the internal sleeve are re-calculated using the same methodology as used in [C.8-4]. The effective thermal conductivity of the MP197HB cask inner sleeve with air gap is calculated in Section C.8.5.1.

An emissivity value 0.9 is used for the white paint on the MP197HB cask neutron shield shell exterior surface as noted in Section A.3.2.1, item 31, Appendix A.3 of [C.8-4]. In addition, for the transfer configuration, the inside surface of the MP197HB cask inner sleeve (see Note 5 of drawing MP197HB-71-1014 of [C.8-4]) is to be painted white. Accordingly, an emissivity value of 0.9 is used for the inner surface of the MP197HB cask inner sleeve.

C.8.3 Specification for Neutron Absorber Thermal Conductivity

The thermal conductivity for the neutron poison plates of the 61BT DSC is provided in Section K.4.3, Appendix K of the Standardized NUHOMS® UFSAR [C.8-3].

C.8.4 Thermal Analysis of HSM Model 102 with 61BT DSC for Storage Conditions

As discussed in Section C.8.1, 61BT DSCs will be stored inside the HSM Model 102 at the WCS CISF. This configuration for storage operations is approved under CoC 1004 and a discussion on the thermal evaluation for this configuration is presented in Chapter K.4 of [C.8-3]. Because this configuration is previously approved, this section only presents a reconciliation of the ambient temperatures between [C.8-3] and the WCS CISF.

C.8.4.1 Ambient Temperature Specification at WCS CISF

As specified in Table 1-2, normal ambient temperature is considered in the range of *44.1°F* to *81.5°F*. Off-normal ambient temperature is considered in the range of *30.1°F* to *113°F*. *Accident ambient temperature is considered as 113°F.*

C.8.4.1.1 Comparison of WCS CISF Ambient Conditions with Ambient Conditions Used in the Standardized NUHOMS® UFSAR

A review of the thermal evaluation presented in Section K.4.4.1, Chapter K.4 of [C.8-3] shows that average daily ambient temperatures of 100°F and 125°F are used for normal and off-normal hot storage conditions, respectively. These temperatures bound the ambient temperatures for normal, off-normal, *and accident* conditions at the WCS CISF. *The* lowest off-normal ambient temperature *evaluated is* the -40°F used in [C.8-3].

Based on this discussion, the thermal evaluation for storage conditions presented in Chapter K.4 of [C.8-3] is bounding for the WCS CISF and no additional evaluations are performed. Sections C.8.4.2 through C.8.4.4 present the references to the appropriate section within [C.8-3] as it relates to the thermal evaluations performed for 61BT DSC and HSM Model 102 for storage conditions.

C.8.4.2 Thermal Model of HSM Model 102 with 61BT DSC

The HEATING7 thermal model of the HSM Model 102 is described in Section 8.1.3 of [C.8-3].

The three-dimensional ANSYS model of the 61BT DSC with a heat load of 18.3 kW is described in Appendix K, Section K.4.4.1 of [C.8-3].

The 61BT DSC model for accident analysis is based on the HSM model described in Section 8.1.3.1 of [C.8-3]. The accident analysis is performed with HSM vents totally blocked for 40 hours and with a maximum ambient steady state temperature of 125°F.

C.8.4.3 HSM Model 102 and 61BT DSC Thermal Model Results

The results of the HSM Model 102 thermal analysis for normal, off-normal and accident conditions are presented in Table 8.1-25 of [C.8-3]. These results are based on a design basis heat load of 19.2 kW for a NUHOMS®-52B DSC. The maximum concrete temperatures presented in Table 8.1-25 of [C.8-3] bound the values for the HSM Model 102 with a 61BT DSC payload because of a lower heat load for the 61BT DSC (18.3 kW v/s 19.2 kW).

The maximum surface temperature distribution determined for the 52B DSC in Section 8.1.3 of [C.8-3] is applied as the boundary condition to the 61BT DSC model with a 18.3 kW heat load in Section K.4.4.1, Appendix K of [C.8-3]. The maximum temperatures of the 61BT DSC components and SNF cladding for normal, off-normal and accident conditions are presented in Table K.4-1, Appendix K of [C.8-3].

The maximum calculated pressures of the 61BT DSC in HSM Model 102 presented in Table K.4-5, Appendix K of [C.8-3].

C.8.4.4 Evaluation of 61BT DSC Storage in HSM Model 102

The thermal performance of the HSM Model 102 module with the 61BT DSC at the WCS CISF under normal, off-normal and accident conditions is bounded by the thermal analysis presented in Section 8.1.3 and Appendix K.4 of [C.8-3]. The bounding evaluation demonstrates that all the 10 CFR Part 72 thermal limits and criteria are met.

C.8.5 Thermal Analysis of MP197HB Cask with 61BT DSC for Transfer Operations

As discussed in Section C.8.1, the 61BT DSC will be transported to the WCS CISF under the NRC Certificate of Compliance No. 9302 [C.8-2]. Within the WCS CISF, the transfer operations i.e. movement of the canister from the MP197HB cask into the storage module will be performed under 10 CFR Part 72. This section presents the thermal evaluation for this on-site transfer operation.

C.8.5.1 Thermal Model of MP197HB Cask with 61BT DSC

The MP197HB cask in the transportation configuration is shown in the design drawings included in Section A.1.4.10.1, Chapter A.1 of [C.8-4]. The ANSYS model of the MP197HB cask is presented in Section A.3.3.1.1, Appendix A.3 of [C.8-4]. ANSYS 10.0 [C.8-5] is used for the MP197HB cask modeling and thermal analysis. This transportation model of the MP197HB cask is modified to replicate the transfer configuration of the MP197HB cask as follows:

- The impact limiters are removed
- Convection, insolation and radiation are applied on additional surfaces exposed to ambient as a result of removing the impact limiters
- Helium gas within the MP197HB cask/canister annulus is replaced with air during transfer operations. In addition, the internal sleeve of the MP197HB cask is considered to be painted white (see Note 5 of drawing MP197HB-71-1014 of [C.8-4]).

The thermal properties of the materials used in the analysis of the MP197HB cask with 61BT DSC in transfer mode are the same as those presented in Section A.3.2.1, Appendix A.3 of [C.8-4] except for the effective conductivity of the internal sleeve. ANSYS *10.0* [C.8-5] is used for the MP197HB cask modeling and thermal analysis.

The effective thermal conductivity for the MP197HB cask inner sleeve with air gap in axial ($k_{eff,axl}$) and radial ($k_{eff,rad}$) directions is recalculated using the methodology described in Item 5, Section A.3.3.1.3 of [C.8-4]. Table below lists the effective thermal conductivity of inner sleeve of the MP197HB cask for transfer.

Effective Thermal Conductivity of MP197HB Cask Inner Sleeve with Air Gap

Temperature (°F)	$k_{eff,axl}$ **(Btu/hr-in-°F)**	$k_{eff,rad}$ **(Btu/hr-in-°F)**
70	0.403	7.646
100	0.420	7.710
150	0.445	7.798
200	0.469	7.878
250	0.494	7.941
300	0.519	8.005
350	0.543	8.061
400	0.567	8.109

C.8.5.2 MP197HB Cask Thermal Model Results

Normal and Off-Normal Conditions:

As noted in Table 1-2, the maximum ambient temperature for normal and off-normal conditions are 81.5°F and 113°F, respectively. However, an ambient temperature of 105°F is conservatively used in the thermal evaluation for transfer operations at the WCS CISF.

The maximum temperatures of the components of the MP197HB cask loaded with the 61BT DSC for transfer at the WCS CISF *at an* ambient temperature of 105°F) are presented in the table below. Also listed for comparison are the maximum component temperatures of the MP197HB cask loaded with the 61BT DSC for transportation [C.8-4].

Comparison of MP197HB Cask Component Maximum Temperatures for Transportation v/s Transfer of 61BT DSC

Transfer/Transportation Operation	**Transportation MP197HB Cask with 61BT DSC(2) Normal T_{amb}=100°F**	**Transfer at WCS CISF MP197HB Cask with 61BT DSC (1)**
Heat load	18.3 kW	18.3 kW
Component	T_{max}, °F	T_{max}, °F
Canister shell	365	386
Inner sleeve	286	260
Cask inner shell	284	248
Gamma shield	283	247
Outer shell	276	222
Shield shell	248	204
Cask lid	228	142
Cask bottom plate	277	166

1 – Daily ambient average temperature of 105°F is used for analysis.

2 – From Table A.3-8 of [C.8-4].

As seen from table above, the maximum MP197HB cask component temperatures for transfer at *the WCS CISF* are below those for transportation at 100°F in the MP197HB cask. The maximum temperatures of the MP197HB cask components for the transfer case decreases compared to the transportation case due to the increased heat rejection from the MP197HB cask external surface to the ambient. This is due to the removal of impact limiters (which cover parts of MP197HB cask outside surface) and higher emissivity of white paint used on the inner surface of the MP197HB cask inner sleeve.

The maximum 61BT DSC shell temperature increases by 21°F. This increase is due to the use of air in the MP197HB cask/canister annulus versus the use of helium in the transportation case.

The maximum temperatures of the components of the MP197HB cask at the WCS CISF for normal and off-normal transfer conditions are listed in Table C.8-1.

Since the maximum 61BT DSC surface temperature for transfer is higher than the maximum 61BT DSC surface temperature for transportation, the 61BT DSC shell temperature profile from the MP197HB cask transfer evaluation is mapped to the 61BT DSC basket model described in Section K.4.4.1, Appendix K.4 of [C.8-3]. The results of this evaluation provide the maximum 61BT DSC basket component temperatures and the maximum SNF cladding temperature for off-normal conditions.

The maximum temperatures of the components of the 61BT DSC and the maximum SNF cladding temperature at the WCS CISF for normal and off-normal transfer conditions are listed in Table C.8-2.

61BT DSC Cavity Pressure (Normal and Off-Normal Conditions)

As seen from Table C.8-2, the average cavity gas temperature for off-normal transfer of the 61BT DSC in the MP197HB cask is 369°F. This is lower than the average cavity gas temperature of 480°F used in the 61BT DSC cavity pressure evaluation for transfer in the OS197 transfer cask from Table K.4-2, Appendix K of [C.8-3]. Therefore, the internal pressure of the 61BT DSC cavity in the MP197HB cask during transfer under off-normal conditions at the WCS CISF is bounded by the internal pressure of the 61BT DSC cavity in the OS197 transfer cask during transfer under normal conditions.

The pressure values from Table K.4-5, Appendix K of [C.8-3] for normal and off-normal conditions bound internal pressure for the 61BT DSC for transfer in the MP197HB cask at the WCS CISF.

Accident Conditions:

Fire accident is the only postulated hypothetical accident condition (HAC) considered in the thermal evaluation during transfer of 61BT DSC in MP197HB cask. Based on the discussion in Section K.4.6.5 of [C.8-3], a 300-gallon diesel fire with duration of 15 minutes is considered during transfer operations. The same accident is also considered during transfer operations at the WCS CISF.

However, the fire duration of 15 minutes considered in transfer operations is half of the 30-minute fire duration considered for transportation in Section A.3.4, Appendix A.3 of [C.8-4]. This ensures that the heat input from the fire to the MP197HB cask/canister is lower during transfer operations compared to the transportation operations. In addition, the bounding HAC evaluations performed in Section A.3.4, Appendix A.3 of [C.8-4] considers a minimum heat load of 26 kW compared to the maximum heat load of 18.3 kW for 61BT DSC.

One change to the MP197HB cask is that the impact limiters are not present during the transfer fire accident unlike the transportation fire evaluation presented in Section A.3.4, Appendix A.3 of [C.8-4]. The ends of the cask might experience slightly higher heat input into the cask compared to the fire accident evaluation performed for transportation and might impact the components exposed to fire. The only components at the ends of the cask that have a temperature limit are the cask seals. However, since there is no confinement function provided by the MP197HB cask under transfer operations, the cask seals are not required under transfer operations. Therefore, there is no adverse impact on the cask performance because of the increased heat input towards the ends.

Based on the above discussion, the maximum temperatures of the MP197HB cask components presented in Table A.3-19 (for load case with internal sleeve) of [C.8-4] for the transportation configuration bound the values for the transfer case. Table C.8-1 presents these bounding maximum temperatures for the MP197HB cask components for the HAC conditions during transfer operations at WCS CISF.

For the maximum SNF cladding and 61BT DSC components, as discussed in Section K.4.6.5, Appendix K.4 of [C.8-3], the calculated maximum 61BT DSC surface temperature in a fire transient is less than the blocked vent case maximum canister surface temperature. Therefore, the maximum 61BT DSC temperatures and maximum SNF cladding temperature under HAC conditions are bounded by the maximum temperatures for the HSM Model 102 blocked vent conditions. The bounding temperature values for the 61BT DSC under HAC conditions are presented in Table C.8-2.

The 61BT DSC cavity internal pressure for accident case remains unchanged since the bounding case is the HSM Model 102 blocked vent as discussed in Section K.4.6.5 of [C.8-3]. The bounding pressure values from Table K.4-5 of [C.8-3] under accident conditions are used for the internal pressure for the 61BT DSC for storage and transfer in the MP197HB cask at the WCS CISF.

C.8.5.3 Evaluation of MP197HB Cask Performance

The thermal performance of the MP197HB cask with the 61BT DSC at the WCS CISF is evaluated under normal, off-normal, and accident conditions of operation as described above and is shown to satisfy all the 10 CFR Part 72 thermal limits and criteria.

C.8.6 References

C.8-1 Not Used.

C.8-2 U.S. Nuclear Regulatory Commission, "Certificate of Compliance No. 9302, Revision 7 for the Model No. NUHOMS®-MP197 and NUHOMS®-MP197HB Packages (Docket 71-9302).

C.8-3 AREVA TN, "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel," NUH-003, Revision 14, September 2014.

C.8-4 AREVA TN Document, NUH09.101 Rev. 17, "NUHOMS® -MP197 Transportation Package Safety Analysis Report." (Basis for NRC CoC 71-9302).

C.8-5 ANSYS Mechanical APDL, Release 10.0.

C.8-6 U.S. Nuclear Regulatory Commission, Spent Fuel Project Office, Interim Staff Guidance -11 (ISG-11), Revision 3, "Cladding Considerations for the Transportation and Storage of Spent Fuel," November 17, 2003.

Table C.8-1
Maximum Temperature of MP197HB Cask Components for 61BT DSC Transfer at the WCS CISF

	Canister Heat Load 18.3 kW				
	Normal T_{amb}=*44.1* °F	Normal T_{amb}=*81.5* °F	Off-normal T_{amb}=*30.1* °F	Off-normal T_{amb}=*94.6* °F	Accident(1) T_{amb}=*113* °F
Component	T_{max}, °F				
Inner sleeve	<260			260	409
Cask inner shell	<248			248	413
Gamma shield	<247			247	508
Outer shell	<222			222	645
Shield shell	<204			204	1071
Cask lid	<142			142	367
Cask bottom plate	<166			166	309

1 – Bounded by value from Table A.3-19 of [C.8-4].

Table C.8-2
NUHOMS® 61BT DSC Fuel Cladding and Canister Component Temperatures for Transfer in MP197HB Cask at the WCS CISF

	Normal Conditions			Off-Normal Conditions		Accident Conditions	
Component	**Maximum Temperature[1] (°F)**	**Minimum Temperature[5] (°F)**	**Allowable Range (°F)**	***Maximum Temperature* (°F)**	**Allowable Range (°F)**	**Maximum Temperature[4] (°F)**	**Allowable Range (°F)**
Canister Shell	<387	-20	[2]	387	[2]	<662	[2]
Basket Rails	<519	-20	[2]	519	[2]	<722	[2]
Fuel Compartment	<637	-20	[2]	637	[2]	<787	[2]
SNF Cladding	<658	-20	752[3]	658	752[3]	<809	1058[3]
Average Cavity Gas	<369	-20	N/A	369	N/A	<651	N/A

1 – Bounded by off-normal condition.

2 – The components perform their intended safety function within the operating range.

3 – From ISG-11, Revision 3 [C.8-6].

4 – Bounded by HSM blocked vent condition, Section K.4.6.5 [C.8-3].

5 – Assuming no credit for decay heat and a daily average ambient temperature of -20°F. The -20°F off-normal temperature is used to bound the *minimum* normal *ambient* temperature *of 44.1°F listed in Table 1-2*.

APPENDIX C.9
RADIATION PROTECTION
Standardized NUHOMS®-61BT System

Table of Contents

List of Tables

List of Figures

C.9. RADIATION PROTECTION

The Standardized NUHOMS® System Cask System with the NUHOMS® 61BT DSC radiation protection evaluations are documented in Section K.5 of the "Standardized NUHOMS® Horizontal Modular Storage System Safety Analysis Report" [C.9-1].

C.9.1 Radiation Protection Design Features

Details of the Storage Area shielding design features for the Standardized NUHOMS® System Cask System which includes the 61BT DSC stored in an HSM Model 102 are documented in Section 7.3.2.1 *and K.5* of Reference [C.9-1]. *Details of the shielding design features for the MP197HB cask are provided in Section A.5.1.1 of Reference [C.9-2]. Drawing showing the shield thicknesses for the NUHOMS®-61BT DSC and MP197HB cask are listed in Section C.4.6 and for the HSM Model 102 in Section A.4.6.*

C.9.2 Occupational Exposure Evaluation

C.9.2.1 Analysis Methodology

Dose rates are known in the vicinity of the HSM Model 102 and MP197HB casks based upon the existing FSAR [C.9-1] and SAR [C.9-2]. The operational sequence is determined for each system, as well as the associated number of workers, their location, and duration per operation. The collective dose per step is then computed as:

$$C = D*N*T,$$

where

C is the collective dose (person-mrem),

D is the dose rate for each operation (mrem/hr),

N is the number of workers for that operation, and

T is the duration of the operation (hr)

Once the collective dose is determined for each step, the collective doses are summed to create the total collective dose. The total collective dose is determined for a single receipt/transfer operation.

C.9.2.2 Dose Assessment

A dose assessment is performed for receipt and transfer of an 61BT DSC to HSM Model 102 using the MP197HB cask.

Seven general locations around the cask are defined, as shown in the top half of Figure C.9-1: top, top edge, top corner, side, bottom corner, bottom edge, and bottom. These seven general locations are reduced to only three locations for which dose rate information is available, as shown in the bottom half of Figure C.9-1: top, side, and bottom.

A loading operation is divided into receipt and transfer operations. Dose rates for receipt operations are obtained from the transportation SAR for the MP197HB cask*, as discussed below*. Dose rates for the transfer operations are obtained from *Table K.5-2 of* the storage FSAR *[C.9-1]* for the HSM Model 102.

For some configurations, dose rates are not available in the reference transportation SAR or storage FSAR. In these instances, bounding dose rates are obtained for similar systems:

- For receipt of the 61BT DSC inside the MP197HB cask, bounding dose rates for receipt of the 69BTH DSC inside the MP197HB cask *from Table A.5-1 of reference [C.9-2]* are utilized. This approach is conservative because the 69BTH DSC contains a larger source than the 61BT DSC.

- For transfer of the 61BT DSC inside the MP197HB cask, bounding dose rates for transfer of the 69BTH DSC inside the OS200 transfer cask *from Table Y.5-3 of reference [C.9-1]* are utilized. This approach is conservative because the OS200 transfer cask contains less shielding than the MP197HB cask, and the 69BTH DSC contains a larger source than the 61BT DSC.

The configurations used in the dose rate analysis are summarized in Table C.9-1. Results for the various loading scenarios are provided in Table C.9-2 and Table C.9-3. Separate tables are developed for receipt and transfer operations. These tables provide the process steps, number of workers, occupancy time, distance, dose rate, and collective dose for all operations.

The total collective dose for an operation is the sum of the receipt and transfer collective doses. The total collective dose for receipt and transfer of NUHOMS®-61BT DSC to an HSM Model 102 using the MP197HB cask: 1016 person-mrem.

The total collective dose for unloading a 61BT DSC from an HSM Model 102 and preparing it for transport off-site is bounded by the loading operations (1016 person-mrem). Operations for removing the 61BT DSC from the HSM Model 102 and off-site shipment are identical to loading operations, except in reverse order. The collective dose for unloading is bounded because during storage at the WCS CISF the source terms will have decayed reducing surface dose rates. The total collective dose is the sum of the receipt, transfer, retrieval, and shipment is 2032 person-mrem.

C.9.3 References

C.9-1 AREVA TN Document NUH-003, Revision 14, “Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel.” (Basis for NRC CoC 72-1004).

C.9-2 AREVA TN Document, NUH09.101 Rev. 17, “NUHOMS® -MP197 Transportation Package Safety Analysis Report.” (Basis for NRC CoC 71-9302).

Table C.9-1
***Analyses Used for* Receipt and Transfer Configurations**

Actual Configuration	Receipt Analysis Configuration	Transfer Analysis Configuration
61BT DSC transferred from the MP197HB cask into an HSM Model 102	69BTH DSC (bounds 61BT DSC) inside MP197HB cask [C.9-2]	69BTH DSC (bounds 61BT DSC) inside OS200 transfer cask (bounds MP197HB cask) [C.9-1]

Table C.9-2
Occupational Collective Dose for Receipt of MP197HB Cask Loaded with 61BT DSC

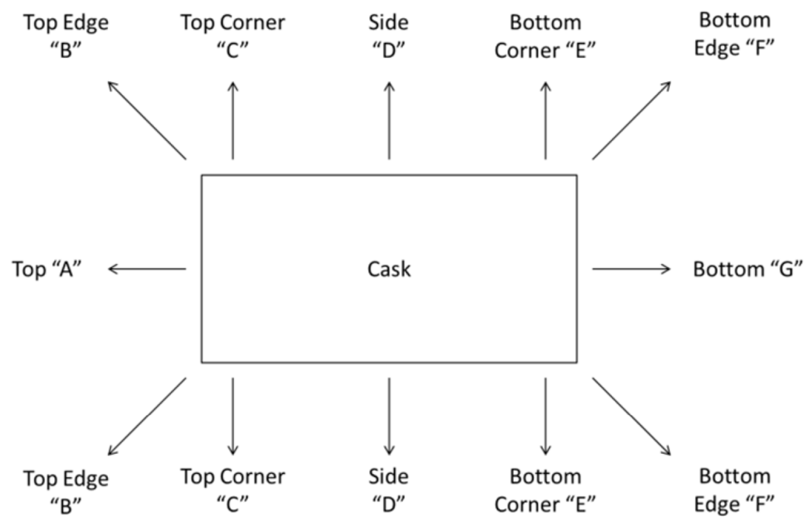
Process Step	Number of Workers	Occupancy Time (hours)	Worker Location Around Cask	Worker Distance (m)	Total Dose Rate (mrem/hr)	Total Dose (person-mrem)*
Verify that the tamperproof seals are intact.	1	0.07	Top	1	3.62	2
	1	0.07	Bottom	1	22.2	
Remove the tamperproof seals.	1	0.07	Top	1	3.62	2
	1	0.07	Bottom	1	22.2	
Remove the hex bolts from the impact limiters and replace them with the impact limiter hoist rings provided. Remove the impact limiters from the cask.	2	0.5	Top Edge	1	3.62	26
	2	0.5	Bottom Edge	1	22.2	
Remove the transportation skid personnel barrier and tie-down straps	3	0.5	Side	1	129	194
Remove the external aluminum fins, if present	---	---	---	---	---	0
Take contamination smears on the outside surfaces of the cask. If necessary, decontaminate the cask.	2	0.17	Top	1	62.24	181
	2	0.17	Side	1	129	
	2	0.17	Bottom	1	338.56	
Install the front and rear trunnions and torque the bolts.	2	0.5	Top Corner	1	3.62	26
	2	0.5	Bottom Corner	1	22.2	
If the packaging contains high burnup fuel assemblies, perform a Radiation Survey (both neutron and gamma) and a Thermal Survey of the cask loaded with the contents to evaluate the axial radiation and thermal source distributions.	2	0.17	Top	1	62.24	181
	2	0.17	Side	1	129	
	2	0.17	Bottom	1	338.56	
Lift the cask from the conveyance. Place cask onto the on-site transfer vehicle or other location.	2	0.5	Side	1	129	129
Transfer the cask to a staging module.	1	0.2	Side	1	129	26
					Total (person-mrem)	767

*Rounded up to nearest whole number

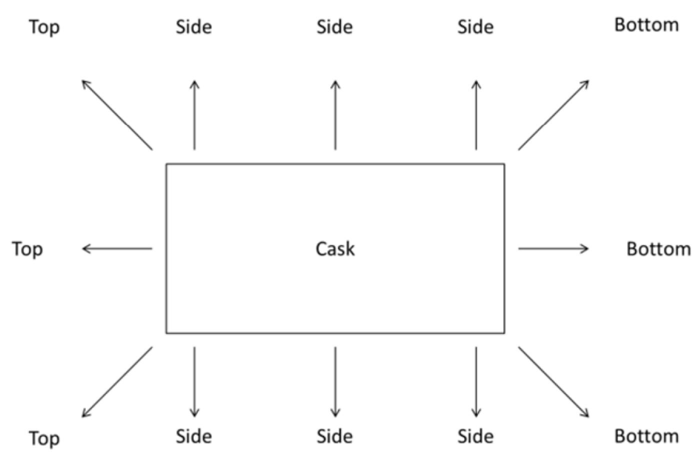
Table C.9-3
Occupational Collective Dose for Transfer of 61BT DSC from MP197HB Cask to HSM Model 102

Process Step	Number of Workers	Occupancy Time (hours)	Worker Location Around Cask	Worker Distance (m)	Total Dose Rate (mrem/hr)	Total Dose (person-mrem)*
Position the Cask Close to the HSM	---	---	---	Far	Background	0
Remove the Cask Lid	2	0.67	Top/Avg. Front HSM	1	41	55
Align and Dock the Cask with the HSM	2	0.25	Top Corner/Avg. Front HSM	1	99	50
Position and Align Ram with Cask	2	0.5	Top Corner/Avg. Front HSM	1	99	99
Remove Ram Access Cover Plate	1	0.083	Bottom	1	258	22
Transfer the DSC to the HSM	---	---	---	Far	Background	0
Un-Dock the Cask	2	0.083	Side/Avg. Front HSM	1	43	8
Install the HSM Access Door	2	0.5	Avg. Front HSM	1	15	15
					Total (person-mrem)	249

*Rounded up to nearest whole number



Detailed Cask Locations



Simplified Cask Locations

Figure C.9-1
Worker Locations Around Cask

APPENDIX C.10
CRITICALITY EVALUATION
Standardized NUHOMS®-61BT System

Table of Contents

C.10. CRITICALITY EVALUATION

The design criteria for the Standardized NUHOMS®-61BT System require that the canister is designed to remain subcritical under normal, off-normal, and accident conditions associated with spent nuclear fuel (SNF) handling, storage and off-site transportation. The design of the canister is such that, under all credible conditions, the highest effective neutron multiplication factor (k_{eff}) remains less than the upper safety limit (USL) of 0.9414 including an administrative margin of 0.05, code bias and bias uncertainties.

C.10.1 Discussion and Results

The 61BT DSC criticality analysis is documented in Chapter K.6 of the "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel" [C.10-1]. This criticality analysis bounds the conditions for transfer and on-site storage at the Waste Control Specialists, LLC (WCS) Consolidated Interim Storage Facility (CISF) because there is no credible event which would result in the flooding of a canister in HSM storage which would result in k_{eff} exceeding the worst case 10 CFR 72 storage conditions evaluated in [C.10-1]. Specific information on the criticality safety analysis which bounds the WCS CISF is discussed in this section.

The 61BT DSC consists of a SNF basket and canister body (shell, canister, inner bottom and top cover plates and shield plugs). The basket structure consists of assemblies of stainless steel SNF compartments held in place by basket rails and holddown rings. The four and nine compartment assemblies are held together by welded stainless steel boxes wrapped around the SNF compartments, which also retain the neutron poison plates between the compartments in the assemblies. The borated aluminum or boron carbide/aluminum metal matrix composite plates or Boral® poison plates provide the necessary criticality control. The compartments are assembled together to store 61 SNF assemblies. The canister is designed to store 61 intact, or up to 16 damaged and the remainder intact, for a total of 61, standard BWR SNF assemblies with or without fuel channels. The canister is also authorized to store SNF assemblies containing Blended Low Enriched Uranium (BLEU) fuel material. Subcriticality during wet loading or unloading, drying, sealing, transfer, and storage operations is maintained through the geometric separation of the SNF assemblies by the basket assembly and the neutron absorbing capability of the 61BT DSC materials.

The continued efficacy of the neutron absorbers is assured when the canister arrives as the WCS CISF because the basket, including poison material, is designed and analyzed to maintain its configuration for all normal, off-normal and accident conditions of storage and for normal and hypothetical accidents during transport in the MP197HB cask as documented in Section 6.4.1.3 of the "NUHOMS®-MP197 Transport Packaging Safety Analysis Report" [C.10-4].

The design basis criticality analysis performed for the 61BT DSC assumes the most reactive configuration of the canister and contents in an infinite array of casks bounding all conditions of receipt, transfer and storage at the WCS CISF where the canisters will remain dry under all conditions of transfer and storage including normal, off-normal and accident conditions as demonstrated in Chapter 12.

The results of the evaluations demonstrate that the maximum calculated k_{eff}, including statistical uncertainty and bias, are less than 0.9414.

C.10.2 Package Fuel Loading

Section 2.1 of the Technical Specifications [C.10-3] lists the SNF assemblies authorized for storage at the WCS CISF. Section 6.2 Spent Fuel Loading of [C.10-1] provides the Package Fuel Loading.

C.10.3 Model Specification

Section 6.3 Model Specification of [C.10-1] provides a discussion of the criticality model canister regional densities used to calculate the bounding k_{eff} for the 61BT DSC.

C.10.4 Criticality Calculation

Section 6.4 Criticality Calculation of [C.10-1] provides a discussion of the criticality calculations that demonstrate that the maximum calculated k_{eff} for the 61BT DSC is less than 0.9414.

C.10.5 Critical Benchmark Experiments

Section 6.5 Critical Benchmark Experiments of [C.10-1] provides a discussion of the benchmark experiments and applicability, details of benchmark calculations, and the results of benchmark calculations, including calculation of the USL.

C.10.6 References

C.10-1 AREVA TN Document NUH-003, Revision 14, "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel." (Basis for NRC CoC 72-1004).

C.10-2 AREVA TN Americas, "Technical Specifications for the Standardized NUHOMS® Horizontal Modular Storage System", USNRC Docket Number 72-1004.

C.10-3 Proposed SNM-1050, WCS *Consolidated* Interim Storage Facility Technical Specifications, Amendment 0.

C.10-4 AREVA TN Document, NUH09.101 Rev. 17, "NUHOMS® -MP197 Transportation Package Safety Analysis Report." (Basis for NRC CoC 71-9302).

APPENDIX C.11
CONFINEMENT EVALUATION
Standardized NUHOMS®-61BT System

Table of Contents

C.11 CONFINEMENT EVALUATION

The design criteria for the NUHOMS® 61BT DSC require that the DSC is designed to maintain confinement of radioactive material under normal, off-normal, and accident conditions associated with fuel handling, storage and off-site transportation.

C.11.1 Confinement Boundary

The NUHOMS®-61BT DSC confinement is documented in Appendix K Chapter 7 of the "Standardized NUHOMS® System Updated Final Safety Analysis Report" [C.11-1]. Section K.7.1 of reference [C.11-1] details the requirements of the confinement boundary. *Figure K.3.1-1 of reference [C.11-1] provides a figure that shows the components and welds that make up the confinement boundary for the 61BT DSC. Drawings for the canisters, including the confinement boundary are referenced in Section C.4.6. In addition, a bounding evaluation in Section C.7.8 is presented to demonstrate that the confinement boundary for the 61BT DSC does not exceed ASME B&PV Subsection NB Article NB-3200 (Level A allowables) during normal conditions of transport to provide reasonable assurance that the confinement boundary is not adversely impacted by transport to the WCS CISF.*

The Technical Specifications for Standards NUHOMS® [C.11-2] outline the requirements for preventing the leakage of radioactive materials in the 61BT-DSC. Section 4.2, "Codes and Standards," lists the codes and standards for design, fabrication, and inspection of the 61BT DSC, including alternatives to the ASME Code for the 61BT DSC confinement boundary and basket.

Section 3.1, "Fuel Integrity," of the Technical Specifications for the Standardized NUHOMS® [C.11-2] includes limiting condition for operation (LCO) 3.1.1 for DSC bulkwater removal medium and vacuum drying pressure and LCO 3.1.2 for DSC helium backfill pressure. These LCOs create a dry, inert atmosphere, which contributes to preventing the leakage of radioactive material.

C.11.2 Requirements for Normal Conditions of Storage

Section K.7.2 of reference [C.11-1] describes how the 61BT-DSC is designed and tested to be "leaktight" to prevent the leakage of radioactive materials. The Technical Specification for Standardized NUHOMS® [C.11-2] outlines the requirements for preventing the leakage of radioactive materials in the 61BT-DSC. *Section 4.2, "Codes and Standards," lists the codes and standards for design, fabrication and inspection of the 61BT DSC, including alternatives to the ASME Code for the 61BT DSC confinement boundary and basket.*

Section 3.1, "Fuel Integrity", of the Technical Specifications for the Standardized NUHOMS® [C.11-2] includes limiting condition for operation (LCO) 3.1.1 for DSC bulkwater removal medium and vacuum drying pressure and LCO 3.1.2 for DSC helium backfill pressure. These LCOs create a dry, inert atmosphere, which contributes to preventing the leakage of radioactive material.

C.11.3 Confinement Requirements for Hypothetical Accident Conditions

Section K.7.3 of reference [C.11-1] provides a discussion on how the Standardized NUHOMS® - 61BT DSC is designed and tested to be "leaktight" to prevent the leakage of radioactive materials following hypothetical accident conditions. The Technical Specification for Standardized NUHOMS® [C.11-2] outlines the requirements for preventing the leakage of radioactive materials following hypothetical accident conditions in the 61BT-DSC. *Section 4.2, "Codes and Standards," lists the codes and standards for design, fabrication and inspection of the 61BT DSC, including alternatives to the ASME Code for the 61BT DSC confinement boundary and basket.*

Section 3.1, "Fuel Integrity," of the Technical Specifications for the Standardized NUHOMS® [C.11-2] includes limiting condition for operation (LCO) 3.1.1 for DSC bulkwater removal medium and vacuum drying pressure and LCO 3.1.2 for DSC helium backfill pressure. These LCOs create a dry, inert atmosphere, which contributes to preventing the leakage of radioactive material.

C.11.4 References

C.11-1 AREVA TN Document NUH-003, Revision 14, "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel." (Basis for NRC CoC 72-1004).

C.11-2 AREVA TN, "Technical Specifications for the Standardized NUHOMS® Horizontal Modular Storage System," *Amendment 13,* USNRC Docket Number 72-1004.

APPENDIX C.12
ACCIDENT ANALYSIS
Standardized NUHOMS®-61BT System

Table of Contents

C.12. ACCIDENT ANALYSIS

This section describes the postulated off-normal and accident events that could occur during transfer and storage for the Standardized NUHOMS® 61BT System canister in a HSM Model 102 storage overpack and use of the MP197HB cask for transfer operations. Detailed analyses are provided in the "Standardized NUHOMS® Horizontal Modular Storage System Safety Analysis Report" [C.12-1] for the canister and HSM Model 102 are referenced herein. Qualification for use of the MP197HB cask as a transfer cask for off-normal and accident conditions is also addressed.

C.12.1 Off-Normal Operations

The off-normal conditions considered for the Standardized NUHOMS® System are off-normal transfer loads, extreme temperatures and a postulated release of radionuclides.

C.12.1.1 Off-Normal Transfer Loads

Off-Normal transfer loads are addressed in Section K.11.1.1 of [C.12-1] which is a "jammed" canister during loading or unloading from the HSM Model 102.

Postulated Cause of the Event

The postulated cause of the event is described in Sections K.11.1.1.1 and 8.1.2 of [C.12-1].

Detection of the Event

Detection of the event is described in Sections K.11.1.1.2 and 8.1.2.1.A of [C.12-1].

Analysis of Effects and Consequences

Sections K.11.1.1.3, K.3.6.2 and K.3.6.1.3.3 of [C.12-1] provides a discussion of the analysis performed and effects and consequences of the event. There is no breach of the confinement pressure boundary and, therefore, no potential for release of radioactive materials.

Corrective Actions

Consistent with Sections K.11.1.1.4 and 8.1.2.1.E of [C.12-1], the required corrective action is to reverse the direction of the force being applied to the canister by the ram, and return the canister to its previous position. Since no permanent deformation of the canister occurs, the sliding transfer of the canister to its previous position is unimpeded. The transfer cask alignment is then rechecked, and the transfer cask repositioned as necessary before attempts at transfer are renewed.

C.12.1.2 Extreme Ambient Temperatures

The design of the Standardized NUHOMS® System envelopes the extreme temperatures at the Waste Control Specialists, LLC (WCS) Consolidated Interim Storage Facility (CISF) as demonstrated in Section C.8.4.

Postulated Cause of the Event

The postulated cause of the event is described in Sections K.11.1.2.1 and 8.1.2.2 of [C.12-1]

Detection of the Event

Detection of the event is described in Sections K.11.1.2.2 and 8.1.2.2 of [C.12-1].

Analysis of Effects and Consequences

Section K.11.1.2.3 of [C.12-1] and Section C.8.6 provides a discussion of the analysis performed and effects and consequences of the event. There is no breach of the confinement pressure boundary and, therefore, no potential for release of radioactive materials.

Corrective Actions

Consistent with Section K.11.1.2.4 of [C.12-1], restrictions for on-site handling of the transfer cask with a loaded canister under extreme temperature conditions are presented in the Technical Specifications [C.12-2].

C.12.1.3 Off-Normal Release of Radionuclides

As described in Section K.11.1.3 of [C.12-1], the canister is designed, fabricated and tested to be leak-tight, therefore there is no possibility for release of radionuclides from the canister under normal, off-normal and accident conditions.

C.12.2 Postulated Accident

The postulated accident conditions for the Standardized NUHOMS®-61BT System with the MP197HB cask in the transfer configuration addressed in this SAR section are:

- Blockage of Air Inlets/Outlets
- Drop Accidents
- Earthquakes
- Lightning
- Fire/Explosion
- Flood
- Tornado Wind and Missiles
- Reduced HSM Air Inlet and Outlet Shielding

C.12.2.1 Blockage of Air Inlets/Outlets

Cause of Accident

Sections K.11.2.7.1 and 8.2.7.1 of [C.12-1] provides the potential causes for blocked air vents for the HSM Model 102.

Accident Analysis

The structural and thermal consequences of blocking the air inlets and outlets are addressed in Sections K.11.2.7.2, K.3.7.7, K.3.4.4.3 and K.4.6 of [C.12-1]. In addition, Chapter C.8 demonstrates that the thermal analysis performed for the Standardized NUHOMS® System with the canister and HSM Model 102 in [C.12-1] is bounding for WCS CISF conditions.

Accident Dose Calculations

Section K.11.2.7.3 of [C.12-1], there are no radiological consequences for this accident condition.

Corrective Actions

Consistent with Sections K.11.2.7.4 and 8.2.7.4 of [C.12-1], blockage of the HSM Model 102 vents is to be cleared within the 40-hour time frame analyzed to restore HSM ventilation.

C.12.2.2 Drop Accidents

Cause of Accident

Sections K.11.2.5.1 and K.3.7.5.1 of [C.12-1] discusses the cask drop for the MP197HB cask in the transfer configuration when it contains the canister.

Accident Analysis

The structural and thermal consequences for the effect of a drop accident are addressed in Section K.11.2.5.2 for the canister and in Appendix C.8 for the MP197HB cask in the transfer configuration. This analysis demonstrates that the canister remains leak tight and the basket maintains its configuration following the drop event. In addition, Chapter C.8 presents the thermal analysis performed for the MP197HB cask for WCS CISF conditions.

Accident Dose Calculations

The accident dose calculations presented in Section K.11.2.5.3 of [C.12-1], are very conservative because the MP197HB cask consists of a solid neutron shield, the source terms for the contents of the canister have significantly decayed prior to transportation to the WCS CISF and the boundary is approximately 0.75 miles from the WCS CISF.

Corrective Action

Consistent with Sections K.11.2.5.4 and 8.2.5.4 of [C.12-1], the canister will be inspected for damage, as necessary. Removal of the transfer cask top cover plate may require cutting of the bolts in the event of a corner drop onto the top end. These operations will take place in the Cask Handling Building.

Following recovery of the transfer cask and transfer of the canister in the HSM, the transfer cask will be inspected, repaired and tested as appropriate prior to reuse.

For recovery of the cask and contents, it may be necessary to develop a special sling/lifting apparatus to move the transfer cask from the drop site to the cask handling building. This may require several weeks of planning to ensure all steps are correctly organized. During this time, temporary shielding may be added to the transfer cask to minimize on-site exposure to WCS CISF operations personnel. The transfer cask would be roped off to ensure the safety of the personnel.

C.12.2.3 Earthquakes

Cause of Accident

Site-specific ground-surface uniform hazard response spectra (UHRS) with 1E-4 annual frequency of exceedance (AFE) having peak ground acceleration (PGA) of 0.250 g horizontal and 0.175 g vertical are shown in Table 1-2, Table 1-5 and Figure 1-5. *The site-specific response spectra are used in the WCS CISF SSI analysis to obtain the enveloped acceleration spectra at the HSM CG and base. Section C.7.3 demonstrates that the MP197HB cask and Standardized NUHOMS® System components are structurally adequate for the WCS CISF site-specific seismic loading.*

Accident Analysis

The structural and thermal consequences of an earthquake are addressed in Sections K.11.2.2.2, 8.2.3.2 and K.3.7 of [C.12-1]. The MP197HB cask, when mounted on the transfer vehicle during an earthquake is evaluated in Appendix C.7. In addition, Chapter C.8 demonstrates that the thermal analysis performed for the Standardized NUHOMS® System in [C.12-1] is bounding for WCS CISF conditions.

Accident Dose Calculations

As documented in Section K.11.2.2.3 of [C.12-1], there are no radiological consequences as a result of a seismic event.

Corrective Actions

Consistent with Section K.11.2.2.4 of [C.12-1], inspection of HSM Model 102s subsequent to a significant earthquake is required to identify potential damage or change in HSM configuration. Repair of damage to HSM concrete components, including shield walls may be necessary. Movement of HSMs as a result of the seismic event will require evaluation and possible repositioning of HSMs and shielding to preseismic event configuration.

C.12.2.4 Lightning

Cause of Accident

As stated in Sections K.11.2.6.1 and 8.2.6 of [C.12-1], the likelihood of lightning striking the HSM and causing an off-normal or accident condition is not considered a credible event. Simple lightning protection equipment for the HSM structures is considered a miscellaneous attachment acceptable per the HSM design.

Accident Analysis

Should lightning strike in the vicinity of the HSM the normal storage operations of the HSM will not be affected. The current discharged by the lightning will follow the low impedance path offered by the surrounding structures or the grounding system installed around each block of HSMs. The heat or mechanical forces generated by current passing through the higher impedance concrete will not damage the HSM. Since the HSM requires no equipment for its continued operation, the resulting current surge from the lightning will not affect the normal operation of the HSM.

Since no accident conditions will develop as the result of a lightning strike near the HSM, no corrective action would be necessary. In addition, there would be no radiological consequences

C.12.2.5 Fire and Explosion

Cause of Accident

As described in Section K.11.2.10.1 of [C.12-1] combustible materials will not normally be stored at the storage pad. Therefore, a credible fire would be very small and of short duration such as that due to a fire or explosion from a vehicle or portable crane.

However, a hypothetical fire accident is evaluated for the NUHOMS®-61BT System based on a diesel fuel fire. The source of fuel is postulated to be from a ruptured fuel tank of the transfer cask transporter vehicle or portable crane. The bounding capacity of the fuel tank is 300 gallons and the bounding hypothetical fire is an engulfing fire around the transfer cask. Direct engulfment of the HSM is highly unlikely. Any fire within the WCS CISF boundary while the canister is in the HSM would be bounded by the fire during transfer cask movement. The HSM concrete acts as a significant insulating firewall to protect the canister from the high temperatures of the fire.

Accident Analysis

The structural and thermal consequences of a fire accident are addressed in Sections K.12.2.10.2 and K.4.6.5 of [C.12-1]. Appendix C.8 demonstrates that the MP197HB cask performs its safety functions during and after the postulated fire/explosion accident. As stated above, the maximum flammable fuel either during the transfer operation or inside the WCS CISF is 300 gallons of diesel fuel.

Accident Dose Calculations

As documented in Section K.11.2.10.3 of [C.12-1], there are minimal radiological consequences for this accident condition.

Corrective Actions

Consistent with Section K.11.2.10.4 of [C.12-1], evaluation of HSM or cask neutron shield damage as a result of a fire is to be performed to assess the need for temporary shielding (for HSM or cask, if fire occurs during transfer operations) and repairs to restore the transfer cask and HSM to pre-fire design conditions.

C.12.2.6 Flood

Cause of Accident

The Probable Maximum flood is considered to occur as a severe natural phenomenon.

Accident Analysis

As documented in Sections 2.4.2.2 and 3.2.2, the WCS CISF is not in a floodplain and is above the Probable Maximum Flood elevation and, therefore, will remain dry in the event of a flood.

C.12.2.7 Tornado Wind and Missiles

Cause of Accident

In accordance with ANSI-57.9 [C.12-4] and 10 CFR 72.122, the Standardized NUHOMS® System components are designed for tornado effects including tornado wind effects. In addition, the HSM and MP197HB cask in the transfer configuration are also design for tornado missile effects. The Standardized NUHOMS® System components (HSM and canister) are designed and conservatively evaluated for the most severe tornado and missiles anywhere within the United States (Region I as defined in NRC Regulatory Guide 1.76 [C.12-5]) while the WCS CISF is in Region II, a less severe location with respect to tornado and tornado missiles. The MP197HB cask in the transfer configuration is evaluated for Region II tornado and tornado missiles.

Accident Analysis

The structural and thermal consequences of the effects of tornado wind and missile loads on the HSM and canister are addressed in Sections K.11.2.3.2, 8.2.2 and K.3.7.2 of [C.12-1]. Similarly, the structural and thermal consequences of tornado wind and missile loads for the MP197HB cask area addressed in Appendices C.7 and C.8.

Accident Dose Calculations

As documented in Section K.11.2.3.3 of [C.12-1], there are no radiological consequences for this accident condition.

Corrective Actions

Consistent with Sections K.11.2.3.4 and 8.2.2 of [C.12-1], evaluation of HSM damage as a result of a Tornado is to be performed to assess the need for temporary shielding and HSM repairs to return the HSMs to pre-tornado design conditions.

C.12.2.8 Reduced HSM Air Inlet and Outlet Shielding

This event is described in Section 8.2.1 of [C.12-1] for the Standardized NUHOMS® System. This event is a postulated accident of partial loss of shielding for the HSM air inlet and outlet vents provided by the adjacent HSM Model 102. All other components of the NUHOMS® System are assumed to be functioning normally.

Cause of Accident

Sections K.11.2.1.1 and 8.2.1.1 of [C.12-1] provides the causes for the accident.

Accident Analysis

The structural and thermal consequences for the accident are addressed in Section K.11.2.1.2 of [C.12-1].

Accident Dose Calculations

Section K.11.2.1.3 of [C.12-1] provides a bounding evaluation which demonstrates that the 10CFR72 requirements for this postulated event are met. The analysis is bounding because the source terms assumed for the canister at the WCS CISF have experienced significant decay in order to meet shipping requirements and the boundary is approximately 0.75 miles from the WCS CISF which is significantly farther than the 2000 feet assumed in the evaluation.

Corrective Actions

Consistent with Sections K.11.2.1.4 and 8.2.1.4 of [C.12-1], to recover from an accident resulting in a partial loss of adjacent HSM shielding effects, repositioning of the adjacent HSM is required. This can be done using hydraulic jacks or a suitable crane to reposition the affected HSMs. It is estimated that the entire operation could be completed in less than eight hours, of which a mechanic would be on the HSM roof for approximately two hours. During this time he receives a dose of less than 2270 mrem. An additional dose to the mechanic and to the crane operator on the ground during this operation will be less than 597 mrem each (assuming an average distance of ten feet from the center of the HSM front wall). Severe foundation settlement would require that the affected HSMs be taken out of service and that repairs to the foundation be made.

C.12.3 References

C.12-1 AREVA TN Document NUH-003, Revision 14, "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel." (Basis for NRC CoC 72-1004).

C.12-2 Proposed SNM-1050, WCS *Consolidated* Interim Storage Facility Technical Specifications, Amendment 0.

C.12-3 NRC Regulatory Guide 1.60, Rev. 1, "Design Response Spectra for Seismic Design of Nuclear Power Plants," Dec 1973.

C.12-4 American National Standards Institute, American Nuclear Society, ANSI/ANS 57.9 1984, Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type).

C.12-5 NRC Regulatory Guide 1.76, "Design Basis Tornado and Tornado Missiles for Nuclear Power Plants," 1974.