APPENDIX D.1
INTRODUCTION AND GENERAL DESCRIPTION OF INSTALLATION
Standardized NUHOMS®-61BTH Type 1 System

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D.1. INTRODUCTION AND GENERAL DESCRIPTION OF INSTALLATION

No change or additional information required for the Standardized NUHOMS® System containing the NUHOMS® 61BTH DSCs for Chapter 1.

APPENDIX D.2
SITE CHARACTERISTICS
Standardized NUHOMS®-61BTH Type 1 System

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D.2. SITE CHARACTERISTICS

No change or additional information required for the Standardized NUHOMS® System containing the NUHOMS® 61BTH DSCs for Chapter 2.

APPENDIX D.3
PRINCIPAL DESIGN CRITERIA
Standardized NUHOMS®-61BTH Type 1 System

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D.3. PRINCIPAL DESIGN CRITERIA

The Standardized NUHOMS®-61BTH Type 1 System (referred to as 61BTH in this appendix) principal design criteria is documented in Chapter T.2 of the "Standardized NUHOMS® Horizontal Modular Storage System Safety Analysis Report" [D.3-1]. Table D.3-1 provides a comparison of the Standardized NUHOMS®-61BTH Type 1 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®-61BTH Type 1 System bounds the WCS CISF criteria.

D.3.1 SSCs Important to Safety

The classifications of the NUHOMS®-61BTH Type 1 System systems, structures and components, are discussed in Section T.2.3 of the "Standardized NUHOMS® Horizontal Modular Storage System Safety Analysis Report" [D.3-1]. These classifications are summarized in Table D.3-2 for convenience.

D.3.1.1 61BTH-DSCs (Type 1)

The 61BTH-DSC provides fuel assembly support required to maintain the fuel geometry for criticality control. Accidental criticality inside a 61BTH-DSC could lead to off-site doses comparable with the limits in 10 CFR Part 100 which must be prevented. The 61BTH-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 its function to provide confinement of the spent fuel assemblies. The DSCs are important-to-safety (ITS).

D.3.1.2 Horizontal Storage Module

For the Standardized NUHOMS®-61BTH Type 1 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 [D.3-4] and constructed to ACI-318 [D.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).

D.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.

D.3.1.4 NUHOMS® Transfer Equipment

The MP197HB transportation cask is qualified for transfer operations for Standardized NUHOMS®-61BTH Type 1 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.

D.3.2 Spent Fuel to Be Stored

The authorized content for the 61BTH Type 1 DSCs are described in Certificate of Compliance 72-1004 [D.3-6] and the “Standardized NUHOMS® Horizontal Modular Storage System Safety Analysis Report” [D.3-1]*; except fuel assemblies with burnups greater than 45 GWd/MTU will not be stored at the WCS CISF in a 61BTH Type 1 canister*.

Certificate of Compliance 72-1004 Technical Specifications Table 1-1t [D.3-6] provides a description of the fuels stored in the 61BTH Type 1 DSCs as referenced in Section T.2.1 “Spent Fuel to be Stored” of the “Standardized NUHOMS® Horizontal Modular Storage System Safety Analysis Report” [D.3-1]*; except fuel assemblies with burnups greater than 45 GWd/MTU will not be stored at the WCS CISF in a 61BTH Type 1 canister*.

D.3.3 Design Criteria for Environmental Conditions and Natural Phenomena

D.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 T.2.2.1 and Section 3.2.5 of reference [D.3-1] and in Table D.3-1 for the NUHOMS®-MP197HB cask. The 61BTH-DSC and HSM Model 102 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 [D.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 tornadoes 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.

D.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.

D.3.3.3 Seismic Design

The seismic criteria for the Standardized NUHOMS® System HSM Model 102 are provided in Section T.2.2.3 and Section 8.2 of reference [D.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®-61BTH Type 1 System components.*

D.3.3.4 Snow and Ice Loading

The design basis snow and ice loading for the Standardized NUHOMS® -61BTH Type 1 System are provided in Section T.2.2.4 and Section 3.2.4 of reference [D.3-1]. Snow and ice loads for the HSM are conservatively derived from ANSI A58.1 1982 [D.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®-61BTH Type 1 System components envelopes the maximum WCS CISF snow and ice loads of 10 psf.

D.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.

D.3.4 Safety Protection Systems

The safety protection systems of the NUHOMS®-61BTH Type 1 System are discussed in Section T.2.3 of the "Standardized NUHOMS® Horizontal Modular Storage System Safety Analysis Report" [D.3-1].

D.3.4.1 General

The NUHOMS®-61BTH Type 1 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 D.3-2. The key elements of the NUHOMS®-61BTH Type 1 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.

D.3.4.2 Structural

The principal design criteria for the DSCs are presented in Section T.2.5 of the "Standardized NUHOMS® Horizontal Modular Storage System Safety Analysis Report" [D.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" [D.3-10]. The cask is designed to transfer the loaded DSCs to the HSM.

D.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.

D.3.4.4 Shielding/Confinement/Radiation Protection

The shielding performance and radiation protection requirements for the Standardized NUHOMS(R)-61BT System are described in Sections T.2.3.5 and 3.3.5 of Reference [D.3-1]. The confinement performance requirements for the Standardized NUHOMS®-61BT System are described in Section T.2.3.2 of Reference [D.3-1] for storage conditions. In addition, a bounding evaluation in WCS CISF SAR Section D.7.8 is presented to demonstrate that the confinement boundary for the 61BTH Type 1 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.

D.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.

D.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 [D.3-7], with the listing of ASME Code alternatives for the DSCs provided in Tables T.3.1-2 and T.3.1-3 of the "Standardized NUHOMS® Horizontal Modular Storage System Safety Analysis Report" [D.3-1]. The code alternatives applicable to the MP197HB Cask are provided in Appendix A.2.13.13 of reference [D.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.

D.3.4.7 Operating Procedures

The sequence of operations are outlined for the NUHOMS®-61BTH Type 1 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®-61BTH Type 1 System.

D.3.5 References

D.3-1 AREVA TN Americas, "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel," NRC Docket No. 72-1004, AREVA TN Americas Document No. NUH-003, Revision 14.

D.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).

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

D.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).

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

D.3-6 Certificate of Compliance 72-1004, Amendment all.

D.3-7 American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NB, 1998 Edition including 2000 Addenda.

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

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

D.3-10 AREVA TN Document, NUH09.101 Rev. 17, "NUHOMS® -MP197 Transportation Package Safety Analysis Report." (Basis for NRC CoC 71-9302).

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

Design Parameter	WCS CISF Design Criteria	Condition	NUHOMS®-61BTH Type 1 Design Criteria
Type of fuel	Commercial, light water reactor spent fuel	Normal (Bounded)	*Standardized NUHOMS® FSAR Section T.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® FSAR Section, T.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® FSAR Sections 3.2.1 and T.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 D.7.7 and 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 D.3-1
Summary of WCS CISF Principal Design Criteria
(*5* pages)

Design Parameter	WCS CISF Design Criteria	Condition	NUHOMS®-61BTH Type 1 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® FSAR Sections 3.2.1 and T.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 200 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)	*Sections D.7.7 and 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.*s	Accident (Bounded)	*Standardized NUHOMS® FSAR Sections 3.2.2 and T.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 Sections 7.6.4, 7.6.5, D.7.5.3, and D.7.6*
Vent Blockage	For NUHOMS® Systems: Inlet and outlet vents blocked 40 hrs	Accident (Same)	*Standardized NUHOMS® FSAR Section T.4.4.5* Inlet and outlet vents blocked 40 hrs
Fire/Explosion	For NUHOMS® Systems: Equivalent fire 300 gallons of diesel fuel	Accident (Same)	*Standardized NUHOMS® FSAR Sections 3.3.6 and T.2.3.6* Equivalent fire 300 gallons of diesel fuel

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

Design Parameter	WCS CISF Design Criteria	Condition	NUHOMS®-61BTH Type 1 Design Criteria
Cask Drop	For NUHOMS® Systems: Transfer Cask Horizontal side drop or slap down 80 inches(2)	Accident (Same)	*Sections D.7.7 and 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 D.7.7 and C.7.7 (New Evaluation) and Standardized NUHOMS® SAR Section, T.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 D.7.7 and C.7.7 (New Evaluation) and Standardized NUHOMS® FSAR Section, T.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)	*Section D.8.5 (New Evaluation) and Standardized NUHOMS® FSAR Section, T.4.4.3* Normal temperature 0 - 100°F(1)
Off-Normal Temperature	Minimum temperature 30.1°F Maximum temperature *113*°F	Off-Normal (Bounded)	*Section D.8.5 (New Evaluation) and Standardized NUHOMS® FSAR Section, T.4.4.3* Minimum temperature -40.0°F Maximum temperature 125°F
Extreme Temperature	Maximum temperature 113°F	Accident (Bounded)	*Sections D.8.5 (New Evaluation) and Standardized NUHOMS® FSAR Section, T.4.4.3* Maximum temperature 125°F

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

Design Parameter	**WCS CISF Design Criteria**	**Condition**	**NUHOMS®-61BTH Type 1 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)	*Section D.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 T.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 T.3.2, T.3.6.1.1, T.3.6.1.2, T.3.6.1.3 and Tables T.2-14, T.3.2-1 and T.3.2-2* [D.3-1]
Internal and External Pressure Loads	Per design basis for systems listed in Table 1-1	Normal (Same)	*Standardized NUHOMS® FSAR Sections T.3.6.1, T.3.6.2, and Table T.2-14* [D.3-1]
Design Basis Thermal Loads	Per design basis for systems listed in Table 1-1	Normal (Same)	*Standardized NUHOMS® FSAR Sections T.3.6.1.1, T.3.6.1.2, T.3.6.1.3, T.3.6.2 and Table T.2-14* [D.3-1]
Operating Loads	Per design basis for systems listed in Table 1-1	Normal (Same)	*Standardized NUHOMS® FSAR Sections T.3.6.1.1, T.3.6.1.2, T.3.6.1.3 and Table T.2-14* [D.3-1]
Live Loads	Per design basis for systems listed in Table 1-1	Normal (Same)	*Standardized NUHOMS® FSAR Section T.3.6.1.1* Design Load (including snow and ice) 200psf

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

Design Parameter	WCS CISF Design Criteria	Condition	NUHOMS®-61BTH Type 1 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 ≤ 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(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 T.7*
Nuclear Criticality	Per design basis for systems listed in Table 1-1	N/A	*Standardized NUHOMS® FSAR Section T.6*
Decommissioning	Minimize potential contamination	Normal (Same)	*Standardized NUHOMS® FSAR Sections 9.6 and T.1.4* 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 Sections T.2.3.2 and T.7* 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. 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 D.3-2
NUHOMS®-61BTH Type 1 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 D.4
OPERATING SYSTEMS
Standardized NUHOMS®-61BTH Type 1 System

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D.4. OPERATING SYSTEMS

This Appendix provides information on the operating systems applicable to the Standardized NUHOMS® System with the NUHOMS® 61BTH Type 1 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.

D.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 D.4.1.3, the basemat and approach slabs are not-important-to-safety (NITS).

D.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.

D.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 D.4-1. The values shown in Table D.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 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 [D.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 [D.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 D.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.

D.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.

D.4.2 Cask Storage System

This section is applicable to the *NUHOMS® 61BTH Type 1 DSC;* NUHOMS® HSM Model 102 *and MP197HB cask configured for transfer operations*.

D.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® 61BTH Type 1* DSCs (canisters). These canisters provide a convenient means to place quantities of SNF into dry storage in a way that allows easy retrieval of the canisters for off-site shipment.

The NUHOMS® 61BTH Type 1 DSCs 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® 61BTH Type 1 DSCs are shown in drawing NUH61BH-1000-SAR Revision 3 included in Section D.4.6.*

The HSM Model 102 is designed in accordance with 10 CFR 72, and provides horizontal on-site storage of the sealed SNF. The main function of the HSM Model 102 is to provide safe, long-term storage of NUHOMS® 61BTH Type 1 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-71-1005 Revision 4, MP197HB-71-1014 Revision 1, MP197HB-71-1006 Revision 2, MP197HB-71-1002 Revision 6 and MP197HB-71-1004 Revision 4, included in Section C.4.6.

D.4.2.2 Design Description

The NUHOMS® 61BTH Type 1 DSCs are stainless steel flat head pressure vessels that provide confinement that is designed to withstand all normal condition loads as well as 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.

D.4.2.3 Safety Considerations

The NUHOMS® 61BTH Type 1 DSCs are important-to-safety (ITS), Quality Category A components.

The HSM Model 102 is an ITS, Quality Category B component. *The MP-197HB Cask is an ITS, Quality Category A component.*

D.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 D.4.3.3, this equipment is NITS.

D.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 Cask Handling Building and the Storage Area and transfer the canister from the MP197HB cask to the HSM Model 102.

D.4.3.2 Design Description

This 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 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.

D.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 area; therefore, it is NITS and is designed, constructed, maintained, and tested as commercial-grade items.

D.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 [D.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.

D.4.5 References

D.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).

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

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

D.4.6 Supplemental Data Drawings

The following drawing is located as noted below:

1. *"NUHOMS® 61BTH DSC Type 1 Main Assembly (five sheets)," NUH61BH-1000-SAR, Revision 3 (See Section T.1.5 of Appendix T of the "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel" [D.4-1]).*

Table D.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 D.4-2
HSM Model 102 Overall Dimensions

Width	Depth	Height
122”	228”	180”

APPENDIX D.5
OPERATING PROCEDURES
Standardized NUHOMS®-61BTH Type 1 System

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D.5. OPERATING PROCEDURES

This chapter presents the operating procedures for the Standardized NUHOMS® System containing the NUHOMS® 61BTH Type 1 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 61BTH Type 1 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®-61BTH Type 1 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®-61BTH Type 1 System operations are presented in Figure D.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®-61BTH Type 1 DSC.
- HSM is used for the HSM Model 102.

D.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 D.5-1.

D.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 [D.5-1]*, and must remain consistent with* [D.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 [D.5-1].

   Note: The WCS CISF is not authorized to accept high burnup fuel assemblies in the 61BTH Type 1 DSC at this time.
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 [D.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 cask 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 [D.5-3] requirements.

D.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 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 [D.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. 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: 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.

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.

D.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 [D.5-2] requirements, or, perform a temperature measurement for each EOS-HSM in accordance with Section 5.1.3(b) of the Technical Specifications [D.5-2] requirements.

D.5.2 Procedures for Unloading the DSC

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

D.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 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 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*.

D.5.3 References

D.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).

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

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

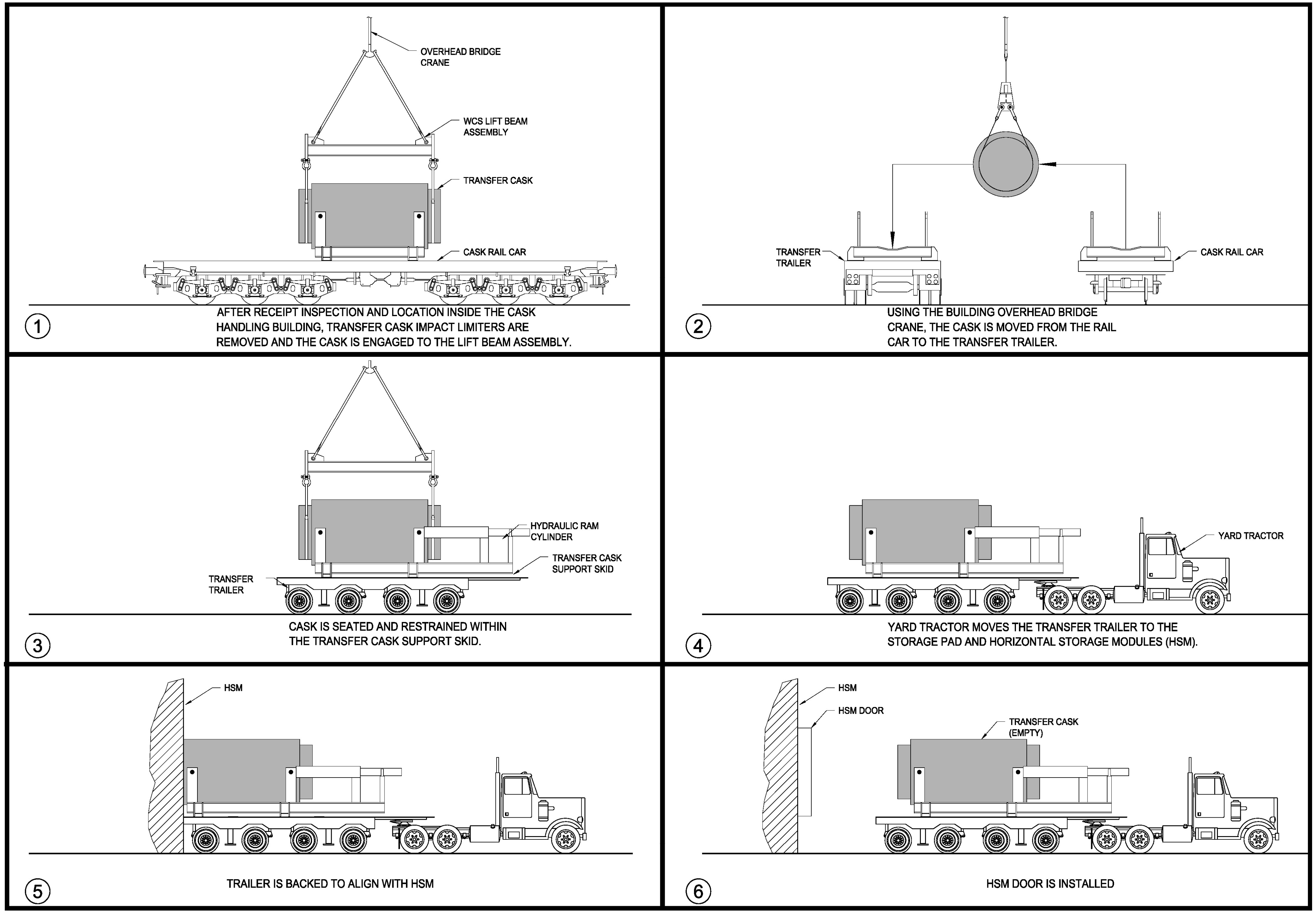

Figure D.5-1
Standardized NUHOMS®-61BTH Type 1 System Loading Operations

APPENDIX D.6
WASTE CONFINEMENT AND MANAGEMENT
Standardized NUHOMS®-61BTH Type 1 System

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D.6. WASTE CONFINEMENT AND MANAGEMENT

No change or additional information required for the Standardized NUHOMS® System containing the NUHOMS® 61BTH DSCs for Chapter 6.

APPENDIX D.7
STRUCTURAL EVALUATION
Standardized NUHOMS®-61BTH Type 1 System

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D.7. STRUCTURAL EVALUATION

This Appendix describes the structural evaluation of the Standardized NUHOMS®-61BTH Type 1 System components utilized for transfer and storage of the 61BTH Type 1 canister at the Waste Control Specialists, LLC (WCS) Consolidated Interim Storage Facility (CISF). As presented in Chapter 1, Table 1-1, the Standardized NUHOMS® System storage components include the 61BTH Type 1 Dry Shielded Canister (DSC or canister) and the HSM Model 102 storage overpack. At the WCS CISF, the MP197HB transportation cask will be 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) [D.7-2]. The 61BTH Type 1 DSC is described in detail in Section T.1.2 of [D.7-2]. Both of these components are approved by the NRC in Certificate of compliance (CoC) No. 1004 for transfer and storage of spent nuclear fuel (SNF) under the requirements of 10 CFR Part 72.

The MP197HB cask is described in Section A.1.2 of the NUHOMS®-MP197 Transportation Package Safety Analysis Report (SAR) [D.7-1]. The MP197HB cask is approved by the NRC in CoC No. 9302 for off-site transportation of SNF under the requirements of 10 CFR Part 71. The evaluation of the MP197HB cask for on-site transfer operations under 10 CFR Part 72 is contained in Appendix C.7.

The evaluation of the 61BTH Type 1 DSC for transfer and storage of SNF is contained in Appendix T of [D.7-2]. The evaluation of the HSM Model 102 is contained in Chapter 8 of the Standardized NUHOMS® Updated Final Safety Analysis Report [D.7-2].

Section D.7.3 presents a seismic reconciliation evaluation for the HSM Model 80/102 and for the 61BTH Type 1 DSC. This reconciliation, in combination with evaluations in the Standardized NUHOMS® Updated Final Safety Analysis Report [D.7-2] and evaluations of the MP197HB cask in Appendix C.7 demonstrate that the MP197HB cask / 61BTH Type 1 / HSM Model 102 transfer and storage system components satisfy all of the 10 CFR Part 72 requirements for storage at the WCS CISF.

Qualification of the 61BTH Type 1 DSC confinement boundary during Normal Conditions of Transport is addressed in Section D.7.8

<u>Transfer Cask</u>

The principal design criteria for the MP197HB cask for service at the WCS CISF are described in Table D.3-1 of Appendix D.3 and 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 and its DSC steel support structure are discussed in Section 3.2.5.1 of the Standardized NUHOMS® Updated Final Safety Analysis Report [D.7-2].

Dry Shielded Canister

The 61BTH Type 1 DSC design approach, design criteria and load combinations for transfer and storage are summarized in Appendix T, Sections T.2 and T.3 of the Standardized NUHOMS® Updated Final Safety Analysis Report [D.7-2].

D.7.1 Discussion

As discussed in Chapter 1, the 61BTH Type 1 DSCs from an Interim Spent Fuel Storage Installation (ISFSI) site will be transported to the WCS CISF in the NUHOMS® MP197HB transportation cask under NRC Certificate of Compliance 9302 [D.7-1]. At the WCS CISF, the 61BTH Type 1 DSCs, described in Appendix T of [D.7-2], are to be stored inside the HSM Model 102 described in Chapter 4 of [D.7-2].

The 61BTH Type 1 DSC is licensed under NRC Certificate of Compliance (CoC) 1004 [D.7-2] for storage in the HSM Model 102 and for transfer operations in the OS197 transfer cask. This appendix reconciles the analyses of the 61BTH Type 1 DSC for transfer operations in the OS197 transfer cask with the transfer operations in the MP197HB cask at the WCS CISF.

As described in Chapter 3, with the exception of seismic loading, the design criteria for the Standardized NUHOMS® components 61BTH Type 1 and HSM Model 102 as described in [D.7-2] envelop the design criteria for the WCS CISF.

Finally, bounding evaluations in Section D.7.8 are referenced to demonstrate that the confinement boundaries for the 61BTH Type 1 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.

D.7.2 Summary of Mechanical Properties of Materials

The material properties for the 61BTH Type 1 DSC are given in Appendix T Section T.3.3 of [D.7-2].

The material properties for the HSM Model 102 are given in Table 8.1-3 of [D.7-2].

The material properties for the MP197HB cask are given in Chapter A.2.2 of [D.7-1].

D.7.3 Seismic Reconciliation of the Canister, HSM Model 102, and MP197HB Cask

The WCS CISF 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 is described in Chapter 2. A comparison of the WCS CISF site-specific response spectra and the Regulatory Guide 1.60 response spectra is shown in Figure D.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 Standardized NUHOMS® System as documented in Section 3.2.3 of [D.7-2].

This section describes the reconciliation evaluations of the 61BTH Type 1 DSC and the HSM Model 102 *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 7%-damped WCS CISF 10,000-year return period uniform hazard response spectra and +/-15% peak-broadened HSM center of gravity (CG) response spectra from the WCS CISF SSI analysis in the HSM's transverse, longitudinal, and vertical directions are shown in Figure D.7-4, Figure D.7-5, and Figure D.7-6, respectively. The +/-15% peak-broadened HSM CG response spectra for damping values of 7%, 3%, and 2% are shown in Figure D.7-7 through Figure D.7-9.* Section C.7.3.2 presents the reconciliation evaluation of the MP197HB cask as a transfer cask.

D.7.3.1 HSM Model 80 and Model 102

The seismic analysis of the HSM (Model 80 and Model 102, *herein* referred *to* as "HSM") is described in Section 8.2.3 of [D.7-2]. This analysis is reconciled in consideration of the *enveloping response spectra at the HSM CG obtained from the WCS CISF SSI analysis, which are shown in Figure D.7-7 through Figure D.7-9.* The same analysis methodology as used for the seismic evaluation of the HSM in Section 8.2.3.2.B in [D.7-2] is used for this reconciliation evaluation.

A dynamic response spectrum analysis is performed using the HSM ANSYS model shown in Figure 8.1-22 of [D.7-2] and the *7% damped response spectra at the HSM CG obtained from the WCS CISF SSI analysis. The ANSYS code Release 10.0 [D.7-4] is used for the analysis. The model includes an 88.7 kips canister, which is the weight of the 61BTH Type 1 DSC and also the bounding weight of the canister types considered in this application.* The forces and moments in the various HSM concrete and steel components of the HSM are evaluated and compared to previous results as applicable.

D.7.3.1.1 HSM Modal Frequency Analysis

A modal frequency analysis is performed to extract the frequencies and associated mode shapes of the HSM model shown in Figure 8.1-22 of [D.7-2]. The modal analysis results indicate that the lowest frequency of *20.76* Hz corresponds to the DSC steel support structure in the transverse horizontal direction. The corresponding mode shapes are shown in Figure D.7-2 and Figure D.7-3. The *other* predominant frequencies corresponding to the HSM concrete/steel support structure are *28.90*Hz, *34.41* Hz, and *44.58* Hz in the axial, transverse, and vertical directions, respectively.

D.7.3.1.2 HSM Response Spectrum Analysis

The 7%-damped response spectra at the HSM CG obtained from the WCS CISF SSI analysis are applied to the ANSYS HSM model to perform a response spectrum analysis. Forces and moments resulting from the analysis are used in the seismic load combination (deadweight + live load + normal thermal + seismic loading).

The effect of the increase in canister weight on the non-seismic load combinations has been evaluated in [D.7-2] for a bounding canister weight of up to 102 kips for the 32PT DSC. Therefore, only the seismic load combination is addressed in this reconciliation evaluation.

The results of the seismic reconciliation analyses are discussed in the following sections.

D.7.3.1.3 Evaluation of the HSM Concrete Components

The forces and moments for each HSM subcomponent (roof slab, walls, floor slab) are determined for the WCS CISF spectra *obtained from the SSI analysis,* and then compared to their respective capacities, calculated as described in Section 8.1.1.5.E of [D.7-2]. The comparison is shown in Table D.7-1. As seen in this table, the demand-to-capacity ratios for all the HSM concrete subcomponents are less than 1.0. Therefore, the HSM concrete components are acceptable for the WCS CISF site-specific seismic loading.

D.7.3.1.4 Evaluation of the DSC Steel Support Structure

The forces and moments and resulting stresses for each DSC steel support structure component are determined for the WCS CISF spectra obtained from the SSI analysis, and then compared to AISC code allowables as described in Section 8.2.10.6 of [D.7-2]. As seen in the comparison shown in Table D.7-2, the maximum stresses or stress interaction ratios are less than the allowables. Therefore, the DSC steel support structure components are qualified and are acceptable for the WCS CISF site-specific seismic loading.

D.7.3.1.5 Evaluation of Miscellaneous Components

D.7.3.1.5.1 Evaluation of the DSC Axial Retainer

The evaluation of the DSC axial retainer is described in Section 8.2.3.2(C)(iii) of [D.7-2]. The seismic load on the retainer is calculated below for the WCS CISF site-specific seismic loading.

[ ]

The maximum shear and bending stresses in the DSC axial retainer are 19.8 ksi and 25.8 ksi, respectively. The allowable shear and bending stresses are 23.5 ksi and 44.3 ksi, respectively. Therefore, the DSC axial retainer stresses are within allowable values.

D.7.3.1.5.2 Evaluation of the Heat Shields

[ ]

The heat shield studs are evaluated for the axial, shear and bending forces due to the WCS CISF site-specific loading. The stiffness of the 3/8” diameter studs is calculated and used to determine the natural frequency of the heat shield panels in the in-plane directions. The corresponding seismic accelerations are combined with deadweight loading to determine the maximum loads on the studs. The maximum axial, bending, and shear stresses in the studs are found to be *1.59* ksi, *14.05* ksi, and *0.40* ksi, respectively. The maximum stress ratio is found to be *0.43* for combined axial plus bending stress.

Therefore, the heat shield plates and studs are acceptable for the WCS CISF seismic loading.

D.7.3.1.6 Evaluation of HSM Seismic Stability and Sliding

The HSM is evaluated for seismic *sliding and overturning stability* due to the WCS CISF site-specific loading. *The maximum sliding distance, rocking angle, and uplift height from the WCS CISF SSI analysis are 0.19", 0.05°, and 0.08", respectively.* Therefore, the sliding *and overturning stability* characteristics of the HSM are acceptable for the WCS CISF seismic loading.

D.7.3.2 MP197HB Cask as On-Site Transfer Cask

The seismic reconciliation is contained in Section C.7.3.2.

D.7.3.3 61BTH Type 1 DSC

Per Section T.3.7.2.1 of Reference [D.7-2], 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 T.3.6.1.3.4 of D.7-2].

D.7.4 Reconciliation of Thermal Loads for the Canister in the HSM Model 102 and in the MP197HB Cask

As noted in Appendix D.8, the thermal performance of the HSM Model 102 with the 61BTH Type 1 DSC at the WCS CISF for normal, off-normal, and accident conditions is bounded by the design basis evaluations as described in Appendix T.4 of [D.7-2]. Since the temperatures of the canister components during storage at the WCS CISF are bounded by the analyses in [D.7-2], 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 61BTH Type 1 DSC for transfer conditions at the WCS CISF for normal, off-normal, and accident conditions in the MP197HB cask are detailed in Appendix D.8. Comparison of the maximum canister component temperatures shown in Table D.8-2 (for transfer conditions at the WCS CISF) and Table T.4-18 of [D.7-2] indicates the following:

- The canister shell temperature for the off-normal condition increases by 8ºF (2%) for transfer in the MP197HB cask at the WCS CISF.
- The canister internal basket component temperatures are lower or essentially equal (1ºF increase for fuel compartment temperature) for transfer in the MP197HB cask at the WCS CISF.

The very small increase in temperature is inconsequential for the thermal stress evaluations as the temperatures used to determine the component material properties and allowable stresses in Table T.3.7-12, Table T.3.7.14, and Table T.3.7.16 of [D.7-2] bound the maximum temperatures during transfer in the MP197HB cask.

Therefore, it is concluded that the temperature distributions and thermal stresses for normal, off-normal, and accident conditions in [D.7-2] are applicable for transfer of the 61BTH Type 1 DSC in the MP197HB cask.

D.7.5 Structural Analysis of Canister (Storage and Transfer)

The structural analysis of the 61BTH Type 1 DSC for normal, off-normal, and accident loads is presented in Sections T.3.6.1, T.3.6.2, and T.3.7 respectively, of [D.7-2]. Loading types applicable to each affected component are summarized in Table T.3.6-1, Table T.3.6-2, and Table T.3.7-1 for normal, off-normal, and accident conditions, respectively, of [D.7-2]. Results for normal and off-normal loads are summarized in Table T.3.7-12 of [D.7-2]. Results for accident loads are presented in Table K.3.7-14 of [D.7-2].

The evaluations of the 61BTH Type 1 DSC for transfer loads performed in [D.7-2] Appendix T and summarized below in Sections D.7.5.1 through D.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. Transportation (and transfer) of the 61BTH Type 1 DSC in the MP197HB cask requires the use of a sleeve installed inside the cask. The dimensions of the above-mentioned geometric parameters for the MP197HB cask with the internal spacer sleeve are compared to the same geometric parameters dimensions for the OS197 transfer cask, as follows:

- Cavity Diameter: OS197 transfer cask 68.00”
  MP197HB cask with sleeve: 68.00”
- Rail Locations: OS197 transfer cask: ±18.5°
  MP197HB cask with sleeve: ±18.5° and ±38°
- Rail Width: OS197 transfer cask: 3.00”
  MP197HB cask with sleeve: 3.00”
- Rail Thickness: OS197 transfer cask: 0.12”
  MP197HB cask with sleeve: (0.62”-0.50” inset =) 0.12”

As shown above, all of the critical dimensions are identical. The MP197HB cask has an additional set of rails (at ± 38º) 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 canister analyses. Since the interface dimensions are the same, the analyses of the 61BTH Type 1 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, contains 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 casnister are based only on the maximum hydraulic ram force and the diameter of the casnister.

Based on the reconciliations presented above, the 61BTH Type 1 DSC calculations performed in [D.7-2] and discussed below in Section D.7.5.1, Section D.7.5.2, and Section D.7.5.3 involving use of the OS197 transfer cask are applicable for loading and unloading of the 61BTH Type 1 DSC with the MP197HB cask.

The following is a summary of the structural analyses of the 61BTH Type 1 DSC shell and basket assemblies.

D.7.5.1 Normal Loads (Storage in HSM Model 102 and Transfer in MP197HB Cask)

The structural analysis of the 61BTH Type 1 DSC for normal loads is presented in Section T.3.6.1 of [D.7-2].

Canister Shell Assembly

Section T.3.6.1.2 of [D.7-2] describes the 61BTH Type 1 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 T.3.6-4 of [D.7-2]. The calculated stresses for each load case are combined in accordance with the load combinations presented in Table T.2-11 of [D.7-2]. The resulting stresses for the controlling load combinations are reported in Section T.3.7.12 of [D.7-2]. All stresses are within the ASME Code allowable stresses.

Basket Assembly

Section T.3.6.1.3 of [D.7-2] describes the 61BTH Type 1 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 T.3.6.1.3.3 and T.3.6.1.3.4 of [D.7-2], respectively. The basket thermal stress analysis is contained in Section T.3.4.4.3 of [D.7-2]. The load cases considered include thermal stress, deadweight, handling/transfer loads, and seismic loads. (The seismic loading 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 T.3.6.1.3.3-C of [D.7-2] presents a table of results for the Handling/Transfer Loads analyses of the 61BTH Type 1 basket. All stresses are within the allowable limits.

Section T.3.6.1.3.4-E of [D.7-2] presents a table of results for the Operation/Storage Loads analyses of the 61BTH Type 1 basket. All stresses are within the allowable limits.

D.7.5.2 Off-Normal Loads

The structural analyses for off-normal loads is contained in Section T.3.6.2 of [D.7-2]. Two limiting off-normal events are defined which envelope the range of expected off-normal structural loads:

- Jammed Canister During Transfer

  Section T.3.6.2.1 of [D.7-2] presents a series of hand calculations to determine the stresses on the canister shell due to various postulated loading conditions (axial sticking of the canister, Binding of the canister). All stresses are within the ASME code limits.

- Off-Normal Thermal Loads

  Off-normal ambient temperatures are defined as -40 °F and 117 °F for the 61BTH Type 1 DSC in [D.7-2] Appendix T.3.6.2.2. The stress results presented in Table T.3.6-4 of [D.7-2] show that the canister stress limits are satisfied for the off-normal thermal loads. The thermal stress analyses in Section T.3.4.4.3 of [D.7-2] show that the stress limits for the basket are satisfied for the off-normal thermal loads. As discussed in Section D.7.4, the thermal stress analyses of the 61BTH Type 1 DSC for transfer in the OS197 transfer cask are applicable for transfer in the MP197HB cask.

D.7.5.3 Accident Loads

The structural analysis of the 61BTH Type 1 DSC for accident loads is presented in Section T.3.7 of [D.7-2]. The following accident conditions affect the canister and are evaluated:

- Earthquake

  The seismic load is reconciled in Section D.7.3.3. As concluded in Section C.7.3.3, the 61BTH Type 1 DSC is acceptable for storage at the WCS CISF.

- Flood

  Evaluation of the canister for flood loads is contained in Section T.3.7.3.2 of [D.7-2]. The ASME Code methodology in NB-3133.3 is used to show that there is a safety margin of at least 1.57 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.

- Accidental Cask Drop

  The 61BTH Type 1 DSC evaluation of the accidental drop is documented in Section T.3.7.4 of [D.7-2]. Equivalent static loading of 75g is used to evaluate the effects of the drops.

The canister shell assembly results are summarized in Table T.3.7-2 of [D.7-2] and show that all applicable ASME stress criteria are satisfied. Stability of the canister shell against buckling is also evaluated in Section T.3.7.4.2.4 of [D.7-2] and shown to satisfy the acceptance criteria of ASME Appendix F.

The 61BTH Type 1 basket assembly drop evaluation is described in Section T.3.7.4.3 of [D.7-2]. Basket assembly results for the side drop and end drop are summarized in Table T.3.7-5 and Table T.3.7-7 of [D.7-2]. All applicable stress limits were met. Stability analyses are performed in Section T.3.7.4.3.3 of [D.7-2] 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.

D.7.6 Structural Analysis of HSM Model 102 with Canister (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 [D.7-2]. 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 [D.7-2]. Results for normal and off-normal loads are summarized in Table 8.1-14 and Table 8.1-19 of [D.7-2]. Results for accident loads are presented in Table 8.2-3, Table 8.2-18, Table 8.2-19, and Table 8.2-20 of [D.7-2].

The analyses and results listed above were originally performed for a bounding canister weight of 80.0 kips. The maximum weight of the 61BTH Type 1 DSC is 88.7 kips [D.7-2 Table T.3.2-1]. As described in Paragraph T.3.6.1.4 of [D.7-2], the DSC steel support structure is evaluated in Appendix M of [D.7-2] for a bounding weight of 102 kips which bounds the maximum weight of the 61BTH Type 1 DSC.

As described in Paragraph T.3.6.1.5, the HSM is qualified in Appendix M of [D.7-2] for a bounding weight of 102 kips which bounds the maximum weight of the 61BTH Type 1 DSC.

The HSM door and heat shields are not affected by the weight of the canister, and therefore is qualified by the design basis calculations described in Section 8.1 and 8.2 of [D.7-2].

The reconciliation for the seismic loading on the HSM Model 102 is contained in Section D.7.3.1.

Summaries of the HSM Model 102 analyses for normal, off-normal, and accident conditions can be found in Sections C.7.6.1, C.7.6.2, and C.7.6.3, respectively. The load combinations and analysis results are summarized in Section C.7.6.4.

Based on these discussions, the stress ratios for the HSM Model 102 loaded with the 61BTH Type 1 canister at the WCS CISF are acceptable.

D.7.7 Structural Analysis of MP197HB Cask as On-Site Transfer Cask

The evaluation of the MP197HB cask as the on-site transfer cask for the 61BT and 61BTH Type 1 DSCs is contained in Appendix C.7.

General information regarding the structural analyses of the MP197HB cask for on-site transfer operations at the WCS CISF is contained in Section C.7.7.1. Evaluations for normal and off-normal conditions are contained in Section C.7.7.2. Evaluations for accident conditions are contained in Section C.7.7.3. Evaluations of cask stability due to design basis tornado and seismic loads and cask resistance to puncture due to tornado-generated missiles are contained in Section C.7.7.4.

Based on the evaluation presented in Section C.7.7 the MP197HB cask is qualified for use as a transfer cask at the WCS CISF.

D.7.8 Structural Evaluation of 61BTH Type 1 DSC Confinement Boundary under Normal Conditions of Transport

The 61BTH Type 1 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 61BTH Type 1 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 D.4.6. The confinement boundary is addressed in Section D.11.1. The 61BTH Type 1 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 [D.7-1]. As described in Section A.2.13.7.1 of [D.7-1], the 61TH DSC is categorized as a Group 2 DSC. The analysis of the Group 2 DSCs (which include the 61BTH Type 1 DSC) are documented Sections A.2.13.7.2 and A.2.13.7.3 of [D.7-1] and the results are reported in Sections A.2.13.7.4.2 A.1 – A.3 of [D.7-1] for Normal Conditions of Transport.

The result of the 61BTH Type 1 DSCs structural analysis is acceptable for the loads and combinations described in Section A.2.13.7.3 of D.7-1] and hence structurally adequate for normal conditions of transport loading conditions.

D.7.9 References

D.7-1 AREVA TN Document, NUH09.101 Rev. 17, "NUHOMS® -MP197 Transportation Package Safety Analysis Report." (Basis for NRC CoC 71-9302).

D.7-2 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).

D.7-3 Blevins, Robert D. Formulas for Natural Frequency and Mode Shape. 2001.

D.7-4 ANSYS Computer Code and User's Manual, Version 10.0 A1.

Table D.7-1
Comparison of Seismic Load Combination Forces and Moments on HSM Concrete Components with Capacities (kip/ft, kip-in/ft)

Component	*Quantity*	*Shear, V_{o1} (Note 1)*	*Shear, V_{o2} (Note 1)*	*Moment, M_1 (Note 2)*	*Moment, M_2 (Note 2)*
Floor Slab	*Demand(3)*	*3.37*	*4.01*	*23.95*	*20.05*
	Capacity(4)	*13.50*	*14.60*	*206.00*	*223.00*
	Ratio	*0.25*	*0.27*	*0.12*	*0.09*
Roof Slab	*Demand(3)*	*4.78*	*5.79*	*112.67*	*113.71*
	Capacity(4)	*42.50*	*44.00*	*1753.00*	*1813.00*
	Ratio	*0.11*	*0.13*	*0.06*	*0.06*
Side Walls	*Demand(3)*	*14.02*	*5.59*	*116.52*	*133.90*
	Capacity(4)	*22.90*	*24.00*	*728.00*	*694.00*
	Ratio	*0.61*	*0.23*	*0.16*	*0.19*
Front Wall	*Demand(3)*	*22.84*	*36.74*	*260.26*	*242.27*
	Capacity(4)	*40.50*	*41.40*	*881.00*	*901.00*
	Ratio	*0.56*	*0.89*	*0.30*	*0.27*
Rear Wall	*Demand(3)*	*5.51*	*4.22*	*69.53*	*74.67*
	Capacity(4)	*14.30*	*15.30*	*305.00*	*457.00*
	Ratio	*0.39*	*0.28*	*0.23*	*0.16*

Notes:

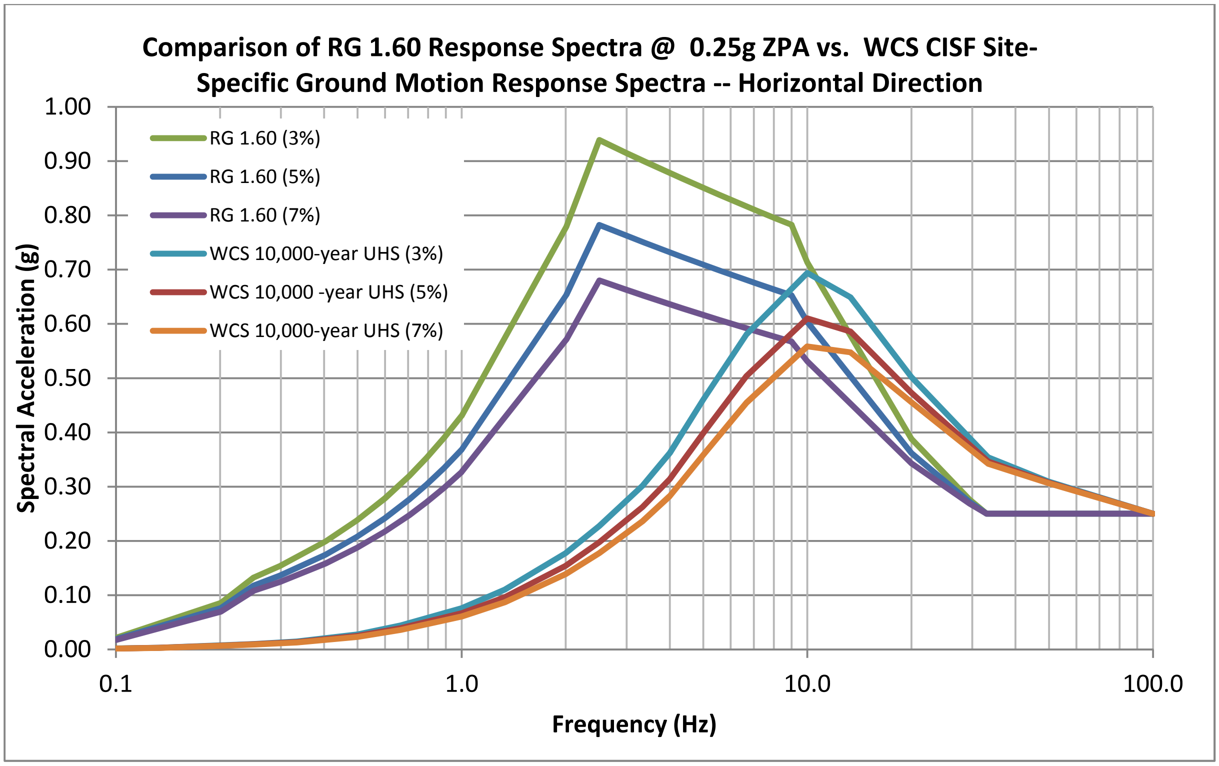
1) V_{o1}, $V_{o2,}$ out of plane shear (beam shear)
2) M_1, M_2, out of plane moments (beam bending moments)
3) Maximum (absolute) values for Seismic Load combination for *spectra from WCS CISF SSI analysis.*
4) Concrete subcomponent capacities are calculated in accordance with ACI 349-85 and documented in Section 8.1.1.5.E of [D.7-2]

Table D.7-2
Comparison of Seismic Load Combination Stresses in DSC Support Structure Components with Capacities

Component	***Calculated Stress***						
	Axial (ksi)	***Strong Axis Bending (ksi)***	***Weak Axis Bending (ksi)***	***Shear (ksi)***	***Interaction Ratio (Demand /Capacity)***	***Allowable Tensile Stress (ksi)***	***Allowable Shear Stress (ksi)***
Rail	*1.96*	*3.03*	*12.49*	*4.97*	*0.48*	-	*18.1*
Cross Beam	*1.43*	*5.52*	*7.34*	*12.90*	*0.40*	-	*18.1*
Column	*6.84*	*4.41*	*4.44*	*0.25*	*0.56*	-	*18.1*
Wall Attachment Channel	*15.52*	-	-	-	-	*23.2*	-
Mounting Plate Bolt	*21.82*	-	-	-	-	*29.1*	-

Notes:
Allowable stresses taken at 270°F and increased by 60% in accordance with ANSI/ANS 57.9.

Table D.7-3
Deleted



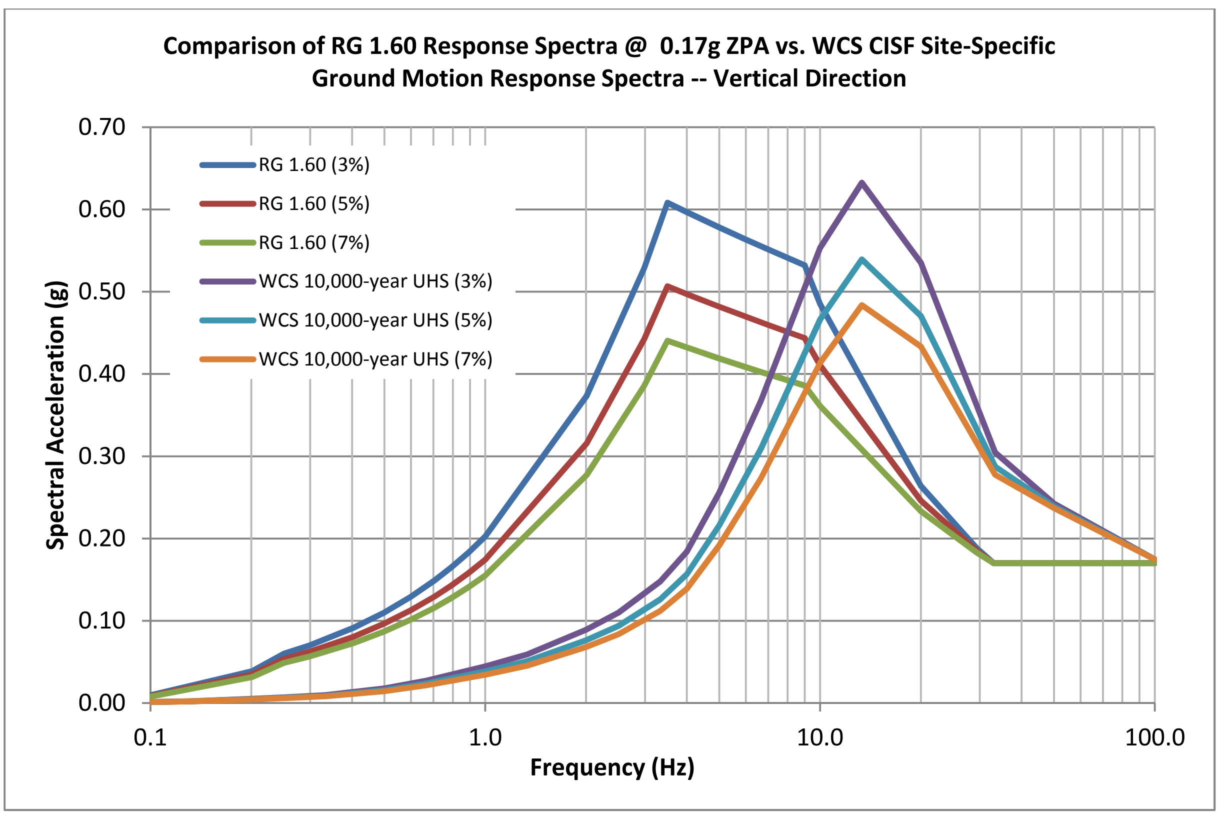


Figure D.7-1
Design Basis Response Spectra for the 61BTH Type 1 DSC, HSM Model 102 and MP197HB Cask compared to the WCS CISF 10,000-year UHS

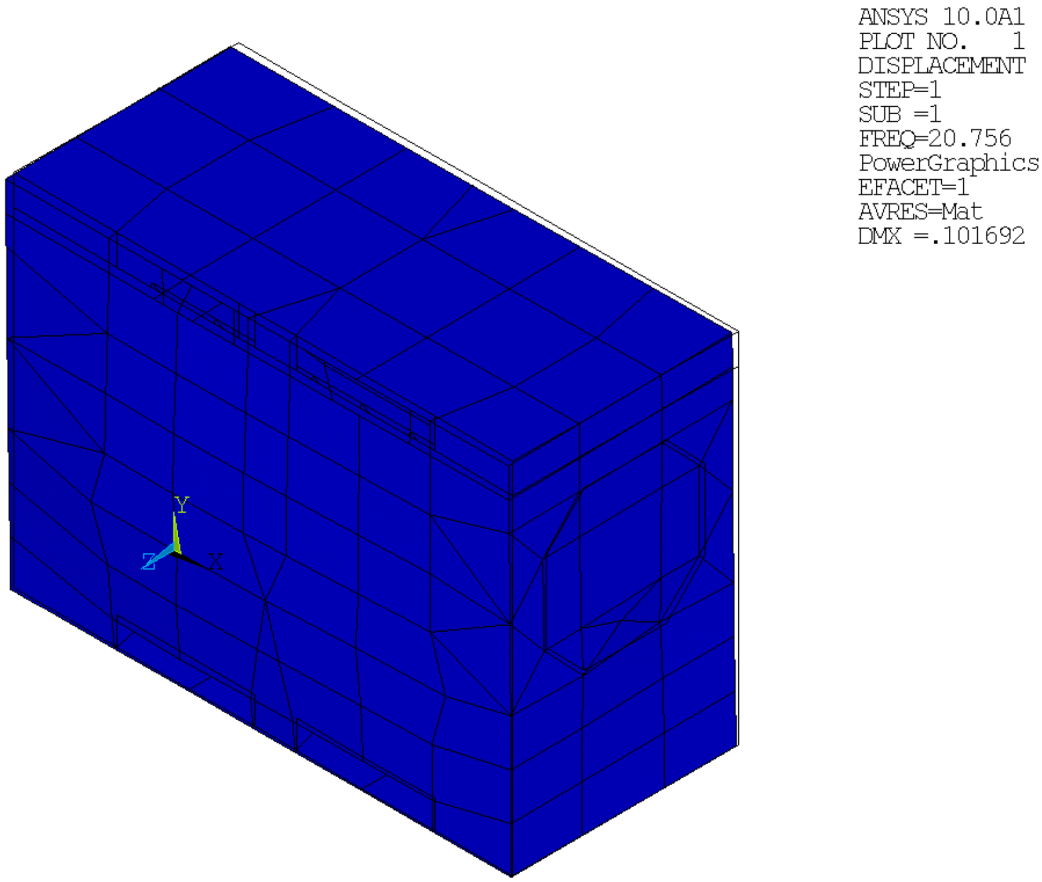


Figure D.7-2
HSM Mode Shape for Mode 1

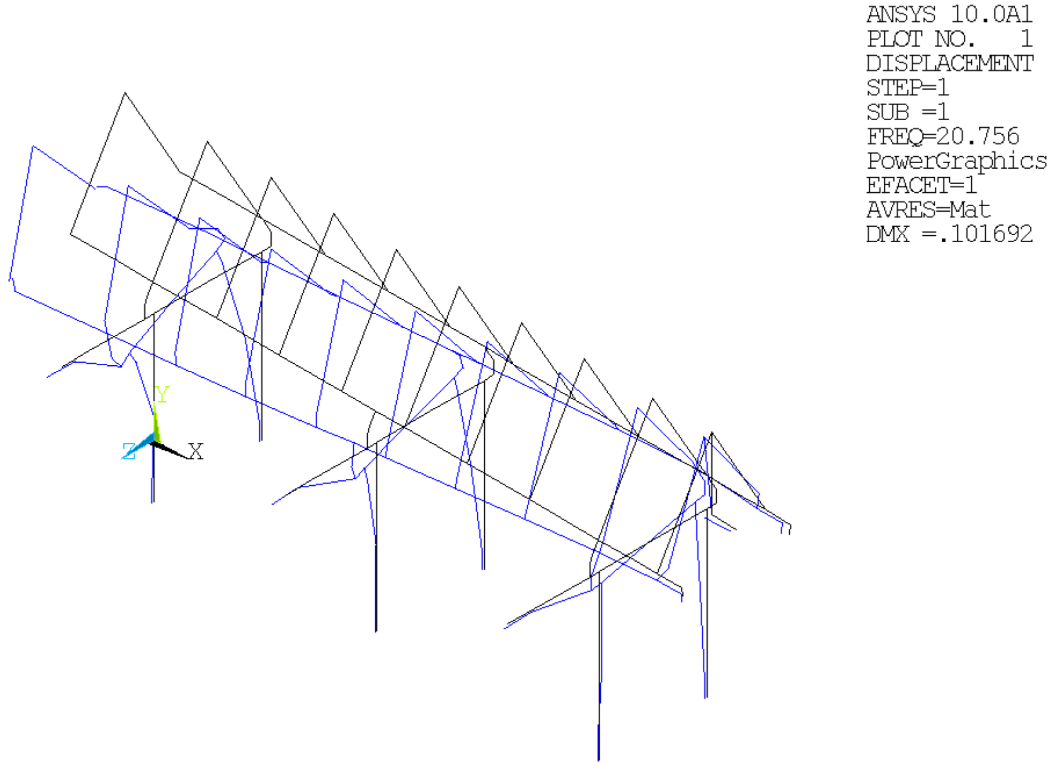


Figure D.7-3
Support Structure Mode Shape for Mode 1

Proprietary Information on Pages D.7-24 through D.7-29
Withheld Pursuant to 10 CFR 2.390

APPENDIX D.8
THERMAL EVALUATION
Standardized NUHOMS®-61BTH Type 1 System

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D.8. THERMAL EVALUATION

This chapter presents the thermal evaluations which demonstrate that the NUHOMS®-61BTH Type 1 Dry Shielded Canister (DSC), stored in the NUHOMS® HSM Model 102 storage module and transferred in the NUHOMS® MP197HB transportation/transfer cask (MP197HB cask), meet the thermal requirements of 10 CFR 72 for the dry storage of spent nuclear fuel (SNF). The NUHOMS®-61BTH System is designed to passively reject decay heat during storage and transfer of SNF for normal, off-normal and accident conditions while maintaining temperatures and pressures within specified regulatory limits.

D.8.1 Discussion

As discussed in Chapter 1.0, the 61BTH Type 1 DSCs from an ISFSI site will be transported to the Waste Control Specialists, LLC (WCS) Consolidated Interim Storage Facility (CISF) in the MP197HB cask under NRC Certificate of Compliance No. 9302 [D.8-2]. At the WCS CISF, the 61BTH Type 1 DSCs, described in Section T.1, Appendix T of the Standardized NUHOMS® UFSAR [D.8-3], are to be stored inside the NUHOMS® HSM Model 102 described in Chapter 4 of [D.8-3]. For on-site transfer of the 61BTH Type 1 DSCs, the MP197HB TC, described in Appendix A.1.2 of the MP197 SAR [D.8-4], is to be used.

The 61BTH Type 1 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 22.0 kW [D.8-3]. The thermal analysis for storage and transfer of the 61BTH Type 1 DSC is presented in Appendix T.4 of [D.8-3].

This Appendix qualifies the 61BTH Type 1 DSC for storage in the HSM Model 102 at the WCS CISF with the same heat load of 22.0 kW under the WCS environmental conditions. No new thermal analysis is performed for storage of the 61BTH Type 1 DSC in this Appendix. Although no new thermal evaluations are performed for the storage conditions, the material properties, thermal models and results from Appendix T.4 of [D.8-3] are referenced in this Appendix for completeness.

The MP197HB TC has previously been certified for transportation of the 61BTH Type 1 DSC [D.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 61BTH Type 1 DSC in the MP197HB cask with a heat load of 22.0 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 are not evaluated in this application.

The thermal design criteria for storage and transfer of 61BTH Type 1 DSC are listed in Section T.4.1, Appendix T of [D.8-3].

This Appendix demonstrates that all the 10 CFR Part 72 thermal requirements for storage and transfer of the 61BTH Type 1 DSC at the WCS CISF are met.

D.8.2 Summary of Thermal Properties of Materials

The material properties of the HSM Model 80/Model 102 storage module are listed in Table 8.1-8 and Table 8.1-9 of [D.8-3] and the material properties of the NUHOMS® 61BTH Type 1 DSC are listed in Section T.4.2 of [D.8-3]. The material properties of the MP197HB TC are listed in Section A.3.2.1 of [D.8-4].

Helium gas within the Cask/Canister annulus is replaced with air during transfer operations. Due to this change, the effective properties for the internal sleeve are re-calculated using the same methodology as used in [D.8-4]. The effective thermal conductivity of inner sleeve component with air gap for transfer in the MP197HB cask at the WCS CISF is calculated in Section D.8.5.1.

An emissivity value of 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 [D.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 [D.8-4]) is to be painted white. Accordingly, an emissivity value of 0.9 is used for the inner surface of the TC inner sleeve.

D.8.3 Specification for Components

The thermal conductivity of the neutron absorber materials made from a single piece or paired with an aluminum sheet for the NUHOMS® 61BTH Type 1 DSC are provided in Section T.4.3, Appendix T of [D.8-3].

D.8.4 Thermal Analysis of HSM Model 102 with Canister for Storage Conditions

As discussed in Section D.8.1, NUHOMS® 61BTH Type 1 DSC 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 T.4 of [D.8-3]. Because this configuration is previously approved, this section only presents a reconciliation of the ambient temperatures between [D.8-3] and the WCS CISF.

D.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.*

D.8.4.1.1 Comparison of WCS CISF Ambient Conditions with Ambient Conditions Used in the Standardized NUHOMS® UFSAR

As described in Chapter T.4, Section T.4.4 of [D.8-3], the thermal evaluation for HSM is presented in Section 8.1.3 of [D.8-3]. A review of the thermal evaluation presented in Section 8.1.3 of [D.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 [D.8-3].

Based on this discussion, the thermal evaluation for storage conditions presented in Chapter T.4 of [D.8-3] is bounding for the WCS CISF and no additional evaluations are performed. Sections D.8.4.2 through D.8.4.5 present the references to the appropriate section within [D.8-3] as it relates to the thermal evaluations performed for NUHOMS® 61BTH Type 1 DSC and HSM Model 102 for storage conditions.

D.8.4.2 Thermal Model of HSM Model 102 with 61BTH Type 1 DSC

The HEATING7 thermal model of the HSM Model 102 is described in Section 8.1.3 of [D.8-3].

The three-dimensional ANSYS model of the 61BTH Type 1 DSC with a heat load of 22.0 kW is described in Section T.4.6.2, Appendix T of [D.8-3]. Section T.4.6 of [D.8-3] presents a thermal analysis for the 61BTH Type 1 DSC.

The 61BTH Type 1 DSC model for accident analysis is based on the HSM model described in Section 8.1.3.1 of [D.8-3]. The accident analysis is performed with HSM vents totally blocked for 40 hours, decay heat of 24 kW and with a maximum ambient steady state temperature of 125°F.

D.8.4.3 HSM Model 102 Thermal Model Results

The thermal evaluation for the 61BTH Type 1 DSC in the HSM Model 102 with a maximum heat load of 22 kW is based on the thermal evaluation of a NUHOMS® 24P DSC in an HSM with a maximum heat load of 24 kW as described in Section T.4.4, Chapter T.4 of [D.8-3]. The thermal evaluation for the 24P DSC in an HSM is described in Section 8.1.3 of [D.8-3].

The results of the HSM Model 102 thermal analysis for normal, off-normal and accident conditions are presented in Table 8.1-24 of [D.8-3].

D.8.4.4 61BTH Type 1 DSC Thermal Model Results

As described in Section T.4.6.6.1, Chapter T.4 of [D.8-3], the shell temperatures calculated in Section 8.1.3.1 and listed in Table 8.1-24 of [D.8-3] for the 24P DSC in the HSM Model 102 with a 24 kW heat load are conservatively applied to the ANSYS model of the 61BTH Type 1 DSC with a 22 kW heat load.

The maximum fuel cladding temperatures for storage of the 61BTH Type 1 DSC in the HSM Model 102, under normal, off-normal and accident conditions are listed in Table T.4-12, Table T.4-17 and Table T.4-21 of [D.8-3], respectively. The maximum component temperatures of the 61BTH Type 1 DSC are presented in Table T.4-13, Table T.4-18 and Table T.4-22 of [D.8-3], respectively.

A review of Table T.4-13 and T.4-18, Chapter T.4 of [D.8-3], shows, that for normal and off-normal conditions, the 61BTH Type 1 DSC component temperatures for the transfer case are much higher than the storage case. Hence, the canister cavity pressures during storage of the 61BTH Type 1 DSC in the HSM Model 102 are bounded by the canister cavity pressures for the transfer of the 61BTH Type 1 DSC in the MP197HB cask. Sections D.8.5.2 and D.8.5.3 present a reconciliation of the 61BTH Type 1 DSC internal pressures for the transfer case.

D.8.4.5 Evaluation of the 61BTH Type 1 DSC Storage in HSM Model 102

The thermal performance of the HSM Model 102 module with the 61BTH Type 1 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 Chapter T.4 of [D.8-3]. The bounding evaluation demonstrates that all the 10 CFR Part 72 thermal limits and criteria are met.

D.8.5 Thermal Analysis of MP197HB Cask with Canister for Transfer Operations

As discussed in Section D.8.1, the 61BTH Type 1 DSC will be transported to the WCS CISF under the NRC Certificate of Compliance No. 9302 [D.8-2]. Within the WCS CISF, the transfer operations i.e. movement of the canister from the transfer 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.

D.8.5.1 Thermal Model of MP197HB TC with 61BTH Type 1 DSC

The MP197HB Transportation Cask configuration is shown in the design drawings included in Section A.1.4.10.1, Chapter A.1 of [D.8-4]. The ANSYS model of the MP197HB TC is presented in Section A.3.3.1.1, Appendix A.3 of [D.8-4]. ANSYS 10.0 [D.8-3] is used for the MP197HB TC modeling and thermal analysis. This transportation model of the MP197HB cask is modified to replicate the transfer configuration of the TC 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 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 [D.8-4])

The thermal properties of the materials used in the analysis of the MP197HB cask with the 61BTH Type 1 DSC in transfer mode are the same as those presented in Section A.3.2.1, Appendix A.3 of [D.8-4] except for the effective conductivity of the internal sleeve.

The effective thermal conductivity for the TC 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 [D.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

D.8.5.2 MP197HB TC 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 61BTH Type 1 DSC for transfer at the WCS CISF *at an* ambient temperature of 105°F daily average temperature are presented in the table below. Also listed for comparison are the maximum component temperatures of the MP197HB cask loaded with the 61BTH Type 1 DSC for normal transportation condition [D.8-4].

Comparison of MP197HB TC Component Maximum Temperatures for Transportation v/s Transfer of 61BTH Type 1 DSC

Transfer/Transportation Operation	**Transportation MP197HB TC with 61BTH Type 1 DSC**(2) Normal T_{amb}=100°F	Transfer MP197HB TC with 61BTH Type 1 DSC (1)
Heat load	22 kW	22 kW
Component	T_{max}, °F	T_{max}, °F
Canister shell	406	423
Inner sleeve	317	286
Cask inner shell	315	272
Gamma shield	314	271
Outer shell	306	242
Shield shell	272	221
Cask lid	248	146
Cask bottom plate	307	175

1 – Daily ambient average temperature of 105°F is used for analysis.

2 – From Table A.3-8 of [D.8-4].

As seen from the table above, the maximum MP197HB cask component temperatures for transfer at *the WCS CISF* are below the maximum component temperatures for transportation at 100°F. The maximum temperature of the MP197HB cask components for the transfer case decrease compared to the transportation case due to the increased heat rejection from the TC 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 internal surface of the MP197HB cask inner sleeve.

The maximum 61BTH Type 1 DSC shell temperature increases by 17°F. This increase is due to the use of air in the cask/canister annulus versus the use of helium in the transportation case.

The maximum temperatures of the MP197HB cask with the 61BTH Type 1 DSC at the WCS CISF for normal and off-normal transfer conditions are listed in Table D.8-1.

Since the maximum 61BTH Type 1 DSC surface temperature for transfer is higher than the maximum 61BTH Type 1 DSC surface temperature for transportation, the 61BTH Type 1 DSC shell temperature profile from the transfer evaluation is mapped to the 61BTH Type 1 DSC basket model described in Section T.4.6.2, Appendix T.4 of [D.8-3]. The results of this evaluation provide the maximum 61BTH Type 1 DSC basket component temperatures and the maximum fuel cladding temperature for off-normal conditions.

The maximum temperatures of the components of the 61BTH Type 1 DSC and the maximum fuel cladding temperature at the WCS CISF for normal and off-normal transfer conditions are presented in Table D.8-2.

<u>61BTH Type 1 DSC Cavity Pressure (Normal and Off-Normal Conditions)</u>

The average helium temperature for the 61BTH Type 1 DSC during off-normal transfer operations in MP197HB cask is 489°F. This is lower than the average helium temperature of 504°F (See Section T.4.6.7.6, Chapter T.4 of [D.8-3] used to determine the maximum internal pressure during off-normal transfer operations in OS197 transfer cask. A similar behavior will be observed for normal transfer operations wherein the average helium temperature of helium within the 61BTH Type 1 DSC during transfer in MP197HB cask will lower compared to the transfer in OS197 transfer cask. Since the average helium temperatures are lower, the maximum internal pressures listed in Table T.4-16 and Table T.4-20, Appendix T of [D.8-3] remains bounding.

D.8.5.3 MP197HB Cask and 61BTH Type 1 DSC Thermal Analysis (Accident Conditions)

Fire accident is the only postulated hypothetical accident condition (HAC) considered in the thermal evaluation during transfer of 61BTH Type 1 DSC in MP197HB cask. Based on the discussion in Section T.4.6.8.3 of [D.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 [D.8-4]. This ensures that the heat input from the fire to the 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 [D.8-4] considers a minimum heat load of 26 kW compared to the maximum heat load of 22 kW for NUHOMS® 61BTH Type 1 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 [D.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 [D.8-4] for the transportation configuration bound the values for the transfer case. Table D.8-1 presents these bounding maximum temperatures for the MP197HB cask components for the HAC conditions during transfer operations at WCS CISF.

Based on the discussion in Section A.3.4.3 of [D.8-4], the maximum the canister shell temperature occurs during post-fire steady state conditions due to the large thermal mass of the basket and the relative large gap between the canister shell and the sleeve. A similar behavior would be expected for the hypothetical fire accident condition at the WCS CISF.

The maximum canister shell temperature during post fire steady-conditions for 61BTH Type 1 DSC is 441°F (See Table A.3-17 of [D.8-4]). Based on the evaluation performed for off-normal steady-state condition in Section D.8.5.2, a maximum temperature increase of 17°F is observed for the 61BTH Type 1 DSC shell temperature during transfer operations in MP197HB cask at the WCS CISF. Considering a similar increase, the maximum canister shell temperature due to fire accident at WCS CISF would be about 458 °F (441 °F +17 °F=458 °F). This canister Shell temperature is lower than the maximum canister shell temperature of 467 °F considered for the accident transfer conditions during transfer in OS197 transfer cask (See Table T.4-22 of [D.8-3]).

Therefore, the maximum 61BTH Type 1 DSC temperatures and maximum fuel cladding temperature under accident conditions for the MP197HB cask are bounded by the accident maximum temperatures for the OS197 transfer cask listed in Tables T.4-21 and T.4-22 of [D.8-3]. These bounding temperature values for the 61BTH Type 1 DSC under OS197 transfer cask accident conditions are presented in Table D.8-2.

<u>61BTH Type 1 DSC Cavity Pressure (Accident Conditions)</u>

Section T.4.6.8.5, Chapter T.4 of [D.8-3] evaluates the maximum accident pressure for the 61BTH DSC. The maximum internal pressure for 61BTH Type 1 DSC occurs during transfer accident conditions in the OS197 transfer cask and are summarized in Table T.4-24, Chapter T.4 of [D.8-3].

As discussed above, the 61BTH Type 1 DSC basket temperatures during accident transfer in the MP197HB TC are bounded by the 61BTH Type 1 DSC basket temperatures during accident transfer in the OS197 transfer cask. Therefore, the maximum 61BTH Type 1 DSC cavity pressure under accident conditions at the WCS CISF is bounded by the maximum accident condition canister cavity pressure of 56.1 psig presented in Table T.4-24, Appendix T.4 of [D.8-3].

D.8.5.4 Evaluation of MP197HB TC Performance

The thermal performance of the MP197HB cask with the 61BTH Type 1 DSC 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.

D.8.6 References

D.8-1 Not Used.

D.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).

D.8-3 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).

D.8-4 AREVA TN Document, NUH09.101 Rev. 17, "NUHOMS® -MP197 Transportation Package Safety Analysis Report." (Basis for NRC CoC 71-9302).

D.8-5 ANSYS Mechanical APDL, Release 10.0.

D.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 D.8-1
Maximum Temperatures of MP197HB TC Components for 61BTH Type 1 DSC Transfer at the WCS CISF

	DSC Heat Load 22 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	<286			286	409
Cask inner shell	<272			272	413
Gamma shield	<271			271	508
Outer shell	<242			242	645
Shield shell	<221			221	1071
Cask lid	<146			146	367
Cask bottom plate	<175			175	309

1 – Bounded by values from Table A.3-19 of [D.8-4].

Table D.8-2
NUHOMS® 61BTH Type 1 DSC Fuel Cladding and DSC Component Temperatures for Transfer in MP197HB TC 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	<424	-20	[2]	424	[2]	<467	[2]
Top Grid	<426	-20	[2]	426	[2]	<531	
Basket Rails	<562	-20	[2]	562	[2]	<609	[2]
Neutron Absorber	<682	-20	[2]	682	[2]	<727	
Fuel Compartment	<683	-20	[2]	683	[2]	<727	[2]
Fuel Cladding	<706	-20	752[3]	706	752[3]	<749	1058[3]
Average Cavity Gas Temperature	<489	NA	NA	489	NA	<550[6]	NA

1 – Bounded by off-normal condition.

2 – The components perform their intended safety function within the operating range.

3 – From ISG-11, Revision 3 [D.8-6].

4 – Bounded by accident transfer condition in OS197 TC. See Table 4-21 and Table 4-22 of [D.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*.

6 – Design basis average He temperature used in Table T.4-24 of [D.8-3].

APPENDIX D.9
RADIATION PROTECTION
Standardized NUHOMS®-61BTH Type 1 System

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D.9. RADIATION PROTECTION

The Standardized NUHOMS® System Cask System with the NUHOMS® 61BTH Type 1 DSC radiation protection evaluations are documented in Section T.5 of the "Standardized NUHOMS® Horizontal Modular Storage System Safety Analysis Report" [D.9-1]. *Details of the shielding design features for the MP-197HB cask are provided in Section A.5.1.1 of reference [D.9-2]. Drawings showing the shield thicknesses for the NUHOMS®-61 BTH Type 1 DSC are listed in Section D.4.6. Drawings showing the shielding thicknesses for the HSM Model 102 are listed in Section A.4.6 and for the MP197HB cask in Section C.4.6.*

D.9.1 Radiation Protection Design Features

Details of the Storage Area shielding design features for the Standardized NUHOMS® System Cask System which includes the 61BTH Type 1 DSC stored in an HSM Model 102 are documented in Section 7.3.2.1 *and T.5* of reference [D.9-1]. *Details of the sheilding design features for the MP-197HB cask are provided in Section A.5.1.1 of reference [D.9-2]. Drawing showing the shield thicknesses for the NUHOMS®-61BTH Type 1 DSC are listed in Section D.4.6. Drawings showing the shielding thicknesses for the HSM Model 102 are listed in Section A.4.6 and for the MP197HB cask in Section C.4.6.*

D.9.2 Occupational Exposure Evaluation

D.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 [D.9-1] and SAR [D.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.

D.9.2.2 Dose Assessment

A dose assessment is performed for receipt and transfer of a 61BTH Type 1 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 D.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 D.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 T.5-2 of* the storage FSAR *[D.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 61BTH Type 1 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 [D.9-2]* are utilized. This approach is conservative because the 69BTH DSC contains a larger source than the 61BTH Type 1 DSC.

- For transfer of the 61BTH Type 1 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 [D.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 61BTH Type 1 DSC.

The configurations used in the dose rate analysis are summarized in Table D.9-1. Results for the various loading scenarios are provided in Table D.9-2 and Table D.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 61BTH Type 1 DSC to an HSM Model 102 using the MP197HB cask: 1016 person-mrem.

The total collective dose for unloading a 61BTH Type 1 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 61BTH Type 1 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 receipt, transfer, retrieval, and shipment is 2032 person-mrem.

D.9.3 References

D.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).

D.9-2 AREVA TN Document, NUH09.101 Rev. 17, "NUHOMS® -MP197 Transportation Package Safety Analysis Report." (Basis for NRC CoC 71-9302).

Table D.9-1
***Analyses Used for* Receipt and Transfer Configurations**

Actual Configuration	Receipt Analysis Configuration	Transfer Analysis Configuration
61BTH Type 1 DSC transferred from the MP197HB cask into an HSM Model 102	69BTH DSC (bounds 61BTH Type 1 DSC) inside MP197HB cask [D.9-2]	69BTH DSC (bounds 61BTH Type 1 DSC) inside OS200 transfer cask (bounds MP197HB cask) [D.9-1]

Table D.9-2
Occupational Collective Dose for Receipt of MP197HB Cask Loaded with 61BTH Type 1 DSC

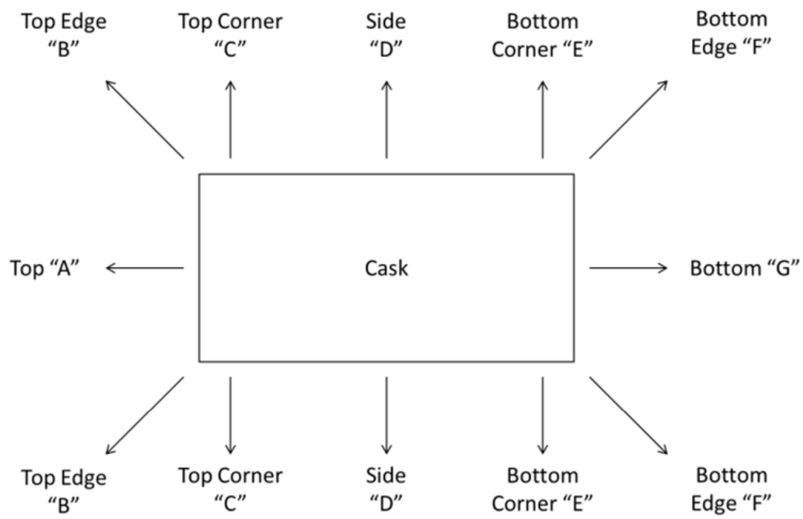
Process Step	Number of Workers	Occupancy Time (hours)	Worker Location Around Cask	Worker Distance (m)	Total Dose Rate (mrem/hr)	Total Dose (person-mrem)*
Verify that the tamperproof seals are intact.	1	0.07	Top	1	3.62	2
	1	0.07	Bottom	1	22.2	
Remove the tamperproof seals.	1	0.07	Top	1	3.62	2
	1	0.07	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

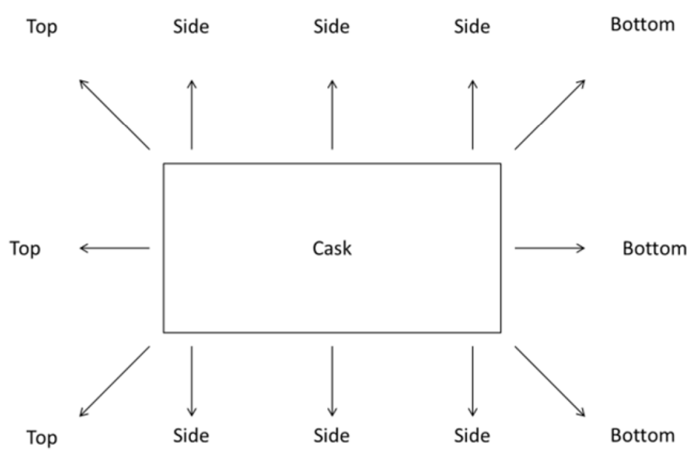
Table D.9-3
Occupational Collective Dose for Transfer of 61BTH Type 1 DSC from MP197HB Cask to HSM Model 102

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 D.9-1
Worker Locations Around Cask

APPENDIX D.10
CRITICALITY EVALUATION
Standardized NUHOMS®-61BTH Type 1 System

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D.10. CRITICALITY EVALUATION

The design criteria for the Standardized NUHOMS® 61BTH Type 1 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 0.9415 which includes an administrative margin of 0.05, code bias and bias uncertainties.

D.10.1 Discussion and Results

The 61BTH Type 1 DSC criticality analysis is documented in Chapter T.6 of the "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel" [D.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 [D.10-1]. Specific information on the criticality safety analysis which bounds the WCS CISF is discussed in this section.

The 61BTH Type 1 DSC consists of a SNF assembly (cylindrical shell, canister top and bottom cover plates and shield plugs or shield plug assemblies) and a basket assembly. The basket structure consists of 2x2 and 3x3 stainless steel SNF compartment assemblies held in place by basket rails in combination with either a holddown ring or an optional top grid assembly provided at the top of the basket. The four 2x2 and five 3x3 compartment assemblies are held together by welded stainless steel boxes wrapped around the SNF compartments, which also retain the neutron poison plates placed between the compartment assemblies. The poison plates provide the necessary criticality control and provide a heat conduction path from the SNF assemblies to the canister shell. The authorized poison plates are borated aluminum, boron carbide/metal matrix composite (MMC) or Boral ®. The canister is authorized to store 61 intact SNF assemblies. It is also authorized to store SNF assemblies containing Blended Low Enriched Uranium (BLEU) fuel material. Reconstituted SNF assemblies containing up to 10 replacement irradiated stainless steel rods per assembly or 61 lower enriched UO_2 rods instead of zircaloy clad enriched UO_2 rods are acceptable for storage. It can also accommodate up to a maximum of 16 damaged SNF assemblies in the 2x2 compartments located at the outer edge of the canister.

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 A.6.5.1.4.1 of the "NUHOMS®-MP197 Transport Packaging Safety Analysis Report" [D.10-4].

The design basis criticality analysis performed for the 61BTH Type 1 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 0.9415.

D.10.2 Package Fuel Loading

Section 2.1 of the Technical Specifications [D.10-3] lists the SNF assemblies authorized for storage at the WCS CISF. Section 6.2 Spent Fuel Loading of [D.10-1] provides the Package Fuel Loading.

D.10.3 Model Specification

Section 6.3 Model Specification of [D.10-1] provides a discussion of the criticality model canister regional densities used to calculate the bounding k_{eff} for the 61BTH Type 1 DSC.

D.10.4 Criticality Calculation

Section 6.4 Criticality Calculation of [D.10-1] provides a discussion of the criticality calculations that demonstrate that the maximum calculated k_{eff} for the 61BTH Type 1 DSC is less than 0.9415.

D.10.5 Critical Benchmark Experiments

Section 6.5 Critical Benchmark Experiments of [D.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.

D.10.6 References

D.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).

D.10-2 AREVA TN, "Technical Specifications for the Standardized NUHOMS® Horizontal Modular Storage System," USNRC Docket Number 72-1004.

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

D.10-4 AREVA TN Document, NUH09.101 Rev. 17, "NUHOMS® -MP197 Transportation Package Safety Analysis Report." (Basis for NRC CoC 71-9302).

APPENDIX D.11
CONFINEMENT EVALUATION
Standardized NUHOMS®-61BTH Type 1 System

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D.11 CONFINEMENT EVALUATION

The design criteria for the NUHOMS® 61BTH Type 1 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.

D.11.1 Confinement Boundary

The 61BTH Type 1 DSC confinement is documented in Appendix T Chapter 7 of the "Standardized NUHOMS® System Updated Final Safety Analysis Report" [D.11-1]. Section T.7.1 of [D.11-1] details the requirements of the confinement boundary. *Figure T.3.1-1 of reference [D.11-1] provides a figure that shows the components and welds that make up the confinement boundary for the 61BTH Type 1 DSC. Drawings for the canisters, including the confinement boundary are referenced in Section D.4.6. In addition, a bounding evaluation in Section D.7.8 is presented to demonstrate that the confinement boundary for the 61BTH Type 1 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 NUHOMS® [D.11-2] outline the requirements for preventing the leakage of radioactive materials in the 61BTH Type 1 DSC. Section 4.2, "Codes and Standards," lists the codes and standards for design, fabrication, and inspection of the 61BTH (Type 1 and Type 2) DSC, including alternatives to the ASME Code for the 61BTH (Type1 and Type 2) DSC confinement boundary and basket.

Section 3.1, "Fuel Integrity," of the Technical Specifications for the Standardized NUHOMS® [D.11-2] includes limiting condition for operations (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.

D.11.2 Requirements for Normal Conditions of Storage

Section T.7.2 of [D.11-1] describes how the 61BTH Type 1 DSC is designed, fabricated and tested to be "leaktight" to prevent the leakage of radioactive materials. The Technical Specifications for Standardized NUHOMS® [D.11-2] outlines the requirements for preventing the leakage of radioactive materials in the 61BTH Type 1 DSC. *Section 4.2, "Codes and Standards," lists the codes and standards for design, fabrication, and inspection of the 61BTH (Type 1 and Type 2) DSC, including alternatives to the ASME Code for the 61BTH (Type 1 and Type 2) DSC confinement boundary and basket.*

Section 3.1, "Fuel Integrity," of the Technical Specifications for the Standardized NUHOMS® [D.11-2] includes limiting condition for operation (LCO) 3.1.1 for DSC bulkwater removal medium and vacuum drying 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.

D.11.3 Confinement Requirements for Hypothetical Accident Conditions

Section T.7.3 of [D.11-1] provides a discussion on how the 61BTH Type 1 DSC is designed, fabricated and tested to be "leaktight" to prevent the leakage of radioactive materials following hypothetical accident conditions. The Technical Specification for Standardized NUHOMS® [D.11-2] outlines the requirements for preventing the leakage of radioactive materials following hypothetical accident conditions in the 61BTH Type 1 DSC. *Section 4.2, "Codes and Standards," lists the codes and standards for design, fabrication, and inspection of the 61BTH (Type 1 and Type 2) DSC, including alternatives to the ASME Code for the 61BTH (Type 1 and Type 2) DSC confinement boundary and basket.*

Section 3.1, "Fuel Integrity," of the Technical Specifications for the Standardized NUHOMS® [D.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.

D.11.4 References

D.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).

D.11-2 AREVA TN Americas, "Technical Specifications for the Standardized NUHOMS® Horizontal Modular Storage System", *Amendment 13,* USNRC Docket Number 72-1004.

APPENDIX D.12
ACCIDENT ANALYSIS
Standardized NUHOMS®-61BTH Type 1 System

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D.12. ACCIDENT ANALYSIS

This section describes the postulated off-normal and accident events that could occur during transfer and storage for the Standardized NUHOMS® -61BTH Type 1 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" [D.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.

D.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.

D.12.1.1 Off-Normal Transfer Loads

Off-Normal transfer loads are addressed in Section T.11.1.1 of [D.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 T.11.1.1.1 and 8.1.2 of [D.12-1].

Detection of the Event

Detection of the event is described in Sections T.11.1.1.2 and 8.1.2.1 of [D.12-1].

Analysis of Effects and Consequences

Sections T.11.1.1.3, T.3.6.2 and T.3.6.1.3.3 of [D.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 T.11.1.1.4 and 8.1.2.1 of [D.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.

D.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 D.8.4.

Postulated Cause of the Event

The postulated cause of the event is described in Sections T.11.1.2.1 and 8.1.2.2 of [D.12-1]

Detection of the Event

Detection of the event is described in Sections T.11.1.2.2 and 8.1.2.2 of [D.12-1].

Analysis of Effects and Consequences

Section T.11.1.2.3 of [D.12-1] and Appendix D.8 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 T.11.1.2.4 of [D.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 [D.12-2].

D.12.1.3 Off-Normal Release of Radionuclides

As described in Section T.11.1.3 of [D.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.

D.12.2 Postulated Accident

The postulated accident conditions for the Standardized NUHOMS®-61BTH Type 1 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

D.12.2.1 Blockage of Air Inlets/Outlets

Cause of Accident

Sections T.11.2.7.1 and 8.2.7.1 of [D.12-1] provides the potential 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 T.11.2.7.2, 8.2.7.2, T.3.7.7, T.3.4.4.3 and T.4 of [D.12-1]. In addition, Chapter D.8 demonstrates that the thermal analysis performed for the Standardized NUHOMS® System with the canister and HSM Model 102 in [D.12-1] is bounding for WCS CISF conditions.

Accident Dose Calculations

Sections T.11.2.7.3 and T.5 of [D.12-1] demonstrates that there are no off-site radiological consequences for this accident condition and minimum occupational exposures to clear the vents.

Corrective Actions

Consistent with Sections T.11.2.7.4 and 8.2.7.4 of [D.12-1], blockage of the HSM Model 102 vents is to be cleared within the 40-hour time frame analyzed to restore HSM ventilation.

D.12.2.2 Drop Accidents

Cause of Accident

Sections T.11.2.5.1 and T.3.7.4.1 of [D.12-1] discusses the cask drop for the MP197HB cask in the transfer configuration when it contains the canister.

Accident Analysis

The structural thermal consequences for the effects of a drop accident are addressed in Section T.11.2.5.2 of [D.12-1] for the canister and in Appendix D.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 D.8 presents the thermal analysis performed for the MP197HB cask for WCS CISF conditions.

Accident Dose Calculations

The accident dose calculations presented in Section T.11.2.5.3 of [D.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 CIFS and the boundary is approximately 0.75 miles from the WCS CISF.

Corrective Action

Consistent with Sections T.11.2.5.4 and 8.2.5.4 of [D.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 personnel.

D.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 D.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 T.11.2.2.2, 8.2.3.2 and T.3.7.2 of [D.12-1]. The MP197HB cask, when mounted on the transfer vehicle during an earthquake is evaluated in Appendix D.7. In addition, Chapter D.8 demonstrates that the thermal analysis performed for the Standardized NUHOMS® System in [D.12-1] is bounding for WCS CISF conditions.

Accident Dose Calculations

As documented in Section T.11.2.2.3 of [D.12-1], there are no radiological consequences as a result of a seismic event.

Corrective Actions

Consistent with Section T.11.2.2.4 of [D.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.

D.12.2.4 Lightning

Cause of Accident

As stated in Sections T.11.2.6.1 and 8.2.6 of [D.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

D.12.2.5 Fire and Explosion

Cause of Accident

As described in Section T.11.2.10.1 of [D.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®-61BTH Type 1 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 of diesel 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 T.12.2.10.2 and T.4.6.8.3 of [D.12-1]. Appendix D.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 T.11.2.10.3 of [D.12-1], there are minimal radiological consequences for this accident condition.

Corrective Actions

Consistent with Section T.11.2.10.4 of [D.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.

D.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.

D.12.2.7 Tornado Wind and Missiles

Cause of Accident

In accordance with ANSI-57.9 [D.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 [D.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 T.11.2.3.2, 8.2.2 and T.3.7.1 of [D.12-1]. Similarly, the structural and thermal consequences of tornado wind and missile loads for the MP197HB cask are addressed in Appendices D.7 and D.8.

Accident Dose Calculations

As documented in Section T.11.2.3.3 of [D.12-1], there are no radiological consequences for this accident condition.

Corrective Actions

Consistent with Sections T.11.2.3.4 of [D.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.

D.12.2.8 Reduced HSM Air Inlet and Outlet Shielding

This event is described in Section 8.2.1 of [D.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 T.11.2.1.1 and 8.2.1.1 of [D.12-1] provides the causes for the accident.

Accident Analysis

The structural and thermal consequences for the accident are addressed in Section T.11.2.1.2 of [D.12-1].

Accident Dose Calculations

Section T.11.2.1.3 of [D.12-1] provides a bounding evaluation which demonstrates that the 10 CFR Part 72 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 100 meters assumed in the evaluation.

Corrective Actions

Consistent with Sections T.11.2.1.4 and 8.2.1.4 of [D.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.

D.12.3 References

D.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).

D.12-2 Proposed SNM-1050, WCS *Consolidated* Interim Storage Facility Technical Specifications, Amendment 0.

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

D.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).

D.12-5 NRC Regulatory Guide 1.76, "Design Basis Tornado and Tornado Missiles for Nuclear Power Plants," 1974.

APPENDIX E.1
INTRODUCTION AND GENERAL DESCRIPTION OF INSTALLATION
NAC-MPC

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E.1. INTRODUCTION AND GENERAL DESCRIPTION OF INSTALLATION

No change or additional information required for the NAC-MPC Cask System containing the Connecticut Yankee MPC and Yankee Rowe MPC for Chapter 1.

APPENDIX E.2
SITE CHARACTERISTICS
NAC-MPC

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E.2. SITE CHARACTERISTICS

No change or additional information required for the NAC-MPC Cask System containing the Connecticut Yankee MPC and Yankee Rowe MPC for Chapter 2.

APPENDIX E.3
PRINCIPAL DESIGN CRITERIA
NAC-MPC

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E.3 PRINCIPAL DESIGN CRITERIA

The NAC-MPC Cask System *principal* design criteria for Connecticut Yankee MPC and Yankee Rowe MPC is documented in Chapter 2 of the NAC-MPC Final Safety Analysis Report (FSAR) [Reference E.3-1]. The *principal* design criteria for the La Crosse MPC is documented in Chapter 2, Appendix 2.A of the NAC-MPC FSAR [Reference E.3-1]. *Table E.3-1 provides a comparison of the NAC-MPC 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 NAC-MPC Cask System is bounded by the WCS CSIF criteria.*

E.3.1 Yankee Rowe MPC and Connecticut Yankee MPC

The Yankee Rower MPC (Yankee-MPC) is designed to store up to 36 Yankee Class spent fuel assemblies. The Yankee Class fuel consists of two types, designated A and B. The Type A assembly incorporates a protruding corner of the fuel rods while the Type B assembly omits one corner of the fuel rods. During reactor operations, the symmetric stacking of the alternating assemblies permitted the insertion of cruciform control blades between the assemblies. Table 2.1-1 of Reference E.3-1 lists the nominal design parameters and the maximum and minimum enrichments of each fuel design type. Not listed in the table are the various inert rod configurations employed in the CE and Exxon fuel types. The Yankee class fuel is described in Section 2.1.1 of Reference E.3-1.

The Connecticut Yankee MPC (CY-MPC) is designed to store up to 26 Connecticut Yankee spent fuel assemblies, but is provided with either a 26-assembly or a 24-assembly basket. The Connecticut Yankee fuel is a 15 x 15 square array PWR assembly. The majority of the Connecticut Yankee fuel is stainless steel clad. About 15% of the fuel to be stored is Zircaloy clad. The 15 x 15 array incorporate 20 guide tubes for insertion of control components. Table 2.1-3 of Reference E.3-1 lists the nominal design parameters of each fuel design type. The Connecticut Yankee fuel is described in Section 2.1.2 of Reference E.3-1.

The design criteria for environmental conditions and natural phenomena for the Yankee-MPC and CY-MPC, which are generically known as the NAC-MPC, are described in Section 2.2 of Reference E.3-1. The applicable portions of Section 2.2 have been reviewed against the environmental conditions at the WCS facility and have been shown to be either bounded by the analysis presented in Reference E.3-1 or require no further analysis than what is presented in Reference E.3-1 because they already meet the regulatory requirements of 10 CFR Part 72.

E.3.1.1 Design Criteria for Environmental Conditions and Natural Phenomena

The design criteria defined in this section identifies the site environmental conditions and natural phenomena to which the storage system could reasonably be exposed during the period of storage. Analyses to demonstrate that the NAC-MPC design meets these design criteria are presented in the relevant chapters of Reference E.3-1.

E.3.1.1.1 Tornado and Wind Loadings

The NAC-MPC may be stored on an unsheltered reinforced concrete storage pad at an ISFSI site. This storage configuration exposes the NAC-MPC to tornado and wind loading. The design basis tornado and wind loading is defined based on Regulatory Guide 1.76 Region I and NUREG-0800. The design basis tornado missile impacts are defined in Paragraph 4, Subsection III, Section 3.5.1.4 of NUREG-0800. Analyses presented in Reference E.3-1, Section 11.2.13, demonstrate that the NAC-MPC design meets these design criteria. Therefore, no further WCS site-specific evaluations are required.

E.3.1.1.2 Water Level (Flood) Design

The NAC-MPC may be exposed to a flood during storage on an unsheltered concrete storage pad at an ISFSI site. The source and magnitude of the probably maximum flood depend on several variables. The NAC-MPC is evaluated for a maximum flood water depth of 50 feet above the base of the storage cask. The flood water velocity is considered to be 15 feet per section.

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.

E.3.1.1.3 Seismic Design

The NAC-MPC may be exposed to a seismic event (earthquake) during storage on an unsheltered concrete pad at an ISFSI. The seismic response spectra experienced by the cask will depend upon the geographical location of the specific site and distance from the epicenter of the earthquake. The only significant effect of a seismic event on an NAC-MPC would be a possible tip-over; however, tip-over does not occur in the evaluated design basis earthquake.

Seismic response of the NAC-MPC is presented in Section 11.2.2 of Reference E.3-1. The seismic ground acceleration that will cause the NAC-MPC to tip over is calculated in Section 11.2.2 using quasi-static analysis methods. Evaluation of the consequences of a tip over event is provided in Section 11.2.12 of Reference E.3-1. Based on these evaluations, the maximum permitted ground accelerations that do not result in cask tip over are 0.25g horizontal and 0.167g vertical at the top surface of the ISFSI. The WCS pad design meets the NAC-MPC pad requirements and is consistent with analyses performed within Reference E.3-1. The existing analysis bounds the WCS site pad design limits for accelerations at the top pad surface. Therefore, no further evaluations are required.

E.3.1.1.4 Snow and Ice Loadings

The criteria for determining design snow loads is based on ANSI/ASCE 7-93, Section 7.0. The NAC-MPC is assumed to have a site location typical for siting Category C, which is defined to be "locations in which snow removal by wind cannot be relied on to reduce roof loads because of terrain, higher structures, or several trees near by." Ground snow loads for the contiguous United States are given in Figures, 5, 6 and 7 of ANSI/ASCE 7-93. A worst case value of 100 pounds per square foot was assumed. Section 2.2.4 of Reference E.3-1 demonstrates the snow load is bounded by the weight of the loaded transfer cask. The snow load is also considered in the load combinations described in Section 3.4.4.2.2 of Reference E.3-1. Therefore, no further WCS site-specific evaluations are required.

E.3.1.1.5 Combined Load Criteria

Each normal, off-normal and accident condition has a combination of load cases that defines the total combined loading for that condition. The individual load cases considered include thermal, seismic, external and internal pressure, missile impacts, drops, snow and ice loads, and/or flood water forces. The load conditions to be evaluated for storage casks are identified in 10 CFR 72 and in the "Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type)" (ANSI/ANS 57.9 – 1992).

The load combinations specified in ANSI/ANS 57.9 – 1992 for concrete structures are applied to the concrete casks as shown in Table 2.2-1 of Reference E.3-1. The concrete cask is designed to the requirements of ACI 349. In calculating the design strength of the NAC-MPC concrete body, nominal strength values are multiplied by a strength reduction factor in accordance with Section 9.3 of ACI 349.

The canister is designed in accordance with the 1995 edition of the ASME Code, Section III, Subsection NB for Class 1 components. The basket structure is designed per ASME Code, Section III, Subsection NG, and the structural buckling of the basket is evaluated per NUREG/CR-6322.

The load combinations for all normal, off-normal, and accident conditions and corresponding service levels are shown in Table 2.2-2 of Reference E.3-1. Stress intensities caused by pressure, temperature, and mechanical loads are combined before comparing to ASME Code allowables, which are listed in Table 2.2-3 of Reference E.3-1.

The transfer cask is a special lifting device and is designed and fabricated to the requirements of ANSI N14.6 and NUREG-0612 for the lifting trunnions and supports. The combined shear stress or maximum tensile strength during the lift (with 10 percent load factor) shall be $\leq S_y/6$ and $S_u/10$ for a nonredundant load path, or shall be $\leq S_y/3$ and $S_u/5$ for redundant load paths. The ferritic steel material used for the load bearing members of the transfer cask shall satisfy the material toughness requirements of ANSI N14.6, paragraph 4.2.6. The structural evaluations presented in Reference E.3-1 demonstrate the transfer cask meets these design criteria.

The structural evaluations presented in Reference E.3-1 demonstrate that the concrete cask, canister, fuel basket, and transfer cask meets or exceeds these design criteria. Therefore, no further WCS site-specific evaluations are required.

E.3.1.1.6 Environmental Temperatures

A temperature of 75°F was selected to bound all annual average temperatures in the United States, except the Florida Keys and Hawaii. The 75°F normal temperature was used as the base for thermal evaluations. The evaluation of this environmental condition is discussed along with the thermal analysis models in Chapter 4.0 of Reference E.3-1. The thermal stress evaluation for the normal operating conditions is provided in Section 3.4.4 of Reference E.3-1. Normal temperature fluctuations are bounded by the severe ambient temperature cases that are evaluated as off-normal and accident conditions.

Off-normal, severe environmental conditions were defined as -40°F with no solar loads and 100°F with solar loads. An extreme environmental condition of 125°F with maximum solar loads is evaluated as an accident case to show compliance with the maximum heat load case required by ANSI-57.9 (Section 11.2.10). Thermal performance was also evaluated for the cases of: (1) half the air inlets blocked; and (2) all air inlets and outlets blocked. Thermal analyses for these cases are presented in Sections 11.1.1 and 11.2.8 of Reference E.3-1. The evaluation based on ambient temperature conditions is presented in Section 4.4 of Reference E.3-1. Solar insolance is as specified in 10 CFR 71.71 and Regulatory Guide 7.8.

Therefore, the maximum average yearly temperature allowed for the NAC-MPC system is 75°F and the maximum 3-day average ambient temperature shall be ≤ 100°F. The allowed temperature extremes, average of a 3-day period, shall be greater than -40°F and less than 125°F. The WCS site extreme temperature range is from 30.1°F to 113°F and the average yearly temperature for the site is conservatively bounded by using the maximum average annual temperature in the 48 contiguous United States of 75°F. This temperature meets the normal condition thermal boundary defined in NUREG-1536. Therefore, no further WCS site-specific evaluations are required.

E.3.1.2 Safety Protection Systems

The NAC-MPC relies upon passive systems to ensure the protection of public health and safety, except in the case of fire or explosion. As discussed in Section 2.3.6 of Reference E.3-1, fire and explosion events are effectively precluded by site administrative controls that prevent the introduction of flammable and explosive materials into areas where an explosion or fire could damage installed NAC-MPC systems. The use of passive systems provides protection from mechanical or equipment failure.

E.3.1.2.1 General

The NAC-MPC is designed for safe, long-term storage of spent nuclear fuel. The NAC-MPC will survive all of the evaluated normal, off-normal, and postulated accident conditions without release of radioactive material or excessive radiation exposure to workers or the general public. The major design considerations that have been incorporated in the NAC-MPC system to assure safe long-term fuel storage are:

1. Continued confinement in postulated accidents
2. Thick concrete and steel biological shield
3. Passive systems that ensure reliability
4. Inert atmosphere to provide corrosion protection for stored fuel cladding

Each NAC-MPC system storage component is classified with respect to its function and corresponding effect on public safety. In accordance with Regulatory Guide 7.10, each system component is assigned a safety classification into Category A, B or C, as shown in Tables 2.3-1 and 2.3-2 of Reference E.3-1. The safety classification is based on review of each component's function and the assessment of the consequences of component failure following the guidelines of NUREG/CR-6407, "Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety."

Category A - Components critical to safe operations whose failure or malfunction could directly result in conditions adverse to safe operations, integrity of spent fuel or public health and safety.

Category B - Components with major impact on safe operations whose failure or malfunction could indirectly result in conditions adverse to safe operations, integrity of spent fuel or public health and safety.

Category C - Components whose failure would not significantly reduce the packaging effectiveness and would not likely result in conditions adverse to safe operations, integrity of spent fuel, or public health and safety.

As discussed in Section 2.3 of Reference E.3-1, the NAC-MPC design incorporates features addressing the above design considerations to assure safe operation during fuel loading, handling, and storage. This section addresses the following:

1. Protection by multiple confinement barriers and systems
2. Protection by equipment and instrumentation selection
3. Nuclear criticality safety
4. Radiological protection
5. Fire and explosion protection

The confinement performance requirements for the NAC-MPC System are described in Chapter 7, Section 7.1.1.3 of Reference E.3-1 for storage conditions. In addition, "NAC-STC Safety Analysis Report" [E.3-2] demonstrates that the confinement boundary is not adversely affected by normal conditions of transport. Specifically, Chapter 2, Section 2.6.13 for the Yankee-MPC and Chapter 2, Section 2.6.15 for the CY-MPC. Therefore, transport to the WCS CISF will not adversely impacted confinement integrity of the NAC-MPC canister.

E.3.1.3 Decommission Considerations

The principle elements of the NAC-MPC storage system are the vertical concrete cask and the transportable storage canister. Section 2.4 of Reference E.3-1 discusses decommissioning considerations of these principle elements.

E.3.2 La Crosse MPC

The La Crosse MPC (MPC-LACBWR) storage system is designed to store up to 68 Dairyland Power Cooperative La Crosse Boiling Water Reactor (LACBWR) fuel assemblies. The spent fuel assemblies stored in MPC-LACBWR are delineated by various factors including manufacturer, type, enrichment, burnup, cool time, and cladding material. The LACBWR fuel consists of two types, Allis Chalmers and Exxon fuel. LACBWR fuel assemblies are comprised of 10x10 array of rods, with Allis Chalmers fuel containing 100 fuel rods and Exxon fuel containing 96 fuel rods and four inert rods. All fuel assemblies are steel clad. Table 2.A.1-1 of Reference E.3-1 lists the nominal design parameters of each fuel type.

LACBWR fuel assembly shrouds (channels) were removed from the spent fuel assemblies prior to dry fuel storage. The zirconium alloy shrouds were compacted in the LACBWR fuel pool. Small quantities of zirconium alloy compaction debris were still present in the spent fuel pool. Visual inspection of the LACBWR fuel assemblies indicated the presence of compaction debris within the fuel assembly boundary (e.g., located on the nozzles or trapped within the fuel rod lattice). As the material is neutronically inert — i.e, it has no effect on the criticality analysis, has no significant activation or heat source compared to the fuel rods and assembly hardware, is a standard component of BWR fuel assembly designs, and has no adverse material interaction with the fuel assembly or basket/canister material — the zirconium alloy compaction debris is allowed to be stored with the fuel assemblies. Presence of this material does not result in the assembly being classified as damaged; it is permitted to be stored with undamaged and damaged fuel assemblies.

The stored fuel assemblies must be undamaged or must be placed inside damaged fuel cans (DFC). Undamaged fuel assemblies may not have cladding defects greater than pin holes or hairline cracks. Unenriched fuel assemblies may not be stored in the MPC-LACBWR system. The short-term and long-term temperature limits for stainless steel-clad fuel are derived based on the limits presented in EPRI Report TR-106440, “Evaluation of Expected Behavior of LWR Stainless Steel-Clad Fuel in Long-Term Dry Storage,” April 1996. In this report, the potential failure modes in both wet and dry storage environments were assessed to develop the bounding conditions for the prevention of any potential cladding degradation phenomena and cladding failure modes of stainless steel clad fuel. The potential cladding degradation mechanisms evaluated include: general corrosion, stress corrosion cracking, localized corrosion, mechanical failures and chemical/metallurgical-based failure mechanisms. The EPRI report is based on several types of stainless steel cladding, including Type 304, 348, 348H and modified 348H, which includes LACBWR fuel. The temperature limit for stainless steel clad fuel is 430ºC for the MPC-LACBWR system.

E.3.2.1 Design Criteria for Environmental Conditions and Natural Phenomena

The design criteria defined in this section identifies the site environmental conditions and natural phenomena to which the storage system could reasonably be exposed during the period of storage. Analyses to demonstrate that the NAC-MPC design meets these design criteria are presented in the relevant chapters of Reference E.3-1.

E.3.2.1.1 Tornado and Wind Loadings

The tornado and wind loadings design criteria that are defined in Section 2.2 of Reference E.3-1 for the NAC-MPC apply to the MPC-LACBWR system in their entirety. These design criteria are described in WCS SAR Appendix E, Section E.3.1.1.1. Therefore, no further WCS site-specific evaluations are required.

E.3.2.1.2 Water Level (Flood) Design

The water level (flood) design criteria that are defined in Section 2.2 of Reference E.3-1 for the NAC-MPC apply to the MPC-LACBWR system in their entirety. These design criteria are described in WCS SAR Appendix E, Section E.3.1.1.2. *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.*

E.3.2.1.3 Seismic Design

The MPC-LACBWR may be exposed to a seismic event (earthquake) during storage on an unsheltered concrete pad at an ISFSI. The seismic response spectra experienced by the cask will depend upon the geographical location of the specific site and distance from the epicenter of the earthquake. The only significant effect of a seismic event on an MPC-LACBWR would be a possible tip-over; however, tip-over does not occur in the evaluated design basis earthquake.

Seismic response of the MPC-LACBWR is presented in Section 11.A.2.2 of Reference E.3-1. The seismic ground acceleration that will cause the MPC-LACBWR to tip over is calculated in Section 11.A.2.2 using quasi-static analysis methods. Evaluation of the consequences of a tip over event is provided in Section 11.A.2.12 of Reference E.3-1. Based on these evaluations, the maximum permitted ground accelerations that do not result in cask tip over are 0.45g horizontal and 0.3g vertical at the top surface of the ISFSI. The WCS pad design meets the MPC-LACBWR pad requirements and is consistent with analyses performed within Reference E.3-1. The existing analysis bounds the WCS site pad design limits for accelerations at the top pad surface. Therefore, the MPC-LACBWR design criteria bounds the WCS site and no further evaluations are required.

E.3.2.1.4 Snow and Ice Loadings

The snow and ice loadings design criteria that are defined in Section 2.2 of Reference E.3-1 for the NAC-MPC apply to the MPC-LACBWR system in their entirety. These design criteria are described in WCS SAR Appendix E, Section E.3.1.1.4. Therefore, no further WCS site-specific evaluations are required.

E.3.2.1.5 Combined Load Criteria

The combined load design criteria that are defined in Section 2.2 of Reference E.3-1 for the NAC-MPC apply to the MPC-LACBWR system in their entirety. These design criteria are described in WCS SAR Appendix E, Section E.3.1.1.5. Therefore, no further WCS site-specific evaluations are required.

E.3.2.1.6 Environmental Temperatures

The environmental temperatures design criteria that are defined in Section 2.2 of Reference E.3-1 for the NAC-MPC apply to the MPC-LACBWR system in their entirety with exception to the maximum extreme heat limit, which is 105°F. The applicable design criteria are described in WCS SAR Appendix E, Section E.3.1.1.6.

Therefore, the maximum average yearly temperature allowed for the NAC-MPC system is 75°F and the maximum 3-day average ambient temperature shall be ≤ 105°F. The allowed temperature extremes, average of a 3-day period, shall be greater than -40°F and less than 125°F. The WCS site extreme temperature range is from 30.1°F to 113°F and the average yearly temperature for the site is conservatively bounded by using the maximum average annual temperature in the 48 contiguous United States of 75°F. This temperature meets the normal condition thermal boundary defined in NUREG-1536. Therefore, no further WCS site-specific evaluations are required.

E.3.2.2 Safety Protection Systems

The MPC-LACBWR relies upon passive systems to ensure the protection of public health and safety, except in the case of fire or explosion. As discussed in Section 2.3.6 of Reference E.3-1, fire and explosion events are effectively precluded by site administrative controls that prevent the introduction of flammable and explosive materials into areas where an explosion or fire could damage installed MPC-LACBWR systems. The use of passive systems provides protection from mechanical or equipment failure.

E.3.2.2.1 General

The MPC-LACBWR is designed for safe, long-term storage of spent nuclear fuel. The MPC-LACBWR will survive all of the evaluated normal, off-normal, and postulated accident conditions without release of radioactive material or excessive radiation exposure to workers or the general public. The major design considerations that have been incorporated in the MPC-LACBWR system to assure safe long-term fuel storage are:

1. Continued confinement in postulated accidents
2. Thick concrete and steel biological shield
3. Passive systems that ensure reliability
4. Inert atmosphere to provide corrosion protection for stored fuel cladding

Each MPC-LACBWR system storage component is classified with respect to its function and corresponding effect on public safety. In accordance with Regulatory Guide 7.10, each system component is assigned a safety classification into Category A, B or C, as shown in Table 2.A.3-1 of Reference E.3-1. The safety classification is based on review of each component's function and the assessment of the consequences of component failure following the guidelines of NUREG/CR-6407, "Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety."

Category A - Components critical to safe operations whose failure or malfunction could directly result in conditions adverse to safe operations, integrity of spent fuel or public health and safety.

Category B - Components with major impact on safe operations whose failure or malfunction could indirectly result in conditions adverse to safe operations, integrity of spent fuel or public health and safety.

Category C - Components whose failure would not significantly reduce the packaging effectiveness and would not likely result in conditions adverse to safe operations, integrity of spent fuel, or public health and safety.

As discussed in Section 2.A.3 of Reference E.3-1, the MPC-LACBWR design incorporates features addressing the above design considerations to assure safe operation during fuel loading, handling, and storage. This section addresses the following:

1. Protection by multiple confinement barriers and systems
2. Protection by equipment and instrumentation selection
3. Nuclear criticality safety
4. Radiological protection
5. Fire and explosion protection

The confinement performance requirements for the NAC-MPC System are described in Chapter 7, Section 7.1.1.3 of Reference E.3-1 for storage conditions. In addition, Reference E.3-2 demonstrates that the confinement boundary is not adversely affected by normal conditions of transport. Specifically, Chapter 2, Section 2.11.6.13 for the MPC-LACBWR. Therefore, transport to the WCS CISF will not adversely impacted confinement integrity of the NAC-MPC canister.

E.3.2.3 Decommissioning Considerations

The principle elements of the MPC-LACBWR storage system are the vertical concrete cask and the transportable storage canister. Section 2.A.4 of Reference E.3-1 discusses decommissioning considerations of these principle elements.

E.3.3 References

E.3-1 NAC-MPC Final Safety Analysis Report, Revision 10, January 2014

E.3-2 NAC-STC Safety Analysis Report, Revision 17, April 2011

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

Design Parameter	WCS CISF Design Criteria	Condition	NAC-MPC Design Criteria
Type of fuel	*Commercial, light water reactor spent fuel*	*Normal (Bounded)*	*NAC-MPC FSAR Section 2.1*
Storage Systems	*Transportable canisters and storage overpacks docketed by the NRC*	*Normal (Bounded)*	*72-1025* *71-9235*
Fuel Characteristics	*Criteria as specified in previously approved licenses for included systems*	*Normal (Bounded)*	*NAC-MPC FSAR Section 2.1*
Tornado (Wind Load)	*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)*	***NAC-MPC FSAR Section 2.2.1.1*** *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 (Missile)	*Automobile: 4000 lb, 112 ft/s (76.4 mph)* *Schedule 40 Pipe: 287 lb, 112 ft/s (76.4 mph)* *Solid Steel Sphere: 0.147 lb, 23 ft/s (15.7 mph)*	*Accident (Bounded)*	***NAC-MPC FSAR Section 2.2.1.3*** *Massive Missile: 3960 lb, 126 mph* *Rigid hardened steel: 275 lb, 126 mph* *Solid Steel Sphere: 0.15 lb, 126 mph*
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)*	***NAC-MPC FSAR Section 2.2.2.1*** *Flood height: 50 ft* *Water velocity: 15 ft/s*

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

Design Parameter	***WCS CISF Design Criteria***	***Condition***	***NAC-MPC Design Criteria***
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)*	***NAC-MPC FSAR Section 2.2.3.1*** *Yankee-MPC and CY-MPC are designed to 0.25 g horizontal and 0.167 g vertical* ***NAC-MPC FSAR Section 2.A.2.1.1*** *MPC-LACBWR is designed to 0.45 g horizontal and 0.3 g vertical* ***NAC-MPC CoC, Technical Specification B 3.4, Section 3.c)*** *Alternatively, the design basis earthquake motion of the ISFSI pad maybe limited so that the acceleration g-load resulting from the collision of the two sliding casks remains bounded by the accident condition analyses presented in Chapter 11 of the NAC-MPC FSAR.*
Vent Blockage	*For MPC Systems:* *Inlet and outlet vents blocked 24 hrs*	*Accident (Same)*	***Yankee-MPC, NAC-MPC FSAR Section 11.2.8.4*** ***CY-MPC, NAC-MPC FSAR Section 11.2.8.4*** ***MPC-LACBWR, NAC-MPC FSAR Section 11.2.8.4*** *Inlet and outlet vents blocked: 24 hrs*
Fire/Explosion	*For MPC Systems:* *Equivalent fire 50 gallons of diesel fuel*	*Accident (Same)*	***NAC-MPC FSAR Section 11.2.5*** *Equivalent fire 50 gallons of diesel fuel*
Cask Drop	*For MPC Systems:* *Drop height 6 inches*	*Accident (Same)*	***NAC-MPC FSAR Section 11.2.11.2*** ***(MPC-LACBWR) NAC-MPC FSAR Section 11.A.2.11.2*** *Drop height 6 inches*
Ambient Temperatures	*Yearly average temperature 67.1°F*	*Normal (Bounded)*	***NAC-MPC FSAR Section 2.2.6*** *Average Annual Ambient Temperature 75°F*
Off-Normal Temperature	*Minimum 3 day avg. temperature 27.9°F* *Maximum 3 day avg. temperature 89.4°F*	*Off-Normal (Bounded)*	***NAC-MPC FSAR Section 2.2.6*** *Minimum 3 day avg. temperature -40°F* *Maximum 3 day avg. temperature 100°F*

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

Design Parameter	***WCS CISF Design Criteria***	***Condition***	***NAC-MPC Design Criteria***
Extreme Temperature	*Maximum temperature 113°F*	*Accident (Bounded)*	***NAC-MPC FSAR Section 2.2.6*** *Maximum temperature 125°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)*	***Yankee-MPC, NAC-MPC FSAR Section 4.4.1.1.2*** ***CY-MPC, NAC-MPC FSAR Section 4.5.1.1*** ***MPC-LACBWR, NAC-MPC FSAR Section 4.A.3.1.1*** *Curved Surface: 1475 Btu/ft^2 for a 24-hour period.* *Flat Horizontal Surface: 2950 Btu/ft^2 for a 24-hour period.*
Snow and Ice	*Snow Load 10 psf*	*Normal (Bounded)*	***NAC-MPC FSAR Section 2.2.4*** *100 psf*
Dead Weight	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*Yankee-MPC Canister – NAC-MPC FSAR Section 3.4.4.1.2* *Yankee-MPC Storage Cask – NAC-MPC FSAR Section 3.4.4.2.1* *CY-MPC Canister – NAC-MPC FSAR Section 3.4.4.3.2* *CY-MPC Storage Cask – NAC-MPC FSAR Section 3.4.4.4.1* *MPC-LACBWR Concrete Cask – NAC-MPC FSAR Section 3.A.4.4.3.1* *MPC-LACBWR Canister – NAC-MPC FSAR Section 3.A.4.4.1.2*
Internal and External Pressure Loads	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*Yankee-MPC Canister – NAC-MPC FSAR Section 3.4.4.1.3* *CY-MPC Canister – NAC-MPC FSAR Section 3.4.4.3.2* *MPC-LACBWR Canister – NAC-MPC FSAR Section 3.A.4.4.1.3*
Design Basis Thermal Loads	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*Yankee-MPC – NAC-MPC FSAR Section 4.4* *CY-MPC – NAC-MPC FSAR Section 4.5* *MPC-LACBWR – NAC-MPC FSAR Section 4.A*

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

Design Parameter	***WCS CISF Design Criteria***	***Condition***	***NAC-MPC Design Criteria***
Operating Loads	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*NAC-MPC – NAC-MPC FSAR Section 3.4.4 (Yankee-MPC and CY-MPC)* *MPC-LACBWR – NAC-MPC FSAR Section 3.A.4.4*
Live Loads	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*Yankee-MPC Storage Cask – NAC-MPC FSAR Section 3.4.4.2.2* *CY-MPC Storage Cask – NAC-MPC FSAR Section 3.4.4.4.2* *MPC-LACBWR Concrete Cask – NAC-MPC FSAR Section 3.A.4.4.3.2*
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)*	***NAC-MPC FSAR Section 10.2.2*** *Public wholebody, organ or skin ≤ 5 Rem*
Radiological Protection	*Public wholebody ≤ 25 mrem/yr*[(1)] *Public thyroid ≤ 75 mrem/yr*[(1)] *Public critical organ ≤ 25 mrem/yr*[(1)]	*Normal (Same)*	***NAC-MPC FSAR Section 10.4*** *Exposure to the Public ≤ 25 mrem/yr*
Confinement	*Per design basis for systems listed in Table 1-1*	*N/A*	*NAC-MPC FSAR Chapter 7* *Leaktight*
Nuclear Criticality	*Per design basis for systems listed in Table 1-1*	*N/A*	*NAC-MPC FSAR Chapter 6* K_{eff}<.95
Decommissioning	*Minimize potential contamination*	*Normal (Same)*	***Yankee-MPC – NAC-MPC FSAR Section 2.4*** ***CY-MPC – NAC-MPC FSAR Section 2.4*** ***MPC-LACBWR – NAC-MPC FSAR Section 2.A.4*** *Minimize potential contamination*

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

Design Parameter	***WCS CISF Design Criteria***	***Condition***	***NAC-MPC 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)*	*Cask/canister handling system prevent breach of confinement boundary under all conditions* *Storage system allows ready retrieval of canister for shipment off-site (Chapter 8)*

Note

1. *In accordance with 10 CFR 72.104(a)(3), limits include any other radiation from uranium fuel cycle operations within the region.*

APPENDIX E.4
OPERATING SYSTEMS
NAC-MPC

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E.4 OPERATING SYSTEMS

The principal components of the NAC-MPC system are the canister, the vertical concrete cask and the transfer cask. The loaded canister is moved to and from the concrete cask with the transfer cask. The transfer cask provides radiation shielding while the canister is being transferred. The canister is placed in the concrete cask by positioning the transfer cask with the loaded canister on top of the concrete cask and lowering the canister into the concrete cask. Figure E.4-1 depicts the major components of the NAC-MPC system and shows the transfer cask positioned on the top of the concrete cask.

The NAC-MPC is provided in three configurations. The first is designed to store up to 36 intact Yankee Class spent fuel and reconfigured fuel assemblies and is referred to as the Yankee-MPC. The second is designed to store up to 26 Connecticut Yankee fuel assemblies, reconfigured fuel assemblies and damaged fuel in CY-MPC damaged fuel cans, and is referred to as the CY-MPC. The Yankee-MPC and CY-MPC systems are described in WCS SAR Appendix E, Section E4.1 and are generically referred to as the NAC-MPC. The third configuration, referred to as MPC-LACBWR, is designed to store up to 68 Dairyland Power Cooperative (DPC) La Crosse Boiling Water Reactor (LACBWR) spent fuel assemblies with up to 32 damaged fuel cans. The MPC-LACBWR system is described in WCS SAR Appendix E, Section E4.2.

Section E.4.4 provides reference to all applicable license drawings (i.e., only Yankee-MPC, CY-MPC, and MPC-LACBWR fuel storage systems) from Reference [E.4-1].

In addition to these previously NRC approved license drawings, this WCS SAR appendix includes two site-specific GTCC waste canister storage configuration drawings for previously loaded Yankee Rowe and Connecticut Yankee GTCC waste canisters (GTCC-Canister-YR and GTCC-Canister-CY, respectively).

E.4.1 Yankee Rowe MPC and Connecticut Yankee MPC

This following provides a general description of the major components of the NAC-MPC system used to store the Yankee Rowe MPC (Yankee-MPC) and the Connecticut Yankee MPC (CY-MPC) and a description of the system operations. The terminology used throughout this report is summarized in Table 1-1 of Reference E.4-1.

E.4.1.1 Transportable Storage Canister and Baskets

The Transportable Storage Canister (TSC) contains a basket that is designed to accommodate either Yankee Class or Connecticut Yankee (CY) spent fuel. The Yankee-MPC basket holds up to 36 intact Yankee Class spent fuel assemblies and reconfigured fuel assemblies (RFAs) up to a total contents weight of 30,600 pounds, including up to four fuel assemblies or RFAs loaded in damaged fuel cans. The CY-MPC basket holds up to 26 spent fuel assemblies and RFAs up to a total contents weight of 35,100 pounds, including up to four fuel assemblies or RFAs loaded in damaged fuel cans. See Figure E.4-2 for an illustration of the NAC-MPC TSC and basket.

The Yankee-MPCs and CY-MPCs were loaded with spent fuel and welded closed at their respective sites. There are no active components associated with the loaded and welded closed TSCs. Thus, no further loading or closing operations are required to be performed on the TSC and basket at the WCS facility. Further details about the TSC and basket can be found in Section 1.2.1.1 of Reference E.4-1.

E.4.1.2 Vertical Concrete Cask

The vertical concrete cask (storage cask) is the storage overpack for the transportable storage canister (TSC). It provides structural support, shielding, protection from environmental conditions, and natural convection cooling of the canister during long-term storage. Table 1.2-3 of Reference E.4-1 lists the principal physical design parameters of the storage cask for the Yankee-MPC and CY-MPC configurations.

The storage cask is a reinforced concrete (Type II Portland cement) structure with a structural steel inner liner. Inner and outer reinforcing steel (rebar) assemblies are contained within the concrete. The storage cask incorporates reinforced chamfered corners at the edges to facilitate construction. In the Yankee-MPC, a silicone foam insulating material provided by Rogers Corporation, is placed on the base of the cavity to prevent contact between the stainless steel canister and the carbon steel pedestal. The storage cask is shown in Figure E.4-3.

The storage cask has an annular air passage to allow the natural circulation of air around the canister to remove the decay heat from the spent fuel. The decay heat is transferred from the fuel assemblies to the fuel tubes or damaged fuel can in the fuel basket and through the heat transfer disks to the canister wall. Heat flows by radiation and convection from the canister wall to the air circulating through the concrete cask annular air passage and is exhausted through the air outlet vents. This passive cooling system is designed to maintain the peak cladding temperature of both stainless steel and Zircaloy clad fuel well below acceptable limits during long-term storage. This design also maintains the bulk concrete temperature below 150°F and localized concrete temperatures below 200°F in normal operating conditions.

The top of the storage cask is closed by a shield plug and lid. The shield plug for the Yankee MPC is approximately 5 inches thick and incorporates carbon steel plate as gamma radiation shielding and NS-4-FR as neutron radiation shielding. A carbon steel lid that provides additional gamma radiation shielding is installed above the shield plug. For the CY-MPC, the shield plug is similar to the Yankee-MPC except the neutron shielding may be either NS-4-FR or NS-3. The shield plug and lid reduce skyshine radiation and provide a cover and seal to protect the canister from the environment and postulated tornado missiles. At the option of the user, a tamper-indicating seal may be installed on two of the concrete cask lid bolts.

To facility movement of the storage cask at the WCS facility, embedded lift lugs are placed in the concrete. This provides a place for the vertical cask transporter to engage the storage cask in order to lift and subsequently move the storage cask whether there is a loaded TSC in it or not.

Existing Yankee-MPC and CY-MPC storage casks will not be used at the WCS facility. New storage casks will be constructed on site at the WCS facility. Fabrication of the storage cask involves no unique or unusual forming, concrete placement, or reinforcement requirements. The concrete portion of the storage cask is constructed by placing concrete between a reusable, exterior form and the inner metal liner. Reinforcing bars are placed near the inner and outer concrete surfaces to provide structural integrity. The inner liner and base of the storage cask are shop fabricated. An optional supplemental shielding fixture may be installed in the air inlets of the Yankee-MPC to reduce the radiation dose rate at the base of the cask. The principal fabrication specifications for the storage cask are shown in Table E.4-2.

E.4.1.3 Transfer Cask

The transfer cask, with its lifting yoke, is primarily a lifting device used to move the canister assembly. It provides biological shielding when it contains a loaded canister. The transfer cask is used for the vertical transfer of the canister between work stations and the storage cask, or transport cask. The general arrangement of the transfer cask and canister is shown in Figure E.4-4 and Figure E.4-5, and the arrangement of the transfer cask and concrete cask is shown in Figure E.4-6. The configuration of the transfer cask, canister and concrete cask during loading of the concrete cask is shown in Figure E.4-7.

Table 1.2-5 of Reference E.4-1 shows the principal design parameters of the transfer cask used for the Yankee-MPC and CY-MPC configurations. As shown, the basic design of the transfer cask is similar, with the CY-MPC transfer cask being approximately 30 inches longer and 2.5 inches larger in diameter than the Yankee-MPC transfer cask.

The transfer cask is a multiwall (steel/lead/NS-4-FR neutron shield/steel) design, which limits the average contact radiation dose rate to less than 300 mrem/hr. The transfer cask design incorporates a top retaining ring, which is bolted in place preventing a loaded canister from being inadvertently removed through the top of the transfer cask. The transfer cask has retractable bottom shield doors. During loading operations, the doors are closed and secured by lock bolts/lock pins, so they cannot inadvertently open. During unloading, the doors are retracted using hydraulic cylinders to allow the canister to be lowered into the storage or transport casks. The transfer cask is shown in Figure E.4-4.

To qualify the transfer cask as a heavy lifting device, it is designed, fabricated, and proof load tested to the requirements of NUREG-0612 and ANSI N14.6. Maintenance is to be performed in accordance with WCS facility procedures that meet the requirements of NUREG-0612.

E.4.1.4 Ancillary Equipment

This section presents a brief description of the principal ancillary equipment needed to operate the NAC-MPC in accordance with its design.

E.4.1.4.1 Adapter Plate

The adapter plate is a carbon steel table that mates the transfer cask to either the vertical concrete (storage) cask or the NAC-STC transport cask. It has a large center hole that allows the transportable storage canister to be raised or lowered through the plate into or out of the transfer cask. Rails are incorporated in the adapter plate to guide and support the bottom shield doors of the transfer cask when they are in the open position. The adapter plate also supports the hydraulic system and the actuators that open and close the transfer cask bottom doors.

E.4.1.4.2 Vertical Cask Transporter

The vertical cask transporter is mobile lifting device that allows for the movement of the vertical concrete storage cask. The transporter engages the storage cask via the embedded lift lugs. After the transporter has engaged the storage cask, it can lift the storage cask and move it to the desired location. When the storage cask has a loaded TSC, the transporter shall not lift the storage higher than the allowed lift limit.

E.4.1.4.3 Rigging and Slings

Load rated rigging attachments and slings are provided for major components. The rigging attachments are swivel hoist rings that allow attachment of the slings to the hook. All slings are commercially purchased to have adequate safety margin to meet the requirements of ANSI N14.6 and NUREG-0612. The slings include a concrete cask lid sling, concrete cask shield plug sling, canister shield lid sling, loaded canister transfer sling (also used to handle the structural lid), and canister retaining ring sling. The appropriate rings or eye bolts are provided to accommodate each sling and component.

The transfer cask lifting yoke is specially designed and fabricated for lifting the transfer cask. It is designed to meet the requirements of ANSI N14.6 and NUREG-0612. It is single-failure-proof by design. The transfer cask lifting yoke is initially load tested to 300 percent of the design load.

E.4.1.4.4 Temperature Instrumentation

The concrete casks may be equipped with temperature-monitoring equipment to measure the outlet air temperature. The Technical Specification requires either daily temperature measurements or daily visual inspection for inlet and outlet screen blockage to ensure the cask heat removal system remains operable.

E.4.1.5 Storage Pad

The NAC-MPC is designed for long-term storage at an ISFSI. At the ISFSI site, the loaded concrete storage casks are placed in the vertical position on a concrete pad in a linear array. The reinforced concrete foundation of the ISFSI pad is capable of sustaining the transient loads from the vertical cask transporter and the general loads of the stored casks. The WCS pad design meets the NAC-MPC pad requirements listed in Table E.4-1.

E.4.2 La Crosse MPC

This following provides a general description of the major components of the La Crosse MPC system used to store the Dairyland Power Cooperative La Crosse Boiling Water Reactor (LACBWR) spent nuclear fuel and a description of the system operations and is referred to as the MPC-LACBWR. The terminology used throughout this report is summarized in Table 1.A-1 of Reference E.4-1.

E.4.2.1 Transportable Storage Canister and Baskets

The Transportable Storage Canister (TSC) contains a basket that is designed to accommodate the LACBWR spent nuclear fuel. The MPC-LACBWR basket holds up to 68 spent fuel assemblies including up to 32 damaged fuel cans. See Figure E.4-9 for an illustration of the NAC-MPC TSC and basket.

The MPC-LACBWR TSCs were loaded with spent fuel and welded closed at the LACBWR site. There are no active components associated with the loaded and welded closed TSCs. Thus, no further loading or closing operations are required to be performed on the TSC and basket at the WCS facility. Further details about the TSC and basket can be found in Section 1.A.2.1.1 of Reference E.4-1.

E.4.2.2 Vertical Concrete Cask

The vertical concrete cask (storage cask) is the storage overpack for the transportable storage canister (TSC). It provides structural support, shielding, protection from environmental conditions, and natural convection cooling of the canister during long-term storage. Table 1.A.2-3 of Reference E.4-1 lists the principal physical design parameters of the storage cask for the MPC-LACBWR configuration.

The storage cask is a reinforced concrete (Type II Portland cement) structure with a structural steel inner liner. Inner and outer reinforcing steel (rebar) assemblies are contained within the concrete. The storage cask incorporates reinforced chamfered corners at the edges to facilitate construction. The storage cask is shown in Figure E.4-10.

The storage cask has an annular air passage to allow the natural circulation of air around the canister to remove the decay heat from the spent fuel. The decay heat is transferred from the fuel assemblies to the fuel tubes or damaged fuel can in the fuel basket and through the heat transfer disks to the canister wall. Heat flows by radiation and convection from the canister wall to the air circulating through the concrete cask annular air passage and is exhausted through the air outlet vents. This passive cooling system is designed to maintain the peak cladding temperature well below acceptable limits during long-term storage. This design also maintains the bulk concrete temperature below 150°F and localized concrete temperatures below 200°F in normal operating conditions.

The top of the storage cask is closed by a lid with integral radiation shield. The radiation shield is approximately 8-inch thick concrete encased in a carbon steel shell extending into the cask cavity from the bottom surface of the 1.5-inch-thick carbon steel lid. The specification summary for the encased concrete is shown in Table E.4-3.

To facility movement of the storage cask at the WCS facility, embedded lift lugs are placed in the concrete. This provides a place for the vertical cask transporter to engage the storage cask in order to lift and subsequently move the storage cask whether there is a loaded TSC in it or not.

Existing MPC-LACBWR storage casks will not be used at the WCS facility. New storage casks will be constructed on site at the WCS facility. Fabrication of the storage cask involves no unique or unusual forming, concrete placement, or reinforcement requirements. The concrete portion of the storage cask is constructed by placing concrete between a reusable, exterior form and the inner metal liner. Reinforcing bars are placed near the inner and outer concrete surfaces to provide structural integrity. The inner liner and base of the storage cask are shop fabricated. Radiation shielding is installed in the air inlets to reduce the radiation dose rates local to the air inlets at the base of the cask. The principal fabrication specifications for the storage cask are shown in Table E.4-2.

E.4.2.3 Transfer Cask

The transfer cask for the MPC-LACBWR is the same transfer cask used for the Yankee-MPC as described in WCS SAR Appendix E, Section E.4.1.3. The transfer cask, with its lifting yoke, is primarily a lifting device used to move the canister assembly. It provides biological shielding when it contains a loaded canister. The transfer cask is used for the vertical transfer of the canister between work stations and the storage cask, or transport cask. The general arrangement of the transfer cask and canister is shown in Figure E.4-11 and Figure E.4-12, and the arrangement of the transfer cask and concrete cask is shown in Figure E.4-13. The configuration of the transfer cask, canister and concrete cask during loading of the concrete cask is shown in Figure E.4-14.

Table 1.A.2-5 of Reference E.4-1 shows the principal design parameters of the transfer cask used for the Yankee-MPC and MPC-LACBWR configurations.

The transfer cask is a multiwall (steel/lead/NS-4-FR neutron shield/steel) design, which limits the average contact radiation dose rate to less than 100 mrem/hr. The transfer cask design incorporates a top retaining ring, which is bolted in place preventing a loaded canister from being inadvertently removed through the top of the transfer cask. The transfer cask has retractable bottom shield doors. During loading operations, the doors are closed and secured by door stops, so they cannot inadvertently open. During unloading, the doors are retracted using hydraulic cylinders to allow the canister to be lowered into the storage or transport casks. The transfer cask is shown in Figure E.4-11.

To qualify the transfer cask as a heavy lifting device, it is designed, fabricated, and proof load tested to the requirements of NUREG-0612 and ANSI N14.6. Maintenance is to be performed in accordance with WCS facility procedures that meet the requirements of NUREG-0612.

E.4.2.4 Ancillary Equipment

This section presents a brief description of the principal ancillary equipment needed to operate the MPC-LACBWR in accordance with its design.

E.4.2.4.1 Adapter Plate

The adapter plate is a carbon steel table that mates the transfer cask to either the vertical concrete (storage) cask or the NAC-STC transport cask. It has a large center hole that allows the transportable storage canister to be raised or lowered through the plate into or out of the transfer cask. Rails are incorporated in the adapter plate to guide and support the bottom shield doors of the transfer cask when they are in the open position. The adapter plate also supports the hydraulic system and the actuators that open and close the transfer cask bottom doors.

E.4.2.4.2 Vertical Cask Transporter

The vertical cask transporter is mobile lifting device that allows for the movement of the vertical concrete storage cask. The transporter engages the storage cask via the embedded lift lugs. After the transporter has engaged the storage cask, it can lift the storage cask and move it to the desired location. When the storage cask has a loaded TSC, the transporter shall not lift the storage higher than the allowed lift limit.

E.4.2.4.3 Rigging and Slings

Load rated rigging attachments and slings are provided for major components. The rigging attachments are swivel hoist rings that allow attachment of the slings to the hook. All slings are commercially purchased to have adequate safety margin to meet the requirements of ANSI N14.6 and NUREG-0612. The slings include a concrete cask lid sling, concrete cask shield plug sling, canister shield lid sling, loaded canister transfer sling (also used to handle the structural lid), and canister retaining ring sling. The appropriate rings or eye bolts are provided to accommodate each sling and component.

The transfer cask lifting yoke is specially designed and fabricated for lifting the transfer cask. It is designed to meet the requirements of ANSI N14.6 and NUREG-0612. It is single-failure-proof by design. The transfer cask lifting yoke is initially load tested to 300 percent of the design load.

E.4.2.4.4 Temperature Instrumentation

The concrete casks may be equipped with temperature-monitoring equipment to measure the outlet air temperature. The Technical Specification requires either daily temperature measurements or daily visual inspection for inlet and outlet screen blockage to ensure the cask heat removal system remains operable.

E.4.2.5 Storage Pad

The MPC-LACBWR is designed for long-term storage at an ISFSI. At the ISFSI site, the loaded concrete storage casks are placed in the vertical position on a concrete pad in a linear array. The reinforced concrete foundation of the ISFSI pad is capable of sustaining the transient loads from the vertical cask transporter and the general loads of the stored casks. The WCS pad design meets the NAC-MPC pad requirements listed in Reference E.4-1.

E.4.3 References

E.4-1 NAC-MPC Final Safety Analysis Report, Revision 10, January 2014

E.4-2 NAC International, "NAC-STC, NAC Storage Transport Cask Safety Analysis Report," Revision 17, CoC 9235 Revision 13, U.S. NRC Docket Number 71-9235.

E.4.4 <u>Supplemental Data</u>

The licensing drawings for the NAC-MPC system are listed in Section 1.7, Drawings, and Section 1.A.7, MPC-LACBWR Licensing Drawings, in volume 1 of the NAC-MPC Final Safety Analysis Report, Revision 10 [E.4-1].

Section 1.7.1 lists the Yankee-MPC license drawings; Section 1.7.2 lists the Yankee Class Reconfigured Fuel Assembly License drawings; and Section 1.7.3 lists the CY-MPC license drawings. These drawings appear in the FSAR immediately after the drawing lists in Section 1.7.

Section 1.A.7 lists the MPC-LACBWR licensing drawings. These drawings appear in the FSAR immediately after the drawing list in Section 1.A.7.

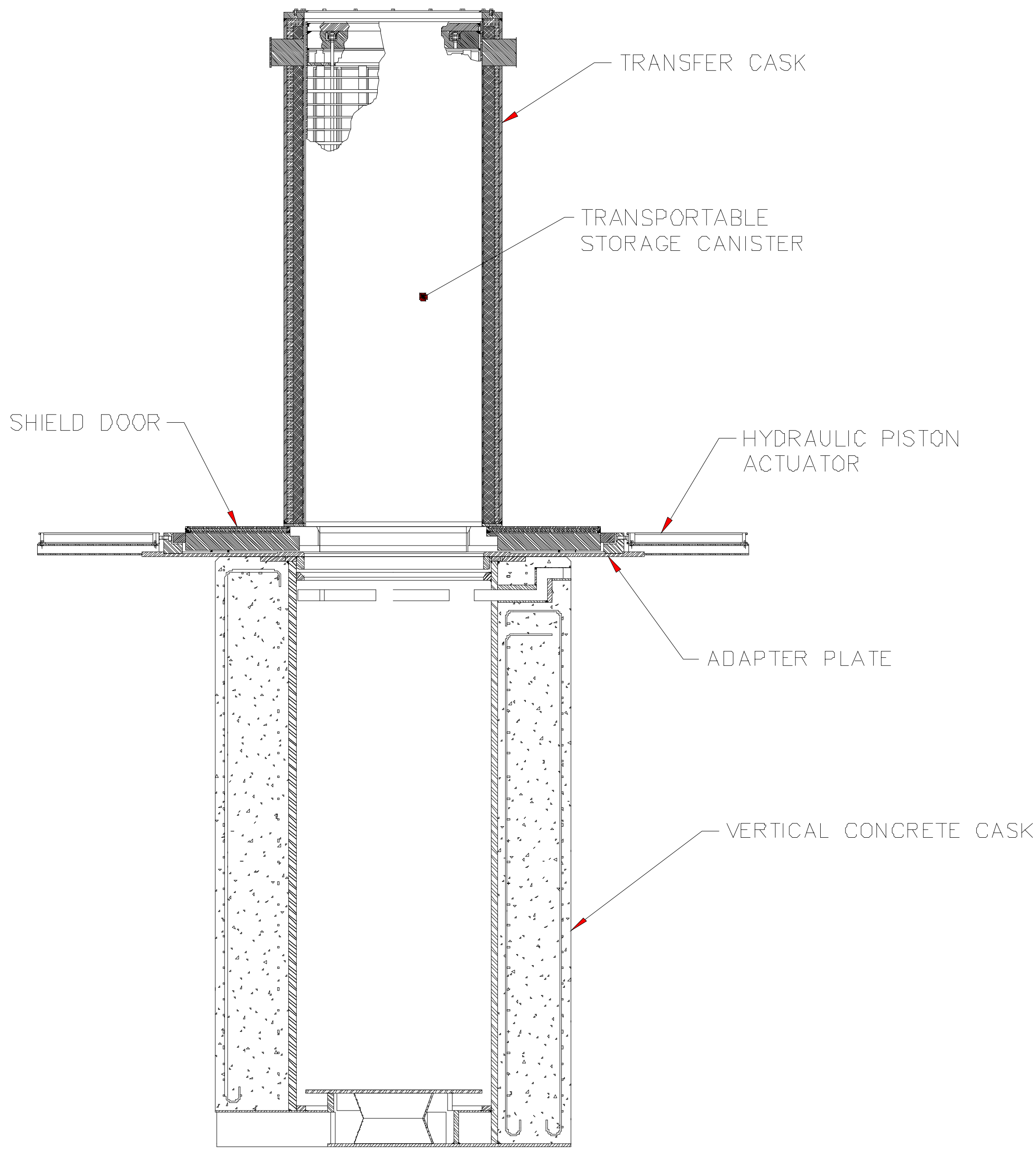

Figure E.4-1
Major Components of the NAC-MPC System

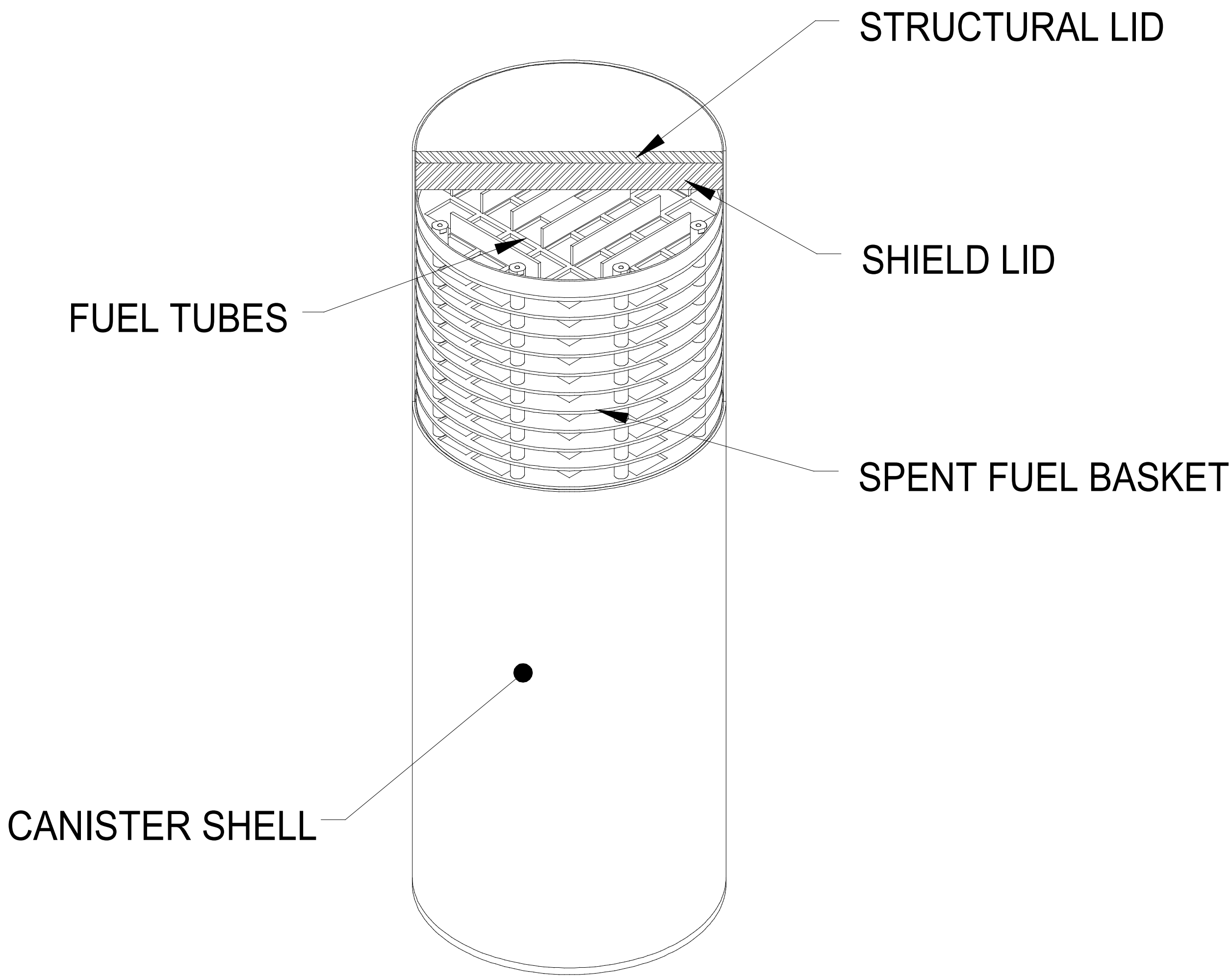

Figure E.4-2
NAC-MPC Transportable Storage Canister Showing the Spent Fuel Basket

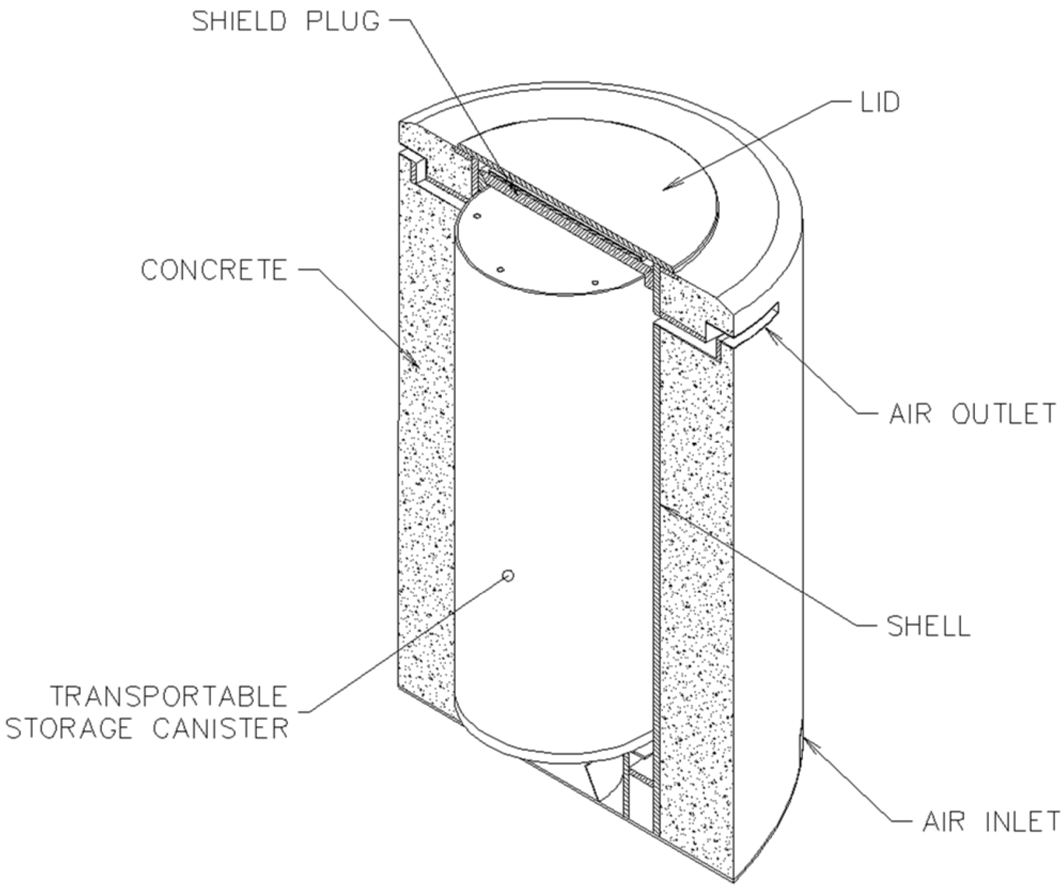

Figure E.4-3
NAC-MPC Vertical Concrete Storage Cask

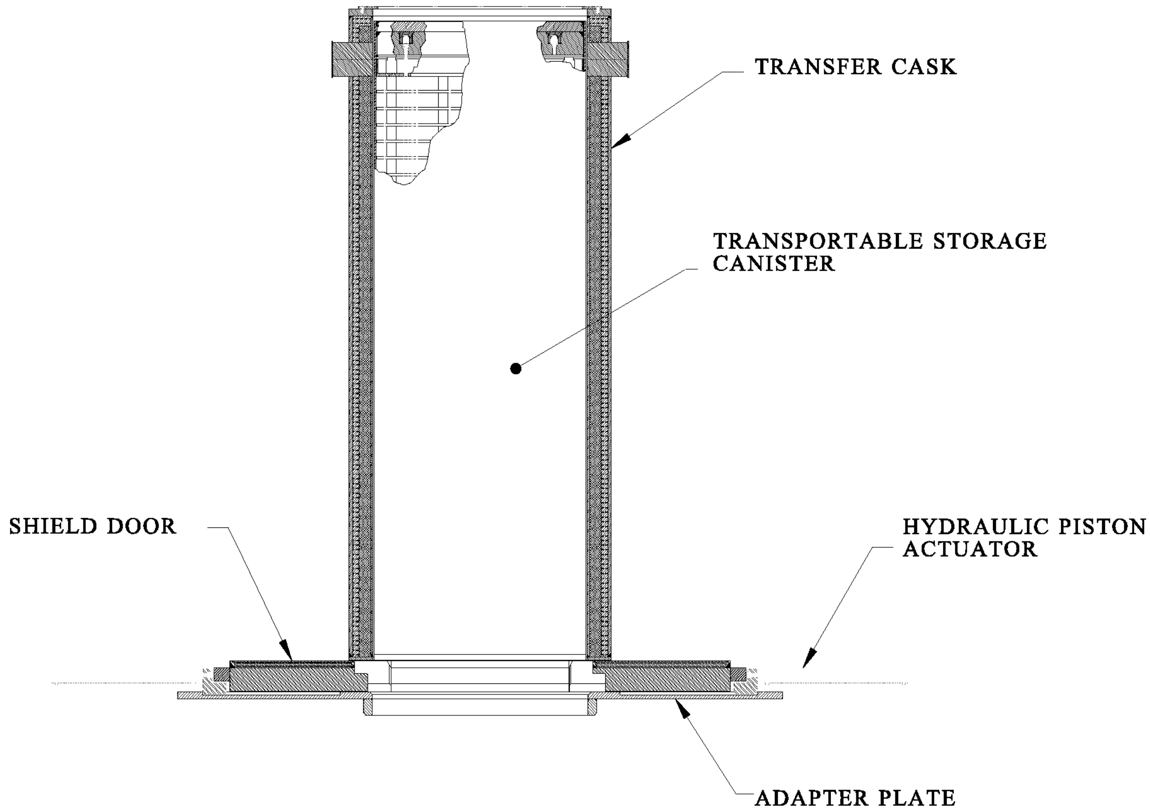

Figure E.4-4
NAC-MPC Transfer Cask

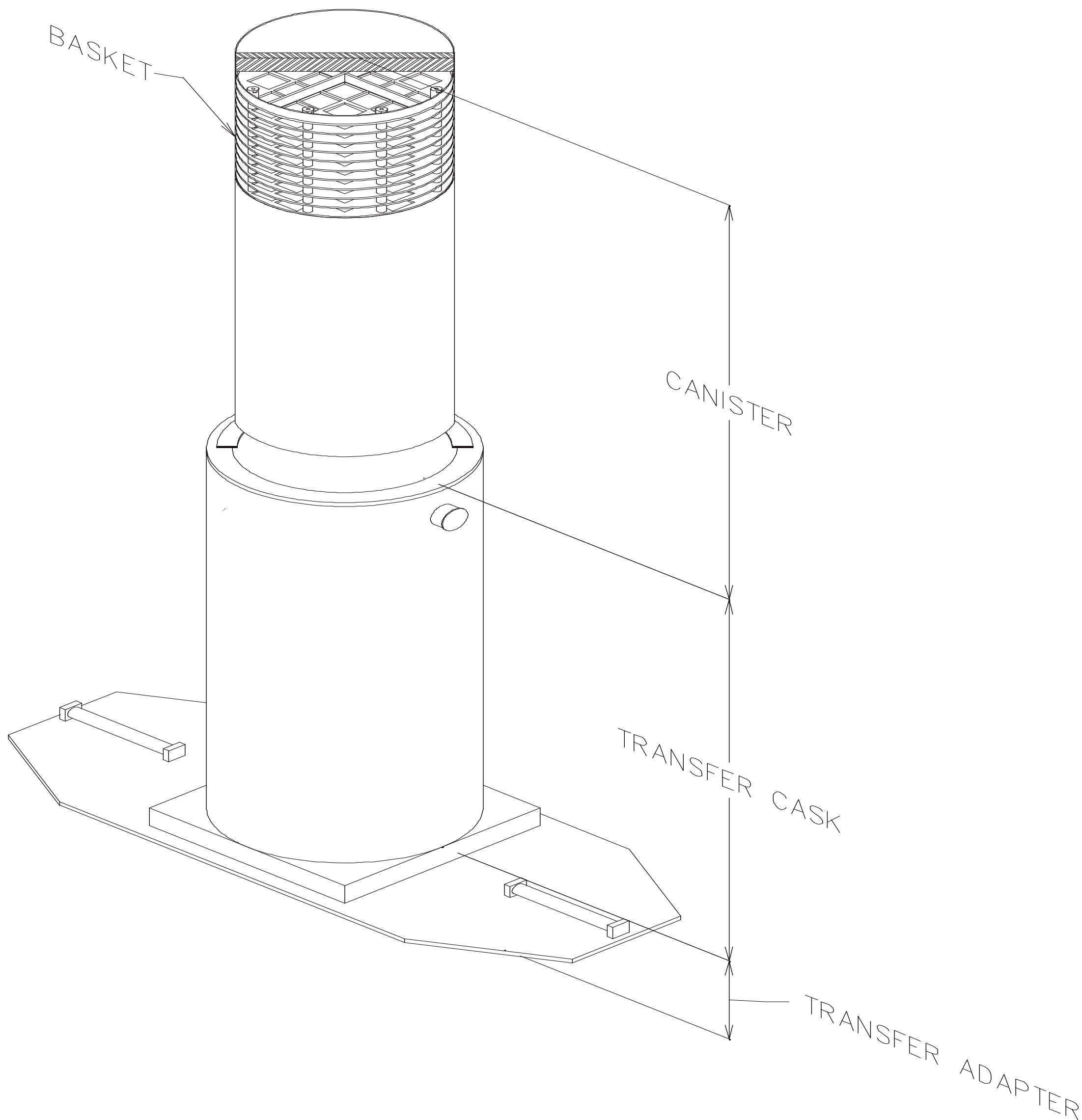

Figure E.4-5
NAC-MPC Transfer Cask and Canister Arrangement

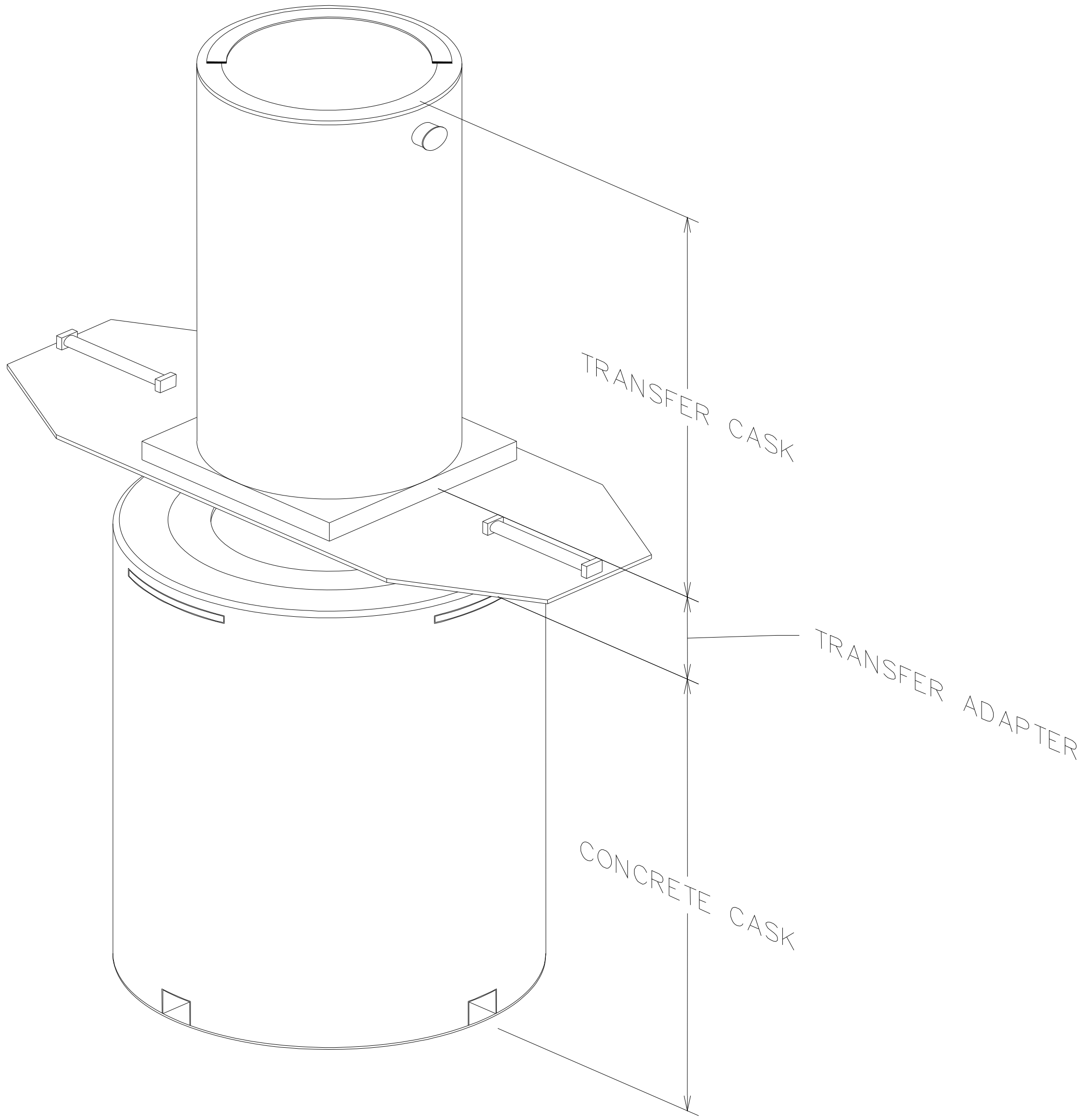

Figure E.4-6
NAC-MPC Vertical Concrete Cask and Transfer Cask Arrangement

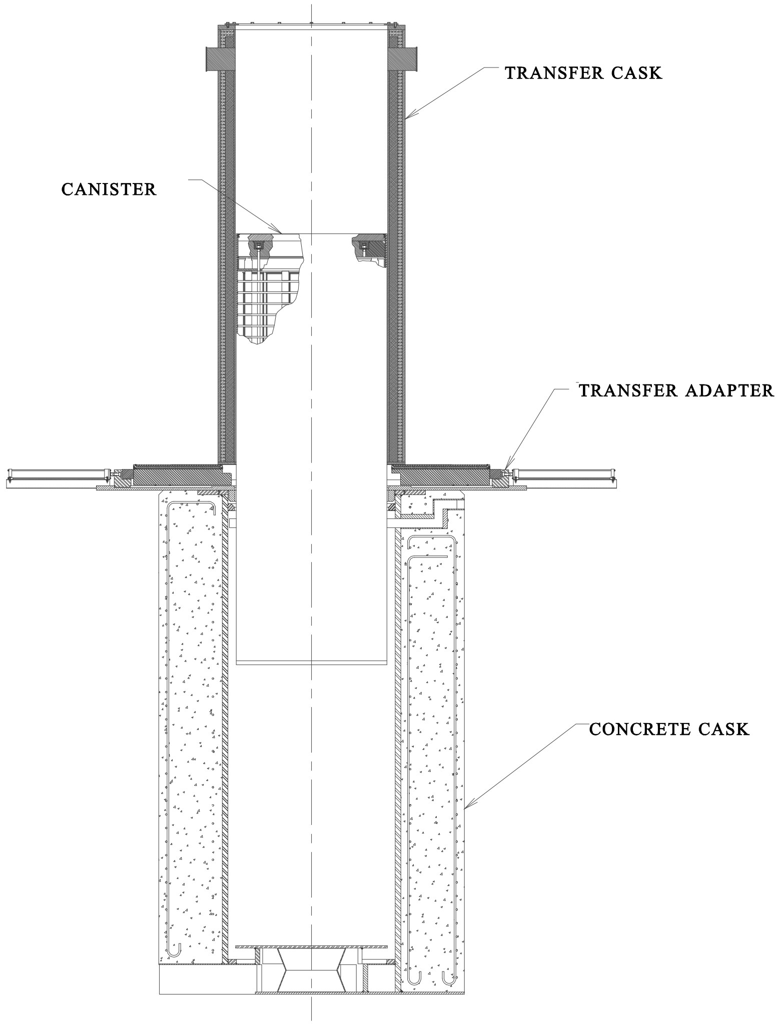

Figure E.4-7
NAC-MPC Major Component Configuration for Loading the Vertical Concrete Cask

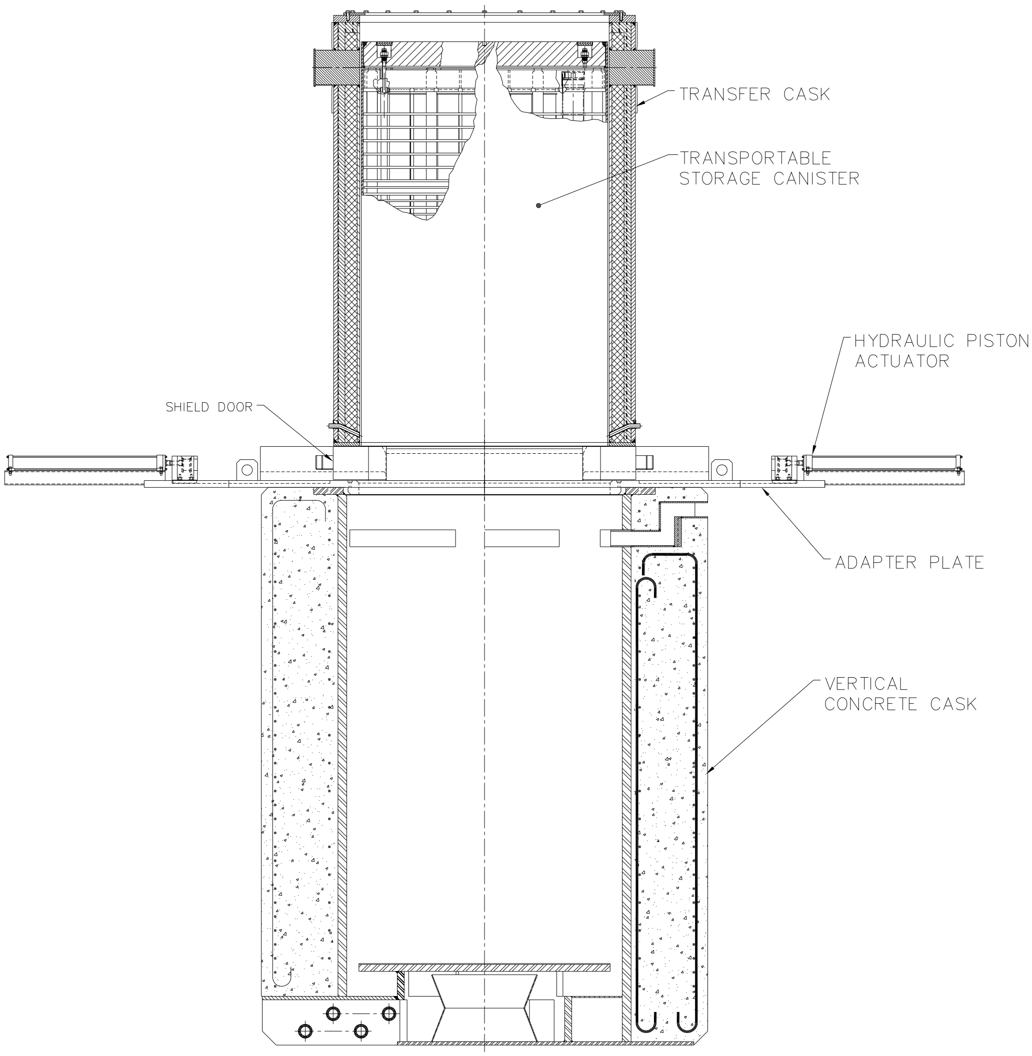

Figure E.4-8
MPC-LACBWR Major Components of the NAC-MPC System

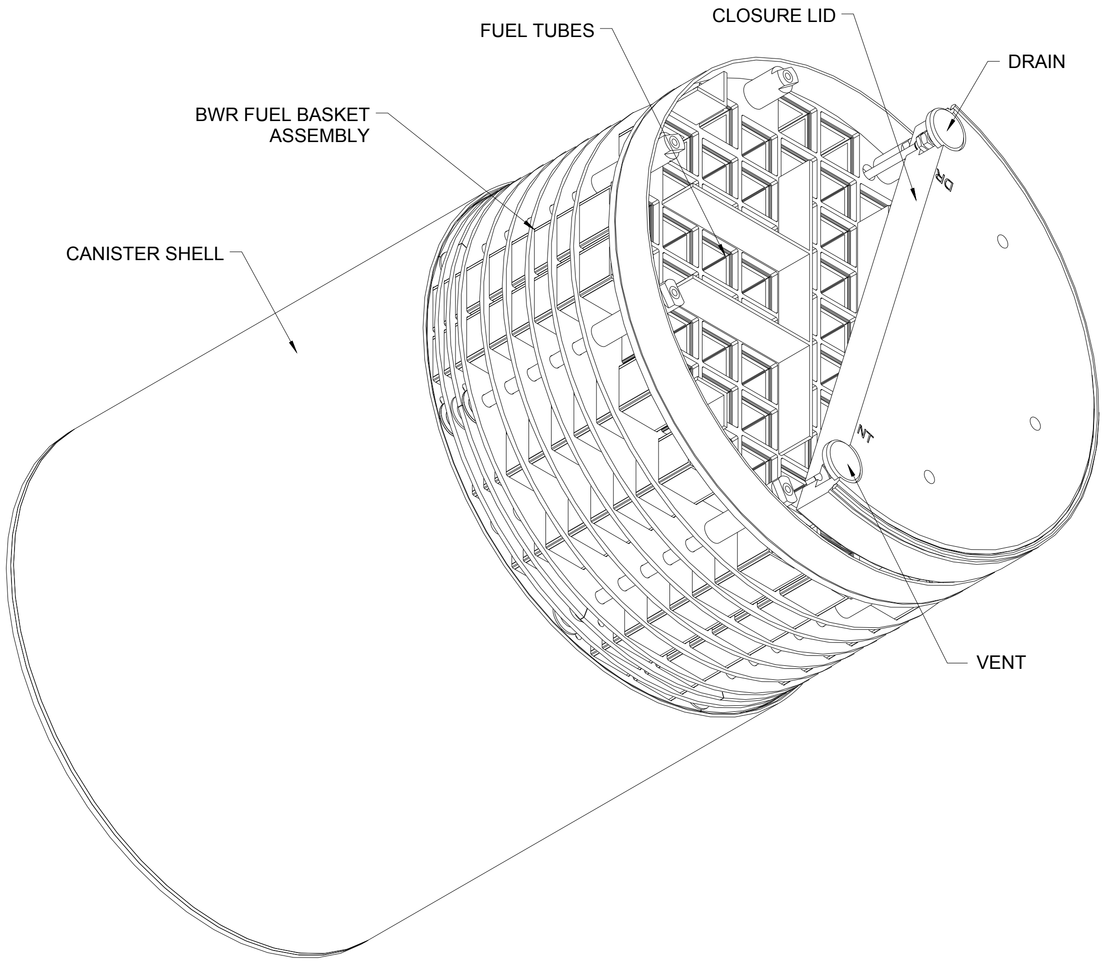

Figure E.4-9
MPC-LACBWR Transportable Storage Canister Showing the Spent Fuel Basket

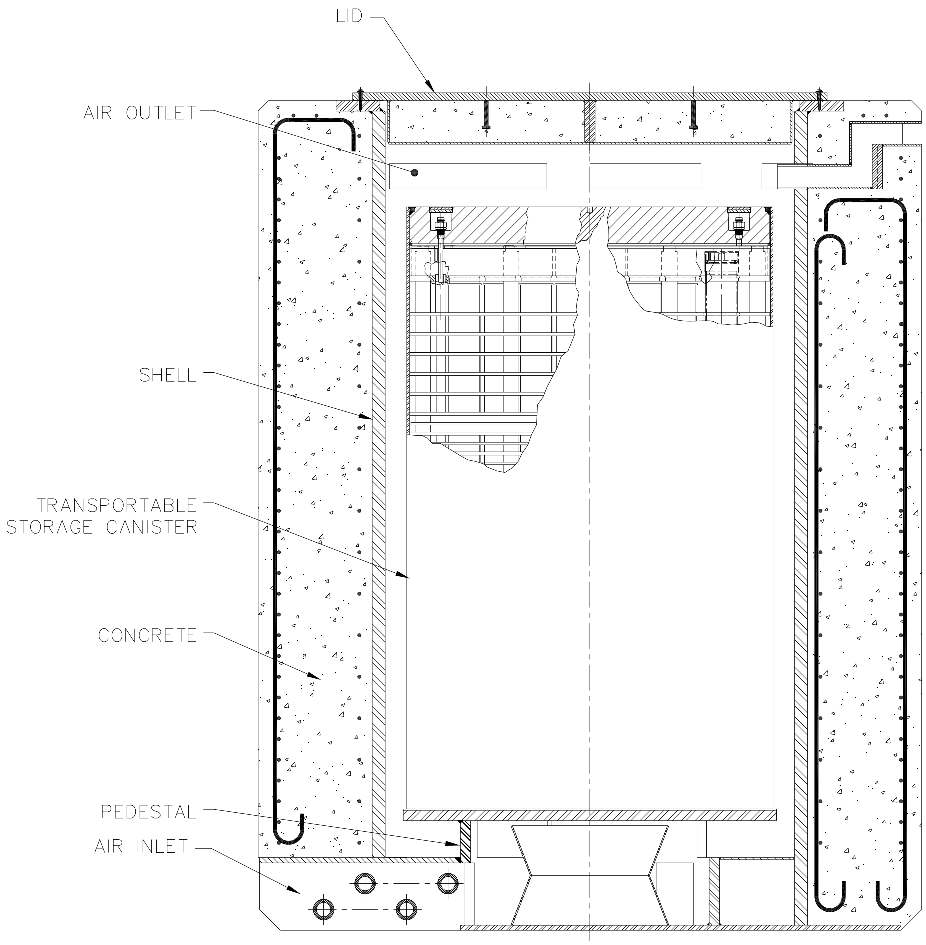

Figure E.4-10
MPC-LACBWR Vertical Concrete Storage Cask

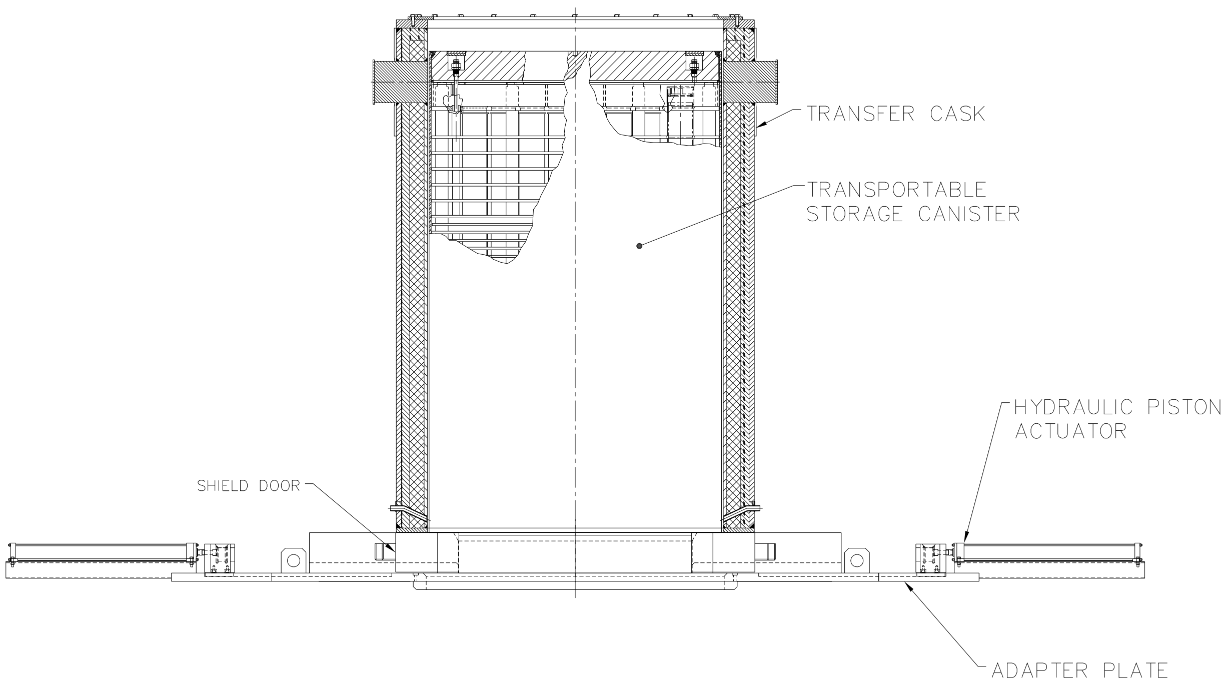

Figure E.4-11
MPC-LACBWR Transfer Cask With Adapter Plate

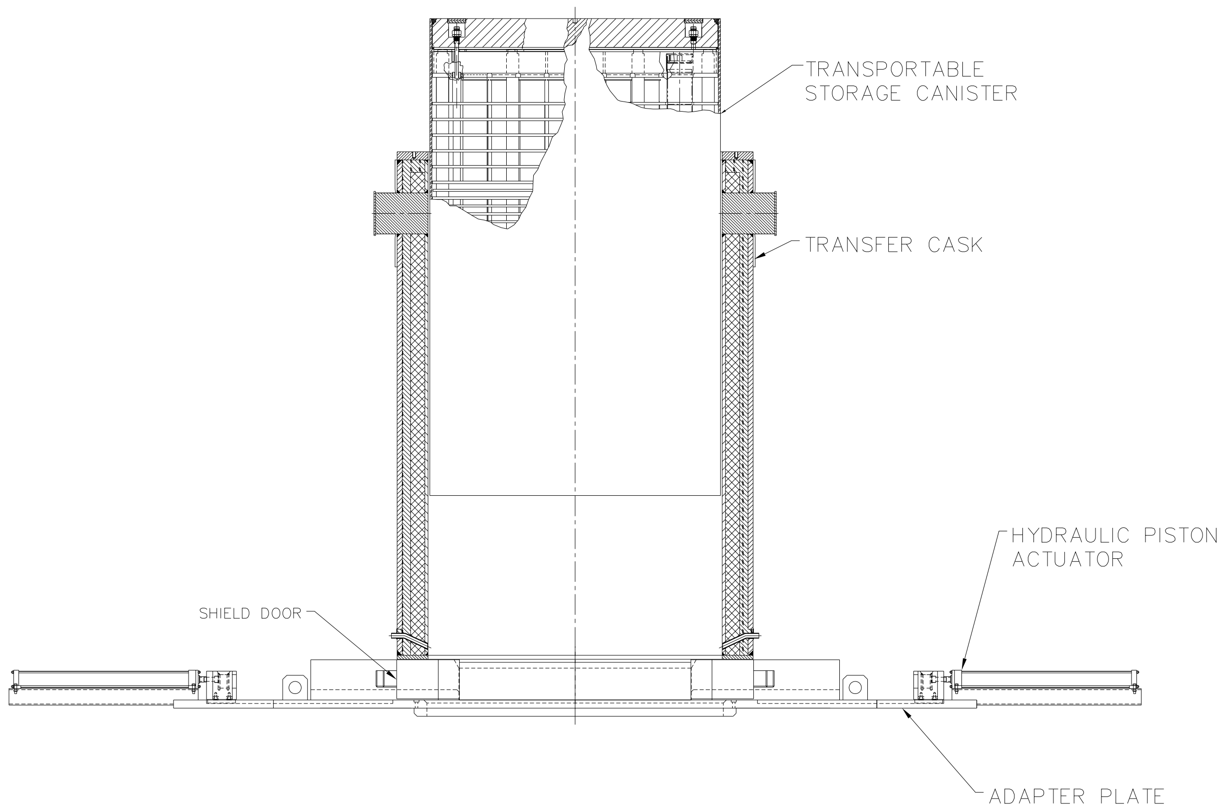

Figure E.4-12
MPC-LACBWR Transfer Cask and Canister Arrangement

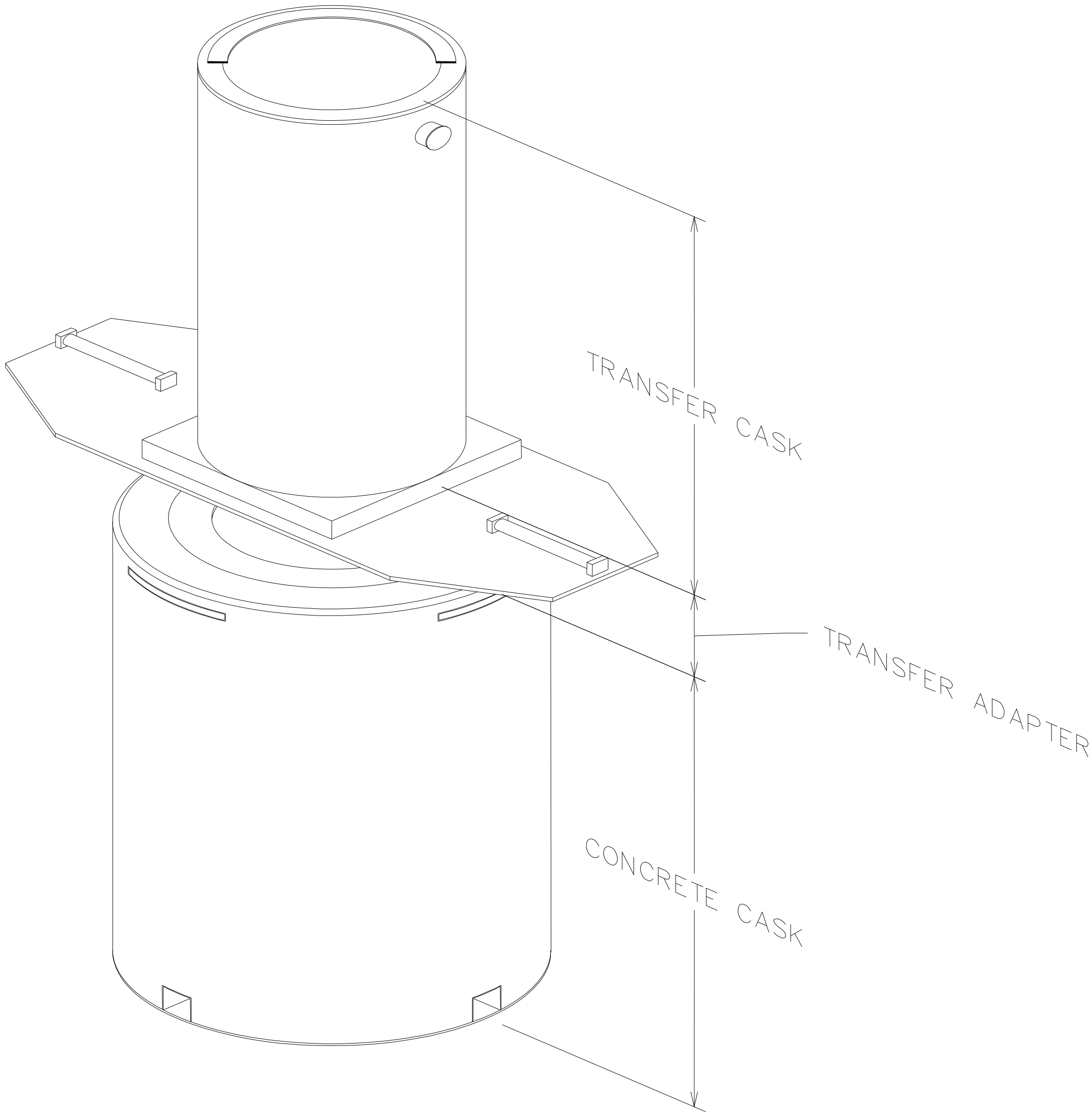

Figure E.4-13
MPC-LACBWR Vertical Concrete Cask and Transfer Cask Arrangement

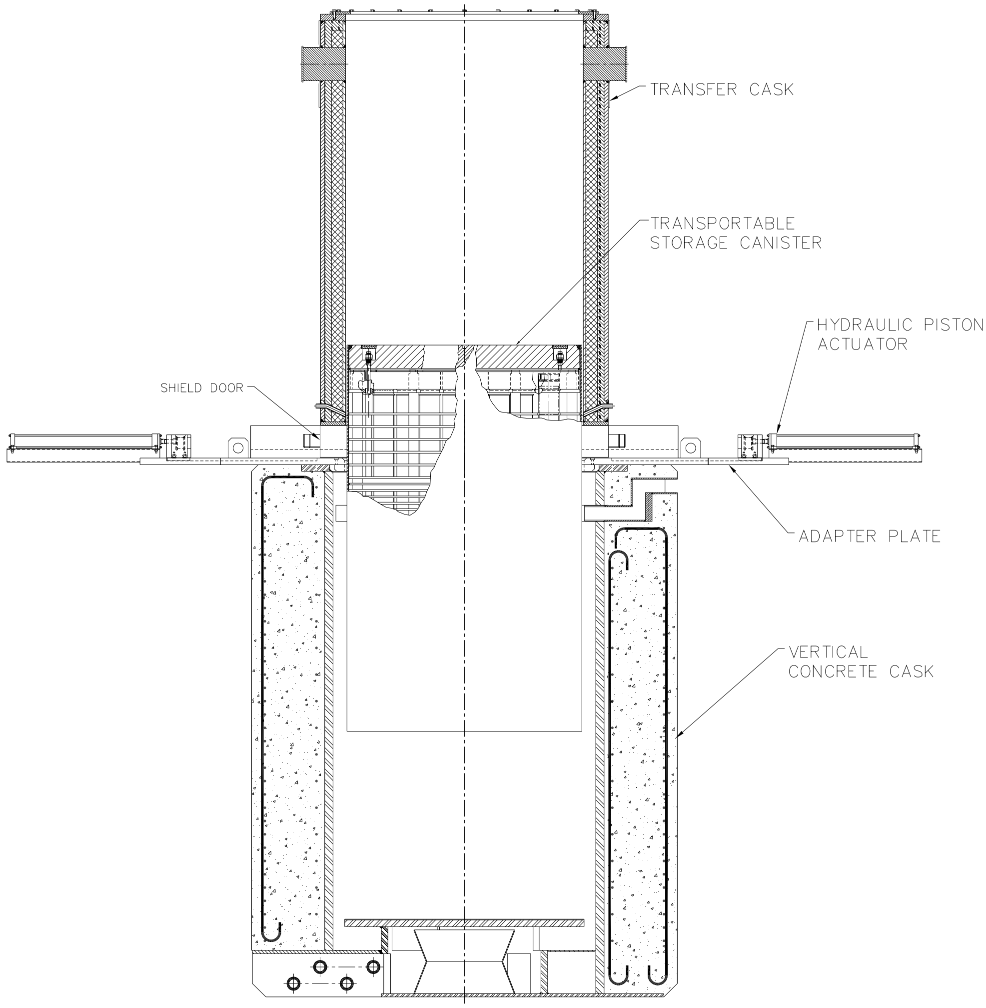

Figure E.4-14
MPC-LACBWR Major Component Configuration for Loading the Vertical Concrete Cask

Table E.4-1
Storage Pad Design and Construction Requirements

Parameter	Yankee-MPC	CY-MPC	MPC-LACBWR
Concrete thickness	36 inches maximum	36 inches maximum	36 inches maximum
Pad subsoil thickness	72 inches minimum	60 inches minimum	60 inches minimum
Specified concrete compressive strength	≤ 4,000 psi at 28 days	≤ 4,000 psi at 28 days	≤ 6,000 psi at 28 days
Concrete dry density (ρ)	$125 \leq \rho \leq 150$ lbs/ft^3	$135 \leq \rho \leq 150$ lbs/ft^3	$125 \leq \rho \leq 150$ lbs/ft^3
Soil in place density (ρ)	$85 \leq \rho \leq 130$ lbs/ft^3	$85 \leq \rho \leq 130$ lbs/ft^3	$110 \leq \rho \leq 120$ lbs/ft^3
Soil Stiffness	k ≤ 300 psi/in	--	--
Soil Modulus of Elasticity	--	≤ 30,000 psi	≤ 10,000 psi

Note:
The concrete pad maximum thickness excludes the ISFSI pad footer. The compressive strength of the concrete should be determined according to the test method given in Section 5.6 of ACI 318. Steel reinforcement is used in the pad footer. The basis for acceptance of concrete shall be as described in Section 5.6 of ACI 318. The soil modulus of elasticity should be determined according to the test method described in ASTM D4719 or in ASTM D1196. The soil stiffness should be determined according to the test method described in Chapter 9 of the Civil Engineering Reference Manual, 6th Edition.

Table E.4-2
Concrete Cask Construction Specification Summary

Materials

- Concrete mix shall be in accordance with the requirements of ACI 318 and ASTM C94.
- Type II Portland Cement, ASTM C150.
- Fine aggregate ASTM C33 and C637.
- Coarse aggregate ASTM C33 and C637.
- Admixtures
  - Water Reducing ASTM C494.
  - Pozzolanic Admixture ASTM C618.
- Compressive Strength 4000 psi at 28 days.
- Specified Air Entrainment in accordance with ACI 318.
- All steel components shall be of material as specified in the referenced drawings.

Welding

- Visual inspection of all welds shall be performed to the requirements of AWS D1.1, Section 8.15.

Construction

- Specimens shall be obtained or prepared for each batch or truck load of concrete per ASTM C172 and ASTM C192.
- Test specimens shall be tested in accordance with ASTM C39.
- Formwork shall be in accordance with ACI 318.
- All sidewall formwork and shoring shall remain in accordance with the requirements of ACI 318
- All bottom formwork and shoring shall remain in place for 14 days.
- Grade, type, and details of all reinforcing steel shall be in accordance with the referenced drawings.
- Embedded items shall conform to ACI 318 and the referenced drawings.
- The placement of concrete shall be in accordance with ACI 318.
- Surface finish shall be in accordance with ACI 318.

Quality Assurance

- The concrete cask shall be constructed under a quality assurance program that meets 10 CFR 72 Subpart G.

Table E.4-3
MPC-LACBWR Concrete Cask Lid Concrete Specification Summary

Concrete mix shall be in accordance with the following ACI 318 requirements: • Standard weight concrete density shall be 140 pcf (minimum) • Total quantity of each pour shall be 50 yd^3 or less • No strength requirements – commercial grade concrete from a commercial grade supplier

APPENDIX E.5
OPERATING PROCEDURES
NAC-MPC

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E.5 OPERATING PROCEDURES

The following are operating procedures for using the NAC-MPC spent fuel storage system configured for the Yankee MPC (Yankee-MPC), Connecticut Yankee MPC (CY-MPC), and the La Crosse MPC (MPC-LACBWR) for storage operations. These procedures are based on the general guidance found in Chapter 8 and Appendix 8.A of the NAC-MPC Final Safety Analysis Report (FSAR) [Reference E.5-1]. The procedures covered are:

1. Installing the transportable storage canister (TSC) in the vertical concrete cask (concrete cask) and transferring it to the storage (ISFSI) pad, and
2. Removal of the loaded canister from the concrete cask.
3. Receipt of the NAC-STC Transport Cask and removal of the loaded canister.

The detailed operating procedures for receiving a loaded NAC Storage Transport Cask (NAC-STC) and unloading the transportable storage canister are described in Section 7.3.1 of the NAC-STC Safety Analysis Report, Docket 71-9235.

Note, Reference E.5-1 does not include a concrete cask design with lifting lugs for vertical lifts. The design of a concrete cask with lifting lugs is shown in References E.5-2 thru Reference E.5-7 for the CY-MPC, Yankee-MPC, and MPC-LACBWR. The design has been analyzed in Reference E.5-8.

Pictograms of the NAC-MPC System operations are presented in Figure E.5-1.

E.5.1 Yankee Rowe MPC and Connecticut Yankee MPC

The Yankee-MPC and CY-MPC are generically known as the NAC-MPC. The following procedures are specific to these TSCs. Operation of the NAC-MPC system requires the use of ancillary equipment items. The ancillary equipment supplied with the system is shown in Table 8.1-1 of Reference E.5-1. The system does not rely on the use of bolted closures, but bolts are used to secure retaining rings and lids. The hoist rings used for lifting the shield lid and the canister, have threaded fittings. Table 8.1-2 of Reference E.5-1 provides the torque values for installed bolts and hoist rings. In addition, supplemental shielding may be employed to reduce radiation exposure for certain tasks specified by these procedures. The use of supplemental shielding is at the discretion of the WCS facility.

E.5.1.1 Loading the Vertical Concrete Cask

This section of the loading procedure assumes that the vertical concrete cask (concrete cask) is located inside the cask transfer facililty, under the site approved crane and that the concrete cask shield plug and lid are not in place and that the bottom pedestal plate cover is installed.

1. Using a site approved crane, place the transfer adapter on the top of the concrete cask.

2. Using the transfer adapter bolt hole pattern, align the adapter to the concrete cask. Bolt the adapter to the cask using four (4) socket head cap screws. (Note: Bolting of the transfer adapter to the cask is optional, if the transfer adapter centering segments/guides are installed.)

3. Verify that the bottom door connectors on the adapter plate are in the fully extended position.

4. If not already done, attach the transfer cask lifting yoke to the site approved crane. Verify that the transfer cask retaining ring is installed.

5. Install six (6) swivel hoist rings in the structural lid of the canister. Verify that the hoist ring threads are fully engaged, and attach two (2) three-legged slings. Stack the slings on the top of the canister so they are available for use in lowering the canister into the concrete cask.

6. Engage the transfer cask trunnions with the transfer cask lifting yoke. Ensure that all lines are disconnected from the transfer cask.

7. Raise the transfer cask and move it over the concrete cask. Lower the transfer cask, ensuring that the bottom door rails and connector tees align with the adapter plate rails and door connectors. Prior to final set down, remove transfer cask door lock bolts/lock pins.

Note: The minimum temperature of the surrounding air must be verified to be higher than 0°F prior to lifting in accordance with Appendix B, Section B3.4(8).

8. Ensure that the bottom door connector tees are engaged with the adapter plate door connectors.

9. Disengage the transfer cask yoke from the transfer cask and from the site approved crane hook.

10. Return the cask site approved crane hook to the top of the transfer cask and engage the two (2) three-legged slings attached to the canister. Lift the canister slightly (about 1/2 inch) to take the canister weight off of the transfer cask bottom doors.

    Note: A load cell may be used to determine when the canister is supported by the crane. Avoid raising the canister to the point that the structural lid engages the transfer cask retaining ring, as this could result in lifting the transfer cask.

    Caution: The top connection of the three-legged slings must be at least 67 inches above the Yankee MPC canister lid, and at least 53 inches above the CY-MPC lid.

11. Using the hydraulic system, open the bottom doors to access the concrete cask cavity.

12. Lower the canister into the concrete cask, using a slow crane speed as the canister nears the bottom of the concrete cask.

13. Disconnect the slings from the crane hook and lower them to the top of the canister. Close the transfer cask bottom doors.

14. Retrieve the transfer cask lifting yoke and attach the yoke to the transfer cask.

15. Lift the transfer cask off the concrete cask and return it to the decontamination area or designated work station.

    Note: For the YR-MPC, ensure that a visible gap exists between the canister and the concrete cask liner (i.e., the canister is not in contact with the concrete cask liner). For the CY-MPC, visually verify that the canister is located within the cylinder of the projection of the support ring.

16. Using the site approved crane, remove the adapter plate from the top of the concrete cask.

17. Remove the swivel hoist rings from the structural lid and replace them with threaded plugs.

18. Using the site approved crane, retrieve the shield plug and install the shield plug in the top of the concrete cask.

19. Using the site approved crane, retrieve the concrete cask lid and install the lid in the top of the concrete cask using six stainless steel bolts.

20. Ensure that there is no foreign material left at the top of the concrete cask. At the option of the user, a tamper-indicating seal wire and seal may be installed.

21. If used, install a supplemental shielding fixture in each of the four air inlets.

    Note: The supplemental shielding fixtures may also be shop installed.

E.5.1.2 Transport and Placement of the Vertical Concrete Cask

This section of the procedure details the movement of the loaded concrete cask from the cask transfer facility to the ISFSI pad using a vertical concrete cask transporter. After placement on the ISFSI pad, the concrete cask surface dose rates must be verified in accordance with the requirements of LCO 3.2.2. The dose rate measurements may be made prior to movement of the concrete cask, at a location along the transport path, or at the ISFSI. Following placement of the concrete cask at the ISFSI, the operability of the concrete cask heat removal system shall be verified in accordance with LCO 3.1.6.

1. Using the vertical cask transporter lift fixture or device, engage the two concrete cask lifting lugs.

2. Lift the loaded concrete cask and move it to the ISFSI pad following the approved onsite transport route.

   Note: Ensure vertical cask transporter lifts the concrete cask evenly using the two lifting lugs.

   Note: Do not exceed the maximum lift height for a loaded concrete cask of 6 inches.

3. Move the concrete cask into position over its intended ISFSI pad storage location. Ensure the surface under the concrete cask is free of foreign objects and debris.

4. Using the vertical transporter, slowly lower the concrete cask into position.

   Note: Ensure that the centerline spacing between concrete casks is 15 feet minimum.

5. Disengage the vertical transporter lift connections from the two concrete cask-lifting lugs. Move the cask transporter from the area.

E.5.1.3 Removal of the Transportable Storage Canister from the Vertical Concrete Cask

Removal of the loaded canister from the concrete cask is expected to occur at the time of shipment of the canistered fuel off site. Alternately, removal could be required in the unlikely event of an accident condition that rendered the concrete cask or canister unsuitable for continued long-term storage or for transport. This procedure identifies the general steps to return the loaded canister to the transfer cask and return the transfer cask to the decontamination station, or other designated work area. Since these steps are the reverse of those undertaken to place the canister in the concrete cask, as described in Section E.5.1.1, they are summarized here. The procedure assumes that the inlet and outlet screens and the temperature-sensing instrumentation, if installed, have been removed.

Mechanical operation steps of the procedure may be performed in an appropriate sequence to allow for operational efficiency. Changing the order of these steps, within the intent of the procedures, has no effect on the safety of the canister removal process and does not violate any requirements stated in the Technical Specifications.

At the option of the user, the canister may be removed from the concrete cask and transferred to another concrete cask or to the NAC-STC transport cask at the ISFSI site. This transfer is done using the transfer cask, which provides shielding for the canister contents during the transfer.

1. Move the concrete cask from the ISFSI pad using the vertical concrete cask transporter.

   Caution: Do not exceed a maximum lift height of 6 inches when raising the concrete cask.

2. Move the transporter to the cask receiving area or other designated work station.

3. Remove the concrete cask shield plug and lid. Install the hoist rings in the canister structural lid. Verify that the hoist ring threads are fully engaged and torque the hoist rings as required in Table 8.1-2 of Reference E.5-1. Attach the lift slings. Install the transfer adapter.

4. Retrieve the transfer cask and position it on the transfer adapter on the top of the concrete cask.

   Note: The minimum temperature of the surrounding air must be verified to be higher than 0°F prior to lifting.

5. Open the shield doors. Attach the canister lift slings to the site approved crane hook.

   Caution: The top connection of the three-legged sling must be at least 67 inches above the Yankee MPC canister lid and at least 53 inches above the CY-MPC canister lid.

6. Raise the canister into the transfer cask. Use caution to avoid contacting the transfer cask retaining ring with the canister.

7. Close the shield doors. Lower the canister to rest on the bottom doors. Disconnect the canister slings from the crane hook.

8. Retrieve the transfer cask lifting yoke. Engage the transfer cask trunnions and move the transfer cask to the decontamination area or designated work station.

   Note: Prior to moving transfer cask, install and secure door lock bolts/ lock pins.

After the transfer cask containing the canister is in the decontamination area or other suitable work station, additional operations may be performed on the canister. It may be transferred to another concrete cask, or placed in the NAC-STC transport cask. The length of time that the loaded canister is in the transfer cask in accordance with LCO 3.1.4.

E.5.1.4 Receiving the NAC-STC Transport Cask and Unloading the Transportable Storage Canister

The following procedure(s) cover inspecting the cask upon receipt, preparing the cask for removal from its conveyance, and unloading the transportable storage canister into the transfer cask. Following unloading of the transportable storage canister into the transfer cask, the previously described procedures should be followed to place the transportable storage canister into dry storage in a vertical concrete cask, or an equivalent, approved storage configuration. Note, the requirements of the transport cask CoC must be followed at all times. In the event there is conflict between the following procedures and the transport CoC requirements, the transport CoC requirements take precedence.

E.5.1.4.1 Performing Receipt Inspection of the Loaded NAC-STC Transport Cask

1. Perform radiation and contamination surveys on the transport vehicle and personnel barrier in accordance with 10 CFR 71 and document the results.
2. Remove the personnel barrier.
3. Complete the radiation and contamination surveys at the cask surfaces and record the results.
4. While the cask is in the horizontal position on the transport vehicle, visually inspect the cask for any physical damage that may have been incurred during transport.
5. Verify that the tamper indicating seals are in place, and verify their numbers.
6. Move the transport vehicle to the cask receiving area and secure the vehicle.
7. Attach slings to the upper impact limiter lifting lugs and the crane hook and remove the tamper indicating seal.
8. Remove the top impact limiter lock wires, jam nuts, attachment nuts, and retaining rods and remove the upper impact limiter from the transport cask.

9. Repeat the operations in Steps 7 and 8 for the bottom impact limiter.
10. Complete radiation and contamination surveys for exposed transport cask surfaces.
11. Release the tiedown assembly from the front support by removing the front tiedown pins and retaining pins.
12. Attach a sling to the tiedown assembly lifting lugs and remove the tiedown assembly from the transport vehicle.
13. Attach the transport cask lifting yoke to a crane hook with the appropriate load rating and engage the two yoke arms with the primary lifting trunnions at the top of the transport cask.
14. Rotate/lift the transport cask to the vertical position and raise the cask off the rear support structure.
15. Place the cask in the vertical position in a decontamination/work area.
16. Wash any dust and dirt off the cask and decontaminate cask exterior, as required.

E.5.1.4.2 Preparing to Unload the Transportable Storage Canister from the NAC-STC Transport Cask

The assumptions underlying this procedure are:

- The NAC-STC Transport Cask is in a vertical position in the designated unloading area.
- The top of the NAC-STC Transport Cask is accessible.
- The NAC-STC contains a sealed transportable storage canister.

The procedures for preparing to unload the transportable storage canister from the NAC-STC Transport Cask are:

1. Remove the interlid port cover bolts and attach a pressure test fixture to the interlid port to measure the pressure in the interlid region.
2. Using an evacuated vacuum bottle attached to the pressure test fixture, sample the gas in the interlid region.

   Caution: Use caution in opening the cask if the sample activity and/or cask pressure are higher than expected based on the canister contents configuration.
3. Remove the NAC-STC Transport Cask outer lid bolts by following the reverse of the installation torquing sequence, install the two closure lid alignment pins, and install the lifting eyes in the cask lid and attach the lid-lifting device to the cask lid and to the overhead crane.
4. Remove the transport cask lid and place the lid in a designated area. [Ensure that the O-ring grooves in the lid are protected so that they will not be damaged during handling.] Decontaminate the lid as necessary. Remove the two alignment pins.
5. Remove the port coverplates from the drain and vent ports in the inner lid with caution. Attach a pressure test fixture to the vent port that will allow the monitoring

of the cask cavity for any pressure buildup that may have occurred during transport. If a positive pressure exists, vent the pressure to the off-gas system.

6. Loosen and remove all inner lid bolts, install the inner lid alignment pins, and install the lid lifting hoist rings.
7. Remove the inner lid from the cask and remove the alignment pins. [Ensure that the O-ring grooves in the lid are protected so that they will not be damaged during handling.]
8. If present, remove the top spacer from the NAC-STC cask cavity and install the adapter ring on the cask.

E.5.1.4.3 Unloading the Transportable Storage Canister from the NAC-STC Transport Cask

A transfer cask is used to unload the transportable storage canister from the transport cask and to transfer it to a storage or disposal overpack. The transfer cask retaining ring or retaining blocks must be installed.

The procedures for unloading the transportable storage canister from the NAC-STC Transport Cask are:

1. Install the canister lifting system the transportable storage canister structural lid.

   Caution: The structural lid may be thermally hot.
2. Attach the canister lifting system to the structural lid and position it to allow engagement to the crane hook/sling.
3. Attach the transfer cask lifting yoke to the cask-handling crane hook and engage the yoke to the lifting trunnions of the transfer cask.
4. Lift the transfer cask and move it above the NAC-STC Transport Cask.
5. Lower the transfer cask to engage actuators of the transfer adapter. Remove the door stops.
6. Once the transfer cask is fully seated, remove the transfer cask lifting yoke and store it in the designated location.
7. Install the transfer cask shield door hydraulic operating system to the actuators and open the transfer cask shield doors.
8. Lower the canister lifting system, the transfer cask and engage the canister lifting sling, or raise the sling set to engage to the hook above the top of the transfer cask.
9. Continue operations to place the canister in an approved storage configuration.

E.5.2 La Crosse MPC

The following procedures are specific to the MPC-LACBWR. Operation of the MPC-LACBWR system requires the use of ancillary equipment items. The ancillary equipment supplied with the system is shown in Table 8.A.1-1 of Reference E.5-1. The system does not rely on the use of bolted closures, but bolts are used to secure retaining rings and lids. The hoist rings used for lifting the shield lid and the canister, have threaded fittings. Table 8.A.1-2 of Reference E.5-1 provides the torque values for installed bolts and hoist rings. In addition, supplemental shielding may be employed to reduce radiation exposure for certain tasks specified by these procedures. The use of supplemental shielding is at the discretion of the WCS facility.

E.5.2.1 Loading the Vertical Concrete Cask

This section of the loading procedure assumes that the vertical concrete cask (concrete cask) is located inside the cask transfer facililty, under the site approved crane and the concrete cask lid is not in place and the bottom pedestal plate cover is installed.

1. Using a site-approved crane, place the transfer adapter on the top of the concrete cask.

2. Align the transfer adapter to the concrete cask, and at the option of the user, bolt the adapter to the concrete cask using four (4) socket head cap screws.

3. Connect the hydraulic actuation system to the transfer adapter and verify that the shield door connectors on the adapter plate are in the fully extended position.

4. If not already completed, attach the transfer cask lifting yoke to the site-approved crane. Verify that the transfer cask retaining ring is installed.

5. Install six (6) swivel hoist rings in the TSC closure lid. Verify that the hoist ring threads are fully engaged, and attach two (2) three-legged slings. Stack the slings on the top of the TSC so they are available for use in lowering the TSC into the concrete cask.

6. Engage the transfer cask trunnions with the transfer cask lifting yoke. Ensure that all lines are disconnected from the transfer cask.

   Note: The minimum temperature of the surrounding air must be verified to be higher than 0°F prior to lifting.

7. Raise the transfer cask and move it to a position above the concrete cask and transfer adapter. Lower the transfer cask, ensuring that the shield door rails and connector tees align with the transfer adapter plate rails and door connectors. Prior to final set-down, remove transfer cask shield door lock bolts/lock pins.

8. Ensure that the shield door connector tees are engaged with the adapter plate door connectors.

9. Disengage the transfer cask lift yoke from the transfer cask.

10. Return the cask site-approved crane hook to the top of the transfer cask and engage the two (2) three-legged slings attached to the TSC. Lift the TSC slightly (approximately 1/2 inch) to take the canister weight off of the transfer cask shield doors.

11. Using the hydraulic system, open the shield doors to access the concrete cask cavity.

12. Lower the TSC into the concrete cask, using a slow crane speed as the TSC nears the bottom of the concrete cask.

13. Disconnect the slings from the crane hook and lower them to the top of the TSC. Close the transfer cask bottom doors.

14. Retrieve the transfer cask lifting yoke and attach the yoke to the transfer cask.

15. Lift the transfer cask off the concrete cask and return it to the decontamination area or designated workstation.

16. Using the site-approved crane, remove the adapter plate from the top of the concrete cask.

17. Remove the swivel hoist rings, slings, and other lifting equipment from the TSC closure lid and install lid hole plugs hand-tight.

18. Using the site-approved crane, retrieve the concrete cask lid and install the lid in the top of the concrete cask and secure using the concrete cask lid bolts. Record the time the concrete cask lid is secured.

19. Ensure that there is no foreign material left at the top of the concrete cask.

E.5.2.2 Transport and Placement of the Vertical Concrete Cask

This section of the procedure details the movement of the loaded concrete cask from the cask transfer facility to the ISFSI pad using a vertical concrete cask transporter. After placement on the ISFSI pad, the concrete cask surface dose rates must be verified in accordance with the requirements of LCO 3.2.2. The dose rate measurements may be made prior to movement of the concrete cask, at a location along the transport path, or at the ISFSI. Following placement of the concrete cask at the ISFSI, the operability of the concrete cask heat removal system shall be verified in accordance with LCO 3.1.6.

1. Using the vertical cask transporter lift fixture or device, engage the two concrete cask lifting lugs.

2. Lift the loaded concrete cask and move it to the ISFSI pad following the approved onsite transport route.

   Note: Ensure vertical cask transporter lifts the concrete cask evenly using the two lifting lugs.

   Note: Do not exceed the maximum lift height for a loaded concrete cask of 6 inches.

3. Move the concrete cask into position over its intended ISFSI pad storage location. Ensure the surface under the concrete cask is free of foreign objects and debris.

4. Using the vertical transporter, slowly lower the concrete cask into position.

   Note: Ensure that the centerline spacing between concrete casks is 15 feet minimum.

5. Disengage the vertical transporter lift connections from the two concrete cask-lifting lugs. Move the cask transporter from the area.

E.5.2.3 Removal of the Transportable Storage Canister from the Vertical Concrete Cask

Removal of the loaded canister from the concrete cask is expected to occur at the time of shipment of the canistered fuel off site. Alternately, removal could be required in the unlikely event of an accident condition that rendered the concrete cask or canister unsuitable for continued long-term storage or for transport. This procedure identifies the general steps to return the loaded canister to the transfer cask and return the transfer cask to the decontamination station, or other designated work area. Since these steps are the reverse of those undertaken to place the canister in the concrete cask, as described in Section E.5.2.1, they are summarized here. The procedure assumes that the inlet and outlet screens and the temperature-sensing instrumentation, if installed, have been removed.

Mechanical operation steps of the procedure may be performed in an appropriate sequence to allow for operational efficiency. Changing the order of these steps, within the intent of the procedures, has no effect on the safety of the canister removal process and does not violate any requirements stated in the Technical Specifications.

At the option of the user, the canister may be removed from the concrete cask and transferred to another concrete cask or to the NAC-STC transport cask at the ISFSI site. This transfer is done using the transfer cask, which provides shielding for the canister contents during the transfer.

1. Move the concrete cask from the ISFSI pad using the vertical concrete cask transporter.

   Caution: Do not exceed a maximum lift height of 6 inches when raising the concrete cask.

2. Move the transporter to the cask receiving area or other designated work station.

3. Remove the concrete cask lid.

4. Install the six hoist rings into the canister closure lid threaded holes.

5. Install transfer adapter on top of the concrete cask.

6. Note: The minimum ambient air temperature (either in the facility or external air temperature, as applicable for the handling sequence) must be ≥ 0ºF for the use of the transfer cask.

7. Place transfer cask onto the transfer adapter and engage the shield door connectors.

8. Open the shield doors, retrieve the lifting slings, and install the slings on the lifting system.

9. Slowly withdraw the TSC from the concrete cask. The chamfer on the underside of the transfer adapter assists in the alignment into the transfer cask.

10. Bring the TSC up to just below the retaining ring. Close the transfer cask shield doors and install the shield door lock pins.

11. Lift transfer cask off the concrete cask and move to the designated workstation.

After the transfer cask containing the canister is in the decontamination area or other suitable work station, additional operations may be performed on the canister. It may be transferred to another concrete cask, or placed in the NAC-STC transport cask. The length of time that the loaded canister is in the transfer cask in accordance with LCO 3.1.4.

E.5.2.4 Receiving the NAC-STC Transport Cask and Unloading the Transportable Storage Canister

The procedures for handling the NAC-STC Transport Cask and unloading the La Crosse MPC canister is the same as that previously described in Paragraphs 5.1.4, 5.1.4.1, 5.1.4.2, and 5.1.4.3.

E.5.3 References

E.5-1 NAC-MPC Final Safety Analysis Report, Revision 10, January 2014

E.5-2 NAC License Drawing, 414-862, “Loaded Vertical Concrete Cask (VCC) CY-MPC”, Rev. 6

E.5-3 NAC License Drawing, 414-866, “Reinforcing Bar and Concrete Placement, Vertical Concrete Cask (VCC) CY-MPC”, Rev. 6

E.5-4 NAC License Drawing, 414-862, “Loaded Vertical Concrete Cask (VCC) MPC-YANKEE”, Rev. 9

E.5-5 NAC License Drawing, 455-866, “Reinforcing Bar and Concrete Placement, Vertical Concrete Cask (VCC) MPC-YANKEE”, Rev. 6

E.5-6 NAC License Drawing, 630045-862, “Loaded Vertical Concrete Cask (VCC) MPC-LACBWR”, Rev. 1

E.5-7 NAC License Drawing, 630045-866, “Reinforcing Bar and Concrete Placement, Vertical Concrete Cask (VCC) MPC-LACBWR”, Rev. 2

E.5-8 NAC Calculation 30039-2020, “MPC Concrete Cask Lift Evaluation”, Rev. 0

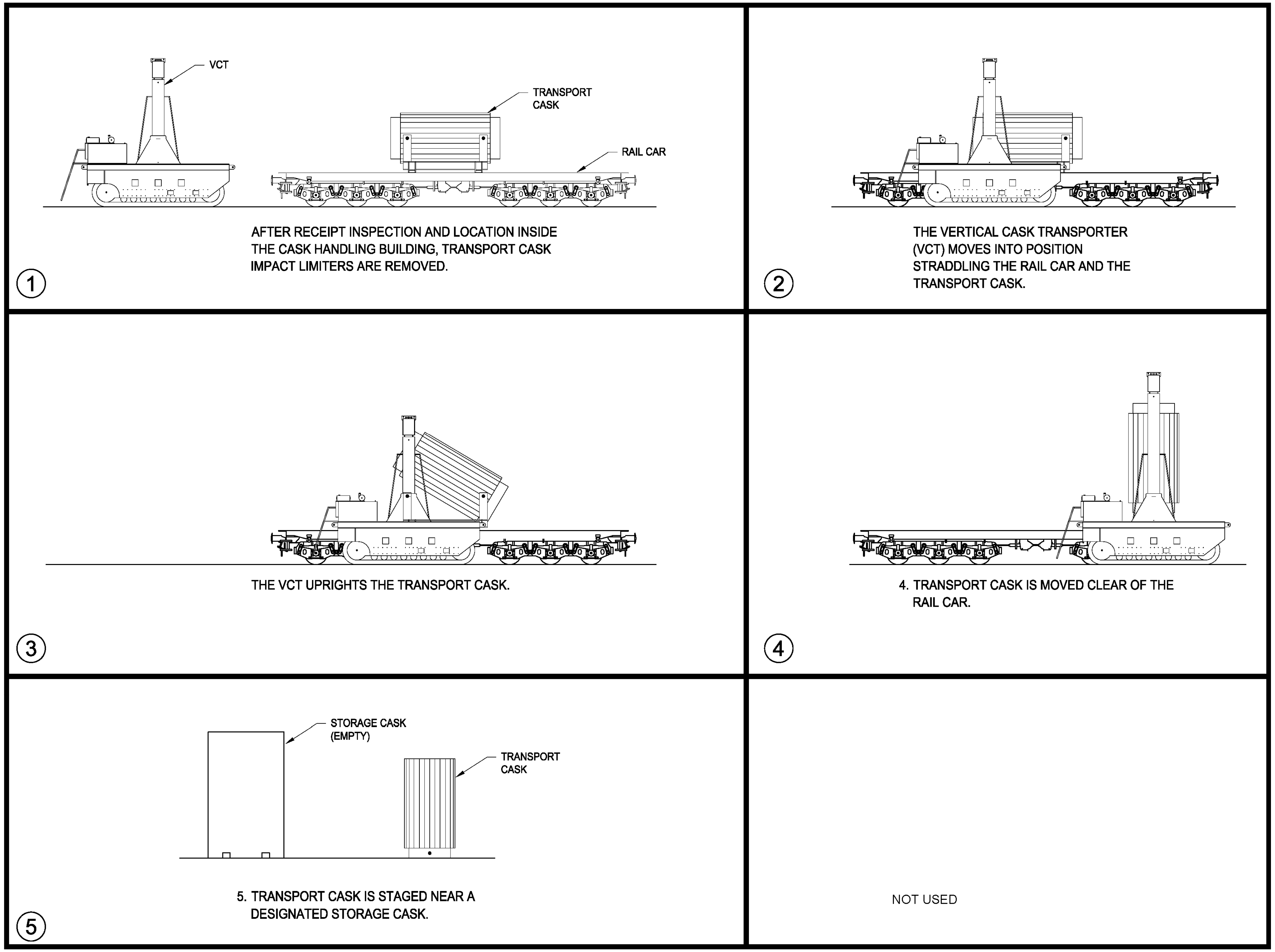

Figure E.5-1
Canister Transfer Operations
2 Pages

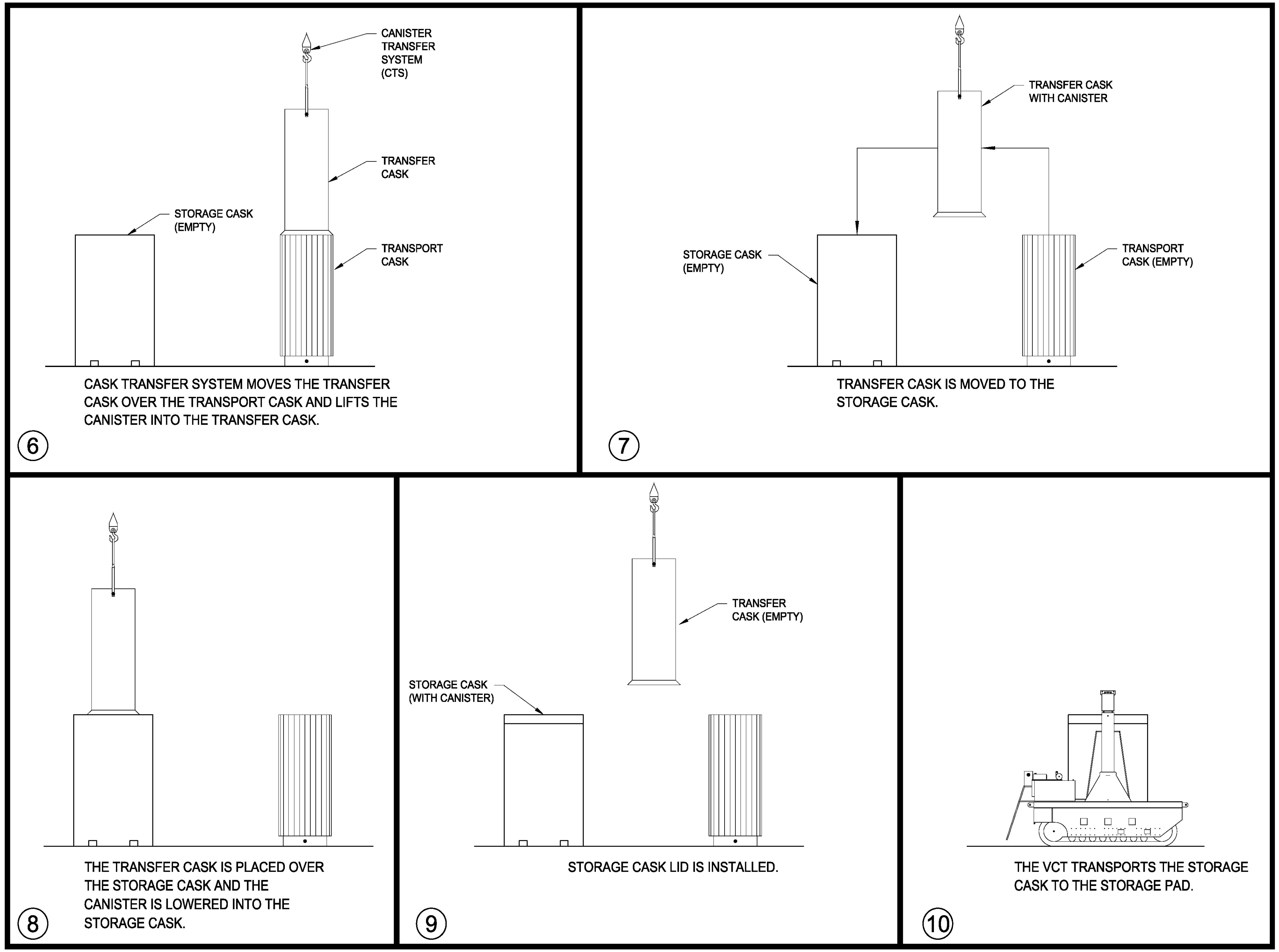

Figure E.5-1
Canister Transfer Operations
2 Pages

APPENDIX E.6
WASTE CONFINEMENT AND MANAGEMENT
NAC-MPC

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E.6. WASTE CONFINEMENT AND MANAGEMENT

No change or additional information required for the NAC-MPC Cask System containing the Connecticut Yankee MPC and Yankee Rowe MPC for Chapter 6.

APPENDIX E.7
STRUCTURAL EVALUATION
NAC-MPC

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E.7 STRUCTURAL EVALUATION

This appendix summarizes the location of the detailed structural analyses for the NAC-MPC system under normal operating conditions in Reference E.7-1. There are three NAC-MPC configurations covered, which includes the Yankee Rowe MPC (Yankee-MPC), Connecticut Yankee MPC (CY-MPC), and the La Crosse MPC (MPC-LACBWR). Off-normal and accident conditions are covered in WCS SAR Appendix E.12.

E.7.1 Yankee Rowe MPC and Connecticut Yankee MPC

The Yankee-MPC and CY-MPC are generically referred to as the NAC-MPC and *Sections E.7.1.1 through E.7.1.10* outline the structural analyses for normal operating conditions presented in Reference *E.7-1*. *Finally, bounding evaluations in Section E.7.1.11 are referenced to demonstrate that the confinement boundaries for the Yankee-MPC and CY-MPC canisters 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.*

E.7.1.1 Structural Design

The structural design of the NAC-MPC system for the Yankee-MPC and CY-MPC are provided in Section 3.1 of Reference E.7-1.

E.7.1.2 Weights and Centers of Gravity

The weights and centers of gravity of the NAC-MPC system for the Yankee-MPC and CY-MPC are provided in Section 3.2 of Reference E.7-1.

E.7.1.3 Mechanical Properties of Materials

The mechanical properties of materials of the NAC-MPC system for the Yankee-MPC and CY-MPC are provided in Section 3.3 of Reference E.7-1.

E.7.1.4 Chemical and Galvanic Reactions

The chemical and galvanic reactions evaluations of the NAC-MPC system for the Yankee-MPC and CY-MPC are provided in Section 3.4.1 of Reference E.7-1.

E.7.1.5 Positive Closure

The positive closure evaluation of the NAC-MPC system for the Yankee-MPC and CY-MPC are provided in Section 3.4.2 of Reference E.7-1.

E.7.1.6 Lifting Devices

The evaluations of the NAC-MPC system lifting devices for the Yankee-MPC and CY-MPC are provided in Reference E.7-1. Note, Reference E.7-1 does not include a concrete cask design with lifting lugs for vertical lifts. The design of a concrete cask with lifting lugs is shown in References E.7-2 thru E.7-5 for the CY-MPC and Yankee-MPC. The design has been analyzed in Reference E.7-8.

E.7.1.7 NAC-MPC Components Under Normal Operating Loads

The evaluations of the NAC-MPC components under normal operating loads for the Yankee-MPC and CY-MPC are provided in Section 3.4.4 of Reference E.7-1.

E.7.1.8 Cold

As described in Section 3.4.5 of Reference E.7-1, the evaluation for severe cold environments for the NAC-MPC system for the Yankee-MPC and CY-MPC are provided in Section 11.1.4 of Reference E.7-1. Stress intensities corresponding to thermal loads in the canister are evaluated by using a finite element model as described in Section 3.4.4 of Reference E.7-1. The thermal stresses that occur in the canister as a results of the maximum off-normal temperature gradients in the canister are bounded by the analysis of extreme cold in Section 11.1.4 of Reference E.7-1. The canister and basket are fabricated from stainless steel an aluminum, which are not subject to a ductile-to-brittle transition in the temperature range of interest.

E.7.1.9 Fuel Rods

The evaluations of the Yankee-MPC and CY-MPC fuel rods are provided in Section 3.5 of Reference E.7-1.

E.7.1.10 Coating Specifications

The coating specifications for the NAC-MPC vertical concrete cask and transfer cask exposed carbon steel surfaces associated with the Yankee-MPC and CY-MPC are provided in Section 3.8 of Reference E.7-1.

E.7.1.11 Structural Evaluation of Yankee-MPC and CY-MPC Canister Confinement Boundaries under Normal Conditions of Transport

The Yankee-MPC and CY-MPC canister primary confinement boundaries consist of a canister shell, bottom closure plate, shield lid, the two (2) port covers, and the welds that join these components. Redundant closure is provided by a structural lid and adjoining canister weld. Additional details, geometry and shell and plate thicknesses are provided on the drawings in Section E.4.4. The confinement boundary is addressed in Section E.11.1.1. The Yankee-MPC and CY-MPC canister shells are evaluated for Normal Conditions of Transport in the NAC-STC Transport cask in Sections 2.6.13 and 2.6.15 of [E.7-9].

The result of the structural analysis is acceptable for the loads and combinations described in Sections 2.6.13 and 2.6.15 of [E.7-9] and hence structurally adequate for normal conditions of transport loading conditions.

E.7.2 La Crosse MPC

Sections E.7.2.1 through E.7.2.10 outline the structural analyses for normal operating conditions presented in Reference E.7-1 for the La Crosse MPC (MPC-LACBWR). *Finally, bounding evaluations in Section E.7.2.11 are referenced to demonstrate that the confinement boundaries for the MPC-LACBWR canisters 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.*

E.7.2.1 Structural Design

The structural design of the MPC-LACBWR is provided in Section 3.A.1 of Reference E.7-1.

E.7.2.2 Weights and Centers of Gravity

The weights and centers of gravity of the MPC-LACBWR is provided in Section 3.A.2 of Reference E.7-1.

E.7.2.3 Mechanical Properties of Materials

The mechanical properties of materials of the MPC-LACBWR is provided in Section 3.A.3 of Reference E.7-1.

E.7.2.4 Chemical and Galvanic Reactions

The chemical and galvanic reactions evaluations of the MPC-LACBWR is provided in Section 3.A.4.1 of Reference E.7-1.

E.7.2.5 Positive Closure

The positive closure evaluation of the MPC-LACBWR is provided in Section 3.A.4.2 of Reference E.7-1.

E.7.2.6 Lifting Devices

The evaluations of the MPC-LACBWR lifting devices is provided in Section 3.A.4.3 of Reference E.7-1. Note, Reference E.7-1 does not include a concrete cask design with lifting lugs for vertical lifts. The design of a concrete cask with lifting lugs is shown in References E.7-6 and E.7-7 for the MPC-LACBWR. The design has been analyzed in Reference E.7-8

E.7.2.7 MPC-LACBWR Components Under Normal Operating Loads

The evaluations of the MPC-LACBWR components under normal operating loads is provided in Section 3.A.4.4 of Reference E.7-1.

E.7.2.8 Fuel Rods

The evaluations of the MPC-LACBWR fuel rods is provided in Section 3.A.5 of Reference E.7-1.

E.7.2.9 Canister Closure Weld Evaluation

The evaluations of the MPC-LACBWR closure weld is provided in Section 3.A.6 of Reference E.7-1.

E.7.2.10 Coating Specifications

The coating specifications for the MPC-LACBWR vertical concrete cask and transfer cask exposed carbon steel surfaces are provided in Section 3.A.8 of Reference E.7-1.

E.7.2.11 Structural Evaluation of MPC-LACBWR Canister Confinement Boundaries under Normal Conditions of Transport

The MPC-LACBWR canister primary confinement boundaries consist of a canister shell, bottom closure plate, closure lid, the two (2) port covers, and the welds that join these components. Redundant closure is provided by two (2) outer port covers and a closure ring. Additional details, geometry and shell and plate thicknesses are provided on the drawings in Section E.4.4. The confinement boundary is addressed in Section E.11.2.1. The MPC-LACBWR canister shell is evaluated for Normal Conditions of Transport in the NAC-STC Transport cask in Section 2.11.6.13 of [E.7-9].

The result of the structural analysis is acceptable for the loads and combinations described in Section 2.11.6.13 of [E.7-9] and hence structurally adequate for normal conditions of transport loading conditions.

E.7.3 References

E.7-1 NAC-MPC Final Safety Analysis Report, Revision 10, January 2014

E.7-2 NAC License Drawing, 414-862, "Loaded Vertical Concrete Cask (VCC) CY-MPC", Rev. 6

E.7-3 NAC License Drawing, 414-866, "Reinforcing Bar and Concrete Placement, Vertical Concrete Cask (VCC) CY-MPC", Rev. 6

E.7-4 NAC License Drawing, 414-862, "Loaded Vertical Concrete Cask (VCC) MPC-YANKEE", Rev. 9

E.7-5 NAC License Drawing, 455-866, "Reinforcing Bar and Concrete Placement, Vertical Concrete Cask (VCC) MPC-YANKEE", Rev. 6

E.7-6 NAC License Drawing, 630045-862, "Loaded Vertical Concrete Cask (VCC) MPC-LACBWR", Rev. 1

E.7-7 NAC License Drawing, 630045-866, "Reinforcing Bar and Concrete Placement, Vertical Concrete Cask (VCC) MPC-LACBWR", Rev. 2

E.7-8 NAC Calculation 30039-2020, "MPC Concrete Cask Lift Evaluation", Rev. 0

E.7-9 NAC-STC Safety Analsyis Report, Revision 17, April 2011

APPENDIX E.8
THERMAL EVALUATION
NAC-MPC

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E.8 THERMAL EVALUATION

The NAC-MPC is provided in three configurations. The first is designed to safely store up to 36 intact Yankee Class spent fuel and reconfigured fuel assemblies and is referred to as the Yankee-MPC. The second is the Connecticut-Yankee MPC, referred to as the CY-MPC, is designed to store up to 26 Connecticut Yankee fuel assemblies, CY-MPC reconfigured fuel assemblies and CY-MPC damaged fuel cans. The third is the La Crosse BWR MPC, referred to as the MPC-LACBWR, designed to store up to 68 La Crosse fuel assemblies, including MPC-LACBWR damaged fuel cans.

The Yankee-MPC system is designed to store Yankee class spent fuel with a maximum heat load of 12.5 kW (12.5 kW/36 assemblies = 0.347 kW per fuel assembly) and reconfigured fuel assemblies with a maximum heat load of 0.102 kW per assembly. The temperatures produced by the design basis fuel bound the temperature effects due to the reconfigured fuel assemblies.

The CY-MPC system is designed to store Connecticut Yankee spent fuel with a maximum total heat load of 17.5 kW, or an average heat load of 0.674 kW per assembly. The maximum heat load of a CY-MPC damaged fuel can, as well as CY-MPC reconfigured fuel assembly, is 0.674 kW.

The MPC-LACBWR system is designed to store Dairyland Power Cooperative La Crosse BWR spent fuel with a maximum total heat load of 4.5 kW, or an average heat load of 66.2 W per assembly for all locations with or without damaged fuel can confinement.

The thermal evaluation of the Yankee-MPC configuration is presented in Section 4.4 of Reference E.8-1. The thermal evaluation of the CY-MPC configuration is presented in Section 4.5 of Reference E.8-1. The thermal evaluation for the MPC-LACBWR configuration is presented in Section 4.A.3 of Appendix 4.A to Reference E.8-1.

The results of the aforementioned analyses determined the site-specific environmental thermal parameters, which must be met for the Yankee-MPC, CY-MPC, and MPC-LACBWR systems at the WCS facility. The following sections details those site-specific thermal parameters for each system and demonstrates that they bound the environmental thermal parameters at the WCS facility.

The NAC-MPC storage system may contain GTCC waste from Yankee Rowe and Connecticut Yankee (GTCC-Canister-YR and GTCC-Canister-CY, respectively). The maximum GTCC waste heat generation allowed for transport in the NAC-STC transportation cask for Yankee Rowe and Connecticut Yankee is 2.9 kW and 5.0 kW, respectively. These heat loads are well below the design basis heat loads of 12.5 kW (Yankee Rowe) and 17.5 kW (Connecticut Yankee) for the storage of PWR fuel. Therefore, the thermal analysis results for the storage of Yankee Rowe and Connecticut Yankee PWR fuel is bounding. No further evaluation is required.

E.8.1 Connecticut Yankee MPC, Yankee Rowe MPC, and La Crosse MPC

Reference E.8-1 provides the thermal evaluations used to determine the limiting environmental conditions (thermal) for the use of the CY-MPC, Yankee-MPC, and MPC-LACBWR. The following are those limiting thermal environmental conditions.

E.8.1.1 Maximum Average Yearly Ambient Temperature

For the CY-MPC, Yankee-MPC, and MPC-LACBWR, the maximum average yearly temperature allowed is 75°F. The average yearly temperature for the site is conservatively bounded by using the maximum average annual temperature in the 48 contiguous United States, of 75°F. This temperature meets the normal condition thermal boundary defined in NUREG-1536. Therefore, no further WCS site-specific evaluations are required.

E.8.1.2 Maximum Average 3-Day Ambient Temperature

The maximum average 3-day ambient temperature allowed is 100°F for the CY-MPC and the Yankee-MPC. The maximum average 3-day ambient temperature allowed for the MPC-LACBWR is 105°F. These limits bound the WCS facility maximum average 3-day ambient temperature *89.4*°F. Therefore, no further site-specific evaluations are needed.

E.8.1.3 Maximum Extreme 3-Day Ambient Temperature Range

For the CY-MPC, Yankee-MPC, and MPC-LACBWR, the maximum allowed temperature extremes, averaged over a 3-day period, shall be greater than -40°F and less than 125°F. This bounds the WCS facility maximum temperature extremes of *-1*°F and *113*°F. No further site-specific evaluations are needed.

E.8.2 References

E.8-1 NAC-MPC Final Safety Analysis Report, Revision 10, January 2014

Appendix E.9
RADIATION PROTECTION
NAC-MPC

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E.9 RADIATION PROTECTION

Chapter 5 of Reference E.9.3-1 provides the shielding evaluation of the NAC-MPC storage system. The system is provided in three configurations. The Yankee Class NAC-MPC is designed to store up to 36 Yankee Class spent fuel assemblies or Yankee Class reconfigured fuel assemblies and is referred to as the Yankee-MPC. The Connecticut Yankee-MPC, referred to as the CY-MPC, is designed to store up to 26 Connecticut Yankee spent fuel assemblies, CY-MPC reconfigured fuel assemblies or CY-MPC damaged fuel cans. The analysis of the Yankee Class spent fuel is performed using the SAS4 code series. The analysis of the Connecticut Yankee spent fuel is performed using the MCBEND code. Separate models are used for each of the fuel types.

The Dairyland Power Cooperative (DPC) La Crosse Boiling Water Reactor (LACBWR) MPC, referred to as MPC-LACBWR, is designed to store up to 68 LACBWR spent fuel assemblies, including up to 32 LACBWR damaged fuel cans. The shielding evaluation of the MPC-LACBWR system is presented in Appendix 5.A of Chapter 5 to Reference E.9.3-1.

The regulation governing spent fuel storage, 10 CFR 72, does not establish specific cask dose rate limits. However, 10 CFR 72.104 and 10 CFR 72.106 specify that for an array of casks in an Independent Spent Fuel Storage Installation (ISFSI), the annual dose to an individual outside the controlled area boundary must not exceed 25 mrem to the whole body, 75 mrem to the thyroid and 25 mrem to any other organ during normal operations. In the case of a design basis accident, the dose to an individual outside the area boundary must not exceed 5 rem to the whole body or any organ. The ISFSI must be at least 100 meters from the owner controlled area boundary. In addition, the occupational dose limits and radiation dose limits for individual members of the public in 10 CFR Part 20 (Subparts C and D) must be met. Reference E.9.3-1, Chapter 10, Section 10.3, demonstrates NAC-MPC compliance with the requirements of 10 CFR 72 with regard to annual and occupational doses at the owner controlled area boundary. Chapter 5 of Reference E.9.3-1 presents the shielding evaluations of the NAC-MPC storage system. Dose rate profiles are calculated as a function of distance from the side, top and bottom of the NAC-MPC storage and transfer casks. Shielded source terms from the NAC-MPC storage cask are calculated to establish owner controlled area boundary dose estimates due to the presence of the ISFSI.

Table E.9-1 provides estimated occupational exposures for receipt and handling of the YR-MPC, CY-MPC, and MPC-LACBWR at the WCS CISF facility. For each procedural step, the number of workers, occupancy time, worker distance, dose rates, and total dose are estimated. Dose rates used were obtained and estimated via the listed references in the table. The total occupational exposure for receiving, transferring and placing these canisters on the storage pad in their storage overpack (VCC) is 823 person-mrem each. The total collective dose for unloading a YR-MPC, CY-MPC or MPC-LACBWR canister from its VCC and preparing it for transport off-site is bounded by the loading operations (823 person-mrem). Operations for retrieving these canisters from the VCC 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 1,646 person-mrem.

E.9.1 Yankee Rowe MPC and Connecticut Yankee MPC

Section 5.1 of Reference E.9.3-1 provides a summary of the results of the shielding evaluation of the NAC-MPC system when the system holds Yankee Class or Connecticut Yankee spent fuel assemblies and non-fuel hardware. Results are provided for the transfer cask and vertical concrete cask components.

A description of the Yankee Class fuel and a summary of the results of the Yankee Class fuel shielding evaluation are presented in Section 5.1.1 of Reference E.9.3-1. The description of the Connecticut Yankee fuel and a summary of the Connecticut Yankee shielding evaluation results are presented in Section 5.1.2 of Reference E.9.3-1.

The NAC-MPC storage system is comprised of a transportable storage canister, a transfer cask, and a vertical concrete storage cask. License drawings for these items are provided in Section *E.4.4*. The transfer cask is used to transfer the loaded canister to the storage cask where it is stored dry until transport. Shielding evaluations are performed for the storage cask with the cavity dry.

E.9.1.1 Yankee-MPC System Shielding Discussion and Results

The transfer cask has a multiwall radial shield comprised of 0.75 inches of carbon steel, 3.5 inches of lead, 2 inches of solid borated polymer (NS-4-FR), and 1.25 inches of carbon steel. An additional 0.625 inch of stainless steel shielding is provided, radially, by the canister shell. Gamma shielding is provided primarily by the steel and lead layers, and neutron shielding is provided primarily by the NS-4-FR. The transfer cask bottom shield design is a solid section of 9.50 inches of carbon steel. The top shielding is provided by the stainless steel canister shield and structural lids, which are 5 inches and 3 inches thick, respectively.

The storage cask radial shield design is comprised of a 3.5-inch thick carbon steel inner liner surrounded by 21 inches of concrete. Gamma shielding is provided by both the carbon steel and concrete, and neutron shielding is provided primarily by the concrete. As in the transfer cask, an additional 0.625 inch thickness of stainless steel radial gamma shielding is provided by the canister shell. The storage cask top shielding design is comprised of 8 inches of stainless steel from the canister lids, a shield plug containing a 1 inch thickness of NS-4-FR and 4.125 inches of carbon steel, and a 1.5 inch thick carbon steel lid. Since the bottom of the storage cask sits on a concrete pad, the storage cask bottom shielding is comprised of 1 inch of stainless steel from the canister bottom plate, 2 inches of carbon steel (pedestal plate) and 1 inch of carbon steel cask base plate. The base plate and pedestal base are structural components that position the canister above the air inlets. The cask base plate supports the storage cask during lifting, and forms the cooling air inlet channels at the cask bottom. An optional carbons steel supplemental shielding fixture, shown in Drawing 455-913, may be installed to reduce the radiation does rates at the air inlets.

The Yankee-MPC storage system accommodates up to 36 CE Yankee Class fuel assemblies with a maximum of 36,000 MWD/MTU burnup and with a minimum 8-year cool time. While 8.1 years cooling is required to meet cask total heat load requirements, 8.0 years is conservatively used as the shielding design basis. CE fuel with this burnup and cool time is defined as the design basis fuel. CE, UN and Westinghouse Yankee Class fuel assemblies with a maximum burnup of 32,000 MWD/MTU at minimum cool times of 8, 13 and 24 years, respectively, may also be loaded in the NAC-MPC. Exxon fuel at 36,000 MWD/MTU requires a minimum cool time of 10 years and 16 years for assemblies containing Zircaloy and stainless steel fuel region hardware, respectively. For shielding evaluation purposes the Exxon assembly type is identical to the CE fuel. The physical parameters of Yankee Class fuel assemblies are presented in Table 5.2.1-1 of Reference E.9.3-1.

A canister may contain one or more reconfigured fuel assemblies. The reconfigured fuel assembly is designed to confine Yankee Class spent fuel rods, or portions thereof, which have been classified as failed. Each assembly can accommodate up to a total of 64 fuel rods, which is significantly less than other Yankee Class fuel assemblies. A depiction of the assembly is provided in Figure 1.3-1 of Reference E.9.3-1. Because the source term (neutron and gamma) is directly proportional to fuel mass, for a given burnup and enrichment, the reconfigured assembly source term is bounded by that of a design basis fuel assembly. Consequently, a separate shielding analysis is not required for the reconfigured fuel assembly.

A canister may also contain damaged fuel cans in the four corner basket locations. To accommodate the damaged fuel can, oversized openings are present in the top and bottom basket weldments. Furthermore, four 9.3-inch square machined areas in the shield lid are necessary to accommodate the top and bottom structure of the damaged fuel cans. The machined area depth is 1.41 inches. The storage cask shielding evaluation of damaged fuel considers the dispersion of 20 fuel rods in the fuel assembly bottom end fitting. Radial dose rates are calculated, with particular emphasis on the dose rates at the air inlets. The transfer cask shielding evaluation of damaged fuel considers the effect on top dose rates due to the amount of material being removed from the shield lid and the proximity of the machined areas to the vent and drain ports. The analysis also considers the additional dose rate on the side and bottom of the transfer cask resulting from the displaced material in the lower end fitting.

Shielding evaluations of the Yankee-MPC transfer and storage casks are performed with SCALE 4.3 for the PC (ORNL) and MCBEND (Serco Assurance). In particular, the SCALE shielding analysis sequence SAS2H (Herman) is used to generate source terms for the design basis fuel, using the 27-group ENDF/B-IV (Jordan) library, 27GROUPNDF4. SAS1 (Knight) is used to perform one-dimensional radial and axial shielding analysis. MCBEND is used to perform the three-dimensional shielding analysis of the storage cask, and a modified version of SAS4 (Tang) is used to perform the three-dimensional shielding analysis of the transfer cask. The SCALE 4.3 SAS4 code sequence has been modified to allow multiple surface detectors; the new code sequence is entitled SAS4A. The use of the surface subdetectors enables the user to obtain surface profiles of the detector response and the surface tallies on the cask surfaces other than the cask shield. Dose tally routines were modified to accept user-defined surface detectors instead of the fixed surfaces, 1m, 2m, and 4m detectors in SCALE 4.3 SAS4. Each surface can be defined by specifying the cylindrical or disk surface tally location and extent. Each surface may be broken into multiple subdetectors. Code modifications were tested against the SCALE 4.3 manual and NAC test cases. Reliability of the subdetectors was verified by comparison to point detector results. The 27-group neutron, 18 group gamma, coupled cross section library (27N-18COUPLE) based on ENDF/B-IV is used in all SCALE shielding evaluations. Source terms include: fuel neutron, fuel gamma, and activated hardware gamma. Dose rate evaluations include the effect of fuel burnup peaking on fuel neutron and gamma source terms.

Dose rate profiles are shown for the storage and transfer casks in Section 5.4.1.4 of Reference E.9.3-1. Maximum dose rates for the storage cask under normal and accident conditions are shown in Table 5.1.1-1 of reference E.9.3-1 for design basis fuel. These dose rates are based on three-dimensional Monte Carlo and one dimensional discrete ordinates calculations. Monte Carlo error (1σ) is indicated in parenthesis. In normal conditions with design basis intact fuel, the storage cask maximum side dose rate is 44.1 (1.2%) mrem/hr at the fuel midplane and 75.5 (0.6%) mrem/hr on the top lid surface above the air outlets. The average dose rates on the side and top of the cask are 35.7 (1.1%) and 34.9 (<1%) mrem/hr, respectively. Since the storage cask is vertical during normal storage operation, the bottom is inaccessible. The maximum surface dose rate at the lower air inlet openings is 191 (1.2%) mrem/hr with supplemental shielding and 803 (<1%) mrem/hr without supplemental shielding. The maximum surface dose rate at the air outlet openings is 116 (1.1%) mrem/hr. Under accident conditions involving a projectile impact and a loss of 6 inches of concrete, the surface dose rate increases to 314 mrem/hr at the impact location with design basis fuel. There are no design basis accidents that result in a tip-over of the Yankee-MPC storage cask.

For the damaged fuel can evaluation, the additive radial dose rate due to the presence of debris from 20 fuel rods in the bottom end fitting is 2.7 (0.2%) mrem/hr. This additional dose, however, does not affect the calculated maximum dose rate on the side of the cask and the average dose rate increases by less than 0.5%. The maximum air inlet dose rate due to the combination of intact and damaged fuel is 219 (1.0%) mrem/hr with supplemental shielding in the inlets.

Maximum dose rates for the transfer cask with design basis intact and damaged fuel and with a wet and dry canister cavity are shown in Tables 5.1.1-2 and 5.1.1-3, of Reference E.9.3-1 respectively. The maximum dose rates with design basis fuel and the canister cavity wet during shield lid welding operations are 210.2 (0.8%), 188.7 (1.1%) and 77.2 (0.7%) mrem/hr on the side, top, and bottom, respectively. The maximum dose rates with design basis fuel and the canister cavity dry during structural lid welding operations are 413.4 (1.5%), 358.9 (2.6%) and 398.0 (3.9%) mrem/hr on the side, top, and bottom, respectively. These values include the addition of 5 inches of carbon steel operational shielding installed on the shield lid during its closure and on the structural lid during its handling and closure. In normal operations during welding of the canister lids, the bottom of the transfer cask is generally inaccessible.

For the damaged fuel can evaluation, additional shielding at the ports is modeled to maintain dose rates ALARA for the shield lid with weld shield models. In the wet canister model, the port cover zone is modeled with half-density stainless steel to simulate the quick disconnect fittings at the ports. For both the dry and wet canister models, an inch of lead is modeled above the ports to simulate additional temporary shielding employed during the welding operations. The maximum dose rate with design basis fuel and the canister cavity wet during shield lid welding operations is 214.1 (0.1%) mrem/hr. An azimuthal peak of 4.0 rem/hr is calculated at the port radius. The maximum dose rate with design basis fuel and the canister cavity dry during structural lid welding operations is 387.9 (0.6%) mrem/hr. Maximum dose rates for the transfer cask with design basis damaged fuel are shown in Table 5.1.1-3 of Reference E.9.3-1.

The damaged fuel case is modeled assuming the fuel content of 20 fuel rods from each of four damaged assemblies is displaced to the lower end fitting region, where the added material is homogeneously represented. No credit is taken for shielding capability of the damaged fuel can; however it is assumed that the can will physically contain the fuel debris. In addition, no credit is taken for the ability of the displaced material to shield the hardware and remaining intact fuel assemblies. Also, no reduction in the intact fuel source term is made to compensate for the displaced material. Results show that the maximum additional contribution to the cask surface dose rate is less than 40 mrem/hr under both wet and dry canister conditions. Specifically, under dry conditions, the maximum radial and bottom axial transfer cask surface dose rates are 444.8 (1.6%) mrem/hr and 435.7 (0.9%) mrem/hr, respectively. Under wet conditions, the maximum bottom axial transfer cask surface dose rate is 96.3 (0.6%) mrem/hr. The wet condition maximum radial surface dose rate is unchanged due to the presence of damaged fuel in the lower end fitting, since the location of the peak remains near the top of the cask due to the assumed draining of water from the cask to facilitate lid welding operations.

E.9.1.2 CY-MPC System Shielding Discussion and Results

The CY-MPC transfer cask has a multi-wall radial shield comprised of 0.75 inches of low alloy steel, 4.0 inches of lead, 2.75 inches of solid borated polymer (NS-4-FR), and 1.25 inches of low alloy steel. An additional 0.625 inch of stainless steel shielding is provided, radially, by the canister shell. Gamma shielding is provided primarily by the steel and lead layers, and neutron shielding is provided primarily by the NS-4-FR. The transfer cask bottom shield design is a solid section of 9.50 inches of low alloy steel. The top shielding is provided by the stainless steel canister shield and structural lids, which are 5 inches and 3 inches thick, respectively.

The storage cask radial shield design is comprised of a 3.5-inch thick carbon steel inner liner surrounded by a 21-inch thickness of concrete. Gamma shielding is provided by both the carbon steel and the concrete. Neutron shielding is provided primarily by the concrete. As in the transfer cask, an additional 0.625 inch thickness of stainless steel radial gamma shielding is provided by the canister shell. The storage cask top shielding design is comprised of 8 inches of stainless steel from the canister lids, a 3.75-inch thick carbon steel shield plug, a 2.0-inch thick layer of either NS-4-FR or NS-3, a 0.375-inch thick carbon steel cover and a 1.50-inch thick carbon steel lid. Since the bottom of the storage cask sits on a concrete pad, the storage cask bottom shielding is comprised of the 1.75-inch thick stainless steel canister bottom plate, the 4.0 inch thick carbon steel weldment base plate, and the 1.0-inch thick carbon steel cask bottom plate. The base plate and bottom plate are structural components that position the canister above the air inlets. The cask bottom plate supports the storage cask during lifting and forms the cooling air inlet channels at the cask bottom.

The CY-MPC accommodates up to 26 Connecticut Yankee fuel assemblies. Both stainless steel clad and Zircaloy clad assemblies are acceptable for storage. The stainless steel clad assemblies have a maximum burnup of 38,000 MWD/MTU and a minimum of a 5-year cool time. The Zircaloy-clad fuel assemblies have a maximum burnup of 43,000 MWd/MTU and a minimum 5 year cool time. The physical parameters of the Connecticut Yankee fuel assemblies are presented in Table 5.2.2-1 of Reference E.9.3-1.

A canister may contain up to four CY-MPC reconfigured fuel assemblies and/or damaged fuel cans positioned in the oversized corner locations in the basket. The CY-MPC reconfigured fuel assembly is designed to confine individual spent fuel rods, or portions thereof, within individual stainless steel tubes. Each CY-MPC reconfigured fuel assembly can accommodate up to 100 fuel rods in a 10 by 10 lattice, which is significantly less than the number of fuel rods in an intact assembly. Because the source term (neutron and gamma) is directly proportional to fuel mass, for a given burnup and enrichment, the source term produced by the fuel rods within the CY MPC reconfigured assembly is bounded by that of a design basis fuel assembly. Consequently, a separate shielding analysis is not required for the reconfigured fuel assembly.

The CY-MPC damaged fuel can may hold a complete Connecticut Yankee fuel assembly, a lattice or a failed rod storage canister. Since the shielding evaluation conservatively assumes that the damaged fuel cans are not present in the canister, the additional shielding provided by the wall of the can would serve to reduce external dose rates. Consequently, there is no increase in dose rate due to the presence of a Connecticut Yankee fuel assembly or lattice having up to 204 fuel rods or the failed rod storage canister having up to 60 fuel rods.

Shielding evaluations of the CY-MPC transfer cask and storage cask are performed using the MCBEND Monte Carlo transport code. Fuel source terms are developed using the SCALE isotopics sequence SAS2H (Herman). Source terms include: fuel neutron, fuel gamma, fuel n gamma, and activated hardware gamma. Dose rate evaluations include the effect of axial fuel burnup peaking on fuel neutron and gamma source terms.

The resulting dose rate profiles, along with the maximum and average radial and axial dose rates are presented for the storage cask and transfer cask analyses in Section 5.4.2 of Reference E.9.3-1. The results are presented for the design basis stainless steel clad and Zircaloy-clad fuel assemblies.

The maximum dose rates for the storage cask under normal conditions are summarized in Tables 5.1.2-1 and Table 5.1.2-2, of Reference E.9.3-1 for stainless steel and Zircaloy-clad design basis fuel assemblies, respectively. The dose rate calculation for the top of the storage cask with stainless steel clad fuel is based on a 1-inch thick layer of NS-4-FR. The results at the top of the storage cask with the Zircaloy clad fuel are shown for a 1-inch thickness of NS-4-FR and for a 1.5-inch thickness of NS-3. Since the Zircaloy-clad fuel dose rates are higher, these results bound those for the stainless steel clad design basis fuel. The thickness of neutron shield material (either NS 4-FR or NS-3) used in the analysis is conservatively less than the 2.0-inch thickness specified (Drawing 414-864). The standard deviation resulting from the Monte Carlo evaluation used by MCBEND (1σ) is indicated in the tables. The storage cask maximum side dose rate occurs for stainless steel clad assemblies (due to the elevated fuel assembly hardware source term) and is 167 (1.7%) mrem/hr at the fuel midplane elevation. The maximum storage cask top axial surface dose rate occurs for the Zircaloy-clad fuel (due to the higher neutron source rate at the higher burnup for this fuel) and is 36 (0.7%) mrem/hr on the top lid surface just above the annulus between the canister and the storage cask liner. Since the storage cask is vertical during normal storage operation, the bottom is inaccessible. Therefore, no bottom axial dose rates are presented. The average dose rates at the inlets and outlets are 85 (3.2%) mrem/hr and 66 (1.5%) mrem/hr, respectively. The maximum dose rates for the transfer cask for the wet and dry canister cavity configurations encountered during canister closure operations are presented in Table 5.1.2-3 and Table 5.1.2-4, of Reference E.9.3-1 for the stainless steel and Zircaloy clad fuel types, respectively.

During shield lid welding operations, including a wet canister cavity, the maximum dose rates with stainless steel clad fuel are 226 (1.2%) and 3830 (5.5%) mrem/hr on the radial surface and top axial surface, respectively. The bottom surface of the cask has a maximum dose rate of 95 (2.2%) mrem/hr with the stainless steel fuel. For Zircaloy-clad fuel, the maximum radial, top axial and bottom axial surface dose rates are 241 (2.2%), 4050 (1.9%), and 84 (2.0%) mrem/hr, respectively. With eight flow mixer components inserted in the centermost basket positions, the additional dose rate in the top axial position is 46 (3.5%) mrem/hr.

During structural lid welding operations, including a dry canister cavity, the maximum dose rates with stainless steel clad design basis fuel are 405 (3.3%) mrem/hr and 2179 (6.5%) mrem/hr on the radial and top axial surfaces, respectively. The bottom surface of the cask has a maximum dose rate of 307 (1.0%) mrem/hr with the stainless steel fuel. For Zircaloy-clad design basis fuel, the maximum side, top, and bottom dose rates are 394 (2.0%), 2117 (3.5%), and 407 (0.8%) mrem/hr, respectively.

The calculated values for the transfer cask shield lid and structural lid configurations include the addition of 5 inches of carbon steel operational shielding installed on top of the shield lid during its closure and on the structural lid during its handling and closure. As shown in the dose rate profiles presented in Section 5.4.2 of Reference E.9.3-1, the maximum top axial surface dose rates are highly localized to the annular region between the operational shield and the inner shell of the transfer cask. This region will not normally be occupied during welding operations.

E.9.2 LaCrosse MPC

Section 5.A.1 of Reference E.9.3-1 provides a summary of the results of the shielding evaluation of the MPC-LACBWR system. Results are provided for the transfer cask and vertical concrete cask components.

E.9.2.1 Shielding Discussion and Results for the MPC-LACBWR Storage System

This section provides a summary of the results of the shielding evaluation of the MPC-LACBWR system. Results are provided for the transfer cask and vertical concrete cask components.

The MPC-LACBWR storage system is comprised of a transportable storage canister, a transfer cask, and a vertical concrete storage cask. License drawings for these items are provided in Section *E.4.4*. The transfer cask containing the canister and the basket is loaded under water in the spent fuel pool. Once filled with fuel, the closure lid is placed on top of the canister and the transfer cask is removed from the pool. After draining approximately 50 gallons of water from the canister, the closure lid is welded, the closure ring is inserted and welded, and the canister is drained and dried. Finally, the port covers are welded in place. The transfer cask is then used to transfer the canister to the storage cask where it is stored dry until transport. Shielding evaluations are performed for the transfer cask with both a wet and dry canister cavity as would occur during the welding of the closure lid. Shielding evaluations are performed for the storage cask with the cavity dry.

The MPC-LACBWR transfer cask has a multi-wall radial shield comprised of 0.75 inch of carbon steel, 3.5 inches of lead, 2 inches of solid borated polymer (NS-4-FR), and 1.25 inches of carbon steel. An additional 0.5 inch of stainless steel shielding is provided radially by the canister shell. Gamma shielding is provided primarily by the steel and lead layers, and neutron shielding is provided primarily by the NS-4-FR. The transfer cask bottom shield design is a solid section of 9.5 inches of low alloy steel. The top shielding is provided by the stainless steel closure lid, which is 7 inches thick. Temporary shielding may be used during welding, draining, drying, and helium backfill operations but is not credited in the shielding analysis. Temporary shielding is removed prior to storage.

The storage cask radial shield design is comprised of a 2.5-inch-thick carbon steel inner liner surrounded by a 22-inch thickness of concrete. Gamma shielding is provided by both the carbon steel and the concrete. Neutron shielding is provided primarily by the concrete. As in the transfer cask, an additional 0.5-inch thickness of stainless steel radial gamma shielding is provided by the canister shell. The storage cask top shielding design is comprised of 7 inches of stainless steel from the canister closure lid, 1.875 inches of carbon steel from the storage cask lid and 8 inches of concrete from the storage cask lid. Since the bottom of the storage cask sits on a concrete pad, the storage cask bottom shielding is comprised of the 1-inch thick stainless steel canister bottom plate, the 2-inch-thick carbon steel weldment base plate and its 0.25-inch-thick stainless steel cover, and the 1-inch thick carbon steel cask bottom plate. The base plate and bottom plate are structural components that position the canister above the air inlets. The cask bottom plate supports the storage cask during lifting and forms the cooling air inlet channels at the cask bottom.

The MPC-LACBWR accommodates up to 68 stainless steel clad LACBWR spent fuel assemblies. LACBWR fuel assemblies were fabricated by two vendors, Allis Chalmers (AC) and Exxon Nuclear Company (ENC). The loading pattern evaluated for these fuel assemblies is illustrated in Figure 5.A.1-1 of Reference E.9.3-1. The physical parameters of the LACBWR fuel assemblies are presented in Table 5.A.2-1 of Reference E.9.3-1.

The fuel inventory at LACBWR contains a significant quantity of Allis Chalmers fuel classified as damaged due to concerns on clad stability. The MPC-LACBWR basket was, therefore, designed to contain up to 32 damaged fuel cans positioned in the peripheral locations in the basket. Due to criticality constraints, the Allis Chalmers fuel will not be permitted for loading in the canister interior locations. Fuel inventory at the LACBWR site allows for the split of Exxon fuel into the canister interior locations (Slot A in Figure 5.A.1-1 of Reference E.9.3-1) and Allis Chalmers fuel into the exterior locations (Slot B in Figure 5.A.1-1 of Reference E.9.3-1). The fuel inventory division resulted in initial shielding evaluations being based on undamaged Exxon fuel in the Slot A locations, with undamaged Allis Chalmers fuel in Slot B locations. The result of this evaluation is summarized in the undamaged fuel dose rates section below.

Undamaged Allis Chalmers fuel is evaluated, as the typical Allis Chalmers fuel assembly retains its nominal shape and retains the majority of the spent fuel within the fuel rod clad. As damaged fuel may not retain its geometry during transfer and storage operations, Section 5.A.1.2 of Reference E.9.3-1 results include dose rates for reconfigured/damaged Allis Chalmers fuel in Slot B locations. To allow for the contingency of loading Exxon fuel into an exterior slot/damaged fuel can, Section 5.A.4.7 of Reference E.9.3-1 provides the justification that the relative source change and, therefore, dose effects are minor. While this discussion is limited to one Exxon fuel assembly per basket, the minor change in source is not considered significant and additional Exxon fuel assemblies may be placed into the basket periphery.

The MPC-LACBWR damaged fuel can may hold a complete fuel assembly. Since the shielding evaluation conservatively assumes that the damaged fuel cans are not present in the canister, the additional shielding provided by the wall of the can would serve to reduce external dose rates.

Shielding evaluations of the MPC-LACBWR transfer and storage casks are performed using the MCNP5, Release 1.30, Monte Carlo transport code [A1 of Reference E.9.3-1]. Fuel source terms are developed using the SCALE isotopics sequence SAS2H (Herman). Source terms include fuel neutron, fuel gamma, fuel n-gamma, and activated hardware gamma. Dose rate evaluations include the effect of axial fuel burnup peaking on fuel neutron and gamma source terms.

The resulting dose rate profiles, along with the maximum and average radial and axial dose rates are presented for the storage cask and transfer cask analyses in Section 5.A.4 of Reference E.9.3-1.

Undamaged Fuel Dose Rates

The maximum dose rates for the storage cask with undamaged fuel are summarized in Table 5.A.1-1 and Table 5.A.1-2, of Reference E.9.3-1. The standard deviation resulting from the Monte Carlo evaluation used by MCNP (1σ) is indicated in the tables. The storage cask maximum side dose rate is 28.9 (1.3%) mrem/hr slightly below the fuel midplane elevation. The maximum storage cask top axial surface dose rate is 18.7 (6.9%) mrem/hr on the top lid surface just above the annulus between the canister and the storage cask liner. Since the storage cask is vertical during normal storage operation, the bottom is inaccessible. Therefore, no bottom axial dose rates are presented. The average dose rates at the inlets and outlets are 38.3 (1.4%) mrem/hr and 2.0 (0.5%) mrem/hr, respectively.

Under accident conditions involving a projectile impact and a loss of 6 inches of concrete, the surface dose rate increases to 278 mrem/hr at the impact location and 105 mrem/hr at a distance of 1 meter from the surface. There are no design basis accidents that result in a tip-over of the MPC-LACBWR storage cask.

The maximum dose rates for undamaged fuel in the transfer cask for the wet and dry canister cavity configurations encountered during canister closure operations are presented in Table 5.A.1-3 and Table 5.A.1-4, respectively of Reference E.9.3-1.

With a wet canister cavity (no port covers), the maximum dose rates are 68.2 (2.3%) and 471.2 (1.7%) mrem/hr on the radial surface and top axial surface, respectively. The bottom surface of the cask has a maximum dose rate of 23.8 (2.2%) mrem/hr.

With a dry canister cavity (port covers installed), the maximum dose rates are 102.2 (5.2%) mrem/hr and 598.7 (1.4%) mrem/hr on the radial and top axial surfaces, respectively. The bottom surface of the cask has a maximum dose rate of 54.2 (2.2%) mrem/hr.

Damaged Fuel Dose Rates

To ensure that the worst case configuration is considered, two damaged fuel scenarios are evaluated for the 32 peripheral basket locations.

The first scenario assumes the damaged fuel collects over the active fuel length of the fuel assembly. This scenario is modeled by filling the fuel rod interstitial volume with UO_2 and increasing the fuel neutron, gamma, and n-gamma source consistent with this increase in mass. A comparison of dose rate profiles for the 68 assembly intact fuel results and 36 intact and 32 damaged assemblies in Section 5.A.4 of Reference E.9.3-1 demonstrates that the damaged fuel model dose rates are less due to the increase in self-shielding from the 32 peripheral assemblies compensating for the increase in source strength.

In the second scenario, damaged fuel is assumed to migrate from the active fuel into the lower end fitting region of the fuel assembly, filling all the modeled void space. However, no credit is taken for the reduction in lower end fitting hardware dose rate due to the added UO_2 mass and self-shielding nor for the reduction in fuel mass migrated from the active fuel region. In this case, storage cask inlet and transfer cask bottom surface dose rates increase due to the addition of damaged fuel. The storage cask inlet dose rate increase is 36.7 mrem/hr, effectively doubling the air inlet dose rate. The transfer cask bottom axial dose rate increase is 22.1 mrem/hr, increasing the bottom axial dose rate by approximately 41%. Note that the radial location of the maximum dose rate at the bottom of the transfer cask differs between the undamaged and damaged fuel models. Damaged fuel maximum dose rates are summarized in Table 5.A.1-5 and Table 5.A.1-6 of Reference E.9.3-1.

E.9.3 References

E.9.3-1 NAC-MPC Final Safety Analysis Report, Revision 10, January 2014.

Table E.9-1
Estimated Occupational Collective Dose for Receipt of NAC-STC Cask Loaded with YR-MPC, CY-MPC, or MPC-LACBWR TSC and Transfer to MPC VCC

8 Sheets

Process Step	***Number of Workers***	***Occupancy Time (hours)***	***Worker Location Around Cask***	***Worker Distance (m)***	***Total Dose Rate (mrem/hr)***	***Total Dose (person-mrem)[1]***	***Reference SAR/FSAR Section/Table/Figure***
Perform radiation and contamination survey of STC Cask.	*2*	*0.5*	*All Around*	*2*	*4*	*2*	*SAR Figure 5.1-6, Figure 5.1-11, and Table 5.1-10*
Inspect top impact limiter security seal and verify it is intact and correct ID.	*1*	*0.25*	*Surface of Top Impact Limiter*	*<1*	*<1*	*1*	*SAR Figure 5.1-6, Figure 5.1-11, and Table 5.1-10*
Remove Personnel Barrier and complete surveys.	*2*	*0.5*	*Center of cask*	*1.5*	*15*	*15*	*SAR Figure 5.1-6, Figure 5.1-11, Figure 5.4-10, and Table 5.1-10*
Visually inspect Cask surface for transport/road damage and record.	*1*	*0.25*	*All Around*	*2*	*<4*	*1*	*SAR Figure 5.1-6, Figure 5.1-11, Figure 5.4-10, and Table 5.1-10*
Attach slings to top Impact Limiter and remove attachment nuts/rods. Remove and store Impact Limiter.	*2*	*0.5*	*Surface of Top Impact Limiter*	*1*	*< 1*	*1*	*SAR Figure 5.1-6, Figure 5.1-11, and Table 5.1-10*
Attach slings to bottom Impact Limiter and remove attachment nots/rods. Remove and store Impact Limiter.	*2*	*0.5*	*Surface of Bottom Impact Limiter*	*1*	*< 1*	*1*	*SAR Figure 5.1-6, Figure 5.1-11, and Table 5.1-10*

Table E.9-1
Estimated Occupational Collective Dose for Receipt of NAC-STC Cask Loaded with YR-MPC, CY-MPC, or MPC-LACBWR TSC and Transfer to MPC VCC

8 Sheets

Process Step	***Number of Workers***	***Occupancy Time (hours)***	***Worker Location Around Cask***	***Worker Distance (m)***	***Total Dose Rate (mrem/hr)***	***Total Dose (person-mrem)[1]***	***Reference SAR/FSAR Section/Table/Figure***
Release Front Tie-Down Assembly.	*2*	*1*	*Top Side STC Cask Surface*	*1*	*25*	*50*	*SAR Figure 5.1-6, Figure 5.1-11, Figure 5.4-10, and Table 5.1-10*
Engage Vertical Cask Transporter (VCT) Lift Arms to Front Trunnions and rotate cask to vertical orientation.	*2*	*1*	*Top Side STC Cask Surface*	*>2*	*5*	*10*	*SAR Figure 5.1-6, Figure 5.1-11, Figure 5.4-10, and Table 5.1-10*
Lift and Remove Cask from Transport Skid Rear Rotation Trunnions and move cask to Canister Transfer Facility (CTF), set cask down and release VCT Lift Arms. Establish Radiation Control boundaries.	*2*	*1*	*Top Side STC Cask Surface*	*>2*	*10*	*20*	*Semi-remote operation*
Using VCT, move empty MPC VCC to transfer position in CTF and set down adjacent to STC cask. Set up appropriate work platforms/man lifts for access to top of casks.	*2*	*1*	*Top of Empty VCC*	*>2*	*0*	*0*	*Empty VCC Handling*
Remove VCC Lid and VCC Shield Plug (if installed).	*2*	*1*	*Top of Empty VCC*	*1*	*0*	*0*	*Empty VCC Handling*

Table E.9-1
Estimated Occupational Collective Dose for Receipt of NAC-STC Cask Loaded with YR-MPC, CY-MPC, or MPC-LACBWR TSC and Transfer to MPC VCC

8 Sheets

Process Step	***Number of Workers***	***Occupancy Time (hours)***	***Worker Location Around Cask***	***Worker Distance (m)***	***Total Dose Rate (mrem/hr)***	***Total Dose (person-mrem)[1]***	***Reference SAR/FSAR Section/Table/Figure***
Install Transfer Adapter on VCC and connect hydraulic system.	*2*	*1*	*Top of Empty VCC*	*1*	*0*	*0*	*Empty VCC Handling*
Remove STC Cask Interlid Port Cover and check for excessive pressure. If pressure is high, take sample and check. If clean vent to HEPA filter.	*1*	*0.5*	*Top of STC*	*0.5*	*10*	*5*	*Top side of STC Upper Forging. SAR Figure 5.1-6, Figure 5.1-11, Figure 5.4-10, and Table 5.1-10*
Remove outer lid bolts, install alignment pins and lifting hoist rings, and remove outer lid and store. Remove alignment pins.	*2*	*1*	*Top of STC*	*0.5*	*20*	*40*	*Top side of STC Upper Forging. SAR Figure 5.1-6, Figure 5.1-11, Figure 5.4-10, and Table 5.1-10. FSAR Table 5.1.2-3 plus STC Inner Lid (7 inch SS and 2 inch NS-4-FR) and STC Outer Lid (5.25 inch SS)*

Table E.9-1
Estimated Occupational Collective Dose for Receipt of NAC-STC Cask Loaded with YR-MPC, CY-MPC, or MPC-LACBWR TSC and Transfer to MPC VCC

8 Sheets

Process Step	Number of Workers	Occupancy Time (hours)	Worker Location Around Cask	Worker Distance (m)	Total Dose Rate (mrem/hr)	Total Dose (person-mrem)[1]	Reference SAR/FSAR Section/Table/Figure
Remove vent and drain port covers, and connect pressure test system to vent port to check for excessive pressure. If pressure is high, take sample and check. If clean vent to HEPA filter.	*1*	*0.5*	*Top of STC*	*0.5*	*40*	*20*	*Top side of STC Upper Forging. SAR Figure 5.1-6, Figure 5.1-11, Figure 5.4-10, and Table 5.1-10. FSAR Table 5.1.2-3 plus STC Inner Lid (7 inch SS and 2 inch NS-4-FR)*
Remove all inner lid bolts, install alignment pins and lid lifting hoist rings/slings and remove inner lid and store. Remove alignment pins.	*2*	*1*	*Top of STC*	*0.5*	*40*	*80*	*Top side of STC Upper Forging SAR Figure 5.1-6, Figure 5.1-11, Figure 5.4-10, and Table 5.1-10. FSAR Table 5.1.2-3 plus STC Inner Lid (7 inch SS and 2 inch NS-4-FR)*
If present, remove top spacer (YR-MPC and MPC-LACBWR only).	*2*	*0.5*	*Top of STC*	*2*	*40*	*40*	*Performed from side of STC FSAR Table 5.1.2-3*
Install adapter ring to inner lid recess and torque captured bolts.	*2*	*0.5*	*Top of STC*	*0.5*	*20*	*20*	*Performed from side of STC FSAR Table 5.1.2-3*
Install transfer adapter plate on adapter ring and install and torque the four bolts.	*2*	*1*	*Top of STC*	*1*	*20*	*40*	*Performed from side of STC FSAR Table 5.1.2-3*

Table E.9-1
Estimated Occupational Collective Dose for Receipt of NAC-STC Cask Loaded with YR-MPC, CY-MPC, or MPC-LACBWR TSC and Transfer to MPC VCC

8 Sheets

Process Step	***Number of Workers***	***Occupancy Time (hours)***	***Worker Location Around Cask***	***Worker Distance (m)***	***Total Dose Rate (mrem/hr)***	***Total Dose (person-mrem)***[1]	***Reference SAR/FSAR Section/Table/Figure***
Install TSC Lid Lifting Adapter Plate on the Structural Lid.	*2*	*1*	*Top of STC*	*0.5*	*30*	*60*	*Performed from side of STC FSAR Table 5.1.2-3*
Using the CTF crane, lower the appropriate MPC Transfer Cask (TFR) and set it down on the transfer adapter on the STC Cask.	*2*	*1.5*	*Top of STC*	*>2*	*<1*	*3*	*Remote handling operation*
Remove the TFR door lock pins and open shield doors with hydraulic system.	*1*	*0.5*	*Top of STC*	*1*	*40*	*20*	*Performed from side of STC FSAR Table 5.1.2-3 and Figure 5.4.2-7*
Using the CTF, lower the Air-Powered Chain Hoist hook through the TFR and engage to the TSC Lift Adapter Plate.	*2*	*1.5*	*Remote Operating Location*	*>2*	*<5*	*15*	*Remote operation using CTF mounted cameras*
Using the Chain Hoist System slowly lift the TSC into the TFR.	*1*	*1*	*Remote Operating Location*	*>2*	*<5*	*5*	*Remote operation using CTF mounted cameras*

Table E.9-1
Estimated Occupational Collective Dose for Receipt of NAC-STC Cask Loaded with YR-MPC, CY-MPC, or MPC-LACBWR TSC and Transfer to MPC VCC

8 Sheets

Process Step	***Number of Workers***	***Occupancy Time (hours)***	***Worker Location Around Cask***	***Worker Distance (m)***	***Total Dose Rate (mrem/hr)***	***Total Dose (person-mrem)[1]***	***Reference SAR/FSAR Section/Table/Figure***
Close the TFR shield doors and install TFR shield door lock pins.	*1*	*0.5*	*Bottom of TFR*	*0.5*	*40*	*20*	*Remote operation to close doors and pins installed from side of STC FSAR Table 5.1.2-3 and Figure 5.4.2-7*
Lower the TSC onto the shield doors and using the CTF, lift the TFR off of the STC adapter plate.	*1*	*1*	*Remote Operating Location*	*>2*	*<5*	*5*	*Remote operation using CTF mounted cameras*
Move the TFR over the VCC and lower onto the VCC adapter plate.	*1*	*1*	*Remote Operating Location*	*>2*	*<5*	*5*	*Remote operation using CTF mounted cameras*
Remove the TFR shield door lock pins.	*1*	*0.5*	*Bottom of TFR*	*0.5*	*40*	*20*	*Pins removed from side of STC FSAR Table 5.1.2-3 and Figure 5.4.2-7*
Using the Chain Hoist System, lift the TSC off of the shield doors and open the shield doors.	*1*	*0.5*	*Remote Operating Location*	*>2*	*<5*	*3*	*Remote operation using CTF mounted cameras*
Using the chain hoist lower the TSC into the VCC.	*1*	*1*	*Remote Operating Location*	*>2*	*<5*	*5*	*Remote operation using CTF mounted cameras*

Table E.9-1
Estimated Occupational Collective Dose for Receipt of NAC-STC Cask Loaded with YR-MPC, CY-MPC, or MPC-LACBWR TSC and Transfer to MPC VCC

8 Sheets

Process Step	***Number of Workers***	***Occupancy Time (hours)***	***Worker Location Around Cask***	***Worker Distance (m)***	***Total Dose Rate (mrem/hr)***	***Total Dose (person-mrem)***[1]	***Reference SAR/FSAR Section/Table/Figure***
Release chain hoist system hook from the TSC Lift Adapter Plate and retract through the TFR.	*1*	*0.5*	*Remote Operating Location*	*>2*	*<5*	*3*	*Remote operation using CTF mounted cameras*
Close TFR shield doors and install TFR shield door lock pins.	*1*	*0.5*	*Bottom of TFR*	*0.5*	*30*	*15*	*Pins installed from side of STC FSAR Table 5.1.2-3 and Figure 5.4.2-7*
Using the CTF, lift and remove the TFR from the top of the VCC.	*1*	*0.5*	*Remote Operating Location*	*>2*	*<5*	*3*	*Remote operation using CTF mounted cameras*
Using mobile crane, remove transfer adapter plate from VCC and store.	*2*	*1*	*Top of VCC*	*1*	*45*	*90*	*FSAR Figure 5.4.2-9 and operation performed on top of transfer adapter mounted on VCC*
Unbolt and remove TSC Lift Adapter Plate from the top of the TSC.	*2*	*1*	*Top of TSC*	*1*	*60*	*120*	*FSAR Figure 5.4.2-9 and operation performed on top of VCC*
Install the VCC Shield Plug (YR-MPC and CY-MPC only).	*2*	*0.5*	*Top of VCC*	*1*	*35*	*35*	*FSAR Figure 5.4.2-9 and operation performed on top of VCC*

Table E.9-1
Estimated Occupational Collective Dose for Receipt of NAC-STC Cask Loaded with YR-MPC, CY-MPC, or MPC-LACBWR TSC and Transfer to MPC VCC

8 Sheets

Process Step	***Number of Workers***	***Occupancy Time (hours)***	***Worker Location Around Cask***	***Worker Distance (m)***	***Total Dose Rate (mrem/hr)***	***Total Dose (person-mrem)[1]***	***Reference SAR/FSAR Section/Table/Figure***
Install and bolt in place the VCC lid.	*2*	*1*	*Top of VCC*	*1*	*25*	*50*	*FSAR Figure 5.4.2-9 and operation performed on top of VCC.*
Using the VCT, lift and move loaded MPC VCC and position it in the designated storage location.	*2*	*1*	*VCT Platform*	*>2*	*10*	*20*	*Operation performed from VCT and FSAR Figure 5.4.2-7*
Prepare empty STC cask for empty return transport.	*2*	*4*	*CTF*	*1*	*0*	*0*	*Empty cask preparation activities*
					Total (person-mrem)	*823*	

Note:

1. Rounded up to the nearest whole number

APPENDIX E.10
CRITICALITY EVALUATION
NAC-MPC

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E.10 CRITICALITY EVALUATION

Chapter 6 of Reference E.10-1 provides the criticality evaluation of the NAC-MPC storage system and demonstrates that the NAC-MPC storage system is subcritical in accordance with the requirements of 10 CFR 72.124(a), 10 CFR 72.236(c) and Chapter 6 of NUREG-1536. The evaluations show that the effective neutron multiplication factor of the NAC MPC system is less than 0.95, including biases and uncertainties under normal, off-normal and accident conditions.

The NAC-MPC storage system is comprised of a transportable storage canister (canister), a transfer cask and a vertical concrete cask (storage cask). The canister comprises a stainless steel canister and a basket. The basket comprises fuel tubes held in place with stainless steel support disks and tie rods. The transfer cask containing the canister and basket is loaded underwater in the spent fuel pool. Once loaded with fuel, the canister is drained, dried, inerted, and welded shut. The transfer cask is then used to transfer the canister to the storage cask where it is stored until transported off-site.

Under normal conditions, such as loading in a spent fuel pool, moderator (water) is present in the canister while it is in the transfer cask. Also, during draining and drying operations, the moderator is present and its density will vary. Thus, the criticality evaluation of the transfer cask includes a variation in moderator density and a determination of optimum moderator density. Assuming the most reactive mechanical basket configuration, moderator intrusion into the canister and moderator intrusion into the fuel cladding (100% fuel failure), bounds all normal, off-normal and accident conditions.

Under normal storage conditions, moderator is not present in the canister. However, access to the environment is possible via the air inlets in the storage cask and the convective heat transfer annulus between the canister and the storage cask steel liner. This provides paths for moderator intrusion during a flood. Under off-normal conditions, moderator intrusion into the convective heat transfer annulus is evaluated. Under accident conditions of the cask loaded with intact fuel, it is hypothetically assumed that the canister confinement fails, and moderator intrusion into the canister and into the fuel cladding (100% fuel failure) is evaluated. This is a highly conservative assumption, since, as shown in Chapters 3 and 11 of Reference E.10-1, there are no design basis normal, off-normal or accident conditions that result in the failure of the canister confinement boundary that would allow the intrusion of water.

The NAC MPC is provided in three configurations. The first is designed to store up to 36 Yankee Class spent fuel assemblies and is referred to as the Yankee-MPC. The second is designed to store up to 26 Connecticut Yankee (CY) spent fuel assemblies and is referred to as the CY-MPC. The third, MPC-LACBWR, is designed to store up to 68 Dairyland Power Cooperative La Crosse Boiling Water Reactor (LACBWR) spent fuel assemblies, including up to 32 LACBWR damaged fuel cans. The transportable storage canister (canister) configurations differ primarily in fuel basket design, but also differ in overall length and weight. There are corresponding differences in the principal dimensions and weights of the transfer cask and vertical concrete casks used with each of these NAC-MPC storage systems.

A description of the Yankee Class fuel and a summary of the results of the Yankee-MPC criticality evaluation are presented in Section 6.1.1 of Reference E.10-1. The description of the Connecticut Yankee fuel and a summary of the CY-MPC criticality results are presented in Section 6.1.2 of Reference E.10-1. The description of the LACBWR fuel and a summary of the MPC-LACBWR criticality results are presented in Appendix 6.A of Reference E.10-1.

The continued efficacy of the neutron absorbers is assured when the canister arrives at 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 NAC-STC cask as documented in of the NAC-STC Safety Analysis Report.

E.10.1 Connecticut Yankee MPC

The CY-MPC configurations are evaluated using the MONK8A Monte Carlo Program. These conservative assumptions include:

1. No fuel burnup (fresh fuel assumption).
2. No fission product build up as a poison.
3. Fuel assemblies of the most reactive type.
4. UO_2 fuel density at 95% of theoretical.
5. No dissolved boron in the spent fuel pool water (water temperature 293°K).
6. Infinite cask array.
7. Moderator intrusion into the intact fuel rod clad/pellet gap under accident conditions.
8. A most reactive mechanical configuration.

In addition, consistent with Section 6, Part IV of NUREG-1536, 75% of the specified minimum ^{10}B loading in the BORAL plates is assumed.

E.10.1.1 CY-MPC System Criticality Discussion and Results

The criticality evaluation of the CY-MPC is performed with the MONK8A (AEA Technology) Monte Carlo Program for Nuclear Criticality Safety Analysis. This code employs the Monte Carlo technique in combination with JEF 2.2-based point energy neutron libraries to determine the effective neutron multiplication factor (keff). The specific libraries are dec96j2v5 for general neutron cross section information and therm96j2v2 for thermal scatter data in the water moderator. MONK8A, with the JEF 2.2 neutron cross section libraries, is benchmarked by comparison to critical experiments relevant to Light Water Reactor fuel in storage and transport casks as shown in Section 6.5.2 of Reference E.10-1. The NUREG/CR-6361 method-based verification performed for MONK8A has established an upper subcritical limit as a function of system parameters. For the CY-MPC system, the upper subcritical limit is 0.9425 (Section 6.5.2 of Reference E.10-1).

Criticality control in the Yankee-MPC canister basket is achieved using geometric control of the fuel assemblies in the basket along with the flux trap principle. Each of the fuel tubes in the canister basket is surrounded by four BORAL sheets with a core areal density of 0.02g 10B/cm^2 (minimum), which are held in place by stainless steel cladding. The center-to-center spacing of the fuel tubes is maintained by the stainless steel support disks. When the canister is flooded with water, neutrons are thermalized in the water gaps between the fuel tubes and are absorbed in the BORAL sheets, reducing the number of neutrons available to cause a fission event in an adjacent fuel assembly.

Two configurations of the CY-MPC basket are available for loading at Connecticut Yankee: the standard 26-assembly basket configuration, and a 24-assembly basket configuration where two basket openings are blocked. The 26-assembly basket configuration is analyzed for Zircaloy-clad assemblies with an initial enrichment of up to 3.93 wt % ^{235}U and stainless steel clad assemblies with an initial enrichment of up to 4.03 wt % ^{235}U. The 24-assembly basket configuration allows the loading of Zircaloy-clad assemblies with an initial enrichment of up to 4.61 wt % ^{235}U and the same stainless steel clad fuel assemblies as the 26-assembly configuration. The 24 assembly design is used for the 53 Westinghouse Vantage 5H fuel assemblies in the Connecticut Yankee spent fuel inventory. Using this reduced capacity only for the Vantage 5H fuel allows the higher uranium enrichments to be accommodated without penalizing the capacity of the system as a whole.

As demonstrated in the Yankee-MPC evaluation, the most reactive configuration is independent of shield geometry for an MPC-sized system. Therefore, the reactivity of the transfer cask loaded with fuel is assumed to accurately represent the reactivity of the storage cask. While the transfer cask and canister are flooded in normal use, there are no credible normal, off-normal or accident condition events that would cause the canister to become flooded while in the concrete cask.

Criticality evaluations of the CY-MPC basket are performed within the transfer cask under normal, off-normal and accident conditions, applying the conservative conditions and assumptions described in Section 6.1 of Reference E.10-1. As specified, these consider the most reactive fuel assembly type, worst case mechanical basket configuration and variations in moderator density. The most reactive CY-MPC fuel loading occurs with the 24-assembly basket configuration fully loaded with Zircaloy-clad fuel assemblies with a maximum enrichment of 4.61 wt % ^{235}U. The 24-assembly basket configuration loaded with the most reactive fuel bounds the most reactive 26-assembly basket configuration loading.

The maximum effective neutron multiplication factor from this loading is 0.3715 under dry conditions and 0.9327 under the postulated accident conditions involving full moderator intrusion. Including two standard deviations establishes a system reactivity threshold, $k_{eff} + 2\sigma$, of 0.9343, which is less than the subcritical limit of 0.9425. Consequently, the most reactive configuration of the CY-MPC, containing the most reactive fuel assemblies in the most reactive configuration, is well below the regulatory criticality safety limit, including all biases and uncertainties under normal, off-normal and accident conditions.

E.10.2 Yankee Rowe MPC

The Yankee-MPC criticality evaluation is performed using the SCALE 4.3 Criticality Safety Analysis Sequence (CSAS). This sequence uses KENO-Va Monte Carlo analysis to determine the effective neutron multiplication factor, keff. These conservative assumptions include:

1. No fuel burnup (fresh fuel assumption).
2. No fission product build up as a poison.
3. Fuel assemblies of the most reactive type.
4. UO_2 fuel density at 95% of theoretical.
5. No dissolved boron in the spent fuel pool water (water temperature 293°K).
6. Infinite cask array.
7. Moderator intrusion into the intact fuel rod clad/pellet gap under accident conditions.
8. A most reactive mechanical configuration.

In addition, consistent with Section 6, Part IV of NUREG-1536, 75% of the specified minimum 10B loading in the BORAL plates is assumed.

E.10.2.1 Yankee-MPC System Criticality Discussion and Results

The criticality evaluation of the Yankee-MPC is performed with the SCALE 4.3 (ORNL) Criticality Safety Analysis Sequence (CSAS)(Landers). This sequence includes KENO-Va (Petrie) Monte Carlo analysis to determine the effective neutron multiplication factor (keff). The 27-group ENDF/B-IV neutron library (Jordan) is used in all calculations. CSAS with the 27 group library is benchmarked by comparison to 63 critical experiments relevant to Light Water Reactor fuel in storage and transport casks.

Criticality control in the Yankee-MPC canister basket is achieved using a flux trap principle. The flux trap principle controls the reactivity in the interior of each of the three basket configurations. In the first of the configurations, all fuel tubes are separated by a flux trap that is formed by surrounding the tube with stainless steel support disks and four 0.01g $10B/cm^2$ (minimum) areal density BORAL sheets, which are held in place by stainless steel covers. In the second configuration, the size of the four fuel tubes (one outer tube in each quadrant of the basket, as shown in Figure 6.3.1-4 of Reference E.10-1) is increased by removing the BORAL sheets from the outside of the tubes. The remainder of the tubes have BORAL sheets on each of the four sides. In the third configuration, the four enlarged fuel tubes, which do not have BORAL sheets, are replaced with screened damaged fuel cans. The remainder of the fuel tubes have BORAL sheets on all four sides. The spacing of the fuel tubes is maintained by the stainless steel support disks. These disks provide water gap spacings between tubes of 0.875, 0.810, or 0.750 inches, depending on the position of the fuel tube in the basket. When the canister is flooded with water, fast neutrons leaking from the fuel assemblies are thermalized in the water gaps and are absorbed in the BORAL sheets before causing a fission in an adjacent fuel assembly. The Yankee-

MPC basket can accommodate up to 36 Yankee Class Zircaloy-clad assemblies with a nominal initial enrichment of 4.0 wt % 235U or 36 Yankee Class stainless steel-clad assemblies with a nominal initial enrichment of 4.94 wt % ^{235}U.

Criticality evaluations are performed for both the transfer and storage casks under normal, off-normal and accident conditions applying the conservative conditions and assumptions described in Section 6.1 of Reference E.10-1. As specified, these consider the most reactive fuel assembly type, worst case mechanical basket configuration and variations in moderator density. The maximum effective neutron multiplication factor with bias and uncertainties for the transfer cask is 0.9021. The maximum multiplication factor with bias and uncertainties for the storage cask is 0.4503 under normal dry storage conditions and 0.9018 under the hypothetical accident conditions involving full moderator intrusion. The maximum bias and uncertainty adjusted reactivities for the basket containing the four enlarged fuel tubes are slightly higher at 0.9175 for transfer conditions and 0.9182 for a hypothetical storage accident condition involving full moderator intrusion.

Analysis of simultaneous moderator density variation inside and outside either the transfer or storage casks shows a monotonic decrease in reactivity with decreasing moderator density. Thus, the full moderator density condition bounds any off-normal or accident situation. Analysis of moderator intrusion into the storage cask heat transfer annulus with the canister dry shows a slight decrease in reactivity from the completely dry condition.

E.10.3 LaCrosse MPC

Appendix 6.A of Reference E.10-1 documents the method, input, and result of the criticality analysis of the LACBWR payload in the NAC-MPC system. The results demonstrate that the effective neutron multiplication factor, keff, of the system under normal conditions, or off-normal and accident events, is less than 0.95 including biases and uncertainties. The MPC-LACBWR system design meets the criticality requirements of 10 CFR 72 and Chapter 6 of NUREG-1536.

E.10.3.1 MPC-LACBWR System Criticality Discussion and Results

The cask system consists of a TSC (Transportable Storage Canister), a transfer cask, and a concrete cask. The system is designed to safely store up to 68 LACBWR fuel assemblies of which up to 32 may be classified as damaged and be placed into damaged fuel cans (DFCs). The TSC is comprised of a stainless steel canister and a basket within which fuel is loaded. The DFC provides a screened container to prevent gross fissile material release into the TSC cavity from failed fuel rod clad. The TSC is loaded into the concrete cask for storage. A transfer cask is used for handling the TSC during loading of spent fuel. Fuel is loaded into the TSC contained within the transfer cask underwater in the spent fuel pool. Once loaded with fuel, the TSC closure lid is welded and the TSC is drained, dried and backfilled with helium. The transfer cask is then used to move the TSC into or out of the concrete cask. The transfer cask provides shielding during the TSC loading and transfer operations.

Under normal conditions, such as loading in a spent fuel pool, moderator (water) is present in the TSC during the initial stages of fuel transfer. During draining and drying operations, moderator with varying density is present. Thus, the criticality evaluation of the transfer cask includes a variation in moderator density and a determination of optimum moderator density. Normal, off-normal, and accident condition optimum moderator density studies cover pellet clad flooding, preferential flooding (i.e., independent variation in the DFC and TSC and outside the TSC) and partial flooding (i.e, variations in moderator elevations). Normal condition structural analysis in Section 3.A of Reference E.10-1 and off-normal and accident structural analysis of the fuel, basket, TSC and cask in Section 11.A of Reference E.10-1 demonstrate that no operating condition induces geometry variations in the system beyond those allowed by the manufacturing tolerances.

Structural analyses demonstrate that the TSC confinement boundary remains intact through all storage operating conditions. Therefore, moderator is not present in the TSC while it is in the concrete cask. However, access to the concrete cask interior environment is possible via the air inlets and outlets and the heat transfer annulus between the TSC and the cask steel liner. This access provides paths for moderator intrusion during a flood. Under off-normal and accident conditions, moderator intrusion into the convective heat transfer annulus is evaluated.

System criticality control is achieved through the use of neutron absorber sheets (BORAL®) attached to the exterior faces of the fuel tubes. Individual fuel assemblies are held in place by stainless steel structural disks. The basket design includes 68 fuel tubes, one tube per fuel assembly or DFC, with the DFC tubes having a slightly larger (oversized) opening.

Criticality evaluations rely on modeled neutron absorber 10B loadings of 0.015 g/cm^2. The modeled areal density is arrived at by multiplying the minimum 0.02 g/cm^2 10B areal density specified for the absorber by a 75% efficiency factor.

MCNP, a three-dimensional Monte Carlo code, is used in the system criticality analysis. Evaluations are primarily based on the ENDF/B-VI continuous energy neutron cross-section library available in the MCNP distribution. Nuclides for which no ENDF/B-VI data is available are set to the latest cross-section sets available in the code distribution. The code and cross-section libraries are benchmarked by comparison to a range of critical experiments relevant to light water reactor fuel in storage and transport casks. An upper subcritical limit (USL) for the system is determined based on guidance given in NUREG/CR-6361.

Key assembly physical characteristics and maximum initial enrichment for the loading of the two LACBWR fuel assembly types are shown in Table 6.A.1-1 of Reference E.10-1, with the allowed loading configuration shown in Figure 6.A.1-1 of Reference E.10-1. Maximum enrichment is defined as planar-average enrichment for the variably enriched Exxon (EX) assemblies.

Undamaged fuel assemblies are evaluated with a full, nominal set of fuel rods. Fuel rod (lattice) locations may contain filler rods. A filler rod must occupy, at a minimum, a volume equivalent to the fuel rod it displaces. Filler rods may be placed into the lattice after assembly in-core use or be designed to replace fuel rods prior to use. The undamaged Exxon assembly must contain its nominal set of inert rods.

The maximum multiplication factors (keff +2σ) are calculated, using conservative assumptions, for the transfer and concrete casks. The USL applied to the analysis results is 0.9372 per Section 6.A.5 of Reference E.10-1. Maximum reactivities are produced by the damaged fuel payloads. The results of the analyses are presented in detail in Section 6.A.3.4 of Reference E.10-1 and are summarized as follows.

Cask Body	Operating Condition	Water Density (g/cc)			$k_{eff}+2\sigma$
		TSC Interior	**DFC Interior**	**TSC Exterior**	
Transfer	--	0.0001	0.0001	0.0001	0.35333
Transfer	--	0.9982	0.9982	0.0001	0.87655
Transfer	--	0.9982	0.9982	0.9982	0.87636
Transfer	--	0.0001	0.9982	0.9982	0.91423
Transfer	--	0.0001	0.9982	0.0001	0.93014
Storage	Normal	0.0001	0.0001	0.0001	0.34222
Storage	Accident	0.0001	0.0001	0.9982	0.33691

The maximum reactivity was established for different baseline configurations, one in which the fuel retained its preirradiation configuration and one where damage occurred, resulting in the potential reconfiguration of fissile material.

Maximum reactivity of the system with fuel in an undamaged condition, i.e., fuel geometry is retained, was calculated to be one where system tolerances are combined to form a worst case, maximum reactivity geometry (also referred to as combined tolerance model). In this configuration, the following tolerances are applied:

- Minimum absorber width and maximum absorber thickness
- Maximum the width and minimum tube thickness
- Maximum size disk opening at the minimum radial location
- Minimum disk pitch at maximum thickness

Fuel assemblies and fuel tubes are moved radial to the center of the canister with fuel assembly clad to pellet gap flooded. This configuration results in a maximum keff of approximately 0.85.

Maximum system reactivity was achieved for the configuration in which damaged fuel is located in the exterior 32 locations of the basket as noted in Figure 6.A.1-1 of Reference E.10-1. In this configuration, undamaged Exxon fuel is located in the 36 interior locations. The maximum damaged fuel configuration is one where fuel clad, in addition to any other assembly steel hardware, is assumed to be removed from the DFC, and the fuel pellet stacks are assumed to be floating in the DFC at maximum square pitch available in the DFC opening. The DFCs are flooded with full density water to maximize neutron moderation, while the canister cavity is dry, reducing neutron absorber effectiveness. As there is no moderator in the canister cavity in the dry canister, preferential flood configuration, system manufacturing tolerances, such as disk thickness, tube thickness, and absorber size, do not affect system reactivity to any statistical extent. Storage casks are evaluated in an infinite array of casks by applying reflective boundary conditions, while transfer cask reactivities are based on a single cask model.

Analysis of moderator density in the canister shows a monotonic decrease in reactivity with decreasing moderator density for undamaged fuel. The full moderator density TSC interior condition bounds any off-normal or accident condition with the exception of the preferentially flooded DFC case. Analysis of moderator intrusion into the concrete cask heat transfer annulus with the dry TSC shows a slight decrease in reactivity from the completely dry condition.

E.10.4 References

E.10-1 NAC-MPC Final Safety Analysis Report, Revision 10, January 2014

APPENDIX E.11
CONFINEMENT EVALUATION
NAC-MPC

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E.11 CONFINEMENT EVALUATION

The NAC-MPC storage system is provided in three configurations. The Yankee-MPC provides storage for up to 36 intact Yankee Class spent fuel assemblies and reconfigured fuel assemblies (RFA). The CY-MPC holds up to 26 Connecticut Yankee spent fuel assemblies, reconfigured fuel assemblies or damaged fuel cans. The MPC-LACBWR provides storage for up to 68 Dairyland Power Cooperative La Crosse Boiling Water Reactor spent fuel assemblies with 32 damaged fuel cans. These three configurations of the NAC-MPC have similar components and operating features, but have different physical dimensions, weights and storage capacities. Confinement features for the Yankee-MPC and CY-MPC systems are addressed in the main body of Chapter 7 of Reference E.11-1. Appendix 7.A of Reference E.11-1 has been added to address the MPC-LACBWR system. *Figures illustrating the confinement boundary for the Yankee-MPC and CY-MPC are found in Figures 7.1-1 and 7.1-2 of Reference E.11-1. The Figure illustrating the confinement boundary for the MPC-LACBWR is found in Figure 7.A.1-1 of Reference E.11-1.*

The codes and standards for the design, fabrication, and inspection of the canister and confinement boundary are detailed in Reference E.11-2. Specifically, Appendix B, Section B.3.3, "Codes and Standards", which states the ASME Boiler and Pressure Vessel Code (ASME Code), 1995 Edition with Addenda through 1995, is the governing Code for the NAC-MPC System canister except that Addenda through 1997, are applied for critical flaw evaluation of the canister closure weld and Section B.3.3.1, "Alternatives to the ASME Code," which lists the Code alternatives for the canister in Table B3-1. Included in this table is the leaktight criterion of ANSI N14.5 for the canister.

Appendix A, Section A 3.1, "NAC-MPC System Integrity," of Reference E.11-2, includes limiting condition for operation (LCO) 3.1.1 for canister maximum vacuum drying time, LCO 3.1.2 for canister vacuum drying pressure, and LCO 3.1.3 for canister helium backfill pressure. These LCOs create a dry, inert, leaktight atmosphere, which contributes to preventing the leakage of radioactive material.

The confinement features of the NAC-MPC system for Yankee Rowe, Connecticut Yankee and La Crosse are such that the potential for canister leakage is not credible. Similarly, the storage of reactor generated GTCC waste from Yankee Rowe and Connecticut Yankee within a welded closed GTCC-Canister-YR and GTCC-Canister-CY does not present the potential for a credible leakage path. In addition, GTCC waste is a non-gas generation media. Thus, there is no means of dispersal from the GTCC-Canister-YR and GTCC-Canister-CY.

E.11.1 Yankee Rowe MPC and Connecticut Yankee MPC

The Transportable Storage Canister (canister) provides long-term storage confinement of the Yankee Class and Connecticut Yankee spent fuel. The canister confinement boundary is closed by welding, which presents a leaktight barrier to the release of contents in all of the evaluated normal, off-normal and accident conditions. The method of closing the confinement boundary is the same for both NAC-MPC configurations.

The NAC-MPC canister contains an inert gas (helium). The confinement boundary retains the helium and also prevents the entry of outside air into the NAC-MPC. The exclusion of air precludes degradation of the fuel rod cladding over time, due to cladding oxidation failures.

The NAC-MPC canister confinement system meets the requirements of 10 CFR 72.24 for protection of the public from release of radioactive material, and 10 CFR 72.122 for protection of the spent fuel contents in long-term storage such that future handling of the contents would not pose an operational safety concern.

The helium purity level of at least 99.9% maintains the quantity of oxidizing contaminant to less than one mole per canister for all loading conditions. Based on the calculations presented in Sections 4.4.5 and 4.5.5 of Reference E.11-1, respectively, the free gas volume of the empty Yankee-MPC or CY MPC canister is less than 300 moles. Conservatively assuming that all of the impurities in 99.9% pure helium are oxidents, a maximum of 0.3 moles of oxidants could exist in the NAC-MPC canister during storage. By limiting the amount of oxidants to less than one mole, the recommended limits for preventing cladding degradation found in the Pacific Northwest Laboratory, "Evaluation of Cover Gas Impurities and Their Effects on the Dry Storage of LWR Spent Fuel," PNL-6365 are satisfied.

E.11.1.1 Confinement Boundary

The confinement boundary is described in detail for the Yankee-MPC and CY-MPC in Section 7.1 of Reference E.11-1. Specific details for the confinement vessel, confinement penetrations, seals & welds, and closure are in Sections 7.1.1, 7.1.2, 7.1.3, and 7.1.4, respectively. *In addition, a bounding evaluation in Section E.7.1.11 is presented to demonstrate that the confinement boundary for the Yankee-MPC and CY-MPC canisters 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.*

E.11.1.2 Requirements for Normal Conditions of Storage

The requirements for normal conditions of storage are described in detail in Section 7.2 of Reference E.11-1. Specific details on the release of radioactive materials and pressurization of the confinement vessel are in Sections 7.2.1 and 7.2.2, respectively.

E.11.1.3 Confinement Requirements for Hypothetical Accident Conditions

The requirements for hypothetical accident conditions are described in detail in Section 7.3 of Reference E.11-1.

E.11.2 LaCrosse MPC

The MPC-LACBWR Transportable Storage Canister (TSC) provides confinement for its radioactive contents in long-term storage. The confinement boundary provided by the TSC is closed by welding, creating a solid barrier to the release of contents in the design basis normal conditions and off-normal or accident events. The welds are visually inspected and nondestructively examined to verify integrity.

The sealed TSC contains helium, an inert gas, at atmospheric pressure. The confinement boundary retains the helium and also prevents entry of outside air into the TSC in long-term storage. The exclusion of air from the confinement boundary precludes fuel rod cladding oxidation failures during storage.

The TSC confinement system meets the requirements of 10 CFR 72.24 for protection of the public from release of radioactive material. The design of the TSC allows the recovery of stored spent fuel should it become necessary per the requirements of 10 CFR 72.122. The TSC meets the requirements of 10 CFR 72.122 (h) for protection of the spent fuel contents in long-term storage such that future handling of the contents would not pose an operational safety concern.

The MPC-LACBWR TSC provides an austenitic stainless steel closure design sealed by welding, precluding the need for continuous monitoring. The analysis for normal conditions and off-normal or accident events demonstrates that the integrity of the confinement boundary is maintained in all the evaluated conditions. Consequently, there is no release of radionuclides from the TSC resulting in site boundary doses in excess of regulatory requirements. Therefore, the confinement design of the MPC-LACBWR system meets the regulatory requirements of 10 CFR 72 and the acceptance criteria defined in NUREG-1536.

E.11.2.1 Confinement Boundary

The confinement boundary is described in detail for the MPC-LACBWR in Section 7.A.1 of Reference E.11-1. Specific details for the confinement vessel, confinement penetrations, seals & welds, and closure are in Sections 7.A.1.1, 7.A.1.2, 7.A.1.3, and 7.A.1.4, respectively. *In addition, a bounding evaluation in Section E.7.2.11 is presented to demonstrate that the confinement boundary for the MPC-LACBWR canister 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.*

E.11.2.2 Requirements for Normal Conditions of Storage

The requirements for normal conditions of storage are described in detail in Section 7.A.2 of Reference E.11-1. Specific details on the release of radioactive materials and pressurization of the confinement vessel are in Sections 7.A.2.1 and 7.A.2.2, respectively.

E.11.2.3 Confinement Requirements for Hypothetical Accident Conditions

The requirements for hypothetical accident conditions are described in detail in Section 7.A.3 of Reference E.11-1.

E.11.3 References

E.11-1 NAC-MPC Final Safety Analysis Report, Revision 10, January 2014.

E.11-2 Amendment No. 6 to Certificate of Compliance No. 1025 for the NAC International, INC., NAC-MPC Multi-Purpose Canister System, October 4, 2010.

APPENDIX E.12
ACCIDENT ANALYSIS
NAC-MPC

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E.12 ACCIDENT ANALYSIS

The analyses of the off-normal and accident design events, including those identified by ANSI/ANS 57.9-1992, are presented in this Chapter 11 of Reference E.12-1. Section 11.1 of Reference E.12-1 describes the off-normal events that could occur during the use of the NAC-MPC storage system, possibly as often as once per calendar year. Section 11.2 of Reference E.12-1 addresses very low probability events that might occur once during the lifetime of the ISFSI or hypothetical events that are postulated because their consequences may result in the maximum potential impact on the surrounding environment. Section 11.3 of Reference E.12-1 describes the design basis load conditions for the Yankee-MPC transportable storage canister. As described in Section 11.3 of Reference E.12-1, the canister is analyzed for loads imposed during transportation. These transport condition loads envelope the loads for the storage condition analyzed herein.

This Chapter 11 of Reference E.12-1 demonstrates that the NAC-MPC satisfies the requirements of 10 CFR 72.24 and 10 CFR 72.122 for off-normal and accident conditions. These analyses are based on conservative assumptions to ensure that the consequences of off-normal conditions and accident events are bounded by the reported results. The actual response of the NAC-MPC system to the postulated events will be much better than that reported, i.e., stresses, temperatures, and radiation doses will be lower than predicted. If required for a site-specific application, a more detailed evaluation could be used to extend the limits defined by the events evaluated in this section.

The NAC-MPC is provided in three configurations. The first is designed to store up to 36 intact Yankee Class spent fuel and reconfigured fuel assemblies and is referred to as the Yankee-MPC. The second is designed to store up to 26 Connecticut Yankee fuel assemblies, reconfigured fuel assemblies or damaged fuel cans and is referred to as the CY-MPC. The third configuration is designed to store up to 68 Dairyland Power Cooperative La Crosse Boiling Water Reactor (LACBWR) spent fuel assemblies, including up to 32 LACBWR damaged fuel cans, and is referred to as MPC-LACBWR.

The off-normal and accident conditions evaluation for each configuration is presented separately when appropriate due to differences in capacity, weight and principal dimensions. The off-normal and accident conditions evaluation for the MPC-LACBWR configuration is presented in Appendix 11.A of Reference E.12-1.

For the storage of reactor generated GTCC waste previously loaded at Yankee Rowe and Connecticut Yankee, the accident analyses for the storage of their fuel bounds the storage of GTCC waste. The GTCC-Canister-YR and GTCC-Canister-CY and concrete overpacks are similar in design to the spent nuclear fuel canisters and overpacks and the storage heat load for GTCC waste is significantly below that of the stored spent nuclear fuel.

E.12.1 Yankee Rowe MPC and Connecticut Yankee MPC

The following describes the off-normal and accidents evaluated for the Yankee-MPC and CY-MPC. Evaluations related to sit specific fuel components are located in Section 11.4 of Reference E.12-1.

E.12.1.1 Off-Normal Events

Section 11.1 of Reference E.12-1 evaluates postulated events that might occur once during any calendar year of operations. The actual occurrence of any of these events is unlikely. The off-normal condition evaluation for each configuration (i.e., Yankee-MPC and CY-MPC) is presented separately when appropriate in Reference E.12-1 due to differences in capacity, weight and principal dimensions.

The following off-normal events are evaluated in Reference E.12-1. Beside each off-normal event listed is the location in Reference E.12-1 where the details of the analysis are presented.

1. Blockage of half of the air inlets – Section 11.1.1
2. Canister off-normal handling load – Section 11.1.2
3. Failure of instrumentation – Section 11.1.3
4. Several environmental conditions (100°F and -40°F) – Section 11.1.4
5. Small release of radioactive particulate from the canister exterior – Section 11.1.5

E.12.1.2 Accidents

Section 11.2 of Reference E.12-1 provides the results of analyses of the design basis and hypothetical accident conditions evaluated for the NAC-MPC system. The accident conditions evaluation for each configuration (i.e., Yankee-MPC and CY-MPC) is presented separately when appropriate in Reference E.12-1 due to differences in capacity, weight and principal dimensions. Canister closure weld evaluations for accident conditions are presented in Section 11.5 of Reference E.12-1.

The following accidents are evaluated in Reference E.12-1. Beside each accident condition listed is the location in Reference E.12-1 where the details of the analysis are presented.

1. Accident pressurization – Section 11.2.1
2. Earthquake event – Section 11.2.2
3. Explosion – Section 11.2.3
4. Failure of all fuel rods with a subsequent ground level breach of the canister – Section 11.2.4
5. Fire accident – Section 11.2.5
6. Flood – Section 11.2.6
7. Fresh fuel loading in the canister – Section 11.2.7
8. Full blockage of air inlets and outlets – Section 11.2.8
9. Lightning – Section 11.2.9
10. Maximum anticipated heat load (125°F ambient temperature) – Section 11.2.10

11. Storage cask 6-inch drop – Section 11.2.11
12. Tip over of the vertical concrete cask – Section 11.2.12
13. Tornado and tornado driven missiles – Section 11.2.13

E.12.1.3 Concrete Cask Non-Mechanistic Tip-Over Analysis

Tip-over of the concrete cask is a non-mechanistic, hypothetical accident condition that presents a bounding case for evaluation. Existing postulated design basis accidents do not result in the tip-over of the concrete cask. Functionally, the concrete cask does not suffer significant adverse consequences due to this event. The concrete cask, TSC, and basket maintain design basis shielding, geometry control of contents, and contents confinement performance requirements.

For a tip-over event to occur, the center of gravity of the concrete cask and loaded TSC must be displaced beyond its outer radius, i.e., the point of rotation. When the center of gravity passes beyond the point of rotation, the potential energy of the cask and TSC is converted to kinetic energy as the cask and TSC rotate toward a horizontal orientation on the ISFSI pad. The subsequent motion of the cask is governed by the structural characteristics of the cask, the ISFSI pad and the underlying soil.

The concrete cask tip-over analyses of the Yankee Rowe MPC and Connecticut Yankee MPC storage systems at the Consolidated Interim Storage Facility (CISF) are performed using LS-DYNA.

LS-DYNA is an explicit finite element program for the nonlinear dynamic analysis of structures in three dimensions. The objective of these evaluations is to confirm that the maximum amplified accelerations of the top of the basket and the canister for the five systems at the CISF are bounded by the accelerations used in the structural evaluation of the five systems for the original license basis of each system. The LS-DYNA reevaluation of the cask tip over is required, since the concrete pad and soil conditions at the CISF differed from the original license basis.

E.12.1.3.1 Concrete Cask Finite Element Model For Tip-Over Evaluation

The half-symmetry finite element model of the loaded VCC, concrete pad, mudmat, and soil sublayers are constructed of solid brick elements. The details of the finite element model set-up are shown in Figure E.12-2.

E.12.1.3.2 Material Models/Properties

The material properties used in the analysis are given below:

The modulus of elasticity of concrete is calculated using the following equation:

$$E_c = 33\,(w_c)^{1.5}\sqrt{f_c'}$$

Where,

E_c = Modulus of elasticity of concrete, psi

W_c = Unit weight of concrete, lb/ft3

f_c' = Compressive strength of concrete, psi

E.12.1.3.3 Concrete Pad

Mass density, ρ = 148 pcf = 2.217 E-4 lb-sec^2/in^4

Modulus of elasticity, E = 4.602E6 psi

Poisson's ratio, υ = 0.2

Shear modulus, G = 1.918E6 psi

Compressive strength, f_c' = 6000 psi

E.12.1.3.4 Mudmat

Mass density, ρ = 146 pcf = 2.187 E-4 lb-sec^2/in^4

Modulus of elasticity, E = 2.604E6 psi

Poisson's ratio, υ = 0.2

Shear modulus, G = 1.085E6 psi

Compressive strength, f_c' = 2000 psi

E.12.1.3.5 Soil

Table E.12-1
Soil Properties

E.12.1.3.6 VCC Concrete

The concrete properties used for VCC are given Section E.12.1.3.12.1 for the Yankee Rowe MPC and Connecticut Yankee MPC. The densities of VCC and other components used account for the total weight of non-structural components that are not modeled.

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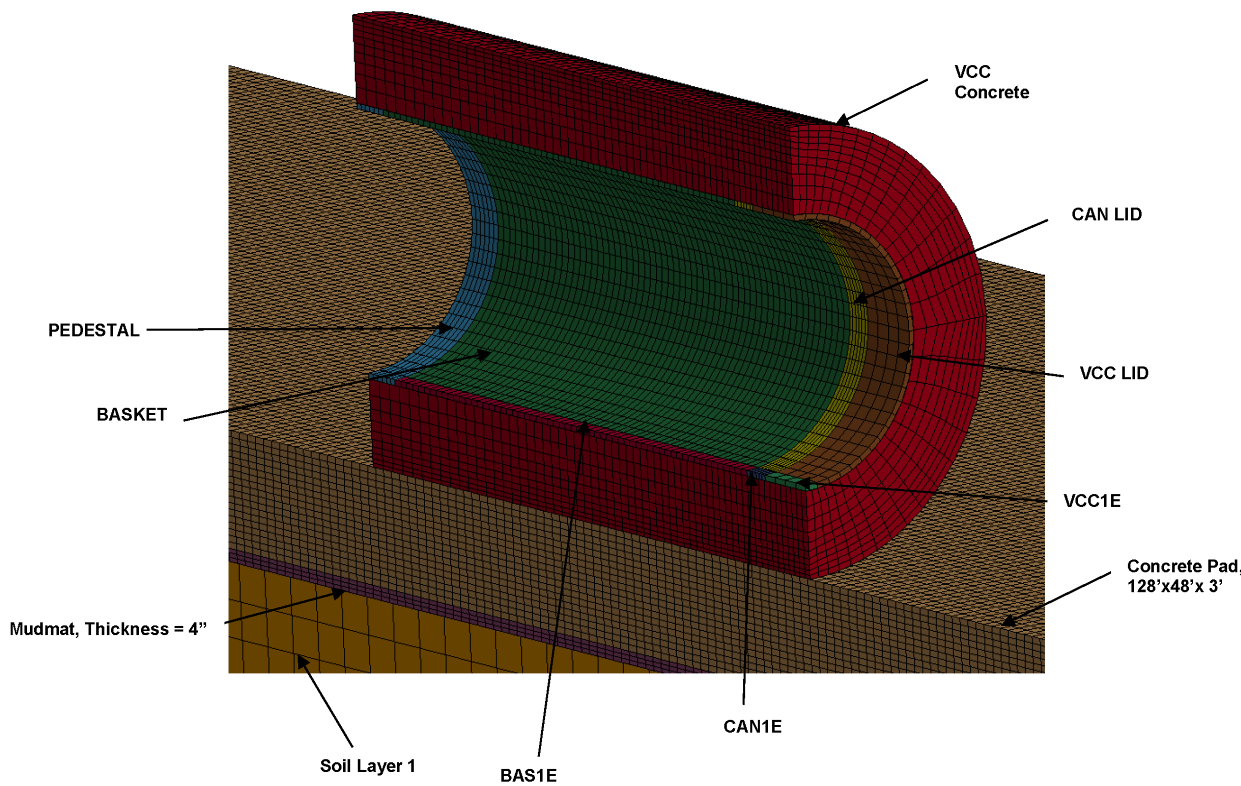

Figure E.12-2
CISF Configuration - Finite Element Model Set-Up (Continued)

E.12.1.3.7 Boundary Conditions

The VCC, liner, concrete pad, mudmat and soil sublayers are modeled using solid elements. The bottom surface of the soil is constrained in the vertical direction. To represent the unlimited expanse of adjacent soil, non-reflecting boundary conditions are applied to the three vertical planes of the soil. Symmetry boundary conditions are applied to the symmetry plane of VCC, concrete pad, mudmat and soil. The bottom of the soil column is vertically restrained. Contact modeling between VCC, liner, basket and canister is modeled using the Surface Contact options available in LS-DYNA.

E.12.1.3.8 Weight of Loaded VCC

The body load due to the gravity (1 g) of the loaded VCC is considered in the analysis and is conservatively applied as a step load. The weights of Yankee Rowe and Connecticut Yankee loaded VCC systems are given in Table E.12-2.

E.12.1.3.9 Tip-Over Velocity

The tip-over condition is simulated by applying angular velocity to the loaded VCC. The angular velocity is calculated by equating the potential energy of VCC due to change in the position of center of gravity (CG) with the kinetic energy due to rotation of the VCC (while standing on its corner with the CG directly over it) as shown below:

Potential Energy = Rotational Kinetic Energy

$$mgh = (I\omega^2)/2$$

Where,

m = Total mass of the loaded VCC, lb-sec^2/in

g = Acceleration due to gravity, 386.4 in/sec^2

w = mg, Total weight of the loaded VCC, lbs

h = Change in height of CG of VCC, in

I = Total mass moment of inertia of loaded VCC about the pivot point, lb-sec^2-in

ω = Angular velocity of loaded VCC, rad/sec

The diagram is shown below:

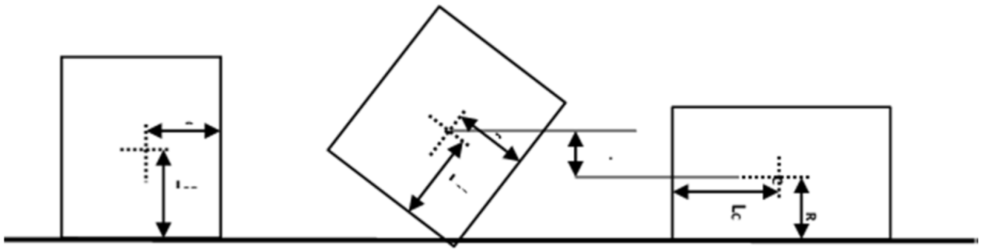

Figure E.12-3
Schematic Representation of the Change in Height of CG of VCC

The change in height of CG of VCC:

$$h = \sqrt{R^2 + L_{CG}{}^2} - R$$

Where,

R = Radius of VCC, in

LCG = Distance of CG from base of VCC, in

Therefore, the angular velocity is given by,

$$\omega = \sqrt{\frac{2mgh}{I}}$$

The angular velocities for various VCC systems are given in Table E.12-2.

Table E.12-2
Total Weights and Tip-Over Angular Velocities of Yankee Rowe MPC and Connecticut Yankee MPC Systems

Storage System	Loaded VCC		Tip-Over Angular Velocity (rad/sec)
	Weight (kips)	Mass (lb-sec2/in)	
MPC Yankee-Rowe	206.1	533.5	1.516
MPC Connecticut-Yankee	251.8	651.7	1.559

E.12.1.3.10 Determination of Amplified Accelerations

The acceleration time histories are taken from the nodes at the top of the basket and the canister which would identify the maximum acceleration of the basket and the canister. The acceleration time histories from the LS-DYNA nodal acceleration file were filtered with a Butterworth filter frequency of 165 Hz. Details of the filter frequency calculation are contained in Reference E.12-2. The general pattern of the acceleration time history of both components is shown in the acceleration time history curve in Figure E.12-4. The initial spike has a duration (t1) of approximately 4 ms while the longer pulse duration (t2) is approximately 40 ms. The initial spike of duration t1 is associated with the initial crushing of the concrete and the equivalent static acceleration used for the basket and canister evaluation is determined using the Dynamic Load Factors (DLF) for a triangular shaped pulse. The DLF for the longer pulse (t2) is determined using the DLF for a sine shaped pulse. The DLF for the basket is dependent on each basket design and basket angular orientation. The DLF for the canister lid region of the TSC is considered to be 1 due to the rigidity of the lid.

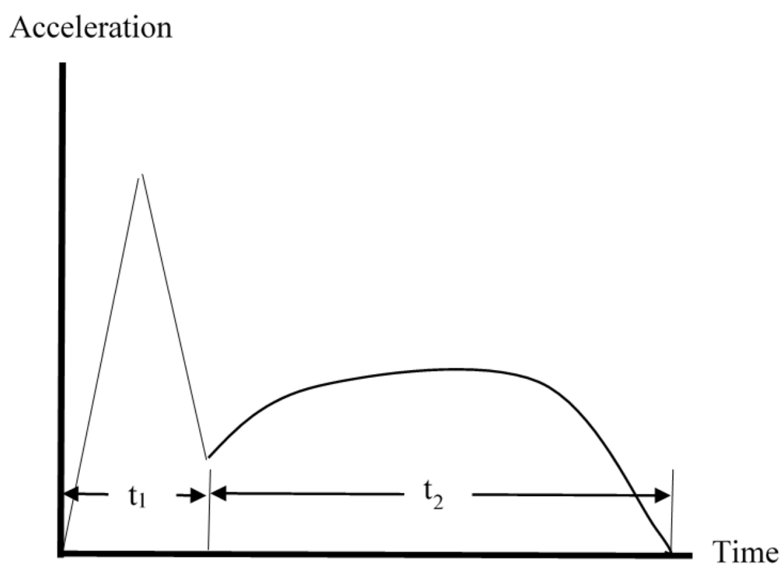

Figure E.12-4
Acceleration Time History

E.12.1.3.11 Cask Specific Evaluations

Models are used to evaluate the loaded concrete cask during tip-over conditions for the Yankee Rowe MPC and Connecticut Yankee MPC systems. The concrete pad represents the concrete pad properties at the CSIF site. The dimensions of the concrete pad are 128 feet (length) x 48 feet (width) with a thickness of 3 feet. The mudmat under the pad had a thickness of 4 inches. The subsoil used the length and width of the pad plus 4 feet on each side. The site soil properties were modeled to a depth of 98.7 feet. The mesh density and element aspect ratio of all the models are consistent.

E.12.1.3.12 Yankee Rowe MPC

The total weight of the loaded MPC Yankee-Rowe VCC used in the analysis is equal to 206.1 kips. Half-symmetry model as discussed in Section E.12.1.3.1 is used in the analysis.

E.12.1.3.12.1 Material Properties of VCC

Material properties of VCC concrete used in the analysis are given below:

Mass density, ρ = 146 pcf = 2.186E-4 lb-sec^2/in^4

Modulus of elasticity, E = 3.682E6 psi

Poisson's ratio, υ = 0.22

Shear modulus, G = 1.509E6 psi

Compressive strength, $f_c' = 4{,}000$ psi

E.12.1.3.12.2 Geometric Properties of VCC

Radius of VCC, R = 64 in

Distance of CG of VCC from base, LCG = 83.2 in

Change in height of CG, h = 40.9 in

The tip-over angular velocity of the VCC is calculated as per the methodology described in Section E.12.1.3.9 and is applied to the MPC Yankee Rowe model in conjunction with the gravity. The deformed shape of the model is shown in Figure E.12-5. Further details regarding numerical and graphical results are contained in Reference E.12-2.

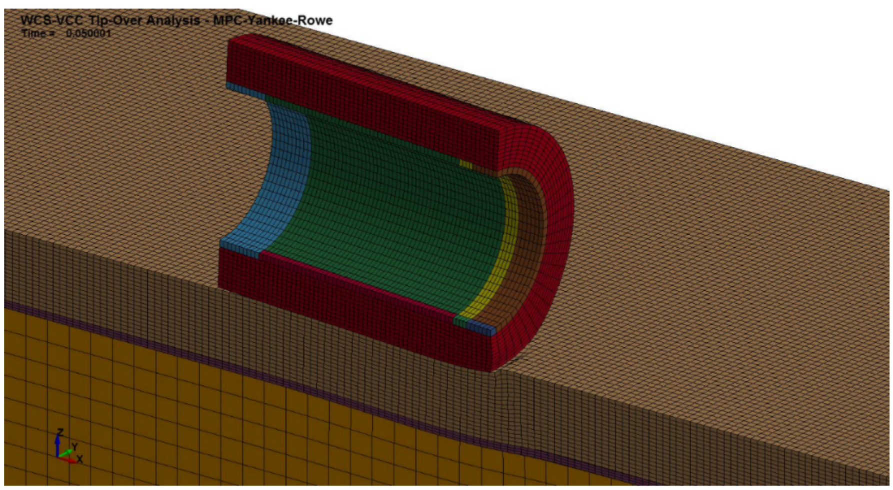

Figure E.12-5
Deformed Shape of Yankee Rowe MPC VCC, Concrete Pad, Mudmat and Soil

The canister lid and attached canister shell peak acceleration is determined to be 23.5g, which would also correspond to the static acceleration to be applied to the model for the canister stress evaluation.

The DLF for the basket evaluation is dependent on the fundamental mode of the basket and the duration of the pulse. For the amplification of the accelerations during the short pulse, the maximum possible DLF for the triangular pulse is 1.52, regardless of the basket fundamental modal frequency and pulse duration. For the accelerations during the long pulse, the maximum DLF for the sine pulse is 1.76, also regardless of the basket fundamental frequency and pulse duration. The Table E.12-3 shows the basket acceleration obtained from the analysis, the maximum DLF for each type of pulse, and the amplified accelerations. The acceleration used in the basket and canister evaluations for the MPC Yankee Rowe system in Reference E.12-1 was 45g's. The peak basket amplified accelerations shown below is 31.8, which bounds the peak canister acceleration. Both accelerations are significantly bounded by the design basis acceleration. Therefore, the basket and canister evaluations contained in Reference E.12-1 are bounding for the conditions at the CISF.

Table E.12-3
Peak Accelerations and DLF for Yankee Rowe MPC VCC Systems

Pulse	Peak Basket Analysis Acceleration (A_p) (g)	DLF	Amplified Acceleration (g) (A_p)×DLF
Short Pulse	20.9	1.52	31.8
Long Pulse	13.4	1.76	23.6

E.12.1.3.13 Connecticut Yankee MPC

The total weight of the loaded MPC Connecticut-Yankee VCC used in the analysis is equal to 251.8 kips. Half-symmetry model as discussed in Section E.12.1.3.1 is used in the analysis.

E.12.1.3.13.1 Material Properties of VCC

Material properties of VCC concrete used in the analysis are given below:

Mass density, ρ = 146.8 pcf = 2.199E-4 lb-sec^2/in^4

Modulus of elasticity, E = 3.715E6 psi

Poisson's ratio, υ = 0.22

Shear modulus, G = 1.523E6 psi

Compressive strength, f_c' = 4,000 psi

E.12.1.3.13.2 Geometric Properties of VCC

Radius of VCC, R = 64 in

Distance of CG of VCC from base, LCG = 98.6 in

Change in height of CG, h = 53.5 in

The tip-over angular velocity of the VCC is calculated as per the methodology described in Section E.12.1.3.9 and is applied to the MPC Connecticut Yankee model in conjunction with the gravity. The deformed shape of the model is shown in Figure E.12-6. Further details regarding numerical and graphical results are contained in Reference E.12-2.

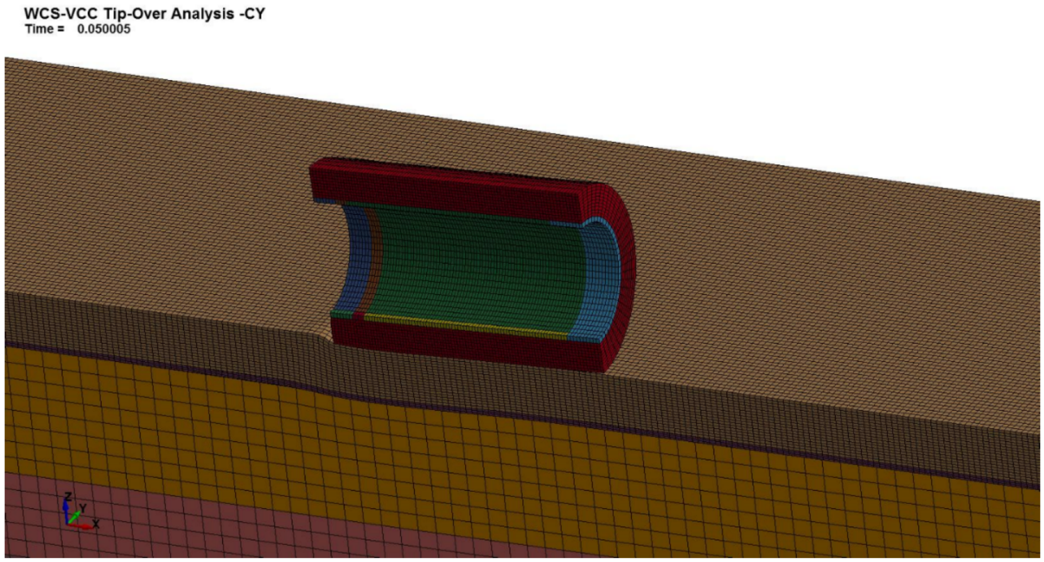

Figure E.12-6
Deformed Shape of Connecticut Yankee MPC VCC, Concrete Pad, Mudmat and Soil

The canister lid and attached canister shell peak acceleration is determined to be 26.1g, which would also correspond to the static acceleration to be applied to the model for the canister stress evaluation.

For the amplification of the accelerations during the short pulse, the maximum possible DLF for the triangular pulse is 1.52 regardless of the basket fundamental modal frequency and pulse duration. Likewise, for the accelerations during the long pulse, the maximum DLF for the sine pulse is 1.76. Table E.12-4 shows the basket acceleration obtained from the analysis, the maximum DLF, and the amplified accelerations. The acceleration used in the basket and canister evaluations for the MPC Connecticut Yankee system in Reference 3 was 40g's. The peak basket amplified accelerations shown below is 35.9, which bounds the peak canister acceleration. Both accelerations are bounded by the design basis acceleration. Therefore, the basket and canister evaluations contained in Reference E.12-1 are bounding for the conditions at the CISF.

Table E.12-4
Peak Accelerations and DLF for Connecticut Yankee MPC VCC Systems

Pulse	Peak Basket Analysis Acceleration (A_p) (g)	DLF	Amplified Acceleration (g) (A_p)×DLF
Short Pulse	23.6	1.52	35.9
Long Pulse	18.2	1.76	32.0

E.12.2 La Crosse MPC

The following describes the off-normal and accidents evaluated for the MPC-LACBWR. Evaluations related to sit specific fuel components are located in Section 11.A.4 of Reference E.12-1.

E.12.2.1 Off-Normal Events

Section 11.A.1 of Reference E.12-1 evaluates postulated events that might occur once during any calendar year of operations. The actual occurrence of any of these events is unlikely.

The following off-normal events are evaluated in Reference E.12-1. Beside each off-normal event listed is the location in Reference E.12-1 where the details of the analysis are presented.

1. Blockage of half of the air inlets – Section 11.A.1.1
2. Canister off-normal handling load – Section 11.A.1.2
3. Failure of instrumentation – Section 11.A.1.3
4. Several environmental conditions (100°F and -40°F) – Section 11.A.1.4
5. Small release of radioactive particulate from the canister exterior – Section 11.A.1.5

E.12.2.2 Accidents

Section 11.A.2 of Reference E.12-1 provides the results of analyses of the design basis and hypothetical accident conditions evaluated for the MPC-LACBWR system. Canister closure weld evaluations for accident conditions are presented in Section 11.A.5 of Reference E.12-1.

The following accidents are evaluated in Reference E.12-1. Beside each accident condition listed is the location in Reference E.12-1 where the details of the analysis are presented.

1. Accident pressurization – Section 11.A.2.1
2. Earthquake event – Section 11.A.2.2
3. Explosion – Section 11.A.2.3
4. Failure of all fuel rods with a subsequent ground level breach of the canister – Section 11.A.2.4
5. Fire accident – Section 11.A.2.5
6. Flood – Section 11.A.2.6
7. Fresh fuel loading in the canister – Section 11.A.2.7
8. Full blockage of air inlets and outlets – Section 11.A.2.8
9. Lightning – Section 11.A.2.9
10. Maximum anticipated heat load (125°F ambient temperature) – Section 11.A.2.10
11. Storage cask 6-inch drop – Section 11.A.2.11
12. Tip over of the concrete cask – Section 11.A.2.12
13. Tornado and tornado driven missiles – Section 11.A.2.13
14. Transfer cask seismic accident condition – Section 11.A.2.14

E.12.2.3 Concrete Cask Non-Mechanistic Tip-Over Analysis

Tip-over of the concrete cask is a non-mechanistic, hypothetical accident condition that presents a bounding case for evaluation. Existing postulated design basis accidents do not result in the tip-over of the concrete cask. Functionally, the concrete cask does not suffer significant adverse consequences due to this event. The concrete cask, TSC, and basket maintain design basis shielding, geometry control of contents, and contents confinement performance requirements.

For a tip-over event to occur, the center of gravity of the concrete cask and loaded TSC must be displaced beyond its outer radius, i.e., the point of rotation. When the center of gravity passes beyond the point of rotation, the potential energy of the cask and TSC is converted to kinetic energy as the cask and TSC rotate toward a horizontal orientation on the ISFSI pad. The subsequent motion of the cask is governed by the structural characteristics of the cask, the ISFSI pad and the underlying soil.

The concrete cask tip-over analyses of the MPC-LACBWR storage system at the Consolidated Interim Storage Facility (CISF) are performed using LS-DYNA.

LS-DYNA is an explicit finite element program for the nonlinear dynamic analysis of structures in three dimensions. The objective of these evaluations is to confirm that the maximum amplified accelerations of the top of the basket and the canister for the five systems at the CISF are bounded by the accelerations used in the structural evaluation of the five systems for the original license basis of each system. The LS-DYNA reevaluation of the cask tip over is required, since the concrete pad and soil conditions at the CISF differed from the original license basis.

E.12.2.3.1 Concrete Cask Finite Element Model For Tip-Over Evaluation

The half-symmetry finite element model of the loaded VCC, concrete pad, mudmat, and soil sublayers are constructed of solid brick elements. The details of the finite element model set-up are shown in Figure E.12-7 and Figure E.12-8.

E.12.2.3.2 Material Models/Properties

The material properties used in the analysis are given below:

The modulus of elasticity of concrete is calculated using the following equation:

$$E_c = 33\ (w_c)^{1.5}\sqrt{f_c'}$$

Where,

E_c = Modulus of elasticity of concrete, psi

W_c = Unit weight of concrete, lb/ft3

f_c' = Compressive strength of concrete, psi

E.12.2.3.3 Concrete Pad

Mass density, ρ = 148 pcf = 2.217 E-4 lb-sec^2/in^4

Modulus of elasticity, E = 4.602E6 psi

Poisson's ratio, υ = 0.2

Shear modulus, G = 1.918E6 psi

Compressive strength, f_c' = 6000 psi

E.12.2.3.4 Mudmat

Mass density, ρ = 146 pcf = 2.187 E-4 lb-sec^2/in^4

Modulus of elasticity, E = 2.604E6 psi

Poisson's ratio, υ = 0.2

Shear modulus, G = 1.085E6 psi

Compressive strength, f_c' = 2000 psi

E.12.2.3.5 Soil

Table E.12-5
Soil Properties

E.12.2.3.6 VCC Concrete

The concrete properties used for VCC are given Section E.12.2.3.12.1 for the MPC-LACBWR storage system. The densities of VCC and other components used account for the total weight of non-structural components that are not modeled.

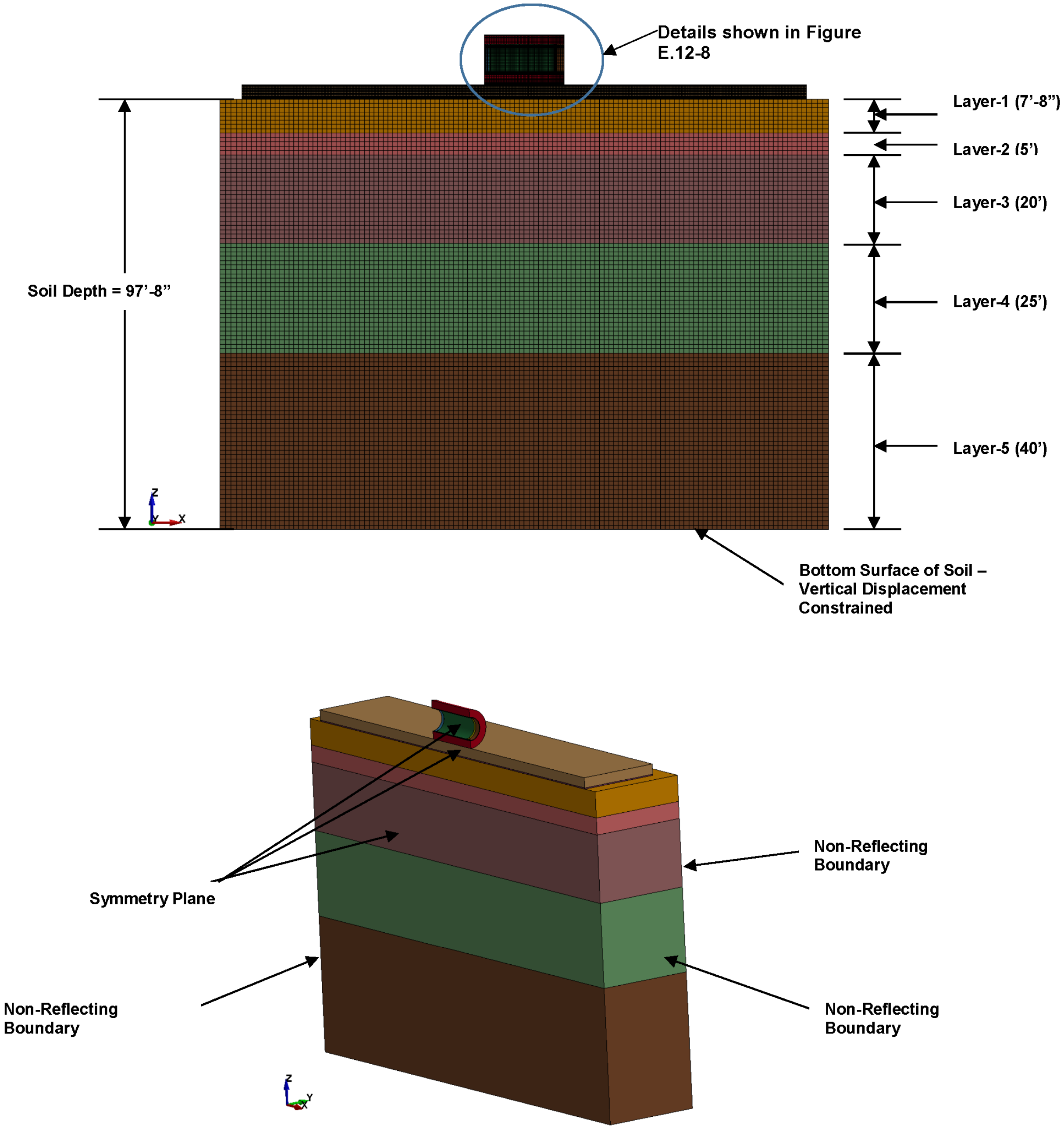

Figure E.12-7
CISF Configuration - Finite Element Model Set-Up

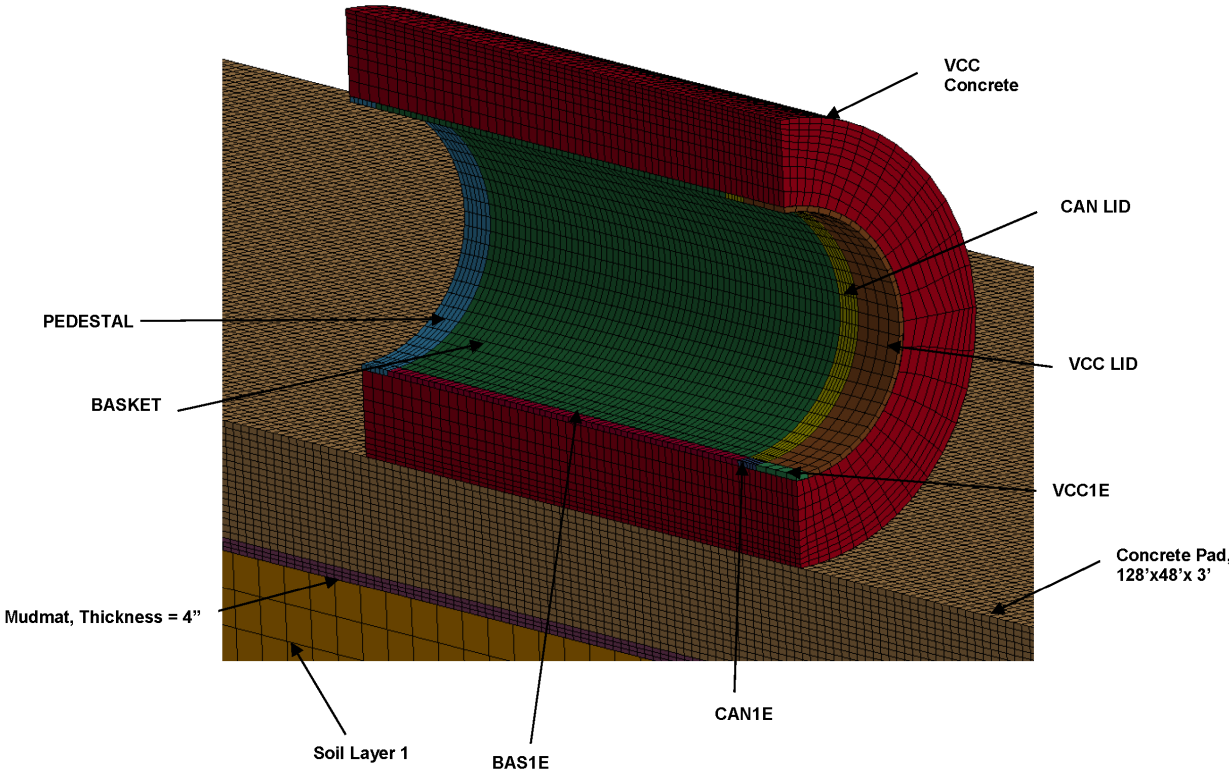

Figure E.12-8
CISF Configuration - Finite Element Model Set-Up (Continued)

E.12.2.3.7 Boundary Conditions

The VCC, liner, concrete pad, mudmat and soil sublayers are modeled using solid elements. The bottom surface of the soil is constrained in the vertical direction. To represent the unlimited expanse of adjacent soil, non-reflecting boundary conditions are applied to the three vertical planes of the soil. Symmetry boundary conditions are applied to the symmetry plane of VCC, concrete pad, mudmat and soil. The bottom of the soil column is vertically restrained. Contact modeling between VCC, liner, basket and canister is modeled using the Surface Contact options available in LS-DYNA.

E.12.2.3.8 Weight of Loaded VCC

The body load due to the gravity (1 g) of the loaded VCC is considered in the analysis and is conservatively applied as a step load. The weights of various loaded VCC systems are given in Table E.12-6.

E.12.2.3.9 Tip-Over Velocity

The tip-over condition is simulated by applying angular velocity to the loaded VCC. The angular velocity is calculated by equating the potential energy of VCC due to change in the position of center of gravity (CG) with the kinetic energy due to rotation of the VCC (while standing on its corner with the CG directly over it) as shown below:

Potential Energy = Rotational Kinetic Energy

$$mgh = (I\omega^2)/2$$

Where,

m = Total mass of the loaded VCC, lb-sec^2/in

g = Acceleration due to gravity, 386.4 in/sec^2

w = mg, Total weight of the loaded VCC, lbs

h = Change in height of CG of VCC, in

I = Total mass moment of inertia of loaded VCC about the pivot point, lb-sec^2-in

ω = Angular velocity of loaded VCC, rad/sec

The diagram is shown below:

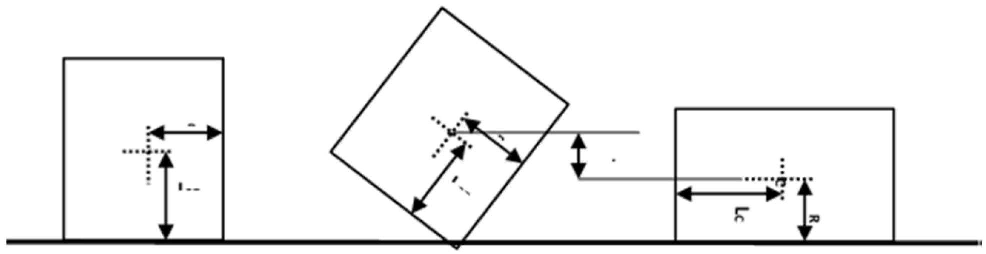

Figure E.12-9
Schematic Representation of the Change in Height of CG of VCC

The change in height of CG of VCC:

$$h = \sqrt{R^2 + {L_{CG}}^2} - R$$

Where,

R = Radius of VCC, in

LCG = Distance of CG from base of VCC, in

Therefore, the angular velocity is given by,

$$\omega = \sqrt{\frac{2mgh}{I}}$$

The angular velocities for various VCC systems are given in Table E.12-6.

Table E.12-6
Total Weights and Tip-Over Angular Velocities of MPC-LACBWR VCC System

Storage System	Loaded VCC		Tip-Over Angular Velocity (rad/sec)
	Weight (kips)	Mass ($lb\text{-}sec^2/in$)	
MPC LACBWR	197.7	511.7	1.520

E.12.2.3.10 Determination of Amplified Accelerations

The acceleration time histories are taken from the nodes at the top of the basket and the canister which would identify the maximum acceleration of the basket and the canister. The acceleration time histories from the LS-DYNA nodal acceleration file were filtered with a Butterworth filter frequency of 165 Hz. Details of the filter frequency calculation are contained in Reference E.12-2. The general pattern of the acceleration time history of both components is shown in the acceleration time history curve in Figure E.12-10 below. The initial spike has a duration (t1) of approximately 4 ms while the longer pulse duration (t2) is approximately 40 ms. The initial spike of duration t1 is associated with the initial crushing of the concrete and the equivalent static acceleration used for the basket and canister evaluation is determined using the Dynamic Load Factors (DLF) for a triangular shaped pulse. The DLF for the longer pulse (t2) is determined using the DLF for a sine shaped pulse. The DLF for the basket is dependent on each basket design and basket angular orientation. The DLF for the canister lid region of the TSC is considered to be 1 due to the rigidity of the lid.

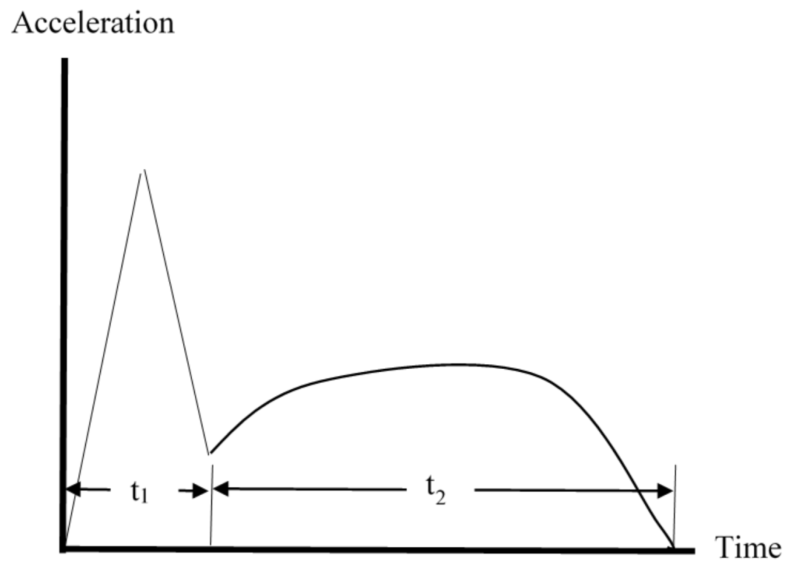

Figure E.12-10
Acceleration Time History

E.12.2.3.11 Cask Specific Evaluations

A model is used to evaluate the loaded concrete cask during tip-over conditions for the MPC-LACBWR system. The concrete pad represents the concrete pad properties at the CSIF site. The dimensions of the concrete pad are 128 feet (length) x 48 feet (width) with a thickness of 3 feet. The mudmat under the pad had a thickness of 4 inches. The subsoil used the length and width of the pad plus 4 feet on each side. The site soil properties were modeled to a depth of 98.7 feet. The mesh density and element aspect ratio of all the models are consistent.

E.12.2.3.12 MPC-LACBWR

The total weight of the loaded MPC LACBWR VCC used in the analysis is equal to 201.6 kips. Half-symmetry model as discussed in Section E.12.2.3.1 is used in the analysis.

E.12.2.3.12.1 Material Properties of VCC

Material properties of VCC concrete used in the analysis are given below:

Mass density, ρ = 146 pcf = 2.186E-4 lb-sec^2/in^4

Modulus of elasticity, E = 3.682E6 psi

Poisson's ratio, υ = 0.22

Shear modulus, G = 1.509E6 psi

Compressive strength, $f_c' = 4000$ psi

E.12.2.3.12.2 Geometric Properties of VCC

Radius of VCC, R = 64 in

Distance of CG of VCC from base, LCG = 83 in

Change in height of CG, h = 40.8 in

The tip-over angular velocity of the VCC is calculated as per the methodology described in Section E.12.2.3.9 and is applied to the MPC LACBWR model in conjunction with the gravity. The deformed shape of the model is shown in Figure E.12-11. Further details regarding numerical and graphical results are contained in Reference E.12-2.

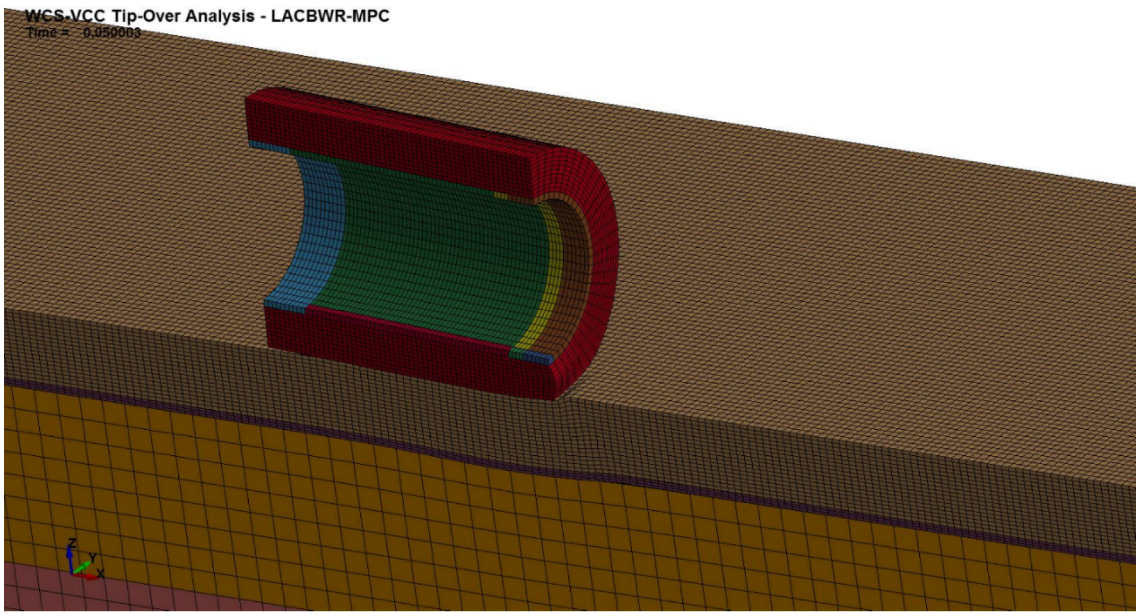

Figure E.12-11
Deformed Shape of MPC-LACBWR VCC, Concrete Pad, Mudmat and Soil

The canister lid and attached canister shell peak acceleration is determined to be 23.5g, which would also correspond to the static acceleration to be applied to the model for the canister stress evaluation.

As indicated in Figure E.12-10, the acceleration time history shows two types of pulses. The DLF for the short pulse is based on a triangular shaped pulse. The DLF associated with the short pulse for the basket evaluation is dependent on the fundamental modal frequency of the MPC LACBWR basket and the time duration of the short pulse. Details of the modal analysis for the MPC LACBWR basket are contained in Reference E.12-3. The bounding DLF associated with the short pulse, which is dependent on basket orientation, is 0.75 resulting in an amplified acceleration for the short pulse of 16.1g's. For the accelerations during the long pulse, the bounding DLF, for the sine pulse is 1.76, regardless of the fundamental modal frequency of the basket. The Table E.12-7 shows the basket acceleration obtained from the transient analysis, the maximum DLF, and the amplified accelerations. The acceleration used in the basket and canister evaluations for the MPC LACBWR system in Reference E.12-1 was 25g's. The peak amplified basket acceleration, which is shown below, is 21.8 and the peak canister acceleration of 23.5, and both of these accelerations are bounded by 25g. Therefore, the basket and canister evaluations contained in Reference E.12-1 are bounding for the conditions at the CISF.

Table E.12-7
Peak Accelerations and DLF for MPC-LACBWR VCC Systems

Pulse	Peak Basket Analysis Acceleration (A_p) (g)	DLF	Amplified Acceleration (g) (A_p)×DLF
Short Pulse	21.4	0.75	16.1
Long Pulse	12.4	1.76	21.8

E.12.3 References

E.12-1 NAC-MPC Final Safety Analysis Report, Revision 10, January 2014

E.12-2 NAC Calculation 30039-2010 Rev 0, "Concrete Cask Tip-Over Evaluation – WCS", NAC International, Norcross, GA

E.12-3 NAC Calculation 30039-2015 Rev 0, "Tip-Over DLF Calculation for WCS", NAC International, Norcross, GA

APPENDIX F.1
INTRODUCTION AND GENERAL DESCRIPTION OF INSTALLATION
NAC-UMS

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F.1. INTRODUCTION AND GENERAL DESCRIPTION OF INSTALLATION

No change or additional information required for the NAC-UMS Universal Storage System for Maine Yankee for Chapter 1.

APPENDIX F.2
SITE CHARACTERISTICS
NAC-UMS

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F.2. SITE CHARACTERISTICS

No change or additional information required for the NAC-UMS Universal Storage System for Maine Yankee for Chapter 2.

APPENDIX F.3
PRINCIPAL DESIGN CRITERIA
NAC-UMS

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F.3 PRINCIPAL DESIGN CRITERIA

The NAC-UMS Universal Storage System principal design criteria for Maine Yankee is documented in Chapter 2 of the NAC-UMS Final Safety Analysis Report (FSAR) Reference [F.3-1]. *Table F.3-1 provides a comparison of the NAC UMS 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 NAC-UMS Cask System is bounded by the WCS CISF criteria.*

F.3.1 Maine Yankee

The Maine Yankee Universal Storage System (NAC-UMS) is designed to store up to 24 PWR spent fuel assemblies. On the basis of fuel assembly length and cross-section, fuel assemblies are grouped into three classes of PWR fuel assemblies. Table 2.1.1-1 of Reference F.3-1 lists the nominal design parameters and the maximum and minimum enrichments of each fuel design type. The PWR fuel evaluations include fuel having thimble plugs and burnable poison rods in guide tube positions and solid stainless steel rods may be inserted into guide tube positions as long as the fuel assembly weight limits in Table 2.1.1-1 are not exceeded. The Maine Yankee fuel is described in Section 2.1.3.1 of Reference F.3-1.

F.3.1.1 Design Criteria for Environmental Conditions and Natural Phenomena

The design criteria for environmental conditions and natural phenomena for the NAC-UMS are described in Section 2.2 of Reference F.3-1. The design criteria defined in this section identifies the site environmental conditions and natural phenomena to which the storage system could reasonably be exposed during the period of storage. Analyses to demonstrate that the UMS design meets these design criteria are presented in the relevant chapters of Reference F.3-1. The applicable portions of Section 2.2 have been reviewed against the environmental conditions at the WCS facility and have been shown to be either bounded by the analysis presented in Reference F.3-1or require no further analysis than what is presented in Reference F.3-1 because they already meet the regulatory requirements of 10 CFR 72.

F.3.1.1.1 Tornado and Wind Loadings

The Vertical Concrete Casks (NAC-UMS) are typically placed outdoors on an unsheltered reinforced concrete storage pad at an ISFSI site. This storage condition exposes the casks to tornado and wind loading. The design basis tornado and wind loadings are defined based on Regulatory Guide 1.76, Region I, and NUREG-0800. The design basis tornado missile impacts are defined in Paragraph 4, Subsection III, Section 3.5.1.4 of NUREG-0800. Analyses presented in Reference F.3-1, Section 11.2.11, demonstrate that the NAC-UMS design meets these design criteria. Therefore, no further WCS site-specific evaluations are required.

F.3.1.1.2 Water Level (Flood) Design

The NAC-UMS may be exposed to a flood during storage on an unsheltered concrete storage pad at an ISFSI site. The source and magnitude of the probable maximum flood depend on several variables. The NAC-UMS is evaluated for a maximum flood water depth of 50 feet above the base of the storage cask. The flood water velocity is considered to be 15 feet per second.

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.

F.3.1.1.3 Seismic Design

The NAC-UMS may be subject to a seismic event (earthquake) during storage on an unsheltered concrete pad at an ISFSI. The seismic response spectra experienced by the cask will depend upon the geographical location of the specific site and distance from the epicenter of the earthquake. The only significant effect of a seismic event on a NAC-UMS would be a possible tip-over of the cask or a collision of two casks due to sliding; however, neither tip-over nor sliding occurs in the evaluated design basis earthquake.

The evaluation of the seismic response of the NAC-UMS to the design basis earthquake is presented in Section 11.2.8 of Reference F.3-1. The seismic ground acceleration that will cause the NAC-UMS to tip over is calculated in Section 11.2.8 using quasi-static analysis methods. Evaluation of the consequences of a tip over event is provided in Section 11.2.12 of Reference F.3-1. Based on these evaluations, the maximum ground acceleration that does not result in cask tip over is 0.42g at the top surface of the ISFSI pad and the maximum ground acceleration that does not result in cask sliding is 0.29g at the top surface of the ISFSI pad. The WCS pad design meets the NAC-UMS pad requirements and is consistent with analyses performed within Reference F.3-1. The existing analysis bounds the WCS site pad design limits for accelerations at the top pad surface. Therefore, no further evaluations are required.

F.3.1.1.4 Snow and Ice Loadings

The criteria for determining design snow loads is based on ANSI/ASCE 7-93, Section 7.0. The NAC-UMS is assumed to have a site location typical for siting Category C, which is defined to be “locations in which snow removal by wind cannot be relied on to reduce roof loads because of terrain, higher structures, or several trees nearby.” Ground snow loads for the contiguous United States are given in Figures, 5, 6 and 7 of ANSI/ASCE 7-93. A worst case value of 100 pounds per square foot was assumed. Section 2.2.4 of Reference F.3-1 demonstrates that the snow load is bounded by the weight of the loaded transfer cask.

The snow load is also considered in the load combinations described in Section 3.4.4.2.2 of Reference F.3-1. Therefore, no further WCS site-specific evaluations are required.

F.3.1.1.5 Combined Load Criteria

Each normal, off-normal and accident condition has a combination of load cases that defines the total combined loading for that condition. The individual load cases considered include thermal, seismic, external and internal pressure, missile impacts, drops, snow and ice loads, and/or flood water forces. The load conditions to be evaluated for storage casks are identified in 10 CFR 72 and in the "Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type)" (ANSI/ANS 57.9 –1992).

The load combinations specified in ANSI/ANS 57.9 –1992 for concrete structures are applied to the concrete casks as shown in Table 2.2-1 of Reference F.3-1. The concrete cask is designed to the requirements of ACI 349. In calculating the design strength of the concrete in the NAC-UMS concrete body, nominal strength values are multiplied by a strength reduction factor in accordance with Section 9.3 of ACI 349.

The canister is designed in accordance with the 1995 edition with 1995 addenda of the ASME Code, Section III, Subsection NB for Class 1 components. The basket structure is designed per ASME Code, Section III, Subsection NG, and the structural buckling of the basket is evaluated per NUREG/CR-6322.

The load combinations for all normal, off-normal, and accident conditions and corresponding service levels are shown in Table 2.2-2 of Reference F.3-1. Stress intensities resulting from pressure, temperature, and mechanical loads are combined before comparing them to the ASME Code allowables listed in Table 2.2-3 of Reference F.3.-1.

The transfer cask is a special lifting device. The lifting trunnions and supports are designed and fabricated to the requirements of ANSI N14.6 and NUREG-0612. The remainder of the structure is designed and fabricated to ANSI/ANS-57.9. The combined shear stress or maximum tensile stress during the lift (with 10 percent load factor) shall be $\leq S_y/6$ and $S_u/10$ for a nonredundant load path, or shall be $\leq S_y/3$ and $S_u/5$ for redundant load paths. The ferritic steel material used for the load bearing members of the transfer cask shall satisfy the material toughness requirements of ANSI N14.6, paragraph 4.2.6. The structural evaluations presented in Reference F.3-1 demonstrate that the transfer cask meets all of the design criteria. Therefore, no further WCS site-specific evaluations are required.

F.3.1.1.6 Environmental Temperatures

A temperature of 76°F was selected to bound all annual average temperatures in the United States, except the Florida Keys and Hawaii. The 76°F normal temperature was used as the basis for thermal evaluations. The evaluation of this environmental condition is discussed along with the thermal analysis models in Chapter 4.0 of Reference F.3-1. The thermal stress evaluation for the normal operating conditions is presented in Section 3.4.4 of Reference F.3-1. Normal temperature fluctuations are bounded by the severe ambient temperature cases that are evaluated as off-normal and accident conditions.

Off-normal, severe environmental conditions are defined as -40°F with no solar loads and 106°F with solar loads. An extreme environmental condition of 133°F with maximum solar loads is evaluated as an accident case (Section 11.2.7 of Reference F.3-1) to show compliance with the maximum heat load case required by ANSI-57.9. Thermal performance is also evaluated for the cases of: (1) half the air inlets blocked; and (2) all air inlets and outlets blocked. Thermal analyses for these cases are presented in Sections 11.1.2 and 11.2.13 of Reference F.3-1. The evaluation based on ambient temperature conditions is presented in Section 4.4 of Reference F.3-1. Solar insolance is as specified in 10 CFR 71.71 and Regulatory Guide 7.8.

Therefore, the maximum average yearly temperature allowed for the NAC-UMS system is 76°F and the maximum 3-day average ambient temperature shall be ≤ 106°F. The allowed temperature extremes, average of a 3-day period, shall be greater than -40°F and less than 133°F. The WCS site extreme temperature range is from 30.1°F to 113°F and the average yearly temperature for the site is conservatively bounded by using the maximum average annual temperature in the 48 contiguous United States of 76°F. This temperature meets the normal condition thermal boundary defined in NUREG-1536. Therefore, no further WCS site-specific evaluations are required.

F.3.1.2 Safety Protection Systems

The NAC-UMS relies upon passive systems to ensure the protection of public health and safety, except in the case of fire or explosion. As discussed in Section 2.3.6 of Reference F.3-1, fire and explosion events are effectively precluded by site administrative controls that prevent the introduction of flammable and explosive materials into areas where an explosion or fire could damage installed NAC-UMS systems. The use of passive systems provides protection from mechanical or equipment failure.

F.3.1.2.1 General

The NAC-UMS is designed for safe, long-term storage of spent nuclear fuel. The NAC-UMS will survive all of the evaluated normal, off-normal, and postulated accident conditions without release of radioactive material or excessive radiation exposure to workers or the general public. The major design considerations that are incorporated in the NAC-UMS to assure safe long-term fuel storage are:

1. Continued confinement in postulated accidents.
2. Thick concrete and steel biological shield.
3. Passive systems that ensure reliability.
4. Inert atmosphere to provide corrosion protection for stored fuel cladding and enhanced heat transfer for the stored fuel.

Each NAC-UMS component is classified with respect to its function and corresponding effect on public safety. In accordance with Regulatory Guide 7.10, each system component is assigned a safety classification into Category A, B or C, as shown in Table 2.3-1 of Reference F.3-1. The safety classification is based on review of each component's function and the assessment of the consequences of component failure following the guidelines of NUREG/CR-6407, "Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety." The safety classification categories are defined as follows:

Category A - Components critical to safe operations whose failure or malfunction could directly result in conditions adverse to safe operations, integrity of spent fuel or public health and safety.

Category B - Components with major impact on safe operations whose failure or malfunction could indirectly result in conditions adverse to safe operations, integrity of spent fuel or public health and safety.

Category C - Components whose failure would not significantly reduce the packaging effectiveness and would not likely result in conditions adverse to safe operations, integrity of spent fuel, or public health and safety.

As discussed in Section 2.3 of Reference F.3-1, the NAC-UMS design incorporates features addressing the above design considerations to assure safe operation during fuel loading, handling, and storage. The section addresses the following:

1. Protection by multiple confinement barriers and systems.
2. Protection by equipment and instrumentation selection
3. Nuclear criticality safety
4. Radiological protection
5. Fire and explosion protection
6. Ancillary Structure (Canister Handling Facility)

The confinement performance requirements for the NAC-UMS System are described in Chapter 7, Section 7.1.1.2 of Reference F.3-1 for storage conditions. In addition, "NAC-UMS Universal Transport Cask Safety Analysis Report" [F.3-2] demonstrates that the confinement boundary is not adversely affected by normal conditions of transport. Specifically, Chapter 2, Section 2.6.12 for the PWR canister. Therefore, transport to the WCS CISF will not adversely impacted confinement integrity of the NAC-UMS canister.

F.3.1.3 Decommissioning Considerations

The principle elements of the NAC-UMS storage system are the vertical concrete cask and the transportable storage canister. Section 2.4 of Reference F.3-1 discusses decommissioning considerations of these principle elements.

F.3.2 References

F.3-1 NAC-UMS Universal Storage System Final Safety Analysis Report, Revision 10, October 2012.

F.3-2 NAC-UMS Universal Transport Cask Safety Analysis Report, Revision 2, 2005.

Table F.3-1
Summary of WCS CISF Principal Design Criteria
(4 pages)

Design Parameter	***WCS CISF Design Criteria***	***Condition***	***NAC-UMS® Design Criteria***
Type of fuel	*Commercial, light water reactor spent fuel*	*Normal (Bounded)*	*WCS CISF SAR Appendix F, Section F.3.2* *NAC-UMS FSAR Chapter 2, Section 2.1*
Storage Systems	*Transportable canisters and storage overpacks docketed by the NRC*	*Normal (Bounded)*	*72-1015* *71-9270*
Fuel Characteristics	*Criteria as specified in previously approved licenses for included systems*	*Normal (Bounded)*	*WCS CISF SAR Appendix F, Section F.3.2* *NAC-UMS FSAR Chapter 2, Section 2.1*
Tornado (Wind Load)	*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)*	***NAC-UMS FSAR Section 2.2.1.1*** *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 (Missile)	*Automobile: 4000 lb, 112 ft/s (76.4 mph)* *Schedule 40 Pipe: 287 lb, 112 ft/s (76.4 mph)* *Solid Steel Sphere: 0.147 lb, 23 ft/s (15.7 mph)*	*Accident (Bounded)*	***NAC-UMS FSAR Section 2.2.1.3*** *Massive Missile: 4000 lb, 126 mph* *Rigid hardened steel: 280 lb, 126 mph* *Solid Steel Sphere: 0.15 lb, 126 mph*
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)*	***NAC-UMS FSAR Section 2.2.2.1*** *Flood height: 50 ft* *Water velocity: 15 ft/s*

Table F.3-1
Summary of WCS CISF Principal Design Criteria
(4 pages)

Design Parameter	***WCS CISF Design Criteria***	***Condition***	***NAC-UMS® Design Criteria***
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)*	***NAC-UMS FSAR Section 11.2.8*** *The maximum allowable ground acceleration for the NAC-UMS system is 0.26g horizontal and 0.29g vertical.*
Vent Blockage	*For UMS Systems:* *Inlet and outlet vents blocked 24 hrs*	*Accident (Same)*	***NAC-UMS FSAR Section 11.2.13.3*** *Inlet and outlet vents blocked: 24 hrs*
Fire/Explosion	*For UMS Systems:* *Equivalent fire 50 gallons of diesel fuel*	*Accident (Same)*	***NAC-UMS FSAR Section 11.2.6.1*** *Equivalent fire 50 gallons of flammable fluid*
Cask Drop	*For UMS Systems:* *VCC's Drop height 24 inches*	*Accident (Same)*	***NAC-UMS FSAR Section 11.2.4*** *VCCs for UMS Systems:* *Drop height 24 inches*
Ambient Temperatures	*Yearly average temperature 67.1°F*	*Normal (Bounded)*	***NAC-UMS FSAR Section 2.2.6*** *Average Annual Ambient Temperature 76°F*
Off-Normal Temperature	*Minimum 3 day avg. temperature 27.9°F* *Maximum 3 day avg. temperature 89.4°F*	*Off-Normal (Bounded)*	***NAC-UMS FSAR Section 2.2.6*** *Minimum 3 day avg. temperature -40°F* *Maximum 3 day avg. temperature 106°F*
Extreme Temperature	*Maximum temperature 113°F*	*Accident (Bounded)*	***NAC-UMS FSAR Section 2.2.6*** *Maximum temperature 133°F*

Table F.3-1
Summary of WCS CISF Principal Design Criteria
(4 pages)

Design Parameter	***WCS CISF Design Criteria***	***Condition***	***NAC-UMS® Design Criteria***
Solar Load (Insolation)	*Horizontal flat surface insolation 2949.4 BTU/day-ft²* *Curved surface solar insolation 1474.7 BTU/day-ft²*	*Normal (Same)*	***NAC-UMS FSAR Section 4.4.1.1*** *Curved Surface: 1475 Btu/ft² for a 24-hour period.* *Flat Horizontal Surface: 2950 Btu/ft2 for a 24-hour period.*
Snow and Ice	*Snow Load 10 psf*	*Normal (Bounded)*	***NAC-UMS FSAR Section 2.2.4*** *101 psf*
Dead Weight	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*Canister - NAC-UMS FSAR Section 3.4.4.1.2* *Cask - NAC-UMS FSAR Section 3.4.4.2.1* *Heaviest Concrete Cask*
Internal and External Pressure Loads	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*Canister - NAC-UMS FSAR Section 3.4.4.1.3* *Maximum internal pressure: 15 psig*
Design Basis Thermal Loads	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*Canister - NAC-UMS FSAR Section 3.4.4.1.1* *Cask - NAC-UMS FSAR Section 3.4.4.2.3* *Highest temperature gradient*
Operating Loads	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*NAC-UMS FSAR Sections 3.4.4 and 3.4.5*
Live Loads	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*Cask - NAC-UMS FSAR Section 3.4.4.2.2*

Table F.3-1
Summary of WCS CISF Principal Design Criteria
(4 pages)

Design Parameter	***WCS CISF Design Criteria***	***Condition***	***NAC-UMS® 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 mrem* *Public lens of eye ≤ 15 mrem*	*Accident (Same)*	***NAC-MPC FSAR 10.2.2*** *Public wholebody, organ or skin ≤ 5 Rem*
Radiological Protection	*Public wholebody ≤ 25 mrem/yr(1)* *Public thyroid ≤ 75 mrem/yr(1)* *Public critical organ ≤ 25 mrem/yr(1)*	*Normal (Same)*	***NAC-MPC FSAR Section 10.4*** *Exposure to the Public ≤ 25 mrem/yr*
Confinement	*Per design basis for systems listed in Table 1-1*	*N/A*	*NAC-UMS FSAR Chapter 7* *Leaktight*
Nuclear Criticality	*Per design basis for systems listed in Table 1-1*	*N/A*	*NAC-UMS FSAR Chapter 6* $K_{eff} < .95$
Decommissioning	*Minimize potential contamination*	*Normal (Same)*	*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)*	*Cask/canister handling system prevent breach of confinement boundary under all conditions* *Storage system allows ready retrieval of canister for shipment off-site*

Note:

1. *In accordance with 10 CFR 72.104(a)(3) limits include any other radiation from uranium fuel cycle operations within the region.*

APPENDIX F.4
OPERATING SYSTEMS
NAC-UMS

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F.4 OPERATING SYSTEMS

The primary components of the NAC-UMS Universal Storage System consist of the transportable storage canister, the vertical concrete cask, and the transfer cask. The NAC-UMS is designed to store up to 24 PWR or up to 56 BWR fuel assemblies. Since the design basis fuel assemblies have different overall lengths, the PWR fuel assemblies are grouped into three classes and the BWR fuel assemblies are grouped into two classes based on overall lengths. To accommodate the different fuel classes the NAC-UMS principal components are provided in an appropriate length for each class of fuel assemblies.

The transportable storage canister is a stainless steel cylindrical shell (with a bottom end plate and closure lids) that confines the fuel basket structure and the contents.

In long-term storage, the transportable storage canister is positioned inside a vertical concrete cask, which provides passive radiation shielding and natural convection cooling. The vertical concrete cask also provides protection during storage for the Transportable Storage Canister under adverse environmental conditions.

The transfer cask is used to lift and place a canister during fuel loading operations and to move a canister to or from the vertical concrete cask. The transfer cask provides radiation shielding while the canister is being transferred.

A loaded canister is placed into a concrete cask by positioning the transfer cask containing the loaded canister on top of the vertical concrete cask and lowering the canister into the concrete cask. The process is reversed for the removal of a canister from a concrete cask. Figure F.4-1 depicts the major components of the NAC-UMS system and shows the transfer cask positioned on the top of the concrete cask.

The Maine Yankee NAC-UMS is described in the following section, Section F.4.1.

Section F.4.3 provides a reference to all applicable license drawings (i.e., NAC-UMS drawings associated with storage PWR fuel and site-specific Maine Yankee fuel drawings) from Reference [F.4.2-1].

In addition to these previously NRC approved license drawings, this WCS SAR appendix includes one site-specific GTCC waste canister storage configuration drawing for previously loaded Maine Yankee GTCC waste canisters (GTCC-Canister-MY).

F.4.1 Maine Yankee

This section provides a general description of the major components of the NAC-UMS system used to store the Maine Yankee spent fuel and a description of the system operations. The terminology used throughout this report is summarized in Table 1-1 of the NAC-UMS FSAR, Reference F.4.2-1.

F.4.1.1 Transportable Storage Canister and Baskets

The Transportable Storage Canister (TSC) contains a basket that positions and supports the stored spent fuel. The major components of the TSC are the shell and bottom, shield lid and structural lid. The shell and the shield and structural lids provide a double welded closure system. The basket assembly provides the structural support and primary heat transfer path for the basket contents, while maintaining a subcritical configuration. The NAC-UMS fuel basket has a capacity of up to 24 PWR fuel assemblies and up to 56 BWR fuel assemblies. Tables 1.2-2 and 1.2-4 of the NAC-UMS FSAR, Reference F.4.2-1, list the major physical design parameters of the TSCs and the fuel baskets, respectively, for the NAC-UMS. See Figures F.4-2 and F.4-3 for illustrations of the NAC-UMS TSC and baskets.

The Maine Yankee NAC-UMS canisters were loaded with spent fuel and welded closed at the plant site. There are no active components associated with the loaded and welded closed TSCs. Thus, no further loading or closing operations are required to be performed on the TSC and basket at the WCS facility. Further details about the TSC and basket can be found in Sections 1.2.1.1 and 1.2.1.2 of Reference F.4.2-1.

F.4.1.2 Vertical Concrete Cask

The vertical concrete cask (storage cask) is the storage overpack for the transportable storage canister (TSC). It provides structural support, shielding, protection from environmental conditions, and natural convection cooling of the canister during long-term storage. Table 1.2-5 of the NAC-UMS FSAR, Reference F.4.2-1, lists the major physical design parameters of the storage cask for the Maine Yankee configuration of the NAC-UMS.

The storage cask is a reinforced concrete (Type II Portland cement) structure with a structural steel inner liner. Inner and outer reinforcing steel (rebar) assemblies are contained within the concrete. The storage cask incorporates reinforced chamfered corners at the edges to facilitate construction. The vertical concrete cask is shown in Figure F.4-4.

The storage cask has an annular air passage to allow the natural circulation of air around the canister to remove the decay heat from the spent fuel. Heat flows by radiation and convection from the canister wall to the air circulating through the concrete cask annular air passage and is exhausted through the air outlet vents. This passive cooling system is designed to maintain the peak cladding temperature of both stainless steel and Zircaloy clad fuel well below acceptable limits during long-term storage. This design also maintains the bulk concrete temperature below 150°F and localized concrete temperatures below 200°F in normal operating conditions.

The top of the storage cask is closed by a shield plug and lid. The shield plug for the Yankee MPC is approximately 5 inches thick and incorporates carbon steel plate as gamma radiation shielding and NS-4-FR as neutron radiation shielding. A carbon steel lid that provides additional gamma radiation shielding is installed above the shield plug. The shield plug and lid reduce skyshine radiation and provide a cover and seal to protect the canister from the environment and postulated tornado missiles.

To facilitate movement of the storage cask at the WCS facility, embedded lift lugs are placed in the concrete on the top of the cask. This provides a place for the vertical cask transporter to engage the storage cask in order to lift and subsequently move the storage cask whether there is a loaded TSC in it or not.

Existing Maine Yankee NAC-UMS storage casks will not be used at the WCS facility. New storage casks will be constructed on site at the WCS facility. Fabrication of the storage cask involves no unique or unusual forming, concrete placement, or reinforcement requirements. The inner liner and base of the storage cask are shop fabricated. The concrete portion of the storage cask is constructed by placing concrete between a reusable, exterior form and the inner metal liner. Reinforcing bars are placed near the inner and outer concrete surfaces to provide structural integrity. The principal construction specifications for the storage cask are listed in Table F.4-1.

F.4.1.3 Transfer Cask

The transfer cask, with its lifting yoke, is primarily a lifting device used to move the canister assembly. It provides biological shielding for a loaded canister. The transfer cask is used for the vertical transfer of the canister between work stations and the storage cask, or transport cask. The general arrangement of the transfer cask and canister is shown in Figure F.4-6, and the arrangement of the transfer cask and concrete cask is shown in Figure F.4-7. The configuration of the transfer cask, canister and concrete cask during loading of the concrete cask is shown in Figure F.4-8. Table 1.2-7 of the NAC-UMS FSAR, Reference F.4.2-1, shows the principal design parameters of the transfer cask used for the Maine Yankee NAC-UMS.

The transfer cask is a multiwall (steel/lead/NS-4-FR neutron shield/steel) design, which limits the average contact radiation dose rate to acceptable levels. The transfer cask design incorporates a top retaining ring, which is bolted in place to prevent a loaded canister from being inadvertently removed through the top of the transfer cask. The transfer cask has retractable bottom shield doors. During loading operations, the doors are closed and secured by lock bolts/lock pins, so they cannot inadvertently open. During unloading or loading, the doors are retracted using hydraulic cylinders to allow the canister to be lowered or raised into, or out of, the storage or transport cask. The transfer cask is shown in Figure F.4-5.

The transfer cask is qualified as a heavy lifting device by being designed, fabricated, and proof load tested to the requirements of NUREG-0612 and ANSI N14.6. Maintenance is to be performed in accordance with WCS facility procedures that meet the requirements of NUREG-0612.

F.4.1.4 Auxiliary Equipment

This section presents a brief description of the principal auxiliary equipment needed to operate the NAC-UMS Universal Storage System in accordance with its design.

F.4.1.4.1 Transfer Adapter

The transfer adapter is a carbon steel table that is positioned on the top of the vertical concrete cask or the transport cask and mates the transfer cask to either of those casks. It has a large center hole that allows the transportable storage canister to be raised or lowered through the plate into or out of the transfer cask. Rails are incorporated in the transfer adapter to guide and support the bottom shield doors of the transfer cask when they are in the open position. The transfer adapter also supports the hydraulic system and the actuators that open and close the bottom doors of the transfer cask.

F.4.1.4.2 Vertical Cask Transporter

The vertical cask transporter is a mobile lifting device that allows for the movement of the vertical concrete cask. The transporter engages the storage cask via the embedded lift lugs on the top of the cask. After the transporter has engaged the storage cask, it can lift the storage cask and move it to the desired location. When the storage cask has a loaded TSC, the transporter shall not lift the storage cask higher than the lift height limit in Table A5-1 of the NAC-UMS Technical Specifications, Reference F.4.2-2.

F.4.1.4.3 Rigging and Slings

Load rated rigging attachments and slings are provided for major components of the NAC-UMS. The rigging attachments are swivel hoist rings that allow attachment of the slings to the hook. All slings are commercially purchased to have adequate safety margin to meet the requirements of ANSI N14.6 and NUREG-0612. The slings include a concrete cask lid sling, concrete cask shield plug sling, canister shield lid sling, loaded canister transfer sling (also used to handle the structural lid), and a canister retaining ring sling. The appropriate rings, or eye bolts, are provided to accommodate each sling and component. Note: A cask user may utilize other slings, as needed, to perform the numerous required lifts of the NAC-UMS components provided that the slings meet all applicable safety requirements.

The transfer cask lifting yoke is a specially designed and fabricated component for lifting the transfer cask. It is designed to meet the requirements of ANSI N14.6 and NUREG-0612. It is designed as a special lifting device for critical loads. The transfer cask lifting yoke is initially load tested to 300 percent of the maximum service load.

F.4.1.4.4 Temperature Instrumentation

The concrete casks may be equipped with temperature-monitoring equipment to measure the outlet air temperature. The Technical Specification, Reference F.4.2-2, requires either daily temperature measurements or daily visual inspection for inlet and outlet blockage to ensure the cask remains operable.

F.4.1.4.5 Storage Pad

The NAC-UMS is designed for long-term storage at an ISFSI. At the ISFSI site, the vertical loaded concrete storage casks are positioned on a concrete pad in a linear array. The reinforced concrete foundation of the ISFSI pad is capable of sustaining the transient loads from the vertical cask transporter and the general loads of the stored casks. The WCS pad design exceeds, or is equivalent to, the NAC-UMS pad requirements listed in Table F.4-2.

F.4.2 References

F.4.2-1 NAC-UMS Universal Storage System Final Safety Analysis Report, Revision 10, October 2012.

F.4.2-2 Amendment No. 5 to Certificate of Compliance No. 1015 for the NAC International, Inc., NAC-UMS Universal Storage System, January 12, 2008.

F.4.2-3 NAC International, "Safety Analysis Report for the UMS® Universal Transport Cask," Revision 2, CoC 9270 Revision 4, U.S. NRC Docket Number 71-9270.

F.4.3 Supplemental Data

Section F.4.3 provides a listing of all applicable license drawings (i.e., NAC-UMS drawings associated with the storage PWR fuel and site-specific Maine Yankee fuel drawings) from Reference [F.4.2-1].

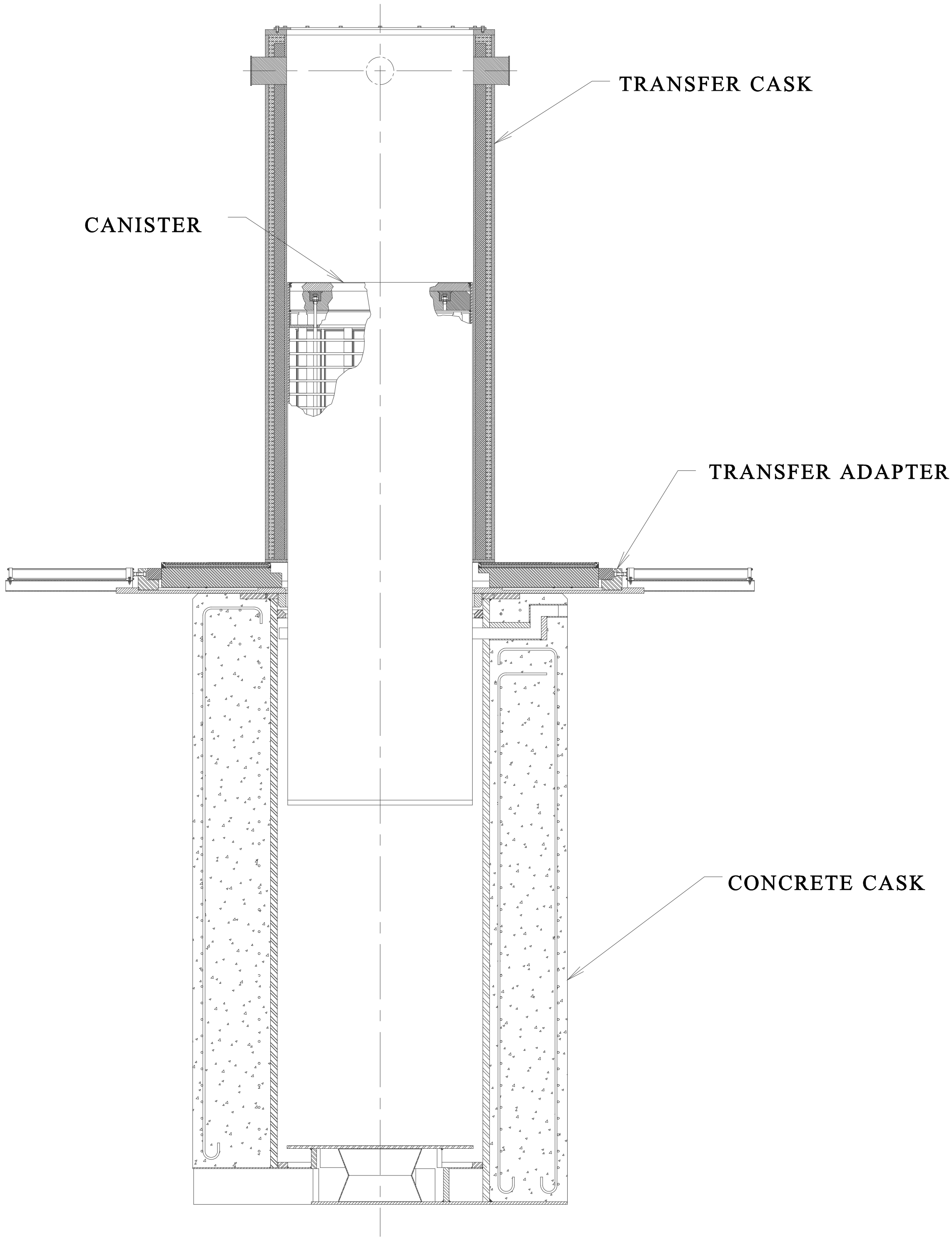

Figure F.4-1
Major Components of the NAC-UMS System

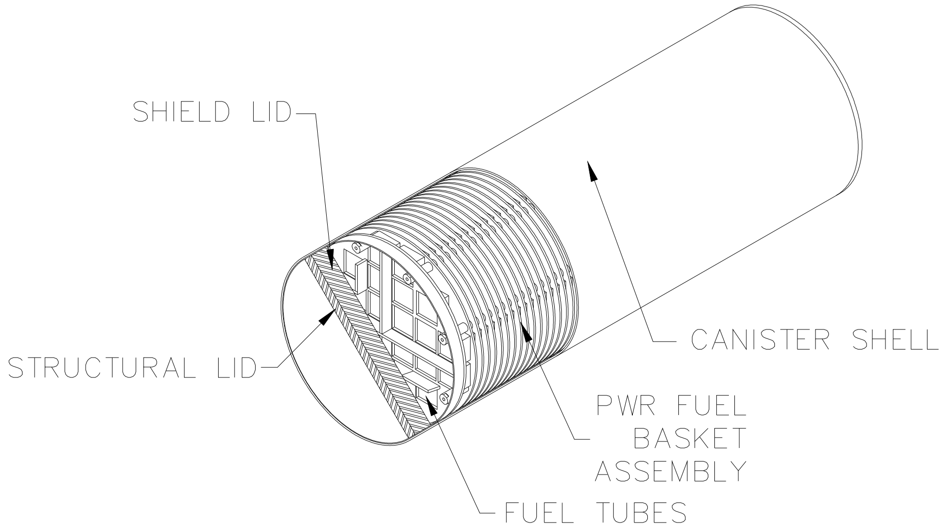

Figure F.4-2
NAC-UMS Transportable Storage Canister Containing PWR Spent Fuel Basket

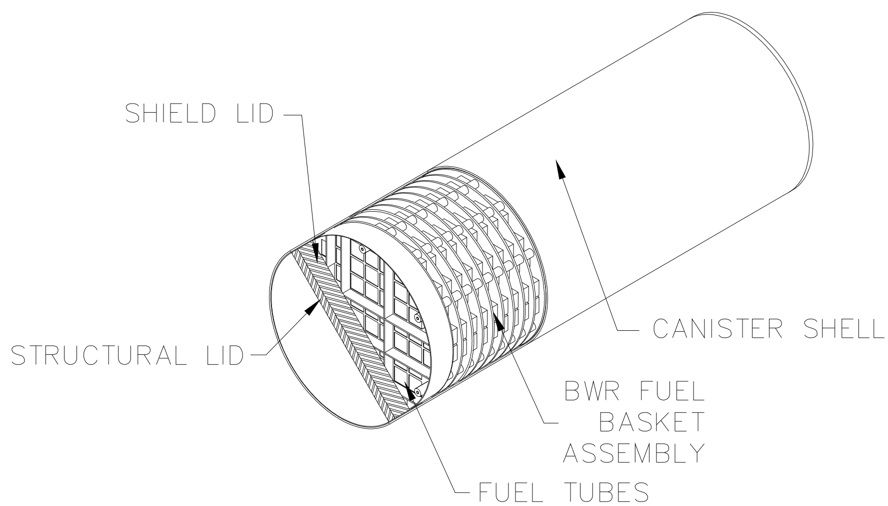

Figure F.4-3
NAC-UMS Transportable Storage Canister Containing BWR Spent Fuel Basket

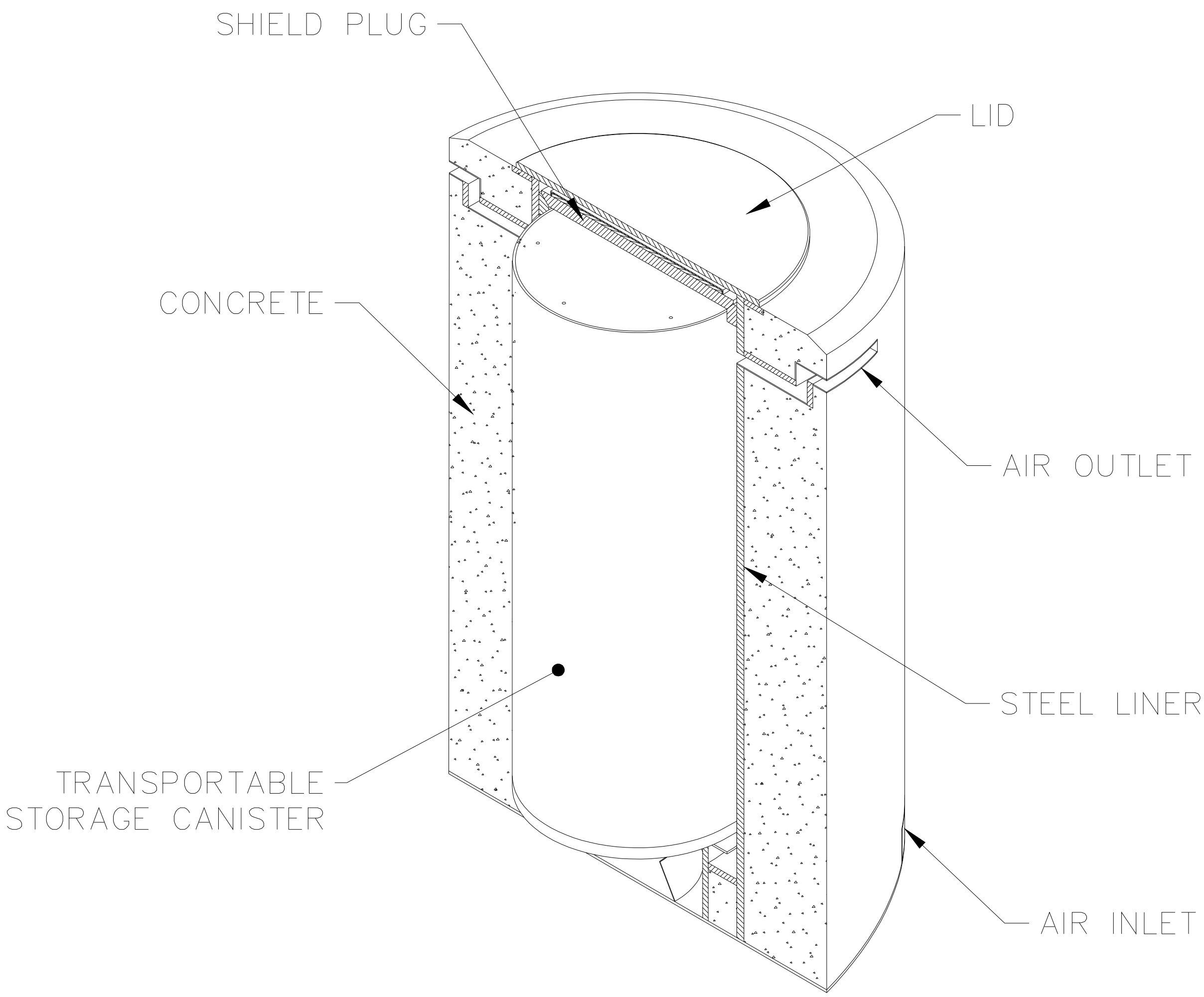

Figure F.4-4
NAC-UMS Vertical Concrete Cask

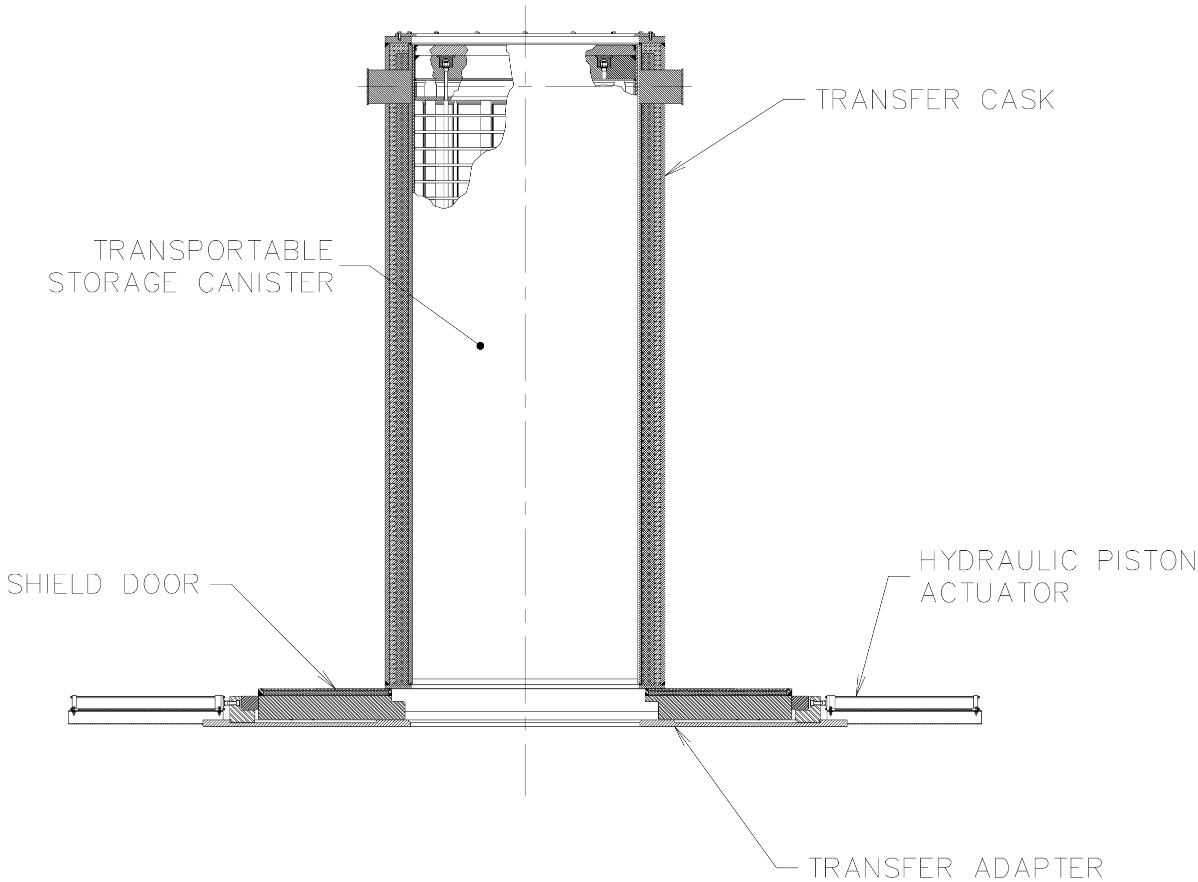

Figure F.4-5
NAC-UMS Transfer Cask

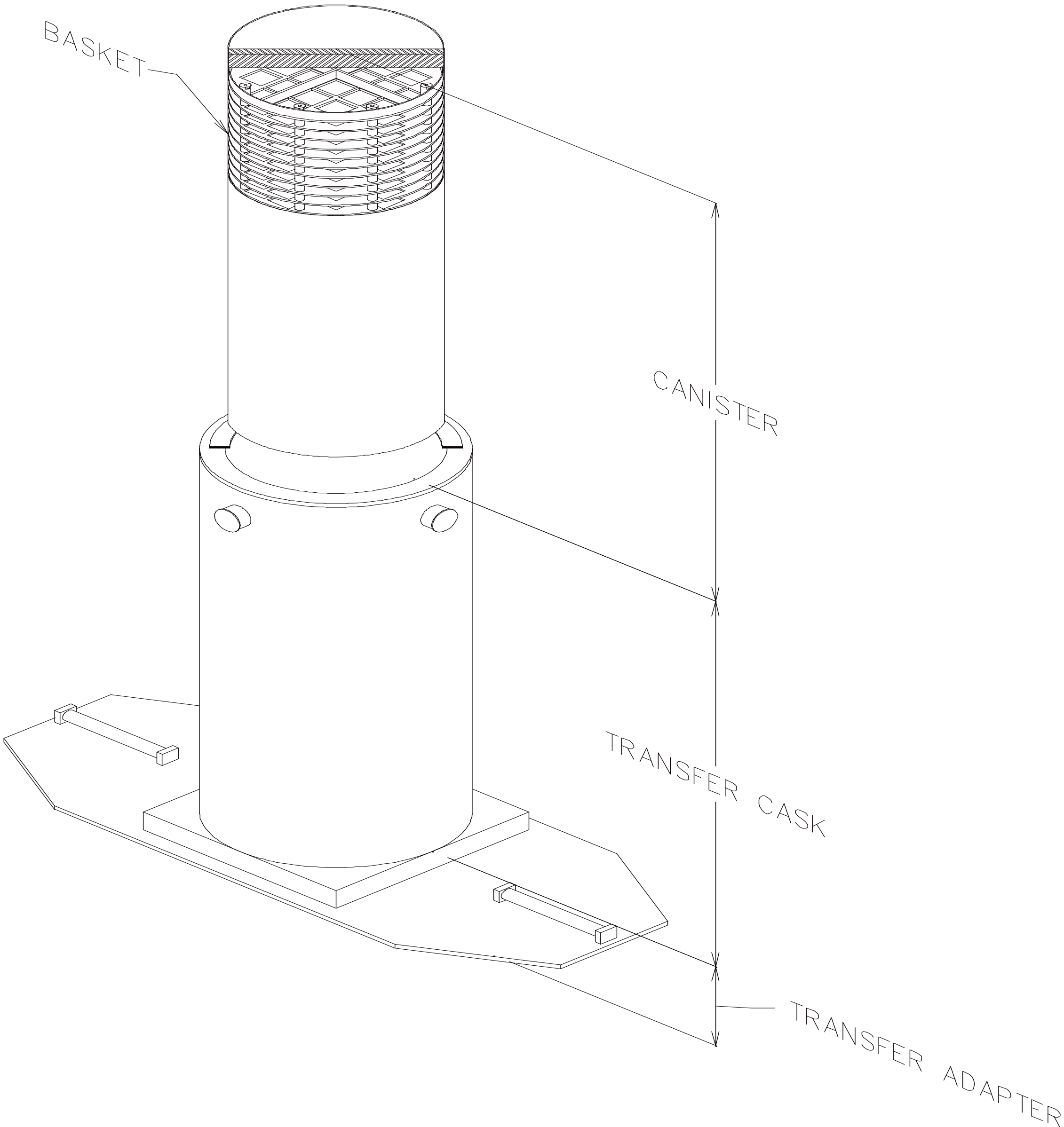

Figure F.4-6
NAC-UMS Transfer Cask and Canister Arrangement

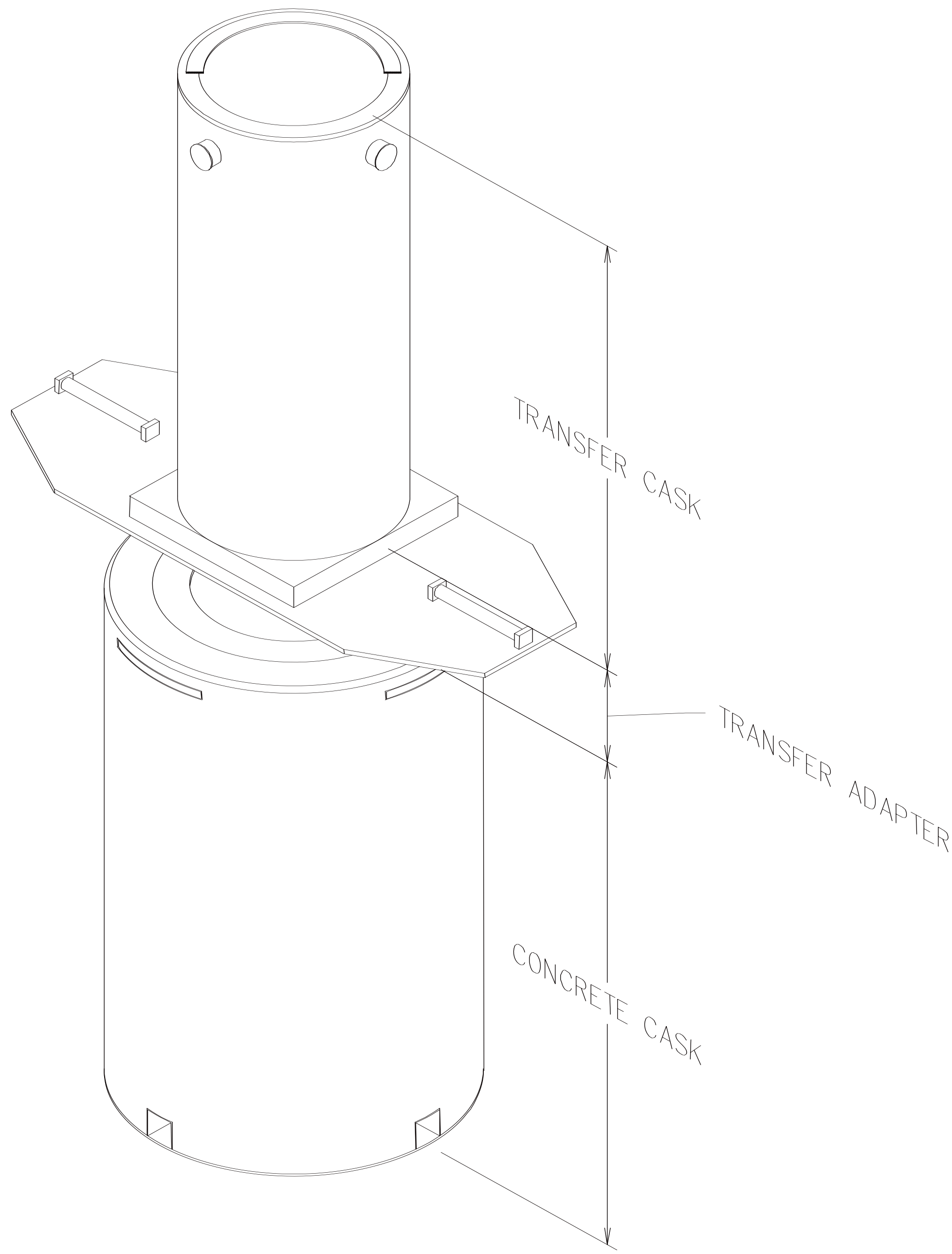

Figure F.4-7
NAC-UMS Vertical Concrete Cask and Transfer Cask Arrangement

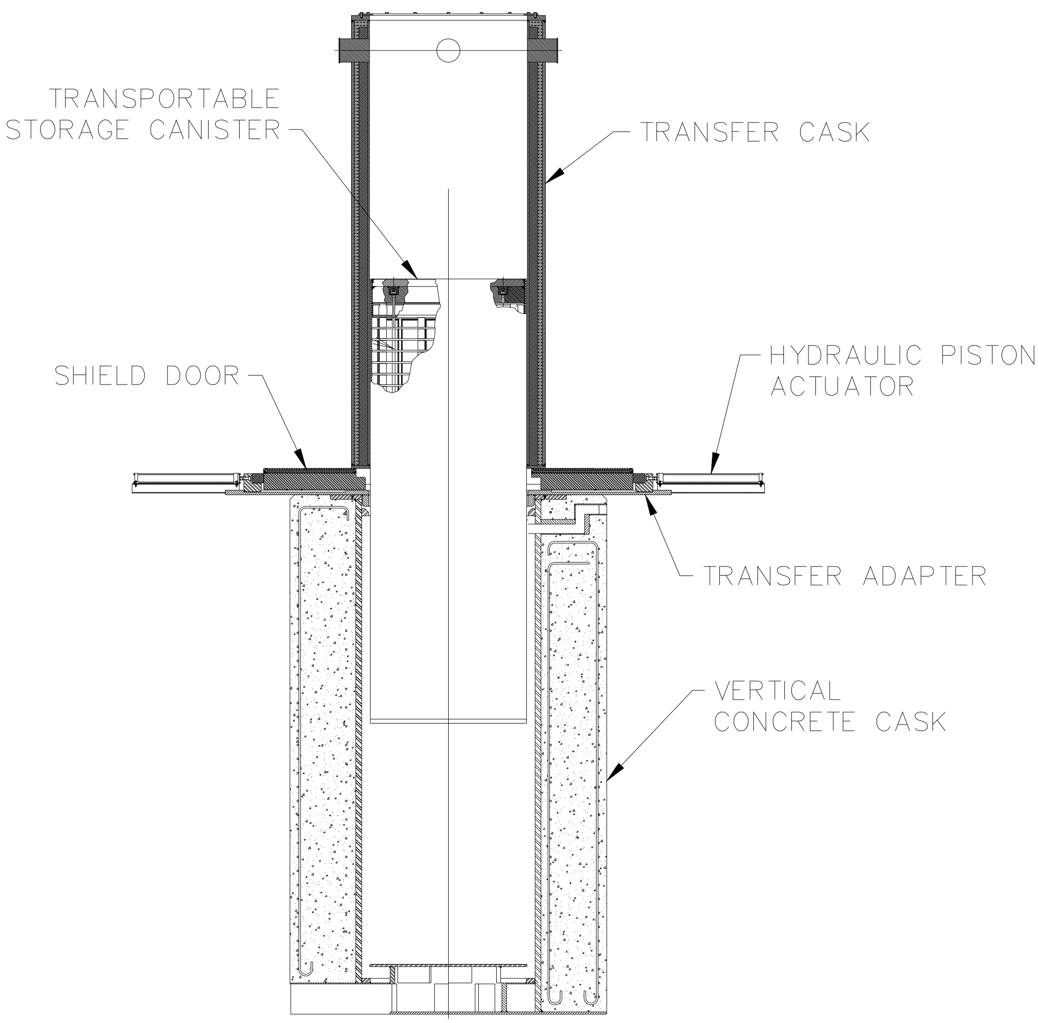

Figure F.4-8
NAC-UMS Major Component Configuration for Loading the Vertical Concrete Cask

Table F.4-1
Concrete Cask Construction Specification Summary

Materials

- Concrete mix shall be in accordance with the requirements of ACI 318 and ASTM C94.
- Type II Portland Cement, ASTM C150.
- Fine aggregate ASTM C33 or C637.
- Coarse aggregate ASTM C33.
- Admixtures
  - Water Reducing and Superplasticizing ASTM C494.
  - Pozzolanic Admixture (Loss on Ignition 6% or less) ASTM C618.
- Compressive Strength 4000 psi per ACI 318.
- Specified Air Entrainment per ACI 318.
- All steel components shall be of material as specified in the referenced drawings.

Welding

- Visual inspection of all welds shall be performed to the requirements of AWS D1.1, Section 8.6.1.

Construction

- A minimum of two concrete samples for each concrete cask shall be taken in accordance with ASTM C172 and ASTM C31 for the purpose of obtaining concrete slump, density, air entrainment, and compressive strength values. The two samples shall not be taken from the same batch or truckload.
- Test specimens shall be tested in accordance with ASTM C39.
- Formwork shall be in accordance with ACI 318.
- All sidewall formwork shall remain in place in accordance with ACI 318.
- Grade, type, and details of all reinforcing steel shall be in accordance with the referenced drawings.
- Embedded items shall conform to ACI 318 and the referenced drawings.
- The placement of concrete shall be in accordance with ACI 318.
- Surface finish shall be in accordance with ACI 318.

Quality Assurance

The concrete cask shall be constructed under a quality assurance program that meets 10 CFR 72 Subpart G. The quality assurance program must be accepted by NAC International and the licensee prior to initiation of the work.

Table F.4-2
Storage Pad Design and Construction Requirements

Parameter	**NAC-UMS**
Concrete thickness	36 inches maximum
Pad subsoil thickness	10 feet minimum
Specified concrete compressive strength	≤ 5,000 psi at 28 days
Concrete dry density (ρ)	$125 \leq \rho \leq 160$ lbs/ft^3
Soil in place density (ρ)	$100 \leq \rho \leq 160$ lbs/ft^3
Soil Modulus of Elasticity	≤ 60,000 psi (PWR)

Note:

The concrete pad maximum thickness excludes the ISFSI pad footer. The compressive strength of the concrete should be determined according to the test method given in Section 5.6 of ACI 318. Steel reinforcement is used in the pad footer. The basis for acceptance of concrete shall be as described in Section 5.6 of ACI 318. The soil modulus of elasticity should be determined according to the test method described in ASTM D4719 or in ASTM D1196. The soil stiffness should be determined according to the test method described in Chapter 9 of the Civil Engineering Reference Manual, 6th Edition.

APPENDIX F.5
OPERATING PROCEDURES
NAC-UMS

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F.5 OPERATING PROCEDURES

The following are operating procedures for using the NAC-UMS Universal Storage System configured for the Maine Yankee UMS storage operations. These procedures are based on the general guidance found in Chapter 8 of the NAC-UMS Final Safety Analysis Report (FSAR) [Reference F.5.2-1]. The procedures covered are:

1. Installing the transportable storage canister (TSC) in the vertical concrete cask (concrete cask) and transferring it to the ISFSI storage pad; and
2. Removing the loaded canister from the concrete cask.
3. Receipt of the NAC-UMS Transport Cask and removal of the loaded canister.

The detailed operating procedures for receiving a loaded NAC-UMS Transport Cask and unloading the transportable storage canister are described in Section 7.3 of the NAC-UMS Transport Cask SAR. [Reference F.5.2-3]

Pictograms of the NAC-UMS System operations are presented in Figure F.5-1.

F.5.1 Maine Yankee

The following procedures are specific to the NAC-UMS transportable storage canisters (TSCs). Operation of the NAC-UMS Universal Storage System requires the use of ancillary equipment items. The ancillary equipment supplied with the system is listed in Table 8.1.1-1 of the NAC-UMS Final Safety Analysis Report (FSAR), Reference F.5.2-1. The NAC-UMS system does not rely on the use of bolted closures, but bolts are used to secure retaining rings and lids. The hoist rings used for lifting the shield lid, the structural lid, and the canister, have threaded fittings. Table 8.1.1-2 of Reference F.5.2-1 provides the torque values for installed bolts and hoist rings. In addition, supplemental shielding may be employed to reduce radiation exposure for certain tasks specified by these procedures. The use of supplemental shielding is at the discretion of the WCS facility.

F.5.1.1 Loading the Vertical Concrete Cask

This section of the loading procedure assumes that the vertical concrete cask is located inside the cask transfer facility on the floor of the work area, under a site-approved crane suitable for lifting the loaded transfer cask. The vertical concrete cask shield plug and lid are not in place, and the bottom pedestal plate cover is installed.

1. Using a site-approved crane, place the transfer adapter on the top of the concrete cask.
2. Using the transfer adapter bolt hole pattern, align the adapter to the concrete cask. Bolt the adapter to the cask using four (4) socket head cap screws. (Note: Bolting of the transfer adapter to the cask is optional, if the transfer adapter centering segments/guides are installed.)
3. Verify that the shield door connectors on the transfer adapter are in the fully extended position.

Note: Steps 4 through 6 may be performed in any order, as long as all items are completed.

4. If not already done, attach the transfer cask lifting yoke to the site-approved cask Handling crane. Verify that the transfer cask retaining ring is installed.
5. Install six (6) swivel hoist rings in the structural lid of the canister and torque to the value specified in Table 8.1.1-2 of Reference F.5.2-1. Attach two (2) three-legged slings to the hoist rings. Stack the slings on the top of the canister so they are available for use in lowering the canister into the concrete storage cask.
6. Engage the transfer cask trunnions with the transfer cask lifting yoke. Ensure that all lines are disconnected from the transfer cask.

7. Raise the transfer cask and move it over the concrete cask. Lower the transfer cask, ensuring that the transfer cask shield door rails and connector tees align with the transfer adapter rails and door connectors. Prior to final set down, remove the transfer cask shield door lock pins (there is a minimum of one per door), or the door stop, as appropriate.

Note: The minimum temperature of the transfer cask (i.e., temperature of the surrounding air) must be verified to be higher than 0ºF prior to lifting, in accordance with Section B 3.4.1(7) of Appendix B of , Reference F.5.2-2.

8. Ensure that the transfer cask shield door connector tees are engaged with the transfer adapter door connectors.
9. Disengage the transfer cask yoke from the transfer cask and from the site-approved cask handling crane hook.
10. Return the site-approved cask handling crane hook to the top of the transfer cask and engage the two (2) three-legged slings previously attached to the canister. Lift the canister slightly (about ½ inch) to take the canister weight off the transfer cask shield doors.

Caution: The top connection of the two (2) three-legged slings must be at least 75 inches above the top of the canister.

Note: A load cell may be used to determine when the canister is supported by the crane.

Caution: Avoid raising the canister to the point that the canister top engages the transfer cask retaining ring, as this could result in lifting the transfer cask.

11. Using the hydraulic system, open the transfer cask shield doors to access the concrete cask cavity.
12. Lower the canister into the concrete cask, using a slow crane speed as the canister nears the pedestal at the base of the concrete cask.
13. When the canister is properly seated, disconnect the slings from the canister at the crane hook, and close the transfer cask shield doors.
14. Retrieve the transfer cask lifting yoke and attach the yoke to the transfer cask.
15. Lift the transfer cask off the vertical concrete cask and return it to the decontamination area or designated workstation.

Note: The canister is intended to be centered in the concrete cask, but the final position of the canister may result in the canister shell being as close as one inch from the concrete cask liner due to system component alignment.

16. Using the site-approved auxiliary crane, remove the transfer adapter from the top of the concrete cask.

17. Remove the swivel hoist rings from the structural lid. At the option of the user, install threaded plugs.
18. Install three swivel hoist rings in the shield plug and torque in accordance with Table 8.1.1-2 of Reference F.5.2-1.
19. Using the site-approved auxiliary crane, retrieve the shield plug and install the shield plug in the top of the concrete cask. Remove the swivel hoist rings from the shield plug.
20. Using the site-approved auxiliary crane, retrieve the concrete cask lid and install the lid in the top of the concrete cask. Secure the lid using six stainless steel bolts. Torque bolts in accordance with Table 8.1.1-2 of Reference F.5.2-1.
21. Ensure that there is no foreign material left at the top of the concrete cask. At the option of the user, a tamper-indicating seal may be installed.
22. If used, install a supplemental shielding fixture in each of the four concrete cask air inlets.

Note: The supplemental shielding fixtures may also be shop installed.

F.5.1.2 Transport and Placement of the Vertical Concrete Cask

This section of the procedure details the movement of the loaded concrete cask from the cask transfer facility to the ISFSI pad using a vertical concrete cask transporter. After placement on the ISFSI pad, the concrete cask surface dose rates must be verified in accordance with the requirements of LCO 3.2.2 of Reference F.5.2-2. The dose rate measurements may be made prior to movement of the concrete cask, at a location along the transport path, or at the ISFSI. Following placement of the concrete cask at the ISFSI, the operability of the concrete cask heat removal system shall be verified in accordance with LCO 3.1.6 of Reference F.5.2-2.

1. Using the vertical cask transporter lift fixture or device, engage the two concrete cask lifting lugs.
2. Lift the loaded concrete cask and move it to the ISFSI pad following the approved onsite transport route.

Note: Ensure vertical cask transporter lifts the concrete cask evenly using the two lifting lugs.

Note: Do not exceed the maximum lift height for a loaded concrete cask of 24 inches.

3. Move the concrete cask into position over its intended ISFSI pad storage location. Ensure the surface under the concrete cask is free of foreign objects and debris.

4. Using the vertical transporter, slowly lower the concrete cask into position.

Note: Ensure that the centerline spacing between concrete casks is 15 feet minimum.

5. Disengage the vertical transporter lift connections from the two concrete cask-lifting lugs. Move the cask transporter from the area.

F.5.1.3 Removal of the Transportable Storage Canister from the Vertical Concrete Cask

Removal of the loaded canister from the vertical concrete cask is expected to occur at the time of shipment of the canistered fuel off site. Alternately, removal could be required in the unlikely event of an accident condition that rendered the concrete cask or canister unsuitable for continued long-term storage or for transport. This procedure identifies the general steps to return the loaded canister to the transfer cask and return the transfer cask to the decontamination station, or other designated work. area or facility. Since these steps are the reverse of those undertaken to place the canister in the concrete cask and move the concrete cask to the ISFSI, as described in Sections F.5.1.1 and F.5.1.2, they are only summarized here. The procedure assumes that the inlet and outlet screens and the temperature-sensing instrumentation, if installed, have been removed.

Mechanical operation steps of the procedures in this section may be completed out of sequence to allow for operational efficiency. Changing the order of these steps, within the intent of the procedures, has no effect on the safety of the canister removal process and does not violate any requirements stated in the Technical Specifications.

At the option of the user, the canister may be removed from the concrete cask and transferred to another concrete cask or to the Universal Transport Cask at the ISFSI site. This transfer is done using the transfer cask, which provides shielding for the canister contents during the transfer.

1. Move the loaded concrete cask from the ISFSI pad using the vertical concrete cask transporter.

Caution: Do not exceed a maximum lift height of 24 inches when raising the concrete cask.

2. Move the transporter and loaded concrete cask to the cask receiving area or other designated workstation.
3. Remove the concrete cask shield plug and lid. Install the hoist rings in the canister structural lid. Verify that the hoist ring threads are fully engaged and torque the hoist rings as required in Table 8.1.1-2 of Reference F.5.2-1. Attach the canister lift slings.
4. Install the transfer adapter on the top of the concrete cask. Retrieve the transfer cask and position it on the transfer adapter on the top of the concrete cask.

Note: The minimum temperature of the surrounding air must be verified to be higher than 0°F prior to lifting.

5. Open the transfer cask shield doors. Attach the canister lift slings to the site approved crane hook.

   Caution: The top connection of the three-legged sling must be at least 75 inches above the canister lid.

6. Raise the canister into the transfer cask. Use caution to avoid contacting the transfer cask retaining ring with the canister.

7. Close the transfer cask shield doors. Lower the canister to rest on the shield doors. Disconnect the canister slings from the crane hook.

8. Retrieve the transfer cask lifting yoke. Engage the transfer cask trunnions and move the transfer cask to the decontamination area or designated workstation.

Note: Prior to moving the transfer cask, install and secure door lock bolts/ lock pins.

After the transfer cask containing the canister is in the decontamination area or other suitable workstation, additional operations may be performed on the canister. The canister may be transferred to another concrete cask, or placed in the NAC-UMS transport cask. The length of time that the loaded canister is in the transfer cask must be in accordance with LCO 3.1.4 of Reference F.5.2-2.

F.5.1.4 Receiving the NAC-UMS Transport Cask and Unloading the Transportable Storage Canister

The following procedure(s) cover inspecting the cask upon receipt, preparing the cask for removal from its conveyance, and unloading the transportable storage canister into the transfer cask. Following unloading of the transportable storage canister into the transfer cask, the previously described procedures should be followed to place the transportable storage canister into dry storage in a vertical concrete cask, or an equivalent, approved storage configuration. Note, the requirements of the transport cask CoC must be followed at all times. *In the event there is conflict between the following procedures and the transport CoC requirements, the transport CoC requirements take precedence.*

F.5.1.4.1 Performing Receipt Inspection of the Loaded NAC-UMS Transport Cask

1. Perform radiation and contamination surveys on the transport vehicle and personnel barrier in accordance with 10 CFR 71 and document the results.

2. Remove the personnel barrier.

3. Complete the radiation and contamination surveys at the cask surfaces and record the results.

4. While the cask is in the horizontal position on the transport vehicle, visually inspect the cask for any physical damage that may have been incurred during transport.
5. Verify that the tamper indicating seals are in place, and verify their numbers.
6. Move the transport vehicle to the cask receiving area and secure the vehicle.
7. Attach slings to the upper impact limiter lifting lugs and the crane hook and remove the tamper indicating seal.
8. Remove the upper impact limiter lock wires, jam nuts, attachment nuts, and retaining rods and remove the upper impact limiter from the transport cask.
9. Repeat the operations in Steps 7 and 8 for the lower impact limiter.
10. Remove the lower impact limiter positioner screws and store the positioner and screws.
11. Complete radiation and contamination surveys for exposed transport cask surfaces.
12. Release the tiedown assembly from the front support by removing the front tiedown pins and retaining pins.
13. Attach a sling to the tiedown assembly lifting lugs and remove the tiedown assembly from the transport vehicle.
14. Attach the transport cask lifting yoke to a crane hook with the appropriate load rating and engage the two yoke arms with the primary lifting trunnions at the top of the transport cask.
15. Rotate/lift the transport cask to the vertical position and raise the cask off the rear support structure.
16. Place the cask in the vertical position in a decontamination/work area.
17. Wash any dust and dirt off the cask and decontaminate cask exterior, as required.

F.5.1.4.2 Preparing to Unload the Transportable Storage Canister from the NAC-UMS Transport Cask

The assumptions underlying this procedure are:

- The NAC-UMS Transport Cask is in a vertical position in the designated unloading area.
- The top of the NAC-UMS Transport Cask is accessible.

The procedures for preparing to unload the transportable storage canister from the NAC-UMS Transport Cask are:

1. Remove the vent port coverplate bolts and attach a pressure test fixture to the vent port to measure the pressure in the cask.
2. Using an evacuated vacuum bottle attached to the pressure test fixture, sample the gas in the cask cavity.

Caution: Use caution in opening the cask if the sample activity and/or cask pressure are higher than expected based on the canister contents configuration.

3. Vent the cask cavity gas to the gaseous waste handling system or through an appropriate HEPA filter system and disconnect the pressure test fixture from the vent port.
4. Remove the NAC-UMS Transport Cask lid bolts by following the reverse of the installation torquing sequence, install the two closure lid alignment pins, and install the lifting eyes in the cask lid and attach the lid-lifting device to the cask lid and to the overhead crane.
5. Remove the transport cask lid and place the lid in a designated area. [Ensure that the O-ring grooves in the lid are protected so that they will not be damaged during handling.] Decontaminate the lid as necessary.
6. Remove the two alignment pins and install the transfer adapter to the top of the transport cask.

F.5.1.4.3 Unloading the Transportable Storage Canister from the NAC-UMS Transport Cask

A transfer cask is used to unload the transportable storage canister from the transport cask and to transfer it to a storage or disposal overpack. The transfer cask retaining ring or retaining blocks must be installed.

The procedures for unloading the transportable storage canister from the NAC-UMS Transport Cask are:

1. Install the canister lifting system to the transportable storage canister structural lid.

Caution: The structural lid may be thermally hot.

2. Attach the canister lifting system to the structural lid and position it to allow engagement to the crane hook/sling.
3. Attach the transfer cask lifting yoke to the cask-handling crane hook and engage the yoke to the lifting trunnions of the transfer cask.
4. Lift the transfer cask and move it above the NAC-UMS Transport Cask.
5. Lower the transfer cask to engage the actuators of the transfer adapter. Remove the door stops.
6. Once the transfer cask is fully seated, remove the transfer cask lifting yoke and store it in the designated location.
7. Install the transfer cask shield door hydraulic operating system to the actuators and open the transfer cask bottom shield doors.
8. Lower the canister lifting system through the transfer cask and engage the canister lifting sling, or raise the sling set to engage to the hook above the top of the transfer cask.

Caution: When raising the canister in Step 9, be careful to minimize any contact between the canister and the cavity wall of the NAC-UMS Transport Cask and between the canister and the cavity wall of the transfer cask.

9. Raise the canister into the transfer cask just far enough to allow the transfer cask bottom shield doors to close, close the doors, and install the door stops.
10. Carefully lower the canister until it rests on the transfer cask bottom shield doors and disengage the canister lifting sling from the crane hook.
11. Retrieve the transfer cask lifting yoke and engage it with the transfer cask trunnions.
12. Lift the transfer cask from the transport cask and move it to the designated location.
13. Continue operations to place the canister in an approved storage configuration.

F.5.2 References

F.5.2-1 NAC-UMS Universal Storage System Final Safety Analysis Report, Revision 10, October 2012.

F.5.2-2 Amendment No. 5 to Certificate of Compliance No. 1015 for the NAC International Inc., NAC-UMS Universal Storage System, January 12, 2008.

F.5.2-3 NAC-UMS Universal Transport Cask Package Safety Analysis Report, Revision 2, November 2005.

F.5.2-4 Revision No. 4 to Certificate of Compliance No. 9270 for the NAC International Inc., NAC-UMS Universal Transport Cask Package, October 26, 2012

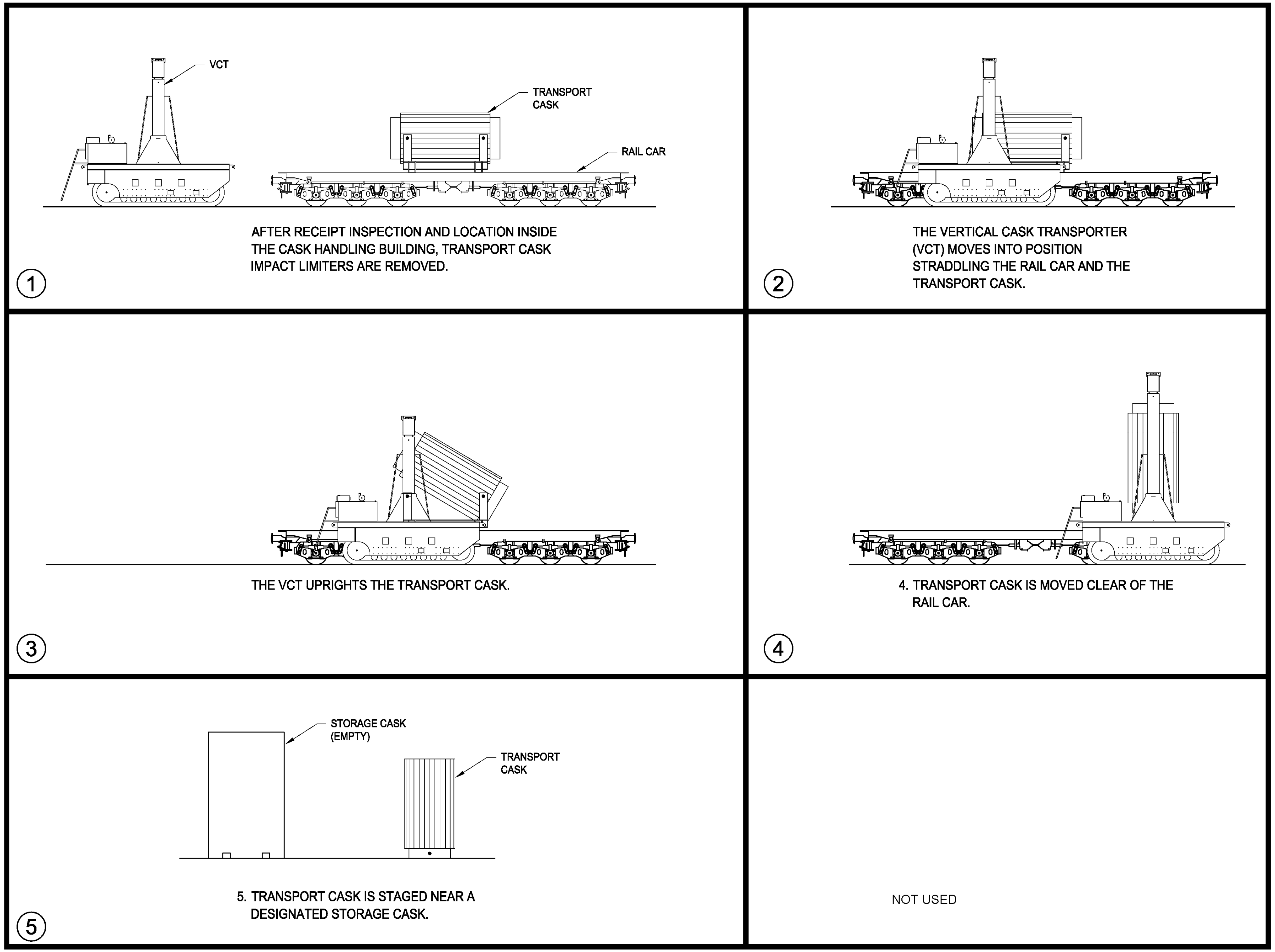

Figure F.5-1
Canister Transfer Operations
2 Pages

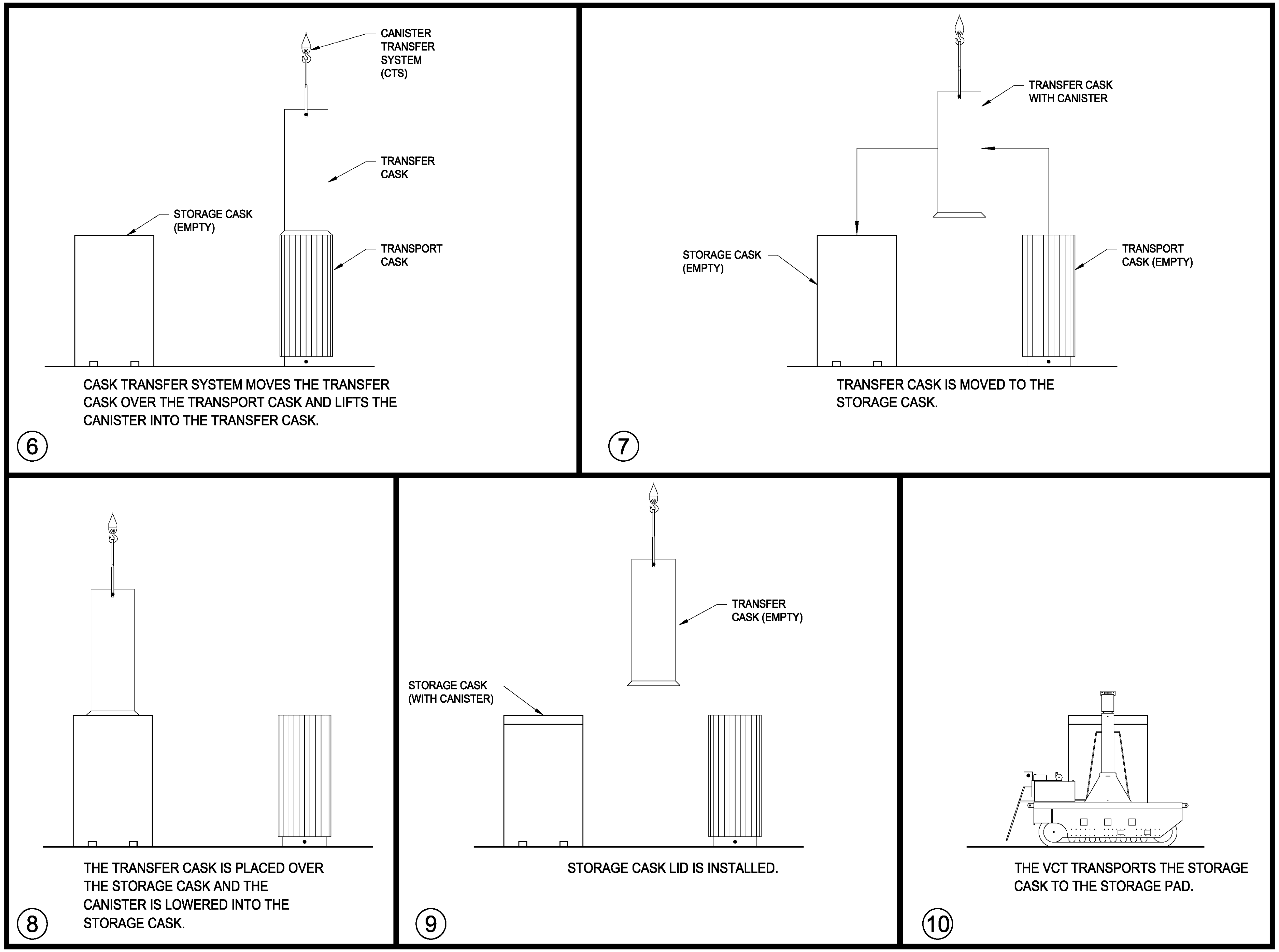

Figure F.5-1
Canister Transfer Operations
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APPENDIX F.6
WASTE CONFINEMENT AND MANAGEMENT
NAC-UMS

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F.6. WASTE CONFINEMENT AND MANAGEMENT

No change or additional information required for the NAC-UMS Universal Storage System for Maine Yankee for Chapter 6.

APPENDIX F.7
STRUCTURAL EVALUATION
NAC-UMS

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F.7 STRUCTURAL EVALUATION

This appendix identifies the sections of the NAC-UMS FSAR, Reference F.7.2-1, where the detailed structural analyses for the NAC-UMS system for normal operating conditions are presented. The structural analyses of the NAC-UMS for off-normal and accident conditions are discussed in WCS SAR Appendix F.12.

F.7.1 Maine Yankee

Sections F.7.1.1 through F.7.1.10 identify the sections of the NAC-UMS FSAR, Reference F.7.2-1, where the detailed structural analyses for the NAC-UMS for normal operating conditions are presented. *Finally, bounding evaluations in Section F.7.1.11 are referenced to demonstrate that the confinement boundaries for the NAC-UMS canisters 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.*

F.7.1.1 Structural Design

The structural design and design criteria for the NAC-UMS system are presented in Section 3.1 of the NAC-UMS FSAR, Reference F.7.2-1. The design criteria for environmental conditions and natural phenomena is presented in WCS SAR Appendix F.3. The following components are described and evaluated in FSAR Chapter 3: canister lifting devices; canister shell, bottom, and structural lid; canister shield lid support ring; fuel basket assembly; transfer cask trunnions, shells, retaining ring, bottom doors, and support rails; vertical concrete cask body; and concrete cask steel components - reinforcement, inner shell, lid, bottom plate, bottom, etc.

F.7.1.2 Weights and Centers of Gravity

The weights and centers of gravity (CGs) for the NAC-UMS system components are presented in Section 3.2 of the NAC-UMS FSAR, Reference F.7.2-1. The component weights and under-the-hook weights for the five system configurations are summarized in Tables 3.2-1 through 3.2-3 of the FSAR.

F.7.1.3 Mechanical Properties of Materials

The materials used in the fabrication of the NAC-UMS components and the mechanical properties of those materials are presented in Section 3.3 of the NAC-UMS FSAR, Reference F.7.2-1. The mechanical properties of the materials with respect to operating temperatures are tabulated in Tables 3.3-1 through 3.3-14 of the FSAR.

F.7.1.4 Chemical and Galvanic Reactions

The materials used in the fabrication and operation of the NAC-UMS are evaluated in Section 3.4.1 of the NAC-UMS FSAR, Reference F.7.2-1, to determine whether chemical, galvanic or other reactions among the materials, contents, and environments can occur Loading, unloading, handling, and storage operations are considered for the environments that may be encountered.

F.7.1.5 Positive Closure

The description and evaluation of the multi-pass welded closure of the NAC-UMS canister are presented in Section 3.4.2 of the NAC-UMS FSAR, Reference F.7.2-1.

F.7.1.6 Lifting Devices

The NAC-UMS system is designed to allow for efficient and safe handling of the system components at cask user facilities using various lifting and handling equipment. The NAC-UMS system lifting devices are described and evaluated in Section 3.4.3 of the NAC-UMS FSAR, Reference F.7.2-1. The structural evaluations consider the bounding conditions and define the acceptance criteria for each aspect of the analysis.

F.7.1.7 NAC-UMS Components Under Normal Operating Conditions

The evaluations of the NAC-UMS components under normal operating condition loads are provided in Section 3.4.4 of the NAC-UMS FSAR, Reference F.7.2-1. The evaluations presented in Section 3.4.4 are based on consideration of the bounding conditions for each aspect of the analysis.

F.7.1.8 Cold

As described in Section 3.4.5 of the NAC-UMS FSAR, Reference F.7.2-1, the evaluation for extreme cold environments for the NAC-UMS system is provided in Section 11.1.1 of Reference F.7.2-1. The structural evaluation of the canister and basket utilizes a finite element model that is described in Section 3.4.4 of Reference F.7.2-1. The off-normal cold condition thermal stresses in the canister are bounded by those of the extreme cold condition evaluated in Section 11.1.1. The canister and basket are fabricated from stainless steel and aluminum, which are not subject to a ductile-to-brittle transition in the temperature range of interest.

F.7.1.9 Fuel Rods

The NAC-UMS is designed to limit fuel cladding temperatures to levels below those where zirconium alloy degradation is expected to lead to fuel clad failure. The discussion of the fuel rods and their temperature limitations while stored in the NAC-UMS is presented in Section 3.5 of the NAC-UMS FSAR, Reference F.7.2-1. The fuel rod temperature evaluation(s) are presented in Section 4.1 of Reference F.7.2-1.

F.7.1.10 Coating Specifications

Coatings are applied to the exposed carbon steel surfaces associated with the NAC-UMS vertical concrete cask and transfer cask to protect those surfaces in their service environment. The coating specifications are provided in Section 3.8 of the NAC-UMS FSAR, Reference F.7.2-1.

Each coating meets the service and performance requirements that are established for the coating by the design and service environment of the component to be covered.

F.7.1.11 Structural Evaluation of NAC-UMS Canister Confinement Boundaries under Normal Conditions of Transport

The NAC-UMS canister primary confinement boundaries consist of a canister shell, bottom closure plate, shield lid, the two (2) port covers, and the welds that join these components. Redundant closure is provided by a structural lid and adjoining canister weld. Additional details, geometry and shell and plate thicknesses are provided on the drawings in Section F.4.3. The confinement boundary is addressed in Section F.11.1.1. NAC-UMS canister shell is evaluated for Normal Conditions of Transport in the NAC-UMS Transport cask in Section 2.6.12 of [F.7.2-3].

The result of the structural analysis is acceptable for the loads and combinations described in Section 2.6.12 of [F.7.2-3] and hence structurally adequate for normal conditions of transport loading conditions.

F.7.2 References

F.7.2-1 NAC-UMS Universal Storage System Final Safety Analysis Report, Revision 10, October 2012.

F.7.2-2 Amendment No. 5 to Certificate of Compliance No. 1015 for the NAC International, Inc., NAC-UMS Universal Storage System, January 12, 2008.

F.7.2-3 NAC-UMS Universal Transport Cask Safety Analysis Report, Revision 2, 2005.

APPENDIX F.8
THERMAL EVALUATION
NAC-UMS

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F.8 THERMAL EVALUATION

This appendix presents the thermal design and analyses of the NAC-UMS Universal Storage System (NAC-UMS) for normal, off-normal, and accident conditions of storage of spent nuclear fuel. The NAC-UMS is designed to safely store up to 24 PWR spent fuel assemblies. The NAC-UMS is designed to accommodate five different lengths of fuel assemblies - three PWR and two BWR. The NAC-UMS design basis heat load is 23.0 KW.

The thermal evaluation of the NAC-UMS for normal operating (maximum average yearly ambient temperature) conditions is presented in Section 4.4 of Reference F.8.2-1. The thermal evaluation of the NAC-UMS for off-normal operating (maximum average 3-day ambient temperature) conditions is presented in Section 11.1.1 of Reference F.8.2-1. The thermal evaluation of the NAC-UMS for extreme operating (maximum extreme 3-day ambient temperature) conditions is presented in Section 11.2.7 of Reference F.8.2-1.

The results of the above referenced analyses document that the NAC-UMS safely operates within allowable temperature limits for the defined site-specific environmental thermal parameters. These parameters are bounding for the NAC-UMS systems at the WCS facility. The following sections detail those defined site-specific environmental thermal parameters for the NAC-UMS and demonstrate that they bound the site-specific environmental thermal parameters defined for the WCS facility.

The NAC-UMS storage system may contain GTCC waste from Maine Yankee (GTCC-Canister-MY). The maximum GTCC waste heat generation allowed for transport in the NAC-UMS transportation cask for Maine Yankee is 4.5 kW. This heat load is well below the design basis heat load of 23.0 kW for the storage of PWR fuel. Therefore, the thermal analysis results for the storage of Maine Yankee PWR fuel is bounding. No further evaluation is required.

F.8.1 Maine Yankee

Chapter 4 of the NAC-UMS Final Safety Analysis Report (FSAR), Reference F.8.2-1, presents the thermal design conditions, the allowable component temperatures and the thermal evaluations for the operation of the NAC-UMS spent fuel storage system. The established bounding thermal environmental conditions are summarized in FSAR Table 4.1-1. The maximum allowable component material temperatures are tabulated in FSAR Table 4.1-3. The bounding thermal environmental conditions are described in the following paragraphs.

F.8.1.1 Maximum Average Yearly Ambient Temperature

This is a long-term storage condition that is analyzed in FSAR Section 4.4. The maximum average yearly ambient design temperature for the NAC-UMS is 76°F. The average yearly temperature for the site is conservatively bounded by using the maximum average annual temperature in the 48 contiguous United States, of 76°F. This temperature meets the normal condition thermal boundary defined in NUREG-1536. Therefore, no further WCS site-specific evaluations are required.

F.8.1.2 Maximum Average 3-Day Ambient Temperature

This is an off-normal severe heat condition that is analyzed in FSAR Section 11.1.1. The maximum average 3-day ambient temperature for the NAC-UMS is 106°F. This temperature bounds the WCS facility maximum average 3-day ambient temperature of *89.4*°F. Therefore, no further site-specific evaluations are needed.

F.8.1.3 Maximum Extreme 3-Day Ambient Temperature

This is an extreme heat accident condition that is analyzed in FSAR Section 11.2.7. *For the NAC-UMS, the maximum allowed temperature extremes, average over a 3-day period, shall be greater than -40°F and less than 133°F.* This bounds the WCS facility maximum temperature extreme of *-1*°F *and 113°F.* No further site-specific evaluations are needed.

F.8.2 References

F.8.2-1 NAC-UMS Universal Storage System Final Safety Analysis Report, Revision 10, October 2012.

F.8.2-2 Amendment No. 5 to Certificate of Compliance No. 1015 for the NAC International, Inc., NAC-UMS Universal Storage System, January 12, 2008.

APPENDIX F.9
RADIATION PROTECTION
NAC-UMS

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F.9 RADIATION PROTECTION

Chapter 5 of the NAC-UMS FSAR, Reference [F.9.2-1], provides the shielding evaluation of the NAC-UMS storage system. The NAC-UMS is designed to safely store up to 24 PWR spent fuel assemblies. The analysis of PWR spent fuel in the NAC-UMS vertical concrete cask and transfer cask is performed using the SAS4 code series. The MCBEND code is used to calculate dose rates at the concrete cask air inlets and outlets. Separate models are used for each of the fuel types.

The regulation governing spent fuel storage, 10 CFR 72, does not establish specific dose rate limits for individual casks in a storage cask array. However, 10 CFR 72.104 and 10 CFR 72.106 specify that for an array of casks in an Independent Spent Fuel Storage Installation (ISFSI), the annual dose to an individual outside the controlled area boundary must not exceed 25 mrem to the whole body, 75 mrem to the thyroid and 25 mrem to any other organ during normal operations. In the case of a design basis accident, the dose to an individual outside the controlled area boundary must not exceed 5 rem to the whole body. The ISFSI must be at least 100 meters from the owner controlled area boundary. In addition, the occupational dose limits and radiation dose limits for individual members of the public established in 10 CFR Part 20 (Subparts C and D) must be met. NAC-UMS FSAR, Reference [F.9.2-1], Chapter 10, Section 10.3, demonstrates NAC-UMS compliance with the requirements of 10 CFR 72 with regard to annual and occupational doses at the owner controlled area boundary. The NAC-UMS FSAR, Reference E.9-1, Chapter 5, presents the shielding evaluations of the NAC-UMS storage system. Dose rate profiles are calculated as a function of distance from the side, top and bottom of the NAC-UMS concrete cask and transfer cask. Shielded source terms from the NAC-UMS concrete cask are calculated to establish owner controlled area boundary dose estimates due to the presence of the ISFSI.

F.9.1 Maine Yankee

A discussion of the shielding evaluation of the NAC-UMS system containing PWR spent fuel assemblies and non-fuel hardware and a summary of the analysis results are presented in Section 5.1 of the NAC-UMS FSAR, Reference [F.9.2-1]. Analysis results are provided for the transfer cask and the vertical concrete cask. A description of the PWR fuel is presented in Section 5.1.1 of Reference [F.9.2-1]. The computer codes used in the NAC-UMS shielding analysis are defined in Section 5.1.2 of Reference [F.9.2-1]. A summary of the calculated dose rates for the NAC-UMS concrete cask and transfer cask are presented in Section 5.1.3 of Reference [F.9.2-1]. The shielding evaluation for the Maine Yankee site-specific spent fuel is presented in Section 5.6.1 of Reference [F.9.2-1].

The NAC-UMS storage system is comprised of a transportable storage canister, a transfer cask (standard or advanced configuration), and a vertical concrete storage cask. Canister handling, fuel loading, and canister closing are operationally identical for both transfer cask configurations. License drawings for these components are provided in Section *F.4.3*. The transfer cask is used to move a loaded canister to, or from, the concrete storage cask and may be used to move a loaded canister to, or from, a transport cask. Shielding evaluations are performed for the storage cask with the canister cavity dry.

F.9.1.1 NAC-UMS System Shielding Discussion

The standard and advanced configuration transfer casks have a radial shield comprised of 0.75 inch of low alloy steel, 4.00 inches of lead, 2.75 inches of solid borated polymer (NS-4-FR), and 1.25 inches of low alloy steel. The 0.625-inch thick stainless steel canister shell provides additional radial shielding. Gamma shielding is primarily provided by the steel and lead, and neutron shielding is provided primarily by the NS-4-FR. The transfer cask bottom shield design is a solid section of 7.5-inch thick low alloy steel and a 1.5-inch thickness of NS-4-FR. The transfer cask top shielding is provided by the stainless steel shield and structural lids of the canister, which are 7 inches and 3 inches thick, respectively. The advanced transfer cask incorporates a trunnion support plate that allows it to lift a heavier canister. The support plate has no significant shielding effect due to its location above the trunnion. The evaluations and results provided for the standard transfer cask are, therefore, applicable to the advanced transfer cask.

The vertical concrete cask radial shield design is comprised of a 2.5-inch thick carbon steel inner liner surrounded by 28.25 inches of concrete. Gamma shielding is provided by both the carbon steel and the concrete. Neutron shielding is primarily provided by the concrete. As in the transfer cask, an additional 0.625-inch thickness of stainless steel radial gamma shielding is provided by the canister shell. The concrete cask top shielding design is comprised of 10 inches of stainless steel i.e., the canister lids, a shield plug containing either a 1-inch thickness of NS-4-FR or 1.5 inches of NS-3 together with 4.1 inches of carbon steel, and a 1.5-inch thick carbon steel lid. Since the bottom of the concrete cask rests on a concrete pad, the cask bottom shielding is comprised of 1.75 inch of stainless steel (canister bottom plate), 2 inches of carbon steel (pedestal plate) and 1 inch of carbon steel (concrete cask base plate). The concrete cask base plate and pedestal base are structural components that position the canister above the air inlets. The cask base plate supports the concrete cask during lifting, and forms the cooling air inlet channels at the cask bottom. An optional carbon steel supplemental shielding fixture, shown in Drawing 790-613, may be installed to reduce the radiation dose rates at the air inlets.

F.9.1.2 NAC-UMS System Shielding Radiation Sources

The NAC-UMS storage system accommodates up to 24 PWR fuel assemblies with a maximum of 40,000 MWd/MTU burnup, an initial enrichment of 3.7 wt % ^{235}U and a minimum 5-year cool time. Westinghouse 17 x 17 fuel with this burnup and cool time is defined as the design basis fuel. The physical parameters of the PWR fuel assemblies are presented in Table 5.2-2 of the NAC-UMS FSAR, Reference [F.9.2-1].

A canister may contain spent fuel configurations that are unique to specific reactor sites. These site-specific fuel configurations result from conditions that occurred during reactor operations, participation in research and development programs, or testing programs intended to improve reactor operations. Site specific fuel configurations include standard fuel with inserted non fuel-bearing components, fuel assemblies with missing or replaced fuel rods or poison rods, fuel assemblies unique to the reactor design, fuel with a parameter that exceeds the design basis parameter, such as enrichment or burnup, consolidated fuel and fuel that is classified as damaged. Site-specific fuel configurations are either shown to be bounded by the analysis of the standard design basis fuel assembly configuration of the same type (PWR or BWR), or are shown to be acceptable contents by specific evaluation of the configuration. This shielding analysis considers both assembly fuel sources and sources from activated non-fuel material such as control element assemblies (CEA), in-core instrument (ICI) segments, and fuel assemblies containing activated stainless steel replacement (SSR) rods and other non-fuel material, including neutron sources. It considers the consolidated fuel, damaged fuel, and fuel debris present in the Maine Yankee spent fuel inventory, in addition to those fuel assemblies having a burnup between 45,000 and 50,000 MWd/MTU.

The Maine Yankee spent fuel inventory also contains fuel assemblies with hollow zirconium alloy tubes, removed fuel rods, axial blankets, poison rods, variable radial enrichment, and low enriched substitute rods. These components do not result in additional sources to be considered in shielding evaluations and are, therefore, enveloped by the standard fuel assembly evaluation.

F.9.1.3 NAC-UMS System Shielding Analysis and Results

Shielding evaluations of the NAC-UMS transfer cask and storage cask are performed with SCALE 4.3 for the PC (ORNL) and MCBEND (Serco Assurance). In particular, the SCALE shielding analysis sequence SAS2H is used to generate source terms for the design basis fuel. SAS1 is used to perform one-dimensional radial and axial shielding analysis. MCBEND is used to perform the three-dimensional shielding analysis of the storage cask, and a modified version of SAS4 is used to perform the three-dimensional shielding analysis of the transfer cask. The SCALE 4.3 SAS4 code sequence has been modified to allow multiple surface detectors; the new code sequence is entitled SAS4A. The use of the surface subdetectors enables the user to obtain surface profiles of the detector response and the surface tallies on the cask surfaces other than the cask shield. Dose tally routines are modified to accept user-defined surface detectors instead of the fixed surfaces detectors in SCALE 4.3 SAS4. The Code modifications were tested against the SCALE 4.3 manual and NAC test cases. Reliability of the subdetectors was verified by comparison to point detector results. The 27-group neutron, 18 group gamma, coupled cross section library (27N-18COUPLE) based on ENDF/B-IV is used in all SCALE shielding evaluations. Source terms include: fuel neutron, fuel gamma, and activated hardware gamma. Dose rate evaluations include the effect of fuel burnup peaking on fuel neutron and gamma source terms.

Dose rate profiles are shown for PWR fuel for the storage cask and transfer cask in Section 5.4.3.1 and 5.4.3.2, respectively, of the NAC-UMS FSAR, Reference [F.9.2-1]. Maximum dose rates for the storage cask under normal and accident conditions are shown in Table 5.1-1 of Reference [F.9.2-1], for design basis PWR fuel. The dose rates are based on three-dimensional Monte Carlo and one-dimensional discrete ordinates calculations. Monte Carlo error (1σ) is indicated in parenthesis. In normal conditions with design basis intact PWR fuel, the storage cask maximum side dose rate is 49 (<1%) mrem/hr at the fuel midplane and 56 (6%) mrem/hr on the top lid surface above the air outlets. The average dose rates on the side and top of the cask are 38 (<1%) and 27 (2%) mrem/hr, respectively. Since the storage cask is vertical during normal storage operation, the bottom is inaccessible. The maximum surface dose rate at the lower air inlet openings is 136 (1%) mrem/hr with supplemental shielding and 694 (<1%) mrem/hr without supplemental shielding. The maximum surface dose rate at the air outlet openings is 63 (1%) mrem/hr. Under accident conditions involving a projectile impact and a loss of 6 inches of concrete, the surface dose rate increases to 250 mrem/hr at the impact location with design basis PWR fuel. There are no design basis accidents that result in a tip-over of the NAC-UMS concrete storage cask.

Maximum dose rates for the standard or advanced transfer cask with a wet and dry canister cavity are shown in Table 5.1-3 of Reference F.9.2-1, for design basis PWR fuel. Under wet canister conditions, the maximum surface dose rates with design basis PWR fuel are 259 (<1%) mrem/hr on the cask side and 579 (<1%) mrem/hr on the cask bottom. The cask side average surface dose rate under wet conditions is 137 (<1%) mrem/hr, and the bottom average surface dose rate is 258 (<1%) mrem/hr. Under dry conditions, the maximum surface dose rates are 410 (<1%) mrem/hr on the cask side and 819 (<1%) mrem/hr on the cask bottom. Cask average surface dose rates are 306 (<1%) mrem/hr on the side and 374 (<1%) mrem/hr on the bottom. In normal operation, the bottom of the transfer cask is inaccessible during welding of the canister lids.

Maine Yankee Site-Specific fuel assembly configurations are either shown to be bounded by the analysis of the standard design basis fuel assembly configuration of the same type (PWR or BWR), or are shown to be acceptable contents by specific evaluation of the configuration.

Table F.9-1 provides estimated occupational exposures for receipt and handling of the NAC-UMS system loaded with PWR fuel at the WCS CISF facility. For each procedural step the number of workers, occupancy time, worker distance, dose rates, and total dose are estimated. Dose rates used were obtained and estimated via the listed references in the table. The total occupational exposure for receiving, transferring and placing these canisters on the storage pad in their storage overpack (VCC) is 864 person-mrem each.

The total collective dose for unloading a NAC-UMS PWR canister from its VCC and preparing it for transport off-site is bounded by the loading operations (864 person-mrem). Operations for retrieving these canisters from the VCC 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 1,728 person-mrem.

F.9.2 References

F.9.2-1 NAC-UMS Universal Storage System Final Safety Analysis Report, Revision 10, October 2012.

F.9.2-2 Amendment No. 5 to Certificate of Compliance No. 1015 for the NAC International, Inc., NAC-UMS Universal Storage System, January 12, 2008.

***Table* F.9-1**
Estimated Occupational Collective Dose for Receipt of NAC Universal Transport Cask Loaded with PWR SNF in Class 1 or 2 TSC and Transfer to UMS Class 1 or Class 2 VCC
6 Sheets

Process Step	***Number of Workers***	***Occupancy Time (hours)***	***Worker Location Around Cask***	***Worker Distance (m)***	***Total Dose Rate (mrem/hr)***	***Total Dose (person-mrem)***[1]	***Reference SAR/FSAR Section/Table/Figure***
Perform radiation and contamination survey of UTC	*2*	*0.25*	*All Around UTC Cask*	*>2*	*10*	*5*	*SAR Figure 5.1-1 and Table 5.1-1*
Inspect top and bottom impact limiter security seals and verify they are intact and correct IDs.	*1*	*0.5*	*Top and Bottom Impact Limiters*	*>1*	*<6*	*3*	*SAR Figure 5.1-1 and Table 5.1-1*
Remove Personnel Barrier and complete surveys	*2*	*0.5*	*Center of cask*	*>1*	*<20*	*20*	*SAR Figure 5.1-1 and Table 5.1-1*
Visually inspect UTC Cask surface for transport/road damage and record	*1*	*0.25*	*All Around UTC Cask*	*2*	*10*	*3*	*SAR Figure 5.1-1 and Table 5.1-1*
Attach slings to top Impact Limiter and remove attachment nuts/rods. Remove and store Impact Limiter. Remove and store front impact limiter positioner and screws.	*2*	*1*	*Top Impact Limiter Surface of UTC*	*1*	*< 1*	*2*	*SAR Figure 5.1-1 and Table 5.1-1*
Attach slings to bottom Impact Limiter and remove attachment nots/rods. Remove and store Impact Limiter. Remove and store bottom impact limiter positioner and screws.	*2*	*1*	*Bottom Impact Limiter Surface of UTC*	*1*	*6*	*12*	*SAR Figure 5.1-1 and Table 5.1-1*
Release Front Tie-Down Assembly	*2*	*1*	*Top Side UTC Surface*	*>1*	*50*	*100*	*SAR Figure 5.1-1 and Table 5.1-1*

Table F.9-1
Estimated Occupational Collective Dose for Receipt of NAC Universal Transport Cask Loaded with PWR SNF in Class 1 or 2 TSC and Transfer to UMS Class 1 or Class 2 VCC
6 Sheets

Process Step	Number of Workers	Occupancy Time (hours)	Worker Location Around Cask	Worker Distance (m)	Total Dose Rate (mrem/hr)	Total Dose (person-mrem)[1]	Reference SAR/FSAR Section/Table/Figure
Engage Vertical Cask Transporter (VCT) Lift Arms to Primary Front Trunnions and rotate cask to vertical orientation	*2*	*1*	*Top Side UTC Surface*	*>2*	*10*	*20*	*SAR Figure 5.1-1 and Table 5.1-1*
Lift and Remove UTC from the Transport Skid Rear Rotation Trunnions and move cask to gantry Canister Transfer Facility (CTF), set cask down and release VCT Lift Arms. Establish Radiation Control boundaries.	*2*	*2*	*Top Side UTC Surface*	*>2*	*10*	*40*	*SAR Figure 5.1-1 and Table 5.1-1*
Using VCT, move empty UMS VCC (Class 1 or 2, as required) to transfer position in CTF and set down adjacent to UTC cask. Set up appropriate work platforms/man lifts for access to top of VCC and UTC.	*2*	*1*	*Top of Empty VCC*	*>2*	*0*	*0*	*Empty VCC*
Remove VCC Lid and bolts, and VCC Shield Plug.	*2*	*1*	*Top of Empty VCC*	*1*	*0*	*0*	*Empty VCC*
Install Transfer Adapter on VCC and connect hydraulic system.	*2*	*1*	*Top of Empty VCC*	*1*	*0*	*0*	*Empty VCC*

***Table* F.9-1**
Estimated Occupational Collective Dose for Receipt of NAC Universal Transport Cask Loaded with PWR SNF in Class 1 or 2 TSC and Transfer to UMS Class 1 or Class 2 VCC
6 Sheets

Process Step	***Number of Workers***	***Occupancy Time (hours)***	***Worker Location Around Cask***	***Worker Distance (m)***	***Total Dose Rate (mrem/hr)***	***Total Dose (person-mrem)[1]***	***Reference SAR/FSAR Section/Table/Figure***
Remove vent port cover and connect pressure test system to vent port to check for excessive pressure. If pressure is high, take sample and check. If clean vent to HEPA filter.	*1*	*0.5*	*Top of UTC*	*0.5*	*50*	*25*	*FSAR Table 5.1-3, FSAR Section 5.1.3.1 + UTC Closure Lid Thickness 6.5-inch SS*
Remove 48 UTC lid bolts, install alignment pins and lid lifting hoist rings/slings and remove inner lid and store. Remove alignment pins.	*2*	*1*	*Top of UTC*	*0.5*	*30*	*60*	*FSAR Table 5.1-3, FSAR Section 5.1.3.1 + UTC Closure Lid Thickness 6.5-inch SS Perform operation from side of UTC cask*
Install adapter ring to inner lid recess and torque captured bolts.	*2*	*0.5*	*Top of UTC*	*0.5*	*30*	*30*	*FSAR Table 5.1-3, and FSAR Section 5.1.3.1. Perform operation from side of UTC cask*
Install transfer adapter plate on adapter ring and install and torque the four transfer adapter plate bolts.	*2*	*1*	*Top of UTC*	*1*	*15*	*30*	*FSAR Table 5.1-3, and FSAR Section 5.1.3.1. Perform operation from side of UTC cask*
Install TSC Lid Lifting Adapter Plate on the Structural Lid.	*2*	*1*	*Top of UTC*	*0.5*	*60*	*120*	*FSAR Table 5.1-3, and FSAR Section 5.1.3.1. Perform operation from side of UTC cask*
Using the CTF crane, lower the appropriate MPC Transfer Cask (TFR) and set it down on the transfer adapter on the UTC Cask.	*2*	*1.5*	*Top of UTC*	*>4*	*<1*	*3*	*Remote handling operation*

***Table* F.9-1**
Estimated Occupational Collective Dose for Receipt of NAC Universal Transport Cask Loaded with PWR SNF in Class 1 or 2 TSC and Transfer to UMS Class 1 or Class 2 VCC
6 Sheets

Process Step	***Number of Workers***	***Occupancy Time (hours)***	***Worker Location Around Cask***	***Worker Distance (m)***	***Total Dose Rate (mrem/hr)***	***Total Dose (person-mrem)***[1]	***Reference SAR/FSAR Section/Table/Figure***
Remove the TFR shield door lock pins and open shield doors with hydraulic system.	*1*	*0.5*	*Top of UTC*	*1*	*15*	*8*	*SAR Figure 5.1-1 and Table 5.1-1 and FSAR Table 5.1-3, and FSAR Section 5.1.3.1. Perform operation from side of TFR and UTC cask*
Using the CTF, lower the Air-Powered Chain Hoist hook through the TFR and engage to the TSC Lift Adapter Plate.	*2*	*1.5*	*Remote Operating Location*	*>4*	*<5*	*15*	*Remote operation using CTF mounted cameras*
Using the Chain Hoist System slowly lift the TSC into the TFR.	*2*	*1*	*Remote Operating Location*	*>4*	*<5*	*10*	*Remote operation using CTF mounted cameras*
Close the TFR shield doors and install lock pins.	*1*	*0.5*	*Bottom of TFR*	*0.5*	*30*	*15*	*Operation from side of TFR. FSAR Section 5.4, Table 5.1-3 and Figure 5.4-11*
Lower the TSC onto the shield doors and using the CTF, lift the TFR off of the UTC transfer adapter plate.	*2*	*1*	*Remote Operating Location*	*>4*	*<5*	*10*	*Remote operation using CTF mounted cameras*
Move the TFR over the VCC and lower onto the VCC transfer adapter plate.	*1*	*1*	*Remote Operating Location*	*>4*	*<5*	*5*	*Remote operation using CTF mounted cameras*
Remove the TFR shield door lock pins.	*1*	*0.5*	*Bottom of TFR*	*0.5*	*30*	*15*	*Operation from side of TFR FSAR Section 5.4, Table 5.1-3 and Figure 5.4-11*

***Table* F.9-1**
Estimated Occupational Collective Dose for Receipt of NAC Universal Transport Cask Loaded with PWR SNF in Class 1 or 2 TSC and Transfer to UMS Class 1 or Class 2 VCC
6 Sheets

Process Step	***Number of Workers***	***Occupancy Time (hours)***	***Worker Location Around Cask***	***Worker Distance (m)***	***Total Dose Rate (mrem/hr)***	***Total Dose (person-mrem)[1]***	***Reference SAR/FSAR Section/Table/Figure***
Using the Chain Hoist System, lift the TSC off of the shield doors and open the shield doors.	*2*	*0.5*	*Remote Operating Location*	*>4*	*<5*	*5*	*Remote operation using CTF mounted cameras*
Using the chain hoist lower the TSC into the VCC.	*2*	*1*	*Remote Operating Location*	*>4*	*<5*	*10*	*Remote operation using CTF mounted cameras*
Release chain hoist system hook from the TSC Lift Adapter Plate and retract chain hoist hook through the TFR.	*1*	*0.5*	*Remote Operating Location*	*>4*	*<5*	*3*	*Remote operation using CTF mounted cameras*
Close TFR shield doors and install lock pins.	*1*	*0.5*	*Bottom of TFR*	*0.5*	*30*	*15*	*Operation from top of VCC. FSAR Section 5.4, Table 5.1-3 and Figure 5.4-5*
Using the CTF, lift and remove the TFR from the top of the VCC.	*1*	*0.5*	*Remote Operating Location*	*>4*	*<5*	*3*	*Remote operation using CTF mounted cameras*
Using mobile crane, remove transfer adapter plate from VCC and store.	*2*	*1*	*Top of VCC*	*1*	*10*	*20*	*Remote operation using CTF mounted cameras after connection of lifting slings*
Unbolt and remove TSC Lift Adapter Plate from the top of the TSC and store.	*2*	*1*	*Top of TSC*	*1*	*75*	*150*	*Operation performed on top of VCC Figure 5.4-5*

Table F.9-1
Estimated Occupational Collective Dose for Receipt of NAC Universal Transport Cask Loaded with PWR SNF in Class 1 or 2 TSC and Transfer to UMS Class 1 or Class 2 VCC
6 Sheets

Process Step	*Number of Workers*	*Occupancy Time (hours)*	*Worker Location Around Cask*	*Worker Distance (m)*	*Total Dose Rate (mrem/hr)*	*Total Dose (person-mrem)*[1]	*Reference SAR/FSAR Section/Table/Figure*
Install the VCC Shield Plug.	*2*	*0.5*	*Top of VCC*	*1*	*25*	*35*	*Operation performed on top of VCC Figure 5.4-5*
Install and bolt in place the VCC lid.	*2*	*1*	*Top of VCC*	*1*	*25*	*50*	*Operation performed on top of VCC Figure 5.4-5*
Using the VCT, lift and move loaded UMS VCC and position it in the designated storage location.	*2*	*1*	*VCT Platform*	*>4*	*10*	*20*	*Operation performed from VCT and FSAR Figure 5.4-2*
Remove installed transport cavity spacer and place in approved IP-1 container. Prepare empty UTC cask for empty return transport. Transfer and rotate UTC on the transport/shipping frame. Install transport tie-downs and impact limiters.	*3*	*9*	*CTF/VCT/Rail Car*	*1 to 4*	*0*	*0*	*Empty cask preparation activities*
					Total (person-mrem)	*864*	

Note:
1. *Rounded up to the nearest whole number*

APPENDIX F.10
CRITICALITY EVALUATION
NAC-UMS

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F.10 CRITICALITY EVALUATION

Chapter 6 of Reference F.10.2-1 provides the criticality evaluation of the NAC-UMS storage system and demonstrates that the NAC-UMS storage system is subcritical in accordance with the requirements of 10 CFR 72.124(a), 10 CFR 72.236(c) and Chapter 6 of NUREG-1536. The evaluations show that the effective neutron multiplication factor of the NAC-UMS system is less than 0.95, including biases and uncertainties under normal, off-normal and accident conditions.

The NAC-UMS Universal Storage System consists of a transportable storage canister, a transfer cask and a vertical concrete storage cask. The canister includes a stainless steel canister and a basket. The basket consists of fuel tubes held in place with stainless steel support disks and tie rods. The transfer cask containing the canister and basket is loaded underwater in the spent fuel pool. Once loaded with fuel, the canister is drained, dried, inerted, and welded closed. The transfer cask is then used to transfer the canister into and out of the concrete storage cask where it is stored until transported off-site.

Under normal conditions, such as loading in a spent fuel pool, moderator (water) is present in the canister while it is in the transfer cask. Also, during draining and drying operations, moderator with varying density is present. Thus, the criticality evaluation of the transfer cask includes a variation in moderator density and a determination of optimum moderator density. Off-normal and accident conditions are bounded by assuming the most reactive mechanical basket configuration as well as moderator intrusion into the fuel cladding (i.e., 100% fuel failure).

Under normal and accident storage conditions, moderator is not present in the canister while it is in the concrete cask. However, access to the environment is possible via the air inlets in the concrete cask and the convective heat transfer annulus between the canister and the concrete cask steel liner. This access provides paths for moderator intrusion during a flood. Under off-normal conditions, moderator intrusion into the convective heat transfer annulus is evaluated. For the initial evaluation without soluble boron credit, under hypothetical accident conditions, it is assumed that the canister confinement fails, and moderator intrusion into the canister and into the fuel cladding (100% fuel failure) is evaluated. This is a conservative assumption, since normal, off-normal and design basis accident analysis shows that the confinement boundary remains undamaged.

The NAC-UMS system is designed to safely store up to 24 PWR fuel assemblies or 56 BWR fuel assemblies. Primarily on the basis of their lengths and cross-sections, the fuel assemblies are categorized into classes: three classes of PWR fuel assemblies and two classes of BWR fuel assemblies. Thus, five transportable storage canisters of different lengths are designed to store the three classes of PWR fuel assemblies and the two classes of BWR fuel assemblies. There are corresponding differences in the principal dimensions and weights of the transfer casks and vertical concrete casks used with each of the NAC-UMS storage systems.

The NAC-UMS spent fuel loading is summarized in the NAC-UMS FSAR (Reference 10.2-1), Section 6.2, with the criticality calculation methodology and the analytical models described in FSAR Section 6.3. The criticality analysis results are presented in Section 6.4. The criticality evaluation for the Maine Yankee site-specific spent fuel is presented in FSAR Section 6.6.

F.10.1 Maine Yankee

The SCALE 4.3 PC CSAS25 sequence and the SCALE 27-group neutron library are used to perform the criticality analysis of the Universal Storage System. These conservative assumptions are incorporated into the criticality analyses:

1. No fuel burnup (fresh fuel assumption).
2. No fission product build up as a poison.
3. Fuel assemblies of the most reactive type.
4. UO_2 fuel density at 95% of theoretical.
5. No dissolved boron in the spent fuel pool water (water temperature 293°K).
6. Infinite cask array.
7. Moderator intrusion into the intact fuel rod clad/pellet gap under accident conditions.
8. A most reactive mechanical configuration.

In addition, consistent with Section 6, Part IV of NUREG-1536, 75% of the specified minimum ^{10}B density in the BORAL plates is assumed.

F.10.1.1 NAC-UMS System Criticality Discussion

The SCALE 4.3 PC CSAS25 sequence and the SCALE 27-group neutron library are used to perform the criticality analysis of the Universal Storage System. This sequence includes the SCALE Material Information Processor, BONAMI-S, NITAWL-S, and KENO-Va. The KENO-Va code uses Monte Carlo techniques to calculate k_{eff}. The 27-group ENDF/B-IV group neutron library is used in all cask criticality calculations. Assembly specific maximum enrichment level determinations, with and without soluble boron, are performed with the ANSWERS MONK8A code. The MONK8A (AEA Technology) Monte Carlo Program for Nuclear Criticality Safety Analysis employs the Monte Carlo technique in combination with JEF 2.2-based point energy neutron libraries to determine the effective neutron multiplication factor (k_{eff}). CSAS with the 27-group library is benchmarked by comparison to 63 critical experiments relevant to Light Water Reactor fuel in storage and transport casks.

Criticality control in the NAC-UMS PWR fuel basket is achieved by using a flux trap, or a combination flux trap and soluble neutron absorber (boron). Individual fuel assemblies are held in place by fuel tubes surrounded by four neutron absorber sheets. The neutron absorber modeled is a borated aluminum neutron absorber. Any similar material meeting the ^{10}B areal density and physical dimension requirement will produce similar reactivity results. A welded stainless steel cover holds the neutron absorber sheets in place. The fuel tubes are separated by a gap that is filled with water when the canister is flooded. Fast neutrons escaping one fuel assembly are moderated in the water gap and are absorbed by the neutron absorber between the assemblies before they can cause a fission in the adjacent assembly. The flux trap gap spacing is maintained by the basket's stainless steel support disks, which separate individual fuel assembly tubes. Alternating stainless steel disks and aluminum heat transfer disks are placed axially at intervals determined by thermal and structural constraints. The PWR basket design includes 30, 32, or 34 support disks and 29, 31, or 33 heat transfer disks, respectively. The minimum loading of the neutron absorber sheets in the PWR fuel tubes is 0.025 g $^{10}B/cm^2$. To reach higher initial enrichments than those allowed by using only the flux trap for criticality control, a separate evaluation, including soluble boron at 1000 ppm in the moderator, is performed. The soluble boron absorbs thermal neutrons inside the assembly, as well as in the flux traps. In combination with the flux traps and fixed neutron poison, the soluble boron allows loading of PWR fuel assemblies with an initial enrichment up to 5.0 wt. % ^{235}U.

F.10.1.2 NAC-UMS System Criticality Analysis and Results

Criticality evaluations are performed for both the transfer and storage casks under normal, off-normal and accident conditions applying the conservative conditions and assumptions described in Section 6.1 of the NAC-UMS FSAR, Reference F.10.2-1. As specified, these evaluations consider the most reactive fuel assembly type, worst case mechanical basket configuration and variations in moderator density. The maximum effective neutron multiplication factor with bias and uncertainties for the transfer cask is 0.93921. The maximum multiplication factor with bias and uncertainties for the storage cask is 0.38329 under normal dry storage conditions and 0.94704 under the hypothetical accident conditions involving full moderator intrusion.

Analysis of simultaneous moderator density variation inside and outside either the transfer or concrete casks shows a monotonic decrease in reactivity with decreasing moderator density. Thus, the full moderator density condition bounds any off-normal or accident condition. Analysis of moderator intrusion into the concrete cask heat transfer annulus with the dry canister shows a slight decrease in reactivity from the completely dry condition.

F.10.2 **References**

F.10.2-1 NAC-UMS Universal Storage System Final Safety Analysis Report, Revision 10, October 2012.

F.10.2-2 Amendment No. 5 to Certificate of Compliance No. 1015 for the NAC International, Inc., NAC-UMS Universal Storage System, January 12, 2008.

APPENDIX F.11
CONFINEMENT EVALUATION
NAC-UMS

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F.11 CONFINEMENT EVALUATION

The NAC-UMS storage system is provided in two configurations, PWR – 3 different lengths and BWR – 2 different lengths. The NAC-UMS provides storage for up to 24 PWR spent fuel assemblies or up to 56 BWR spent fuel assemblies. These configurations of the NAC-UMS have similar components and operating features, but have different physical dimensions, weights and storage capacities.

Confinement features for the NAC-UMS system are addressed in the main body of Chapter 7 of the NAC-UMS FSAR, Reference F.11.2-1. *Figures illustrating the confinement boundary for the NAC-UMS are found in Figures 7.1-1 and 7.1-2 or Reference F.11-1.*

The codes and standards for the design, fabrication, and inspection of the canister and confinement boundary are detailed in Reference F.11-2. Specifically, Appendix B, Section B 3.3, "Codes and Standards," which states the ASME Code, 1995 Edition with Addenda through 1995, is the governing Code for the NAC-UMS canister and Section B 3.3.1, "Exception to Codes, Standards, and Criteria," which lists the Code exception for the canister in Table B3-1. Included in this table is the leaktight criterion of ANSI N14.5 for the canister.

Appendix A, Section A 3.1, "NAC-UMS System Integrity," of Reference F.11.2, includes limiting condition for operations (LCO) 3.1.1 for canister maximum vacuum drying time, LCO 3.1.2 for canister vacuum drying pressure, and LCO 3.1.3 for canister helium backfill pressure. These LCOs create a dry, inert, leaktight atmosphere, which contributes to preventing the leakage of radioactive material.

The confinement features of the NAC-UMS system for PWR fuel are such that the potential for canister leakage is not credible. Similarly, the storage of reactor generated GTCC waste from Maine Yankee within a welded closed GTCC-Canister-MY does not present the potential for a credible leakage path. In addition, GTCC waste is a non-gas generation media. Thus, there is no means of dispersal from the GTCC-Canister-MY.

F.11.1 Maine Yankee

The Transportable Storage Canister (canister) provides long-term storage confinement of the NAC-UMS spent fuel. The canister confinement boundary is closed by welding, which is a leaktight barrier to the release of contents in all of the evaluated normal, off-normal and accident conditions. The method of closing the confinement boundary is the same for both PWR and BWR configurations.

The NAC-UMS canister is backfilled with an inert gas (helium). The confinement boundary retains the helium and prevents the entry of outside air into the NAC-UMS canister. The exclusion of air precludes degradation of the fuel rod cladding due to cladding oxidation failures over time. The helium purity level of at least 99.9% maintains the quantity of oxidizing contaminant to less than one mole per canister for all loading conditions. Conservatively, assuming that all of the impurities in 99.9% pure helium are oxidents, a maximum of 0.3 moles of oxidants could exist in the NAC-UMS canister during storage. By limiting the amount of oxidants to less than one mole, the recommended limits for preventing cladding degradation (Pacific Northwest Laboratory, "Evaluation of Cover Gas Impurities and Their Effects on the Dry Storage of LWR Spent Fuel," PNL-6365) are satisfied.

The NAC-UMS canister confinement system meets the requirements of 10 CFR 72.24 for protection of the public from release of radioactive material, and 10 CFR 72.122 for protection of the spent fuel contents in long-term storage such that future handling of the contents would not pose an operational safety concern. Maine Yankee site-specific spent fuel is stored in the NAC-UMS canister. As discussed in NAC-UMS FSAR (Reference F.11.2-1) Section 4.5.1, the Maine Yankee site-specific fuel configurations do not result in a canister pressure, or temperature, that exceeds the canister design basis. Therefore, there is no credible leakage from a canister containing Maine Yankee site-specific spent fuel.

F.11.1.1 Confinement Boundary

The confinement boundary is described in detail for the NAC-UMS in Section 7.1 of the NAC-UMS FSAR, Reference F.11.2-1. Specific details for the confinement vessel, confinement penetrations, seals & welds, and closure are in Sections 7.1.1, 7.1.2, 7.1.3, and 7.1.4, respectively. *In addition, a bounding evaluation in Section F.7.1.11 is presented to demonstrate that the confinement boundary for the NAC-UMS canister 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.*

F.11.1.2 Confinement Requirements for Normal Conditions of Storage

The confinement requirements for normal conditions of storage are described in detail in Section 7.2 of the NAC-UMS FSAR, Reference F.11.2-1. Specific details on the release of radioactive materials and pressurization of the confinement vessel are in Sections 7.2.1 and 7.2.2, respectively.

F.11.1.3 Confinement Requirements for Hypothetical Accident Conditions

The confinement requirements for hypothetical accident conditions are described in detail in Section 7.3 of the NAC-UMS FSAR, Reference F.11.2-1.

F.11.2 References

F.11-1 NAC-UMS Universal Storage System Final Safety Analysis Report, Revision 10, October 2012.

F.11-2 Amendment No. 5 to Certificate of Compliance No. 1015 for the NAC International, Inc., NAC-UMS Universal Storage System, January 12, 2008.

APPENDIX F.12
ACCIDENT ANALYSIS
NAC-UMS

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F.12 ACCIDENT ANALYSIS

The analyses of the off-normal and accident design events, including those identified by ANSI/ANS 57.9-1992, are presented in Chapter 11 of the NAC-UMS FSAR, Reference F.12.2-1. Section 11.1 of the FSAR addresses the off-normal events that could occur during the use of the NAC-UMS storage system, possibly as often as once per calendar year. Section 11.2 of the FSAR addresses very low probability events that might occur once during the lifetime of the ISFSI or hypothetical events that are postulated because their consequences may result in the maximum potential effect on the surrounding environment. Section 11.2.14 of the FSAR describes the canister closure weld evaluation for the NAC-UMS transportable storage canister. Section 11.2.15 of the FSAR presents the evaluation of accident and natural phenomena events for site-specific spent fuel, including Maine Yankee site-specific spent fuel. Section 11.2.16 presents the structural evaluation of fuel rods for burnup to 60,000 MWd/MTU.

The analyses presented in Chapter 11 of the NAC-UMS FSAR, Reference F.12.2-1, demonstrates that the NAC-UMS satisfies the requirements of 10 CFR 72.24 and 10 CFR 72.122 for off-normal and accident conditions. These analyses are based on conservative assumptions to ensure that the consequences of off-normal conditions and accident events are bounded by the reported results. The actual response of the NAC-UMS system to the postulated events will be much better than that reported, i.e., stresses, temperatures, and radiation doses will be lower than predicted. If required for a site-specific application, a more detailed evaluation could be used to extend the limits defined by the events evaluated in this section.

The NAC-UMS is provided in two configurations – PWR (3 lengths) and BWR (2 lengths). The PWR configuration is designed to store up to 24 spent fuel assemblies. The BWR configuration is designed to store up to 56 fuel assemblies.

The off-normal and accident conditions evaluation for the PWR and the BWR configurations are presented separately, when appropriate, due to differences in capacity, weight and principal dimensions.

For the storage of reactor generated GTCC waste previously loaded at Maine Yankee (GTCC-Canister-MY), the accident analyses for the storage of NAC-UMS PWR fuel bounds the storage of Maine Yankee GTCC waste. The GTCC-Canister-MY and concrete overpacks are similar in design to the PWR fuel canisters and overpacks and the storage heat load for GTCC waste is significantly below that of the stored spent nuclear fuel.

F.12.1 Maine Yankee

The following sections describe the off-normal conditions and accident events evaluated for the NAC-UMS storage system. Evaluations related to site-specific fuel are located in Section 11.2.15 of the NAC-UMS FSAR, Reference F.12.2-1.

F.12.1.1 Off-Normal Events

Section 11.1 of the NAC-UMS FSAR, Reference F.12.2-1, evaluates postulated events that might occur once during any calendar year of storage system operations. The actual occurrence of any of these events is unlikely. The off-normal condition evaluation for the bounding configuration is presented to address differences in capacity, weight, and principal dimensions.

The following off-normal events are evaluated in the NAC-UMS FSAR. Each off-normal event listed includes the identification of the FSAR section in which it is presented.

1. Severe Ambient Temperature Conditions (106°F and -40°F) – Section 11.1.1
2. Blockage of Half of the Air Inlets – Section 11.1.2
3. Off-Normal Canister Handling Load – Section 11.1.3
4. Failure of Instrumentation – Section 11.1.4
5. Small Release of Radioactive Particulate from the Canister Exterior - Section 11.1.5
6. Off-Normal Events Evaluation for Site Specific Spent Fuel – Section 11.1.6

F.12.1.2 Accidents

Section 11.2 of the NAC-UMS FSAR, Reference F.12.2-1, presents the analyses and results of the design basis and hypothetical accident conditions evaluated for the NAC-UMS storage system. In addition to design basis accidents, this section addresses very low probability events, including natural phenomena, that might occur once during the lifetime of the ISFSI and hypothetical events that are postulated to occur because their consequences may result in the maximum potential effect on the immediate environment. The accident condition evaluation for the bounding configuration is presented to address differences in capacity, weight, and principal dimensions.

The following accidents are evaluated in the NAC-UMS FSAR. Each accident condition listed includes the identification of the FSAR section in which it is presented.

1. Accident Pressurization – Section 11.2.1
2. Failure of all Fuel Rods with a Subsequent Ground Level Breach of the Canister – Section 11.2.2
3. Fresh Fuel Loading in the Canister – Section 11.2.3
4. 24-inch Drop of Vertical Concrete Cask – Section 11.2.4
5. Explosion – Section 11.2.5
6. Fire Accident – Section 11.2.6
7. Maximum Anticipated Heat Load (133°F Ambient Temperature) – Section 11.2.7
8. Earthquake Event – Section 11.2.8
9. Flood – Section 11.2.9
10. Lightning – Section 11.2.10
11. Tornado and Tornado Driven Missiles – Section 11.2.11
12. Tip Over of the Vertical Concrete Cask – Section 11.2.12
13. Full Blockage of Vertical Concrete Cask Air Inlets and Outlets – Section 11.2.13
14. Canister Closure Weld Evaluation – 11.2.14
15. Site-Specific Spent Fuel Evaluation – 11.2.15
16. Fuel Rods Structural Evaluation – 11.2.16

F.12.1.3 Concrete Cask Non-Mechanistic Tip-Over Analysis

Tip-over of the concrete cask is a non-mechanistic, hypothetical accident condition that presents a bounding case for evaluation. Existing postulated design basis accidents do not result in the tip-over of the concrete cask. Functionally, the concrete cask does not suffer significant adverse consequences due to this event. The concrete cask, TSC, and basket maintain design basis shielding, geometry control of contents, and contents confinement performance requirements.

For a tip-over event to occur, the center of gravity of the concrete cask and loaded TSC must be displaced beyond its outer radius, i.e., the point of rotation. When the center of gravity passes beyond the point of rotation, the potential energy of the cask and TSC is converted to kinetic energy as the cask and TSC rotate toward a horizontal orientation on the ISFSI pad. The subsequent motion of the cask is governed by the structural characteristics of the cask, the ISFSI pad and the underlying soil.

The concrete cask tip-over analyses of the NAC-UMS storage system at the Consolidated Interim Storage Facility (CISF) are performed using LS-DYNA.

LS-DYNA is an explicit finite element program for the nonlinear dynamic analysis of structures in three dimensions. The objective of these evaluations is to confirm that the maximum amplified accelerations of the top of the basket and the canister for the five systems at the CISF are bounded by the accelerations used in the structural evaluation of the five systems for the original license basis of each system. The LS-DYNA reevaluation of the cask tip over is required, since the concrete pad and soil conditions at the CISF differed from the original license basis.

F.12.1.3.1 Concrete Cask Finite Element Model For Tip-Over Evaluation

The half-symmetry finite element model of the loaded VCC, concrete pad, mudmat, and soil sublayers are constructed of solid brick elements. The details of the finite element model set-up are shown in Figure F.12-1 and Figure F.12-2.

F.12.1.3.2 Material Models/Properties

The material properties used in the analysis are given below:

The modulus of elasticity of concrete is calculated using the following equation:

$$E_c = 33\ (w_c)^{1.5}\sqrt{f_c'}$$

Where,

E_c = Modulus of elasticity of concrete, psi

W_c = Unit weight of concrete, lb/ft3

f_c' = Compressive strength of concrete, psi

F.12.1.3.3 Concrete Pad

Mass density, ρ = 148 pcf = 2.217 E-4 lb-sec^2/in^4

Modulus of elasticity, E = 4.602E6 psi

Poisson's ratio, υ = 0.2

Shear modulus, G = 1.918E6 psi

Compressive strength, f_c' = 6000 psi

F.12.1.3.4 Mudmat

Mass density, ρ = 146 pcf = 2.187 E-4 lb-sec^2/in^4

Modulus of elasticity, E = 2.604E6 psi

Poisson's ratio, υ = 0.2

Shear modulus, G = 1.085E6 psi

Compressive strength, f_c' = 2000 psi

F.12.1.3.5 Soil

Table F.12-1
Soil Properties

F.12.1.3.6 VCC Concrete

The concrete properties used for VCC are given Section F.12.1.3.12.1 for the NAC-UMS system. The densities of VCC and other components used account for the total weight of non-structural components that are not modeled.

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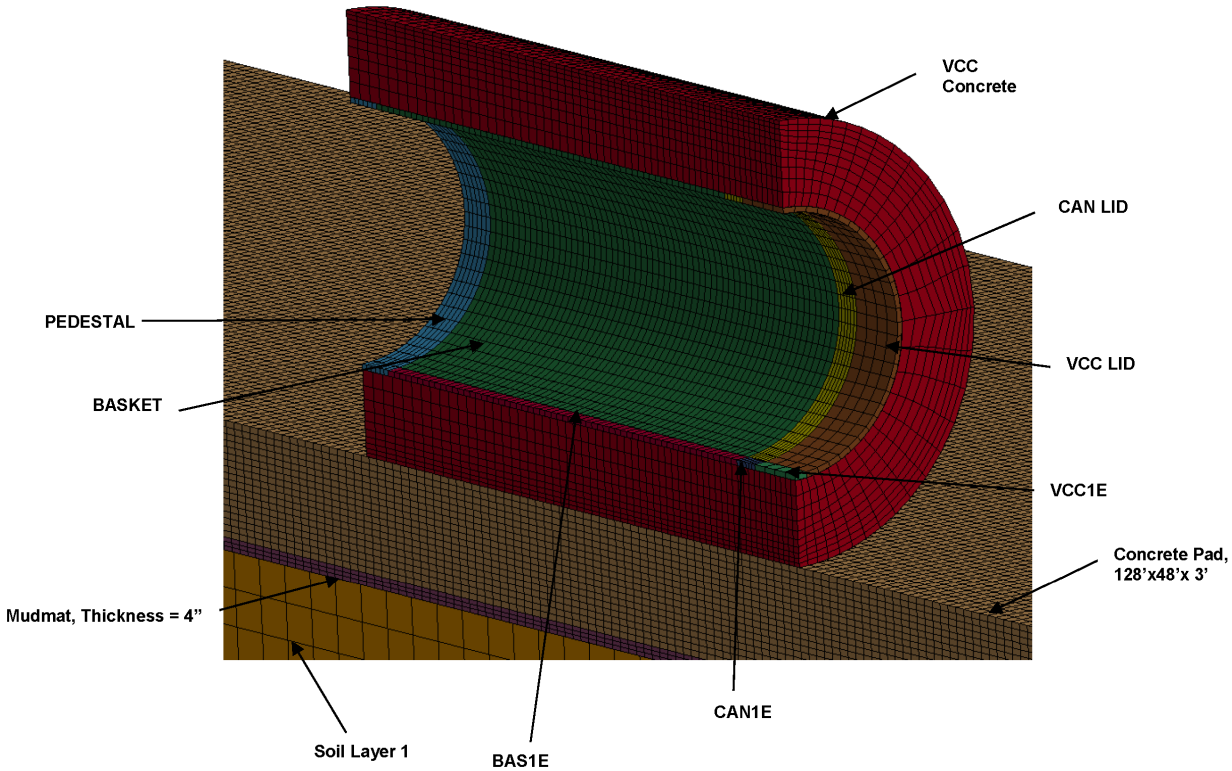

Figure F.12-2
CISF Configuration - Finite Element Model Set-Up (Continued)

F.12.1.3.7 Boundary Conditions

The VCC, liner, concrete pad, mudmat and soil sublayers are modeled using solid elements. The bottom surface of the soil is constrained in the vertical direction. To represent the unlimited expanse of adjacent soil, non-reflecting boundary conditions are applied to the three vertical planes of the soil. Symmetry boundary conditions are applied to the symmetry plane of VCC, concrete pad, mudmat and soil. The bottom of the soil column is vertically restrained. Contact modeling between VCC, liner, basket and canister is modeled using the Surface Contact options available in LS-DYNA.

F.12.1.3.8 Weight of Loaded VCC

The body load due to the gravity (1 g) of the loaded VCC is considered in the analysis and is conservatively applied as a step load. The weights of various loaded VCC systems are given in Table F.12-2.

F.12.1.3.9 Tip-Over Velocity

The tip-over condition is simulated by applying angular velocity to the loaded VCC. The angular velocity is calculated by equating the potential energy of VCC due to change in the position of center of gravity (CG) with the kinetic energy due to rotation of the VCC (while standing on its corner with the CG directly over it) as shown below:

$$\text{Potential Energy} = \text{Rotational Kinetic Energy}$$

$$mgh = (I\omega^2)/2$$

Where,

m = Total mass of the loaded VCC, lb-sec^2/in

g = Acceleration due to gravity, 386.4 in/sec^2

w = mg, Total weight of the loaded VCC, lbs

h = Change in height of CG of VCC, in

I = Total mass moment of inertia of loaded VCC about the pivot point, lb-sec^2-in

ω = Angular velocity of loaded VCC, rad/sec

The diagram is shown below:

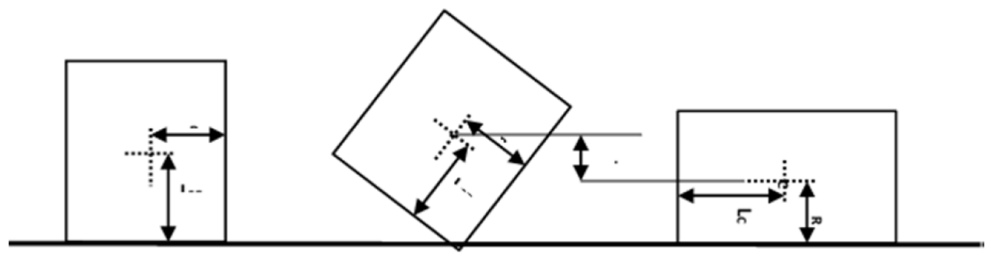

Figure F.12-3
Schematic Representation of the Change in Height of CG of VCC

The change in height of CG of VCC:

$$h = \sqrt{R^2 + L_{CG}{}^2} - R$$

Where,

R = Radius of VCC, in

LCG = Distance of CG from base of VCC, in

Therefore, the angular velocity is given by,

$$\omega = \sqrt{\frac{2mgh}{I}}$$

The angular velocities for various VCC systems are given in Table F.12-2.

Table F.12-2
Total Weights and Tip-Over Angular Velocities of NAC-UMS VCC System

Storage System	Loaded VCC		Tip-Over Angular Velocity (rad/sec)
	Weight (kips)	Mass (lb-sec^2/in)	
UMS Maine-Yankee	324.2	838.5	1.510

F.12.1.3.10 Determination of Amplified Accelerations

The acceleration time histories are taken from the nodes at the top of the basket and the canister which would identify the maximum acceleration of the basket and the canister. The acceleration time histories from the LS-DYNA nodal acceleration file were filtered with a Butterworth filter frequency of 165 Hz. Details of the filter frequency calculation are contained in Reference F.12.2-3. The general pattern of the acceleration time history of both components is shown in the acceleration time history curve in Figure F.12-4. The initial spike has a duration (t1) of approximately 4 ms while the longer pulse duration (t2) is approximately 40 ms. The initial spike of duration t1 is associated with the initial crushing of the concrete and the equivalent static acceleration used for the basket and canister evaluation is determined using the Dynamic Load Factors (DLF) for a triangular shaped pulse. The DLF for the longer pulse (t2) is determined using the DLF for a sine shaped pulse. The DLF for the basket is dependent on each basket design and basket angular orientation. The DLF for the canister lid region of the TSC is considered to be 1 due to the rigidity of the lid.

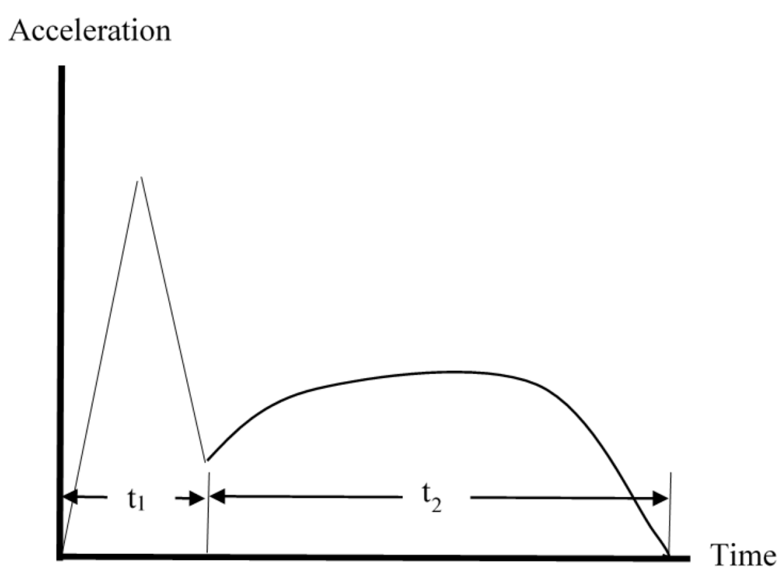

Figure F.12-4
Acceleration Time History

F.12.1.3.11 Cask Specific Evaluations

A model is used to evaluate the loaded concrete cask during tip-over conditions for the NAC-UMS system. The concrete pad represents the concrete pad properties at the CSIF site. The dimensions of the concrete pad are 128 feet (length) x 48 feet (width) with a thickness of 3 feet. The mudmat under the pad had a thickness of 4 inches. The subsoil used the length and width of the pad plus 4 feet on each side. The site soil properties were modeled to a depth of 98.7 feet.

F.12.1.3.12 NAC-UMS

The total weight of the loaded UMS VCC used in the analysis is equal to 324 kips. Half-symmetry model as discussed in Section F.12.1.3.1 is used in the analysis.

F.12.1.3.12.1 Material Properties of VCC

Material properties of VCC concrete used in the analysis are given below:

Mass density, ρ = 153.5 pcf = 2.299E-4 lb-sec^2/in^4

Modulus of elasticity, E = 3.969E6 psi

Poisson's ratio, υ = 0.22

Shear modulus, G = 1.627E6 psi

Compressive strength, f_c' = 4000 psi

F.12.1.3.12.2 Geometric Properties of VCC

Radius of VCC, R = 68 in

Distance of CG of VCC from base, LCG = 117 in

Change in height of CG, h = 67.3 in

The tip-over angular velocity of the VCC is calculated as per the methodology described in Section F.12.1.3.9 and is applied to the UMS model in conjunction with the gravity. The deformed shape of the model is shown in Figure F.12-5. Further details regarding numerical and graphical results are contained in Reference F.12.2.3.

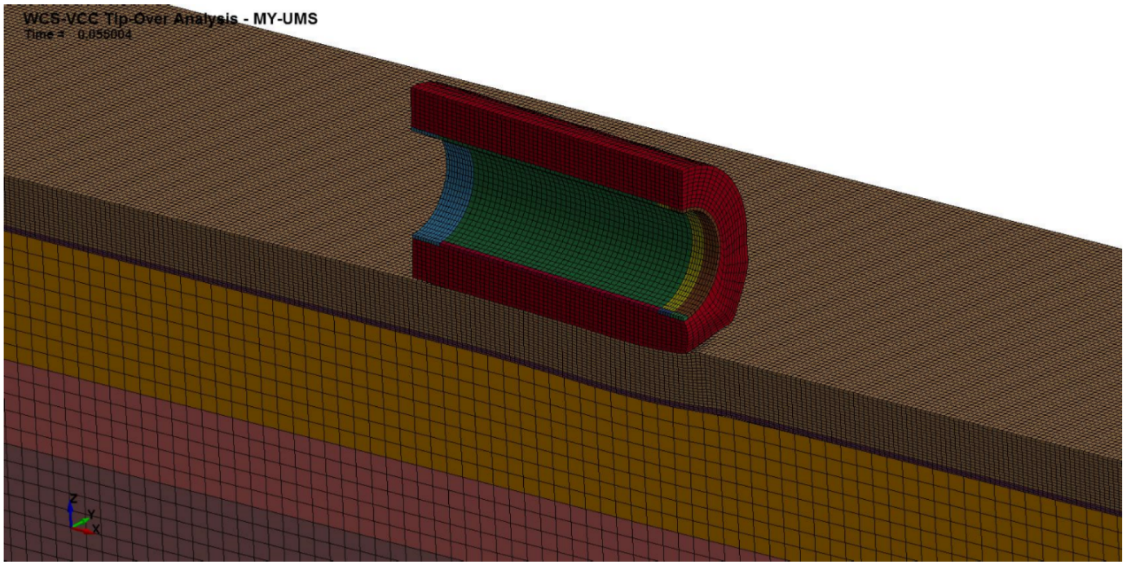

Figure F.12-5
Deformed Shape of UMS VCC, Concrete Pad, Mudmat and Soil

The canister lid and attached canister shell peak acceleration is determined to be 26.6g, which would also correspond to the static acceleration to be applied to the model for the canister stress evaluation.

For the amplification of the accelerations during the short pulse, the maximum possible DLF for the triangular pulse is 1.52 regardless of the basket fundamental modal frequency and pulse duration. Likewise, for the accelerations during the long pulse, the maximum DLF for the sine pulse is 1.76. The Table F.12-3 shows the basket acceleration obtained from the analysis, the maximum DLF, and the amplified accelerations. The acceleration used in the basket and canister evaluations for the UMS system in Reference 4 was 40g's. The peak basket amplified accelerations shown below is 37.7, which bounds the peak canister acceleration. Both accelerations are bounded by the design basis acceleration. Therefore, the basket and canister evaluations contained in Reference F.12.2-1 are bounding for the conditions at the CISF.

Table F.12-3
Peak Accelerations and DLF for UMS VCC Systems

Pulse	Peak Basket Analysis Acceleration (A_p) (g)	DLF	Amplified Acceleration (g) (A_p)×DLF
Short Pulse	24.8	1.52	37.7
Long Pulse	19.8	1.76	34.8

F.12.2 References

F.12.2-1 NAC-UMS Universal Storage System Final Safety Analysis Report, Revision 10, October 2012.

F.12.2-2 Amendment No. 5 to Certificate of Compliance No. 1015 for the NAC International, Inc., NAC-UMS Universal Storage System, January 12, 2008.

F.12.2-3 NAC Calculation 30039-2010 Rev 0, "Concrete Cask Tip-Over Evaluation – WCS", NAC International, Norcross, GA

F.12.2-4 NAC Calculation 30039-2015 Rev 0, "Tip-Over DLF Calculation for WCS", NAC International, Norcross, GA

APPENDIX G.1
INTRODUCTION AND GENERAL DESCRIPTION OF INSTALLATION
NAC-MAGNASTOR

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G.1. INTRODUCTION AND GENERAL DESCRIPTION OF INSTALLATION

No change or additional information required for the MAGNASTOR Cask System for Chapter 1.

APPENDIX G.2
SITE CHARACTERISTICS
NAC-MAGNASTOR

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G.2. SITE CHARACTERISTICS

No change or additional information required for the MAGNASTOR Cask System for Chapter 2.

APPENDIX G.3
PRINCIPAL DESIGN CRITERIA
NAC-MAGNASTOR

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G.3 PRINCIPAL DESIGN CRITERIA

The MAGNASTOR Cask System principal design criteria for undamaged and damaged PWR fuel is documented in Chapter 2 of the MAGNASTOR Final Safety Analysis Report (FSAR) [Reference G.3-1]. *Table G.3-1 provides a comparison of the NAC-MAGNASTOR Cask System principal design criteria and Waste Control Specialists, LLC (WCS) Consolidated Interim Storage Facility (CISF) design criteria provided in Table 1-2, which demonstrates that the NAC-MAGNASTOR Cask System is bounded by the WCS CISF criteria.*

G.3.1 Undamaged and Damaged PWR Fuel

MAGNASTOR is designed to safely store up to 37 undamaged PWR fuel assemblies in the 37 PWR basket assembly. The system is also designed to store up to four damaged fuel cans (DFCs) in the DF basket assembly. The DF Basket Assembly has a capacity of up to 37 undamaged PWR fuel assemblies, including four DFC locations. DFCs may be placed in up to four of the DFC locations. Each DFC may contain an undamaged PWR fuel assembly, a damaged PWR fuel assembly, or PWR fuel debris equivalent to one PWR fuel assembly. Undamaged PWR fuel assemblies may be placed directly in the DFC locations of a DF Basket Assembly.

The fuel assemblies are assigned to two groups of PWR fuel assemblies on the basis of fuel assembly length. The fuel assembly length groupings are included in Chapter 1 of Reference G.3-1.

PWR fuel assemblies that have the parameters shown in Table 2.2-1 of Reference G.3-1 may be stored in MAGNASTOR. PWR fuel assemblies may be stored with nonfuel hardware. Undamaged or damaged PWR fuel assemblies or PWR fuel debris may be stored in a damaged fuel can. PWR fuel assemblies loaded into a DFC shall not contain nonfuel hardware, with the exception of instrument tube tie components and steel inserts.

The minimum initial enrichment limits for PWR fuel are shown in Table 2.2-1 of Reference G.3-1 and exclude the loading of fuel assemblies enriched to less than 1.3 wt% ^{235}U, including unenriched fuel assemblies. Fuel assemblies with low enriched, unenriched, and/or annular axial end-blankets may be loaded into MAGNASTOR.

The design criteria for environmental conditions and natural phenomena for the MAGNASTOR system are described in Section 2.3 of Reference G.3-1. The applicable portions of Section 2.3 have been reviewed against the environmental conditions at the WCS facility and have been shown to be either bounded by the analysis presented in Reference G.3-1 or require no further analysis than what is presented in Reference G.3-1 because they already meet the regulatory requirements of 10 CFR Part 72.

G.3.1.1 Design Criteria for Environmental Conditions and Natural Phenomena

This section presents the design criteria for site environmental conditions and natural phenomena applied in the design basis analyses of MAGNASTOR. Analyses to demonstrate that the design basis system meets the design criteria defined in this section are presented in the relevant chapters of Reference G.3-1.

G.3.1.1.1 Tornado Missiles and Wind Loadings

The concrete casks are typically placed outdoors on an unsheltered reinforced concrete storage pad at an ISFSI site. This storage condition exposes the casks to tornado and wind loading. The design basis tornado and wind loading is defined based on Regulatory Guide 1.76 Region 1 and NUREG-0800. The design basis tornado missile impacts are defined in Paragraph 4, Subsection III, Section 3.5.1.4 of NUREG 0800. Analyses presented in Reference G.3-1, Section 3.7.3.2 and discussed in Reference G.3-1, Section 12.2.11 demonstrates that the MAGNASTOR design meets these criteria. Therefore, no further WCS site-specific evaluations are required.

G.3.1.1.2 Water Level (Flood) Design

The loaded concrete cask may be exposed to a flood during storage on an unsheltered concrete storage pad at an ISFSI site. The source and magnitude of the probable maximum flood depend on specific site characteristics. The MAGNASTOR concrete cask design basis is a maximum floodwater depth of 50 feet above the base of the cask and a floodwater velocity of 15 ft per second.

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.

G.3.1.1.3 Seismic Design

An ISFSI site may be subject to seismic events (earthquakes) during its lifetime. The seismic response spectra experienced by the concrete cask depends upon the geographical location of the specific site and the distance from the epicenter of the earthquake. The possible significant effect of a beyond-design-basis seismic event on the concrete cask would be a tip-over; however, the loaded concrete cask does not tip over during the design-basis seismic event. Although it is a nonmechanistic event, the loaded concrete cask design basis includes consideration of the consequences of a hypothetical cask tip-over event.

Seismic response of the MAGNASTOR system is discussed in Reference G.3-1, Section 12.2.8. The maximum horizontal acceleration at the surface of the concrete storage pad due to an earthquake is evaluated in Reference G.3-1, Section 3.7.3.4. This evaluation shows that MAGNASTOR is stable during a 0.37g earthquake horizontal acceleration (including a 1.1 factor of safety). The vertical acceleration for this evaluation is defined as two-thirds of the horizontal acceleration in accordance with ASCE 4-86.

Additionally, to evaluate concrete cask stress the evaluation in Section 3.7.3.4 of Reference G.3-1 conservatively applies seismic loads of 0.5g in the horizontal direction and 0.5g in the vertical direction. These accelerations reflect a more rigorous seismic loading and, therefore, bound the design basis earthquake event. These compressive stresses are used in the load combinations for the concrete cask discussed in Section G.3.1.1.5, and the combined stress results meet stress criteria for the accident events.

A detailed analysis of the nonmechanistic tip-over event for a bounding PWR configuration is presented in Section 3.7.3.7 of Reference G.3-1 with results discussed in Section 12.2.12 of Reference G.3-1. The concrete cask is analyzed with conservative fuel heights, canister lengths, concrete pad thicknesses, and soil densities. To bound a range of ISFSI geometries, standard pad and oversized pad configurations are evaluated. Accelerations obtained from this tip-over analysis are applied to the TSC and basket structural evaluations presented in Reference G.3-1, Sections 3.7.1 and 3.7.2, respectively. The cask is shown to not suffer significant adverse consequences due to this event. The concrete cask, TSC, and basket maintain performance requirements for design basis structural integrity, shielding, geometry, criticality control of the contents, and content confinement.

The WCS pad design meets the MAGNASTOR pad requirements and is consistent with analyses performed within Reference G.3-1. The existing analysis bounds the WCS site pad design limits for accelerations at the top pad surface. Therefore, no further evaluations are required.

G.3.1.1.4 Snow and Ice Loadings

The criterion for determining design snow loads is based on ANSI/ASCE 7-93, Section 7.0. MAGNASTOR is assumed to have a Category C exposure factor, which is defined to be "locations in which snow removal by wind cannot be relied on to reduce roof loads because of terrain, higher structures, or several trees nearby." Ground snow loads for the contiguous United States are given in Figures, 5, 6, and 7 of ANSI/ASCE 7-93. A worst case value of 100 pounds per square foot is assumed. Section 2.3.4 of Reference G.3-1 states that the snow load is bounded by the weight of the loaded transfer cask on the top of the concrete cask shell and by the tornado missile loading on the concrete cask lid. No further WCS site-specific evaluations are required.

G.3.1.1.5 Combined Load Criteria

Each normal condition and off-normal and accident event has a combination of load cases that defines the total combined loading for that condition/event. The individual load cases considered include thermal, seismic, external and internal pressure, missile impacts, drops, snow and ice loads, and/or flood water forces. The load conditions to be evaluated for storage casks are identified in 10 CFR 72 and ANSI/ANS-57.9.

The load combinations for concrete structures specified in ANSI/ANS-57.9 and ACI 349 are used to evaluate the MAGNASTOR concrete cask and are shown in Table 2.3-1 of Reference G.3-1. The live loads are considered to vary from 0% to 100% to ensure that the worst-case condition is evaluated. In each case, use of 100% of the live load produces the maximum load condition. The steel liner of the MAGNASTOR concrete cask is a stay-in-place form that also provides radiation shielding. The concrete cask is designed to the requirements of ACI 349. In calculating the design strength of concrete in the concrete cask body, nominal strength values are multiplied by a strength reduction factor in accordance with Section 9.3 of ACI 349.

The TSC is designed in accordance with the ASME Code, Section III, Subsection NB. The basket and damaged fuel can (DFC) are designed in accordance with the ASME Code, Section III, Subsection NG. Structural buckling of the basket is evaluated in accordance with NUREG/CR-6322.

The load combinations for all normal conditions and off-normal or accident events and the corresponding ASME service levels are shown in Table 2.3-2 of Reference G.3-1. Stress intensities produced by pressure, temperature, and mechanical loads are combined before comparison to the ASME Code allowable criteria which are listed in Table 2.3-3 of Reference G.3-1.

The load combinations considered for the fuel basket for normal conditions and off-normal or accident events are the same as those identified for the TSC in Table 2.3-2 of Reference G.3-1, except that there are no internal pressure loads. The analysis criteria of the ASME Code, Section III, Subsection NG are employed.

The transfer cask is a special lifting device. It is designed, fabricated, and load tested to meet the requirements of ANSI N14.6 for the handling of vertical loads defined in NUREG 0612. The transfer cask is designed using the following criteria. The combined shear stress or maximum tensile stress during the lift (with 10% dynamic load factor) shall be $\leq S_y/6$ and $S_u/10$. For off-normal (Level C) conditions, membrane stresses shall be less than $1.2S_m$ and membrane plus bending stresses shall be the lesser of $1.8S_m$ and $1.5S_y$. The ferritic steel material used for the load-bearing members of the transfer cask shall satisfy the material toughness requirements of ANSI N14.6, paragraph 4.2.6.

The structural evaluations presented in Reference G.3-1 demonstrate that the MAGNASTOR concrete cask, TSC, fuel baskets, damaged fuel can, and transfer cask meets or exceeds these design criteria. Therefore, no further WCS site-specific evaluations are required.

G.3.1.1.6 Environmental Temperatures

A temperature of 76°F is defined as the design base normal operations temperature for MAGNASTOR in storage. This temperature conservatively bounds the maximum average annual temperature in the 48 contiguous United States, specifically, Miami, FL, at 75.6°F and meets the normal condition thermal boundary defined in NUREG-1536. Use of this design base establishes a bounding condition for existing and potential ISFSI sites in the United States. The evaluation of this environmental condition along with the thermal analysis models are presented in Chapter 4 of Reference G.3-1. The thermal stress evaluation for the normal operating conditions is included in Chapter 3 of Reference G.3-1. Normal temperature fluctuations are bounded by the severe ambient temperature cases that are evaluated as off-normal and accident events.

Off-normal, severe environmental events are defined as -40°F with no solar loads and 106°F with solar loads. An extreme environmental condition of 133°F with maximum solar loads is evaluated as an accident case to show compliance with the maximum heat load case required by ANSI/ANS-57.9. Thermal performance is also evaluated assuming both the half blockage of the concrete cask air inlets and the complete blockage of the air inlets. Solar insolation is as specified in 10 CFR 71.71 and Regulatory Guide 7.8.

Therefore, the maximum average yearly temperature allowed for the MAGNASTOR system is 76°F and the maximum 3-day average ambient temperature shall be ≤ 106°F. The allowed temperature extremes, average of a 3-day period, shall be greater than -40°F and less than 133°F. The WCS site extreme temperature range is from 30.1°F to 113°F and the average yearly temperature for the site is conservatively bounded by using the maximum average annual temperature in the 48 contiguous United States, of 75.6°F. This temperature meets the normal condition thermal boundary defined in NUREG-1536. Therefore, no further WCS site-specific evaluations are required.

G.3.1.2 Safety Protection Systems

MAGNASTOR relies upon passive systems to ensure the protection of public health and safety, except in the case of fire or explosion. As previously discussed, fire and explosion events are effectively precluded by site administrative controls that prevent the introduction of flammable and explosive materials. The use of passive systems provides protection from mechanical or equipment failure.

G.3.1.2.1 General

MAGNASTOR is designed for safe, long-term storage of spent fuel. The system will withstand all of the evaluated normal conditions and off-normal and postulated accident events without release of radioactive material or excessive radiation exposure to workers or the general public. The major design considerations to assure safe, long-term fuel storage and retrievability for ultimate disposal by the Department of Energy in accordance with the requirements of 10 CFR 72 and ISG-2 are as follows.

- Continued radioactive material confinement in postulated accidents.
- Thick steel and concrete biological shield.
- Passive systems that ensure reliability.
- Pressurized inert helium atmosphere to provide corrosion protection for fuel cladding and enhanced heat transfer for the stored fuel.

Retrievability is defined as: "maintaining spent fuel in substantially the same physical condition as it was when originally loaded into the storage cask, which enables any future transportation, unloading and ultimate disposal activities to be performed using the same general type of equipment and procedures as were used for the initial loading."

Each major component of the system is classified with respect to its function and corresponding potential effect on public safety. In accordance with Regulatory Guide 7.10, each major system component is assigned a safety classification as shown in Table 2.4-1 or Reference G.3-1. The safety classification is based on review of the component's function and the assessment of the consequences of its failure following the guidelines of NUREG/CR-6407. The safety classification categories are defined in the following list.

Category A - Components critical to safe operations whose failure or malfunction could directly result in conditions adverse to safe operations, integrity of spent fuel, or public health and safety.

Category B - Components with major impact on safe operations whose failure or malfunction could indirectly result in conditions adverse to safe operations, integrity of spent fuel, or public health and safety.

Category C - Components whose failure would not significantly reduce the packaging effectiveness and would not likely result in conditions adverse to safe operations, integrity of spent fuel, or public health and safety.

As discussed in Section 2.4 of Reference G.3-1, the MAGNASTOR design incorporates features addressing the above design considerations to assure safe operation during fuel loading, handling, and storage of spent nuclear fuel. This section addresses the following:

- Confinement Barriers and Systems
- Concrete Cask Cooling
- Protection by Equipment
- Protection by Instrumentation
- Nuclear Criticality Safety
- Radiological Protection
- Fire Protection
- Explosion Protection
- Auxiliary Structures

The confinement performance requirements for the NAC-MAGNASTOR System are described in Chapter 7, Section 7.2 of Reference G.3-1 for storage conditions. In addition, MAGNATRAN Transport Cask SAR [G.3-2] demonstrates that the confinement boundary is not adversely affected by normal conditions of transport. Specifically, Chapter 2, Section 2.6.12 for the PWR canister. Therefore, transport to the WCS CISF will not adversely impacted confinement integrity of the NAC-MAGNASTOR canister.

G.3.1.3 Decommissioning Considerations

The principal components of MAGNASTOR are the concrete cask and the TSC. Decommissioning of these principal components is discussed in Chapter 15 of Reference G.3-1.

G.3.2 References

G.3-1 MAGNASTOR Final Safety Analysis Report, Revision 7, July 2015

G.3-2 MAGNATRAN Transport Cask SAR, Revision 12A, October 2012

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

Design Parameter	*WCS CISF Design Criteria*	*Condition*	*MAGNASTOR® Design Criteria*
Type of fuel	*Commercial, light water reactor spent fuel*	*Normal (Bounded)*	*MAGNASTOR FSAR Section 2.2*
Storage Systems	*Transportable canisters and storage overpacks docketed by the NRC*	*Normal (Bounded)*	*72-1031* *71-9356 (Pending)*
Fuel Characteristics	*Criteria as specified in previously approved licenses for included systems*	*Normal (Bounded)*	*MAGNASTOR FSAR Section 2.2*
Tornado (Wind Load)	*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)*	***MAGNASTOR FSAR Section 2.3.1.1*** *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 (Missile)	*Automobile: 4000 lb, 112 ft/s (76.4 mph)* *Schedule 40 Pipe: 287 lb, 112 ft/s (76.4 mph)* *Solid Steel Sphere: 0.147 lb, 23 ft/s (15.7 mph)*	*Accident (Bounded)*	***MAGNASTOR FSAR Section 2.3.1.3*** *Massive Missile: 4000 lb, 126 mph* *Rigid hardened steel: 280 lb, 126 mph* *Solid Steel Sphere: 0.15 lb, 126 mph*
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)*	***MAGNASTOR FSAR Section 2.3.2.1*** *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)*	***MAGNASTOR FSAR Section 2.3.3*** *The maximum allowable ground acceleration for the MAGNASTOR system is 0.37g horizontal and 0.25g vertical when the ISFSI pad does not incorporate the use of bollards*

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

Design Parameter	*WCS CISF Design Criteria*	*Condition*	*MAGNASTOR® Design Criteria*
Vent Blockage	*For MAGNASTOR® Systems:* *Inlet vents blocked 72 hrs*	*Accident (Same)*	***MAGNASTOR FSAR Section 4.6.3*** *Inlet vents blocked 72 hrs*
Fire/Explosion	*For MAGNASTOR® Systems:* *Equivalent fire 50 gallons of diesel fuel*	*Accident (Same)*	***MAGNASTOR FSAR Section 4.6.2*** *Equivalent fire 50 gallons of flammable liquid*
Cask Drop	*For MAGNASTOR® Systems:* *VCCs Drop height 24 inches*	*Accident (Same)*	***MAGNASTOR FSAR Section 12.2.4*** *VCCs for MAGNASTOR Systems:* *Drop height 24 inches*
Ambient Temperatures	*Yearly average temperature 67.1°F*	*Normal (Bounded)*	***MAGNASTOR FSAR Section 2.3.6*** *Normal operations temperature 76°F*
Off-Normal Temperature	*Minimum 3 day avg. temperature 27.9°F* *Maximum3 day avg. temperature 89.4°F*	*Off-Normal (Bounded)*	***MAGNASTOR FSAR Section 2.3.6*** *Minimum 3 day avg. temperature -40°F* *Maximum 3 day avg. temperature 106°F*
Extreme Temperature	*Maximum temperature 113°F*	*Accident (Bounded)*	***MAGNASTOR FSAR Section 2.3.6*** *Maximum temperature 133°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)*	***MAGNASTOR FSAR Section 4.4.1.1*** *Curved Surface: 1475 Btu/ft^2 for a 24-hour period.* *Flat Horizontal Surface: 2950 Btu/ft^2 for a 24-hour period.*
Snow and Ice	*Snow Load 10 psf*	*Normal (Bounded)*	***MAGNASTOR FSAR Section 2.3.4*** *Snow Load: 100 psf*
Dead Weight	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*TSC Dead Load – MAGNASTOR FSAR Section 3.5.1.2* *Cask – MAGNASTOR FSAR Section 3.5.3.2*
Internal and External Pressure Loads	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*TSC – MAGNASTOR FSAR Section 3.5.1.3* *Maximum Internal Pressure: 110 psig*

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

Design Parameter	WCS CISF Design Criteria	Condition	MAGNASTOR® Design Criteria
Design Basis Thermal Loads	Per design basis for systems listed in Table 1-1	Normal (Same)	TSC – MAGNASTOR FSAR Section 3.5.1.1
Operating Loads	Per design basis for systems listed in Table 1-1	Normal (Same)	Cask – MAGNASTOR FSAR Section 3.5.1.4
Live Loads	Per design basis for systems listed in Table 1-1	Normal (Same)	Cask – MAGNASTOR FSAR Section 3.5.3.2
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)	**MAGNASTOR FSAR Section 2.4.7.2** Public ≤ 5 Rem from any design base accident
Radiological Protection	Public wholebody ≤ 25 mrem/yr(1) Public thyroid ≤ 75 mrem/yr(1) Public critical organ ≤ 25 mrem/yr(1)	Normal (Same)	**MAGNASTOR FSAR Section 2.4.7.2** Public wholebody ≤ 25 mrem/yr
Confinement	Per design basis for systems listed in Table 1-1	N/A	MAGNASTOR FSAR Chapter 7 Leaktight
Nuclear Criticality	Per design basis for systems listed in Table 1-1	N/A	MAGNASTOR FSAR Chapter 6 K_{eff} <.95
Decommissioning	Minimize potential contamination	Normal (Same)	**MAGNASTOR FSAR Chapter 15** Minimize potential contamination

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

Design Parameter	***WCS CISF Design Criteria***	***Condition***	***MAGNASTOR® 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)*	***MAGNASTOR FSAR Section 2.4.2*** *Cask/canister handling system prevent breach of confinement boundary under all conditions* *MAGNASTOR FSAR Section 2.5* *Storage system allows ready retrieval of canister for shipment off-site*

Note

1. *In accordance with 10 CFR 72.104(a)(3) limits include any other radiation from uranium fuel cycle operations within the region.*

APPENDIX G.4
OPERATING SYSTEMS
NAC-MAGNASTOR

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G.4 OPERATING SYSTEMS

MAGNASTOR is a spent fuel dry storage system consisting of a concrete cask and a welded stainless steel TSC with a welded closure to safely store spent fuel. The TSC is stored in the central cavity of the concrete cask. The concrete cask provides structural protection, radiation shielding, and internal airflow paths that remove the decay heat from the TSC contents by natural air circulation. MAGNASTOR is designed and analyzed for a 50-year service life.

The loaded TSC is moved to and from the concrete cask using the transfer cask. The transfer cask provides radiation shielding during TSC closure and preparation activities. The TSC is transferred into the concrete cask by positioning the transfer cask with the loaded TSC on top of the concrete cask, opening the shield doors, and lowering the TSC into the concrete cask. Figure G.4-1 depicts the major components of MAGNASTOR in such a configuration.

Section G.4.3 provides a reference to all applicable license drawings (i.e., only undamaged and damaged PWR fuel storage systems) from Reference [G.4-1]. In addition to these previously NRC approved license drawings, this WCS SAR appendix includes one site-specific GTCC waste canister storage configuration drawing for previously loaded Zion GTCC waste canisters (GTCC-Canister-ZN).

G.4.1 Undamaged and Damaged PWR Fuel

MAGNASTOR provides for the long-term storage of PWR fuel assemblies as listed in Chapter 2 of Reference G.4-1. During long-term storage, the system provides an inert environment, passive structural shielding, cooling and criticality control, and a welded confinement boundary. The structural integrity of the system precludes the release of contents in any of the design basis normal conditions and off normal or accident events, thereby assuring public health and safety during use of the system. The following provides a general description of the major components of MAGNASTOR. The terminology used throughout these sections is summarized in Section 1.1 of Reference G.4-1.

G.4.1.1 Transportable Storage Canister (TSC)

The stainless steel TSC assembly holds the fuel basket structure and confines the contents (see Figure G.4-2). The TSC is defined as the confinement boundary during storage. The welded TSC weldment, closure lid, closure ring, and redundant port covers prevent the release of contents under normal conditions and off-normal or accident events. The fuel basket assembly provides the structural support and a heat transfer path for the fuel assemblies, while maintaining a subcritical configuration for all of the evaluated normal conditions and off-normal or accident events. Two lengths of TSCs accommodate all evaluated PWR fuel assemblies.

The major components of the TSC assembly are the shell, base plate, closure lid assembly, closure ring, and redundant port covers for the vent and drain ports, which provide the confinement boundary during storage. TSCs are provided in four configurations designated TSC1 through TSC4. The design characteristics, overall dimensions and materials of fabrication for the different TSC configurations are provided in Table 1.3-1 of Reference G.4-1.

The MAGNASTOR TSCs are loaded with spent fuel and welded closed at their respective sites. There are no active components associated with the loaded and welded closed TSCs. Thus, no further loading or closing operations are required to be performed on the TSC and basket at the WCS facility. Further details about the TSC can be found in Section 1.3.1.1 of Reference G.4-1.

G.4.1.2 Fuel Baskets

Each TSC contains a PWR fuel basket, which positions and supports the stored fuel. The PWR fuel basket design is an arrangement of square fuel tubes held in a right-circular cylinder configuration using support weldments that are bolted to the outer fuel tubes. The design parameters for the two lengths of PWR fuel baskets are provided in Table 1.3-1 of Reference G.4-1.

Fuel tubes support an enclosed neutron absorber sheet on up to four interior sides of the fuel tube. The neutron absorber panels, in conjunction with minimum TSC cavity water boron levels, provide criticality control in the basket. Each neutron absorber panel is covered by a sheet of stainless steel to protect the material during fuel loading and to keep it in position. The neutron absorber and stainless steel cover are secured to the fuel tube using weld posts located across the width and along the length of the fuel tube.

Each PWR fuel basket has a capacity of up to 37 undamaged fuel assemblies. Square tubes are assembled in an array where the tubes function as independent fuel positions and as sidewalls for the adjacent fuel positions in what is called a developed cell array. Consequently, the 37 fuel positions are developed using only 21 tubes. The array is surrounded by weldments that serve both as sidewalls for some perimeter fuel positions and as the structural load path from the array to the TSC shell wall.

The system is also designed to store up to four damaged fuel cans (DFCs) in the DF Basket Assembly. The DF Basket Assembly has a capacity of up to 37 undamaged PWR fuel assemblies, including four DFC locations. DFCs may be placed in up to four of the DFC locations. The arrangement of tubes and fuel positions is the same as in the standard fuel basket, but the design of each of the four corner support weldments is modified with additional structural support to provide an enlarged position for a damaged fuel can at the outermost corners of the fuel basket. A damaged fuel can or an undamaged PWR fuel assembly may be loaded in a damaged fuel can corner location.

Further details about the MAGNASTOR 37 PWR and DF basket assemblies can be found in Section 1.3.1.2 of Reference G.4-1.

G.4.1.3 Concrete Cask

The concrete cask is the storage overpack for the TSC and it is designed to hold both lengths of TSCs. The concrete cask provides structural support, shielding, protection from environmental conditions, and natural convection cooling of the TSC during long-term storage. The principal dimensions and materials of fabrication of the concrete cask are shown in Table 1.3-1 of Reference G.4-1.

The concrete cask is a reinforced structural plain concrete shield wall with a structural steel inner liner and base. The reinforced structural plain concrete shield wall and steel liner provide the neutron and gamma radiation shielding for the stored spent fuel. Reinforcing steel (rebar) is encased within the concrete. The reinforced structural plain concrete shield wall provides the structural strength to protect the TSC and its contents in natural phenomena events such as tornado wind loading and wind-driven missiles and during nonmechanistic tip-over events (refer to Figure G4.1-3). The concrete surfaces remain accessible for inspection and maintenance over the life of the cask, so that any necessary restoration actions may be taken to maintain shielding and structural conditions.

The concrete cask may be supplied in four different configurations designated CC1 through CC4. CC1 is the standard 225.27-in high cylinder. CC2 is also 225.27-in high, but is a segmented design. The CC3 and CC4 configurations are shorter variants at 218.3 inches high. CC1, CC2 and CC4 are equipped with a 1.75-in thick carbon steel liner, while CC3 has a 3-in thick carbon steel liner. CC1, CC2 and CC4 are equipped with standard concrete lids, having a constant thickness, while CC3 lid has a thicker center section for enhanced shielding. Both the CC3 and CC4 cask configurations are equipped with additional shielding at the air inlets.

The concrete cask provides an annular air passage to allow the natural circulation of air around the TSC to remove the decay heat from the contents. The lower air inlets and upper air outlets are steel-lined penetrations in the concrete cask body. Each air inlet/outlet is covered with a screen. The weldment baffle directs the air upward and around the pedestal that supports the TSC. Decay heat is transferred from the fuel assemblies to the TSC wall by conduction, convection, and radiation. Heat is removed by convection and radiation from the TSC shell to the air flowing upward through the annular air passage and to the concrete cask inner liner, respectively. Heat radiated to the liner can be transferred to the air annulus and by conduction through the concrete cask wall. The heated air in the annulus exhausts through the air outlets. The passive cooling system is designed to maintain the peak fuel cladding temperature below acceptable limits during long-term storage. The concrete cask thermal design also maintains the bulk concrete temperature and surface temperatures below the American Concrete Institute (ACI) limits under normal operating conditions. The inner liner of the concrete cask incorporates standoffs that provide lateral support to the TSC in side impact accident events.

A carbon steel and concrete lid is bolted to the top of the concrete cask. (See Table G.4-2 for the Concrete Cask Lid – Concrete Specification Summary.) The lid reduces skyshine radiation and provides a cover to protect the TSC from the environment and postulated tornado missiles.

To facilitate movement of the storage cask at the WCS facility, lifting lugs are embedded into the concrete. This provides a place for the vertical cask transporter to engage the storage cask in order to lift and subsequently move empty and loaded storage casks.

Existing MAGNASTOR storage casks will not be used at the WCS facility. New storage casks will be constructed on site at the WCS facility. Fabrication of the concrete cask requires no unique or unusual forming, concrete placement, or reinforcement operations. The concrete portion of the cask is constructed by placing concrete between a reusable, exterior form and the steel liner. Reinforcing bars are used near the inner and outer concrete surfaces to provide structural integrity. Note: inner rebar cage is optional. The structural steel liner and base are shop fabricated. Refer to Table G.4-1 for the fabrication specifications for the concrete cask.

Daily visual inspection of the air inlet and outlet screens for blockage assures that airflow through the cask meets licensed requirements. A description of the visual inspection is included in the Technical Specifications, Chapter 13 of Reference G.4-1. As an alternative to daily visual inspections, the loaded concrete cask in storage may include the capability to measure air temperature at the four outlets. Each air outlet may be equipped with a remote temperature detector mounted in the outlet air plenum. The air temperature-monitoring system, designed to provide verification of heat dissipation capabilities, can be designed for remote or local read-out capabilities at the option of the licensee. The temperature-monitoring system can be installed on all or some of the concrete casks at the Independent Spent Fuel Storage Installation (ISFSI) facility.

G.4.1.4 Transfer Cask

The transfer cask is designed, fabricated, and tested to meet the requirements of ANSI N14.6 as a special lifting device. The transfer cask provides biological shielding and structural protection for a loaded TSC, and is used to lift and move the TSC between workstations. The transfer cask is also used to shield the vertical transfer of a TSC into a concrete cask or a transport cask.

The transfer cask is available in two configurations—MTC1 and MTC2. MTC1 consists of carbon steel shells. MTC2 is a shorter version consisting of stainless steel shells. The principal dimensions and materials of fabrication of the transfer cask are provided in Table 1.3-1 of Reference G.4-1.

The transfer cask designs incorporate a retaining ring or three retaining blocks, pin-locked in place, or a bolted retaining ring, to prevent a loaded TSC from being inadvertently lifted through its top opening. The transfer cask has retractable bottom shield doors. During TSC loading and handling operations, the shield doors are closed and secured. After placement of the transfer cask on the concrete cask, the doors are retracted using hydraulic cylinders and a hydraulic supply. The TSC is then lowered into a concrete cask for storage. Refer to Figure G.4-1 for the general arrangement of the transfer cask, TSC, and concrete cask during loading.

Sixteen penetrations, eight at the top and eight at the bottom, are available to provide for the introduction of forced air, gas, or water to the transfer cask annulus in order to reduce loaded TSC temperatures during transfer operations. The transfer cask annulus can be isolated using inflatable seals located between the transfer cask inner shell and the outer surface of the TSC near the upper and lower ends of the transfer cask.

G.4.1.5 Damaged Fuel Can

The MAGNASTOR Damaged Fuel Can (DFC), shown in Figure 1.3-4 of Reference G.4-1, is provided to accommodate damaged PWR fuel assemblies or fuel debris equivalent to one PWR fuel assembly. Up to four DFCs may be loaded, one into each outer corner, in the MAGNASTOR DF Basket Assembly.

The primary function of the DFC is to confine the fuel material within the can to minimize the potential for dispersal of the fuel material into the TSC cavity. In normal operation, the DFC is in a vertical orientation. Further details about the MAGNASTOR DFC can be found in Section 1.3.1.5 of Reference G.4-1.

G.4.1.6 Storage Pad

The MAGNSTOR system is designed for long-term storage at an ISFSI. At the ISFSI site, the loaded concrete storage casks are placed in the vertical position on a concrete pad in a linear array. The reinforced concrete foundation of the ISFSI pad is capable of sustaining the transient loads from the vertical cask transporter and the general loads of the stored casks. The WCS pad design meets the MAGNASTOR pad requirements and is consistent with analyses performed within Reference G.4-1.

G.4.1.7 Auxiliary Equipment

This list shows the auxiliary equipment generally needed to use MAGNASTOR.

- automated, remote, and /or manual welding equipment to perform TSC field closure welding operations
- an engine-driven or towed frame or a heavy-haul trailer to move the concrete cask to and from the storage pad and to position the concrete cask on the storage pad
- draining, drying, hydrostatic testing, helium backfill, and water cooling systems for preparing the TSC and contents for storage
- hydrogen monitoring equipment to confirm the absence of explosive or combustible gases during TSC closure welding
- an adapter plate and a hydraulic supply system
- a lifting yoke for lifting and handling the transfer cask and rigging equipment for lifting and handling system components

In addition to these items, the system requires utility services (electric, helium, air, clean borated water, etc.), standard torque wrenches, tools and fittings, and miscellaneous hardware.

G.4.2 References

G.4-1 MAGNASTOR Final Safety Analysis Report, Revision 7, July 2015.

G.4-2 NAC International, "Safety Analysis Report for the MAGNATRAN Transport Cask," Revisions 12A, 14A, 15A, and 16A U.S. NRC Docket Number 71-9356.

G.4.3 Supplemental Data

The licensing drawings for the MAGNASTOR® System are listed in Section 1.8, License Drawings of the MAGNASTOR® System Final Safety Analysis Report, Revision 7 [G.4-1]. These drawings appear in the FSAR immediately after the drawing list in Section 1.8.1.

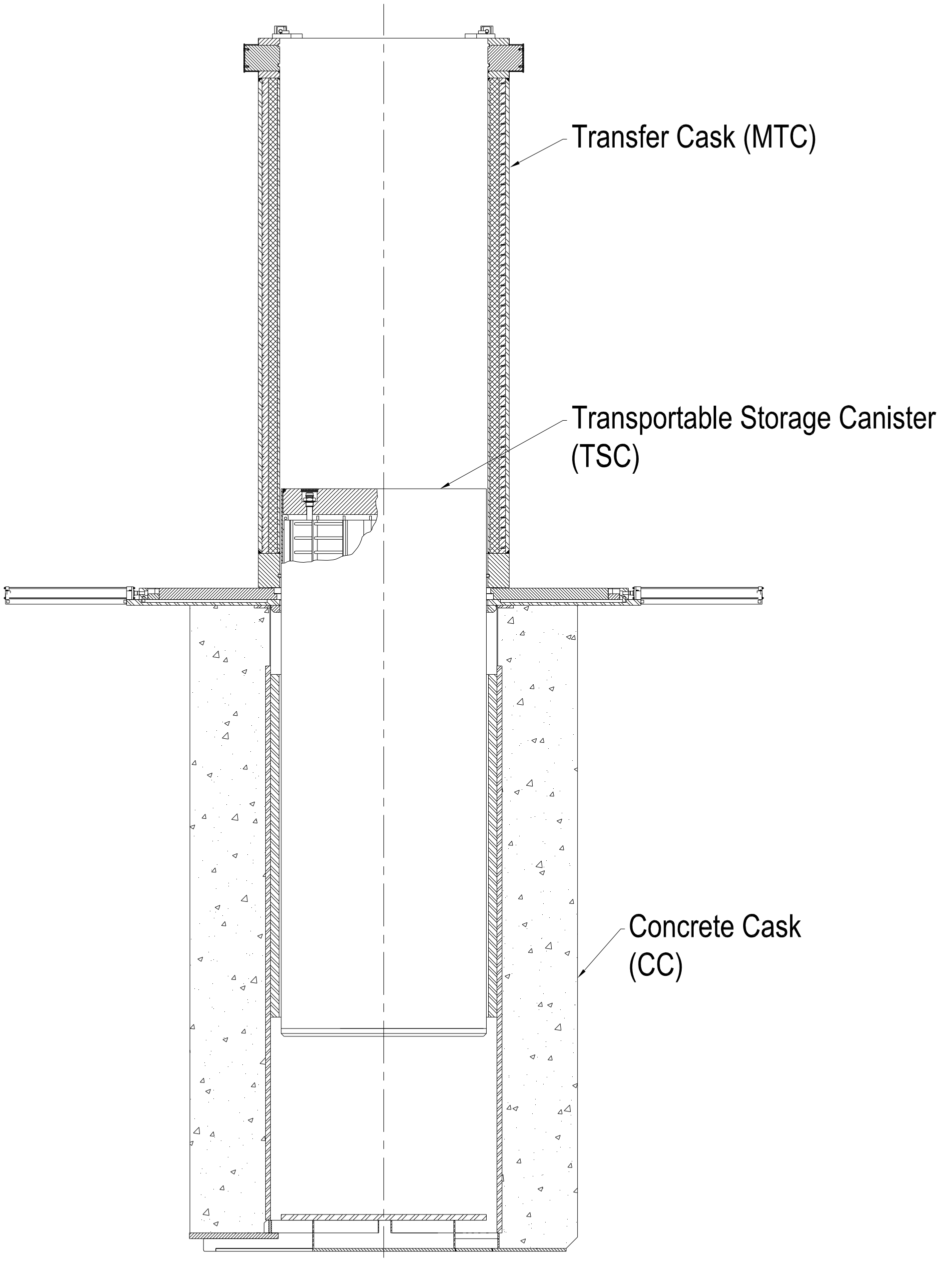

Figure G.4-1
Major Component Configuration for Loading the Concrete Cask

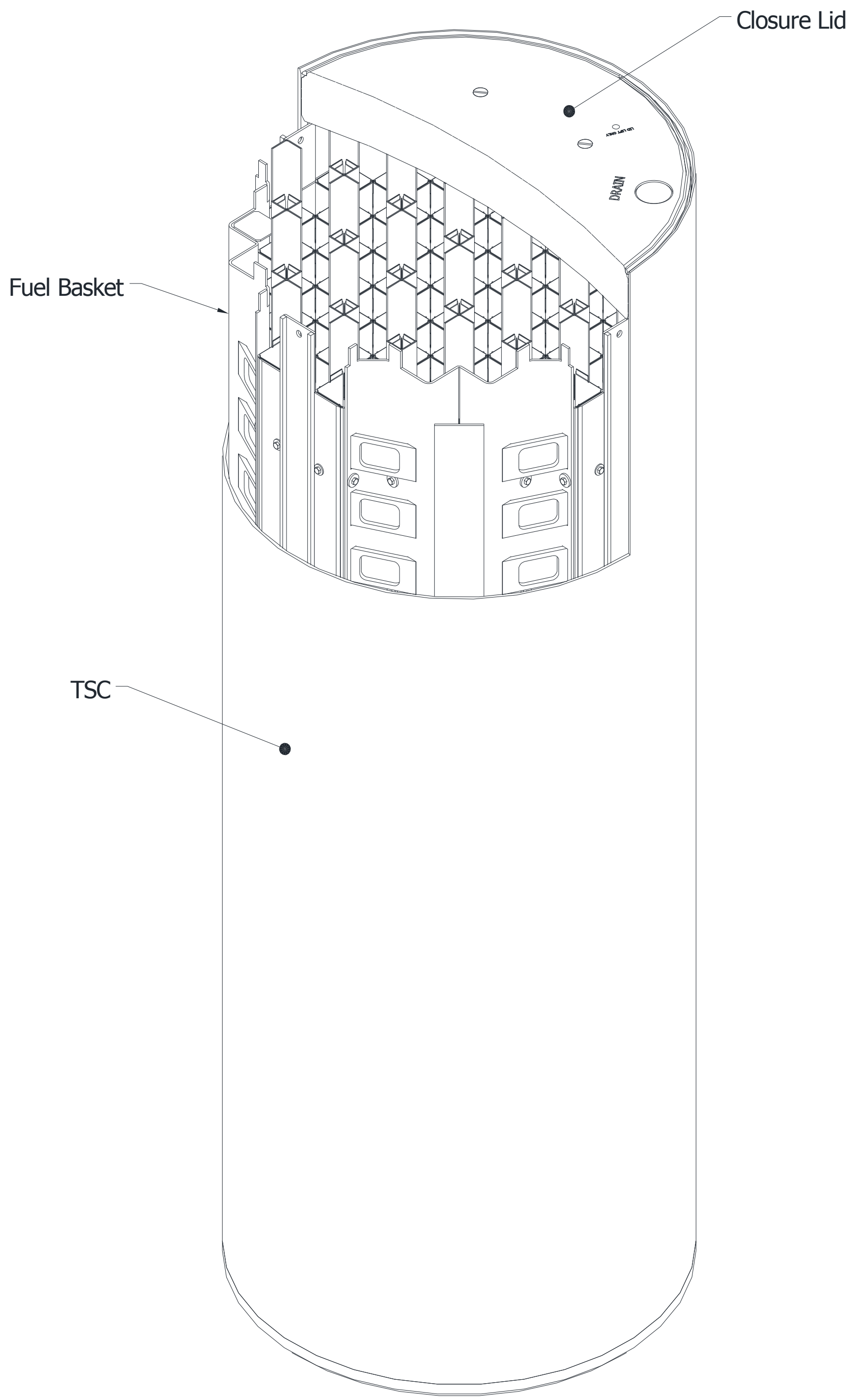

Figure G.4-2
TSC and Basket

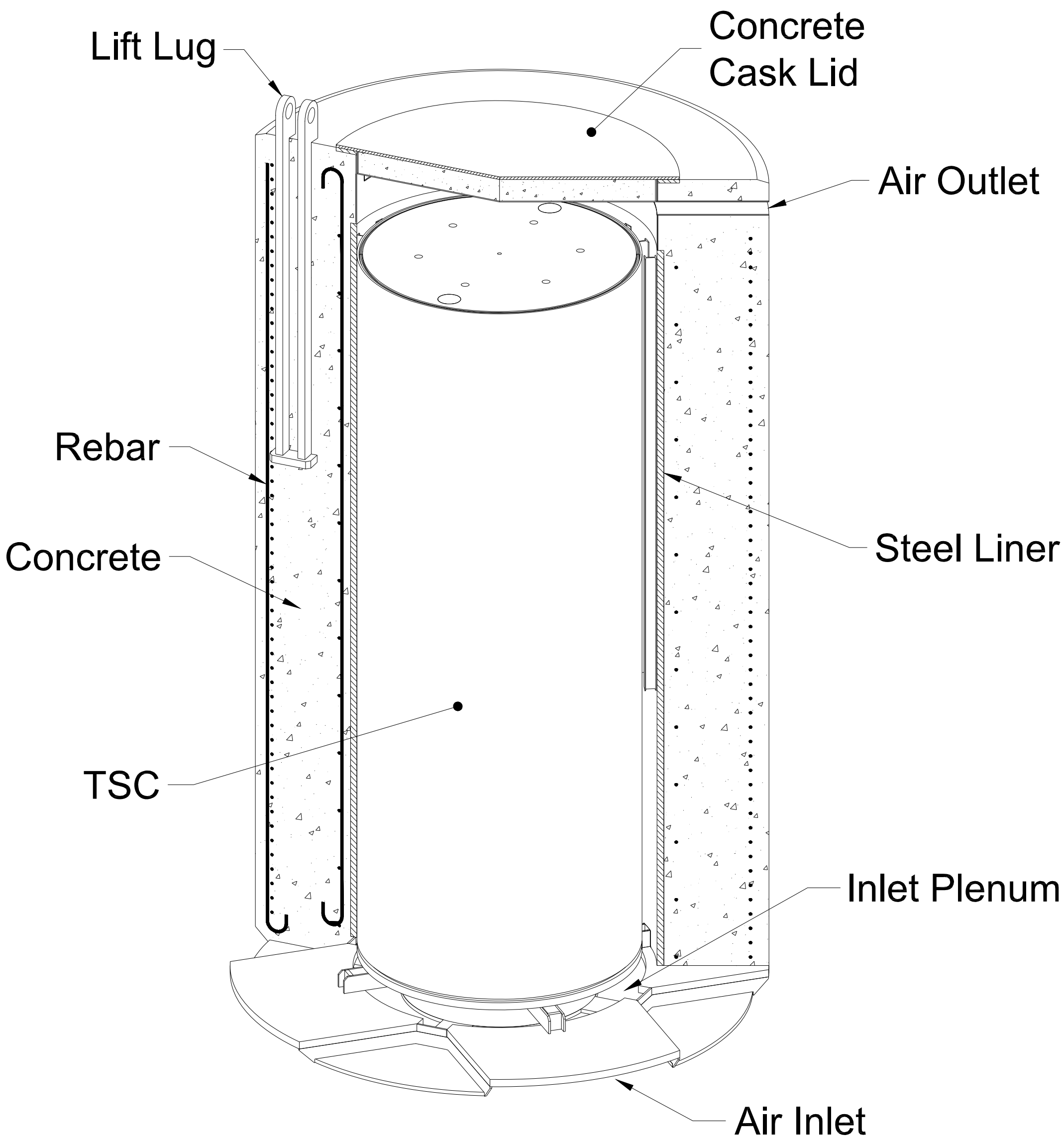

Figure G.4-3
Concrete Cask

Table G.4-1
Concrete Cask Construction Specification Summary

Materials

- Concrete mix shall be in accordance with the requirements of ACI 318 and ASTM C94.
- Type II Portland Cement, ASTM C150.
- Fine aggregate ASTM C33 or C637.
- Coarse aggregate ASTM C33.
- Aggregates that conform to the particle size requirements of a U.S. state’s transportation agency, which is in general use in the area, should be considered as having a satisfactory service record with regard to those concrete properties affected by the respective grading requirement.
- Admixtures
  - Water Reducing and Superplasticizing ASTM C494.
  - Pozzolanic Admixture (loss on ignition 6% or less) ASTM C618.
- Compressive strength 4000 psi minimum at 28 days.
- Specified air entrainment per ACI 318.
- All steel components shall be of the material as specified in the referenced drawings.

Construction

- A minimum of two samples for each concrete cask shall be taken in accordance with ASTM C172 and ASTM C31 for the purpose of obtaining concrete slump, density, air entrainment, and 28-day compressive strength values. The two samples shall not be taken from the same batch or truck load.
- Test specimens shall be tested in accordance with ASTM C39.
- Formwork shall be in accordance with ACI 318.
- All sidewall formwork shall remain in place in accordance with the requirements of ACI 318.
- Grade, type, and details of all reinforcing steel shall be in accordance with the referenced drawings.
- Embedded items shall conform to ACI 318 and the referenced drawings.
- The placement of concrete shall be in accordance with ACI 318.
- Surface finish shall be in accordance with ACI 318.
- Welding and inspection requirements and acceptance criteria are specified in Chapter 10.

Quality Assurance

- The concrete cask shall be constructed under a quality assurance program that meets 10 CFR 72, Subpart G.

Table G.4-2
Concrete Cask Lid – Construction Specification Summary

Concrete mix shall be in accordance with the following ACI 318 requirements:

- Standard weight concrete density shall be 140 pcf (minimum)
- No strength requirements – commercial grade concrete from a commercial grade supplier

APPENDIX G.5
OPERATING PROCEDURES
NAC-MAGNASTOR

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G.5 OPERATING PROCEDURES

The following are operating procedures for using the MAGNASTOR spent fuel storage system. These procedures are based on the general guidance found in Chapter 9 of the MAGNASTOR Final Safety Analysis Report (FSAR) [Reference G.5-1]. The procedures covered are:

1. Transferring the loaded TSC to the Concrete Cask.

2. Transporting and placing the loaded Concrete Cask.

3. Removing the loaded TSC from a Concrete Cask.

4. Receiving the MAGNATRAN Transport Cask and Unloading the loaded TSC.

The operating procedure for transferring a loaded TSC from a MAGNASTOR concrete cask to the MAGNATRAN Transport Cask is described in the MAGNATRAN Safety Analysis Report, Docket 71-9356. Also, the detailed operating procedures for receiving a loaded MAGNATRAN Transport Cask and unloading the transportable storage canister are described in Section 7.2 of the MAGNATRAN Safety Analysis Report.

System user personnel shall use this information to prepare the detailed, site-specific procedures for loading, handling, storing, and unloading MAGNASTOR. Users may add, delete, or change the sequence of specific steps of the procedures to accommodate site-specific requirements provided that the general order of the tasks associated with TSC closure and storage is preserved and that the specific requirements for fastener torque values, temperature limits for operations, and other defined values in the procedure are also met.

All facility-specific procedures prepared by users must fully comply with the MAGNASTOR Certificate of Compliance (CoC) and Technical Specifications, including the approved contents and design features.

Tables in Chapter 3 of Reference G.5-1 provide the handling weights for the major components of MAGNASTOR and the loads to be lifted during various phases of the loading and unloading operations. Licensees/users must perform appropriate reviews and evaluations to ensure that the lifted loads do not exceed rated load limits of user-supplied lifting equipment and comply with the facility's heavy-load program.

Pictograms of the NAC-MAGNASTOR System operations are presented in Figure G.5-1.

G.5.1 Undamaged and Damaged PWR Fuel

Operation of the MAGNASTOR system requires the use of auxiliary equipment. Refer to Table 9.1-1 of Reference G.5-1 for a listing of the major auxiliary equipment generally required by the user to operate the system. MAGNASTOR provides effective shielding for operations personnel; however, the licensee/user may utilize supplemental shielding to further reduce operator radiation exposure. The planned location, type, and possible interactions of the temporary supplemental shielding with MAGNASTOR shall be appropriately evaluated by the licensee/user.

G.5.1.1 Transferring the TSC to the Concrete Cask

This section describes the sequence of operations required to complete the transfer of a loaded TSC from the transfer cask into a concrete cask, and preparation of the concrete cask for movement to the ISFSI pad.

1. Position an empty concrete cask with the lid assembly removed in the designated TSC transfer location.

   Note: The concrete cask can be positioned on the ground, or on a deenergized air pad set, roller skid, heavy-haul trailer, rail car, or transfer cart. The transfer location can be in a truck/rail bay inside the loading facility or an external area accessed by the facility cask handling crane.

   Note: The minimum ambient air temperature (either in the facility or external air temperature, as applicable for the handling sequence) must be ≥ 0ºF for the use of the concrete cask, per Section 4.3.1.g. of the MAGNASTOR Technical Specifications.

2. Inspect all concrete cask openings for foreign objects and remove if present; install supplemental shielding in four outlets.
3. Install a four-legged sling set to the lifting points on the transfer adapter.
4. Using the crane, lift the transfer adapter and place it on top of the concrete cask ensuring that the guide ring sits inside the concrete cask lid flange. Remove the sling set from the crane and move the slings out of the operational area.
5. Connect a hydraulic supply system to the hydraulic cylinders of the transfer adapter.
6. Verify the movement of the connectors and move the connector tees to the fully extended position.
7. Connect the lift yoke to the crane and engage the lift yoke to the transfer cask trunnions. Ensure all lines, temporary shielding and work platforms are removed to allow for the vertical lift of the transfer cask.

Note: The minimum ambient air temperature (either in the facility or external air temperature, as applicable for the handling sequence) must be ≥ 0ºF for the use of the transfer cask, per Section 4.3.1.f. of the MAGNASTOR Technical Specifications.

8. Raise the transfer cask and move it into position over the empty concrete cask.
9. Slowly lower the transfer cask into the engagement position on top of the transfer adapter to align with the door rails and engage the connector tees.
10. Following set down, remove the lock pins from the shield door lock tabs.
11. Install a stabilization system for the transfer cask, if required by the facility heavy load handling or seismic analysis programs.
12. Disengage the lift yoke from the transfer cask trunnions and move the lift yoke from the area.
13. As appropriate to the TSC lifting system being used, move the lifting system to a position above the transfer cask. If redundant sling sets are being used, connect the sling sets to the crane hook.
14. Using the TSC lifting system, lift the TSC slightly (approximately ½-1 inch) to remove the TSC weight from the shield doors.

    Note: The lifting system operator must take care to ensure that the TSC is not lifted such that the retaining blocks (MTC1/MTC2) or the retaining ring (MTC2) is engaged by the top of the TSC.

15. Open the transfer cask shield doors with the hydraulic system to provide access to the concrete cask cavity.
16. Using the cask handling crane in slow speed (or other approved site-specific handling system), slowly lower the TSC into the concrete cask cavity until the TSC is seated on the pedestal.

    Note: The transfer adapter and the standoffs in the concrete cask will ensure the TSC is appropriately centered on the pedestal within the concrete cask.

    Note: The completion of the transfer of the TSC to the concrete cask (i.e., the top of the TSC is in the concrete cask cavity) completes the TSC transfer evolution time from Step 69 in Section 9.1.1.

17. When the TSC is seated, disconnect the slings (or other handling system) from the lifting system, and lower the sling sets through the transfer cask until they rest on top of the TSC.
18. Retrieve the lift yoke and engage the lift yoke to the transfer cask trunnions.
19. Remove the seismic/heavy load restraints from the transfer cask, if installed.

20. Close the shield doors using the hydraulic system and reinstall the lock pins into the shield door lock tabs.
21. Lift the transfer cask from the top of the concrete cask and return it to the cask preparation area for next fuel loading sequence or to its designated storage location.
22. Disconnect hydraulic supply system from the transfer adapter hydraulic cylinders.
23. Remove redundant sling sets, swivel hoist rings, or other lifting system components from the top of the TSC, if installed.
24. Verify all equipment and tools have been removed from the top of the TSC and transfer adapter.
25. Connect the transfer adapter four-legged sling set to the crane hook and lift the transfer adapter off the concrete cask. Place the transfer adapter in its designated storage location and remove the slings from the crane hook. Remove supplemental shielding from outlets.

    Note: If the optional low profile concrete cask is used, proceed to Step 26. If the standard concrete cask is provided, proceed to Step 38.
26. Install three swivel hoist rings and the three-legged sling set on the concrete cask shield ring.
27. Using the crane, lift the shield ring and place it into position inside of the concrete cask top flange.
28. Remove the three-legged sling and swivel hoist rings.
29. Using the designated transport equipment, move the loaded concrete cask out of the low clearance work area or truck/rail bay.
30. Install the three swivel hoist rings into the three threaded holes and attach the three-legged sling set to the shield ring.
31. Using an external or mobile crane, lift and remove the shield ring. Place the shield ring in position for the next loading sequence or return it to its designated storage location.
32. Install four swivel hoist rings in the threaded holes of the concrete cask extension using the manufacturer-specified torque.
33. Install the four-legged sling set and attach to the crane hook.

    Note: A mobile crane of sufficient capacity may be required for concrete cask extension and lid installations performed outside the building.

34. Perform visual inspection of the top of the concrete cask and verify all equipment and tools have been removed.

    Note: Take care to minimize personnel access to the top of the unshielded loaded concrete cask due to shine from the TSC.

35. Lift the concrete cask extension and move it into position over the concrete cask, ensuring alignment of the two anchor cavities with their mating lift anchor embedment.

36. Lower the concrete cask extension into position and remove the sling set from the crane hook.

37. Remove the four swivel hoist rings and cables from the concrete cask extension.

    Note: If concrete cask transport is to be performed by a vertical cask transporter, proceed to Step 38.

38. Install the lift lugs into the anchor cavities of the concrete cask extension, or directly on top of the lifting embedment for the standard concrete cask, if applicable to the concrete cask design utilized.

39. Install the lift lug bolts through each lift lug and into the threaded holes in the embedment base. Torque each of the lug bolts to the value specified in Table 9.1-2 of Reference G.5-1.

40. Install three swivel hoist rings into the concrete cask lid and attach the three-legged sling set. Attach the lifting sling set to the crane hook.

41. At the option of the user, install the weather seal on the concrete cask lid flange. Lift the concrete cask lid and place it in position on the top of the flange.

42. Remove the sling set and swivel hoist rings and install the concrete cask lid bolts. Torque to the value specified in Table 9.1-2 of Reference G.5-1.

43. Move the loaded concrete cask into position for access to the site-specific transport equipment.

G.5.1.2 Transporting and Placing the Loaded Concrete Cask

This section describes the general procedures for moving a loaded concrete cask to the ISFSI pad using a vertical cask transporter.

1. Using the vertical cask transporter lift fixture or device, engage the two concrete cask lifting lugs.

2. Lift the loaded concrete cask and move it to the ISFSI pad following the approved onsite transport route.

Note: Ensure vertical cask transporter lifts the concrete cask evenly using the two lifting lugs.

Note: Do not exceed the maximum lift height for a loaded concrete cask of 24 inches, per Section 4.3.1.h. of the MAGNASTOR Technical Specifications.

3. Move the concrete cask into position over its intended ISFSI pad storage location. Ensure the surface under the concrete cask is free of foreign objects and debris.

   Note: The spacing between adjacent loaded concrete casks must be at least 15 feet.

4. Using the vertical transporter, slowly lower the concrete cask into position.
5. Disengage the vertical transporter lift connections from the two concrete cask lifting lugs. Move the cask transporter from the area.
6. Detorque and remove the lift lug bolts from each lifting lug, if the lugs are to be reused.

   Note: At the option of the user, the lift lugs may be left installed during storage operations.

7. Lift out and remove the concrete cask lift lugs. Store the lift lugs for the next concrete cask movement.
8. Install the lug bolts through the extension base (or through the cover plate for the standard concrete cask) and into the threaded holes. Torque each bolt to the value specified in Table 9.1-2 of Reference G.5-1.
9. For the casks with extensions containing anchor cavities, install the weather seal and cover plates. Install the bolts and washers and torque to the value specified in Table 9.1-2 of Reference G.5-1.
10. If optional temperature monitoring is implemented, install the temperature monitoring devices in each of the four outlets of the concrete cask and connect to the site's temperature monitoring system.
11. Install inlet and outlet screens to prevent access by debris and small animals.

    Note: Screens may be installed on the concrete cask prior to TSC loading to minimize operations personnel exposure.

12. Scribe and/or stamp the concrete cask nameplate to indicate the loading date. If not already done, scribe or stamp any other required information.
13. Perform a radiological survey of the concrete cask within the ISFSI array to confirm dose rates comply with ISFSI administrative boundary and site boundary dose limits.

14. Initiate a daily temperature monitoring program or daily inspection program of the inlet and outlet screens to verify continuing effectiveness of the heat removal system.

G.5.1.3 Removing the Loaded TSC from a Concrete Cask

This procedure assumes the loaded concrete cask is returned to the reactor loading facility for unloading. However, transfer of the TSC to another concrete cask can be performed at the ISFSI without the need to return to the loading facility, provided a cask transfer facility that meets the requirements specified in the Technical Specifications is available.

As the steps to move a loaded concrete cask are essentially the reverse of the procedures in Section G.5.1.1 and Section G.5.1.2, the procedural steps are only summarized here.

1. Remove inlet and outlet screens and temperature measuring equipment (if installed).

   Note: The minimum ambient air temperature (either in the facility or external air temperature, as applicable for the handling sequence) must be ≥ 0ºF for the use of the concrete cask, per Section 4.3.1.g. of the MAGNASTOR Technical Specifications.

2. For concrete casks to be transported by a vertical cask transporter, remove anchor cavity cover plates, remove the lid assembly bolts, and install the lift lugs. Torque the lift lug bolts for each lift lug to the value specified in Table 9.1-2 of Reference G.5-1. Attach the concrete cask to the vertical cask transporter.

3. For concrete casks to be transported on a flat-bed vehicle, install an air pad rig set in the inlets. Inflate the air pads and move concrete cask onto the vehicle deck.

   Note: Ensure that air pads are not installed longer than eight hours to complete concrete cask transfer.

4. Move the loaded concrete cask to the facility.

5. Remove the concrete cask lid. Install concrete cask shield ring, if required.

6. Install the six hoist rings into the canister closure lid threaded holes. Remove shield ring, if installed.

   Note: Utilize high temperature-resistant slings (≤ 350°F)

7. Install transfer adapter on top of the concrete cask.

8. Place transfer cask onto the transfer adapter and engage the shield door connectors.

Note: The minimum ambient air temperature (either in the facility or external air temperature, as applicable for the handling sequence) must be ≥ 0ºF for the use of the transfer cask, per Section 4.3.1.f. of the MAGNASTOR Technical Specifications.

9. Open the shield doors, retrieve the lifting slings, and install the slings on the lifting system.
10. Slowly withdraw the TSC from the concrete cask. The chamfer on the underside of the transfer adapter assists in the alignment into the transfer cask.
11. Bring the TSC up to just below the retaining blocks (MTC1/MTC2) or the retaining ring (MTC2). Close the transfer cask shield doors and install the shield door lock pins.
12. Lift transfer cask off the concrete cask and move to the designated workstation.

After the transfer cask with the loaded TSC is in, or adjacent to, the facility, the operational sequence to load another concrete cask is performed in accordance with the procedures in Section G.5.1.1. Note that the amount of time that a loaded TSC can remain in the transfer cask without cooling is limited to 11 hours from the time the TSC is removed from the concrete cask. Internal or external cooling of the TSC is required to be initiated within 11 hours as described in Section 9.3 of Reference G.5-1.

G.5.1.4 Receiving the MAGNATRAN Transport Cask and Unloading the Loaded TSC

The following procedure(s) cover inspecting the cask upon receipt, preparing the cask for removal from its conveyance, and unloading the transportable storage canister into the transfer cask. Following unloading of the transportable storage canister into the transfer cask, the previously described procedures should be followed to place the transportable storage canister into dry storage in a vertical concrete cask, or an equivalent, approved storage configuration. Note, the requirements of the transport cask CoC must be followed at all times. *In the event there is conflict between the following procedures and the transport CoC requirements, the transport CoC requirements take precedence.*

G.5.1.4.1 Performing Receiving Inspection of the Loaded MAGNATRAN Transport Cask

1. Upon receipt of the loaded MAGNATRAN transport cask, perform and record radiation and removable contamination surveys on the transport vehicle, personnel barrier and package surfaces to verify that radiation dose rates and contamination levels comply with the requirements of 10 CFR 20.1906, the limits of 10 CFR 71.87(i), and the limits of 10 CFR 71.47.
2. Remove the personnel barrier and complete radiation and contamination surveys of the now-accessible package surfaces to verify that radiation dose rates and contamination levels comply with the requirements of 10 CFR 20.1906, the limits of 10 CFR 71.87(i), and the limits of 10 CFR 71.47.
3. Perform a visual receipt inspection of the vehicle and package to identify any transport damage. Clean the vehicle and cask of road dirt and debris. Cleaning of the package exterior shall ensure that surfaces are cleaned of chloride-containing salts and other corrosive agents. Confirm the acceptable removal of chloride-containing salts and other corrosive agents.
4. Verify the tamper indicating device (TID) installed on the upper impact limiter is intact and the identification number matches the number documented on the shipping papers. Make appropriate notifications if tampering is suspected. Remove the TID.
5. Move the transport vehicle to the cask unloading area. Secure the vehicle by applying the brakes or chocking the wheels. Attach impact limiter slings to the upper impact limiter and a suitable crane hook and take up the slack in the slings.
6. Remove the impact limiter lock wires and the jam and attachment nuts. Remove the impact limiter retaining rods. Remove the upper impact limiter and store it in the upright position in a clean area.
7. Repeat Steps 5-6 for the lower impact limiter.
8. Complete radiation and contamination surveys for exposed transport cask surfaces.
9. Release the front tie-down assembly from the top forging of the cask and remove the rotation trunnion tie-downs. Remove the two trunnion plugs and store the plugs and bolts to prevent damage. Visually inspect the trunnion recesses for any damage.
10. Using a crane and slings, lift and position a lifting trunnion, install the attachment bolts, and torque the bolts as specified. Repeat for the second lifting trunnion.
11. Attach the cask lifting yoke to the cask handling crane hook. Verify the proper operation of the lift arm pneumatic actuation system. Position the cask lifting yoke arms adjacent to the cask lifting trunnions and close the arms using the actuation system. Visually verify proper yoke arm engagement.

12. Lift and rotate the cask to the vertical orientation on the rotation trunnions. Lift the cask from the transport frame/vehicle rear support structure and position the cask vertically in the designated unloading area.
13. Disengage the yoke from the cask lifting trunnions and remove it from the immediate area. Wash any dust and dirt off the cask and decontaminate cask exterior, as required
14. Install appropriate work platforms, scaffolding or lifts to facilitate access to the top of the cask.

G.5.1.4.2 Preparing to unload the transportable storage canister (TSC) from the MAGNATRAN Transport Cask

The assumptions underlying this procedure are:

- The MAGNATRAN Transport Cask is in a vertical position in the designated unloading area.
- The top of the MAGNATRAN Transport Cask is accessible.

The procedures for preparing to unload the TSC from the MAGNATRAN Transport Cask are:

1. Detorque and remove the lid port coverplate bolts. Visually inspect the bolt threads for damage and store them. Remove the coverplate and store it.
2. Attach a pressure fixture, including a pressure gauge, evacuated gas sample bottle and a valve to the lid port quick-disconnect valve. Measure the cask internal pressure. Withdraw a sample of the cavity gas using the evacuated sample bottle and determine the cask cavity's gaseous activity. If activity and pressure levels are acceptable per facility criteria, vent the cavity gas to an appropriate filter/system. Disconnect the pressure fixture from the lid port.
3. Detorque and remove the cask lid bolts using the reverse of the torquing sequence shown on the lid. Clean and inspect the bolt threads for damage and store them.
4. Install and torque swivel hoist rings, as specified, in the four threaded lifting holes in the cask lid. Install and hand-tighten the lid alignment pins in their designated hole locations.
5. Attach an appropriate lid sling set to the swivel hoist rings (or equivalent site-specific approved lid lifting system) and a suitable crane. Lift and remove the cask lid. Decontaminate and store the lid to prevent damage to the seal surfaces and cask cavity spacer, if installed. Record the time the lid is removed.

Caution: In order to ensure that the fuel clad temperatures do not exceed 400ºC, as established by ISG-11, Revision 3, a fuel TSC containing maximum heat load contents (i.e., PWR - 23 kW; BWR - 22 kW) shall be removed from the MAGNATRAN following cask lid removal and placed in a safe condition (i.e., in a MTC or equivalent transfer device). The maximum time to complete the operational sequence shall be < 6 hours. This maximum transfer and preparation time is not applicable to the loading of GTCC waste TSCs as the ISG-11 temperature limits are not applicable.

G.5.1.4.3 Unloading the transportable storage canister (TSC) from the MAGNATRAN Transport Cask

A transfer cask (MTC) is used to unload the transportable storage canister (TSC) from the transport cask and to transfer it to a storage or disposal overpack. The transfer cask retaining ring or retaining blocks must be installed.

The procedures for unloading the transportable storage canister from the MAGNATRAN Transport Cask are:

1. Remove the lid alignment pins, and using a suitable crane and sling set, install the transfer shield ring in the lid recess.

   Note: The transfer shield ring aligns the transfer adapter to the cask cavity, provides additional side shielding and protects the cask lid seating surface from damage.
2. Position the transfer adapter on the top of the transport cask and connect the shield door ancillary hydraulic actuation system.
3. Install the TSC lifting system swivel hoist rings and lifting slings (or other appropriate TSC lifting system meeting the facility’s heavy load program) to the threaded holes in the TSC closure lid and torque as specified.
4. Using the MTC lift yoke, lift the empty MTC and place it on the transfer adapter on top of the transport cask. Ensure that the connector assemblies are in the engaged position. Remove the door stops.
5. Disengage the MTC lift yoke and remove it from the area.
6. Open the MTC bottom shield doors using the ancillary hydraulic actuation system. Connect the handling crane to the TSC lifting sling set(s) or the site-specific approved lifting system meeting the facility’s heavy load program. Verify that the MTC retaining device is in the engaged position and raise the loaded TSC from the transport cask cavity into the MTC.

7. Using the ancillary hydraulic actuation system, close the MTC bottom shield doors and set the TSC down on the doors. Install the shield door stops.
8. Disengage the TSC lifting sling set(s) from the cask handling crane or disengage the site-specific approved lifting system meeting the facility's heavy load program.
9. Using the MTC lift yoke, engage the lift yoke to the MTC lifting trunnions. Lift the MTC containing the loaded TSC and move it to the designated location for further processing, on-site storage or unloading.

Continue operations to place the canister in an approved storage configuration as described in Paragraph G.5.1.1.

G.5.2 References

G.5-1 MAGNASTOR Final Safety Analysis Report, Revision 7, July 2015

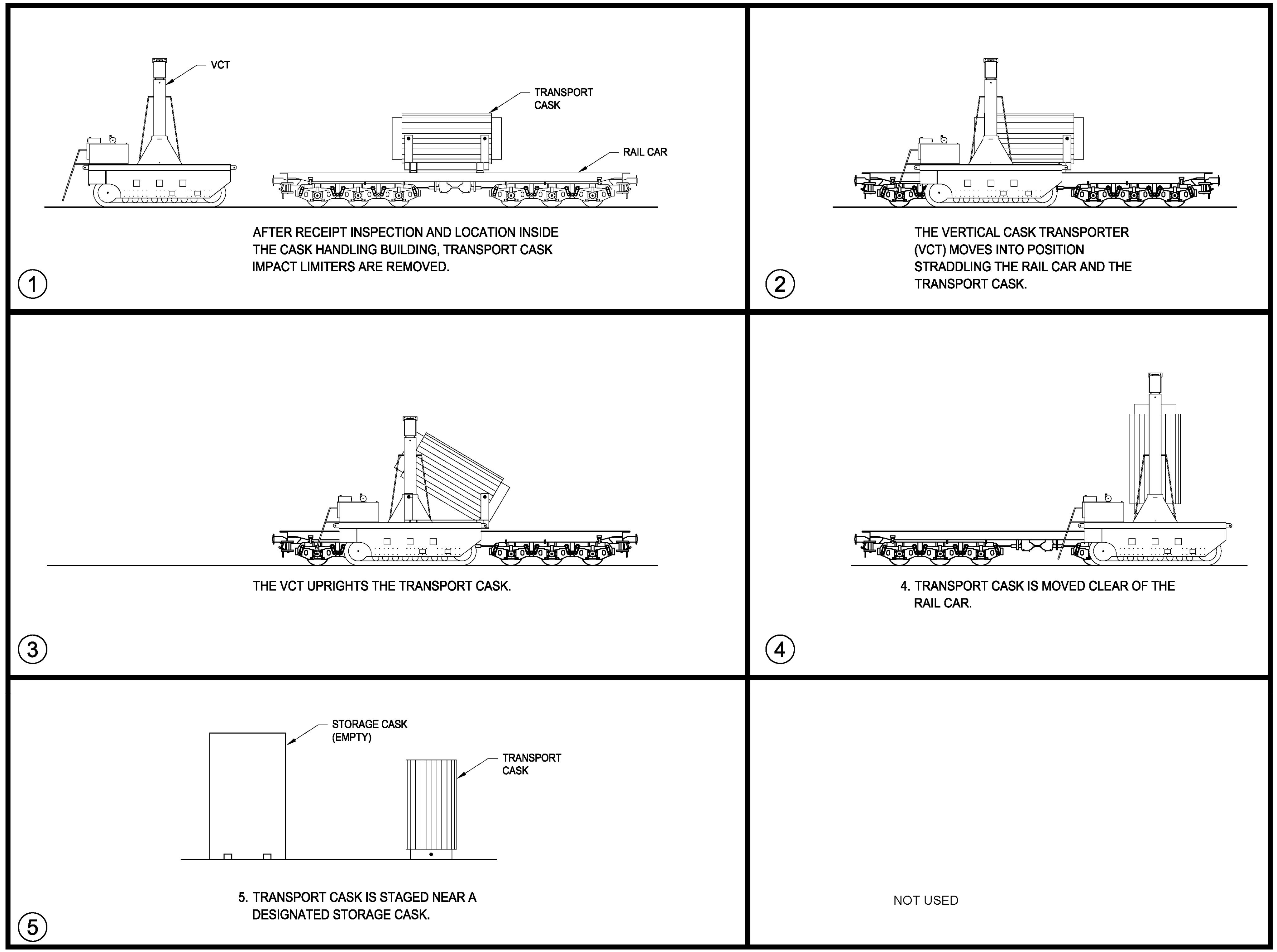

Figure G.5-1
Canister Transfer Operations
2 Pages

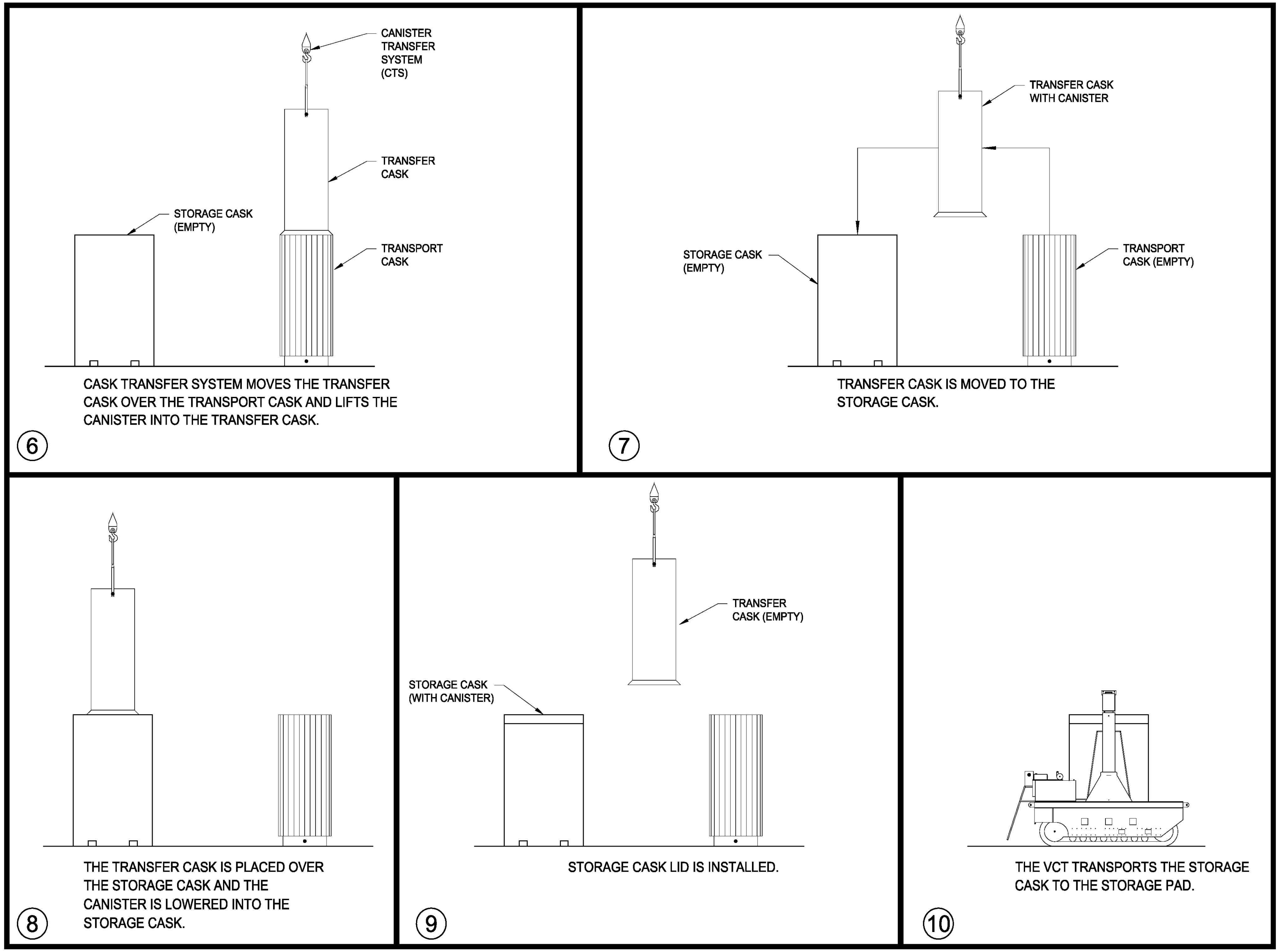

Figure G.5-1
Canister Transfer Operations
2 Pages

APPENDIX G.6
WASTE CONFINEMENT AND MANAGEMENT
NAC-MAGNASTOR

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G.6. WASTE CONFINEMENT AND MANAGEMENT

No change or additional information required for the MAGNASTOR Cask System for Chapter 6.

APPENDIX G.7
STRUCTURAL EVALUATION
NAC-MAGNASTOR

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G.7 STRUCTURAL EVALUATION

This appendix summarizes the location of the detailed structural analyses for the MAGNASTOR system under normal operating conditions in Reference G.7-1. Off-normal and accident events are covered in WCS SAR Appendix G.12.

G.7.1 Undamaged and Damaged PWR Fuel

Sections G.7.1.1 through G.7.1.8 outline the structural analyses of normal operating conditions for MAGNASTOR with undamaged and damaged PWR fuel presented in Reference G.7-1. *Finally, bounding evaluations in Section G.7.1.9 are referenced to demonstrate that the confinement boundaries for the MAGNASTOR canisters 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.*

G.7.1.1 Structural Design

Details of the structural design of the MAGNASTOR system are provided in Section 3.1 of Reference G.7-1.

G.7.1.2 Weights and Centers of Gravity

The weights and centers of gravity of the MAGNASTOR system are provided in Section 3.2 of Reference G.7-1.

G.7.1.3 Materials

The significant physical, chemical, mechanical, and thermal properties of materials used in components of MAGNASTOR are defined, and the material specifications, tests and acceptance conditions important to material use are identified in Chapter 8 of Reference G.7-1.

G.7.1.4 Chemical and Galvanic Reactions

The materials used in the fabrication and operation of MAGNASTOR are evaluated in Section 8.10 of Reference G.7-1 to determine whether chemical, galvanic or other reactions among the materials, contents, and environments can occur.

G.7.1.5 Positive Closure

The positive closure evaluation for MAGNASTOR is provided in Section 3.4.2 of Reference G.7-1.

G.7.1.6 Lifting Devices

The evaluations of the MAGNASTOR system's lifting devices are provided in Section 3.4.3 of Reference G.7-1.

G.7.1.7 Normal Operating Conditions

The analyses of the major structural components of MAGNASTOR for normal conditions of storage are provided in Section 3.5 of Reference G.7-1.

G.7.1.8 Fuel Rods

The structural evaluations of PWR fuel rods for the storage conditions of the MAGNASTOR system are provided in Section 3.8 of Reference G.7-1.

G.7.1.9 Structural Evaluation of NAC-MAGNASTOR Canister Confinement Boundaries under Normal Conditions of Transport

The NAC-MAGNASTOR canister primary confinement boundaries consist of a canister shell, bottom closure plate, closure lid, the two port covers, and the welds that join these components. Redundant closure is provided by two outer port covers and a closure ring. Additional details, geometry, and shell and plate thicknesses are provided on the figures in Section G.4. The confinement boundary is addressed in Section G.11.1.1. The evaluation findings for the NAC-MAGNASTOR canister shell for normal conditions of transport are provided in Section 2.6.12 of [G.7-2].

The result of the structural analysis is acceptable for the loads and combinations described in Section 2.6.12 of [G.7-2], and is therefore structurally adequate for normal conditions of transport loading conditions.

G.7.2 References

G.7-1 MAGNASTOR Final Safety Analysis Report, Revision 7, July 2015.

G.7-2 *MAGNATRAN Transport Cask Safety Analysis Report, Revision 12A, October 2012.*

APPENDIX G.8
THERMAL EVALUATION
NAC-MAGNASTOR

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G.8 THERMAL EVALUATION

Chapter 4 of Reference G.8-1 presents the thermal design and analyses of MAGNASTOR. Results of the analyses contained therein demonstrate that with the design basis contents, MAGNASTOR meets the thermal performance requirements of 10 CFR 72, NUREG-1567, and NUREG-1536.

The MAGNASTOR design basis heat load is 35.5 kW for PWR fuel. The fuel loading may be in the 37 PWR Basket Assembly, i.e., up to 37 undamaged PWR fuel assemblies, or up to 37 PWR minimum reduced cool time fuel, or in the DF Basket Assembly, which has a capacity of up to 37 undamaged fuel assemblies including four DFC locations. Damaged fuel cans may be located in the DFC locations at the four outer corners of the DF basket assembly. Both the PWR fuel basket and the DF basket assembly can accommodate a uniform heat load of 959 W per assembly, or a preferential loading pattern as discussed in Section 4.1 of Reference G.8-1.

MAGNASTOR system thermal evaluations are performed using conservative environmental thermal parameters. The following sections details those thermal parameters and shows that they bound the site-specific thermal environmental parameters at the WCS facility.

G.8.1 Undamaged and Damaged PWR Fuel

Chapter 4 of Reference G.8-1 provides the thermal analyses used evaluate the thermal performance of the MAGNASTOR system. The limiting environmental conditions (thermal) used in these evaluations are presented and compared to WCS site specific conditions in the following sections. Additionally, surveillance requirements used to ensure the concrete cask heat removal system is operable are presented.

G.8.1.1 Maximum Average Yearly Ambient Temperature

For the MAGNASTOR system, the maximum average yearly temperature allowed is 76°F. The the average yearly temperature for the site is conservatively bounded by using the maximum average annual temperature in the 48 contiguous United States, of 75.6°F. This temperature meets the normal condition thermal boundary defined in NUREG-1536. Therefore, no further WCS site-specific evaluations are required.

G.8.1.2 Maximum Average 3-Day Ambient Temperature

The maximum average 3-day ambient temperature allowed is 106°F for the MAGNASTOR system. This temperature bounds the WCS facility maximum average 3-day ambient temperature of *89.4*°F. Therefore, no further site-specific evaluations are needed.

G.8.1.3 Maximum Extreme 3-Day Ambient Temperature Range

For the MAGNASTOR system, the maximum allowed temperature extremes, averaged over a 3-day period, shall be greater than -40°F and less than 133°F. This bounds the WCS facility maximum temperature extreme of *-1*°F and *113*°F. No further site-specific evaluations are needed.

G.8.1.4 Thermal Performance Surveillance Requirements

For the MAGNASTOR system, in order to confirm that the concrete cask heat removal system is operable, one of the following two surveillance options with a frequency of 24 hours is required:

1. Visually verify all concrete cask air inlet and outlet screens are free of blockage.

2. Verify the difference between the concrete cask air outlet average temperature and the ambient temperature is less than 119ºF for the PWR concrete cask configurations CC1, CC2, and CC4 or less than 134ºF for PWR concrete cask configuration CC3.

G.8.2 References

G.8-1 MAGNASTOR Final Safety Analysis Report, Revision 7, July 2015

APPENDIX G.9
RADIATION PROTECTION
NAC-MAGNASTOR

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G.9 RADIATION PROTECTION

This appendix summarizes the shielding analysis for the MAGNASTOR system. Specific dose rate limits for individual casks in a storage array are not established by 10 CFR 72. Annual dose limit criteria for the ISFSI-controlled area boundary are established by 10 CFR 72.104 and 10 CFR 72.106 for normal operating conditions and for design basis accident conditions, respectively. These regulations require that, for an array of casks in an ISFSI, the annual dose to an individual outside the controlled area boundary must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ during normal operations. For a design basis accident, the dose to an individual outside the controlled area boundary must not exceed 5 rem to the whole body. In addition, the occupational dose limits and radiation dose limits established in 10 CFR Part 20 (Subparts C and D) for individual members of the public must be met.

The MAGNASTOR system is designed with two transfer cask and four concrete cask configurations. Transfer casks are designed with either carbon steel shells (MTC1) or stainless steel shells (MTC2). Concrete casks are designed in:

- A standard shielding configuration (one piece – CC1 and segmented – CC2) with a 1.75-inch liner thickness (PWR and BWR systems);
- An augmented shielding configuration (CC3) with a 3-inch liner thickness, an increased lid thickness and additional shielding at the air inlets (PWR system);
- And a short, standard shielding configuration cask (CC4) with a 1.75-inch liner thickness and additional shielding at the air inlets (PWR system).

Canisters may be sealed with either an all stainless steel closure lid or a composite carbon steel and stainless steel lid assembly. The composite lid assembly bounds the all stainless steel lid in shielding evaluations due to the lower density of carbon steel.

Chapter 5 of Reference G.9-1 describes the shielding design and the analysis used to establish bounding radiological dose rates for the safe storage of up to 37 undamaged PWR fuel assemblies in the MAGNASTOR 37 PWR basket assembly. The MAGNASTOR system is also designed to store up to four damaged fuel cans (DFCs) in the DF Basket Assembly. The DF Basket Assembly has a capacity of up to 37 undamaged PWR fuel assemblies, including four DFC locations. DFCs may be placed in up to four of the DFC locations. Each DFC may contain an undamaged PWR fuel assembly or damaged fuel, which may be a damaged PWR fuel assembly or PWR fuel debris equivalent to one PWR fuel assembly. Undamaged PWR fuel assemblies may be placed directly in the DFC locations of a DF Basket Assembly.

PWR fuel assemblies may contain nonfuel hardware – i.e., reactor control components (RCCs), burnable poison rod assemblies (BPRAs), guide tube plug devices (GTPDs), neutron sources/neutron source assemblies (NSAs), hafnium absorber assemblies (HFRAs), instrument tube tie components, in-core instrument thimbles, and steel rod inserts (used to displace water from the lower section of guide tubes), and components of these devices, such as individual rods. The analysis shows that for the design basis fuel, the system meets the requirements of 10 CFR 72.104 and 10 CFR 72.106 and complies with the requirements of 10 CFR 20 with regard to annual and occupational doses at the owner-controlled area boundary.

Minimum cool times prior to fuel transfer and storage are specified as a function of minimum assembly average fuel enrichment and maximum assembly average burnup (MWd/MTU). To minimize the number of loading tables, PWR and BWR fuel assemblies are grouped by bounding fuel and hardware mass. Key characteristics of each assembly grouping are shown in Section 5.2 of Reference G.9-1. Refer to Section 5.8.9 of Reference G.9-1 for detailed loading tables meeting the system heat load limits.

Source terms for the various vendor-supplied fuel types are generated using the SCALE 4.4 sequence as discussed in Section 5.2 of Reference G.9-1. Three-dimensional MCNP shielding evaluations provide dose rates for transfer and concrete casks at distances up to four meters. NAC-CASC, a modified version of the SKYSHINE-III code, calculates site boundary dose rates for either a single cask or cask array. See Section 5.6 of Reference G.9-1 for more detail on the shielding codes.

Table G.9-1 provides estimated occupational exposures for receipt and handling of the NAC-MAGNASTOR system loaded with PWR fuel at the WCS CISF facility. For each procedural step the number of workers, occupancy time, worker distance, dose rates, and total dose are estimated. Dose rates used were obtained and estimated via the listed references in the table. The total occupational exposure for receiving, transferring and placing these canisters on the storage pad in their storage overpack (VCC) is 1,023 person-mrem each.

The total collective dose for unloading a NAC-MAGNASTOR PWR canister from its VCC and preparing it for transport off-site is bounded by the loading operations (1,023 person-mrem). Operations for retrieving these canisters from the VCC 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 2,046 person-mrem.

G.9.1 Undamaged and Damaged PWR Fuel

Section 5.1 of Reference G.9-1 provides a summary of the results of the shielding evaluation of the MAGNASTOR system. With the exception of the offsite dose discussion, the dose results are presented based on bounding heat loads and corresponding source terms based on a 35.5 kW PWR cask heat load. Offsite dose results are produced by similar bounding values of a 40 kW PWR cask heat load. Cool time tables for the thermally restricting payloads are listed in Section 5.8.9 of Reference G.9-1. Based on the code validation discussion in Section 5.2 of Reference G.9-1, a 5% uncertainty is applied to the heat loads for fuel burnups above 45 GWd/MTU. This results in an extension in minimum allowed cool time for high burnup fuel assemblies. All dose rates calculated at higher cask heat loads are bounding for the reduced heat load. For any fuel type, burnup, initial enrichment, and cool time combination allowed, additional cool time and, therefore, reduced sources are associated with the lower cask heat load. This conclusion applies also to the PWR preferential loading patterns.

A reduced minimum cool time of 2.5 years and four-zone preferential loading pattern (max 1.8 kW/assy heat load) are evaluated in Section 5.9 of Reference G.9-1 for undamaged or damaged PWR assembles in the CC4 or MTC2.

Dose rates (detector tallies) presented in Chapter 5 of Reference G.9-1 are calculated using Monte Carlo methods and, therefore, contain a result and statistical uncertainty of the result. The statistical uncertainty is expressed as a percentage and referred to as fractional standard deviation (FSD) or relative uncertainty.

G.9.1.1 Transfer Cask Shielding Discussion and Dose Results

The transfer cask radial shield is comprised of steel inner and outer shells connected by solid steel top and bottom forgings. *License drawings for these components are provided in Section G.4.3.* The shell encloses a lead gamma shield and a solid borated polymer (NS-4-FR) neutron shield. The TSC shell and the basket internal structure provide additional radial shielding. The transfer operation bottom shielding is provided by the TSC bottom plate and solid steel transfer cask doors. The TSC closure lid provides radiation shielding at the top of the TSC.

The three-dimensional transfer cask shielding analysis provides a complete, nonhomogenized representation of the transfer cask and TSC structure. The model assumes the following TSC/transfer cask configuration for all dose rate evaluations.

- Dry canister cavity: The majority of the TSC operations, in particular closure lid welding, are performed with the TSC cavity filled with water. Evaluating a dry canister cavity is conservative. Note that the water filling the TSC/transfer cask annulus between the inflatable seals is modeled. Transfer cask dose rates from a wet canister, while containing an increased neutron source due to a higher subcritical multiplication resulting from a higher k_{eff}, are lower than those of the dry system due to the additional radiation shielding provided by the water within and surrounding the source region. Confirmatory calculations comparing dry, wet and partially flooded canister configurations are included in Section 5.8.11 of Reference G.9-1.
- 6-in auxiliary weld shield: Closure lid weld operations are typically performed with an automated weld system that is mounted on a weld platform. The presence of this platform provides significant auxiliary shielding during the TSC closure operation.
- Homogenization of the fuel assembly into five source regions: While TSC and concrete cask features are discretely modeled, the fuel assembly is homogenized into upper and lower end-fitting (nozzle) regions, upper and lower plenum regions (lower plenum regions are modeled only for B&W fuel assemblies), and an active fuel region. For shielded applications, such as in the heavily shielded spent fuel transfer and concrete casks, homogenizing the fuel region does not introduce a significant bias in the dose results presented.

Undamaged Fuel Dose Rates

The carbon steel and stainless steel transfer cask maximum calculated dose rates are shown in Table 5.1.3-1 and Table 5.1.3-4 of Reference G.9-1. Payload types producing maximum surface dose rates are listed in Table 5.1.3-3 and Table 5.1.3-6 of Reference G.9-1. TSC surface contamination release dose rates are shown in Section 5.6.5. Dose rates are based on a three-dimensional Monte Carlo analysis using surface detectors. Uncertainty in Monte Carlo results is indicated in parentheses. Further detail on the detector geometry is included in Section 5.5 of Reference G.9-1. There is no design basis off-normal or accident event that will affect the shielding performance of the transfer cask.

Transfer cask top-, side-, and bottom-surface average dose rates are 254 (1.1 %) mrem/hr, 895 (<1%) mrem/hr, and 3,000 (<1%) mrem/hr, respectively. Access to the bottom of the cask is limited to pool-to-workstation transfer operations and the workstation-to-vertical concrete cask transfer operations. Site ALARA plans should specify limited access to areas below and around the loaded transfer cask during lifting and transfer operations.

Damaged Fuel Dose Rates

Damaged PWR fuel assemblies may be loaded in damaged fuel cans in the four corner assembly locations of the PWR damaged fuel basket. DFC slots are locations 4, 8, 30 and 34 in Figure 5.8.12-10 of Reference G.9-1. To ensure that the worst case configuration is considered, two damaged fuel scenarios are evaluated.

The first scenario assumes the damaged fuel collects over the active fuel length of the fuel assembly. This scenario is modeled by filling the fuel assembly interstitial volume with UO_2 and increasing the fuel neutron, gamma and n-gamma source consistent with this increase in mass. Dose rate profiles for the 37-assembly undamaged assemblies are compared with profiles for 33 undamaged and 4 damaged assemblies in Section 5.8.12 of Reference G.9-1. Based on the self-shielding of the added mass compensating for the increase in source, damaged fuel dose rates for the first scenario are bounded by either the corresponding undamaged fuel dose rates or the second damaged fuel scenario.

In the second scenario, damaged fuel is assumed to migrate from the active fuel into the lower end fitting region of the fuel assembly, filling all the modeled void space. However, no credit is taken for the reduction in the lower end fitting hardware dose rate due to the added UO_2 mass and self-shielding nor for the reduction in fuel mass migrated from the active fuel region. In this case, transfer cask bottom surface dose rates increase due to the addition of damaged fuel. The transfer cask bottom axial dose rate increases 53 mrem/hr, increasing the bottom axial dose rate by approximately 0.9 percent.

Damaged fuel dose rates are computed using the carbon steel transfer cask, as it produces higher dose rates than the stainless steel transfer cask due to the higher density of stainless steel versus carbon steel.

Damaged fuel maximum dose rates in the carbon steel transfer cask are summarized in Table 5.1.3-9 of Reference G.9-1.

G.9.1.2 Concrete Cask Shielding Discussion and Dose Results

The concrete cask is composed of body and lid components. *License drawings for these components are provided in Section G.4.3.* The body contains the air inlets, air outlets, and the cavity for TSC placement. The lid provides environmental closure for the TSC. The radial shield design is comprised of a carbon steel inner liner surrounded by concrete. The concrete contains radial and axial rebar for structural support. As in the transfer cask, the TSC shell provides additional radial shielding. The concrete cask top shielding design is comprised of the TSC lid and concrete cask lid. The concrete cask lid incorporates both concrete and steel plate to provide additional gamma shielding. The bottom shielding is comprised of the stainless steel TSC bottom plate, the pedestal/air inlet structure, and a carbon steel base plate. Radiation streaming paths consist of air inlets located at the bottom and air outlets located above the top of the TSC, and above the annulus between the concrete cask body and the

TSC. Air inlets and outlets are radial openings to the concrete cask. The inlets and outlets are axially offset from the source regions to minimize dose and meet ALARA principles.

No auxiliary shielding is considered in the concrete cask shielding evaluation. All components relevant to safety performance are explicitly included in the concrete cask model. Homogenization of materials used in the models is limited to the fuel assembly as described in Section 5.1.1 of Reference G.9-1.

Undamaged Fuel Dose Rates

Refer to Table 5.1.3-2, Table 5.1.3-5, and Table 5.1.3-7 of Reference G.9-1 for a summary of the concrete cask normal condition and accident event maximum calculated dose rates for the standard (CC1/ CC2), augmented shield (CC3), and short, standard (CC4) cask configurations. Listed maximum dose rates include fuel and nonfuel hardware contributions. Payload types producing maximum surface dose rates are listed in Table 5.1.3-3, Table 5.1.3-6, and Table 5.1.3-8 of Reference G.9-1. Refer to Section 5.6.5 of Reference G.9-1 for TSC surface contamination release dose rates. Dose rates are based on three-dimensional Monte Carlo analysis using surface detectors. Further detail on the detector geometry is included in Section 5.5.

The maximum concrete cask side (cylindrical) average surface dose rate is 58 (<1%) mrem/hour. On the concrete cask top (disk), the average surface dose rate is 104 (2%) mrem/hour. Average dose rates for the standard shielding concrete cask are more than twice as high on the radial surface and approximately 20% higher on the axial surface than the augmented shielding cask configuration for the PWR system (augmented cask shield analysis limited to PWR payloads). The maximum inlet and outlet dose rates are 434 and 59 mrem/hr, respectively. No design basis normal condition or accident event exposes the bottom of the concrete cask.

Damaged Fuel Dose Rates

The two damaged fuel scenarios described in Section G.9.1.1 are also evaluated for the concrete cask.

The first scenario assumes the damaged fuel collects over the active fuel length of the fuel assembly. Dose rate profiles for the 37- undamaged assemblies are compared with profiles for 33 undamaged and 4 damaged assemblies in Section 5.8.12 of Reference G.9-1. Based on the self-shielding of the added mass compensating for the increase in source, damaged fuel dose rates for the first scenario are bounded by either the corresponding undamaged fuel dose rates or the second damaged fuel scenario.

In the second scenario, damaged fuel is assumed to migrate from the active fuel into the lower end fitting region of the fuel assembly, filling all the modeled void space. In this case, concrete cask inlet and radial dose rates increase due to the addition of damaged fuel. The concrete cask inlet dose rate increase is 38 mrem/hr, increasing the inlet dose rate by approximately 9 percent. The maximum concrete cask radial dose rate increases to 82.3 mrem/hr, an increase of approximately 4 percent.

Damaged fuel dose rates are computed using the standard concrete cask (CC1/CC2) or the short, standard concrete cask (CC4), as they produce higher dose rates than the augmented shield concrete cask.

Damaged fuel maximum dose rates in the standard concrete cask are summarized in Table 5.1.3-10 of Reference G.9-1.

G.9.1.3 Offsite Dose Discussion and Results

Contributions from concrete casks to site radiation dose exposure are limited to either radiation emitted from the concrete cask surface or a hypothetical release of surface contamination from the TSC. As documented in Section 5.6.5 of Reference G.9-1, there is no significant site dose effect from the expected surface contamination of the system. The TSCs are comprised of a welded shell, bottom plate and lid structure. The vent and drain ports in the lid are covered by redundant welded plates. There is, therefore, no credible leakage from the system, and no significant effluent source can be released from the TSC contents. Details on the TSC confinement boundary are provided in Appendix G.11, with leakage test information provided in Section 10.1.3 of Reference G.9-1.

Controlled area boundary exposure from the concrete cask surface radiation is evaluated using the NAC-CASC code. (As previously stated, NAC-CASC is a modified version of SKYSHINE- III.) NAC-CASC calculates the direct dose rate as well as the air scattered contribution of the total dose rate. As the detectors are below the top surface of the cask, only the cylindrical shell (radial) cask surface current contributes a direct component to the total dose rate. NAC-CASC primary enhancements to SKYSHINE-III allow the input of an angular surface current, the input of cylindrical shell (side) and disk (top) geometries, and the accounting of concrete cask self-shielding (i.e., radiation emitted from one cask intersecting another cask in the array—in particular, front/back row interaction in the array). The cylindrical shell and top surfaces are Monte Carlo sampled to generate the surface current input into the code. Each of the sampled locations represents a point source to which the SKYSHINE-III line beam response functions are applicable.

The NAC-CASC (SKYSHINE-III) method assumes that radiation emitted from the source does not interact with the cask/source structure after emission (beyond the additional routines added by NAC to account for self-shielding). This assumption does not represent a significant effect on site dose rates as the calculated surface current is near normal to the surface and any backscatter to the cask from the air surrounding the array would then require a second backscatter from the cask surface to reach a detector location. As detector locations for site exposure are at significant distances from the array (typically 100+ meters), there would not be a significant contribution from radiation having undergone such repeated large angle scatter.

Both a single cask and a 2×10 array of casks are evaluated for site exposure evaluations. Each cask in the array is assigned the maximum dose (surface current) source allowed by the cask loading tables. A combination of the maximum cask side and top dose cases provides for a conservative estimate on the controlled area boundary exposure, since the different fuel types produce the highest cask surface dose components.

G.9.2 References

G.9-1 MAGNASTOR Final Safety Analysis Report, Revision 7, July 2015.

Table G.9-1
Estimated Occupational Collective Dose for Receipt of NAC MAGNATRAN Cask Loaded with PWR SNF in MAGNASTOR TSC and Transfer to MAGNASTOR VCC
7 Sheets

Process Step	***Number of Workers***	***Occupancy Time (hours)***	***Worker Location Around Cask***	***Worker Distance (m)***	***Total Dose Rate (mrem/hr)***	***Total Dose (person-mrem)[1]***	***Reference SAR/FSAR Table/Figure***
Perform radiation and contamination survey of MAGNATRAN Cask.	*2*	*0.5*	*All Around MAGNATRAN Cask*	*>2*	*10*	*10*	*SAR Figure 5.1-1, Table. 5.1-3, Figure 5.8-7, Figure 5.8-11, Figure 5.8-14, Figure 5.8-15*
Inspect top impact limiter security seal and verify it is intact and correct ID.	*1*	*.25*	*Top Impact Limiter*	*>1*	*<20*	*1*	*SAR Figure 5.1-1, Table. 5.1-3, Figure 5.8-7, Figure 5.8-11, Figure 5.8-14, Figure 5.8-15*
Remove Personnel Barrier and complete surveys.	*2*	*0.5*	*Center of MAGNATRAN Cask*	*1*	*<20*	*32*	*SAR Figure 5.1-1, Table. 5.1-3, Figure 5.8-7, Figure 5.8-11, Figure 5.8-14, Figure 5.8-15*
Visually inspect MAGNATRAN Cask surface for transport/road damage and record.	*1*	*0.25*	*All Around Cask*	*>2*	*10*	*3*	*SAR Figure 5.1-1, Table. 5.1-3, Figure 5.8-7, Figure 5.8-11, Figure 5.8-14, Figure 5.8-15*
Attach slings to top Impact Limiter and remove 32 retention nuts/rods. Remove and store Impact Limiter.	*2*	*1*	*Top of MAGNATRAN Cask*	*>1*	*< 5*	*10*	*SAR Figure 5.1-1, Table. 5.1-3, Figure 5.8-7, Figure 5.8-11, Figure 5.8-14, Figure 5.8-15*
Attach slings to bottom Impact Limiter and remove 32 retention nuts/rods. Remove and store Impact Limiter.	*2*	*1*	*Bottom of MAGNATRAN Cask*	*>1*	*< 5*	*10*	*SAR Figure 5.1-1, Table. 5.1-3, Figure 5.8-7, Figure 5.8-11, Figure 5.8-14, Figure 5.8-15*
Release Front Tie-Down Assembly.	*2*	*1*	*Top Side MAGNATRAN Cask Surface*	*1*	*50*	*100*	*SAR Figure 5.1-1, Table. 5.1-3, Figure 5.8-7, Figure 5.8-11, Figure 5.8-14, Figure 5.8-15*

Table G.9-1
Estimated Occupational Collective Dose for Receipt of NAC MAGNATRAN Cask Loaded with PWR SNF in MAGNASTOR TSC and Transfer to MAGNASTOR VCC
7 Sheets

Process Step	*Number of Workers*	*Occupancy Time (hours)*	*Worker Location Around Cask*	*Worker Distance (m)*	*Total Dose Rate (mrem/hr)*	*Total Dose (person-mrem)[1]*	*Reference SAR/FSAR Table/Figure*
Remove front trunnion plugs and bolts, and ring segments, and store.	*2*	*0.5*	*Top Side MAGNATRAN Cask Surface*	*1*	*50*	*50*	*SAR Figure 5.1-1, Table. 5.1-3, Figure 5.8-7, Figure 5.8-11, Figure 5.8-14, Figure 5.8-15*
Install front trunnions and bolts and torque to specified value.	*2*	*1*	*Top Side MAGNATRAN Cask Surface*	*1*	*50*	*100*	*SAR Figure 5.1-1, Table. 5.1-3, Figure 5.8-7, Figure 5.8-11, Figure 5.8-14, Figure 5.8-15*
Engage Vertical Cask Transporter (VCT) Lift Arms to Front Trunnions and rotate cask to vertical orientation on rear rotation trunnions.	*2*	*1*	*Top Side MAGNATRAN Cask Surface*	*>2*	*10*	*20*	*SAR Figure 5.1-1, Table. 5.1-3, Figure 5.8-7, Figure 5.8-11, Figure 5.8-14, Figure 5.8-15*
Lift and Remove MAGNATRAN from the Transport Skid Rear supports and move cask to gantry Canister Transfer Facility (CTF), set cask down and release VCT Lift Arms. Establish Radiation Control boundaries.	*2*	*2*	*Top Side MAGNATRAN Cask Surface*	*>2*	*10*	*40*	*SAR Figure 5.1-1, Table. 5.1-3, Figure 5.8-7, Figure 5.8-11, Figure 5.8-14, Figure 5.8-15*

Table G.9-1
Estimated Occupational Collective Dose for Receipt of NAC MAGNATRAN Cask Loaded with PWR SNF in MAGNASTOR TSC and Transfer to MAGNASTOR VCC
7 Sheets

Process Step	*Number of Workers*	*Occupancy Time (hours)*	*Worker Location Around Cask*	*Worker Distance (m)*	*Total Dose Rate (mrem/hr)*	*Total Dose (person-mrem)[1]*	*Reference SAR/FSAR Table/Figure*
Using VCT, move empty MAGNASTOR VCC to transfer position in CTF and set down adjacent to MAGNATRAN cask. Set up appropriate work platforms/man lifts for access to top of VCC and MAGNATRAN.	*2*	*1*	*Top Of Empty MAGNASTOR VCC*	*>2*	*0*	*0*	*Empty VCC*
Remove VCC Lid and bolts, and VCC Shield Plug.	*2*	*1*	*Top Of Empty MAGNASTOR VCC*	*1*	*0*	*0*	*Empty VCC*
Install Transfer Adapter on VCC and connect hydraulic system.	*2*	*1*	*Top Of Empty MAGNASTOR VCC*	*1*	*0*	*0*	*Empty VCC*
Remove vent port cover and connect pressure test system to vent port to check for excessive pressure. If pressure is high, take sample and check. If clean vent to HEPA filter.	*1*	*0.5*	*Top of Cask*	*0.5*	*50*	*25*	*FSAR Table 5.1.3.1, FSAR Section 5.8.3.3.2 + MAGNATRAN Closure Lid Thickness 7.75 in.*
Remove 48 MAGNATRAN lid bolts, install alignment pins and lid lifting hoist rings/slings and remove inner lid and store. Remove alignment pins.	*2*	*1*	*Top of Cask*	*0.5*	*30*	*60*	*FSAR Table 5.1.3.1, FSAR Section 5.8.3.3.2 + MAGNATRAN Closure Lid Thickness 7.75 in.*

Table G.9-1
Estimated Occupational Collective Dose for Receipt of NAC MAGNATRAN Cask Loaded with PWR SNF in MAGNASTOR TSC and Transfer to MAGNASTOR VCC
7 Sheets

Process Step	*Number of Workers*	*Occupancy Time (hours)*	*Worker Location Around Cask*	*Worker Distance (m)*	*Total Dose Rate (mrem/hr)*	*Total Dose (person-mrem)*[1]	*Reference SAR/FSAR Table/Figure*
Install adapter ring to inner lid recess and torque captured bolts.	*2*	*0.5*	*Top of Cask*	*0.5*	*30*	*30*	*FSAR Table 5.1.3.1, FSAR Section 5.8.3.3.2 Remote operation from side of MAGNATRAN*
Install transfer adapter plate on adapter ring and install and torque the four transfer adapter plate bolts.	*2*	*1*	*Top of Cask*	*1*	*15*	*30*	*FSAR Table 5.1.3.1, FSAR Section 5.8.3.3.2 Remote operation from side of MAGNATRAN*
Install TSC Lid Lifting Adapter Plate and bolts on the MAGNASTOR Closure Lid, and torque to specified value.	*2*	*1*	*Top of Cask*	*0.5*	*75*	*150*	*FSAR Table 5.1.3.1, FSAR Section 5.8.3.3.2 Remote operation from side of MAGNATRAN*
Using the CTF crane, lower the appropriate MAGNASTOR Transfer Cask (MTC) and set it down on the transfer adapter on the MAGNATRAN Cask.	*2*	*1.5*	*Top of Cask*	*>4*	*<1*	*3*	*Remote handling operation*
Remove the MTC door lock pins and open shield doors with hydraulic system.	*1*	*0.5*	*Top of Cask*	*1*	*15*	*8*	*FSAR Table 5.1.3.1, FSAR Section 5.8.3.3.2 + 2 inch TSC Lid Lift Adapter Plate Remote operation from side of MTC/MAGNATRAN*

Table G.9-1
Estimated Occupational Collective Dose for Receipt of NAC MAGNATRAN Cask Loaded with PWR SNF in MAGNASTOR TSC and Transfer to MAGNASTOR VCC
7 Sheets

Process Step	***Number of Workers***	***Occupancy Time (hours)***	***Worker Location Around Cask***	***Worker Distance (m)***	***Total Dose Rate (mrem/hr)***	***Total Dose (person-mrem)[1]***	***Reference SAR/FSAR Table/Figure***
Using the CTF, lower the Air-Powered Chain Hoist hook through the MTC and engage to the TSC Lift Adapter Plate.	*2*	*1.5*	*Remote Operating Location*	*>4*	*<5*	*15*	*Remote operation using CTF mounted cameras*
Using the Chain Hoist System slowly lift the TSC into the MTC.	*2*	*1*	*Remote Operating Location*	*>4*	*<5*	*10*	*Remote operation using CTF mounted cameras*
Close the MTC shield doors and install lock pins.	*1*	*0.5*	*Bottom of MTC*	*0.5*	*30*	*15*	*Operation from side of MTC FSAR Section 5.8.3.3.2 and Figure 5.8.3-17*
Lower the TSC onto the shield doors and using the CTF, lift the MTC off of the MAGNATRAN transfer adapter plate.	*2*	*1*	*Remote Operating Location*	*>4*	*<5*	*10*	*Remote operation using CTF mounted cameras*
Move the MTC over the VCC and lower onto the VCC transfer adapter plate.	*1*	*1*	*Remote Operating Location*	*>4*	*<5*	*5*	*Remote operation using CTF mounted cameras*
Remove the MTC door lock pins.	*1*	*0.5*	*Bottom of MTC*	*0.5*	*30*	*15*	*Operation from side of MTC on top of VCC transfer adapter FSAR Section 5.8.3.3.2 and Figure 5.8.3-17 and Figure 5.8.3-10*

Table G.9-1
Estimated Occupational Collective Dose for Receipt of NAC MAGNATRAN Cask Loaded with PWR SNF in MAGNASTOR TSC and Transfer to MAGNASTOR VCC
7 Sheets

Process Step	***Number of Workers***	***Occupancy Time (hours)***	***Worker Location Around Cask***	***Worker Distance (m)***	***Total Dose Rate (mrem/hr)***	***Total Dose (person-mrem)***[1]	***Reference SAR/FSAR Table/Figure***
Using the Chain Hoist System, lift the TSC off of the shield doors and open the shield doors.	*2*	*0.5*	*Remote Operating Location*	*>4*	*<5*	*5*	*Remote operation using CTF mounted cameras*
Using the chain hoist lower the TSC into the VCC.	*2*	*1*	*Remote Operating Location*	*>4*	*<5*	*10*	*Remote operation using CTF mounted cameras*
Release chain hoist system hook from the TSC Lift Adapter Plate and retract chain hoist hook through the MTC.	*1*	*0.5*	*Remote Operating Location*	*>4*	*<5*	*3*	*Remote operation using CTF mounted cameras*
Close MTC shield doors and install lock pins.	*1*	*0.5*	*Bottom of MTC*	*0.5*	*30*	*15*	*Operation from side of MTC on top of VCC transfer adapter FSAR Figure 5.8.3-10*
Using the CTF, lift and remove the MTC from the top of the VCC.	*1*	*0.5*	*Remote Operating Location*	*>4*	*<5*	*3*	*Remote operation using CTF mounted cameras*
Unbolt and remove TSC Lift Adapter Plate from the top of the TSC and store.	*2*	*1*	*Top of MAGNASTOR TSC*	*1*	*75*	*150*	*FSAR Figure 5.8.3-20 and operation performed on top of transfer adapter mounted on VCC*

Table G.9-1
Estimated Occupational Collective Dose for Receipt of NAC MAGNATRAN Cask Loaded with PWR SNF in MAGNASTOR TSC and Transfer to MAGNASTOR VCC
7 Sheets

Process Step	***Number of Workers***	***Occupancy Time (hours)***	***Worker Location Around Cask***	***Worker Distance (m)***	***Total Dose Rate (mrem/hr)***	***Total Dose (person-mrem)[1]***	***Reference SAR/FSAR Table/Figure***
Using mobile crane, remove transfer adapter plate from VCC and store.	*2*	*1*	*Top of MAGNASTOR VCC*	*1*	*10*	*20*	*Remote operation using CTF mounted cameras after connection of lifting slings*
Install and bolt in place the VCC lid.	*2*	*1*	*Top of MAGNASTOR VCC*	*1*	*25*	*50*	*Operation performed from top of VCC Figure 5.8.3-10*
Using the VCT, lift and move loaded UMS VCC and position it in the designated storage location.	*2*	*1*	*VCT Platform*	*>4*	*10*	*20*	*Operation performed from VCT and FSAR Figure 5.8.3-8*
Prepare empty MAGNATRAN cask for empty return transport. Transfer and rotate to horizontal MAGNATRAN cask on the transport/shipping frame. Install transport tie-downs, impact limiters and personnel barrier.	*3*	*9*	*CTF/VCT/Rail Car*	*1 to 4*	*0*	*0*	*Empty cask preparation activities*
					Total (person-mrem)	*1,023*	

Note:

1. *Rounded up to the nearest whole number*

APPENDIX G.10
CRITICALITY EVALUATION
NAC-MAGNASTOR

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G.10 CRITICALITY EVALUATION

Chapter 6 of Reference G.10-1 documents the method, input, and result of the criticality analysis of the MAGNASTOR system. The results demonstrate that the effective neutron multiplication factor, k_{eff}, of the system under normal conditions, or off-normal and accident events, is less than 0.95 including biases and uncertainties. The system design meets the criticality requirements of 10 CFR 72 and Chapter 6 of NUREG-1536.

G.10.1 Undamaged and Damaged PWR Fuel

MAGNASTOR consists of a TSC (Transportable Storage Canister), a transfer cask, and a concrete cask. The system is designed to safely store up to 37 undamaged PWR fuel assemblies in the 37 PWR basket assembly. The system is also designed to store up to four damaged fuel cans (DFCs) in the DF Basket Assembly. The DF Basket Assembly has a capacity of up to 37 undamaged PWR fuel assemblies, including 4 DFC locations. DFCs may be placed in up to four of the DFC locations. Each DFC may contain an undamaged PWR fuel assembly, a damaged PWR fuel assembly, or PWR fuel debris equivalent to one PWR fuel assembly. Undamaged PWR fuel assemblies may be placed directly in the DFC locations of a DF Basket Assembly.

The TSC is comprised of a stainless steel canister and a basket within which fuel is loaded. The PWR system each includes two TSC lengths to store fuel assemblies without the requirement of spacers. Spacers may be employed to simplify loading or unloading operations. The TSC is loaded into the concrete cask for storage. A transfer cask is used for handling the TSC during loading of spent fuel. Fuel is loaded into the TSC contained within the transfer cask underwater in the spent fuel pool. Once loaded with fuel, the TSC closure lid is welded and the TSC is drained, dried and backfilled with helium. The transfer cask is then used to move the TSC into or out of the concrete cask. The transfer cask provides shielding during the TSC loading and transfer operations. Multiple-size concrete and transfer casks accommodate all variations of TSCs.

Under normal conditions, such as loading in a spent fuel pool, moderator (water) is present in the TSC during the initial stages of fuel transfer. During draining and drying operations, moderator with varying density is present. Thus, the criticality evaluation of the transfer cask includes a variation in moderator density and a determination of optimum moderator density. Cask accident conditions are bounded by inclusion in the analysis of the most reactive mechanical basket configuration as well as moderator intrusion into the fuel cladding. The PWR TSC is evaluated at minimum soluble boron levels during flooded conditions.

Structural analyses demonstrate that the TSC confinement boundary remains intact through all storage operating conditions. Therefore, moderator is not present in the TSC while it is in the concrete cask. However, access to the concrete cask interior environment is possible via the air inlets and outlets and the heat transfer annulus between the TSC and the cask steel liner. This access provides paths for moderator intrusion during a flood. Under off-normal and accident conditions, moderator intrusion into the convective heat transfer annulus is evaluated.

PWR system criticality control is achieved through a combination of neutron absorber sheets on the interior faces of the fuel tubes/developed cells and soluble boron. Individual fuel assemblies are held in place by the fuel tubes, by developed cells formed from fuel tubes, or by a combination of fuel tubes and side or corner weldments. The neutron absorber modeled is a borated aluminum sheet. Any material meeting the physical dimension requirements specified on the License Drawings and the effective 10B areal density specified in Table 6.1.1-5 of Reference G.10-1 will produce similar reactivity results. A combination of steel cover sheets and weld posts holds the neutron absorber sheets in place. The PWR undamaged fuel basket design includes 21 fuel tubes forming 37 fuel-assembly-sized openings while the PWR damaged fuel basket design includes 17 fuel tubes and four corner weldments forming 37 openings. A sketch of a cross-section of the damaged fuel basket is shown in figure 6.1.1-2 of Reference G.10-1.

Initial criticality evaluations rely on neutron absorber sheet effective ^{10}B loadings of 0.036 g/cm^2 for the PWR system. The system is also evaluated for effective ^{10}B loading of 0.030 and 0.027 g/cm^2 for PWR baskets. Depending on the PWR payload, variable soluble boron concentrations in the pool water are necessary to achieve sufficient neutron absorber content in the system. The soluble boron absorbs thermal neutrons inside the assembly, in addition to the neutrons removed by the absorber sheets on the tubes.

The minimum as-manufactured loading of the neutron absorber sheets depends on the effectiveness of the absorber and the minimum effective absorber areal density. Effectiveness of the absorber is influenced by the uniformity and quantity of the ^{10}B nuclide within the absorber base material. Table 6.1.1-5 of Reference G.10-1 translates the effective absorber content to absorber materials at 75% and 90% credit.

MCNP, a three-dimensional Monte Carlo code, is used in the system criticality analysis. Evaluations are primarily based on the ENDF/B-VI continuous energy neutron cross-section library available in the MCNP distribution. Nuclides for which no ENDF/B-VI data is available are set to the latest cross-section sets available in the code distribution. The code and cross-section libraries are benchmarked by comparison to a range of critical experiments relevant to light water reactor fuel in storage and transport casks. An upper subcritical limit (USL) for the system is determined based on guidance given in NUREG/CR-6361.

Key assembly physical characteristics, maximum initial enrichment, and soluble boron requirements for each PWR fuel assembly type are shown in Reference G.10-1 Table 6.1.1-1, Table 6.1.1-2 and Table 6.1.1-6. PWR results represent the bounding values for fuel assemblies with and without nonfuel inserts in the guide tubes. Maximum enrichment is defined as peak rod enrichment for PWR. The maximum initial peak planar-average enrichment is the maximum planar-average enrichment at any height along the axis of the fuel assembly.

Assemblies are evaluated with a full, nominal set of fuel rods. Fuel rod (lattice) locations may contain filler rods. A filler rod must occupy, at a minimum, a volume equivalent to the fuel rod it displaces. Filler rods may be placed into the lattice after assembly in-core use or be designed to replace fuel rods prior to use, such as integral burnable absorber rods.

The assembly must contain its nominal set of guide and instrument tubes. Analysis demonstrated that variations in the guide/instrument tube thickness and diameter have no significant effect on system reactivity.

The continued efficacy of the neutron absorbers is assured when the canister arrives at 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 MAGNATRAN cask as documented in of the MAGNATRAN Safety Analysis Report.

G.10.1.1 Undamaged Fuel Criticality Results

The maximum multiplication factors (k_{eff} +2σ) are calculated, using conservative assumptions, for the transfer and concrete cask. The USL applied to the analysis results is 0.9376 per Section 6.5.2 of Reference G.10-1. The results of the analyses are presented in detail in Sections 6.4.3 and 6.7 of Reference G.10-1, and are summarized as follows.

Cask Body	Gap Condition	Operating Condition	Water Density (g/cc) Interior	Water Density (g/cc) Exterior	PWR $k_{eff} + 2\sigma$
Transfer	Dry	Normal	0.9982	0.0001	0.93183
Transfer	Wet	Normal	0.9982	0.0001	0.93712
Transfer	Dry	Normal	0.9982	0.9982	0.92975
Transfer	Wet	Normal	0.9982	0.9982	0.93615
Storage	Dry	Normal	0.0001	0.0001	0.48145
Storage	Dry	Accident	0.0001	0.9982	0.47104

Analysis of simultaneous moderator density variation inside and outside either the transfer or concrete cask shows a monotonic decrease in reactivity with decreasing moderator density. In the PWR system, reactivity increases as moderator density rises from void conditions, but there is no significant reactivity difference at water densities above 0.9 g/cm^3. The use of soluble boron in PWR systems, specified in parts per million of moderator, flattens out the reactivity curve by increasing absorber quantity in conjunction with increasing moderator. The full moderator density TSC interior condition bounds any off-normal or accident condition. Analysis of moderator intrusion into the concrete cask heat transfer annulus with the dry TSC shows a slight decrease in reactivity from the completely dry condition.

G.10.1.2 Damaged Fuel Criticality Results

The PWR system is designed to safely store up to 37 PWR fuel assemblies of which up to 4 may be classified as damaged and be placed into damaged fuel cans (DFCs) in the four corner basket locations. The DFC provides a screened container to prevent gross fissile material release into the TSC cavity from failed fuel rod cladding. The results of the analyses are presented in detail in Section 6.7.8 of Reference G.10-1 and are summarized as follows. All results are below the USL of 0.9376.

Cask Body	Gap Condition	Operating Condition	Water Density (g/cc)		PWR
			Interior	Exterior	$k_{eff} + 2\sigma$
Transfer	Wet	Normal	0.9982	N/A[a]	0.93757
Storage	Dry	Normal	0.0001	0.0001	0.49142
Storage	Dry	Accident	0.0001	0.9982	0.48211

[a] Exterior moderator has been demonstrated in Section 6.7.3 of Reference G.10-1 to not affect system reactivity for a fully flooded TSC.

Three damaged fuel configurations are evaluated. Damaged fuel includes fuel debris. In the first configuration, undamaged fuel is loaded into a DFC to demonstrate the effect of the additional stainless steel from the DFC and the DFC corner weldments. In the second configuration, damaged fuel is postulated to lose its cladding and the array is modeled at an increased pitch. In the third configuration, mixtures of fuel and water simulate small fuel rubble inside the DFC.

Three moderator configurations are evaluated. Moderator density studies are performed on the preferentially flooded DFC, partially flooded cask, and mixture moderator density. In the preferentially flooded DFC scenario, the DFC is assumed to vary in moderator density with a wet and dry canister. A partial draindown of the TSC to the top of the active fuel is referred to as partial flooding. A study on the mixture moderator density is performed to ensure that the homogenized mixture remains undermoderated.

For each of the fuel types, with and without nonfuel inserts in the active fuel region of the undamaged assemblies, several combinations of minimum soluble boron and maximum initial enrichments are determined. The allowable loadings are documented in Table 6.1.1-6 of Reference G.10-1.

G.10.2 References

G.10-1 MAGNASTOR Final Safety Analysis Report, Revision 7, July 2015

APPENDIX G.11
CONFINEMENT EVALUATION
NAC-MAGNASTOR

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G.11 CONFINEMENT EVALUATION

The MAGNASTOR TSC provides confinement for its radioactive contents in long-term storage. The confinement boundary provided by the TSC is closed by welding, creating a solid barrier to the release of contents in the design basis normal conditions and off-normal or accident events. The welds are visually inspected and nondestructively examined to verify integrity. *The figure illustrating the confinement boundary for the NAC-MAGNASTOR is found in Figure 7.1-1 of Reference G.11-1.*

The sealed TSC contains a pressurized inert gas (helium). The confinement boundary retains the helium and also prevents the entry of outside air into the TSC in long-term storage. The exclusion of air precludes fuel rod cladding oxidation failures during storage.

The TSC confinement system meets the requirements of 10 CFR 72.24 for protection of the public from release of radioactive material. The design of the TSC allows the recovery of stored spent fuel should it become necessary per the requirements of 10 CFR 72.122. The TSC meets the requirements of 10 CFR 72.122 (h) for protection of the spent fuel contents in long-term storage such that future handling of the contents would not pose an operational safety concern.

The codes and standards for the design, fabrication, and inspection of the canister and confinement boundary are detailed in Reference G.11-2. Specifically, Appendix A, Section 4.2, "Codes and Standards," which states the ASME code, 2001 Edition with Addenda through 2003, Section III, Subsection NB, is the governing Code for the design, material procurement, fabrication, and testing of the canister and Section 4.2.1, "Alternatives to Codes, Standard, and Criteria," which lists the approved alternatives to the ASME Code in Table 2.1-2 in the NAC MAGNASTOR Final Safety Analysis Report (FSAR). In addition, Section 4.1.4, "TSC Confinement Integrity," which states the leaktight criterion for the canister in ANSI N14.5.

Appendix A, Section 3.1, "MAGNASTOR System Integrity," of Reference G.11-2, includes limiting condition for operation (LCO) 3.1.1 for canister maximum vacuum drying time, canister vacuum drying pressure, and canister helium backfill density. These LCOs create a dry, inert, leaktight atmosphere, which contributes to preventing the leakage of radioactive material.

G.11.1 Undamaged and Damaged PWR Fuel

The confinement boundary of the TSC consists of the TSC shell, bottom plate, closure lid, inner vent and drain port covers, and the welds that join these components. The redundant closure of the TSC confinement boundary consists of the closure ring, the outer vent and drain port covers, and the welds that join these components to the TSC shell and closure lid. The confinement boundary is shown in Figure 7.1-1 of Reference G.11-1. The confinement boundary does not incorporate bolted closures or mechanical seals. The confinement boundary welds are described in Table 7.1-1 of Reference G.11-1.

G.11.1.1 Confinement Boundary

The confinement boundary of the MAGNASTOR system is described in detail in Section 7.1 of Reference G.11-1. Specific details for the confinement vessel, confinement penetrations, seals and welds, and closure are in Sections 7.1.1, 7.1.2, 7.1.3, and 7.1.4, respectively. *In addition, a bounding evaluation in Section G.7.1.9 is presented to demonstrate that the confinement boundary for the NAC-MAGNASTOR canister does not exceed ASME Boiler and Pressure Vessel 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.*

G.11.1.2 Requirements for Normal Conditions of Storage

The requirements for normal conditions of storage for the MAGNASTOR system are described in detail in Section 7.2 of Reference G.11-1. Specific details on the release of radioactive materials and pressurization of the confinement vessel are in Sections 7.2.1 and 7.2.2, respectively.

G.11.1.3 Confinement Requirements for Hypothetical Accident Conditions

The requirements for hypothetical accident conditions are described in detail in Section 7.3 of Reference G.11-1.

G.11.2 References

G.11-1 MAGNASTOR Final Safety Analysis Report, Revision 7, July 2015.

G.11-2 Amendment No.5 to Certificate of Compliance No. 1031 for the NAC International, Inc., NAC-MAGNASTOR System, June 29, 2015.

APPENDIX G.12
ACCIDENT ANALYSIS
NAC-MAGNASTOR

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G.12 ACCIDENT ANALYSIS

The results of the analyses of the off-normal and accident events, including those identified by ANSI/ANS 57.9-1992, are presented in Chapter 12 of Reference G.12-1. Section 12.1 describes the off-normal events that could occur during the use of MAGNASTOR, possibly as often as once per calendar year. Section 12.2 addresses very low probability events that might occur once during the lifetime of MAGNASTOR or hypothetical events that are postulated because their consequences may result in the maximum potential effect on the surrounding environment. The detailed analysis of each evaluated event is presented in the appropriate technical chapters – structural, thermal, shielding, criticality, confinement, or radiation protection. In the analyses in those chapters, the bounding parameters (i.e., maximum concrete cask weight and center of gravity) are conservatively used, as appropriate, to determine the capability of MAGNASTOR to withstand the effects of the analyzed events.

The load conditions imposed on the TSCs and the fuel baskets by the design basis normal, off normal and accident events of storage are less severe than those imposed by the transport conditions–including the 30-foot drop impacts and the fire accident (10 CFR 71) . Consequently, the evaluation of the TSCs and the fuel baskets for transport conditions bounds the storage condition results reported in this chapter.

This chapter demonstrates that MAGNASTOR is in compliance with the requirements of 10 CFR 72.24 and 10 CFR 72.122 for off-normal and accident events. The evaluations provided are based on conservative assumptions and demonstrate that MAGNASTOR will provide safe storage of spent fuel during all analyzed off-normal and accident events.

G.12.1 Undamaged and Damaged PWR Fuel

The following describes the off-normal and accident events evaluated for the MAGNASTOR system.

G.12.1.1 Off-Normal Events

Section 12.1 of Reference G.12-1 evaluates postulated off-normal events that might occur once during any calendar year of operations. The actual occurrence of any of these events is, therefore, infrequent.

The following off-normal events are evaluated. Beside each listed off-normal event is the location in Reference G.12-1 where the details of the analyses are presented.

1. Severe Ambient Temperature Events (106°F and -40°F) – Section 12.1.1
2. Blockage of One-Half of the Air Inlets – Section 12.1.2
3. Off-Normal TSC Handling Load – Section 12.1.3
4. Failure of Instrumentation – Section 12.1.4
5. Small Release of Radioactive Particulate from the TSC Exterior – Section 12.1.5
6. Crane Failure During Loaded Transfer Cask Movements – Section 12.1.6
7. Crane/Hoist Failure During TSC Transfer to VCC – Section 12.7

G.12.1.2 Accidents and Natural Phenomena

Section 12.2 of Reference G.12-1 presents the results of analyses of the design basis and hypothetical accident events evaluated for MAGNASTOR. In addition to design basis accidents, this section addresses very low-probability events, including natural phenomena that might occur once over the lifetime of the ISFSI, or hypothetical events that are postulated to occur because their consequences may result in the maximum potential effect on the immediate environment.

MAGNASTOR includes TSCs of two different lengths to accommodate two lengths of PWR fuel. In the accident analyses of this section, the bounding cask parameters (such as weight and center of gravity) are conservatively used, as appropriate, to determine the cask's capability to withstand the effects of the accidents. The results of these analyses show that any credible potential accident will result in a dose of ≤5 rem beyond the postulated controlled area. Consequently, MAGNASTOR is demonstrated to have a substantial design margin of safety, and will provide protection to the public and to site operations personnel during storage of spent fuel.

The following accidents and natural phenomena are evaluated. Beside each listed event is the location in Reference G.12-1 where the details of the analyses are presented.

1. Accident Pressurization – Section 12.2.1
2. Failure of All Fuel Rods with a Ground-level Breach of the TSC – Section 12.2.2
3. Fresh Fuel Loading in the TSC – Section 12.2.3
4. 24-Inch Drop of the Concrete Cask – Section 12.2.4
5. Explosion – Section 12.2.5
6. Fire Accident – Section 12.2.6
7. Maximum Anticipated Heat Load (133°F Ambient Temperature) – Section 12.2.7
8. Earthquake Event – Section 12.2.8
9. Flood – Section 12.2.9
10. Lightning Strike – Section 12.2.10
11. Tornado and Tornado-Driven Missiles – Section 12.2.11
12. Tip-Over of Concrete Cask – Section 12.2.12
13. Full Blockage of the Concrete Cask Air Inlets – Section 12.2.13

G.12.1.3 Concrete Cask Non-Mechanistic Tip-Over Analysis

Tip-over of the concrete cask is a non-mechanistic, hypothetical accident condition that presents a bounding case for evaluation. Existing postulated design basis accidents do not result in the tip-over of the concrete cask. Functionally, the concrete cask does not suffer significant adverse consequences due to this event. The concrete cask, TSC, and basket maintain design basis shielding, geometry control of contents, and contents confinement performance requirements.

For a tip-over event to occur, the center of gravity of the concrete cask and loaded TSC must be displaced beyond its outer radius, i.e., the point of rotation. When the center of gravity passes beyond the point of rotation, the potential energy of the cask and TSC is converted to kinetic energy as the cask and TSC rotate toward a horizontal orientation on the ISFSI pad. The subsequent motion of the cask is governed by the structural characteristics of the cask, the ISFSI pad and the underlying soil.

The concrete cask tip-over analyses of the MAGNASTOR storage systemsat the Consolidated Interim Storage Facility (CISF) are performed using LS-DYNA.

LS-DYNA is an explicit finite element program for the nonlinear dynamic analysis of structures in three dimensions. The objective of these evaluations is to confirm that the maximum amplified accelerations of the top of the basket and the canister for the five systems at the CISF are bounded by the accelerations used in the structural evaluation of the five systems for the original license basis of each system. The LS-DYNA reevaluation of the cask tip over is required, since the concrete pad and soil conditions at the CISF differed from the original license basis.

G.12.1.3.1 Concrete Cask Finite Element Model For Tip-Over Evaluation

The half-symmetry finite element model of the loaded VCC, concrete pad, mudmat, and soil sublayers are constructed of solid brick elements. The details of the finite element model set-up are shown in Figure G.12-2.

G.12.1.3.2 Material Models/Properties

The material properties used in the analysis are given below:

The modulus of elasticity of concrete is calculated using the following equation:

$$E_c = 33\ (w_c)^{1.5}\sqrt{f_c'}$$

Where,

E_c = Modulus of elasticity of concrete, psi

W_c = Unit weight of concrete, lb/ft3

f_c' = Compressive strength of concrete, psi

G.12.1.3.3 Concrete Pad

Mass density, ρ = 148 pcf = 2.217 E-4 lb-sec^2/in^4

Modulus of elasticity, E = 4.602E6 psi

Poisson's ratio, υ = 0.2

Shear modulus, G = 1.918E6 psi

Compressive strength, f_c' = 6000 psi

G.12.1.3.4 Mudmat

Mass density, ρ = 146 pcf = 2.187 E-4 lb-sec^2/in^4

Modulus of elasticity, E = 2.604E6 psi

Poisson's ratio, υ = 0.2

Shear modulus, G = 1.085E6 psi

Compressive strength, f_c' = 2000 psi

G.12.1.3.5 Soil

[ ]

The properties of soil at various depths are given in Table G.12-1.

Table G.12-1
Soil Properties

G.12.1.3.6 VCC Concrete

The concrete properties used for VCC are given Section G.12.1.3.12.1 for the MAGNSTOR storage system. The densities of VCC and other components used account for the total weight of non-structural components that are not modeled.

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Withheld Pursuant to 10 CFR 2.390

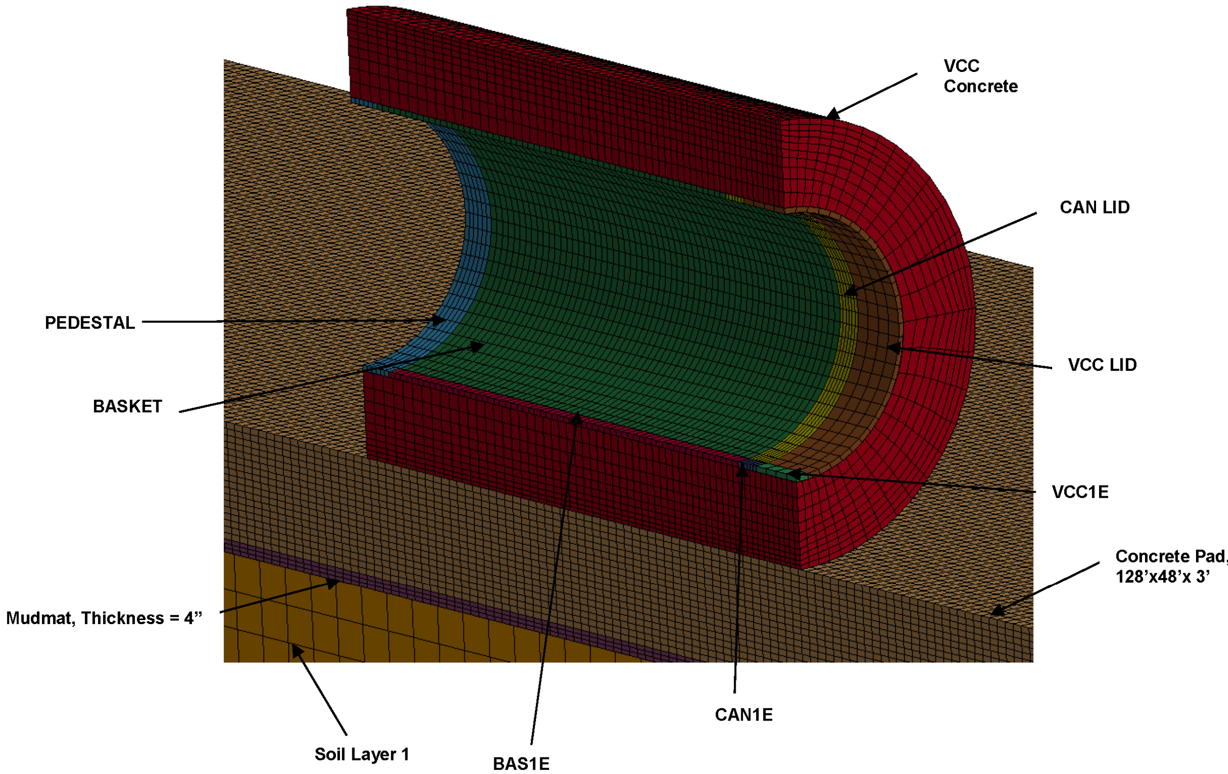

Figure G.12-2
CISF Configuration - Finite Element Model Set-Up (Continued)

G.12.1.3.7 Boundary Conditions

The VCC, liner, concrete pad, mudmat and soil sublayers are modeled using solid elements. The bottom surface of the soil is constrained in the vertical direction. To represent the unlimited expanse of adjacent soil, non-reflecting boundary conditions are applied to the three vertical planes of the soil. Symmetry boundary conditions are applied to the symmetry plane of VCC, concrete pad, mudmat and soil. The bottom of the soil column is vertically restrained. Contact modeling between VCC, liner, basket and canister is modeled using the Surface Contact options available in LS-DYNA.

G.12.1.3.8 Weight of Loaded VCC

The body load due to the gravity (1 g) of the loaded VCC is considered in the analysis and is conservatively applied as a step load. The weights of various loaded VCC systems are given in Table G.12-2.

G.12.1.3.9 Tip-Over Velocity

The tip-over condition is simulated by applying angular velocity to the loaded VCC. The angular velocity is calculated by equating the potential energy of VCC due to change in the position of center of gravity (CG) with the kinetic energy due to rotation of the VCC (while standing on its corner with the CG directly over it) as shown below:

Potential Energy = Rotational Kinetic Energy

$$mgh = (I\omega^2)/2$$

Where,

m = Total mass of the loaded VCC, lb-sec^2/in

g = Acceleration due to gravity, 386.4 in/sec^2

w = mg, Total weight of the loaded VCC, lbs

h = Change in height of CG of VCC, in

I = Total mass moment of inertia of loaded VCC about the pivot point, lb-sec^2-in

ω = Angular velocity of loaded VCC, rad/sec

The diagram is shown below:

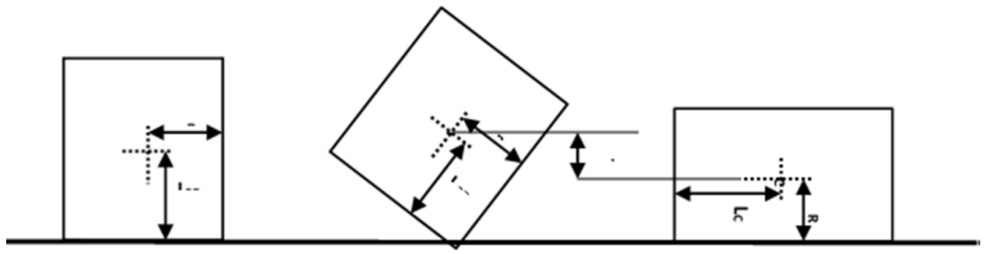

Figure G.12-3
Schematic Representation of the Change in Height of CG of VCC

The change in height of CG of VCC:

$$h = \sqrt{R^2 + L_{CG}{}^2} \ - R$$

Where,

R = Radius of VCC, in

LCG = Distance of CG from base of VCC, in

Therefore, the angular velocity is given by,

$$\omega = \sqrt{\frac{2mgh}{I}}$$

The angular velocities for various VCC systems are given in Table G.12-2.

Table G.12-2
Total Weights and Tip-Over Angular Velocities of MAGNASTOR VCC System

Storage System	Loaded VCC		Tip-Over Angular Velocity (rad/sec)
	Weight (kips)	Mass (lb-sec^2/in)	
MAGNASTOR	323.5	837.2	1.522

G.12.1.3.10 Determination of Amplified Accelerations

The acceleration time histories are taken from the nodes at the top of the basket and the canister which would identify the maximum acceleration of the basket and the canister. The acceleration time histories from the LS-DYNA nodal acceleration file were filtered with a Butterworth filter frequency of 165 Hz. Details of the filter frequency calculation are contained in Reference G.12-2. The general pattern of the acceleration time history of both components is shown in the acceleration time history curve in Figure G.12-4. The initial spike has a duration (t1) of approximately 4 ms while the longer pulse duration (t2) is approximately 40 ms. The initial spike of duration t1 is associated with the initial crushing of the concrete and the equivalent static acceleration used for the basket and canister evaluation is determined using the Dynamic Load Factors (DLF) for a triangular shaped pulse. The DLF for the longer pulse (t2) is determined using the DLF for a sine shaped pulse. The DLF for the basket is dependent on each basket design and basket angular orientation. The DLF for the canister lid region of the TSC is considered to be 1 due to the rigidity of the lid.

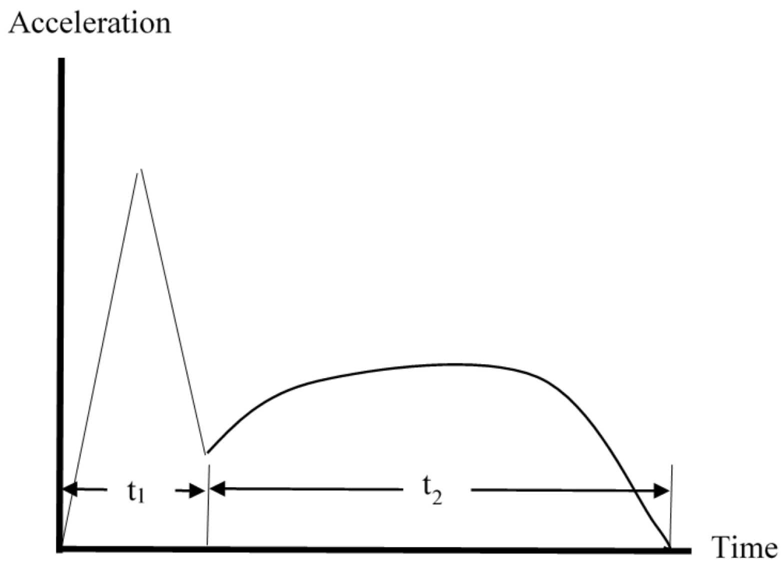

Figure G.12-4
Acceleration Time History

G.12.1.3.11 Cask Specific Evaluations

A model is used to evaluate the loaded concrete cask during tip-over conditions for the MAGNASTOR systems. The concrete pad represents the concrete pad properties at the CSIF site. The dimensions of the concrete pad are 128 feet (length) x 48 feet (width) with a thickness of 3 feet. The mudmat under the pad had a thickness of 4 inches. The subsoil used the length and width of the pad plus 4 feet on each side. The site soil properties were modeled to a depth of 98.7 feet. The mesh density and element aspect ratio of all the models are consistent.

G.12.1.3.12 MAGNASTOR

The total weight of the loaded MAGNASTOR VCC used in the analysis is equal to 323.5 kips. Half-symmetry model as discussed in Section G.12.1.3.1 is used in the analysis.

G.12.1.3.12.1 Material Properties of VCC

Material properties of VCC concrete used in the analysis are given below:

Mass density, ρ = 172.2 pcf = 2.579E-4 lb-sec^2/in^4

Modulus of elasticity, E = 4.716E6 psi

Poisson's ratio, υ = 0.22

Shear modulus, G = 1.933E6 psi

Compressive strength, f_c'= 4000 psi

G.12.1.3.12.2 Geometric Properties of VCC

Radius of VCC, R = 68 in

Distance of CG of VCC from base, LCG = 108.31 in

Change in height of CG, h = 59.9 in

The tip-over angular velocity of the VCC is calculated as per the methodology described in Section G.12.1.3.9 and is applied to the MAGNASTOR model in conjunction with the gravity. The deformed shape of the model is shown in Figure G.12-5. Further details regarding numerical and graphical results are contained in Reference 1.

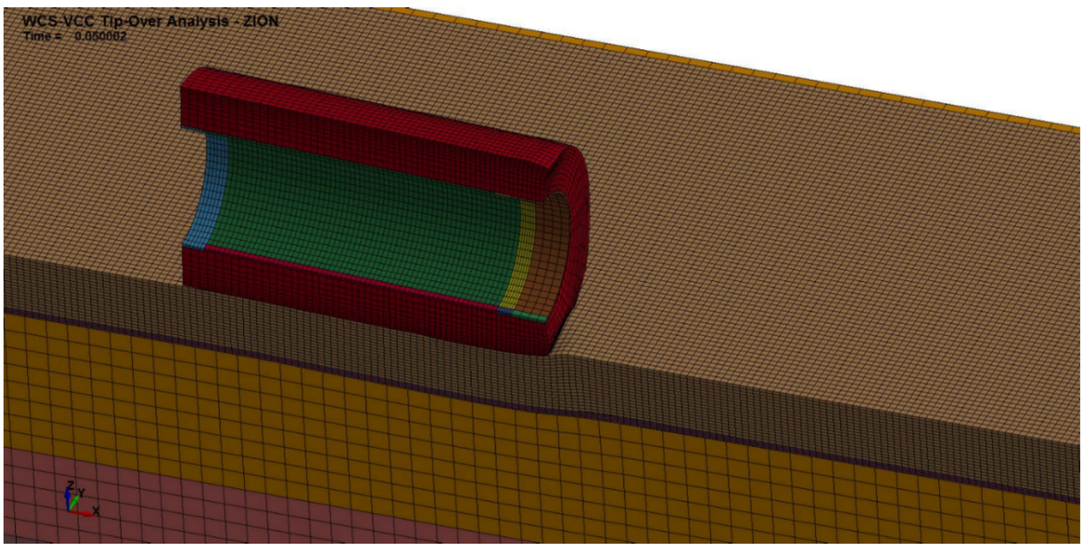

Figure G.12-5
Deformed Shape of MAGNASTOR VCC, Concrete Pad, Mudmat and Soil

The canister lid and attached canister shell peak acceleration is determined to be 28.8g, which would also correspond to the static acceleration to be applied to the model for the canister stress evaluation.

As indicated in Figure G.12-4, the acceleration time history shows two types of pulses. The DLF for the short pulse is based on a triangular shaped pulse. The DLF associated with the short pulse for the basket evaluation is dependent on the fundamental modal frequency of the MAGNASTOR basket and the time duration of the short pulse. Details of the modal analysis for the MAGNASTOR basket are contained in Reference G.12-3. The bounding DLF associated with the short pulse, which is dependent on basket orientation, is 1.05 resulting in an amplified acceleration for the short pulse of 29.2 g's. For the accelerations during the long pulse, the bounding DLF, for the sine pulse is 1.76, regardless of the fundamental modal frequency of the basket. The DLF of 1.76 for the sine pulse is conservatively applied to the peak transient analysis acceleration. The table below shows the basket acceleration obtained from the transient analysis, the maximum DLF, and the amplified accelerations. The acceleration used in the basket and canister evaluations for the MAGNASTOR system in Reference 5 was 35g's. The peak amplified basket acceleration, which is shown below, is 33.1 and the peak canister acceleration of 28.8, and both of these accelerations are bounded by 35g. Therefore, the basket and canister evaluations contained in Reference G.12-1 are bounding for the conditions at the CISF.

G.12.2 References

G.12-1 MAGNASTOR Final Safety Analysis Report, Revision 7, July 2015

G.12-2 NAC Calculation 30039-2010 Rev 0, "Concrete Cask Tip-Over Evaluation – WCS", NAC International, Norcross, GA

G.12-3 NAC Calculation 30039-2015 Rev 0, "Tip-Over DLF Calculation for WCS", NAC International, Norcross, GA

APPENDIX H.1
INTRODUCTION AND GENERAL DESCRIPTION OF INSTALLATION CANISTERIZED GTCC WASTE

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H.1 INTRODUCTION AND GENERAL DESCRIPTION OF INSTALLATION

H.1.1 Introduction

Consistent with Chapter 1 of this SAR, the WCS CISF is intended to provide dry storage capacity for commercial spent nuclear fuel (SNF) and Greater-than-Class C (GTCC) waste contained in a dual-purpose (transportation/storage) cask and canister. This Appendix describes GTCC waste storage at the WCS CISF in both NUHOMS® and VCC storage overpacks. An overview of the CISF and the Storage Overpacks is provided in Chapter 1 of this SAR.

This Appendix demonstrates compliance with the requirements of the site-specific license provisions of 10 CFR 72.6 and follows the guidance in ISG-17 [H.1-1] regarding the GTCC waste storage program at the WCS CISF. Specifically, the GTCC waste storage program described here ensures that (1) adequate protective measures are in place to confirm safe storage within the WCS CISF, (2) the co-location of GTCC waste does not have an adverse effect on the safe storage of SNF and the safe operation of the WCS CISF, and (3) the storage of GTCC waste will not have an adverse effect on public health and safety, and the environment.

The GTCC wastes, as stored at the WCS CISF, are (1) only reactor-related, (2) in solid form, and (3) stored in a separate container (i.e., GTCC waste is not stored in a cask that also contains SNF).

GTCC waste containers contain solid reactor-related waste only, consisting of activated reactor vessel internals and other in-core instrumentation. A description and characterization of the GTCC waste is provided in Appendix H.7 and Section H.3.1.1. There is no liquid or process GTCC waste stored at the WCS CISF.

The external characteristics of the GTCC canister are similar, if not identical, to those of the SNF canisters and the GTCC canisters are to be stored in the same storage overpacks as the SNF canisters. To the extent possible, the same procedures and individuals with the same training and qualifications as those used in SNF transfer operations are used. The organization, programs, and protective measures in place to ensure safe storage of the SNF remain in place to ensure continued safe storage of the canisterized SNF and the canisterized GTCC waste.

Storage of canisterized GTCC waste at the WCS CISF has no adverse effect on the safe storage of the SNF and safe operation of the WCS CISF. The storage of the canisterized GTCC waste has no adverse effect on public health and safety or the environment.

H.1.1.1 Principal Functions of the Installation

In addition to the storage of canisterized SNF assemblies, the WCS CISF design provides temporary dry storage for canisterized GTCC waste. The WCS CISF is designed for dry transfer operations.

H.1.2 General Description of the Installation

A general description of the installation is provided in Section 1.2 of this SAR.

H.1.2.1 GTCC Waste Canisters

The GTCC waste canisters are high integrity stainless steel, welded vessels that provide confinement of radioactive materials, encapsulates the waste in an inert atmosphere, and provides biological shielding (in the axial directions) during canister transfer and storage. It provides full canisterization for the GTCC waste during transfer and storage in the storage overpacks. The GTCC waste canisters are stored within the WCS CISF boundaries. The design requirements and design descriptions for the authorized canisters are provided in Appendices H.3 and H.4.

H.1.3 General System Description

H.1.3.1 Storage Systems

The Storage Systems authorized for storage at the WCS CISF are described in Sections 1.2.4.1 and 1.3 and are listed in Table 1-1 of this SAR.

H.1.3.2 Transfer System

The Transfer Systems authorized for use at the WCS CISF are described in Section 1.3.1 of this SAR.

H.1.4 Identification of Agents and Contractors

See Section 1.5 of this SAR.

H.1.5 Material Incorporated by Reference

See Section 1.6 of this SAR.

H.1.6 References

H.1-1 Spent Fuel Project Office Interim Staff Guidance–17 "Interim Storage of Greater Than Class C Waste."

APPENDIX H.2
SITE CHARACTERISTICS
CANISTERIZED GTCC WASTE

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H.2 SITE CHARACTERISTICS

See Chapter 2 of this SAR.

APPENDIX H.3
PRINCIPAL DESIGN CRITERIA
CANISTERIZED GTCC WASTE

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H.3 PRINCIPAL DESIGN CRITERIA

This section describes the principal design criteria, which are unique to the canisterized GTCC waste storage program at the WCS CISF. The design criteria for the WCS CISF are presented in Chapter 3 of this SAR.

H.3.1 Purpose of Installation

In addition to the SNF storage, the WCS CISF is designed to provide interim storage for canisterized GTCC waste.

The transfer and storage of canisterized GTCC waste and general operating functions at the WCS CISF are similar to those described in Chapters 1 – 15 and system specific Appendices (A-G) for SNF. The existing structures containing the SNF assemblies are neither altered nor disturbed during the transfer and storage of canisterized GTCC waste.

H.3.1.1 Material to be Stored

Canisterized GTCC waste is non-fuel related material generated as a result of plant operation and decommissioning where the radionuclide concentration limits for Class C waste in 10 CFR 61.55 are exceeded. This waste may include such components as incore components, core support structures, and small reactor related miscellaneous parts resulting from the reactor vessel internals segmentation/decommissioning processes. All waste stored within the GTCC canister are activated metals, incore instrument tips, and associated surface contamination.

The total amount of canisterized GTCC waste to be stored at the WCS CISF is up to 231.3 MT (510,000 pounds).

The physical, thermal and radiological characteristics of GTCC canisters are described in the Rancho Seco FSAR, Appendix C [H.3-1], for the GTCC waste proposed for storage at the WCS CISF for storage in a NUHOMS® System. The GTCC waste stored in NAC systems is described in the applicable transportation cask SAR and Certificate of Compliance (CoC) listed by docket number in Table 1-1. GTCC waste for NAC systems could be received from Maine Yankee (GTCC-Canister-MY), Connecticut Yankee (GTCC-Canister-CY), Yankee Rowe (GTCC-Canister-YR), and Zion (GTCC-Canister-ZN). For GTCC-Canister-MY, the GTCC waste is described in the NAC-UMS transportation cask SAR, Section 1.3.1.1.2 [H.3-2]. For GTCC-Canister-CY and GTCC-Canister-YR, the GTCC waste is described in the NAC-STC transportation cask SAR, Section 1.2.3.2 [H.3-3]. For GTCC-Canister-ZN, the GTCC waste is described in the NAC-MAGNATRAN SAR, Section 1.3.2 [H.3-4].

H.3.1.2 General Operating Functions

The operating functions related to the GTCC waste canisters are similar to those addressed in Chapter 5 and the referenced Operating Procedures in the referenced Appendices for the applicable cask systems listed in Table 5-1.

Each aspect of radiation protection, containment, and heat rejection is accomplished through passive means.

H.3.2 Structural and Mechanical Safety Criteria

The GTCC waste canisters are components that are classified as important-to-safety along with the other components described in Section 3.4 and Table 3-5 and the reference appendices for the applicable cask systems listed in Table 3-1 of this SAR.

H.3.2.1 Seismic Design

The GTCC waste canisters are analyzed for seismic loading equal to those ground accelerations described in Section 3.2.3 and are determined acceptable. Resulting stresses in the GTCC shell assembly are bounded by the SNF canister stress results because the total GTCC waste canisters loaded weights are bounded by that analyzed for the SNF canisters.

H.3.2.2 Load Combination Criteria

H.3.2.2.1 Storage Overpacks

The design approach, design criteria and loading combinations for the storage overpacks are addressed in the referenced Appendices for the applicable cask system listed in Table 3-1.

H.3.2.2.2 GTCC Waste Canisters

Table 1-1 includes the authorized GTCC canisters which are designed to withstand the effects of the site characteristics and environmental conditions associated with normal operation, maintenance, and testing of the WCS CISF and to withstand postulated off-normal and accident conditions. Environmental conditions are provided in Table 1-2.

H.3.3 Safety Protection System

H.3.3.1 General

The WCS CISF is designed for safe containment during GTCC waste storage. The components, structures, and equipment, which are designed to assure that this safety objective is met, are summarized in Section 3.4 and the referenced Appendices for the applicable cask system listed in Table 3-1. In addition, the GTCC waste canister is designated as a component important to safety. The key elements of the WCS CISF and its operation that require special design consideration are:

1. *The closure seal welds on the GTCC waste canister shells to form a confinement boundary to maintain a helium atmosphere.*

2. *Minimizing personnel radiation exposure during GTCC waste canister transfer and storage operations.*

3. *Design of the casks and GTCC waste canisters for postulated accidents.*

4. *Design of the storage overpacks with passive ventilation system for effective decay heat removal to ensure the integrity of the GTCC waste canister.*

H.3.3.2 Protection by Equipment and Instrumentation Selection

H.3.3.2.1 Equipment

Handling operations of GTCC waste canisters are the same as for the SNF canisters.

H.3.3.2.2 Instrumentation

No instrumentation is required for the storage of GTCC waste canisters.

H.3.3.3 Nuclear Criticality Safety

Nuclear criticality is not applicable to the design of GTCC waste canisters.

H.3.3.4 Radiological Protection

The WCS CISF is designed to maintain on-site and offsite doses ALARA during transfer operations and long term storage conditions. The storage of GTCC waste canisters does not alter nor impact the access control, shielding, or radiological alarm systems described in balance of this SAR.

H.3.3.5 Fire and Explosion Protection

Fire and explosion protection is addressed in Section 3.3.6 of this SAR. Storage of GTCC waste does not affect the outcome of this analysis.

H.3.3.6 Materials Handling and Storage

H.3.3.6.1 GTCC Waste Handling and Storage

The handling of GTCC waste canisters within the WCS CISF is addressed in Chapter 5 and the referenced Operating Procedures in the referenced Appendices for the applicable cask system listed in Table 5-1.

H.3.3.6.2 Radioactive Waste Treatment

The WCS CISF does not generate radioactive waste. Any secondary waste generated during transportation cask receipt and decontamination operations in the Cask Handling Building (CHB) are handled as described in Section 6.1.4.

H.3.3.6.3 Waste Storage Facilities

Waste storage facilities are neither required nor provided for at the WCS CISF.

H.3.3.7 Industrial and Chemical Safety

No hazardous chemicals or chemical reactions are involved in the operation of the WCS CISF. Industrial safety relating to handling of the cask and waste canister are addressed by procedures, which meet Occupational Safety and Health Administration (OSHA) requirements.

H.3.4 Decommissioning Considerations

WCS CISF decommissioning considerations are addressed in Section 13.6.

H.3.5 Summary of WCS CISF Design Criteria

The GTCC waste canisters are designed as Important-to-Safety components. For design requirements specific to the Storage Systems containing SNF, see the reference appendices for the applicable cask systems listed in Table 3-1 of this SAR.

H.3.6 References

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

H.3-2 NAC International, "Safety Analysis Report for the UMS® Universal Transport Cask," Revision 2, CoC 9270 Revision 4, USNRC Docket Number 71-9270.

H.3-3 NAC International, "NAC-STC, NAC Storage Transport Cask Safety Analysis Report," Revision 17, CoC 9235 Revision 13, USNRC Docket Number 71-9235.

H.3-4 NAC International, "Safety Analysis Report for the MAGNATRAN Transport Cask," Revisions 12A, 14A, 15A, and 16A, USNRC Docket Number 71-9356.

APPENDIX H.4
INSTALLATION DESIGN
CANISTERIZED GTCC WASTE

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H.4 *INSTALLATION DESIGN*

H.4.1 Summary Description

The layout and principal features of the WCS CISF are described in Section 4.1 of this SAR.

H.4.2 Storage Systems

The WCS CISF uses the Storage Overpacks for storage of SNF canisters as well as GTCC waste canisters. All canisters (SNF and GTCC) for a given system identified in Table 1-1 have the same exterior dimensions, are functionally identical, and designed to be accepted by the applicable identified transportation cask, transfer cask and Storage Overpack.

H.4.2.1 Design Basis and Safety Assurance

The intent of the WCS CISF is to provide safe containment during dry storage of SNF and GTCC waste. Consistent with 10 CFR 72.3, the only components at the WCS CISF important-to-safety are those identified in Table 3-4 and Table 3-5. The Storage Overpacks and canisters are self-contained, independent, passive systems and do not rely on any other systems or components for their operation. The other components identified as important-to-safety in Table 3-4 and Table 3-5 such as the Canister Transfer System, Transfer Casks, GTCC waste canisters, and SNF canisters rely on other systems during receipt and transfer operations; but in storage, the GTCC waste canisters and SNF canisters are self-contained, independent, and passive.

The following sections discuss the conformance of the WCS CISF with applicable 10 CFR Part 72 design criteria.

H.4.2.2 Compliance with General Design Criteria

H.4.2.2.1 10 CFR 72.122 Overall Requirements

1. *Quality standards* *Quality assurance requirements are addressed in Section 1.4.4.3.*

2. *Protection against environmental conditions and natural phenomena* *Extreme environmental conditions for the WCS CISF are defined in Table 1-2 and Chapter 12. The design criteria in Section 3.2 require that the storage systems be designed to withstand the design earthquake, high ambient temperature and humidity, and extreme winds.*

3. *Protection against fire and explosion* *The design criteria require that the storage system be designed so that it can continue to perform its safety functions effectively under credible fire and explosion exposure conditions. As addressed in Section 3.3.6, no large fire or explosion within the WCS CISF is considered credible.*

4. *Sharing of structures, systems, and components* *Section 4.1.2 states that the storage system and other WCS CISF support systems are not shared with any other facilities except the counting laboratories as addressed in Section 9.5.2, and WCS CISF activities do not impair any activities at the other WCS facilities adjacent to the WCS CISF.*

5. *Proximity of sites* *The design and operation of the WCS CISF results in minimal risk to the health and safety of the public.*

6. *Testing and maintenance of systems and components* *The design criteria require that the Storage Overpacks be designed to permit inspection, maintenance, and testing. Although the canisterized GTCC storage system requires minimum maintenance, the design of the WCS CISF allows for appropriate testing, inspection, and maintenance, if required.*

7. *Emergency capability* *Scenarios requiring emergency actions are neither considered credible, nor postulated to occur. Nevertheless, the WCS Consolidated Emergency Response Plan is in effect to meet the requirements in 10 CFR 72.32.*

8. *Confinement barriers and systems* *The design of the storage systems ensures that GTCC waste remains contained within its canister, is protected from degradation during storage and that the waste is maintained in a safe condition.*

9. *Instrumentation and control systems* *No control systems are needed for the storage systems to perform their safety functions. The parameters that affect the long-term safe storage of SNF are structural integrity of confinement, shielding, and passive cooling (heat rejection). Technical Specifications are in place to ensure adequate thermal performance of the Storage Overpacks.*

10. *Control room or control areas* *The WCS CISF is a passive installation, with no need for operator actions. No control room is needed for normal WCS CISF operations.*

11. *Utility services* *There are no utility or emergency systems required to perform safety functions at the WCS CISF. Section 4.3 addresses auxiliary system requirements.*

12. *Retrievability* *The design features of the GTCC canisters affecting retrievability are functionally identical to those used for the SNF canisters. By using a design similar to that of SNF canisters, the stored waste could be transferred directly to a DOE facility after DOE acceptance of the waste. The steps involved in retrieving the canisterized GTCC waste for offsite shipment are provided in Chapter 5 and the referenced Operating Procedures in the referenced Appendices for the applicable cask system listed in Table 5-1.*

H.4.2.2.2 10 CFR 72.124 Criteria for Nuclear Criticality Safety

Criticality control is not applicable to the storage of canisterized GTCC waste.

H.4.2.2.3 10 CFR 72.126 Criteria for Radiological Protection

Criteria for radiological protection do not differ from the transfer and storage of canisterized SNF described in this SAR.

H.4.2.2.4 10 CFR 72.128 Criteria for Spent Fuel, High-level Radioactive Waste, Reactor-Related Greater than Class C Waste and other Radioactive Waste Handling and Storage

Criteria for waste transfer and storage do not differ from transfer and storage of canisterized SNF described in this SAR.

H.4.2.2.5 10 CFR 72.130 Criteria for Decommissioning

Operation of the WCS CISF does not result in contamination on the outside surface of the GTCC canisters or any other WCS CISF components above administrative limits.

Decommissioning considerations for the WCS CISF are addressed in Section 13.6 of this SAR.

H.4.2.3 Structural Specifications

Safe storage of canisterized GTCC waste depends only on the capability of the storage system to fulfill its design functions. The design criteria for the storage system ensures that its exposure to credible site hazards does not impair its safety function.

H.4.2.4 Individual Unit Description

H.4.2.4.1 Storage Overpacks

Table 1-1 identifies the storage overpack applicable for each GTCC waste canister authorized for storage at the WCS CISF. The location for descriptions of the various storage overpacks is provided in Table 4-1 with the description provided in the referenced Appendices for the applicable cask system.

H.4.2.4.2 GTCC Waste Canisters

The GTCC waste canisters authorized for storage at the WCS CISF are high integrity stainless steel, welded vessels which provide confinement of radioactive materials, encapsulate the waste in a helium atmosphere, and together with a transfer cask or Storage Overpack, provide biological shielding during canister transfer and long term storage.

The GTCC waste canisters are all licensed for transport under a 10 CFR Part 71 CoC listed in Table 1-1. Drawings for each of the authorized GTCC waste canisters are listed in Section H.4.8.

The auxiliary systems that support the transfer operations associated with the GTCC waste canisters are described in Section 4.3 of this SAR.

H.4.3 Decontamination System

H.4.3.1 Equipment Decontamination

The only decontamination activity performed at the WCS CISF is the removal of contamination from the outside surfaces of the transportation cask upon arrival at the site. Such contamination would be due to possible weeping of the transportation cask surface during transport to the site because the transport cask may have been immersed in fuel pools prior to arrival at the WCS CISF. The canisters and storage overpacks arrive clean and remain clean for all transfer and storage operations at the WCS CISF.

H.4.3.2 Personnel Decontamination

No personnel decontamination facilities are needed at the WCS CISF. Personnel decontamination is conducted, if necessary, using the WCS Radiation Protection Program procedures.

H.4.4 Repair and Maintenance

H.4.4.1 Repair

No repair operations are anticipated once the GTCC waste canisters are placed into storage.

H.4.4.2 Maintenance

Periodic maintenance is not required. Maintenance of a minor nature can be performed within the Storage Area, without the need to move the canisters. Major maintenance operations are not required at the WCS CISF related to the GTCC waste canisters. Storage system design features minimize or eliminate the need for maintenance. The GTCC waste canister shells are made of corrosion-resistant stainless steel. The GTCC shell internal is backfilled with helium preventing corrosion on the inside of the canister.

H.4.5 Cathodic Protection

The WCS CISF is dry and above ground so that cathodic protection in the form of impressed current is not required. The normal operating environment for all metallic components is above ambient air temperatures so that there is no opportunity for condensation on those surfaces.

The austenitic stainless steel GTCC canisters require no corrosion protection for any foreseeable event. Any carbon steel portions inside the canisters are contained within a sealed, dried, and inert environment backfilled with helium and is not subject to corrosion.

H.4.6 Waste Handling Operation Systems

GTCC waste canister handling operations are performed with the same equipment used for handling canisters containing SNF. Radiation protection of individuals involved in handling canisters is addressed in Chapter 9.

The steps involved for receiving, transferring, storing and eventual retrieval and shipment off-site for the canisterized GTCC are the same as those for canisters containing SNF and are provided in Chapter 5 and the referenced Operating Procedures in the referenced Appendices for the applicable cask system listed in Table 5-1.

H.4.7 References

H.4-1 NAC International, "NAC-STC, NAC Storage Transport Cask Safety Analysis Report," Revision 17, CoC 9235 Revision 13, U.S. NRC Docket Number 71-9235.

H.4-2 NAC International, "Safety Analysis Report for the UMS® Universal Transport Cask," Revision 2, CoC 9270 Revision 4, U.S. NRC Docket Number 71-9270.

H.4-3 NAC International, "Safety Analysis Report for the MAGNATRAN Transport Cask," Revisions 12A, 14A, 15A, and 16A, U.S. NRC Docket Number 71-9356.

H.4.8 Supplemental Data Drawings

This section provides a listing of all applicable license drawings associated with the storage of the authorized GTCC waste canisters at the WCS CISF. The drawings are incorporated by reference or enclosed as noted below.

The following drawings are for the NUHOMS® MP187 Cask System GTCC Canister:

1. *"NUHOMS® System GTCC Canister Main Assembly (five sheets)," 13302-1005, Revision 0 (Included at the end of this Section).*

2. *"NUHOMS® System GTCC Canister Closure Installation (one sheet)," 13302-1007, Revision 0 (Included at the end of this Section).*

The following are for the NAC-MPC GTCC-Canister-CY and GTCC-Canister-YR

3. *"Basket Assembly, GTCC, CY-MPC," Sheets 1 thru 4, 414-887, Rev. 4 (See Section 1.3.2 of the "NAC-STC, NAC Storage Transport Cask Safety Analysis Report" [H.4-1])*

4. *"Canister Shell, GTCC, CY-MPC," Sheets 1 thru 2, 414-888, Rev. 4 (See Section 1.3.2 of the "NAC-STC, NAC Storage Transport Cask Safety Analysis Report" [H.4-1])*

5. *"Assembly, Transportable Storage Canister (TSC), GTCC, CY-MPC," Sheets 1 through 3, 414-889, Rev. 7 (See Section 1.3.2 of the "NAC-STC, NAC Storage Transport Cask Safety Analysis Report" [H.4-1])*

6. *"Loaded Vertical Concrete Cask (VCC), CY-MPC, Waste Control Specialists (WCS)," Sheets 1 of 1, 30039-863, Rev. 0 (included at the end of this Section)*

7. *"Basket Assembly, 24 GTCC Container, MPC-Yankee," Sheets 1 through 3, 455-887, Rev. 4 (See Section 1.3.2 of the "NAC-STC, NAC Storage Transport Cask Safety Analysis Report" [H.4-1])*

8. *"Assembly, Transportable Storage Canister (TSC), 24 GTCC Container, MPC-Yankee," Sheets 1 through 2, 455-888, Rev. 8 (See Section 1.3.2 of the "NAC-STC, NAC Storage Transport Cask Safety Analysis Report" [H.4-1])*

9. *"Loaded Vertical Concrete Cask (VCC), MPC-YANKEE, Waste Control Specialists (WCS)," Sheets 1 through 2, 30039-862, Rev. 0 (included at the end of this Section)*

The following are for the NAC-UMS GTCC-Canister-MY

10. *"GTCC Waste Basket, Maine Yankee, NAC-UMS," Sheets 1 through 2 790-611, Revision 6 (See Section 1.3.4 of "Safety Analysis Report for the UMS® Universal Transport Cask" [H.4-2])*

11. *"GTCC Waste Canister, Maine Yankee, NAC-UMS," Sheets 1 through 2, 790-612, Rev. 9 (See Section 1.3.4 of "Safety Analysis Report for the UMS® Universal Transport Cask" [H.4-2])*

12. *"Loaded Vertical Concrete Cask (VCC), NAC-UMS, Waste Control Specialists (WCS)," Sheets 1 through 2, 30039-590, Rev. 0 (included at the end of this Section)*

The following are for the MAGNASTOR GTCC-Canister-MY and GTCC-Canister-ZN

13. *"GTCC Waste Basket Liner, MAGNASTOR," Sheets 1 through 2, 71160-711, Rev. 1 (See Section 1.4.3 of the "Safety Analysis Report for the MAGNATRAN Transport Cask" [H.4-3])*

14. *"Shell Weldment, GTCC TSC, MAGNASTOR," Sheets 1 through 2, 71160-781, Rev. 1 (See Section 1.4.3 of the "Safety Analysis Report for the MAGNATRAN Transport Cask" [H.4-3])*

15. *"GTCC TSC, Assembly, MAGNASTOR," Sheets 1 through 2, 71160-785, Rev. 3 (See Section 1.4.3 of the "Safety Analysis Report for the MAGNATRAN Transport Cask" [H.4-3])*

16. *"Loaded Vertical Concrete Cask (VCC), MAGNASTOR, Waste Control Specialists (WCS)", Sheets 1 of 1, 30039-591, Rev. 0 (included at the end of this Section)*

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PARTS LIST	
ALL DIMENSIONS ARE APPLICABLE AT 70°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.	TRANSNUCLEAR
DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1994. FRACTIONS N/A; DECIMALS .XX ± .05, .XXX ± .015; ANGLES ± 1°	TITLE: SACRAMENTO MUNICIPAL UTILITY DISTRICT NUHOMS® SYSTEM GTCC CANISTER MAIN ASSEMBLY
BREAK AND DEBURR ALL SHARP EDGES .02	
3rd ANGLE PROJECTION	
DO NOT SCALE DRAWING	DWG. NO. 13302-1005; SCALE NONE; SHEET 1 OF 5; REV. NO. 0

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

ALL DIMENSIONS ARE APPLICABLE AT 70°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL ASSEMBLY UNLESS NOTED OTHERWISE.

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1994.

FRACTIONS	DECIMALS	ANGLES
N/A	.XX ± .05 .XXX ± .015	± 1°

BREAK AND DEBURR ALL SHARP EDGES .02

3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

TRANSNUCLEAR

TITLE: SACRAMENTO MUNICIPAL UTILITY DISTRICT
NUHOMS® SYSTEM
GTCC CANISTER
MAIN ASSEMBLY

DWG. NO.	SCALE	SHEET	REV. NO.
13302-1005	NONE	2 OF 5	0

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

ALL DIMENSIONS ARE APPLICABLE AT 70°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL ASSEMBLY UNLESS NOTED OTHERWISE.	TRANSNUCLEAR
DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1994. FRACTIONS N/A; DECIMALS .XX ± .05, .XXX ± .015; ANGLES ± 1°	TITLE: SACRAMENTO MUNICIPAL UTILITY DISTRICT NUHOMS® SYSTEM GTCC CANISTER MAIN ASSEMBLY
BREAK AND DEBURR ALL SHARP EDGES .02	
3rd ANGLE PROJECTION	
DO NOT SCALE DRAWING	DWG. NO. 13302-1005; SCALE NONE; SHEET 3 OF 5; REV. NO. 0

DWG. NO. 13302-1005 SHEET 4 OF 5

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

ALL DIMENSIONS ARE APPLICABLE AT 70°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL ASSEMBLY UNLESS NOTED OTHERWISE.

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1994.

FRACTIONS	DECIMALS	ANGLES
N/A	.XX ± .05 .XXX ± .015	± 1°

BREAK AND DEBURR ALL SHARP EDGES .02

3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

TRANSNUCLEAR

TITLE: SACRAMENTO MUNICIPAL UTILITY DISTRICT
NUHOMS® SYSTEM
GTCC CANISTER
MAIN ASSEMBLY

DWG. NO.	SCALE	SHEET	REV. NO.
13302-1005	NONE	4 OF 5	0

13302-1005 DWG. NO. 5 OF 5 SHEET

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

ALL DIMENSIONS ARE APPLICABLE AT 70°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL ASSEMBLY UNLESS NOTED OTHERWISE.	TRANSNUCLEAR
DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1994. FRACTIONS N/A; DECIMALS .XX ± .05, .XXX ± .015; ANGLES ± 1°	TITLE: SACRAMENTO MUNICIPAL UTILITY DISTRICT NUHOMS® SYSTEM GTCC CANISTER MAIN ASSEMBLY
BREAK AND DEBURR ALL SHARP EDGES .02	
3rd ANGLE PROJECTION	
DO NOT SCALE DRAWING	DWG. NO. 13302-1005; SCALE NONE; SHEET 5 OF 5; REV. NO. 0

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

ALL DIMENSIONS ARE APPLICABLE AT 70°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.	TRANSNUCLEAR	
DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1994. FRACTIONS N/A DECIMALS .XX ± N/A .XXX ± N/A ANGLES ± N/A	TITLE: SACRAMENTO MUNICIPAL UTILITY DISTRICT NUHOMS® SYSTEM GTCC CANISTER CLOSURE INSTALLATION	
BREAK AND DEBURR ALL SHARP EDGES N/A		
3rd ANGLE PROJECTION		
DO NOT SCALE DRAWING	DWG. NO. 13302-1007	SCALE NONE / SHEET 1 OF 1 / REV. NO. 0

DWG. NO. 13302-1007 SHEET 1 OF 1

R-232822

Security-Related Information
Figure Withheld Under 10 CFR 2.390.

NAC INTERNATIONAL

LOADED VERTICAL CONCRETE CASK (VCC) NAC-UMS®, WASTE CONTROL SPECIALISTS (WCS)

REV	CHANGE
0	INITIAL ISSUE

UNLESS OTHERWISE STATED	
NEXT ASSEMBLY	N/A
DRAWING TYPE	LICENSE

PROJECT	DRAWING	REV
30039	590	0

SH 1 OF 2

Security-Related Information
Figure Withheld Under 10 CFR 2.390.

NAC INTERNATIONAL

LOADED VERTICAL
CONCRETE CASK (VCC)
NAC-UMS®
WASTE CONTROL SPECIALISTS
(WCS)

PROJECT	DRAWING	REV
30039	590	0

SH 2 OF 2

R-232824

REV	CHANGE
0	INITIAL ISSUE

Security-Related Information Figure Withheld Under 10 CFR 2.390.

NAC INTERNATIONAL

LOADED CONCRETE CASK, MAGNASTOR, WASTE CONTROL SPECIALISTS (WCS)

UNLESS OTHERWISE STATED

NEXT ASSEMBLY N/A

DRAWING TYPE LICENSE

GROUP	NAME	DATE
		9/1/16
		9-1-16
		9-2-16
		9-2-16
		9/6/16
		9/9/16

PROJECT 30039 DRAWING 591 REV 0

SH 1 OF 1

R-232826

REV	CHANGE
0	INITIAL ISSUE

Security-Related Information
Figure Withheld Under 10 CFR 2.390.

UNLESS OTHERWISE STATED

ALL DIMENSIONS ARE IN INCHES

NEXT ASSEMBLY N/A

DRAWING TYPE LICENSE

GROUP	NAME	DATE
	[signature]	9/2/16
	[signature]	9-2-16
	[signature]	9-2-16
	[signature]	9-2-16
	[signature]	9/6/16
	[signature]	9/7/16

NAC INTERNATIONAL

LOADED VERTICAL CONCRETE CASK (VCC) MPC-YANKEE, WASTE CONTROL SPECIALISTS (WCS)

PROJECT 30039 DRAWING 862 REV 0

SH 1 OF 2

Security-Related Information
Figure Withheld Under 10 CFR 2.390.

NAC INTERNATIONAL

LOADED VERTICAL
CONCRETE CASK (VCC)
MPC-YANKEE
WASTE CONTROL SPECIALISTS
(WCS)

PROJECT 30039	DRAWING 862	REV 0	SH 2 OF 2

R-232828

REV	CHANGE
0	INITIAL ISSUE

Security-Related Information
Figure Withheld Under 10 CFR 2.390.

NAC INTERNATIONAL

LOADED VERTICAL
CONCRETE CASK (VCC)
CY-MPC,
WASTE CONTROL SPECIALISTS
(WCS)

UNLESS OTHERWISE STATED

ALL DIMENSIONS ARE IN INCHES

DRAWING TYPE: LICENSE

GROUP	NAME	DATE
	[illegible]	9/2/16
	[illegible]	9-2-16
	[illegible]	9-2-16
	[illegible]	9-2-16
	[illegible]	9/6/16
	[illegible]	9/9/16

PROJECT 30039

DRAWING 863

REV 0

SH 1 OF 1

APPENDIX H.5
OPERATION SYSTEMS
CANISTERIZED GTCC WASTE

Table of Contents

H.5 OPERATION SYSTEMS

The tasks required to receive, transfer and store the GTCC waste canisters at the WCS CISF are the same as those provided in Chapter 5 and the referenced Operating Procedures in the referenced Appendices for the applicable cask system listed in Table 5-1.

H.5.1 Operation Description

The GTCC waste canisters are designed to be functionally identical to the SNF canisters of the same system. Existing receipt, transfer and storage procedures, to the extent possible are therefore used for receiving, transferring and storing the GTCC waste canisters. The procedures for these operations applicable to the GTCC waste cansiters are provided in Chapter 5 and the referenced Operating Procedures in the referenced Appendices for the applicable cask system listed in Table 5-1.

H.5.2 GTCC Waste Handling Systems

GTCC waste canister handling is identical to that described in the procedures provided in Chapter 5 and the referenced Operating Procedures in the referenced Appendices for the applicable cask system listed in Table 5-1 except that no SNF is contained in the GTCC waste canisters. The remaining handling systems including transfer systems and equipment and safety features remain unchanged.

APPENDIX H.6
WASTE CONFINEMENT AND MANAGEMENT
CANISTERIZED GTCC WASTE

Table of Contents

H.6 WASTE CONFINEMENT AND MANAGEMENT

H.6.1 Waste Sources

There are no radioactive wastes generated by the storage of GTCC waste at the WCS CISF. The radioactive wastes generated in the CHB are from the potential need to remove contamination (decontaminate) from the outside surfaces of the transportation cask upon arrival at the site. Such contamination would be due to possible weeping of the transportation cask surface during transport to the site because the transport cask may have been immersed in fuel pools prior to arrival at the WCS CISF.

H.6.2 Off-gas Treatment and Ventilation

There is no radioactive off-gas generated by the receipt, transfer and storage of GTCC waste canisters at the WCS CISF.

H.6.3 Liquid Waste Treatment and Retention

There are no liquid wastes generated by the receipt, transfer and storage of GTCC waste canisters at the WCS CISF.

H.6.4 Solid Wastes

There are no solid wastes generated by the storage of GTCC waste canisters at the WCS CISF. Solid low-level radioactive wastes are generated at the WCS CISF as a result of contamination surveillance and transportation cask decontamination activities. These wastes are collected, packaged and temporarily stored at the WCS CISF as described in Section 6.4 of this SAR.

H.6.5 Radiological Impact of Normal Operations - Summary

There are no gaseous effluents, liquid effluents or solid wastes generated by the storage of GTCC waste canisters at the WCS CISF. Section 6.4 describes how the small amounts of solid wastes generated during receipt of the transportation casks are handled.

APPENDIX H.7
RADIATION PROTECTION
CANISTERIZED GTCC WASTE

Table of Contents

H.7 RADIATION PROTECTION

H.7.1 Ensuring that Occupational Radiation Exposures Are As Low As Is Reasonably Achievable (ALARA)

The policy and design considerations to maintain exposures ALARA are addressed in Chapter 9 of this SAR.

H.7.2 Radiation Sources

H.7.2.1 Characterization of Sources

Canisterized GTCC waste is non-fuel related material generated as a result of plant operation and decommissioning where the radionuclide concentration limits for Category C in 10 CFR 61.55 are exceeded. This waste may include such components as incore components, core support structures, and small reactor related miscellaneous parts resulting from the reactor vessel internals segmentation/decommissioning processes. All waste stored within the GTCC canister are activated metals, incore instrument tips, and associated surface contamination.

The total amount of canisterized GTCC waste to be stored at the WCS CISF is approximately 510,000 pounds.

The radiological characteristics of GTCC canisters are described in Section 7.2.1 and Table 7-1 of the Rancho Seco FSAR, Appendix C [H.7-1], for the GTCC waste proposed for storage at the WCS CISF for storage in a NUHOMS® System. The GTCC waste stored in NAC systems is described in the applicable transportation cask SAR and Certificate of Compliance (CoC) listed by docket number in Table 1-1. GTCC waste for NAC systems are received from Maine Yankee (GTCC-Canister-MY), Connecticut Yankee (GTCC-Canister-CY), Yankee Rowe (GTCC-Canister-YR), and Zion (GTCC-Canister-ZN). For GTCC-Canister-MY, the GTCC waste is described in the NAC-UMS transportation cask SAR, Section 1.3.1.1.2 [H.7-2]. For GTCC-Canister-CY and GTCC-Canister-YR, the GTCC waste is described in the NAC-STC transportation cask SAR, Section 1.2.3.2 [H.7-3]. For GTCC-Canister-ZN, the GTCC waste is described in the NAC-MAGNATRAN SAR, Section 1.3.2 [H.7-4].

H.7.2.2 Airborne Radioactive Material Sources

The release of airborne radioactive material is not a credible event with the system designs and procedures to be used. The GTCC waste canisters are sealed and the exterior surfaces clean upon receipt and remain sealed inside the clean canister while at the WCS CISF.

H.7.3 Radiation Protection Design Features

H.7.3.1 Shielding

H.7.3.1.1 Radiation Shielding Design Features

Shielding design features of the Storage Overpacks and Transfer Casks are addressed in Section 9.3.3.3 and the referenced sections in the referenced Appendices for the applicable cask system listed in Table 9-4 of this SAR. The shielding design features for the GTCC waste canisters are similar to the SNF canisters for the associated storage system. The outer dimensions of the GTCC waste canisters are identical to those of the SNF canisters in the associated system. Drawings showing materials of construction and thickness for the GTCC waste canisters are provided in Section H.4.8 of this SAR.

H.7.3.1.2 Shielding Analysis

The shielding analysis for the NUHOMS® MP187 Cask System GTCC Canister is addressed in Section 7.3.1.2 of Appendix C of [H.7-1]. The evaluation concludes that the GTCC waste canister contribution to the dose rates around the transfer cask, Storage Overpack, and therefore the site boundary is less than that calculated for the design basis SNF under normal and accident conditions. Therefore, the shielding evaluations provided for the NUHOMS® MP187 Cask System with SNF canisters in Appendix A.9 are bounding and the site dose evaluations in Chapter 9 which assume all SNF canisters in the evaluation are bounding.

As detailed in Section 5.5.1.2 of the NAC-UMS Transport SAR [H.7-2], the dose rates due to Maine Yankee GTCC waste are bounded by the dose rates for canisterized design basis SNF, as presented in UMS Transport SAR Section 5.1.3. As detailed in Section 5.1.4.2 of the NAC-STC Transport SAR [H.7-3], the dose rates due to Yankee Rowe GTCC waste are bounded by the dose rates for canistered Yankee Class fuel. As detailed in Section 5.1.4.3 of the NAC-STC Transport SAR [H.7-3], the dose rates due to Connecticut Yankee GTCC waste are bounded by the dose rates for canistered Connecticut Yankee Class fuel. As detailed in Tables 5.1-3 and 5.1-7 of the NAC-MAGNATRAN Transport SAR [H.7-4], the dose rates due to Zion GTCC waste are bounded by the dose rates for design basis canisterized undamaged PWR fuel.

H.7.3.2 Ventilation

The Storage Overpack ventilation designs are identical to those for SNF canisters which have much higher heat loads as compared to the GTCC waste canisters.

H.7.3.3 Area Radiation and Airborne Radioactivity Monitoring Instrumentation

The same area radiation and airborne radioactivity monitoring instrumentation is applicable to GTCC waste storage and is addressed in Section 9.3.5.

H.7.4 Estimated Onsite Collective Dose Assessment

H.7.4.1 Operational and Site Dose Assessment

Receipt, transfer activities and storage of the GTCC waste canisters are bounded by the same activities with canisters containing SNF. As addressed in Section H.7.3.1.2, occupational and site dose evaluations include the storage of GTCC waste canister which are modeled as spent nuclear fuel canisters.

H.7.5 Health Physics Program

The organization, equipment, facilities and procedures of the radiation protection program are addressed in Section 9.5 and are applicable to the GTCC waste canister operations.

H.7.6 Estimated Offsite Collective Dose Assessment

H.7.6.1 Effluent and Environmental Monitoring Program

No effluents are released from the WCS CISF during operation. There are no gaseous or liquid wastes generated during storage of the GTCC waste canisters. Since no effluents are released from the WCS CISF no effluent monitoring program is required.

H.7.6.2 Analysis of Multiple Contributions

As addressed in Section H.7.3.1.2, dose rates from the canisterized GTCC waste are bounded by the dose rates from canisters containing SNF in the same system. Therefore, by assuming that the Storage Overpacks contain a SNF canister, the onsite and offsite direct and scattered dose rates are bounding when some of the Storage Overpacks contain GTCC waste canisters.

It is therefore concluded that the radiation exposure due to storage of the GTCC waste canisters adjacent to the SNF storage do not exceed the regulatory requirements of 10 CFR Part 72 and 40 CFR Part 190.

H.7.6.3 Estimated Dose Equivalents

Since no airborne effluents are postulated to emanate from the WCS CISF, the direct and air scattered radiation exposures addressed in previous sections comprises the total radiation exposure to the public. No estimation of effluent dose equivalents is necessary.

H.7.6.4 Liquid Release

No radioactive liquids are released from the WCS CISF.

H.7.7 References

H.7-1 "Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report," NRC Docket No. 72-11, Revision 4.

H.7-2 NAC International, "Safety Analysis Report for the UMS® Universal Transport Cask," Revision 2, CoC 9270 Revision 4, USNRC Docket Number 71-9270.

H.7-3 NAC International, "NAC-STC, NAC Storage Transport Cask Safety Analysis Report," Revision 17, CoC 9235 Revision 13, USNRC Docket Number 71-9235.

H.7-4 NAC International, "Safety Analysis Report for the MAGNATRAN Transport Cask," Revisions 12A, 14A, 15A, and 16A, USNRC Docket Number 71-9356.

APPENDIX H.8
ANALYSIS OF DESIGN
CANISTERIZED GTCC WASTE

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H.8 ANALYSIS OF DESIGN

In previous sections of this SAR, the features of the WCS CISF which are important to safety have been identified and addressed. The purpose of this section is to present the engineering evaluations for normal and off-normal operating conditions, and to establish and qualify the system for a range of credible and hypothetical accidents.

H.8.1 Normal and Off-Normal Operations

The normal and off-normal WCS CISF operations for dead weight, operational loads, and live loads are listed in Table 1-2 and addressed in Chapter 3 of this SAR. The various GTCC waste canisters are comparable to the SNF canisters in the following parameters:

- *The nominal thickness of the various GTCC waste canister shells and cover plates are equal to, or greater than the thickness specified for the SNF canisters for the associated Cask System listed in Table 1-1 of this SAR.*
- *The material properties specified for the various GTCC waste canister shell assemblies have identical chemical and physical properties as the material specified for the SNF canisters for the associated Cask System listed in Table 1-1 of this SAR.*
- *The required thickness of the welds in the various GTCC waste canister shells is equal to or greater than the nominal thickness specified for the SNF canisters for the associated Cask System listed in Table 1-1 of this SAR.*

In addition, the GTCC waste specified for the various GTCC waste canisters are comprised of large pieces of steel and not SNF. The contents remain intact under all possible loading conditions as they are inherently much more rigid than the SNF assemblies.

The GTCC waste canisters contain insignificant heat load. Internal pressures are therefore not anticipated to be significantly greater than the helium backfill pressures. In addition, temperature variations in the GTCC waste canister shell assemblies are small. Since the heat load is small and the material temperatures are only be slightly greater than ambient, the temperature variations at any point in the shells are approximately equal to the variation in ambient temperature. These small temperature cycles do not result in damage to, or failure of, the various GTCC waste canister shell assemblies.

H.8.2 Accident Analyses for the WCS CISF

The accident conditions for cask drop, canister leakage, earthquake, and fire are listed in Table 1-2 of this SAR. The various GTCC waste canisters are comparable to the SNF canisters for the associated Cask System listed in Table 1-1 of this SAR for the parameters provided in Section H.8.1 above. Accident pressurization is not considered a credible event due to the very low heat load of the GTCC waste canisters.

H.8.2.1 Accidental GTCC Canister/Cask Drop

Section 5.2.2 of the Technical Specifications [H.8-1] addresses required inspections following a cask drop.

H.8.2.2 GTCC Canister Leakage

The various GTCC canister shells are designed with pressure retaining features to prevent leakage of contaminated materials. There are no credible conditions that can breach the canister shell or fail the welds at each end of the canisters. The GTCC waste closure lid welds are multi-pass closure welds and are the same as closure welds for canisters loaded with SNF. Performance of a multi-pass closure weld on GTCC waste canisters ensures no leakage path through the closure lid to shell weld. Some of the canisters also include a redundant closure lid with multi pass welds providing an additional barrier to leakage at the ends.

H.8.2.3 Accident Pressurization

The various GTCC canisters contain insignificant heat loads. In addition, temperature variations in the various GTCC shell assemblies are small. Since the heat load is small and the material temperatures are only slightly greater than ambient, the temperature variations at any point in the shell are approximately equal to the variation in ambient temperature. These small temperature cycles do not result in damage to, or failure of, the GTCC shell assemblies.

H.8.2.4 Earthquake

A seismic event is not expected to negatively impact the GTCC waste canisters. The GTCC waste canisters are comparable to the previously analyzed SNF canisters for the associated Cask System listed in Table 1-1 of this SAR.

Evaluations of the effects and consequences of the earthquake event for the Storage Overpacks are addressed in Chapter 12 and the referenced Appendices for the applicable cask system listed in Table 12-1.

H.8.2.5 Fire

The evaluations are presented in Chapter 12 and the referenced Appendices for the applicable cask system listed in Table 12-1.

H.8.3 References

H.8-1 Proposed SNM-1050, WCS Consolidated Interim Storage Facility Technical Specifications, Amendment 0.

APPENDIX H.9
CONDUCT OF OPERATIONS
CANISTERIZED GTCC WASTE

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H.9 *CONDUCT OF OPERATIONS*

The organization and general plans for operating the WCS CISF are not altered or modified by the addition of the GTCC waste canisters. The external characteristics of the various GTCC waste canisters are functionally identical to those of the SNF canisters for the associated Cask System listed in Table 1-1 of this SAR. Existing procedures, qualifications and training used for the SNF receipt, transfer and storage operations are used to the extent possible for the GTCC waste canisters.

The VP Operations is responsible for the overall operation and maintenance of the WCS CISF and for ensuring the safe storage of the canisterized SNF and GTCC waste.

Administrative programs such as radiation protection, environmental monitoring, emergency preparedness, quality assurance, and training need not be modified for the receipt, transfer and storage of the GTCC waste canisters.

H.9.1 Organizational Structure

Organizational structure is not altered by receiving, transferring and storing the GTCC waste canisters.

H.9.2 Pre-Operational Testing and Operation

Functional tests of receipt operations, transfer operations, and storage and retrieval for the canisterized SNF are the same as for the various GTCC waste canisters for the associated Cask System listed in Table 1-1 of this SAR. Therefore, functional tests of equipment, transfer operations, and Storage Overpack loading and retrieval are performed as part of preparation for the canisters containing SNF of the same system and new or additional pre-operational testing and operation steps are not required for GTCC waste canisters.

H.9.3 Training Program

The various GTCC waste canisters are functionally identical to the SNF canisters for the associated Cask System listed in Table 1-1 of this SAR. The training program addressed in Section 13.3 of this SAR is applicable to the GTCC waste canister operations.

H.9.4 Normal Operations

The preparation, review, approval, and adherence to procedures described in Section 13.4 of this SAR cover the GTCC waste canister operations.

H.9.5 Emergency Planning

The Emergency Plan covers receipt, transfer and storage of the various GTCC waste canisters at the WCS CISF. See Section 13.5 of this SAR for emergency planning details.

H.9.6 Decommissioning Plan

The WCS CISF Decommissioning Plan covers receipt, transfer and storage of the various GTCC waste canisters at the WCS CISF. See Section 13.6 of this SAR for discussion of the Decommissioning Plan for the WCS CISF.

APPENDIX H.10
OPERATING CONTROLS AND LIMITS
CANISTERIZED GTCC WASTE

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H.10 *OPERATING CONTROLS AND LIMITS*

H.10.1 Proposed Operating Controls and Limits

The WCS CISF storage system is unaffected by the storage of canisterized GTCC waste.

Controls and limits on the GTCC waste canisters are applied to provide assurance that the WCS CISF uses the same controls and limits as those for the canisters containing SNF. Operating controls and limits are addressed in the Technical Specifications [H.10-1] and Chapter 14. Use of the organizational and administrative systems and procedures, record keeping, review, audit, and reporting requirements coupled with the requirements of this SAR ensures that the operations involved in the storage of canisterized GTCC waste at the WCS CISF are performed in a safe manner. This includes the verification of the GTCC waste canisters prior to and during placement into the storage overpacks.

H.10.2 Development of Operating Controls and Limits

The bases for the operating controls and limits specified in Chapter 14 are applicable to GTCC waste canister handling and storage at the WCS CISF to maintain the public health and safety. The Technical Specifications and/or SAR for canisterized spent nuclear fue1 storage are unaffected by the presence of canisterized GTCC waste.

H.10.3 References

H.10-1 Proposed SNM-1050, WCS Consolidated Interim Storage Facility Technical Specifications, Amendment 0.

APPENDIX H.11
QUALITY ASSURANCE
CANISTERIZED GTCC WASTE

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H.11 QUALITY ASSURANCE

The Waste Control Specialists LLC Quality Assurance Program Description is not altered or modified by the GTCC waste canisters. Section 1.4.4.3 of this SAR includes discussion and the reference to the Waste Control Specialists LLC Quality Assurance Program Description.