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 WCS Consolidated Interim Storage Facility (*WCS* 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 *CISF* 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 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 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 *CISF* 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 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 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 *CISF* 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 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-ft^2 Curved surface solar insolation 1474.7 BTU/day-ft^2	Normal (Same)	**NAC-UMS FSAR Section 4.4.1.1** Curved Surface: 1475 Btu/ft^2 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 *CISF* 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 *CISF*. 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 *CISF*, 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 *CISF*. New storage casks will be constructed on site at the WCS *CISF*. 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 *CISF* 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 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].

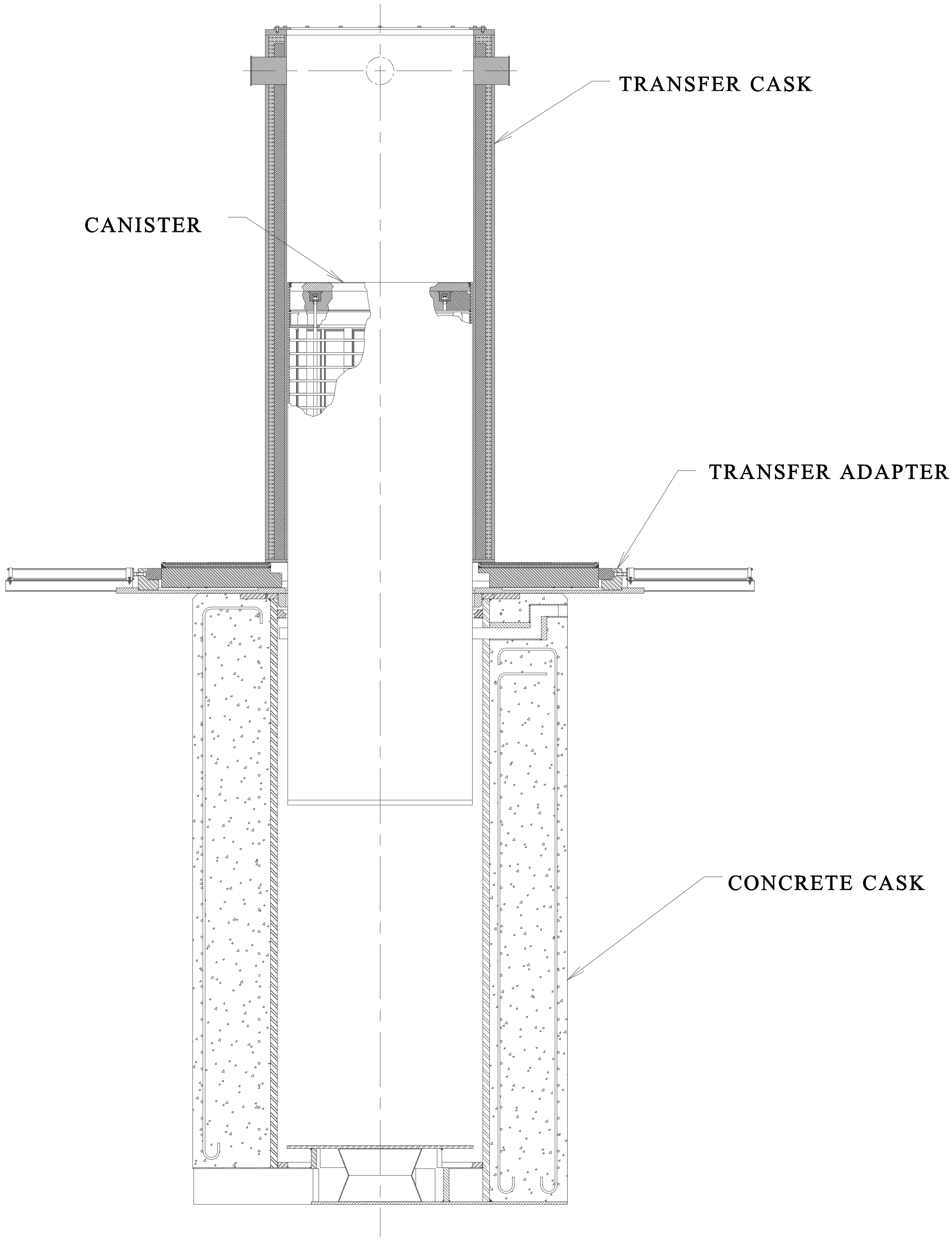

Figure F.4-1
Major Components of the NAC-UMS System

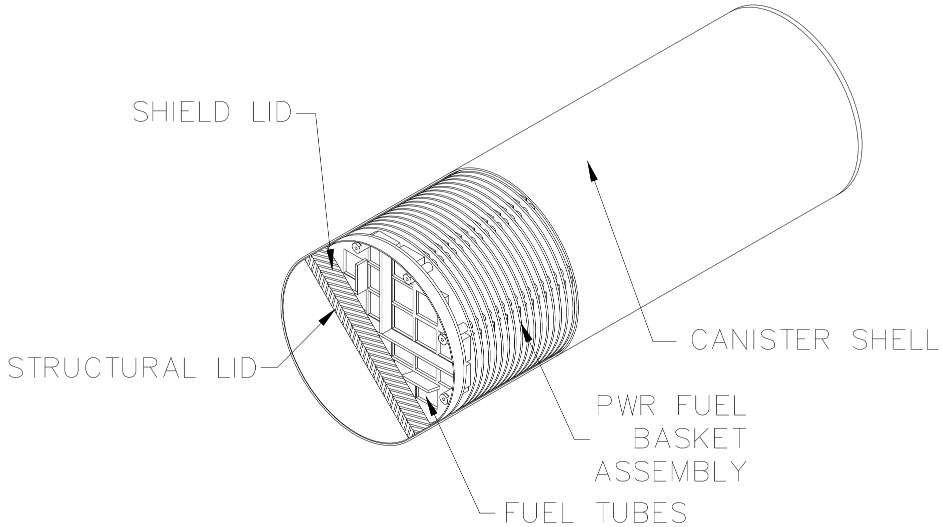

Figure F.4-2
NAC-UMS Transportable Storage Canister Containing PWR Spent Fuel Basket

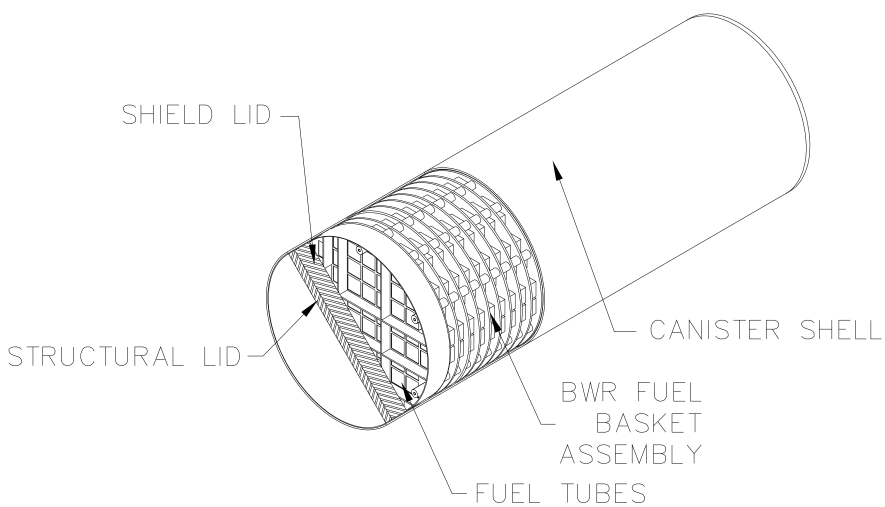

Figure F.4-3
NAC-UMS Transportable Storage Canister Containing BWR Spent Fuel Basket

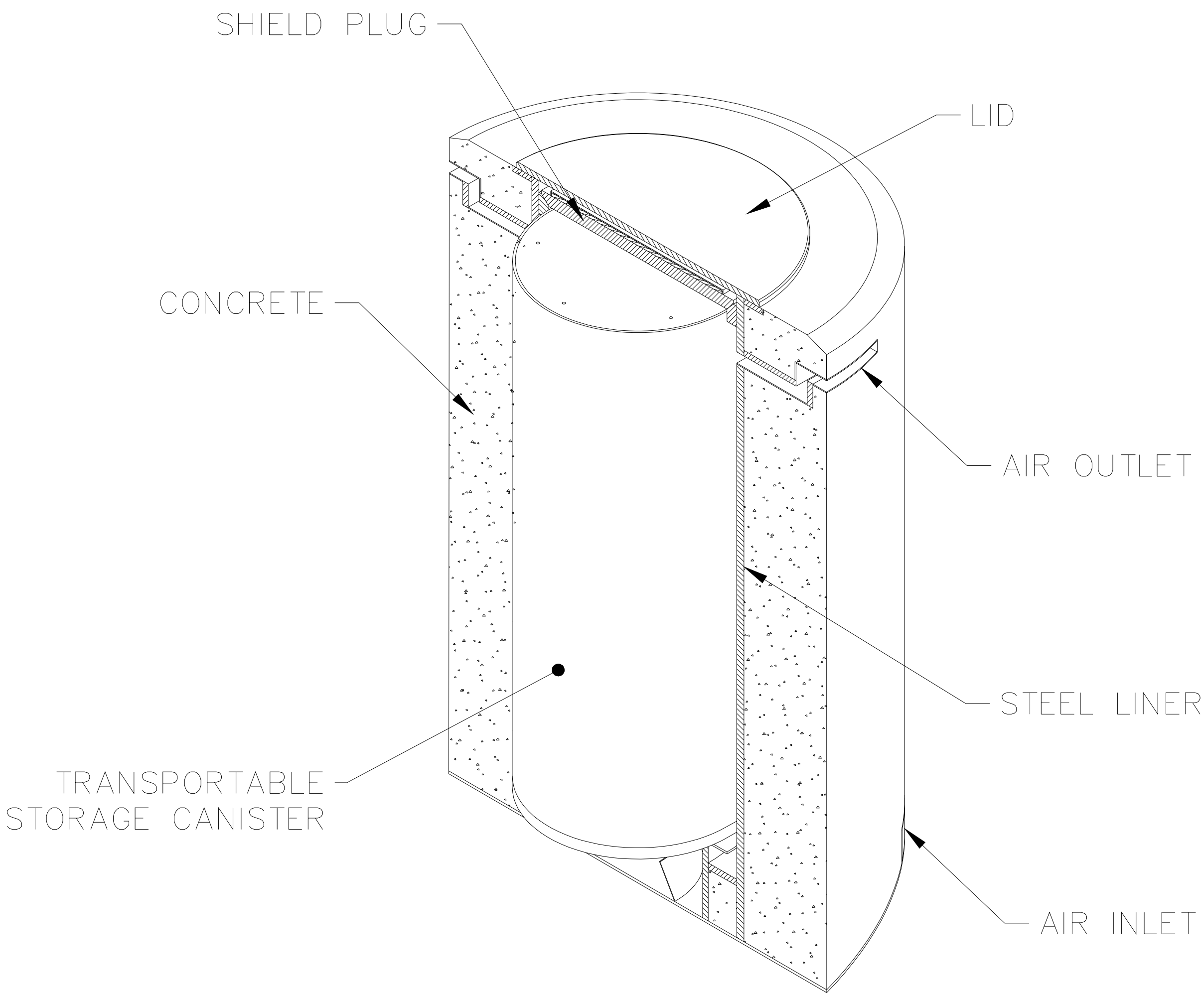

Figure F.4-4
NAC-UMS Vertical Concrete Cask

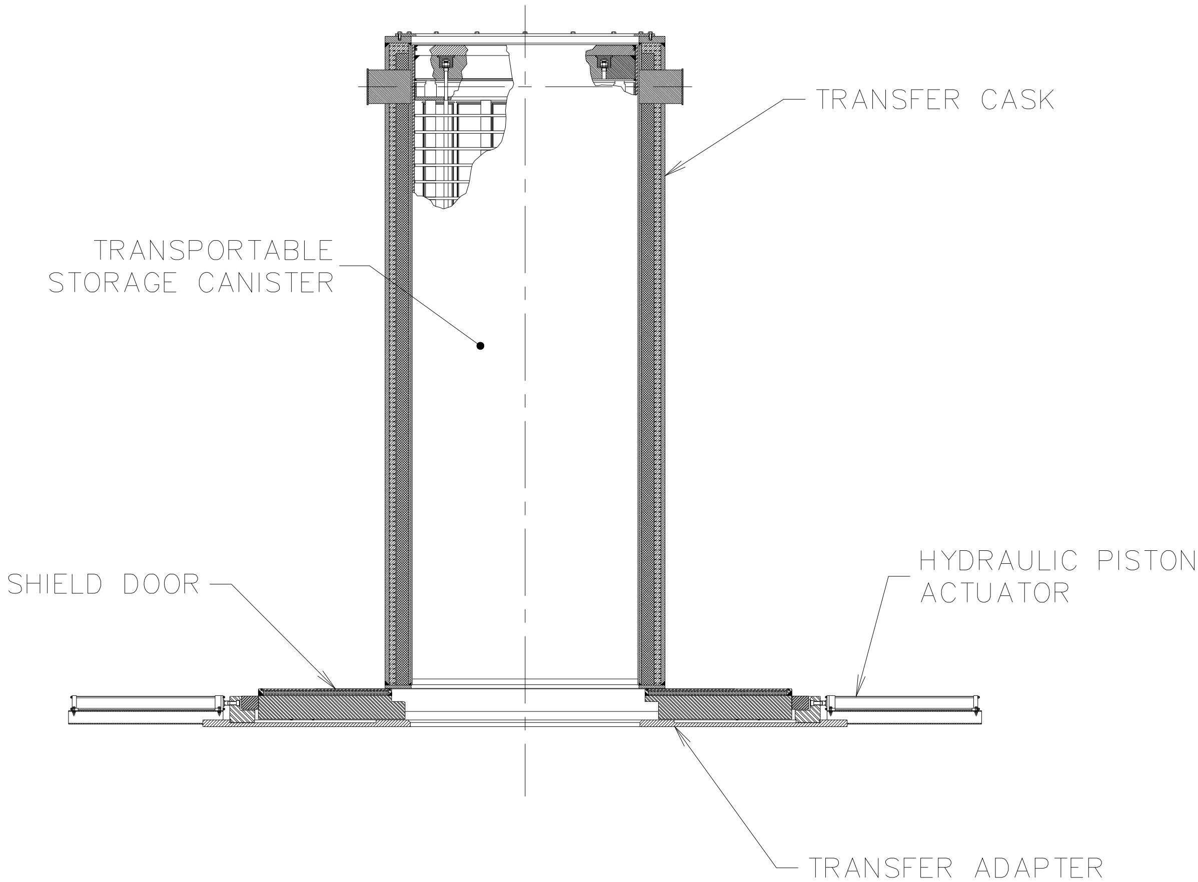

Figure F.4-5
NAC-UMS Transfer Cask

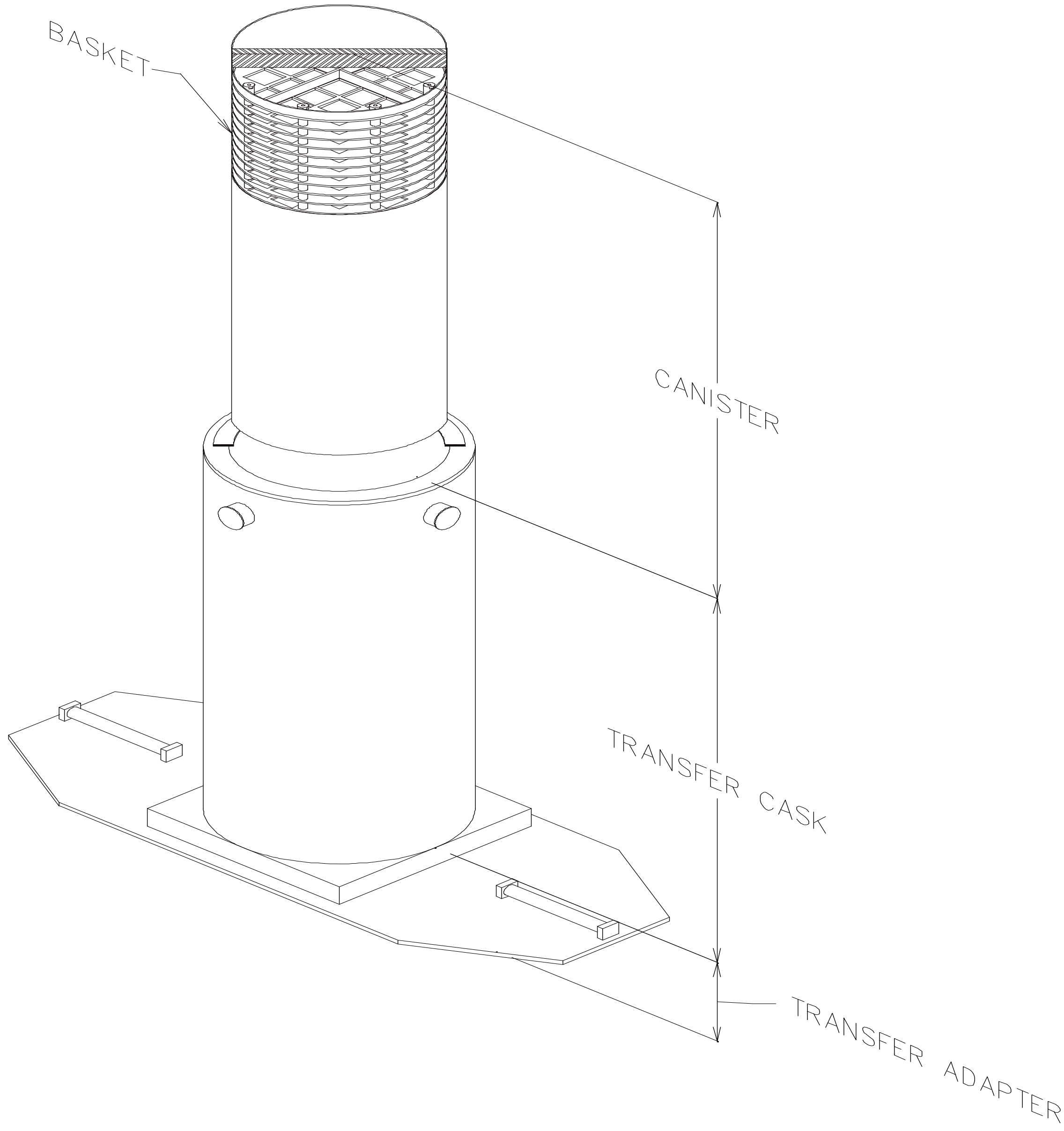

Figure F.4-6
NAC-UMS Transfer Cask and Canister Arrangement

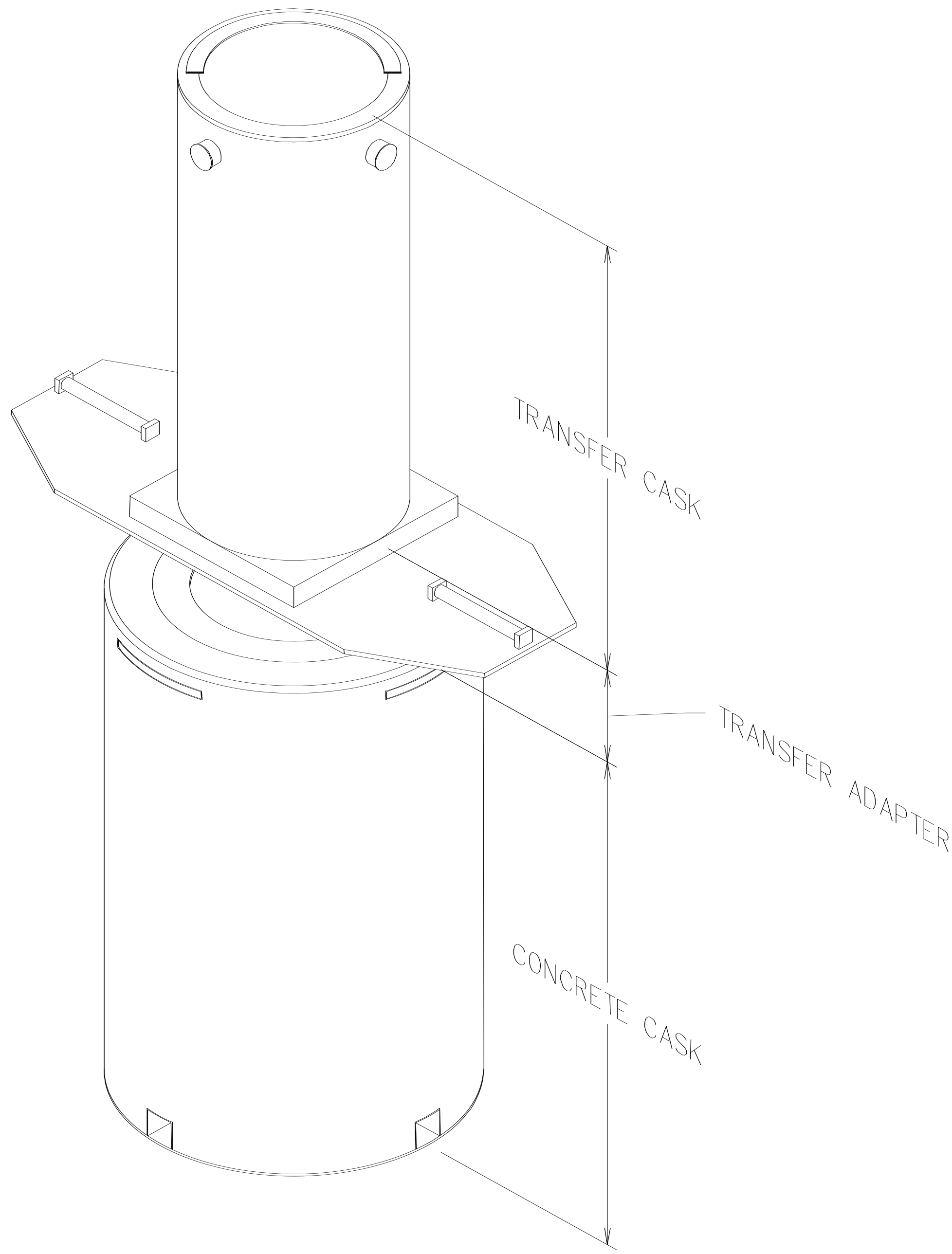

Figure F.4-7
NAC-UMS Vertical Concrete Cask and Transfer Cask Arrangement

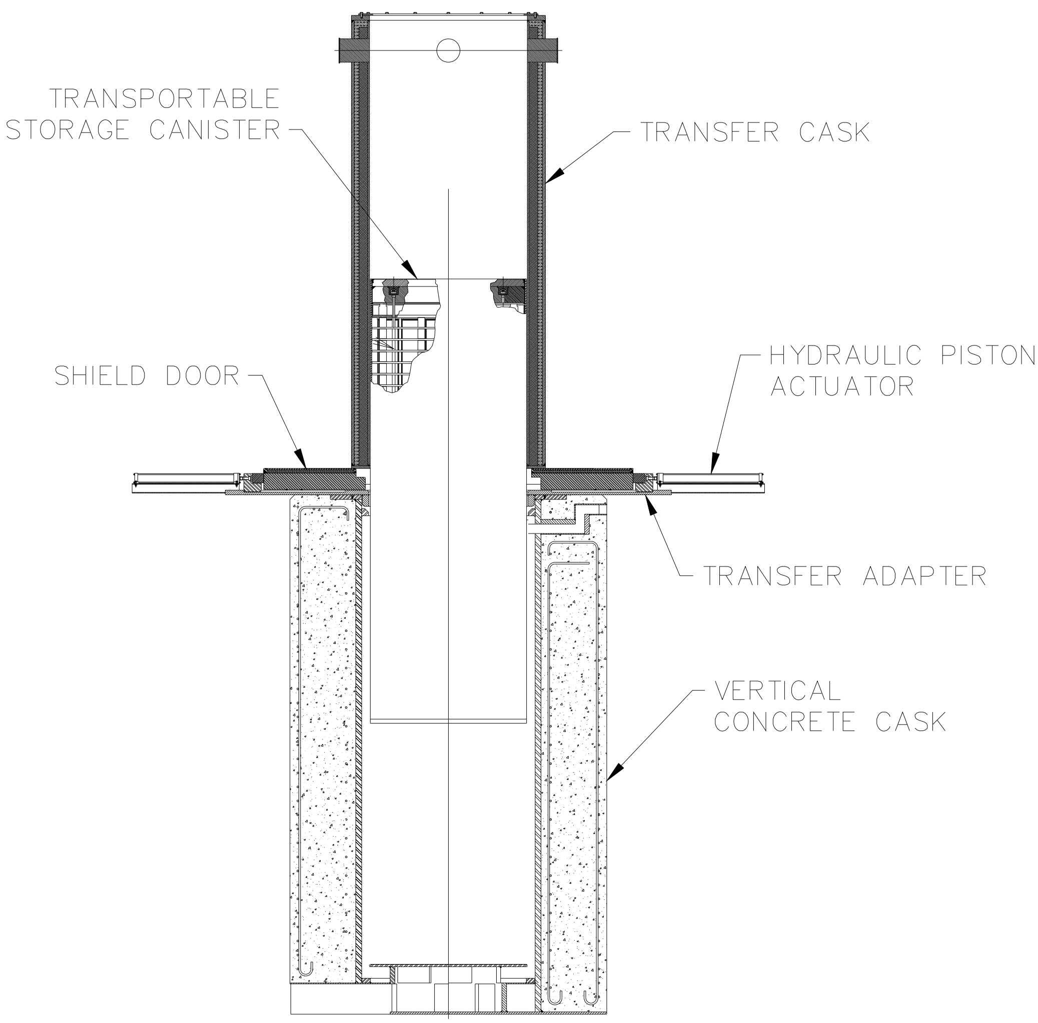

Figure F.4-8
NAC-UMS Major Component Configuration for Loading the Vertical Concrete Cask

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 *CISF*.

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

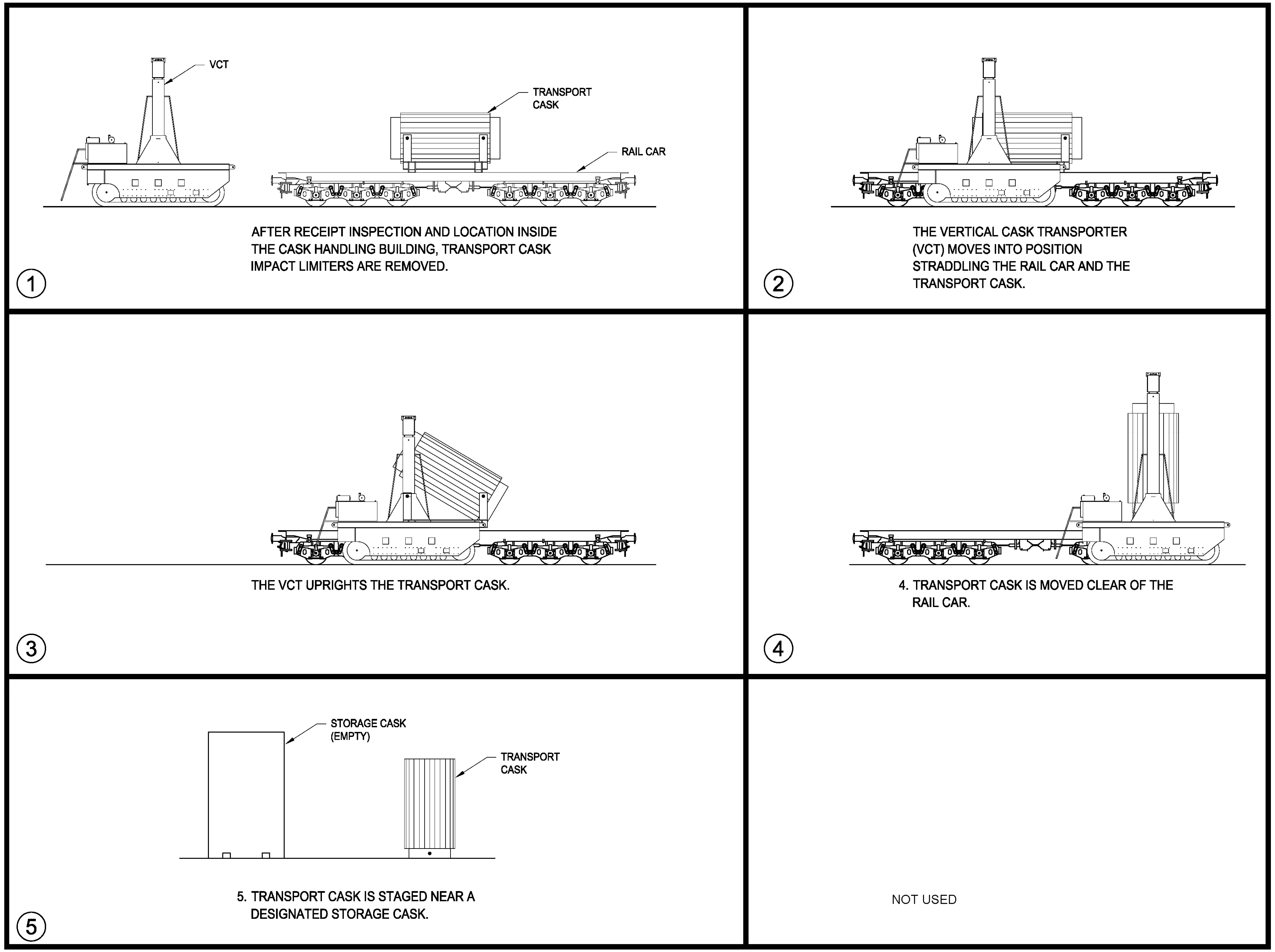

Figure F.5-1
Canister Transfer Operations
2 Pages

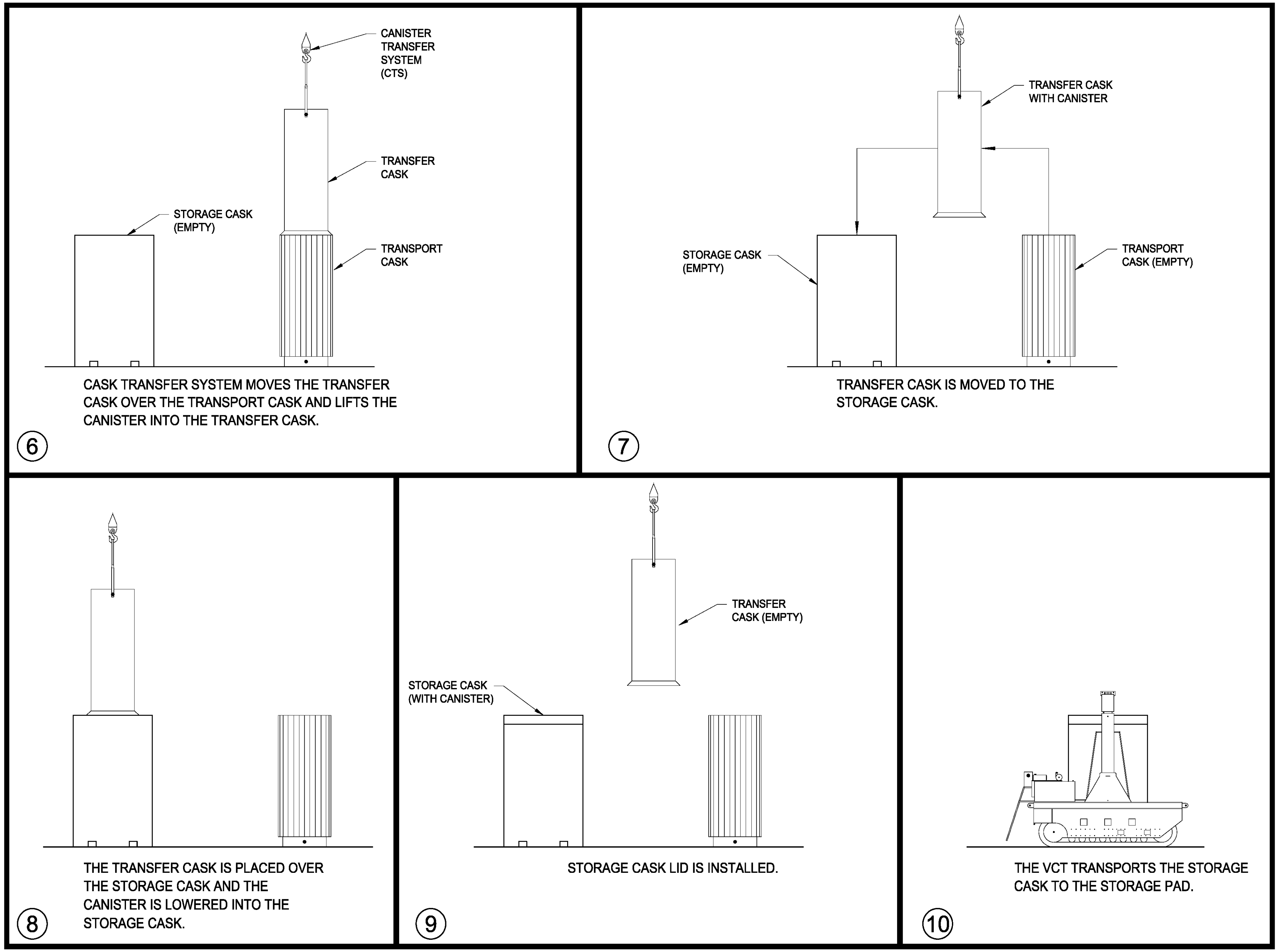

Figure F.5-1
Canister Transfer Operations
2 Pages

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 *CISF* 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 *CISF* 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 *CISF*. 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 *CISF*.

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 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 *CISF* 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 *CISF* 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. 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
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

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
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
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

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 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
Install the VCC Shield Plug.	2	0.5	Top of VCC	1	25	35	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 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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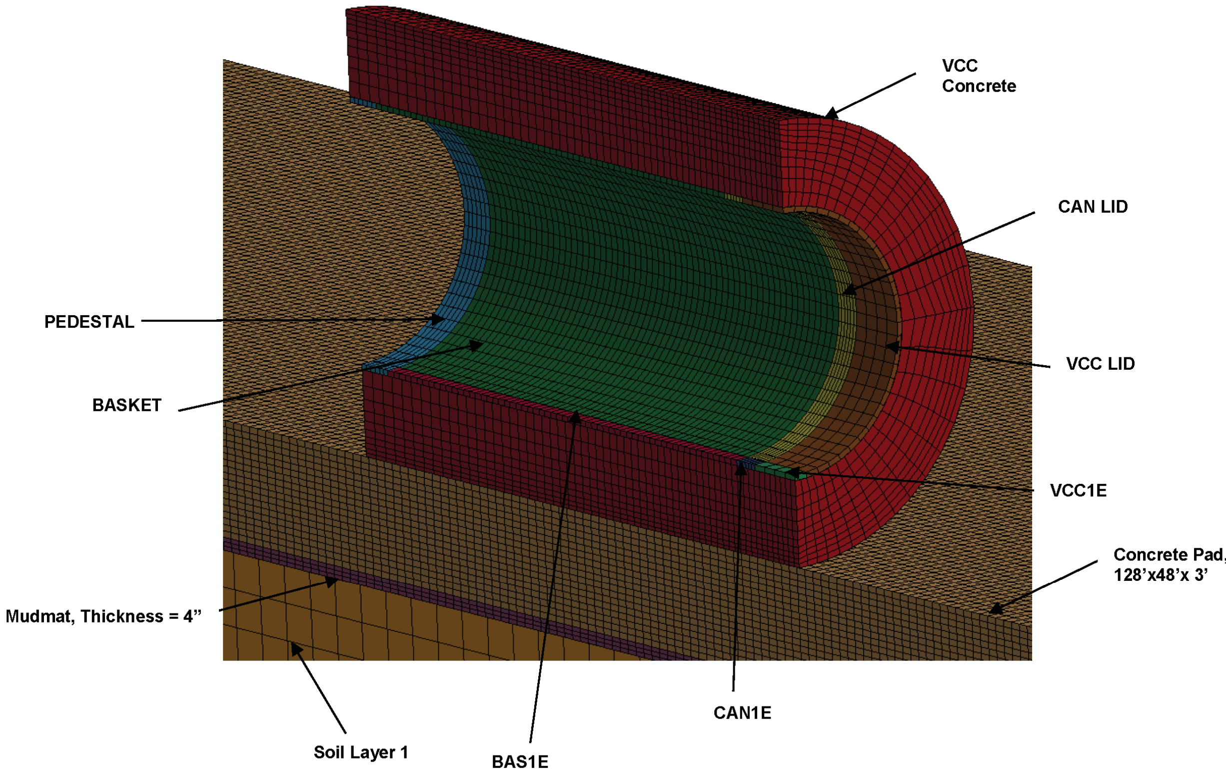

Figure F.12-2
CISF Configuration - Finite Element Model Set-Up (Continued)

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:

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:

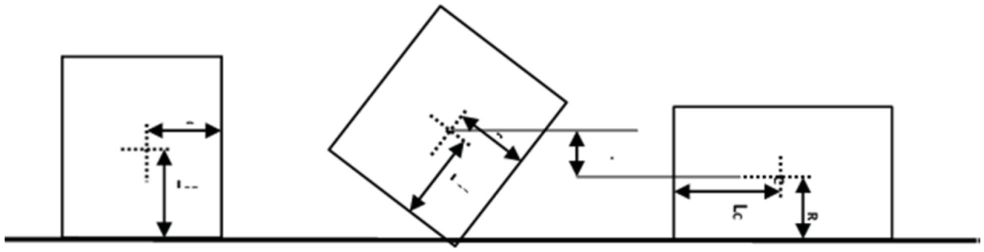

Figure F.12-3
Schematic Representation of the Change in Height of CG of VCC

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 ($lb\text{-}sec^2/in$)	
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.

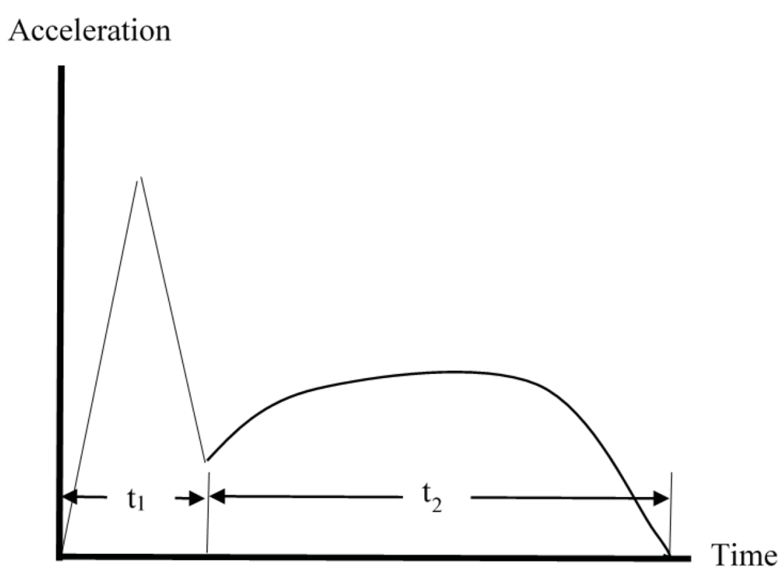

Figure F.12-4
Acceleration Time History

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.

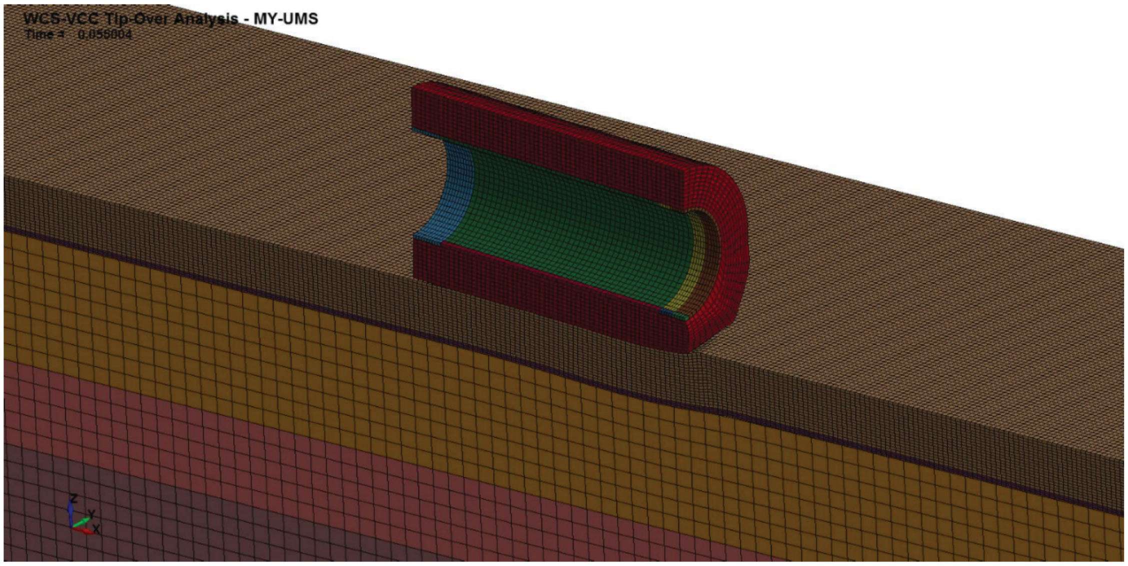

Figure F.12-5
Deformed Shape of UMS VCC, Concrete Pad, Mudmat and Soil

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