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

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E.1. INTRODUCTION AND GENERAL DESCRIPTION OF INSTALLATION

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

APPENDIX E.2
SITE CHARACTERISTICS
NAC-MPC

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E.2. SITE CHARACTERISTICS

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

APPENDIX E.3
PRINCIPAL DESIGN CRITERIA
NAC-MPC

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E.3 PRINCIPAL DESIGN CRITERIA

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

E.3.1 Yankee Rowe MPC and Connecticut Yankee MPC

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

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

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

E.3.1.1 Design Criteria for Environmental Conditions and Natural Phenomena

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

E.3.1.1.1 Tornado and Wind Loadings

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

E.3.1.1.2 Water Level (Flood) Design

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

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

E.3.1.1.3 Seismic Design

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

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

E.3.1.1.4 Snow and Ice Loadings

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

E.3.1.1.5 Combined Load Criteria

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

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

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

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

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

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

E.3.1.1.6 Environmental Temperatures

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

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

Therefore, the maximum average yearly temperature allowed for the NAC-MPC system is 75°F and the maximum 3-day average ambient temperature shall be ≤ 100°F. The allowed temperature extremes, average of a 3-day period, shall be greater than -40°F and less than 125°F. The WCS *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 75°F. This temperature meets the normal condition thermal boundary defined in NUREG-1536. Therefore, no further site-specific evaluations are required.

E.3.1.2 Safety Protection Systems

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

E.3.1.2.1 General

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

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

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

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

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

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

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

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

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

E.3.1.3 Decommission Considerations

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

E.3.2 La Crosse MPC

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

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

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

E.3.2.1 Design Criteria for Environmental Conditions and Natural Phenomena

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

E.3.2.1.1 Tornado and Wind Loadings

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

E.3.2.1.2 Water Level (Flood) Design

The water level (flood) design criteria that are defined in Section 2.2 of Reference E.3-1 for the NAC-MPC apply to the MPC-LACBWR system in their entirety. These design criteria are described in WCS *CISF* SAR Appendix E, Section E.3.1.1.2. As documented in Sections 2.4.2.2 and 3.2.2, the WCS CISF is not in a floodplain and is above the Probable Maximum Flood elevation and, therefore, will remain dry in the event of a flood.

E.3.2.1.3 Seismic Design

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

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

E.3.2.1.4 Snow and Ice Loadings

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

E.3.2.1.5 Combined Load Criteria

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

E.3.2.1.6 Environmental Temperatures

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

Therefore, the maximum average yearly temperature allowed for the NAC-MPC system is 75°F and the maximum 3-day average ambient temperature shall be ≤ 105°F. The allowed temperature extremes, average of a 3-day period, shall be greater than -40°F and less than 125°F. The WCS *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 75°F. This temperature meets the normal condition thermal boundary defined in NUREG-1536. Therefore, no further site-specific evaluations are required.

E.3.2.2 Safety Protection Systems

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

E.3.2.2.1 General

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

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

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

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

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

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

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

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

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

E.3.2.3 Decommissioning Considerations

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

E.3.3 References

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

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

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

Design Parameter	WCS CISF Design Criteria	Condition	NAC-MPC Design Criteria
Type of fuel	Commercial, light water reactor spent fuel	Normal (Bounded)	NAC-MPC FSAR Section 2.1
Storage Systems	Transportable canisters and storage overpacks docketed by the NRC	Normal (Bounded)	72-1025 71-9235
Fuel Characteristics	Criteria as specified in previously approved licenses for included systems	Normal (Bounded)	NAC-MPC FSAR Section 2.1
Tornado (Wind Load)	Max translational speed: 40 mph Max rotational speed: 160 mph Max tornado wind speed: 200 mph Radius of max rotational speed: 150 ft Tornado pressure drop: 0.9 psi Rate of pressure drop: 0.4 psi/sec	Accident (Bounded)	**NAC-MPC FSAR Section 2.2.1.1** Max translational speed: 70 mph Max rotational speed: 290 mph Max tornado wind speed: 360 mph Radius of max rotational speed: 150 ft Tornado pressure drop: 3.0 psi Rate of pressure drop: 2.0 psi/sec
Tornado (Missile)	Automobile: 4000 lb, 112 ft/s (76.4 mph) Schedule 40 Pipe: 287 lb, 112 ft/s (76.4 mph) Solid Steel Sphere: 0.147 lb, 23 ft/s (15.7 mph)	Accident (Bounded)	**NAC-MPC FSAR Section 2.2.1.3** Massive Missile: 3960 lb, 126 mph Rigid hardened steel: 275 lb, 126 mph Solid Steel Sphere: 0.15 lb, 126 mph
Floods	The WCS CISF is not in a floodplain and is above the Probable Maximum Flood elevation and will remain dry in the event of a flood.	Accident (Bounded)	**NAC-MPC FSAR Section 2.2.2.1** Flood height: 50 ft Water velocity: 15 ft/s

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

Design Parameter	WCS CISF Design Criteria	Condition	NAC-MPC Design Criteria
Seismic (Ground Motion)	Site-specific ground-surface uniform hazard response spectra (UHRS) with 1E-4 annual frequency of exceedance (AFE) having peak ground acceleration (PGA) of 0.250 g horizontal and 0.175 g vertical. (Table 1-5 and Figure 1-5)	Accident (Bounded)	**NAC-MPC FSAR Section 2.2.3.1** Yankee-MPC and CY-MPC are designed to 0.25 g horizontal and 0.167 g vertical **NAC-MPC FSAR Section 2.A.2.1.1** MPC-LACBWR is designed to 0.45 g horizontal and 0.3 g vertical **NAC-MPC CoC, Technical Specification B 3.4, Section 3.c)** Alternatively, the design basis earthquake motion of the ISFSI pad maybe limited so that the acceleration g-load resulting from the collision of the two sliding casks remains bounded by the accident condition analyses presented in Chapter 11 of the NAC-MPC FSAR.
Vent Blockage	For MPC Systems: Inlet and outlet vents blocked 24 hrs	Accident (Same)	**Yankee-MPC, NAC-MPC FSAR Section 11.2.8.4** **CY-MPC, NAC-MPC FSAR Section 11.2.8.4** **MPC-LACBWR, NAC-MPC FSAR Section 11.2.8.4** Inlet and outlet vents blocked: 24 hrs
Fire/Explosion	For MPC Systems: Equivalent fire 50 gallons of diesel fuel	Accident (Same)	**NAC-MPC FSAR Section 11.2.5** Equivalent fire 50 gallons of diesel fuel
Cask Drop	For MPC Systems: Drop height 6 inches	Accident (Same)	**NAC-MPC FSAR Section 11.2.11.2** **(MPC-LACBWR) NAC-MPC FSAR Section 11.A.2.11.2** Drop height 6 inches
Ambient Temperatures	Yearly average temperature 67.1°F	Normal (Bounded)	**NAC-MPC FSAR Section 2.2.6** Average Annual Ambient Temperature 75°F
Off-Normal Temperature	Minimum 3 day avg. temperature 27.9°F Maximum 3 day avg. temperature 89.4°F	Off-Normal (Bounded)	**NAC-MPC FSAR Section 2.2.6** Minimum 3 day avg. temperature -40°F Maximum 3 day avg. temperature 100°F

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

Design Parameter	WCS CISF Design Criteria	Condition	NAC-MPC Design Criteria
Extreme Temperature	Maximum temperature 113°F	Accident (Bounded)	**NAC-MPC FSAR Section 2.2.6** Maximum temperature 125°F
Solar Load (Insolation)	Horizontal flat surface insolation 2949.4 BTU/day-ft^2 Curved surface solar insolation 1474.7 BTU/day-ft^2	Normal (Same)	**Yankee-MPC, NAC-MPC FSAR Section 4.4.1.1.2** **CY-MPC, NAC-MPC FSAR Section 4.5.1.1** **MPC-LACBWR, NAC-MPC FSAR Section 4.A.3.1.1** Curved Surface: 1475 Btu/ft^2 for a 24-hour period. Flat Horizontal Surface: 2950 Btu/ft^2 for a 24-hour period.
Snow and Ice	Snow Load 10 psf	Normal (Bounded)	**NAC-MPC FSAR Section 2.2.4** 100 psf
Dead Weight	Per design basis for systems listed in Table 1-1	Normal (Same)	Yankee-MPC Canister – NAC-MPC FSAR Section 3.4.4.1.2 Yankee-MPC Storage Cask – NAC-MPC FSAR Section 3.4.4.2.1 CY-MPC Canister – NAC-MPC FSAR Section 3.4.4.3.2 CY-MPC Storage Cask – NAC-MPC FSAR Section 3.4.4.4.1 MPC-LACBWR Concrete Cask – NAC-MPC FSAR Section 3.A.4.4.3.1 MPC-LACBWR Canister – NAC-MPC FSAR Section 3.A.4.4.1.2
Internal and External Pressure Loads	Per design basis for systems listed in Table 1-1	Normal (Same)	Yankee-MPC Canister – NAC-MPC FSAR Section 3.4.4.1.3 CY-MPC Canister – NAC-MPC FSAR Section 3.4.4.3.2 MPC-LACBWR Canister – NAC-MPC FSAR Section 3.A.4.4.1.3
Design Basis Thermal Loads	Per design basis for systems listed in Table 1-1	Normal (Same)	Yankee-MPC – NAC-MPC FSAR Section 4.4 CY-MPC – NAC-MPC FSAR Section 4.5 MPC-LACBWR – NAC-MPC FSAR Section 4.A

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

Design Parameter	WCS CISF Design Criteria	Condition	NAC-MPC Design Criteria
Operating Loads	Per design basis for systems listed in Table 1-1	Normal (Same)	NAC-MPC – NAC-MPC FSAR Section 3.4.4 (Yankee-MPC and CY-MPC) MPC-LACBWR – NAC-MPC FSAR Section 3.A.4.4
Live Loads	Per design basis for systems listed in Table 1-1	Normal (Same)	Yankee-MPC Storage Cask – NAC-MPC FSAR Section 3.4.4.2.2 CY-MPC Storage Cask – NAC-MPC FSAR Section 3.4.4.4.2 MPC-LACBWR Concrete Cask – NAC-MPC FSAR Section 3.A.4.4.3.2
Radiological Protection	Public wholebody ≤ 5 Rem Public deep dose plus individual organ or tissue ≤ 50 Rem Public shallow dose to skin or extremities ≤ 50 mrem Public lens of eye ≤ 15 mrem	Accident (Same)	**NAC-MPC FSAR Section 10.2.2** Public wholebody, organ or skin ≤ 5 Rem
Radiological Protection	Public wholebody ≤ 25 mrem/yr(1) Public thyroid ≤ 75 mrem/yr(1) Public critical organ ≤ 25 mrem/yr(1)	Normal (Same)	**NAC-MPC FSAR Section 10.4** Exposure to the Public ≤ 25 mrem/yr
Confinement	Per design basis for systems listed in Table 1-1	N/A	NAC-MPC FSAR Chapter 7 Leaktight
Nuclear Criticality	Per design basis for systems listed in Table 1-1	N/A	NAC-MPC FSAR Chapter 6 K_{eff}<.95
Decommissioning	Minimize potential contamination	Normal (Same)	**Yankee-MPC – NAC-MPC FSAR Section 2.4** **CY-MPC – NAC-MPC FSAR Section 2.4** **MPC-LACBWR – NAC-MPC FSAR Section 2.A.4** Minimize potential contamination

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

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

Note

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

APPENDIX E.4
OPERATING SYSTEMS
NAC-MPC

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E.4 OPERATING SYSTEMS

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

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

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

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

E.4.1 Yankee Rowe MPC and Connecticut Yankee MPC

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

E.4.1.1 Transportable Storage Canister and Baskets

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

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

E.4.1.2 Vertical Concrete Cask

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

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

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

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

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

Existing Yankee-MPC and CY-MPC storage casks will not be used at the WCS *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 concrete portion of the storage cask is constructed by placing concrete between a reusable, exterior form and the inner metal liner. Reinforcing bars are placed near the inner and outer concrete surfaces to provide structural integrity. The inner liner and base of the storage cask are shop fabricated. An optional supplemental shielding fixture may be installed in the air inlets of the Yankee-MPC to reduce the radiation dose rate at the base of the cask. The principal fabrication specifications for the storage cask are shown in Table E.4-2.

E.4.1.3 Transfer Cask

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

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

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

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

E.4.1.4 Ancillary Equipment

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

E.4.1.4.1 Adapter Plate

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

E.4.1.4.2 Vertical Cask Transporter

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

E.4.1.4.3 Rigging and Slings

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

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

E.4.1.4.4 Temperature Instrumentation

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

E.4.1.5 Storage Pad

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

E.4.2 La Crosse MPC

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

E.4.2.1 Transportable Storage Canister and Baskets

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

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

E.4.2.2 Vertical Concrete Cask

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

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

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

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

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

Existing MPC-LACBWR storage casks will not be used at the WCS *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 concrete portion of the storage cask is constructed by placing concrete between a reusable, exterior form and the inner metal liner. Reinforcing bars are placed near the inner and outer concrete surfaces to provide structural integrity. The inner liner and base of the storage cask are shop fabricated. Radiation shielding is installed in the air inlets to reduce the radiation dose rates local to the air inlets at the base of the cask. The principal fabrication specifications for the storage cask are shown in Table E.4-2.

E.4.2.3 Transfer Cask

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

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

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

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

E.4.2.4 Ancillary Equipment

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

E.4.2.4.1 Adapter Plate

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

E.4.2.4.2 Vertical Cask Transporter

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

E.4.2.4.3 Rigging and Slings

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

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

E.4.2.4.4 Temperature Instrumentation

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

E.4.2.5 Storage Pad

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

E.4.3 References

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

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

E.4.4 Supplemental Data

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

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

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

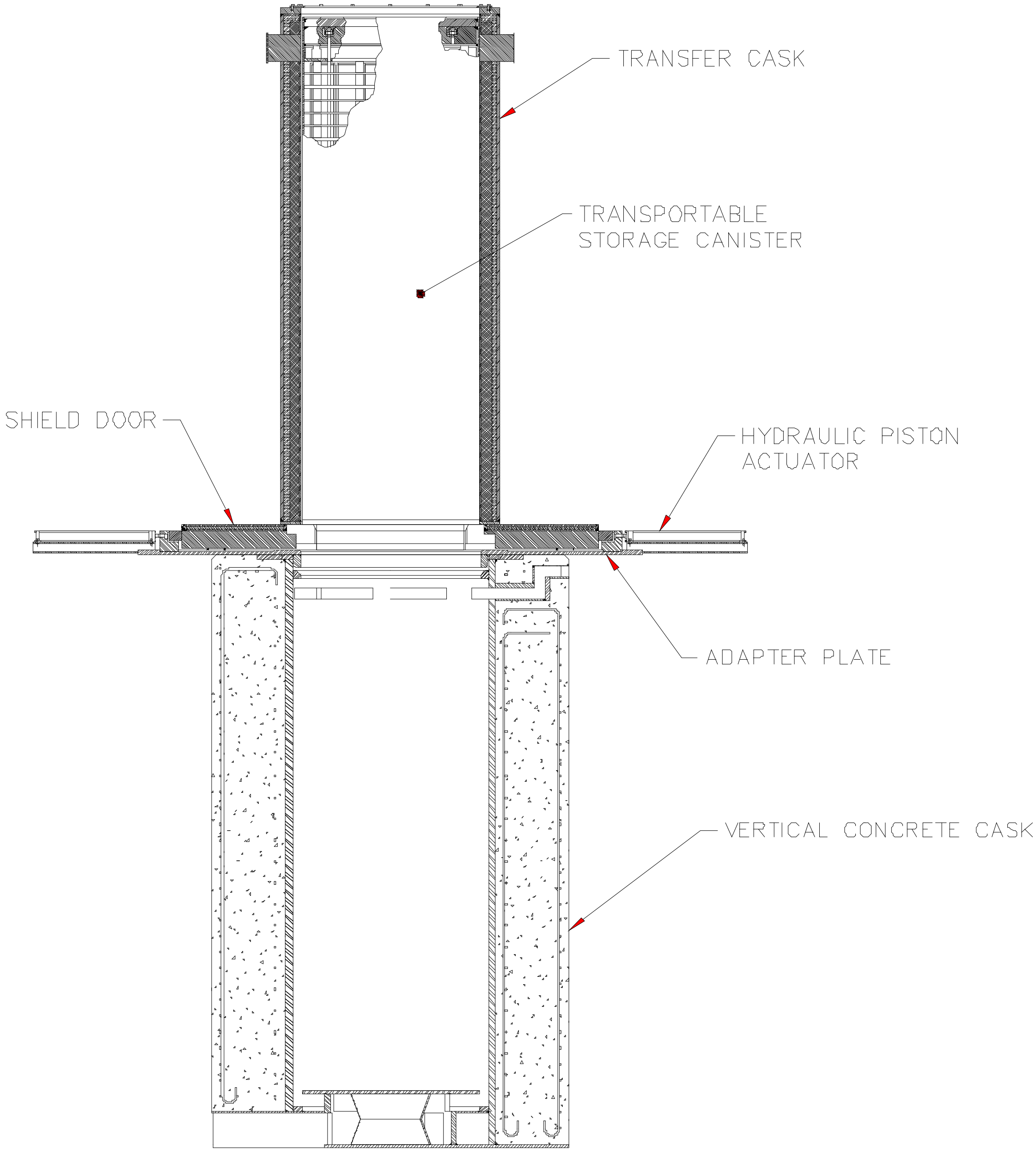

Figure E.4-1
Major Components of the NAC-MPC System

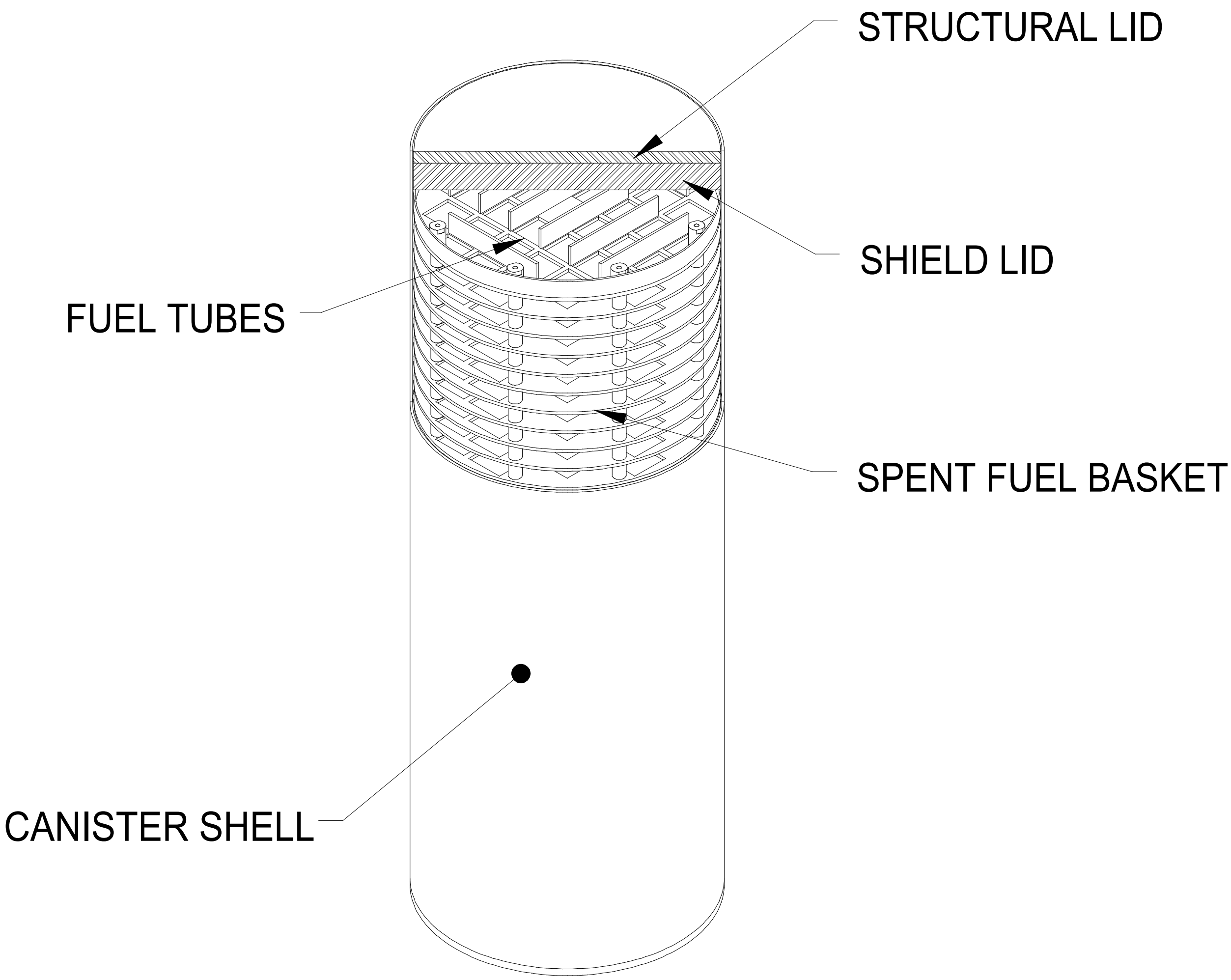

Figure E.4-2
NAC-MPC Transportable Storage Canister Showing the Spent Fuel Basket

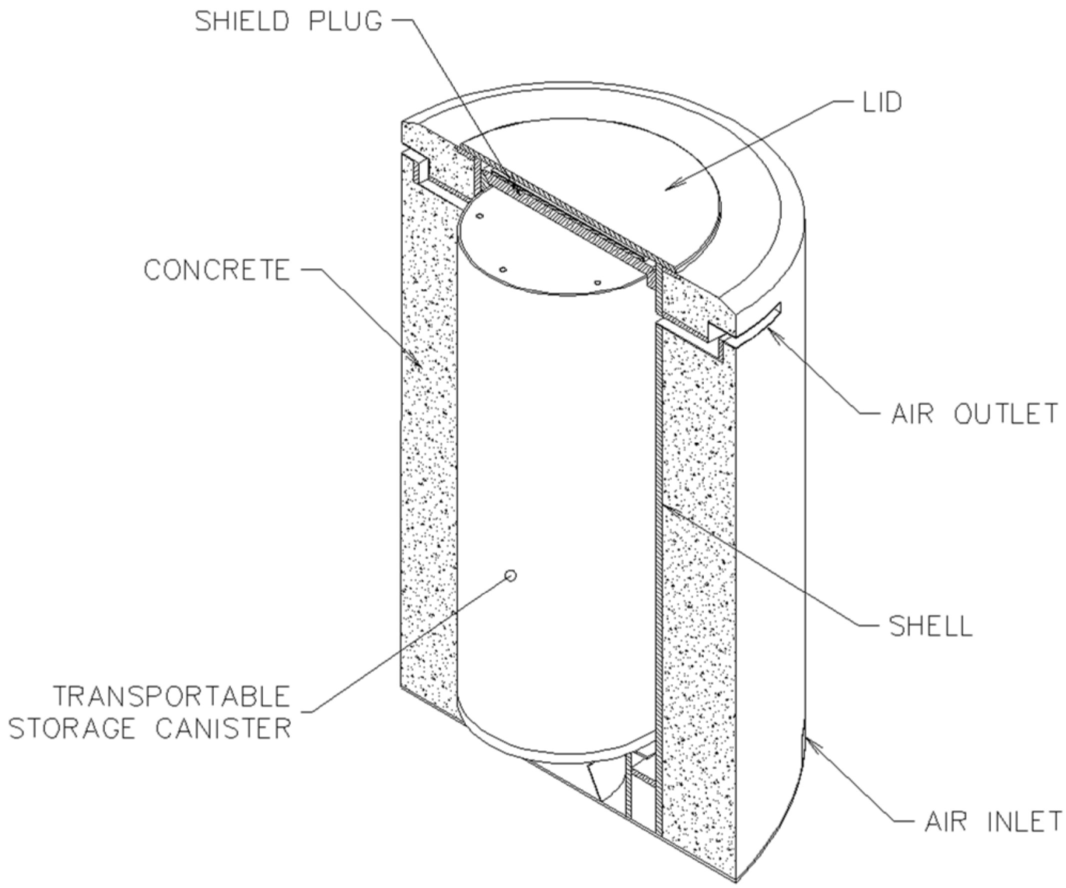

Figure E.4-3
NAC-MPC Vertical Concrete Storage Cask

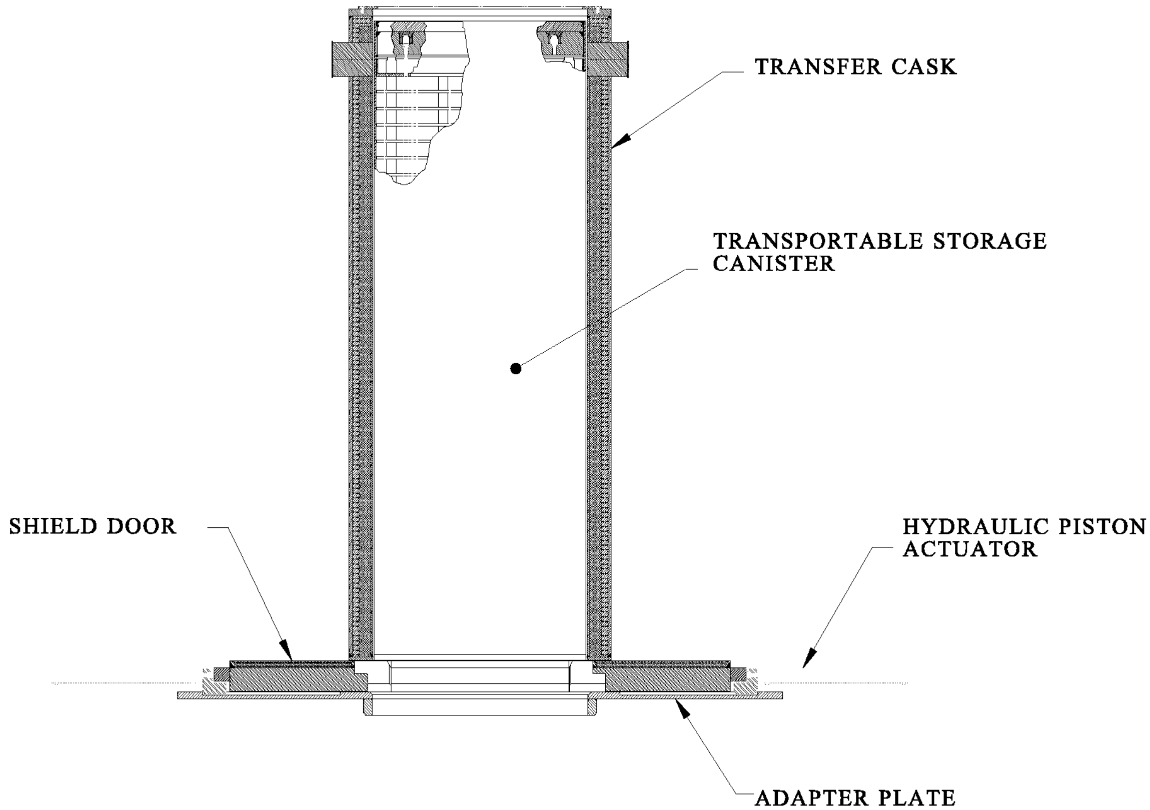

Figure E.4-4
NAC-MPC Transfer Cask

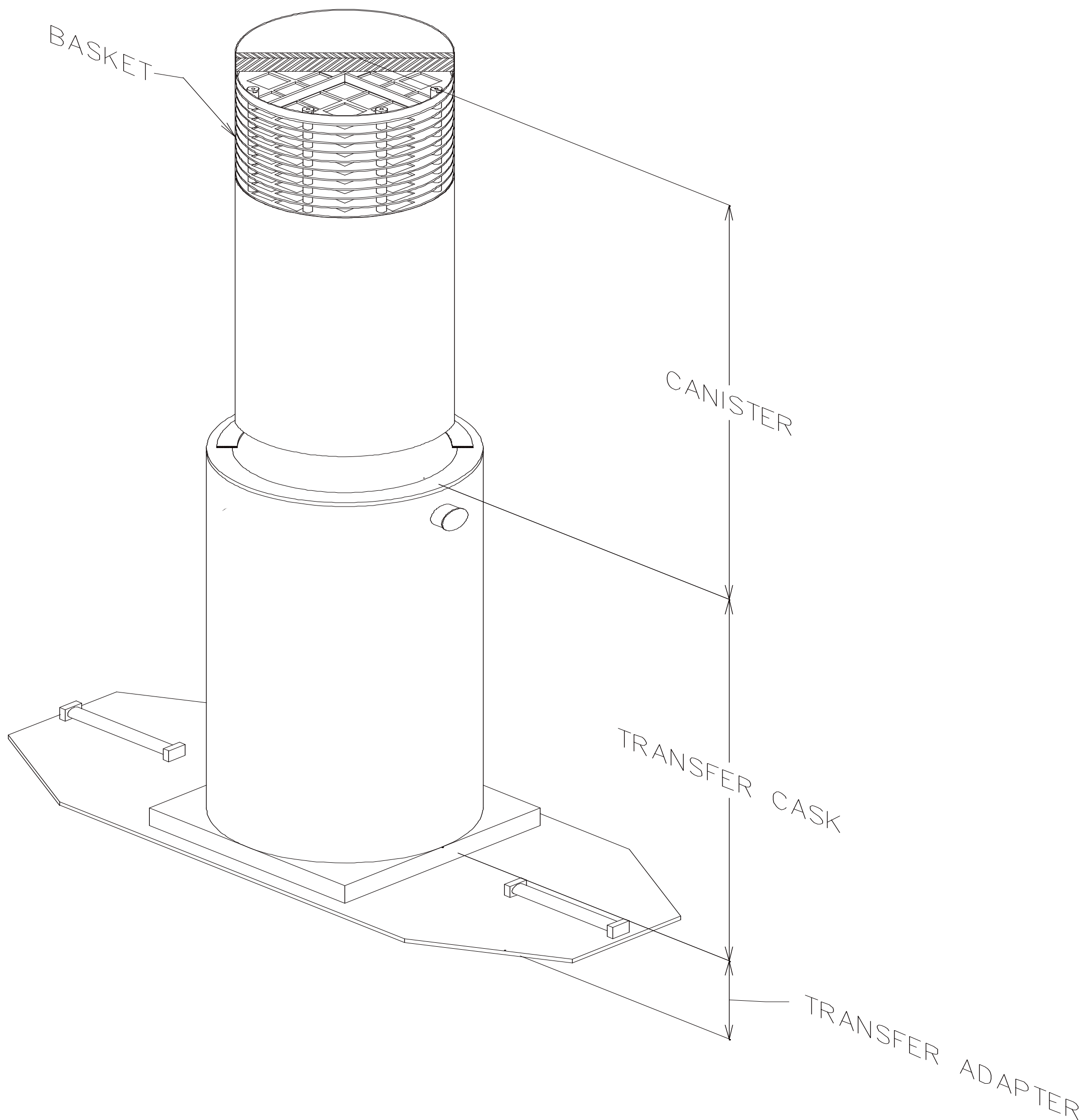

Figure E.4-5
NAC-MPC Transfer Cask and Canister Arrangement

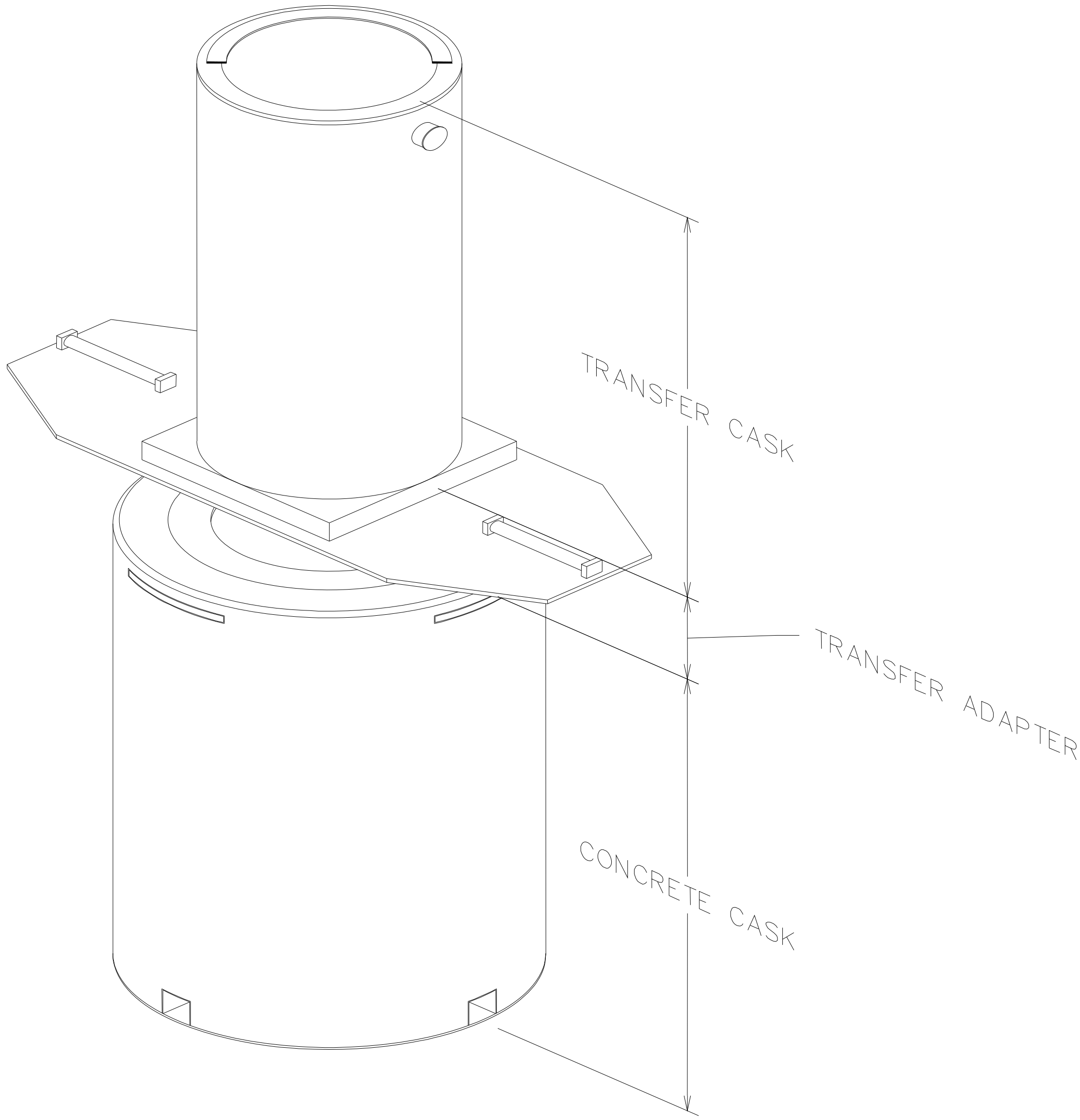

Figure E.4-6
NAC-MPC Vertical Concrete Cask and Transfer Cask Arrangement

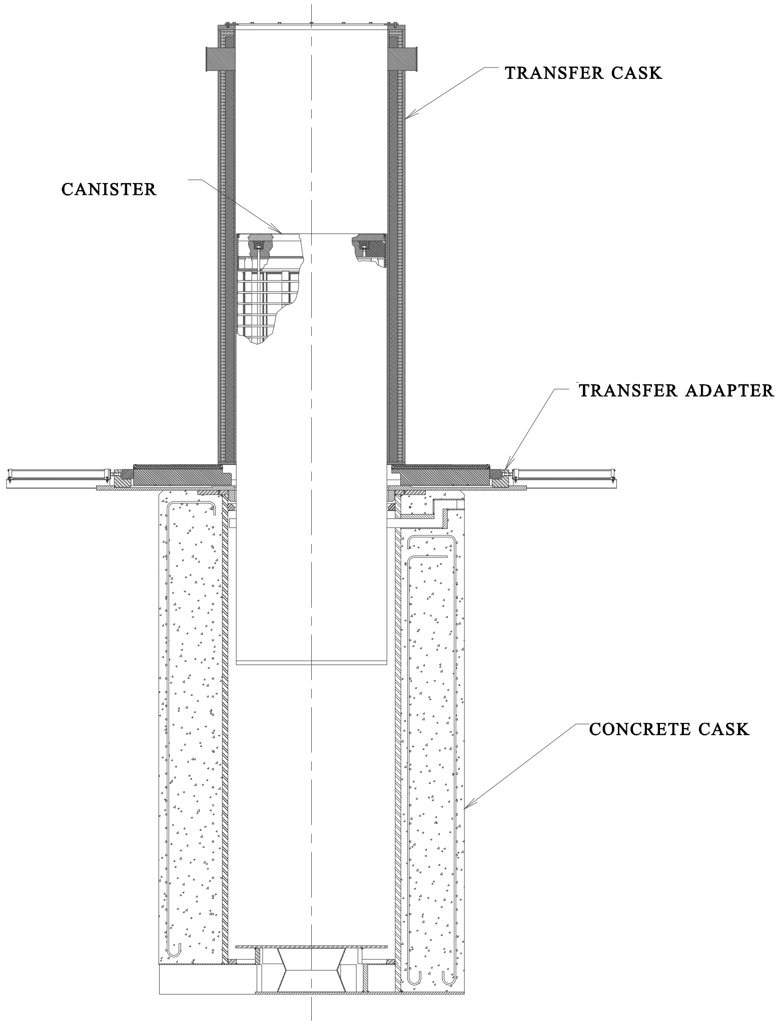

Figure E.4-7
NAC-MPC Major Component Configuration for Loading the Vertical Concrete Cask

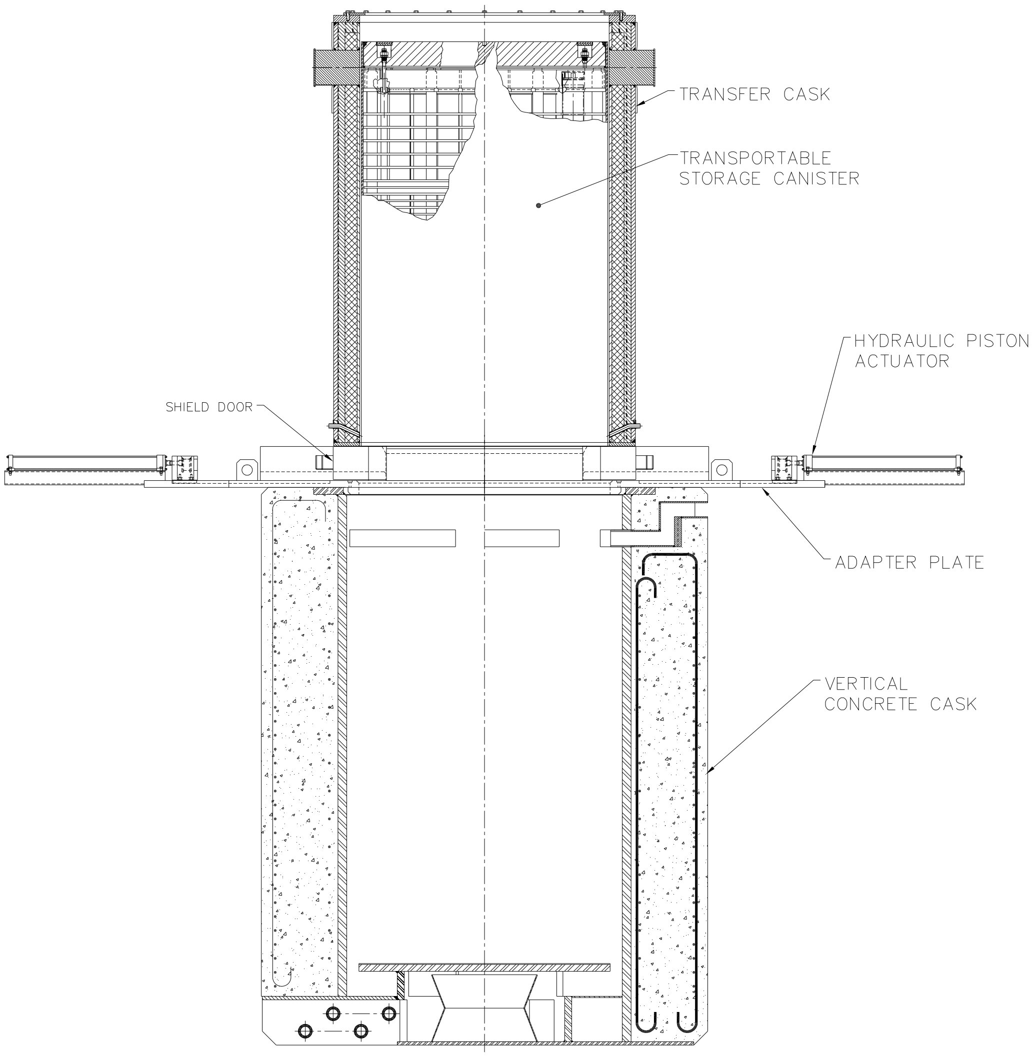

Figure E.4-8
MPC-LACBWR Major Components of the NAC-MPC System

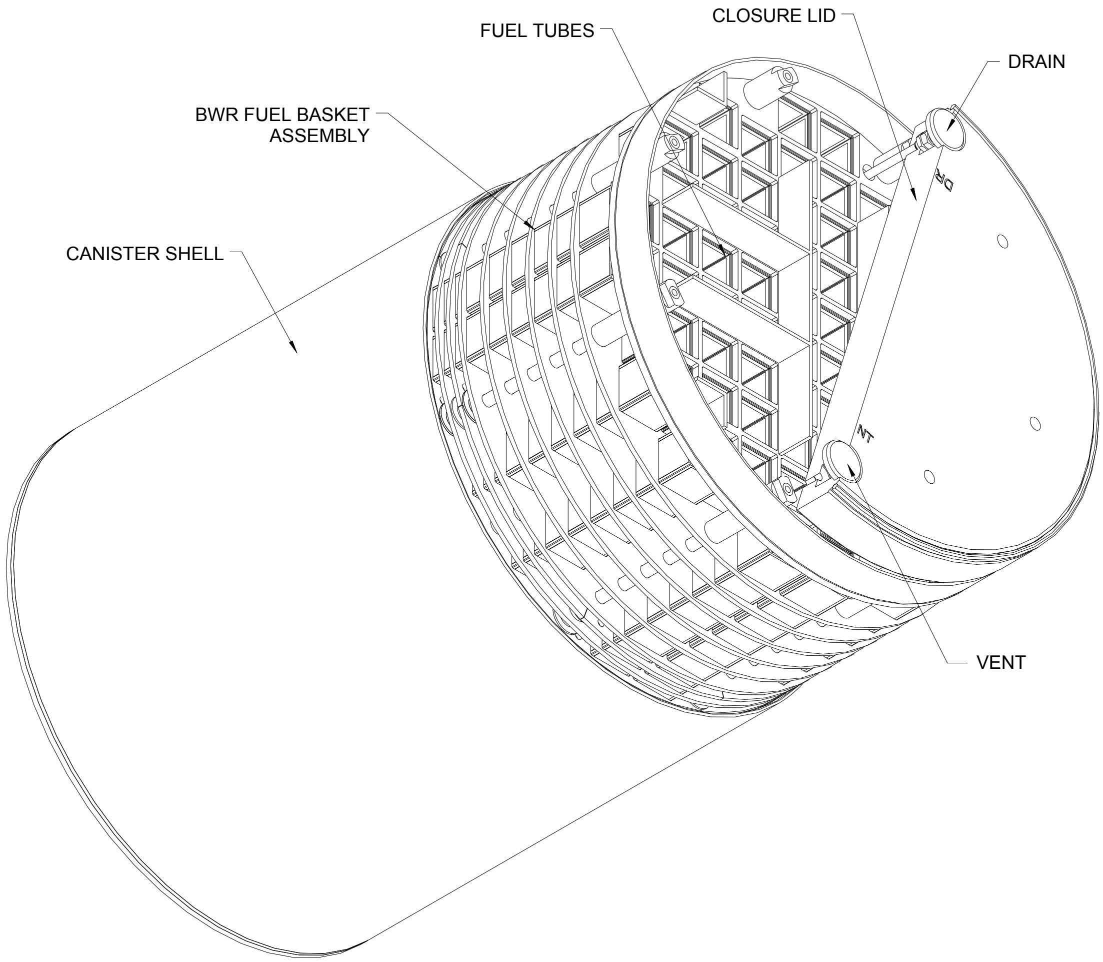

Figure E.4-9
MPC-LACBWR Transportable Storage Canister Showing the Spent Fuel Basket

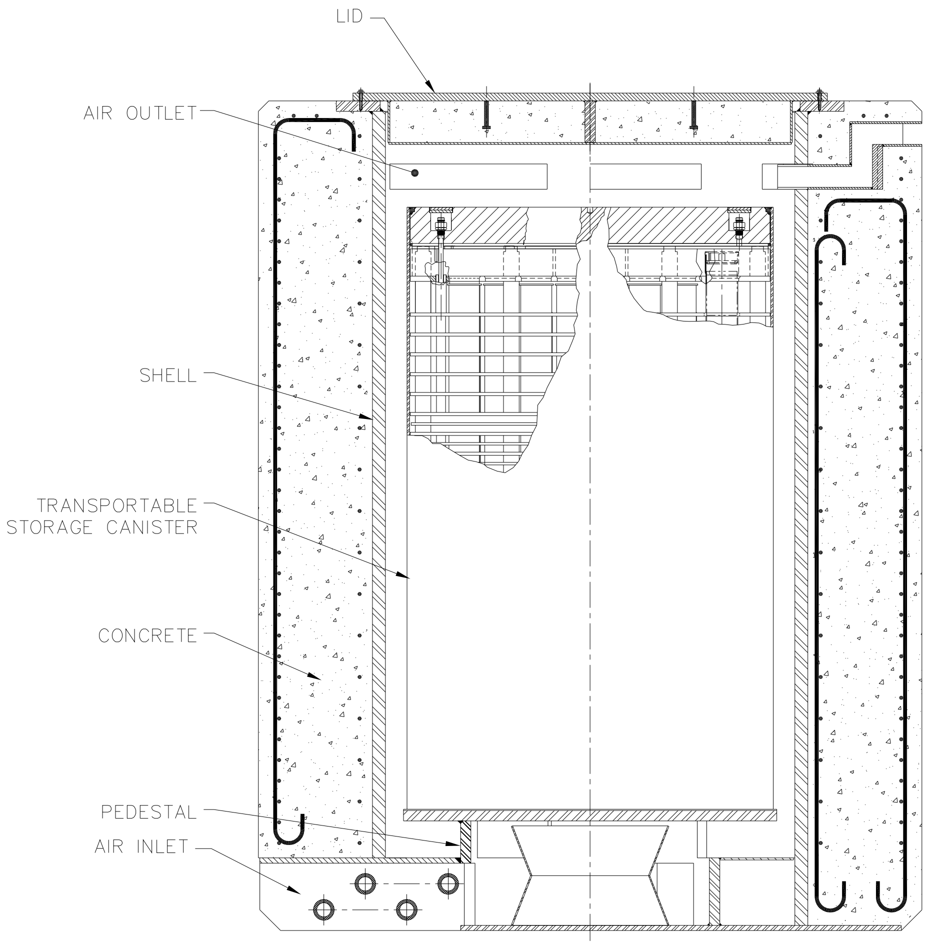

Figure E.4-10
MPC-LACBWR Vertical Concrete Storage Cask

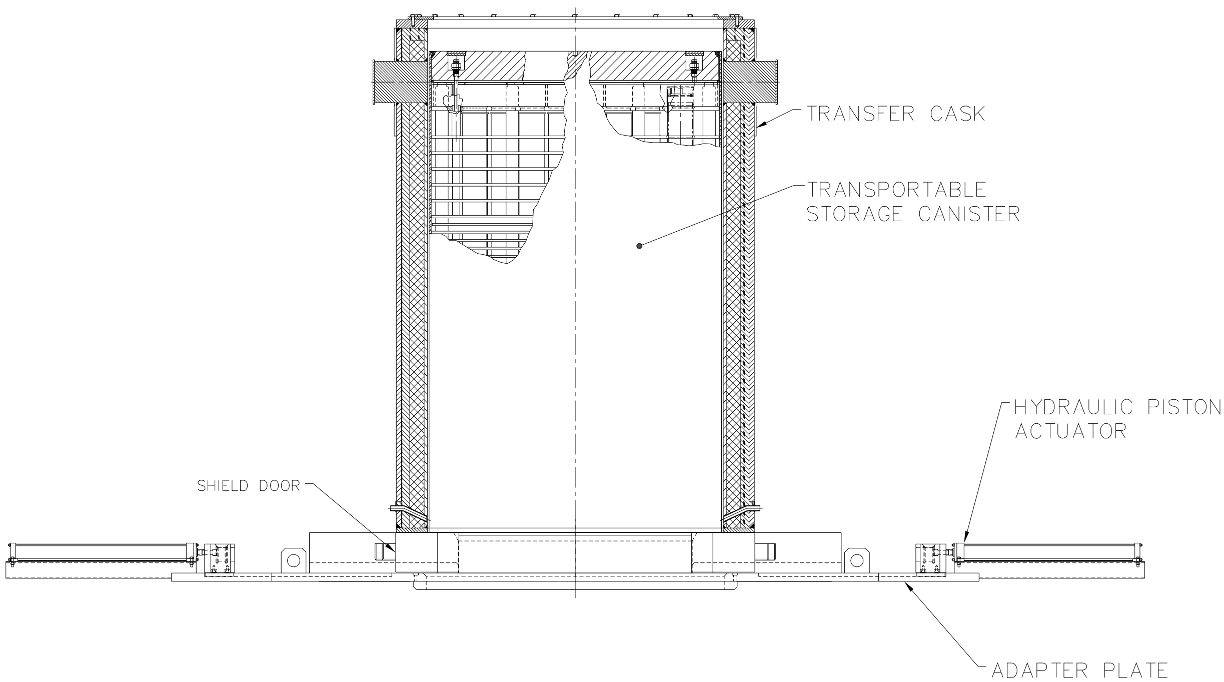

Figure E.4-11
MPC-LACBWR Transfer Cask With Adapter Plate

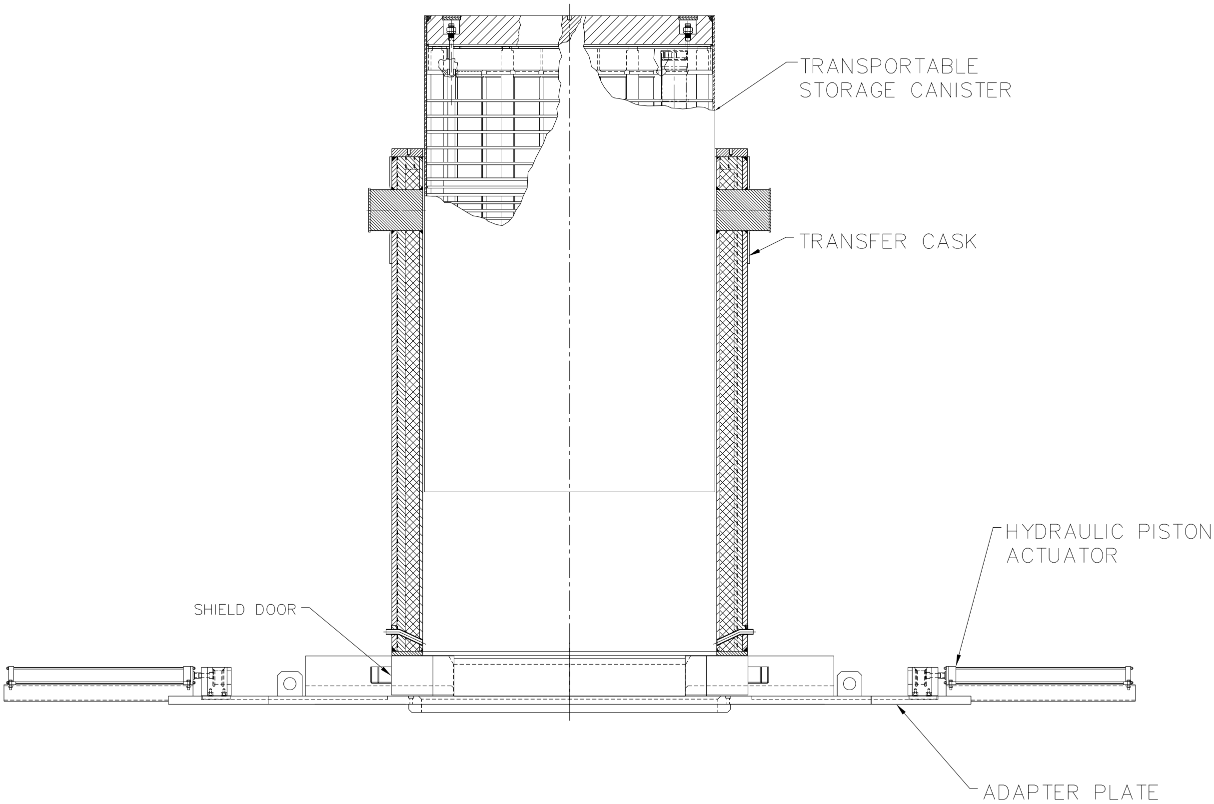

Figure E.4-12
MPC-LACBWR Transfer Cask and Canister Arrangement

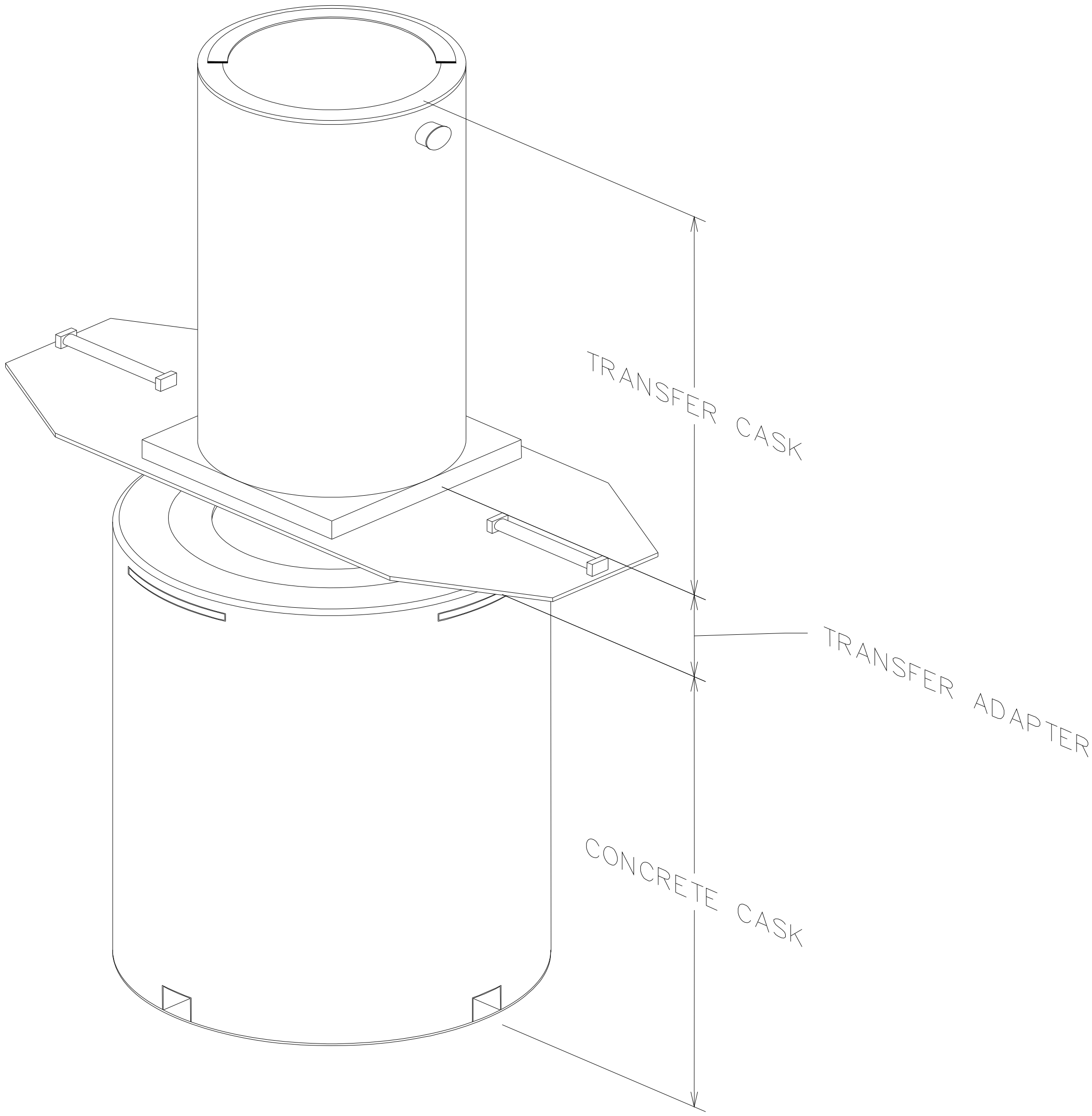

Figure E.4-13
MPC-LACBWR Vertical Concrete Cask and Transfer Cask Arrangement

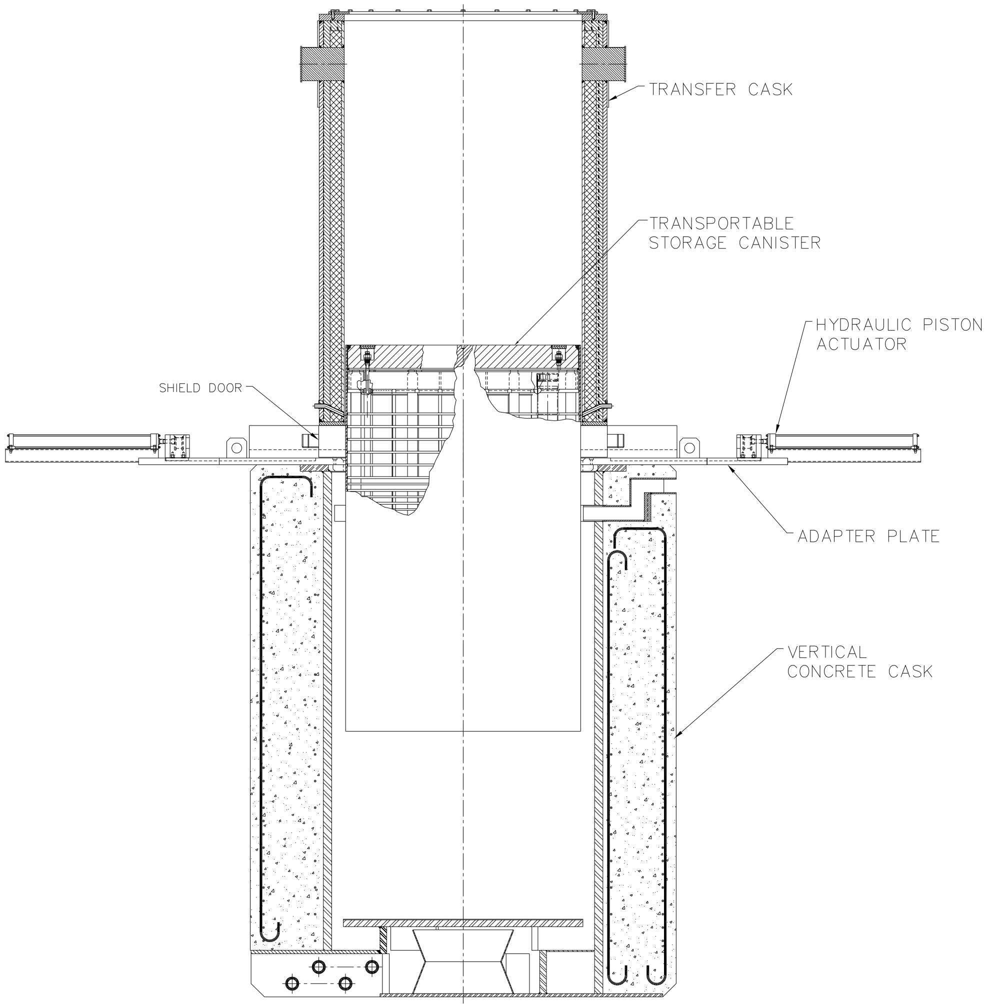

Figure E.4-14
MPC-LACBWR Major Component Configuration for Loading the Vertical Concrete Cask

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

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

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

Table E.4-2
Concrete Cask Construction Specification Summary

Materials

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

Welding

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

Construction

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

Quality Assurance

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

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

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

APPENDIX E.5
OPERATING PROCEDURES
NAC-MPC

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E.5 OPERATING PROCEDURES

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

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

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

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

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

E.5.1 Yankee Rowe MPC and Connecticut Yankee MPC

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

E.5.1.1 Loading the Vertical Concrete Cask

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

E.5.1.2 Transport and Placement of the Vertical Concrete Cask

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The assumptions underlying this procedure are:

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

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

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

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

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

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

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

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

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

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

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

E.5.2 La Crosse MPC

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

E.5.2.1 Loading the Vertical Concrete Cask

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

E.5.2.2 Transport and Placement of the Vertical Concrete Cask

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3. Remove the concrete cask lid.

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

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

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

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

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

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

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

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

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

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

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

E.5.3 References

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

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

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

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

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

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

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

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

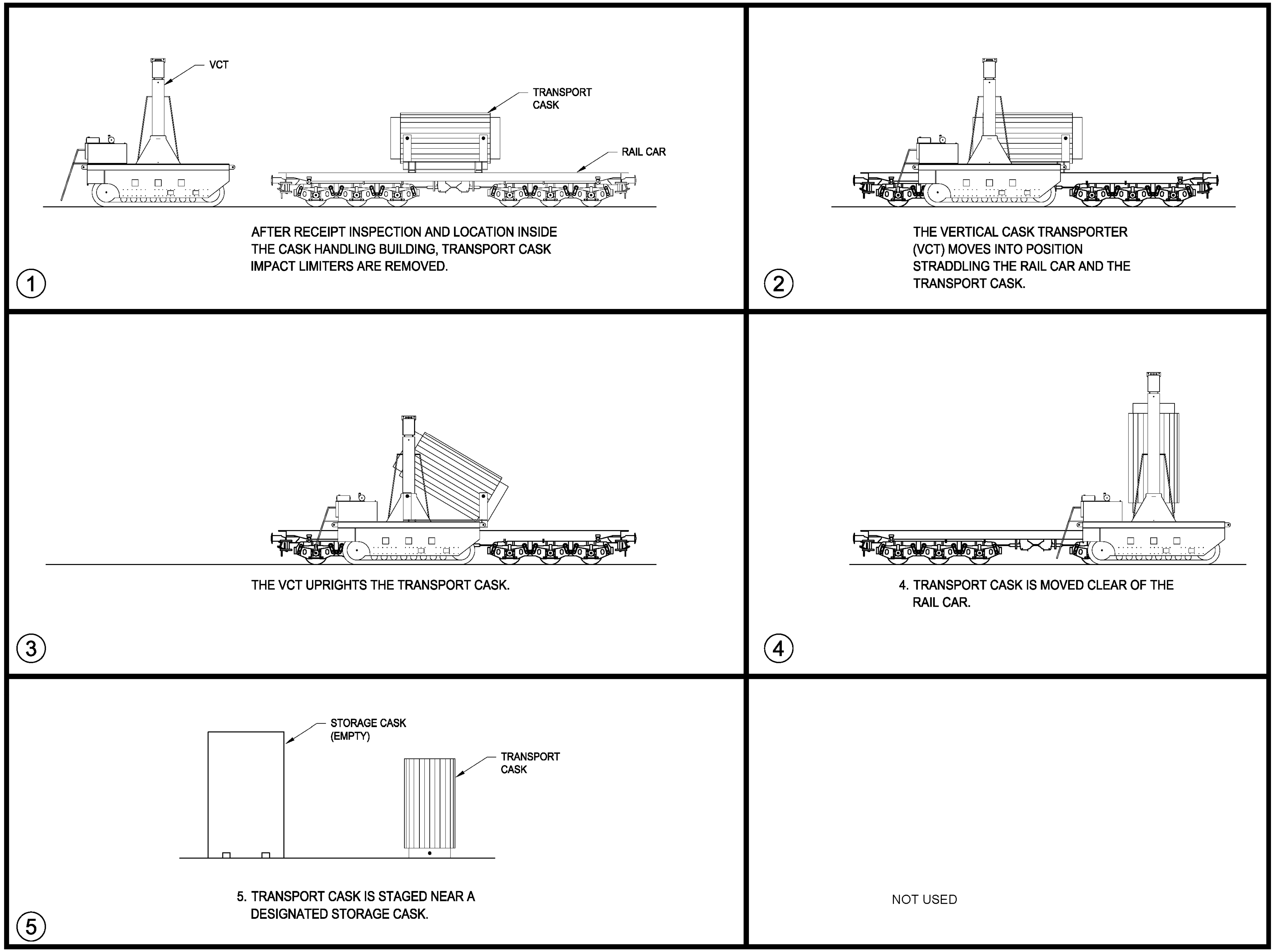
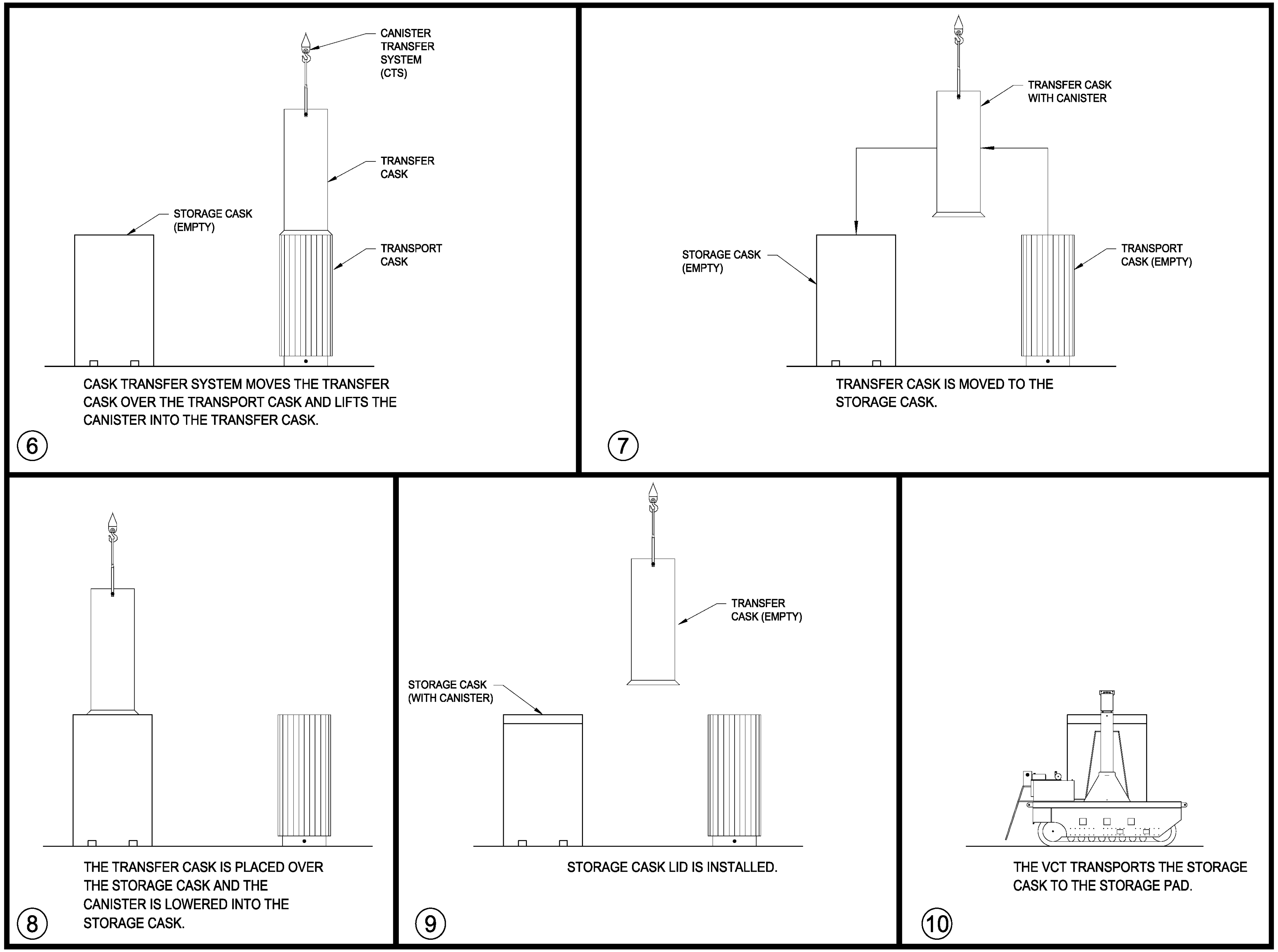


Figure E.5-1
Canister Transfer Operations
2 Pages



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Canister Transfer Operations
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APPENDIX E.6
WASTE CONFINEMENT AND MANAGEMENT
NAC-MPC

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E.6. WASTE CONFINEMENT AND MANAGEMENT

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

APPENDIX E.7
STRUCTURAL EVALUATION
NAC-MPC

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E.7 STRUCTURAL EVALUATION

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

E.7.1 Yankee Rowe MPC and Connecticut Yankee MPC

The Yankee-MPC and CY-MPC are generically referred to as the NAC-MPC and Sections E.7.1.1 through E.7.1.10 outline the structural analyses for normal operating conditions presented in Reference E.7-1. Finally, bounding evaluations in Section E.7.1.11 are referenced to demonstrate that the confinement boundaries for the Yankee-MPC and CY-MPC canisters do not exceed ASME B&PV Subsection NB Article NB-3200 (Level A allowables) during normal conditions of transport to provide reasonable assurance that the confinement boundary is not adversely impacted by transport to the WCS CISF.

E.7.1.1 Structural Design

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

E.7.1.2 Weights and Centers of Gravity

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

E.7.1.3 Mechanical Properties of Materials

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

E.7.1.4 Chemical and Galvanic Reactions

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

E.7.1.5 Positive Closure

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

E.7.1.6 Lifting Devices

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

E.7.1.7 NAC-MPC Components Under Normal Operating Loads

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

E.7.1.8 Cold

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

E.7.1.9 Fuel Rods

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

E.7.1.10 Coating Specifications

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

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

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

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

E.7.2 La Crosse MPC

Sections E.7.2.1 through E.7.2.10 outline the structural analyses for normal operating conditions presented in Reference E.7-1 for the La Crosse MPC (MPC-LACBWR). Finally, bounding evaluations in Section E.7.2.11 are referenced to demonstrate that the confinement boundaries for the MPC-LACBWR canisters do not exceed ASME B&PV Subsection NB Article NB-3200 (Level A allowables) during normal conditions of transport to provide reasonable assurance that the confinement boundary is not adversely impacted by transport to the WCS CISF.

E.7.2.1 Structural Design

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

E.7.2.2 Weights and Centers of Gravity

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

E.7.2.3 Mechanical Properties of Materials

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

E.7.2.4 Chemical and Galvanic Reactions

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

E.7.2.5 Positive Closure

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

E.7.2.6 Lifting Devices

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

E.7.2.7 MPC-LACBWR Components Under Normal Operating Loads

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

E.7.2.8 Fuel Rods

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

E.7.2.9 Canister Closure Weld Evaluation

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

E.7.2.10 Coating Specifications

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

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

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

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

E.7.3 References

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

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

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

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

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

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

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

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

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

APPENDIX E.8
THERMAL EVALUATION
NAC-MPC

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E.8 THERMAL EVALUATION

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

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

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

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

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

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

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

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

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

E.8.1.1 Maximum Average Yearly Ambient Temperature

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

E.8.1.2 Maximum Average 3-Day Ambient Temperature

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

E.8.1.3 Maximum Extreme 3-Day Ambient Temperature Range

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

E.8.2 References

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

Appendix E.9
RADIATION PROTECTION
NAC-MPC

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E.9 RADIATION PROTECTION

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

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

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

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

The collective dose for unloading is bounded because during storage at the WCS CISF the source terms will have decayed reducing surface dose rates. The total collective dose is the sum of the receipt, transfer, retrieval, and shipment is 1,646 person-mrem.

E.9.1 Yankee Rowe MPC and Connecticut Yankee MPC

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

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

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

E.9.1.1 Yankee-MPC System Shielding Discussion and Results

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

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

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

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

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

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

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

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

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

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

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

E.9.1.2 CY-MPC System Shielding Discussion and Results

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

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

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

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

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

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

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

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

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

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

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

E.9.2 LaCrosse MPC

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

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

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

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

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

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

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

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

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

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

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

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

Undamaged Fuel Dose Rates

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

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

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

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

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

Damaged Fuel Dose Rates

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

The first scenario assumes the damaged fuel collects over the active fuel length of the fuel assembly. This scenario is modeled by filling the fuel rod interstitial volume with UO2 and increasing the fuel neutron, gamma, and n-gamma source consistent with this increase in mass. A comparison of dose rate profiles for the 68 assembly intact fuel results and 36 intact and 32 damaged assemblies in Section 5.A.4 of Reference E.9.3-1 demonstrates that the damaged fuel model dose rates are less due to the increase in self-shielding from the 32 peripheral assemblies compensating for the increase in source strength.

In the second scenario, damaged fuel is assumed to migrate from the active fuel into the lower end fitting region of the fuel assembly, filling all the modeled void space. However, no credit is taken for the reduction in lower end fitting hardware dose rate due to the added UO2 mass and self-shielding nor for the reduction in fuel mass migrated from the active fuel region. In this case, storage cask inlet and transfer cask bottom surface dose rates increase due to the addition of damaged fuel. The storage cask inlet dose rate increase is 36.7 mrem/hr, effectively doubling the air inlet dose rate. The transfer cask bottom axial dose rate increase is 22.1 mrem/hr, increasing the bottom axial dose rate by approximately 41%. Note that the radial location of the maximum dose rate at the bottom of the transfer cask differs between the undamaged and damaged fuel models. Damaged fuel maximum dose rates are summarized in Table 5.A.1-5 and Table 5.A.1-6 of Reference E.9.3-1.

E.9.3 References

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

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

8 Sheets

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

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

8 Sheets

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

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

8 Sheets

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

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

8 Sheets

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

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

8 Sheets

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

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

8 Sheets

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

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

8 Sheets

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

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

8 Sheets

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

Note:
1. Rounded up to the nearest whole number

APPENDIX E.10
CRITICALITY EVALUATION
NAC-MPC

Table of Contents

E.10 CRITICALITY EVALUATION

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

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

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

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

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

differences in the principal dimensions and weights of the transfer cask and vertical concrete casks used with each of these NAC-MPC storage systems.

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

The continued efficacy of the neutron absorbers is assured when the canister arrives at the WCS CISF because the basket, including poison material, is designed and analyzed to maintain its configuration for all normal, off-normal and accident conditions of storage and for normal and hypothetical accidents during transport in the NAC-STC cask as documented in of the NAC-STC Safety Analysis Report.

E.10.1 Connecticut Yankee MPC

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

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

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

E.10.1.1 CY-MPC System Criticality Discussion and Results

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

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

Two configurations of the CY-MPC basket are available for loading at Connecticut Yankee: the standard 26-assembly basket configuration, and a 24-assembly basket configuration where two basket openings are blocked. The 26-assembly basket configuration is analyzed for Zircaloy-clad assemblies with an initial enrichment of up

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

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

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

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

E.10.2 Yankee Rowe MPC

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

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

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

E.10.2.1 Yankee-MPC System Criticality Discussion and Results

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

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

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

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

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

E.10.3 LaCrosse MPC

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

E.10.3.1 MPC-LACBWR System Criticality Discussion and Results

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

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

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

System criticality control is achieved through the use of neutron absorber sheets (BORAL®) attached to the exterior faces of the fuel tubes. Individual fuel assemblies

are held in place by stainless steel structural disks. The basket design includes 68 fuel tubes, one tube per fuel assembly or DFC, with the DFC tubes having a slightly larger (oversized) opening.

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

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

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

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

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

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

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

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

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

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

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

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

E.10.4 References

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

APPENDIX E.11
CONFINEMENT EVALUATION
NAC-MPC

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E.11 CONFINEMENT EVALUATION

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

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

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

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

E.11.1 Yankee Rowe MPC and Connecticut Yankee MPC

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

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

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

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

E.11.1.1 Confinement Boundary

The confinement boundary is described in detail for the Yankee-MPC and CY-MPC in Section 7.1 of Reference E.11-1. Specific details for the confinement vessel, confinement penetrations, seals & welds, and closure are in Sections 7.1.1, 7.1.2, 7.1.3, and 7.1.4, respectively. In addition, a bounding evaluation in Section E.7.1.11 is presented to demonstrate that the confinement boundary for the Yankee-MPC and CY-MPC canisters do not exceed ASME B&PV Subsection NB Article NB-3200 (Level A allowables) during normal conditions of transport to provide reasonable assurance that the confinement boundary is not adversely impacted by transport to the WCS CISF.

E.11.1.2 Requirements for Normal Conditions of Storage

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

E.11.1.3 Confinement Requirements for Hypothetical Accident Conditions

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

E.11.2 LaCrosse MPC

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

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

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

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

E.11.2.1 Confinement Boundary

The confinement boundary is described in detail for the MPC-LACBWR in Section 7.A.1 of Reference E.11-1. Specific details for the confinement vessel, confinement penetrations, seals & welds, and closure are in Sections 7.A.1.1, 7.A.1.2, 7.A.1.3, and 7.A.1.4, respectively. In addition, a bounding evaluation in Section E.7.2.11 is presented to demonstrate that the confinement boundary for the MPC-LACBWR canister does not exceed ASME B&PV Subsection NB Article NB-3200 (Level A allowables) during normal conditions of transport to provide reasonable assurance that the confinement boundary is not adversely impacted by transport to the WCS CISF.

E.11.2.2 Requirements for Normal Conditions of Storage

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

E.11.2.3 Confinement Requirements for Hypothetical Accident Conditions

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

E.11.3 References

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

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

APPENDIX E.12
ACCIDENT ANALYSIS
NAC-MPC

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E.12 ACCIDENT ANALYSIS

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

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

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

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

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

E.12.1 Yankee Rowe MPC and Connecticut Yankee MPC

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

E.12.1.1 Off-Normal Events

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

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

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

E.12.1.2 Accidents

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

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

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

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

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

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

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

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

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

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

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

E.12.1.3.2 Material Models/Properties

The material properties used in the analysis are given below:

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

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

Where,

E_c = Modulus of elasticity of concrete, psi

W_c = Unit weight of concrete, lb/ft3

f_c' = Compressive strength of concrete, psi

E.12.1.3.3 Concrete Pad

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

Modulus of elasticity, E = 4.602E6 psi

Poisson's ratio, υ = 0.2

Shear modulus, G = 1.918E6 psi

Compressive strength, f_c' = 6000 psi

E.12.1.3.4 Mudmat

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

Modulus of elasticity, E = 2.604E6 psi

Poisson's ratio, υ = 0.2

Shear modulus, G = 1.085E6 psi

Compressive strength, f_c' = 2000 psi

E.12.1.3.5 Soil

Table E.12-1
Soil Properties

E.12.1.3.6 VCC Concrete

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

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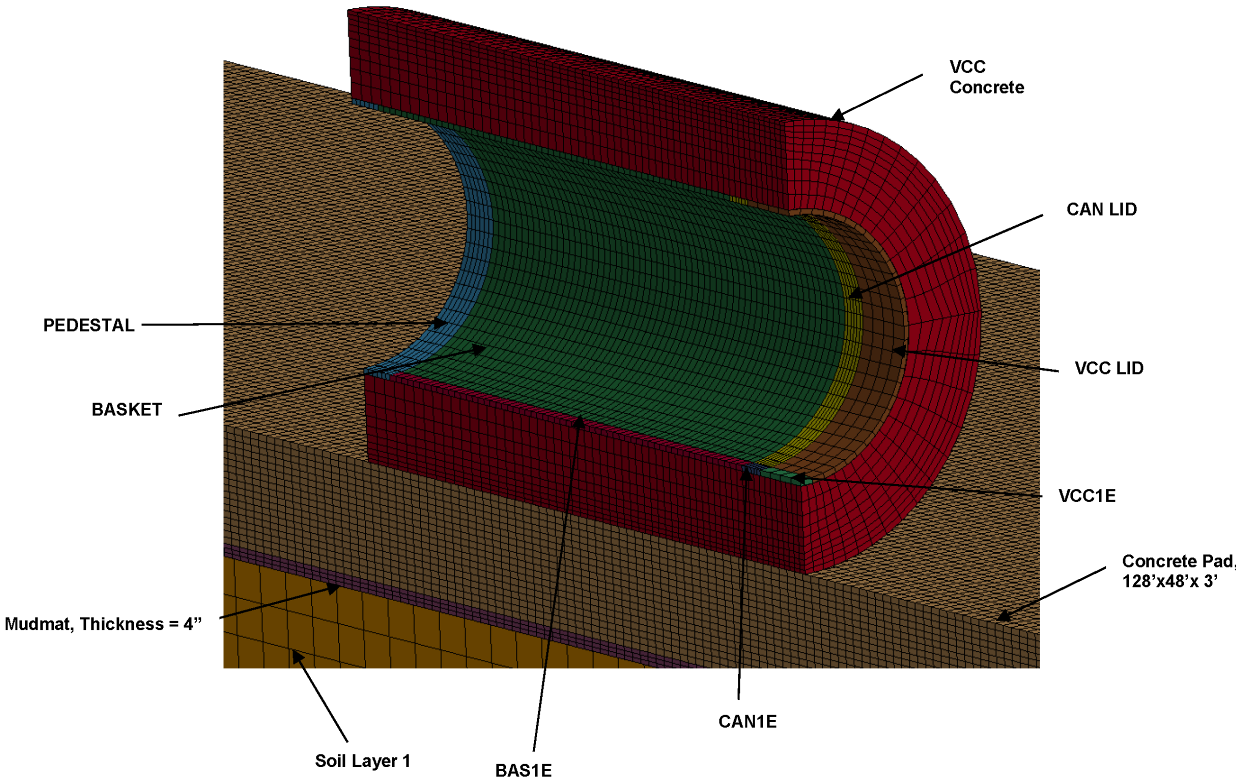

Figure E.12-2
CISF Configuration - Finite Element Model Set-Up (Continued)

E.12.1.3.7 Boundary Conditions

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

E.12.1.3.8 Weight of Loaded VCC

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

E.12.1.3.9 Tip-Over Velocity

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

Potential Energy = Rotational Kinetic Energy

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

Where,

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

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

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

h = Change in height of CG of VCC, in

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

ω = Angular velocity of loaded VCC, rad/sec

The diagram is shown below:

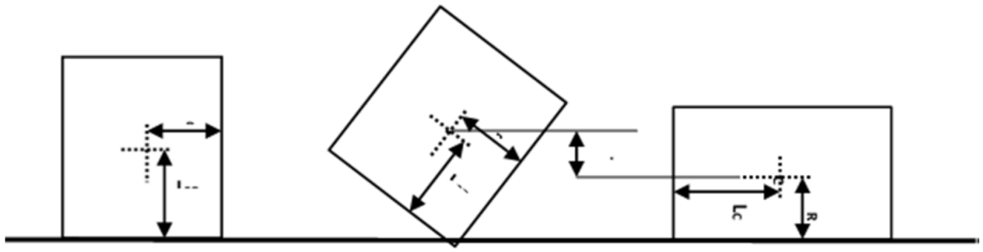

Figure E.12-3
Schematic Representation of the Change in Height of CG of VCC

The change in height of CG of VCC:

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

Where,

R = Radius of VCC, in

LCG = Distance of CG from base of VCC, in

Therefore, the angular velocity is given by,

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

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

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

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

E.12.1.3.10 Determination of Amplified Accelerations

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

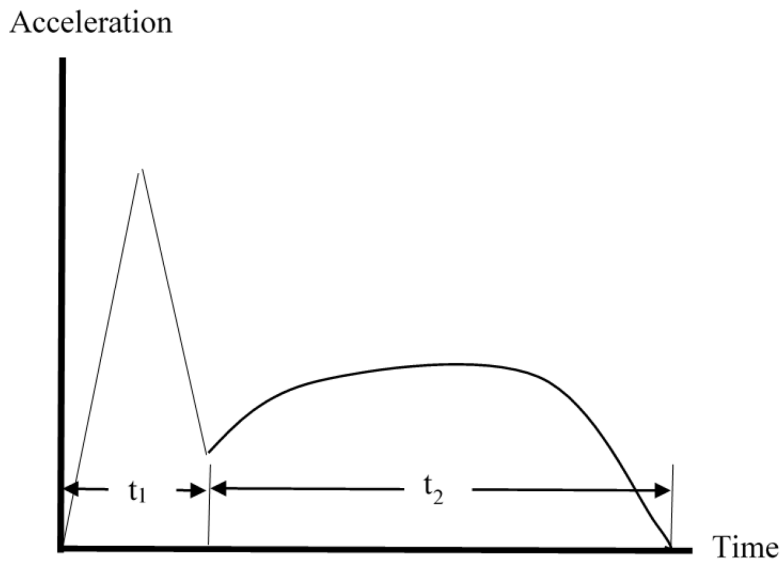

Figure E.12-4
Acceleration Time History

E.12.1.3.11 Cask Specific Evaluations

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

E.12.1.3.12 Yankee Rowe MPC

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

E.12.1.3.12.1 Material Properties of VCC

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

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

Modulus of elasticity, E = 3.682E6 psi

Poisson's ratio, υ = 0.22

Shear modulus, G = 1.509E6 psi

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

E.12.1.3.12.2 Geometric Properties of VCC

Radius of VCC, R = 64 in

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

Change in height of CG, h = 40.9 in

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

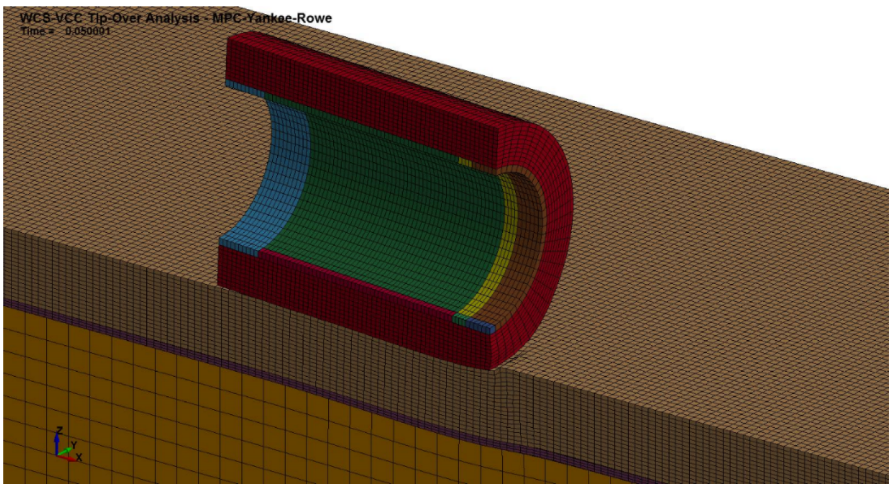

Figure E.12-5
Deformed Shape of Yankee Rowe MPC VCC, Concrete Pad, Mudmat and Soil

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

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

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

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

E.12.1.3.13 Connecticut Yankee MPC

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

E.12.1.3.13.1 Material Properties of VCC

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

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

Modulus of elasticity, E = 3.715E6 psi

Poisson's ratio, υ = 0.22

Shear modulus, G = 1.523E6 psi

Compressive strength, f_c' = 4,000 psi

E.12.1.3.13.2 Geometric Properties of VCC

Radius of VCC, R = 64 in

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

Change in height of CG, h = 53.5 in

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

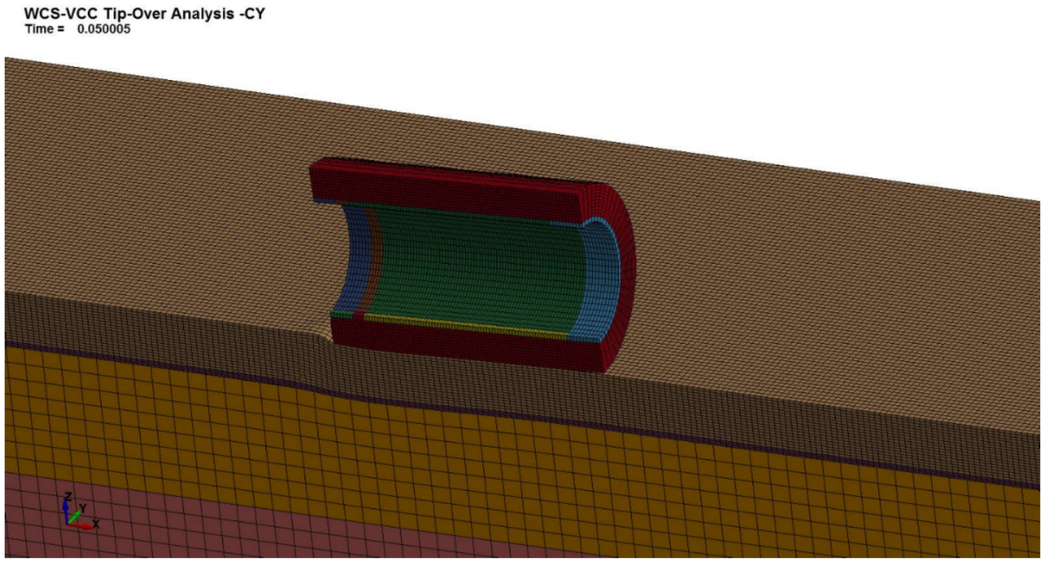

Figure E.12-6
Deformed Shape of Connecticut Yankee MPC VCC, Concrete Pad, Mudmat and Soil

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

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

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

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

E.12.2 La Crosse MPC

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

E.12.2.1 Off-Normal Events

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

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

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

E.12.2.2 Accidents

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

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

1. Accident pressurization – Section 11.A.2.1
2. Earthquake event – Section 11.A.2.2
3. Explosion – Section 11.A.2.3
4. Failure of all fuel rods with a subsequent ground level breach of the canister – Section 11.A.2.4
5. Fire accident – Section 11.A.2.5
6. Flood – Section 11.A.2.6
7. Fresh fuel loading in the canister – Section 11.A.2.7
8. Full blockage of air inlets and outlets – Section 11.A.2.8
9. Lightning – Section 11.A.2.9
10. Maximum anticipated heat load (125°F ambient temperature) – Section 11.A.2.10
11. Storage cask 6-inch drop – Section 11.A.2.11
12. Tip over of the concrete cask – Section 11.A.2.12
13. Tornado and tornado driven missiles – Section 11.A.2.13
14. Transfer cask seismic accident condition – Section 11.A.2.14

E.12.2.3 Concrete Cask Non-Mechanistic Tip-Over Analysis

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

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

The concrete cask tip-over analyses of the MPC-LACBWR storage system at the Consolidated Interim Storage Facility (CISF) are performed using LS-DYNA.

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

E.12.2.3.1 Concrete Cask Finite Element Model For Tip-Over Evaluation

The half-symmetry finite element model of the loaded VCC, concrete pad, mudmat, and soil sublayers are constructed of solid brick elements. The details of the finite element model set-up are shown in Figure E.12-7 and Figure E.12-8.

E.12.2.3.2 Material Models/Properties

The material properties used in the analysis are given below:

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

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

Where,

E_c = Modulus of elasticity of concrete, psi

W_c = Unit weight of concrete, lb/ft3

f_c' = Compressive strength of concrete, psi

E.12.2.3.3 Concrete Pad

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

Modulus of elasticity, E = 4.602E6 psi

Poisson’s ratio, υ = 0.2

Shear modulus, G = 1.918E6 psi

Compressive strength, f_c' = 6000 psi

E.12.2.3.4 Mudmat

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

Modulus of elasticity, E = 2.604E6 psi

Poisson’s ratio, υ = 0.2

Shear modulus, G = 1.085E6 psi

Compressive strength, f_c' = 2000 psi

E.12.2.3.5 Soil

Table E.12-5
Soil Properties

[ ]

E.12.2.3.6 VCC Concrete

The concrete properties used for VCC are given Section E.12.2.3.12.1 for the MPC-LACBWR storage system. The densities of VCC and other components used account for the total weight of non-structural components that are not modeled.

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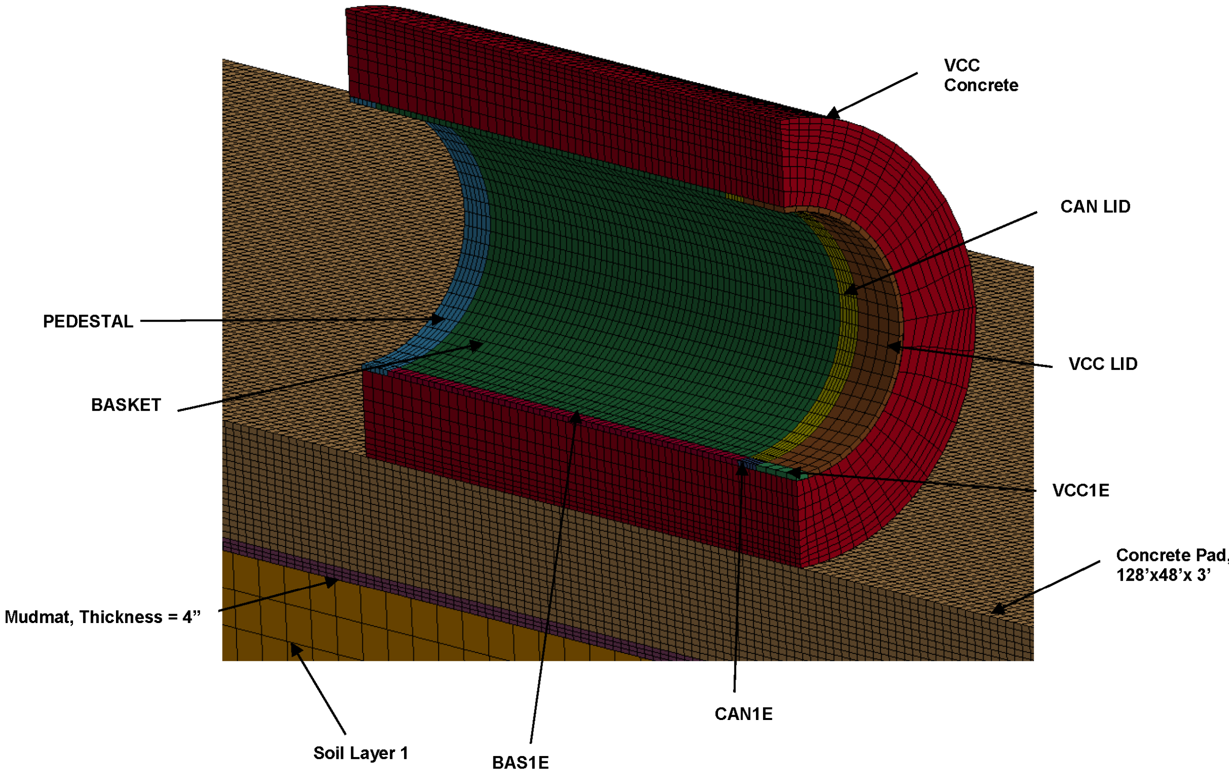

Figure E.12-8
CISF Configuration - Finite Element Model Set-Up (Continued)

E.12.2.3.7 Boundary Conditions

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

E.12.2.3.8 Weight of Loaded VCC

The body load due to the gravity (1 g) of the loaded VCC is considered in the analysis and is conservatively applied as a step load. The weights of various loaded VCC systems are given in Table E.12-6.

E.12.2.3.9 Tip-Over Velocity

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

Potential Energy = Rotational Kinetic Energy

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

Where,

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

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

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

h = Change in height of CG of VCC, in

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

ω = Angular velocity of loaded VCC, rad/sec

The diagram is shown below:

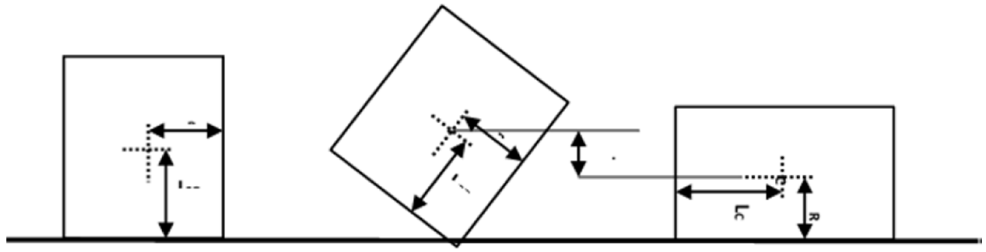

Figure E.12-9
Schematic Representation of the Change in Height of CG of VCC

The change in height of CG of VCC:

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

Where,

R = Radius of VCC, in

LCG = Distance of CG from base of VCC, in

Therefore, the angular velocity is given by,

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

The angular velocities for various VCC systems are given in Table E.12-6.

Table E.12-6
Total Weights and Tip-Over Angular Velocities of MPC-LACBWR VCC System

Storage System	Loaded VCC		Tip-Over Angular Velocity (rad/sec)
	Weight (kips)	Mass (lb-sec^2/in)	
MPC LACBWR	197.7	511.7	1.520

E.12.2.3.10 Determination of Amplified Accelerations

The acceleration time histories are taken from the nodes at the top of the basket and the canister which would identify the maximum acceleration of the basket and the canister. The acceleration time histories from the LS-DYNA nodal acceleration file were filtered with a Butterworth filter frequency of 165 Hz. Details of the filter frequency calculation are contained in Reference E.12-2. The general pattern of the acceleration time history of both components is shown in the acceleration time history curve in Figure E.12-10 below. The initial spike has a duration (t1) of approximately 4 ms while the longer pulse duration (t2) is approximately 40 ms. The initial spike of duration t1 is associated with the initial crushing of the concrete and the equivalent static acceleration used for the basket and canister evaluation is determined using the Dynamic Load Factors (DLF) for a triangular shaped pulse. The DLF for the longer pulse (t2) is determined using the DLF for a sine shaped pulse. The DLF for the basket is dependent on each basket design and basket angular orientation. The DLF for the canister lid region of the TSC is considered to be 1 due to the rigidity of the lid.

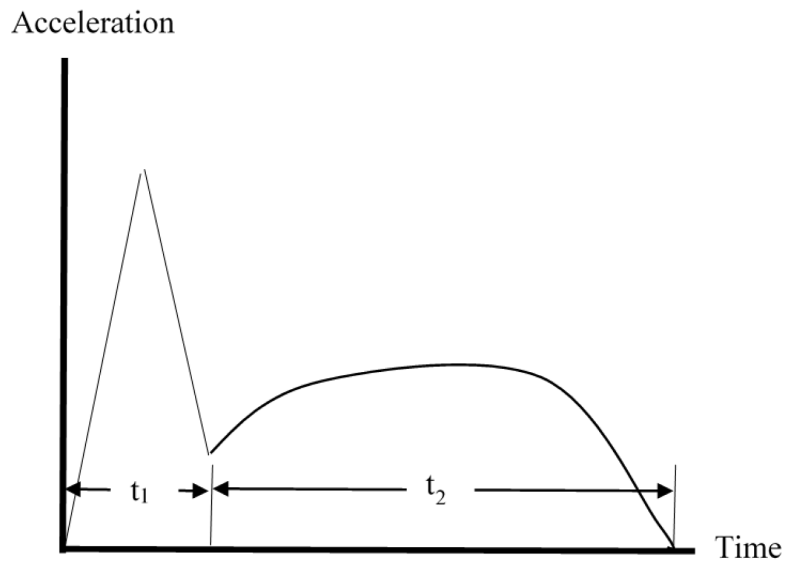

Figure E.12-10
Acceleration Time History

E.12.2.3.11 Cask Specific Evaluations

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

E.12.2.3.12 MPC-LACBWR

The total weight of the loaded MPC LACBWR VCC used in the analysis is equal to 201.6 kips. Half-symmetry model as discussed in Section E.12.2.3.1 is used in the analysis.

E.12.2.3.12.1 Material Properties of VCC

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

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

Modulus of elasticity, E = 3.682E6 psi

Poisson's ratio, υ = 0.22

Shear modulus, G = 1.509E6 psi

Compressive strength, $f_c' = 4000$ psi

E.12.2.3.12.2 Geometric Properties of VCC

Radius of VCC, R = 64 in

Distance of CG of VCC from base, LCG = 83 in

Change in height of CG, h = 40.8 in

The tip-over angular velocity of the VCC is calculated as per the methodology described in Section E.12.2.3.9 and is applied to the MPC LACBWR model in conjunction with the gravity. The deformed shape of the model is shown in Figure E.12-11. Further details regarding numerical and graphical results are contained in Reference E.12-2.

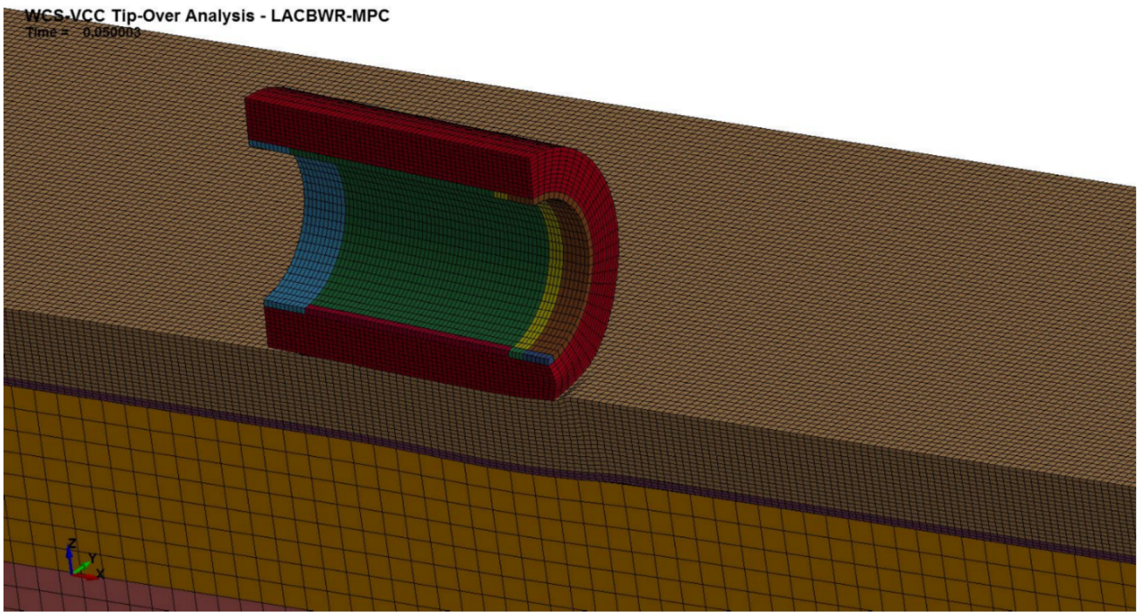

Figure E.12-11
Deformed Shape of MPC-LACBWR VCC, Concrete Pad, Mudmat and Soil

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

As indicated in Figure E.12-10, the acceleration time history shows two types of pulses. The DLF for the short pulse is based on a triangular shaped pulse. The DLF associated with the short pulse for the basket evaluation is dependent on the fundamental modal frequency of the MPC LACBWR basket and the time duration of the short pulse. Details of the modal analysis for the MPC LACBWR basket are contained in Reference E.12-3. The bounding DLF associated with the short pulse, which is dependent on basket orientation, is 0.75 resulting in an amplified acceleration for the short pulse of 16.1g's. For the accelerations during the long pulse, the bounding DLF, for the sine pulse is 1.76, regardless of the fundamental modal frequency of the basket. The Table E.12-7 shows the basket acceleration obtained from the transient analysis, the maximum DLF, and the amplified accelerations. The acceleration used in the basket and canister evaluations for the MPC LACBWR system in Reference E.12-1 was 25g's. The peak amplified basket acceleration, which is shown below, is 21.8 and the peak canister acceleration of 23.5, and both of these accelerations are bounded by 25g. Therefore, the basket and canister evaluations contained in Reference E.12-1 are bounding for the conditions at the CISF.

Table E.12-7
Peak Accelerations and DLF for MPC-LACBWR VCC Systems

Pulse	Peak Basket Analysis Acceleration (A_p) (g)	DLF	Amplified Acceleration (g) (A_p)×DLF
Short Pulse	21.4	0.75	16.1
Long Pulse	12.4	1.76	21.8

E.12.3 References

E.12-1 NAC-MPC Final Safety Analysis Report, Revision 10, January 2014

E.12-2 NAC Calculation 30039-2010 Rev 0, “Concrete Cask Tip-Over Evaluation – WCS”, NAC International, Norcross, GA

E.12-3 NAC Calculation 30039-2015 Rev 0, “Tip-Over DLF Calculation for WCS”, NAC International, Norcross, GA