1.2 GENERAL DESCRIPTION OF HI-STORM 100 System

1.2.1 System Characteristics

The basic HI-STORM 100 System consists of interchangeable MPCs providing a confinement boundary for BWR or PWR spent nuclear fuel, a storage overpack providing a structural and radiological boundary for long-term storage of the MPC placed inside it, and a transfer cask providing a structural and radiological boundary for transfer of a loaded MPC from a nuclear plant spent fuel storage pool to the storage overpack. Figures 1.2.1 and 1.2.1A provide example cross sectional views of the HI-STORM 100 System with an MPC inserted into HI-STORM 100 and HI-STORM 100S storage overpacks, respectively. Figure 1.1.1B provides similar information for the HI-STORM 100 System using a HI-STORM 100S Version B overpack. Each of these components is described below, including information with respect to component fabrication techniques and designed safety features. All structures, systems, and components of the HI-STORM 100 System, which are identified as Important to Safety are specified in Table 2.2.6. This discussion is supplemented with a full set of drawings in Section 1.5.

The HI-STORM 100 System is comprised of three discrete components:

i. multi-purpose canister (MPC)
ii. storage overpack (HI-STORM)
iii. transfer cask (HI-TRAC)

Necessary auxiliaries required to deploy the HI-STORM 100 System for storage are:

i. vacuum drying (or other moisture removal) system
ii. helium (He) backfill system (or other system capable of the same backfill condition)
iii. lifting and handling systems
iv welding equipment
v. transfer vehicles/trailer

All MPCs have *an*~~identical exterior dimensions that render them interchangeable. The~~ outer diameter of ~~the MPC is~~ 68-3/8 inches[†] and ~~the~~*an* overall length ~~is~~*of approximately* 190-1/2 inches. See Section 1.5 for the MPC drawings. Due to the differing storage contents of each MPC, the maximum loaded weight differs among MPCs. See Table 3.2.1 for each MPC weight. However, the maximum weight of a loaded MPC is approximately 44-1/2 tons. Tables 1.2.1 and 1.2.2 contain the key system data and parameters for the MPCs.

A single, base HI-STORM overpack design is provided which is capable of storing each type of MPC. The overpack inner cavity is sized to accommodate the MPCs. The inner diameter of the overpack inner shell is 73-1/2 inches and the height of the cavity is 191-1/2 inches. The overpack inner shell is provided with channels distributed around the inner cavity to present an inside

[†] Dimensions discussed in this section are considered nominal values.

diameter of 69-1/2 inches. The channels are intended to offer a flexible medium to absorb some of the impact during a non-mechanistic tip-over, while still allowing the cooling air flow through the ventilated overpack. The outer diameter of the overpack is 132-1/2 inches. The overall height of the HI-STORM 100 overpack is 239-1/2 inches.

There are two variants of the HI-STORM 100S overpack, differing from each other only in height and weight. The HI-STORM 100S(232) is 232 inches high, and the HI-STORM 100S(243) is 243 inches high. The HI-STORM 100S(243) is approximately 10,100 lbs heavier assuming standard density concrete. Hereafter in the text, these two versions of the HI-STORM 100S overpack will only be referred to as HI-STORM 100S and will be discussed separately only if the design feature being discussed is different between the two overpacks. See Section 1.5 for drawings.

There are also two variants of the HI-STORM 100S Version B overpack, differing from each other only in height and weight. The HI-STORM 100S-218 is 218 inches high, and the HI-STORM 100S-229 is 229 inches high. The HI-STORM 100S-229 is approximately 8,700 lbs heavier, including standard density concrete. Hereafter in the text, these two versions of the HI-STORM 100S Version B overpack will only be referred to as HI-STORM 100S Version B and will be discussed separately only if the design feature being discussed is different between the two overpacks. See Section 1.5 for drawings.

The weight of the overpack without an MPC varies from approximately 135 tons to 160 tons. See Table 3.2.1 for the detailed weights.

Before proceeding to present detailed physical data on the HI-STORM 100 System, it is of contextual importance to summarize the design attributes which enhance the performance and safety of the system. Some of the principal features of the HI-STORM 100 System which enhance its effectiveness as an SNF storage device and a safe SNF confinement structure are:

- the honeycomb design of the MPC fuel basket;
- the effective distribution of neutron and gamma shielding materials within the system;
- the high heat dissipation capability;
- engineered features to promote convective heat transfer;
- the structural robustness of the steel-concrete-steel overpack construction.

The honeycomb design of the MPC fuel baskets renders the basket into a multi-flange plate weldment where all structural elements (i.e., box walls) are arrayed in two orthogonal sets of plates. Consequently, the walls of the cells are either completely co-planar (i.e., no offset) or orthogonal with each other. There is complete edge-to-edge continuity between the contiguous cells.

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Among the many benefits of the honeycomb construction is the uniform distribution of the metal mass of the basket over the entire length of the basket. Physical reasoning suggests that a uniformly distributed mass provides a more effective shielding barrier than can be obtained from a nonuniform basket. In other words, the honeycomb basket is a most effective radiation attenuation device. The complete cell-to-cell connectivity inherent in the honeycomb basket structure provides an uninterrupted heat transmission path, making the MPC an effective heat rejection device.

The composite shell construction in the overpack, steel-concrete-steel, allows ease of fabrication and eliminates the need for the sole reliance on the strength of concrete.

A description of each of the components is provided in the following sections, along with information with respect to its fabrication and safety features. This discussion is supplemented with the full set of drawings in Section 1.5.

1.2.1.1 Multi-Purpose Canisters

The MPCs are welded cylindrical structures as shown in cross sectional views of Figures 1.2.2 through 1.2.4. The outer diameter ~~and cylindrical height~~ of each MPC ~~are~~*is* fixed. Each spent fuel MPC is an assembly consisting of a honeycombed fuel basket, a baseplate, canister shell, a lid, and a closure ring, as depicted in the MPC cross section elevation view, Figure 1.2.5. The number of spent nuclear fuel storage locations in each of the MPCs depends on the fuel assembly characteristics.

There are eight MPC models, distinguished by the type and number of fuel assemblies authorized for loading. Section 1.2.3 and Table 1.2.1 summarize the allowable contents for each MPC model. Section 2.1.9 provides the detailed specifications for the contents authorized for storage in the HI-STORM 100 System. Drawings for the MPCs are provided in Section 1.5.

The MPC provides the confinement boundary for the stored fuel. Figure 1.2.6 provides an elevation view of the MPC confinement boundary. The confinement boundary is defined by the MPC baseplate, shell, lid, port covers, and closure ring. The confinement boundary is a strength-welded enclosure of all stainless steel construction.

The PWR MPC-24, MPC-24E and MPC-24EF differ in construction from the MPC-32 (including the MPC-32F) and the MPC-68 (including the MPC-68F and MPC-68FF) in one important aspect: the fuel storage cells in the MPC-24 series are physically separated from one another by a "flux trap", for criticality control. The PWR MPC-32 and -32F are designed similar to the MPC-68 (without flux traps) and its design includes credit for soluble boron in the MPC water during wet fuel loading and unloading operations for criticality control.

The MPC fuel baskets of non-flux trap construction (namely, MPC-68, MPC-68F, MPC-68FF, MPC-32, and MPC-32F) are formed from an array of plates welded to each other at their intersections. In the flux-trap type fuel baskets (MPC-24, MPC-24E, and MPC-24EF), formed angles are interposed onto the orthogonally configured plate assemblage to create the required flux-trap channels (see MPC-24 and MPC-24E fuel basket drawings in Section 1.5). In both configurations, two key attributes of the basket are preserved:

i. The cross section of the fuel basket simulates a multi-flanged closed section beam, resulting in extremely high bending rigidity.

ii. The principal structural frame of the basket consists of co-planar plate-type members (i.e., no offset).

This structural feature eliminates the source of severe bending stresses in the basket structure by eliminating the offset between the cell walls that must transfer the inertia load of the stored SNF to the basket/MPC interface during the various postulated accident events (e.g., non-mechanistic tipover, uncontrolled lowering of a cask during on-site transfer, or off-site transport events, etc.).

The MPC fuel basket is positioned and supported within the MPC shell by a set of basket supports welded to the inside of the MPC shell. Between the periphery of the basket, the MPC shell, and the basket supports, optional aluminum heat conduction elements (AHCEs) may have been installed in the early vintage MPCs fabricated, certified, and loaded under the original version or Amendment 1 of the HI-STORM 100 System CoC. The presence of these aluminum heat conduction elements is acceptable for MPCs loaded under the original CoC or Amendment 1, since the governing thermal analysis for Amendment 1 conservatively modeled the AHCEs as restrictions to convective flow in the basket, but took no credit for heat transfer through them. The heat loads authorized under Amendment 1 bound those for the original CoC, with the same MPC design. For MPCs loaded under Amendment 2 or a later version of the HI-STORM 100 CoC, the aluminum heat conduction elements shall not be installed. MPCs both with and without aluminum heat conduction elements installed are compatible with all HI-STORM overpacks. If used, these heat conduction elements are fabricated from thin aluminum alloy 1100 in shapes and a design that allows a snug fit in the confined spaces and ease of installation. If used, the heat conduction elements are installed along the full length of the MPC basket except at the drain pipe location to create a nonstructural thermal connection that facilitates heat transfer from the basket to shell. In their operating condition, the heat conduction elements contact the MPC shell and basket walls.

Lifting lugs attached to the inside surface of the MPC canister shell serve to permit placement of the empty MPC into the HI-TRAC transfer cask. The lifting lugs also serve to axially locate the MPC lid prior to welding. These internal lifting lugs are not used to handle a loaded MPC. Since the MPC lid is installed prior to any handling of a loaded MPC, there is no access to the lifting lugs once the MPC is loaded.

The top end of the MPC incorporates a redundant closure system. Figure 1.2.6 shows the MPC closure details. The MPC lid is a circular plate (fabricated from one piece, or two pieces - split top and bottom) edge-welded to the MPC outer shell. If the two-piece lid design is employed, only the top piece is analyzed as part of the enclosure vessel pressure boundary. The bottom piece acts as a radiation shield and is attached to the top piece with a non-structural, non-pressure retaining weld. The lid is equipped with vent and drain ports that are utilized to remove moisture and air from the MPC, and backfill the MPC with a specified amount of inert gas (helium). The vent and drain ports are covered and seal welded before the closure ring is installed. The closure ring is a circular ring

edge-welded to the MPC shell and lid. The MPC lid provides sufficient rigidity to allow the entire MPC loaded with SNF to be lifted by threaded holes in the MPC lid.

For fuel assemblies that are shorter than the design basis length, upper and lower fuel spacers (as appropriate) maintain the axial position of the fuel assembly within the MPC basket. The upper fuel spacers are threaded into the underside of the MPC lid as shown in Figure 1.2.5. The lower fuel spacers are placed in the bottom of each fuel basket cell. The upper and lower fuel spacers are designed to withstand normal, off-normal, and accident conditions of storage. An axial clearance of approximately 2 to 2-1/2 inches is provided to account for the irradiation and thermal growth of the fuel assemblies. The suggested values for the upper and lower fuel spacer lengths are listed in Tables 2.1.9 and 2.1.10 for each fuel assembly type. The actual length of fuel spacers will be determined on a site-specific or fuel assembly-specific basis.

The MPC *confinement boundary* is constructed entirely from stainless steel alloy materials ~~(except for the neutron absorber and optional aluminum heat conduction elements)~~. *All MPC components that may come into contact with spent fuel pool water or the ambient environment (with the exception of neutron absorber, aluminum seals on vent and drain port caps, and optional aluminum heat conduction elements) must be constructed from stainless steel alloy materials.* ~~No carbon steel parts are permitted in the MPC.~~ Concerns regarding interaction of coated carbon steel materials and various MPC operating environments [1.2.1] are not applicable to the MPC. All structural components in a MPC shall be made of Alloy X, a designation which warrants further explanation.

Alloy X is a material that is expected to be acceptable as a Mined Geological Disposal System (MGDS) waste package and which meets the thermophysical properties set forth in this document.

At this time, there is considerable uncertainty with respect to the material of construction for an MPC that would be acceptable as a waste package for the MGDS. Candidate materials being considered for acceptability by the DOE include:

- Type 316
- Type 316LN
- Type 304
- Type 304LN

The DOE material selection process is primarily driven by corrosion resistance in the potential environment of the MGDS. As the decision regarding a suitable material to meet disposal requirements is not imminent, the MPC design allows the use of any one of the four Alloy X materials.

For the MPC design and analysis, Alloy X (as defined in this FSAR) may be one of the following materials. Any steel part in an MPC may be fabricated from any of the acceptable Alloy X materials listed below, except that the steel pieces comprising the MPC shell (i.e., the 1/2" thick cylinder) must be fabricated from the same Alloy X stainless steel type.

- Type 316

- Type 316LN
- Type 304
- Type 304LN

The Alloy X approach is accomplished by qualifying the MPC for all mechanical, structural, neutronic, radiological, and thermal conditions using material thermophysical properties that are the least favorable for the entire group for the analysis in question. For example, when calculating the rate of heat rejection to the outside environment, the value of thermal conductivity used is the lowest for the candidate material group. Similarly, the stress analysis calculations use the lowest value of the ASME Code allowable stress intensity for the entire group. Stated differently, we have defined a material, which is referred to as Alloy X, whose thermophysical properties, from the MPC design perspective, are the least favorable of the candidate materials.

The evaluation of the Alloy X constituents to determine the least favorable properties is provided in Appendix 1.A.

The Alloy X approach is conservative because no matter which material is ultimately utilized in the MPC construction, the Alloy X approach guarantees that the performance of the MPC will exceed the analytical predictions contained in this document.

1.2.1.2 Overpacks

1.2.1.2.1 HI-STORM Overpack

The HI-STORM overpacks are rugged, heavy-walled cylindrical vessels. Figures 1.1.3B, 1.2.7, 1.2.8, and 1.2.8A provide cross sectional views of the HI-STORM 100 System, showing all of the overpack designs. The HI-STORM 100A overpack design is an anchored variant of the HI-STORM 100 and 100S designs and hereinafter is identified by name only when the discussion specifically applies to the anchored overpack. The HI-STORM 100A differs only in the diameter of the overpack baseplate and the presence of bolt holes and associated anchorage hardware (see Figures 1.1.4 and 1.1.5). The main structural function of the storage overpack is provided by carbon steel, and the main shielding function is provided by plain concrete. The overpack plain concrete is enclosed by cylindrical steel shells, a thick steel baseplate, and a top plate. The overpack lid has appropriate concrete shielding to provide neutron and gamma attenuation in the vertical direction.

The storage overpack provides an internal cylindrical cavity of sufficient height and diameter for housing an MPC. The inner shell of the overpack has channels attached to its inner diameter. The channels provide guidance for MPC insertion and removal and a flexible medium to absorb impact loads during the non-mechanistic tip-over, while still allowing the cooling air flow to circulate through the overpack. Shims may be attached to channels to allow the proper inner diameter dimension to be obtained.

The storage system has air ducts to allow for passive natural convection cooling of the contained MPC. A minimum of four air inlets and four air outlets are located at the lower and upper extremities of the storage system, respectively. The location of the air outlets in the HI-STORM 100

and the HI-STORM 100S (including Version B) design differ in that the outlet ducts for the HI-STORM 100 overpack are located in the overpack body and are aligned vertically with the inlet ducts at the bottom of the overpack body. The air outlet ducts in the HI-STORM 100S and 100S Version B are integral to the lid assembly and are not in vertical alignment with the inlet ducts. See the drawings in Section 1.5 for details of the overpack air inlet and outlet duct designs. The air inlets and outlets are covered by a screen to reduce the potential for blockage. Routine inspection of the screens (or, alternatively, temperature monitoring) ensures that blockage of the screens themselves will be detected and removed in a timely manner. Analysis, described in Chapter 11 of this FSAR, evaluates the effects of partial and complete blockage of the air ducts.

The air inlets and air outlets are penetrations through the thick concrete shielding provided by the HI-STORM 100 overpack. The outlet air ducts for the HI-STORM 100S and 100S Version B overpack designs, integral to the lid, present a similar break in radial shielding. Within the air inlets and outlets, an array of gamma shield cross plates are installed (see Figure 5.3.19 for a pictorial representation of the gamma shield cross plate designs). These gamma shield cross plates are designed to scatter any radiation traveling through the ducts. The result of scattering the radiation in the ducts is a significant decrease in the local dose rates around the air inlets and air outlets. The configuration of the gamma shield cross plates is such that the increase in the resistance to flow in the air inlets and outlets is minimized. For the HI-STORM 100 and 100S overpack designs, the shielding analysis conservatively credits only the mandatory version of the gamma shield cross plate design because they provide less shielding than the optional design. Conversely, the thermal analysis conservatively evaluates the optional gamma shield cross plate design because it conservatively provides greater resistance to flow than the mandatory design. There is only one gamma shield cross plate design employed with the HI-STORM 100S Version B overpack design, which has been appropriately considered in the shielding and thermal analyses.

Four threaded anchor blocks at the top of the overpack are provided for lifting. The anchor blocks are integrally welded to the radial plates which in turn are full-length welded to the overpack inner shell, outer shell, and baseplate (HI-STORM 100) or the inlet air duct horizontal plates (HI-STORM 100S) (see Figure 1.2.7). The HI-STORM 100S Version B overpack design incorporates partial-length radial plates at the top of the overpack to secure the anchor blocks and uses both gussets and partial-length radial plates at the bottom of the overpack for structural stability. Details of this arrangement are shown in the drawings in Section 1.5.

The four anchor blocks are located on 90° arcs around the circumference of the top of the overpack lid. The overpack may also be lifted from the bottom using specially-designed lifting transport devices, including hydraulic jacks, air pads, Hillman rollers, or other design based on site-specific needs and capabilities. Slings or other suitable devices mate with lifting lugs that are inserted into threaded holes in the top surface of the overpack lid to allow lifting of the overpack lid. After the lid is bolted to the storage overpack main body, these lifting bolts shall be removed and replaced with flush plugs.

The plain concrete between the overpack inner and outer steel shells is specified to provide the necessary shielding properties (dry density) and compressive strength. The concrete shall be in accordance with the requirements specified in Appendix 1.D.

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The principal function of the concrete is to provide shielding against gamma and neutron radiation. However, in an implicit manner it helps enhance the performance of the HI-STORM overpack in other respects as well. For example, the massive bulk of concrete imparts a large thermal inertia to the HI-STORM overpack, allowing it to moderate the rise in temperature of the system under hypothetical conditions when all ventilation passages are assumed to be blocked. The case of a postulated fire accident at the ISFSI is another example where the high thermal inertia characteristics of the HI-STORM concrete control the temperature of the MPC. Although the annular concrete mass in the overpack shell is not a structural member, it does act as an elastic/plastic filler of the inter-shell space, such that, while its cracking and crushing under a tip-over accident is not of significant consequence, its deformation characteristics are germane to the analysis of the structural members.

Density and compressive strength are the key parameters that delineate the performance of concrete in the HI-STORM System. The density of concrete used in the inter-shell annulus, pedestal (HI-STORM 100 and –100S overpacks only), and overpack lid has been set as defined in Appendix 1.D. For evaluating the physical properties of concrete for completing the analytical models, conservative formulations of Reference [1.0.5] are used.

To ensure the stability of the concrete at temperature, the concrete composition has been specified in accordance with NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems" [1.0.3]. Thermal analyses, presented in Chapter 4, show that the temperatures during normal storage conditions do not threaten the physical integrity of the HI-STORM overpack concrete.

There are three base HI-STORM overpack designs - HI-STORM 100, HI-STORM 100S, and HI-STORM 100S Version B. The significant differences among the three are overpack height, MPC pedestal height, location of the air outlet ducts, and the vertical alignment of the inlet and outlet air ducts. The HI-STORM 100 overpack is approximately 240 inches high from the bottom of the baseplate to the top of the lid bolts and 227 inches high without the lid installed. There are two variants of the HI-STORM 100S overpack design, differing only in height and weight. The HI-STORM 100S(232) is approximately 232 inches high from the bottom of the baseplate to the top of the lid in its final storage configuration and approximately 211 inches high without the lid installed. The HI-STORM 100S(243) is approximately 243 inches high from the bottom of the baseplate to the top of the lid in its final storage configuration and approximately 222 inches high without the lid installed. There are also two variants of the HI-STORM 100S Version B overpack design, differing only in height and weight. The HI-STORM 100S-218 is approximately 218 inches high from the bottom of the baseplate to the top of the lid in its final storage configuration and approximately 199 inches high without the lid installed. The HI-STORM 100S-229 is approximately 229 inches high from the bottom of the baseplate to the top of the lid in its final storage configuration and 210 inches high without the lid installed.

The HI-STORM 100S Version B overpack design does not include a concrete-filled pedestal to support the MPC. Instead, the MPC rests upon a steel plate that maintains the MPC sufficiently above the inlet air ducts to prevent direct radiation shine through the ducts. To facilitate this change, the inlet air ducts for the HI-STORM 100S Version B are shorter in height but larger in width. See the drawings in Section 1.5 for details.

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The anchored embodiment of the HI-STORM overpack is referred to as HI-STORM 100A or HI-STORM 100SA. The HI-STORM 100S version B overpack design may not be deployed in the anchored configuration at this time. As explained in the foregoing, the HI-STORM overpack is a steel weldment, which makes it a relatively simple matter to extend the overpack baseplate, form lugs, and then anchor the cask to the reinforced concrete structure of the ISFSI. In HI-STORM terminology, these lugs are referred to as "sector lugs." The sector lugs, as shown in Figure 1.1.5 and the drawing in Section 1.5, are formed by extending the HI-STORM overpack baseplate, welding vertical gussets to the baseplate extension and to the overpack outer shell and, finally, welding a horizontal lug support ring in the form of an annular sector to the vertical gussets and to the outer shell. The baseplate is equipped with regularly spaced clearance holes (round or slotted) through which the anchor studs can pass. The sector lugs are bolted to the ISFSI pad using anchor studs that are made of a creep-resistant, high-ductility, environmentally compatible material. The bolts are pre-loaded to a precise axial stress using a "stud tensioner" rather than a torque wrench. Pre-tensioning the anchors using a stud tensioner eliminates any shear stress in the bolt, which is unavoidable if a torquing device is employed (Chapter 3 of the text "Mechanical Design of Heat Exchangers and Pressure Vessel Components", by Arcturus Publishers, 1984, K.P. Singh and A.I. Soler, provides additional information on stud tensioners). The axial stress in the anchors induced by pre-tensioning is kept below 75% of the material yield stress, such that during the seismic event the maximum bolt axial stress remains below the limit prescribed for bolts in the ASME Code, Section III, Subsection NF (for Level D conditions). Figures 1.1.4 and 1.1.5 provide visual depictions of the anchored HI-STORM 100A configuration. This configuration also applies to the HI-STORM 100SA.

The anchor studs pass through liberal clearance holes (circular or slotted) in the sector lugs (0.75" minimum clearance) such that the fastening of the studs to the ISFSI pad can be carried out without mechanical interference from the body of the sector lug. The two clearance hole configurations give the ISFSI pad designer flexibility in the design of the anchor embedment in the ISFSI concrete. The axial force in the anchors produces a compressive load at the overpack/pad interface. This compressive force, F, imputes a lateral load bearing capacity to the cask/pad interface that is equal to μF ($\mu \leq 0.53$ per Table 2.2.8). As is shown in Chapter 3 of this FSAR, the lateral load-bearing capacity of the HI-STORM/pad interface (μF) is many times greater than the horizontal (sliding) force exerted on the cask under the postulated DBE seismic event. Thus, the potential for lateral sliding of the HI-STORM 100A System during a seismic event is precluded, as is the potential for any bending action on the anchor studs.

The seismic loads, however, will produce an overturning moment on the overpack that would cause a redistribution of the compressive contact pressure between the pad and the overpack. To determine the pulsation in the tensile load in the anchor studs and in the interface contact pressure, bounding static analysis of the preloaded configuration has been performed. The results of the static analysis demonstrate that the initial preloading minimizes pulsations in the stud load. A confirmatory non-linear dynamic analysis has also been performed using the time-history methodology described in Chapter 3, wherein the principal nonlinearities in the cask system are incorporated and addressed. The calculated results from the dynamic analysis confirm the static analysis results and that the presence of pre-stress helps minimize the pulsation in the anchor stud stress levels during the seismic event, thus eliminating any concern with regard to fatigue failure under extended and

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repetitive seismic excitations.

The sector lugs in HI-STORM 100A are made of the same steel material as the baseplate and the shell (SA516- Gr. 70) which helps ensure high quality fillet welds used to join the lugs to the body of the overpack. The material for the anchor studs can be selected from a family of allowable stud materials listed in the ASME Code (Section II). A representative sampling of permitted materials is listed in Table 1.2.7. The menu of materials will enable the ISFSI owner to select a fastener material that is resistant to corrosion in the local ISFSI environment. For example, for ISFSIs located in marine environments (e.g., coastal reactor sites), carbon steel studs would not be recommended without concomitant periodic inspection and coating maintenance programs. Table 1.2.7 provides the chemical composition of several acceptable fastener materials to help the ISFSI owner select the most appropriate material for his site. The two mechanical properties, ultimate strength σ_u and yield strength σ_y are also listed. For purposes of structural evaluations, the lower bound values of σ_u and σ_y from the menu of materials listed in Table 1.2.7 are used (see Table 3.4.10).

As shown in the drawing, the anchor studs are spaced sufficiently far apart such that a practical reinforced concrete pad with embedded receptacles can be designed to carry the axial pull from the anchor studs without overstressing the enveloping concrete monolith. The design specification and supporting analyses in this FSAR are focused on qualifying the overpack structures, including the sector lugs and the anchor studs. The design of the ISFSI pad, and its anchor receptacle will vary from site to site, depending on the geology and seismological characteristics of the sub-terrain underlying the ISFSI pad region. The data provided in this FSAR, however, provide the complete set of factored loads to which the ISFSI pad, its sub-grade, and the anchor receptacles must be designed within the purview of ACI-349-~~97~~ [1.0.4]. Detailed requirements on the ISFSI pads for anchored casks are provided in Section 2.0.4.

1.2.1.2.2 HI-TRAC (Transfer Cask) - Standard Design

Like the storage overpack, the HI-TRAC transfer cask is a rugged, heavy-walled cylindrical vessel. The main structural function of the transfer cask is provided by carbon steel, and the main neutron and gamma shielding functions are provided by water and lead, respectively. The transfer cask is a steel, lead, steel layered cylinder with a water jacket attached to the exterior. Figure 1.2.9 provides a typical cross section of the standard design HI-TRAC 125 with the pool lid installed. See Section 1.2.1.2.3 for discussion of the optional HI-TRAC 125D design.

The transfer cask provides an internal cylindrical cavity of sufficient size for housing an MPC. The top lid of the HI-TRAC 125 has additional neutron shielding to provide neutron attenuation in the vertical direction (from SNF in the MPC below). The MPC access hole through the HI-TRAC top lid is provided to allow the lowering/raising of the MPC between the HI-TRAC transfer cask, and the HI-STORM or HI-STAR overpacks. The standard design HI-TRAC (comprised of HI-TRAC 100 and HI-TRAC 125) is provided with two bottom lids, each used separately. The pool lid is bolted to the bottom flange of the HI-TRAC and is utilized during MPC fuel loading and sealing operations. In addition to providing shielding in the axial direction, the pool lid incorporates a seal that is designed to hold clean demineralized water in the HI-TRAC inner cavity, thereby preventing contamination of the exterior of the MPC by the contaminated fuel pool water. After the MPC has

been drained, dried, and sealed, the pool lid is removed and the HI-TRAC transfer lid is attached (standard design only). The transfer lid incorporates two sliding doors that allow the opening of the HI-TRAC bottom for the MPC to be raised/lowered. Figure 1.2.10 provides a cross section of the HI-TRAC with the transfer lid installed.

In the standard design, trunnions are provided for lifting and rotating the transfer cask body between vertical and horizontal positions. The lifting trunnions are located just below the top flange and the pocket trunnions are located above the bottom flange. The two lifting trunnions are provided to lift and vertically handle the HI-TRAC, and the pocket trunnions provide a pivot point for the rotation of the HI-TRAC for downending or upending.

Two standard design HI-TRAC transfer casks of different weights are provided to house the MPCs. The ~~125 ton~~ HI-TRAC~~-~~*125* weight does not exceed 125 tons during any loading or transfer operation. The ~~100 ton~~ HI-TRAC~~-~~*100* weight does not exceed 100 tons during any loading or transfer operation. The internal cylindrical cavities of the two standard design HI-TRACs are identical. However, the external dimensions are different. The ~~100 ton~~ HI-TRAC~~-~~*-100* has a reduced thickness of lead and water shielding and consequently, the external dimensions are different. The structural steel thickness is identical in the two HI-TRACs. This allows most structural analyses of the ~~125 ton~~ HI-TRAC~~-~~*125* to bound the ~~100 ton~~ HI-TRAC~~-~~*-100* design. Additionally, as the two HI-TRACs are identical except for a reduced thickness of lead and water, the ~~125 ton~~ HI-TRAC~~-~~*-125* has a larger thermal resistance than the smaller and lighter ~~100 ton~~ HI-TRAC~~-~~*-100*. Therefore, for normal conditions the ~~125 ton~~ HI-TRAC~~-~~*-125* thermal analysis bounds that of the ~~100 ton~~ HI-TRAC *-100*. Separate shielding analyses are performed for each HI-TRAC since the shielding thicknesses are different between the two.

1.2.1.2.3 <u>HI-TRAC 125D Transfer Cask</u>

As an option to using either of the standard HI-TRAC transfer cask design, users may choose to use the optional HI-TRAC 125D design. Figure 1.2.9A provides a typical cross section of the standard design HI-TRAC~~-~~125 with the pool lid installed. Like the standard design, the HI-TRAC 125D is designed and constructed in accordance with ASME III, Subsection NF, with certain NRC-approved alternatives, as discussed in Section 2.2.4. Functionally equivalent, the major differences between the HI-TRAC 125D design and the standard design are as follows:

- No pocket trunnions are provided for downending/upending
- The transfer lid is not required
- A new ancillary, the HI-STORM mating device (Figure 1.2.18) is required during MPC transfer operations
- A wider baseplate with attachment points for the mating device is provided
- The baseplate incorporates gussets for added structural strength
- The number of pool lid bolts is reduce

The interface between the MPC and the transfer cask is the same between the standard design and the HI-TRAC 125D design. The optional design is capable of withstanding all loads defined in the

design basis for the transfer cask during normal, off-normal, and accident modes of operation with adequate safety margins. In lieu of swapping the pool lid for the transfer lid to facilitate MPC transfer, the pool lid remains on the HI-TRAC 125D until MPC transfer is required. The HI-STORM mating device is located between, and secured with bolting to, the top of the HI-STORM overpack and the HI-TRAC 125D transfer cask. The mating device is used to remove the pool lid to provide a pathway for MPC transfer between the overpack and the transfer cask. Section 1.2.2.2 provides additional detail on the differences between the standard transfer cask design and the HI-TRAC 125D design during operations.

1.2.1.3 Shielding Materials

The HI-STORM 100 System is provided with shielding to ensure the radiation and exposure requirements in 10CFR72.104 and 10CFR72.106 are met. This shielding is an important factor in minimizing the personnel doses from the gamma and neutron sources in the SNF in the MPC for ALARA considerations during loading, handling, transfer, and storage. The fuel basket structure of edge-welded composite boxes and neutron absorber panels attached to the fuel storage cell vertical surfaces provide the initial attenuation of gamma and neutron radiation emitted by the radioactive spent fuel. The MPC shell, baseplate, lid and closure ring provide additional thicknesses of steel to further reduce the gamma flux at the outer canister surfaces.

In the HI-STORM storage overpack, the primary shielding in the radial direction is provided by concrete and steel. In addition, the storage overpack has a thick circular concrete slab attached to the lid, and the HI-STORM 100 and 100S have a thick circular concrete pedestal upon which the MPC rests. This concrete pedestal is not necessary in the HI-STORM 100S Version B overpack design. These slabs provide gamma and neutron attenuation in the axial direction. The thick overpack lid and concrete shielding integral to the lid provide additional gamma attenuation in the upward direction, reducing both direct radiation and skyshine. Several steel plate and shell elements provide additional gamma shielding as needed in specific areas, as well as incremental improvements in the overall shielding effectiveness. Gamma shield cross plates, as depicted in Figure 5.3.19, provide attenuation of scattered gamma radiation as it exits the inlet and outlet air ducts.

In the HI-TRAC transfer cask radial direction, gamma and neutron shielding consists of steel-lead-steel and water, respectively. In the axial direction, shielding is provided by the top lid, and the pool or transfer lid, as applicable. In the HI-TRAC pool lid, layers of steel-lead-steel provide an additional measure of gamma shielding to supplement the gamma shielding at the bottom of the MPC. In the transfer lid, layers of steel-lead-steel provide gamma attenuation. For the HI-TRAC 125 transfer lid, the neutron shield material, Holtite-A, is also provided. The HI-TRAC 125 and HI-TRAC 125D top lids are composed of steel-neutron shield-steel, with the neutron shield material being Holtite-A. The HI-TRAC 100 top lid is composed of steel only providing gamma attenuation.

1.2.1.3.1 Fixed Neutron Absorbers

1.2.1.3.1.1 Boral™

Boral is a thermal neutron poison material composed of boron carbide and aluminum (aluminum

powder and plate). Boron carbide is a compound having a high boron content in a physically stable and chemically inert form. The boron carbide contained in Boral is a fine granulated powder that conforms to ASTM C-750-80 nuclear grade Type III. The Boral cladding is made of alloy aluminum, a lightweight metal with high tensile strength which is protected from corrosion by a highly resistant oxide film. The two materials, boron carbide and aluminum, are chemically compatible and ideally suited for long-term use in the radiation, thermal, and chemical environment of a nuclear reactor, spent fuel pool, or dry cask.

The documented historical applications of Boral, in environments comparable to those in spent fuel pools and fuel storage casks, dates to the early 1950s (the U.S. Atomic Energy Commission's AE-6 Water-Boiler Reactor [1.2.2]). Technical data on the material was first printed in 1949, when the report "Boral: A New Thermal Neutron Shield" was published [1.2.3]. In 1956, the first edition of the Reactor Shielding Design Manual [1.2.4] was published and it contained a section on Boral and its properties.

In the research and test reactors built during the 1950s and 1960s, Boral was frequently the material of choice for control blades, thermal-column shutters, and other items requiring very good thermal-neutron absorption properties. It is in these reactors that Boral has seen its longest service in environments comparable to today's applications.

Boral found other uses in the 1960s, one of which was a neutron poison material in baskets used in the shipment of irradiated, enriched fuel rods from Canada's Chalk River laboratories to Savannah River. Use of Boral in shipping containers continues, with Boral serving as the poison in current British Nuclear Fuels Limited casks and the Storable Transport Cask by Nuclear Assurance Corporation [1.2.5].

Boral has been licensed by the NRC for use in numerous BWR and PWR spent fuel storage racks and has been extensively used in international nuclear installations.

Boral has been exclusively used in fuel storage applications in recent years. Its use in spent fuel pools as the neutron absorbing material can be attributed to its proven performance and several unique characteristics, such as:

- The content and placement of boron carbide provides a very high removal cross section for thermal neutrons.
- Boron carbide, in the form of fine particles, is homogeneously dispersed throughout the central layer of the Boral panels.
- The boron carbide and aluminum materials in Boral do not degrade as a result of long-term exposure to radiation.
- The neutron absorbing central layer of Boral is clad with permanently bonded surfaces of aluminum.

- Boral is stable, strong, durable, and corrosion resistant.

Boral absorbs thermal neutrons without physical change or degradation of any sort from the anticipated exposure to gamma radiation and heat. The material does not suffer loss of neutron attenuation capability when exposed to high levels of radiation dose.

Holtec International's QA Program ensures that Boral is manufactured under the control and surveillance of a Quality Assurance/Quality Control Program that conforms to the requirements of 10CFR72, Subpart G. Holtec International has procured over 200,000 panels of Boral from AAR Advanced Structures in over 30 projects. Boral has always been purchased with a minimum ^{10}B loading requirement. Coupons extracted from production runs were tested using the wet chemistry procedure. The actual ^{10}B loading, out of thousands of coupons tested, has never been found to fall below the design specification. The size of this coupon database is sufficient to provide reasonable assurance that all future Boral procurements will continue to yield Boral with full compliance with the stipulated minimum loading. Furthermore, the surveillance, coupon testing, and material tracking processes which have so effectively controlled the quality of Boral are expected to continue to yield Boral of similar quality in the future. Nevertheless, to add another layer of insurance, only 75% ^{10}B credit of the fixed neutron absorber is assumed in the criticality analysis consistent with Chapter 6.0, IV, 4.c of NUREG-1536, Standard Review Plan for Dry Cask Storage Systems.

Operating experience in nuclear plants with fuel loading of Boral equipped MPCs as well as laboratory test data indicate that the aluminium used in the manufacture of the Boral may react with water, resulting in the generation of hydrogen. The numerous variables (i.e., aluminium particle size, pool temperature, pool chemistry, etc.) that influence the extent of the hydrogen produced make it impossible to predict the amount of hydrogen that may be generated during MPC loading or unloading at a particular plant. Therefore, due to the variability in hydrogen generation from the Boral-water reaction, the operating procedures in Chapter 8 require monitoring for combustible gases and either exhausting or purging the space beneath the MPC lid during loading and unloading operations when an ignition event could occur (i.e., when the space beneath the MPC lid is open to the welding or cutting operation).

1.2.1.3.1.2 METAMIC®

METAMIC® is a neutron absorber material developed by the Reynolds Aluminum Company in the mid-1990s for spent fuel reactivity control in dry and wet storage applications. Metallurgically, METAMIC® is a metal matrix composite (MMC) consisting of a matrix of 6061 aluminum alloy reinforced with Type 1 ASTM C-750 boron carbide. METAMIC® is characterized by extremely fine aluminum (325 mesh or better) and boron carbide powder. Typically, the average B_4C particle size is between 10 and 15 microns. As described in the U.S. patents held by METAMIC, Inc.[*†], the high performance and reliability of METAMIC® derives from the particle size distribution of its

[*] U.S. Patent No. 5,965,829, "Radiation Absorbing Refractory Composition".
[†] U.S. Patent No. 6,042,779, "Extrusion Fabrication Process for Discontinuous Carbide Particulate Metal Matrix Composites and Super, Hypereutectic Al/Si."

constituents, rendered into a metal matrix composite by the powder metallurgy process. This yields excellent and uniform homogeneity.

The powders are carefully blended without binders or other additives that could potentially adversely influence performance. The maximum percentage of B_4C that can be dispersed in the aluminum alloy 6061 matrix is approximately 40 wt.%, although extensive manufacturing and testing experience is limited to approximately 31 wt.%. The blend of powders is isostatically compacted into a green billet under high pressure and vacuum sintered to near theoretical density.

According to the manufacturer, billets of any size can be produced using this technology. The billet is subsequently extruded into one of a number of product forms, ranging from sheet and plate to angle, channel, round and square tube, and other profiles. For the METAMIC® sheets used in the MPCs, the extruded form is rolled down into the required thickness.

METAMIC® has been subjected to an extensive array of tests sponsored by the Electric Power Research Institute (EPRI) that evaluated the functional performance of the material at elevated temperatures (up to 900ºF) and radiation levels (1E+11 rads gamma). The results of the tests documented in an EPRI report (Ref. [1.2.11]) indicate that METAMIC® maintains its physical and neutron absorption properties with little variation in its properties from the unirradiated state. The main conclusions provided in the above-referenced EPRI report are summarized below:

- The metal matrix configuration produced by the powder metallurgy process with a complete absence of open porosity in METAMIC® ensures that its density is essentially equal to the theoretical density.

- The physical and neutronic properties of METAMIC® are essentially unaltered under exposure to elevated temperatures (750° F - 900° F).

- No detectable change in the neutron attenuation characteristics under accelerated corrosion test conditions has been observed.

In addition, independent measurements of boron carbide particle distribution show extremely small particle-to-particle distance[‡‡] and near-perfect homogeneity.

An evaluation of the manufacturing technology underlying METAMIC® as disclosed in the above-referenced patents and of the extensive third-party tests carried out under the auspices of EPRI makes METAMIC® an acceptable neutron absorber material for use in the MPCs. Holtec's technical position on METAMIC® is also supported by the evaluation carried out by other organizations (see, for example, USNRC's SER on NUHOMS-61BT, Docket No. 72-1004).

[‡‡] Medium measured neighbor-to-neighbor distance is 10.08 microns according to the article, "METAMIC Neutron Shielding", by K. Anderson, T. Haynes, and R. Kazmier, EPRI Boraflex Conference, November 19-20, 1998.

Consistent with its role in reactivity control, all METAMIC® material procured for use in the Holtec MPCs will be qualified as important-to-safety (ITS) Category A item. ITS category A manufactured items, as required by Holtec's NRC-approved Quality Assurance program, must be produced to essentially preclude the potential of an error in the procurement of constituent materials and the manufacturing processes. Accordingly, material and manufacturing control processes must be established to eliminate the incidence of errors, and inspection steps must be implemented to serve as an independent set of barriers to ensure that all critical characteristics defined for the material by the cask designer are met in the manufactured product.

All manufacturing and in-process steps in the production of METAMIC® shall be carried out using written procedures. As required by the company's quality program, the material manufacturer's QA program and its implementation shall be subject to review and ongoing assessment, including audits and surveillances as set forth in the applicable Holtec QA procedures to ensure that all METAMIC® panels procured meet with the requirements appropriate for the quality genre of the MPCs. Additional details pertaining to the qualification and production tests for METAMIC® are summarized in Subsection 9.1.5.3.

Because of the absence of interconnected porosities, the time required to dehydrate a METAMIC®-equipped MPC is expected to be less compared to an MPC containing Boral.

NUREG/CR-5661 (Ref. [1.2.14]) recommends limiting poison material credit to 75% of the minimum ^{10}B loading because of concerns for potential "streaming" of neutrons, and allows for greater percentage credit in criticality analysis "if comprehensive acceptance tests, capable of verifying the presence and uniformity of the neutron absorber, are implemented". The value of 75% is characterized in NUREG/CR-5661 as a very conservative value, based on experiments with neutron poison containing relatively large B_4C particles, such as BORAL with an average particle size in excess of 100 microns. METAMIC®, however, has a much smaller particle size of typically between 10 and 15 microns on average. Any streaming concerns would therefore be drastically reduced.

Analyses performed by Holtec International show that the streaming due to particle size is practically non-existent in METAMIC®. Further, EPRI's neutron attenuation measurements on 31 and 15 B_4C weight percent METAMIC® showed that METAMIC® exhibits very uniform ^{10}B areal density. This makes it easy to reliably establish and verify the presence and microscopic and macroscopic uniformity of the ^{10}B in the material. Therefore, 90% credit is applied to the minimum ^{10}B areal density in the criticality calculations, i.e. a 10% penalty is applied. This 10% penalty is considered conservative since there are no significant remaining uncertainties in the ^{10}B areal density. In Chapter 9 the qualification and on production tests for METAMIC® to support 90% ^{10}B credit are specified. With 90% credit, the target weight percent of boron carbide in METAMIC® is 31 for all MPCs, as summarized in Table 1.2.8, consistent with the test coupons used in the EPRI evaluations [1.2.11]. The maximum permitted value is 33.0 wt% to allow for necessary fabrication flexibility.

Because METAMIC® is a solid material, there is no capillary path through which spent fuel pool water can penetrate METAMIC® panels and chemically react with aluminum in the interior of the

material to generate hydrogen. Any chemical reaction of the outer surfaces of the METAMIC® neutron absorber panels with water to produce hydrogen occurs rapidly and reduces to an insignificant amount in a short period of time. Nevertheless, combustible gas monitoring for METAMIC® -equipped MPCs and purging or exhausting the space under the MPC lid during welding and cutting operations, is required until sufficient field experience is gained that confirms that little or no hydrogen is released by METAMIC® during these operations.

Mechanical properties of 31 wt.% METAMIC® based on coupon tests of the material in the as-fabricated condition and after 48 hours of an elevated temperature state at 900ºF are summarized below from the EPRI report [1.2.11].

Mechanical Properties of 31wt.% B_4C METAMIC		
Property	As-Fabricated	After 48 hours of 900ºF Temperature Soak
Yield Strength (psi)	32937 ± 3132	28744 ± 3246
Ultimate Strength (psi)	40141 ± 1860	34608 ± 1513
Elongation (%)	1.8 ± 0.8	5.7 ± 3.1

The required flexural strain of the neutron absorber to ensure that it will not fracture when the supporting basket wall flexes due to the worst case lateral inertial loading, has been set at 0.2% for the MPCs. The 1% minimum elongation of 31wt.% B_4C METAMIC® indicated by the above table means that METAMIC® will have a minimum factor of safety of five against cracking under the most severe postulated mechanical accident conditions for the MPCs.

EPRI's extensive characterization effort [1.2.11], which was focused on 15 and 31 wt.% B_4C METAMIC® served as the principal basis for a recent USNRC SER for 31wt.% B_4C METAMIC® for used in wet storage [1.2.12]. Additional studies on METAMIC® [1.2.13], EPRI's and others work provide the confidence that 31wt.% B_4C METAMIC® will perform its intended function in the MPCs.

1.2.1.3.1.3 Locational Fixity of Neutron Absorbers

Both Boral and METAMIC® neutron absorber panels are completely enclosed in Alloy X (stainless steel) sheathing that is stitch welded to the MPC basket cell walls along their entire periphery. The edges of the sheathing are bent toward the cell wall to make the edge weld. Thus, the neutron absorber is contained in a tight, welded pocket enclosure. The shear strength of the pocket weld joint, which is an order of magnitude greater than the weight of a fuel assembly, guarantees that the neutron absorber and its enveloping sheathing pocket will maintain their as-installed position under all loading, storage, and transient evolutions. Finally, the pocket joint detail ensures that fuel assembly insertion or withdrawal into or out of the MPC basket will not lead to a disconnection of the sheathing from the cell wall.

1.2.1.3.2 Neutron Shielding

The specification of the HI-STORM overpack and HI-TRAC transfer cask neutron shield material is predicated on functional performance criteria. These criteria are:

- Attenuation of neutron radiation to appropriate levels;
- Durability of the shielding material under normal conditions, in terms of thermal, chemical, mechanical, and radiation environments;
- Stability of the homogeneous nature of the shielding material matrix;
- Stability of the shielding material in mechanical or thermal accident conditions to the desired performance levels; and
- Predictability of the manufacturing process under adequate procedural control to yield an in-place neutron shield of desired function and uniformity.

Other aspects of a shielding material, such as ease of handling and prior nuclear industry use, are also considered, within the limitations of the main criteria. Final specification of a shield material is a result of optimizing the material properties with respect to the main criteria, along with the design of the shield system, to achieve the desired shielding results.

Neutron attenuation in the HI-STORM overpack is provided by the thick walls of concrete contained in the steel vessel, lid, and pedestal (only for the HI-STORM 100 and 100S overpack designs). Concrete is a shielding material with a long proven history in the nuclear industry. The concrete composition has been specified to ensure its continued integrity at the long term temperatures required for SNF storage.

The HI-TRAC transfer cask is equipped with a water jacket providing radial neutron shielding. Demineralized water will be utilized in the water jacket. To ensure operability for low temperature conditions, ethylene glycol (25% in solution) will be added to reduce the freezing point for low temperature operations (e.g., below 32°F) [1.2.7].

Neutron shielding in the HI-TRAC 125 and 125D transfer casks in the axial direction is provided by Holtite-A within the top lid. HI-TRAC 125 also contains Holtite-A in the transfer lid. Holtite-A is a poured-in-place solid borated synthetic neutron-absorbing polymer. Holtite-A is specified with a nominal B_4C loading of 1 weight percent for the HI-STORM 100 System. Appendix 1.B provides the Holtite-A material properties germane to its function as a neutron shield. Holtec has performed confirmatory qualification tests on Holtite-A under the company's QA program.

In the following, a brief summary of the performance characteristics and properties of Holtite-A is provided.

Density

The specific gravity of Holtite-A is 1.68 g/cm^3 as specified in Appendix 1.B. To conservatively bound any potential weight loss at the design temperature and any inability to reach the theoretical density, the density is reduced by 4% to 1.61 g/cm^3. The density used for the shielding analysis is conservatively assumed to be 1.61 g/cm^3 to underestimate the shielding capabilities of the neutron shield.

Hydrogen

The weight concentration of hydrogen is 6.0%. However, all shielding analyses conservatively assume 5.9% hydrogen by weight in the calculations.

Boron Carbide

Boron carbide dispersed within Holtite-A in finely dispersed powder form is present in 1% (nominal) weight concentration. Holtite-A may be specified with a B_4C content of up to 6.5 weight percent. For the HI-STORM 100 System, Holtite-A is specified with a nominal B_4C weight percent of 1%.

Design Temperature

The design temperatures of Holtite-A are provided in Table 1.B.1. The maximum spatial temperatures of Holtite-A under all normal operating conditions must be demonstrated to be below these design temperatures, as applicable.

Thermal Conductivity

The Holtite-A neutron shielding material is stable below the design temperature for the long term and provides excellent shielding properties for neutrons. A conservative, lower bound conductivity is stipulated for use in the thermal analyses of Chapter 4 (Section 4.2) based on information in the technical literature.

1.2.1.3.3 Gamma Shielding Material

For gamma shielding, the HI-STORM 100 storage overpack primarily relies on massive concrete sections contained in a robust steel vessel. A carbon steel plate, the shield shell, is located adjacent to the overpack inner shell to provide additional gamma shielding (Figure 1.2.7)[†]. Carbon steel supplements the concrete gamma shielding in most portions of the storage overpack, most notably the pedestal (HI-STORM 100 and 100S overpack designs only) and the lid. To reduce the radiation streaming through the overpack air inlets and outlets, gamma shield cross plates are installed in the

[†] The shield shell design feature was deleted in June, 2001 after overpack serial number 7 was fabricated. Those overpacks without the shield shell are required to have a higher concrete density in the overpack body to provide compensatory shielding. See Table 1.D.1.

ducts (Figures 1.2.8 and 1.2.8A) to scatter the radiation. This scattering acts to significantly reduce the local dose rates adjacent to the overpack air inlets and outlets. See Figure 5.3.19 and the drawings in Section 1.5 for more details of the gamma shield cross plate designs for each overpack design.

In the HI-TRAC transfer cask, the primary gamma shielding is provided by lead. As in the storage overpack, carbon steel supplements the lead gamma shielding of the HI-TRAC transfer cask.

1.2.1.4 Lifting Devices

Lifting of the HI-STORM 100 System may be accomplished either by attachment at the top of the storage overpack ("top lift"), as would typically be done with a crane, or by attachment at the bottom ("bottom lift"), as would be effected by a number of lifting/handling devices.

For a top lift, the storage overpack is equipped with four threaded anchor blocks arranged circumferentially around the overpack. These anchor blocks are used for overpack lifting as well as securing the overpack lid to the overpack body. The storage overpack may be lifted with a lifting device that engages the anchor blocks with threaded studs and connects to a crane or similar equipment.

A bottom lift of the HI-STORM 100 storage overpack is effected by the insertion of four hydraulic jacks underneath the inlet vent horizontal plates (Figure 1.2.1). A slot in the overpack baseplate allows the hydraulic jacks to be placed underneath the inlet vent horizontal plate. The hydraulic jacks lift the loaded overpack to provide clearance for inserting or removing a device for transportation.

The standard design HI-TRAC transfer cask is equipped with two lifting trunnions and two pocket trunnions. The HI-TRAC 125D is equipped with only lifting trunnions. The lifting trunnions are positioned just below the top forging. The two pocket trunnions are located above the bottom forging and attached to the outer shell. The pocket trunnions are designed to allow rotation of the HI-TRAC. All trunnions are built from a high strength alloy with proven corrosion and non-galling characteristics. The lifting trunnions are designed in accordance with NUREG-0612 and ANSI N14.6. The lifting trunnions are installed by threading into tapped holes just below the top forging.

The top of the MPC lid is equipped with four threaded holes that allow lifting of the loaded MPC. These holes allow the loaded MPC to be raised/lowered through the HI-TRAC transfer cask using lifting cleats. The threaded holes in the MPC lid are designed in accordance with NUREG-0612 and ANSI N14.6.

1.2.1.5 Design Life

The design life of the HI-STORM 100 System is 40 years. This is accomplished by using material of construction with a long proven history in the nuclear industry and specifying materials known to withstand their operating environments with little to no degradation. A maintenance program, as specified in Chapter 9, is also implemented to ensure the HI-STORM 100 System will exceed its

design life of 40 years. The design considerations that assure the HI-STORM 100 System performs as designed throughout the service life include the following:

HI-STORM Overpack and HI-TRAC Transfer Cask

- Exposure to Environmental Effects
- Material Degradation
- Maintenance and Inspection Provisions

MPC

- Corrosion
- Structural Fatigue Effects
- Maintenance of Helium Atmosphere
- Allowable Fuel Cladding Temperatures
- Neutron Absorber Boron Depletion

The adequacy of the HI-STORM 100 System for its design life is discussed in Sections 3.4.11 and 3.4.12.

1.2.2 Operational Characteristics

1.2.2.1 Design Features

The HI-STORM 100 System incorporates some unique design improvements. These design innovations have been developed to facilitate the safe long term storage of SNF. Some of the design originality is discussed in Subsection 1.2.1 and below.

The free volume of the MPCs is inerted with 99.995% pure helium gas during the spent nuclear fuel loading operations. Table 1.2.2 specifies the helium fill requirements for the MPC internal cavity.

The HI-STORM overpack has been designed to synergistically combine the benefits of steel and concrete. The steel-concrete-steel construction of the HI-STORM overpack provides ease of fabrication, increased strength, and an optimal radiation shielding arrangement. The concrete is primarily provided for radiation shielding and the steel is primarily provided for structural functions.

The strength of concrete in tension and shear is conservatively neglected. Only the compressive strength of the concrete is accounted for in the analyses.

The criticality control features of the HI-STORM 100 are designed to maintain the neutron multiplication factor k-effective (including uncertainties and calculational bias) at less than 0.95 under all normal, off-normal, and accident conditions of storage as analyzed in Chapter 6. This level of conservatism and safety margins is maintained, while providing the highest storage capacity.

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1.2.2.2 Sequence of Operations

Table 1.2.6 provides the basic sequence of operations necessary to defuel a spent fuel pool using the HI-STORM 100 System. The detailed sequence of steps for storage-related loading and handling operations is provided in Chapter 8 and is supported by the drawings in Section 1.5. A summary of the general actions needed for the loading and unloading operations is provided below. Figures 1.2.16 and 1.2.17 provide a pictorial view of typical loading and unloading operations, respectively.

Loading Operations

At the start of loading operations, the HI-TRAC transfer cask is configured with the pool lid installed. The HI-TRAC water jacket is filled with demineralized water or a 25% ethylene glycol solution depending on the ambient temperature conditions. The lift yoke is used to position HI-TRAC in the designated preparation area or setdown area for HI-TRAC inspection and MPC insertion. The annulus is filled with plant demineralized water, and an inflatable annulus seal is installed. The inflatable seal prevents contact between spent fuel pool water and the MPC shell reducing the possibility of contaminating the outer surfaces of the MPC. The MPC is then filled with water (borated if necessary). Based on the MPC model and fuel enrichment, this may be borated water or plant demineralized water (see Section 2.1). HI-TRAC and the MPC are lowered into the spent fuel pool for fuel loading using the lift yoke. Pre-selected assemblies are loaded into the MPC and a visual verification of the assembly identification is performed.

While still underwater, a thick shielding lid (the MPC lid) is installed. The lift yoke is remotely engaged to the HI-TRAC lifting trunnions and is used to lift the HI-TRAC close to the spent fuel pool surface. As an ALARA measure, dose rates are measured on the top of the HI-TRAC and MPC prior to removal from the pool to check for activated debris on the top surface. The MPC lift bolts (securing the MPC lid to the lift yoke) are removed. As HI-TRAC is removed from the spent fuel pool, the lift yoke and HI-TRAC are sprayed with demineralized water to help remove contamination.

HI-TRAC is removed from the pool and placed in the designated preparation area. The top surfaces of the MPC lid and the upper flange of HI-TRAC are decontaminated. The inflatable annulus seal is removed, and an annulus shield is installed. The annulus shield provides additional personnel shielding at the top of the annulus and also prevents small items from being dropped into the annulus. The Automated Welding System baseplate shield (if used) is installed to reduce dose rates around the top of the cask. The MPC water level is lowered slightly and the MPC lid is seal-welded using the Automated Welding System (AWS) or other approved welding process. Liquid penetrant examinations are performed on the root and final passes. A multi-layer liquid penetrant or volumetric examination is also performed on the MPC lid-to-shell weld. The MPC water is displaced from the MPC by blowing pressurized helium or nitrogen gas into the vent port of the MPC, thus displacing the water through the drain line. At the appropriate time in the sequence of activities, based on the type of test performed (hydrostatic or pneumatic), a pressure test of the MPC enclosure vessel is performed.

For MPCs containing all moderate burnup fuel, a Vacuum Drying System (VDS) may be used to

remove moisture from the MPC cavity. The VDS is connected to the MPC and is used to remove liquid water from the MPC in a stepped evacuation process. The stepped evacuation process is used to preclude the formation of ice in the MPC and Vacuum Drying System lines. The internal pressure is reduced and held for a duration to ensure that all liquid water has evaporated. This process is continued until the pressure in the MPC meets the technical specification limit and can be held there for the required amount of time.

For storage of high burnup fuel and as an option for storage of moderate burnup fuel, the reduction of residual moisture in the MPC to trace amounts is accomplished using a Forced Helium Dehydration (FHD) system, as described in Appendix 2.B. Relatively warm and dry helium is recirculated through the MPC cavity, which helps maintain the SNF in a cooled condition while moisture is being removed. The warm, dry gas is supplied to the MPC drain port and circulated through the MPC cavity where it absorbs moisture. The humidified gas travels out of the MPC and through appropriate equipment to cool and remove the absorbed water from the gas. The dry gas may be heated prior to its return to the MPC in a closed loop system to accelerate the rate of moisture removal in the MPC. This process is continued until the temperature of the gas exiting the demoisturizing module described in Appendix 2.B meets the specified limit.

Following moisture removal, the MPC is backfilled with a predetermined amount of helium gas. The helium backfill ensures adequate heat transfer during storage and provides an inert atmosphere for long-term fuel integrity. Cover plates are installed and seal-welded over the MPC vent and drain ports with liquid penetrant examinations performed on the root and final passes. *These seal welds are then helium leakage tested.*

The MPC closure ring is then placed on the MPC, aligned, tacked in place, and seal welded, providing redundant closure of the MPC lid and cover plates confinement closure welds. Tack welds are visually examined, and the root and final welds are inspected using the liquid penetrant examination technique to ensure weld integrity. The annulus shield is removed and the remaining water in the annulus is drained. The AWS Baseplate shield is removed. The MPC lid and accessible areas of the top of the MPC shell are smeared for removable contamination and HI-TRAC dose rates are measured. The HI-TRAC top lid is installed and the bolts are torqued. The MPC lift cleats are installed on the MPC lid. The MPC lift cleats are the primary lifting point of the MPC.

Rigging is installed between the MPC lift cleats and the lift yoke. . The rigging supports the MPC within HI-TRAC while the pool lid is replaced with the transfer lid. For the standard design transfer cask, the HI-TRAC is manipulated to replace the pool lid with the transfer lid. The MPC lift cleats and rigging support the MPC during the transfer operations.

MPC transfer from the HI-TRAC transfer cask into the overpack may be performed inside or outside the fuel building. Similarly, HI-TRAC and HI-STORM may be transferred to the ISFSI in several different ways. The loaded HI-TRAC may be handled in the vertical or horizontal orientation. The loaded HI-STORM can only be handled vertically.

For MPC transfers inside the fuel building, the empty HI-STORM overpack is inspected and staged with the lid removed, the alignment device positioned, and, for the HI-STORM 100 overpack, the

vent duct shield inserts installed. If using HI-TRAC 125D, the HI-STORM mating device is secured to the top of the empty overpack (Figure 1.2.18). The loaded HI-TRAC is placed using the fuel building crane on top of HI-STORM, or the mating device, as applicable. After the HI-TRAC is positioned atop the HI-STORM or secured to the mating device, as applicable, the MPC is raised slightly. With the standard HI-TRAC design, the transfer lid door locking pins are removed and the doors are opened. With the HI-TRAC 125D, the pool lid is removed using the mating device. The MPC is lowered into HI-STORM. Following verification that the MPC is fully lowered, slings are disconnected and lowered onto the MPC lid. For the HI-STORM 100, the doors are closed and the HI-TRAC is prepared for removal from on top of HI-STORM (with HI-TRAC 125D, the transfer cask must first be disconnected from the mating device). For the HI-STORM 100S and HI-STORM 100S Version B, the standard design HI-TRAC may need to be lifted above the overpack to a height sufficient to allow closure of the transfer lid doors without interfering with the MPC lift cleats. The HI-TRAC is then removed and placed in its designated storage location. The MPC lift cleats and slings are removed from atop the MPC. The alignment device, vent duct shield inserts, and/or mating device is/are removed, as applicable. The pool lid is removed from the mating device and re-attached to the HI-TRAC 125D prior to its next use. The HI-STORM lid is installed, and the upper vent screens and gamma shield cross plates are installed. The HI-STORM lid studs are installed and torqued.

For MPC transfers outside of the fuel building, the empty HI-STORM overpack is inspected and staged with the lid removed, the alignment device positioned, and, for the HI-STORM 100, the vent duct shield inserts installed. For HI-TRAC 125D, the mating device is secured to the top of the overpack. The loaded HI-TRAC is transported to the cask transfer facility in the vertical or horizontal orientation. A number of methods may be utilized as long as the handling limitations prescribed in the technical specifications are not exceeded.

To place the loaded HI-TRAC in a horizontal orientation, a transport frame or “cradle” is utilized. If the cradle is equipped with rotation trunnions they are used to engage the HI-TRAC 100 or 125 pocket trunnions. While the loaded HI-TRAC is lifted by the lifting trunnions, the HI-TRAC is lowered onto the cradle rotation trunnions. Then, the crane lowers and the HI-TRAC pivots around the pocket trunnions and is placed in the horizontal position in the cradle.

The HI-TRAC 125D does not include pocket trunnions in its design. Therefore, the user must downend the transfer cask onto the transport frame using appropriately designed rigging in accordance with the site’s heavy load control program.

If the loaded HI-TRAC is transferred to the cask transfer facility in the horizontal orientation, the HI-TRAC transport frame and/or cradle are placed on a transport vehicle. The transport vehicle may be an air pad, railcar, heavy-haul trailer, dolly, etc. If the loaded HI-TRAC is transferred to the cask transfer facility in the vertical orientation, the HI-TRAC may be lifted by the lifting trunnions or seated on the transport vehicle. During the transport of the loaded HI-TRAC, standard plant heavy load handling practices shall be applied including administrative controls for the travel path and tie-down mechanisms.

~~For MPCs containing any HBF *and a decay heat load above a specified threshold heat load*, the~~

~~Supplemental Cooling System (SCS) is required to be operational during the time the loaded and backfilled MPC is in HI-TRAC to ensure fuel cladding temperatures remain within limits. The SCS is discussed in detail in Section 4.5 and the design criteria for the system are provided in Appendix 2.C. The SCS is not required when the MPC is inside the *HI-STORM* overpack, regardless of decay heat load.~~

After the loaded HI-TRAC arrives at the cask transfer facility, the HI-TRAC is upended by a crane if the HI-TRAC is in a horizontal orientation. The loaded HI-TRAC is then placed, using the crane located in the transfer area, on top of HI-STORM, which has been inspected and staged with the lid removed, vent duct shield inserts installed, the alignment device positioned, and the mating device installed, as applicable.

After the HI-TRAC is positioned atop the HI-STORM or the mating device, the MPC is raised slightly. In the standard design, the transfer lid door locking pins are removed and the doors are opened. With the HI-TRAC 125D, the pool lid is removed using the mating device. The MPC is lowered into HI-STORM. Following verification that the MPC is fully lowered, slings are disconnected and lowered onto the MPC lid. For the HI-STORM 100, the doors are closed and HI-TRAC is removed from on top of HI-STORM or disconnected from the mating device, as applicable. For the HI-STORM 100S and the HI-STORM 100S Version B, the standard design HI-TRAC may need to be lifted above the overpack to a height sufficient to allow closure of the transfer lid doors without interfering with the MPC lift cleats. The HI-TRAC is then removed and placed in its designated storage location. The MPC lift cleats and slings are removed from atop the MPC. The alignment device, vent duct shield inserts, and mating device is/are removed, as applicable. The pool lid is removed from the mating device and re-attached to the HI-TRAC 125D prior to its next use. The HI-STORM lid is installed, and the upper vent screens and gamma shield cross plates are installed. The HI-STORM lid studs and nuts are installed.

After the HI-STORM has been loaded either within the fuel building or at a dedicated cask transfer facility, the HI-STORM is then moved to its designated position on the ISFSI pad. The HI-STORM overpack may be moved using a number of methods as long as the handling limitations listed in the technical specifications are not exceeded. The loaded HI-STORM must be handled in the vertical orientation, and may be lifted from the top by the anchor blocks or from the bottom by the inlet vents. After the loaded HI-STORM is lifted, it may be placed on a transport mechanism or continue to be lifted by the lid studs and transported to the storage location. The transport mechanism may be an air pad, crawler, railcar, heavy-haul trailer, dolly, etc. During the transport of the loaded HI-STORM, standard plant heavy load handling practices shall be applied including administrative controls for the travel path and tie-down mechanisms. Once in position at the storage pad, vent operability testing is performed to ensure that the system is functioning within its design parameters.

In the case of HI-STORM 100A, the anchor studs are installed and fastened into the anchor receptacles in the ISFSI pad in accordance with the design requirements.

Unloading Operations

The HI-STORM 100 System unloading procedures describe the general actions necessary to prepare the MPC for unloading, cool the stored fuel assemblies in the MPC, flood the MPC cavity, remove the lid welds, unload the spent fuel assemblies, and recover HI-TRAC and empty the MPC. Special precautions are outlined to ensure personnel safety during the unloading operations, and to prevent the risk of MPC overpressurization and thermal shock to the stored spent fuel assemblies.

The MPC is recovered from HI-STORM either at the cask transfer facility or the fuel building using any of the methodologies described in Section 8.1. The HI-STORM lid is removed, the alignment device positioned, and, for the HI-STORM 100, the vent duct shield inserts are installed, and the MPC lift cleats are attached to the MPC. For HI-TRAC 125D, the mating device is installed. Rigging is attached to the MPC lift cleats. For the HI-STORM 100S and HI-STORM 100S Version B with the standard HI-TRAC design, the transfer doors may need to be opened to avoid interfering with the MPC lift cleats. For HI-TRAC 125D, the mating device (possibly containing the pool lid) is secured to the top of the overpack. HI-TRAC is raised and positioned on top of HI-STORM or secured to the mating device, as applicable. For HI-TRAC 125D, the pool lid is ensured to be out of the transfer path for the MPC. The MPC is raised into HI-TRAC. Once the MPC is raised into HI-TRAC, the standard design HI-TRAC transfer lid doors are closed and the locking pins are installed. For HI-TRAC 125D, the pool lid is installed and the transfer cask is unsecured from the mating device. HI-TRAC is removed from on top of HI-STORM. ~~As required based on the presence of high burnup fuel *and the decay heat load*, the Supplemental Cooling System is installed and placed into operation.~~

The HI-TRAC is brought into the fuel building and, for the standard design, manipulated for bottom lid replacement. The transfer lid is replaced with the pool lid. The MPC lift cleats and rigging support the MPC during lid transfer operations.

HI-TRAC and its enclosed MPC are returned to the designated preparation area and the rigging, MPC lift cleats, and HI-TRAC top lid are removed. The annulus is filled with plant demineralized water (borated, if necessary). The annulus and HI-TRAC top surfaces are protected from debris that will be produced when removing the MPC lid.

The MPC closure ring and vent and drain port cover plates are core drilled. Local ventilation is established around the MPC ports. The RVOAs are attached to the vent and drain port. The RVOAs allow access to the inner cavity of the MPC, while providing a hermetic seal. The MPC is cooled using appropriate means, if necessary, to reduce the MPC internal temperature to allow water flooding. Following the fuel cool-down, the MPC is flooded with borated or unborated water, as required.. The MPC lid-to-MPC shell weld is removed. Then, all weld removal equipment is removed with the MPC lid left in place.

The MPC lid is rigged to the lift yoke and the lift yoke is engaged to HI-TRAC lifting trunnions. If weight limitations require, the neutron shield jacket is drained. HI-TRAC is placed in the spent fuel pool and the MPC lid is removed. All fuel assemblies are returned to the spent fuel storage racks and the MPC fuel cells are vacuumed to remove any assembly debris. HI-TRAC and MPC are returned

to the designated preparation area where the MPC water is removed. The annulus water is drained and the MPC and HI-TRAC are decontaminated in preparation for re-utilization.

1.2.2.3 Identification of Subjects for Safety and Reliability Analysis

1.2.2.3.1 Criticality Prevention

Criticality is controlled by geometry and neutron absorbing materials in the fuel basket. The MPC-24/24E/24EF (all with lower enriched fuel) and the MPC-68/68F/68FF do not rely on soluble boron credit during loading or the assurance that water cannot enter the MPC during storage to meet the stipulated criticality limits.

Each MPC model is equipped with neutron absorber plates affixed to the fuel cell walls as shown on the drawings in Section 1.5. The minimum ^{10}B areal density specified for the neutron absorber in each MPC model is shown in Table 1.2.2. These values are chosen to be consistent with the assumptions made in the criticality analyses.

The MPC-24, MPC-24E and 24EF(all with higher enriched fuel) and the MPC-32 and MPC-32F take credit for soluble boron in the MPC water for criticality prevention during wet loading and unloading operations. Boron credit is only necessary for these PWR MPCs during loading and unloading operations that take place under water. During storage, with the MPC cavity dry and sealed from the environment, criticality control measures beyond the fixed neutron poisons affixed to the storage cell walls are not necessary because of the low reactivity of the fuel in the dry, helium filled canister and the design features that prevent water from intruding into the canister during storage.

1.2.2.3.2 Chemical Safety

There are no chemical safety hazards associated with operations of the HI-STORM 100 dry storage system. A detailed evaluation is provided in Section 3.4.

1.2.2.3.3 Operation Shutdown Modes

The HI-STORM 100 System is totally passive and consequently, operation shutdown modes are unnecessary. Guidance is provided in Chapter 8, which outlines the HI-STORM 100 unloading procedures, and Chapter 11, which outlines the corrective course of action in the wake of postulated accidents.

1.2.2.3.4 Instrumentation

As stated earlier, the HI-STORM 100 confinement boundary is the MPC, which is seal welded, non-destructively examined and pressure tested. The HI-STORM 100 is a completely passive system with appropriate margins of safety; therefore, it is not necessary to deploy any instrumentation to monitor the cask in the storage mode. At the option of the user, temperature elements may be

utilized to monitor the air temperature of the HI-STORM overpack exit vents in lieu of routinely inspecting the ducts for blockage. See Subsection 2.3.3.2 for additional details.

1.2.2.3.5 Maintenance Technique

Because of their passive nature, the HI-STORM 100 System requires minimal maintenance over its lifetime. No special maintenance program is required. Chapter 9 describes the acceptance criteria and maintenance program set forth for the HI-STORM 100.

1.2.3 Cask Contents

The HI-STORM 100 System is designed to house different types of MPCs. The MPCs are designed to store both BWR and PWR spent nuclear fuel assemblies. Tables 1.2.1 and 1.2.2 provide key system data and parameters for the MPCs. A description of acceptable fuel assemblies for storage in the MPCs is provided in Section 2.1. This includes fuel assemblies classified as damaged fuel assemblies and fuel debris in accordance with the definitions of these terms in Table 1.0.1. A summary of the types of fuel authorized for storage in each MPC model is provided below. All fuel assemblies, non-fuel hardware, and neutron sources must meet the fuel specifications provided in Section 2.1. All fuel assemblies classified as damaged fuel or fuel debris must be stored in damaged fuel containers.

MPC-24

The MPC-24 is designed to accommodate up to twenty-four (24) PWR fuel assemblies classified as intact fuel assemblies, with or without non-fuel hardware.

~~MPC-24E~~

~~The MPC-24E is designed to accommodate up to twenty-four (24) PWR fuel assemblies, with or without non-fuel hardware. Up to four (4) fuel assemblies may be classified as damaged fuel assemblies, with the balance being classified as intact fuel assemblies. Damaged fuel assemblies must be stored in fuel storage locations 3, 6, 19, and/or 22 (see Figure 1.2.4).~~

MPC-24E and MPC-24EF

The *MPC-24E and* MPC-24EF *are*~~is~~ designed to accommodate up to twenty-four (24) PWR fuel assemblies, with or without non-fuel hardware. Up to four (4) fuel assemblies may be classified as damaged fuel assemblies or fuel debris, with the balance being classified as intact fuel assemblies. Damaged fuel assemblies and fuel debris must be stored in fuel storage locations 3, 6, 19, and/or 22 (see Figure 1.2.4).

~~MPC-32~~

~~The MPC-32 is designed to accommodate up to thirty-two (32) PWR fuel assemblies with or without non-fuel hardware. Up to eight (8) of these assemblies may be classified as damaged fuel~~

~~assemblies, with the balance being classified as intact fuel assemblies. Damaged fuel assemblies must be stored in fuel storage locations 1, 4, 5, 10, 23, 28, 29, and/or 32 (see Figure 1.2.3).~~

MPC-32 and MPC-32F

The *MPC-32 and* MPC-32F *are*~~is~~ designed to store up to thirty two (32) PWR fuel assemblies with or without non-fuel hardware. Up to eight (8) of these assemblies may be classified as damaged fuel assemblies or fuel debris, with the balance being classified as intact fuel assemblies. Damaged fuel assemblies and fuel debris must be stored in fuel storage locations 1, 4, 5, 10, 23, 28, 29, and/or 32 (see Figure 1.2.3).

~~MPC-68~~

~~The MPC-68 is designed to accommodate up to sixty-eight (68) BWR intact and/or damaged fuel assemblies, with or without channels. For the Dresden Unit 1 or Humboldt Bay plants, the number of damaged fuel assemblies may be up to a total of 68. For damaged fuel assemblies from plants other than Dresden Unit 1 and Humboldt Bay, the number of damaged fuel assemblies is limited to sixteen (16) and must be stored in fuel storage locations 1, 2, 3, 8, 9, 16, 25, 34, 35, 44, 53, 60, 61, 66, 67, and/or 68 (see Figure 1.2.2).~~

MPC-68F

The MPC-68F is designed to accommodate up to sixty-eight (68) Dresden Unit 1 or Humboldt Bay BWR fuel assemblies (with or without channels) made up of any combination of fuel assemblies classified as intact fuel assemblies, damaged fuel assemblies, and up to four (4) fuel assemblies classified as fuel debris.

MPC-68 and MPC-68FF

The *MPC-68 and* MPC-68FF ~~is~~ *are* designed to accommodate up to sixty-eight (68) BWR fuel assemblies with or without channels. Any number of these fuel assemblies may be Dresden Unit 1 or Humboldt Bay BWR fuel assemblies classified as intact fuel or damaged fuel. Dresden Unit 1 and Humboldt Bay fuel debris is limited to eight (8) DFCs. DFCs containing Dresden Unit 1 or Humboldt Bay fuel debris may be stored in any fuel storage location. For BWR fuel assemblies from plants other than Dresden Unit 1 and Humboldt Bay, the total number of fuel assemblies classified as damaged fuel assemblies or fuel debris is limited to sixteen (16), with up to eight (8) of the 16 fuel assemblies classified as fuel debris. These fuel assemblies must be stored in fuel storage locations 1, 2, 3, 8, 9, 16, 25, 34, 35, 44, 53, 60, 61, 66, 67, and/or 68 (see Figure 1.2.2). The balance of the fuel storage locations may be filled with intact BWR fuel assemblies, up to a total of 68.

Table 1.2.1

KEY SYSTEM DATA FOR HI-STORM 100 SYSTEM

ITEM	QUANTITY	NOTES
Types of MPCs ~~included in this revision of the submittal~~	8	5 for PWR 3 for BWR
MPC storage capacity†:	MPC-24 MPC-24E MPC-24EF	Up to 24 intact ZR or stainless steel clad PWR fuel assemblies with or without non-fuel hardware. Up to 4 damaged fuel assemblies ~~may be stored in the MPC-24E and up to 4 damaged fuel assemblies~~ and/or fuel assemblies classified as fuel debris may be stored in the *MPC-24E or* MPC-24EF. OR
	MPC-32 MPC-32F	Up to 32 intact ZR or stainless steel clad PWR fuel assemblies with or without non-fuel hardware. Up to 8 damaged fuel assemblies ~~may be stored in the MPC-32 and up to 8 damaged fuel assemblies~~ and/or fuel assemblies classified as fuel debris may be stored in the *MPC-32 or* MPC-32F.
	~~MPC-68~~	~~Any combination of Dresden Unit 1 or Humboldt Bay damaged fuel assemblies in damaged fuel containers and intact fuel assemblies, up to a total of 68. For damaged fuel other than Dresden Unit 1 and Humboldt Bay, the number of fuel assemblies is limited to 16, with the balance being intact fuel assemblies.~~ ~~OR~~

† See Section 2.1 for a complete description of cask authorized cask contents and fuel specifications.

Table 1.2.1 (continued)
KEY SYSTEM DATA FOR HI-STORM 100 SYSTEM

ITEM	QUANTITY	NOTES
MPC storage capacity:	MPC-68F	Up to 4 damaged fuel containers with ZR clad Dresden Unit 1 (D-1) or Humboldt Bay (HB) BWR fuel debris and the complement damaged ZR clad Dresden Unit 1 or Humboldt Bay BWR fuel assemblies in damaged fuel containers or intact Dresden Unit 1 or Humboldt Bay BWR intact fuel assemblies. OR
	MPC-68 MPC-68FF	Up to 68 Dresden Unit 1 or Humboldt Bay intact fuel or damaged fuel and up to 8 damaged fuel containers containing D-1 or HB fuel debris. For other BWR plants, up to 16 damaged fuel containers containing BWR damaged fuel and/or fuel debris with the complement intact fuel assemblies, up to a total of 68. The number of damaged fuel containers containing BWR fuel debris is limited to 8 for all BWR plants.

Table 1.2.2
KEY PARAMETERS FOR HI-STORM 100 MULTI-PURPOSE CANISTERS

	PWR	BWR
Pre-disposal service life (years)	40	40
Design temperature, max./min. (^{o}F)	725^{o†}/-40^{o††}	725^{o†}/-40^{o††}
Design internal pressure (psig) Normal conditions Off-normal conditions Accident Conditions	 100 110 200	 100 110 200
Total heat load, max. (kW)	~~28.74~~*36.9*	~~28.19~~*36.9*
Maximum permissible peak fuel cladding temperature: Long Term Normal (^{o}F) Short Term Operations (^{o}F) Off-Normal and Accident (^{o}F)	 752 752 or 1058††† 1058	 752 752 or 1058††† 1058
MPC internal environment Helium fill (99.995% fill helium purity)	(all pressure ranges are at a reference temperature of 70°F)	(all pressure ranges are at a reference temperature of 70°F)
MPC-24 (heat load ≤ 27.77 kW)	≥ 29.3 psig and ≤ ~~33.3~~~~47.5~~*48.5* psig OR 0.1212 +/-10% g-moles/liter	
(heat load > 27.77 kW)	≥ ~~*44.5*~~*45.5 psig and* ≤ ~~*47.5*~~*48.5 psig*	
MPC-24E/24EF (heat load ≤ 28.17 kW)	≥ 29.3 psig and ≤ ~~33.3~~~~47.5~~*48.5* psig OR 0.1212 +/-10% g-moles/liter	
(heat load > 28.17 kW)	> ~~*44.5*~~*45.5 psig and* <	

† Maximum normal condition design temperatures for the MPC fuel basket. A complete listing of design temperatures for all components is provided in Table 2.2.3.

†† Temperature based on off-normal minimum environmental temperatures specified in Section 2.2.2.2 and no fuel decay heat load.

††† See Section 4.5 for discussion of the applicability of the 1058°F temperature limit during MPC drying.

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MPC-68/68F/68FF (heat load ≤ 28.19 kW) *(heat load > 28.19 kW)* MPC-32/32F (heat load ≤ 28.74 kW) *(heat load > 28.74 kW)*	~~*47.5*~~*48.5 psig* ≥ 29.3 psig and ≤ ~~48.8~~*48.5* psig ≥ ~~*44.5*~~*45.5 psig and* ≤ ~~*47.5*~~*48.5 psig*	≥ 29.3 psig and ≤ ~~33.3~~*48.5* psig OR 0.1218 +/-10% g-moles/liter ≥ ~~*44.5*~~*45.5 psig and* ≤ ~~*47.5*~~*48.5 psig*

Table 1.2.2 (cont'd)
KEY PARAMETERS FOR HI-STORM 100 MULTI-PURPOSE CANISTERS

Maximum permissible multiplication factor (k_{eff}) including all uncertainties and biases	< 0.95	< 0.95
Fixed Neutron Absorber (Boral / Metamic) ^{10}B Areal Density (g/cm^2)	0.0267/0.0223 (MPC-24) 0.0372/0.0310 (MPC-24E, MPC-24EF MPC-32 & MPC-32F)	0.0372/0.0310 (MPC-68 & MPC-68FF) 0.01/NA (MPC-68F) (See Note 1)
End closure(s)	Welded	Welded
Fuel handling	Opening compatible with standard grapples	Opening compatible with standard grapples
Heat dissipation	Passive	Passive

NOTES:

1. All MPC-68F canisters are equipped with Boral neutron absorber.

Tables 1.2.3 through 1.2.5

INTENTIONALLY DELETED

Table 1.2.6

HI-STORM 100 OPERATIONS SEQUENCE

Site-specific handling and operations procedures will be prepared, reviewed, and approved by each owner/user.	
1	HI-TRAC and MPC lowered into the fuel pool without lids
2	Fuel assemblies transferred into the MPC fuel basket
3	MPC lid lowered onto the MPC
4	HI-TRAC/MPC assembly moved to the decon pit and MPC lid welded in place, volumetrically or multi-layer PT examined, and pressure tested
5	MPC dewatered, moisture removed, backfilled with helium, and the closure ring welded
6	HI-TRAC annulus drained and external surfaces decontaminated
7	MPC lifting cleats installed and MPC weight supported by rigging
8	HI-TRAC pool lid removed and transfer lid attached (not applicable to HI-TRAC 125D)
9	MPC lowered and seated on HI-TRAC transfer lid (not applicable to HI-TRAC 125D)
9a	HI-STORM mating device secured to top of empty HI-STORM overpack (HI-TRAC 125D only)
10	HI-TRAC/MPC assembly transferred to atop HI-STORM overpack or mating device, as applicable
11	MPC weight supported by rigging and transfer lid doors opened (standard design HI-TRAC) or pool lid removed (HI-TRAC 125D)
12	MPC lowered into HI-STORM overpack, and HI-TRAC removed from atop HI-STORM overpack/mating device
12a	HI-STORM mating device removed (HI-TRAC 125D only)
13	HI-STORM overpack lid installed and bolted in place
14	HI-STORM overpack placed in storage at the ISFSI pad
15	For HI-STORM 100A (or 100SA) users, the overpack is anchored to the ISFSI pad by installation of nuts onto studs and torquing to the minimum required torque.

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Table 1.2.7

REPRESENTATIVE ASME BOLTING AND THREADED ROD MATERIALS ACCEPTABLE
FOR THE HI-STORM 100A ANCHORAGE SYSTEM

ASME MATERIALS FOR BOLTING

Composition	I.D.	Type Grade or UNC No.	Ultimate Strength (ksi)	Yield Strength (ksi)	Code Permitted Size Range†
C	SA-354	BC K04100	125	109	t ≤ 2.5”
¾ Cr	SA-574	51B37M	170	135	t ≥ 5/8”
1 Cr – 1/5 Mo	SA-574	4142	170	135	t ≥ 5/8”
1 Cr-1/2 Mo-V	SA-540	B21 (K 14073)	165	150	t ≤ 4”
5 Cr – ½ Mo	SA-193	B7	125	105	t ≤ 2.5”
$2N_i$ – ¾ Cr – ¼ Mo	SA-540	B23 (H-43400)	135	120	
$2N_i$ – ¾ Cr – 1/3 Mo	SA-540	B-24 (K-24064)	135	120	
17Cr-4Ni-4Cu	SA-564	630 (H-1100)	140	115	
17Cr-4Ni-4Cu	SA-564	630 (H-1075)	145	125	
25Ni-15Cr-2Ti	SA-638	660	130	85	
22CR-13Ni-5Mn	SA-479	XM-19 (S20910)	135	105	

Note: The materials listed in this table are representative of acceptable materials and have been abstracted from the ASME Code, Section II, Part D, Table 3. Other materials listed in the Code are also acceptable as long as they meet the size requirements, the minimum requirements on yield and ultimate strength (see Table 2.0.4), and are suitable for the environment.

† Nominal diameter of the bolt (or rod) as listed in the Code tables. Two-inch diameter studs/rods are specified for the HI-STORM 100A.

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Table 1.2.8

METAMIC® DATA FOR HOLTEC MPCs

MPC Type	Min. B-10 areal density required by criticality analysis (g/cm^2)	Nominal Weight Percent of B_4C and Reference **METAMIC®** Panel Thickness			
		100% Credit	90% Credit	75% Credit	Ref. Thickness (inch)
MPC-24	0.020	27.6	31	37.2	0.075
MPC-68, -68FF, -32, -32F, -24E, and -24EF	0.0279	27.8	31	37.4	0.104

CHAPTER 2†: PRINCIPAL DESIGN CRITERIA

This chapter contains a compilation of design criteria applicable to the HI-STORM 100 System. The loadings and conditions prescribed herein for the MPC, particularly those pertaining to mechanical accidents, are far more severe in most cases than those required for 10CFR72 compliance. The MPC is designed to be in compliance with both 10CFR72 and 10CFR71 and therefore certain design criteria are overly conservative for storage. This chapter sets forth the loading conditions and relevant acceptance criteria; it does not provide results of any analyses. The analyses and results carried out to demonstrate compliance with the design criteria are presented in the subsequent chapters of this report.

This chapter is in full compliance with NUREG-1536, except for the exceptions and clarifications provided in Table 1.0.3. Table 1.0.3 provides the NUREG-1536 review guidance, the justification for the exception or clarification, and the Holtec approach to meet the intent of the NUREG-1536 guidance.

2.0 PRINCIPAL DESIGN CRITERIA

The design criteria for the MPC, HI-STORM overpack, and HI-TRAC transfer cask are summarized in Tables 2.0.1, 2.0.2, and 2.0.3, respectively, and described in the sections that follow.

2.0.1 MPC Design Criteria

General

The MPC is designed for 40 years of service, while satisfying the requirements of 10CFR72. The adequacy of the MPC design for the design life is discussed in Section 3.4.12.

Structural

The MPC is classified as important to safety. The MPC structural components include the internal fuel basket and the enclosure vessel. The fuel basket is designed and fabricated as a core support structure, in accordance with the applicable requirements of Section III, Subsection NG of the ASME Code, with certain NRC-approved alternatives, as discussed in Section 2.2.4. The enclosure vessel is designed and fabricated as a Class 1 component pressure vessel in accordance with Section III, Subsection NB of the ASME Code, with certain NRC-approved alternatives, as discussed in Section 2.2.4. The principal exception is the MPC lid, vent and drain port cover plates, and closure ring welds to the MPC lid and shell, as discussed in Section 2.2.4. In addition, the threaded holes in

† This chapter has been prepared in the format and section organization set forth in Regulatory Guide 3.61. However, the material content of this chapter also fulfills the requirements of NUREG-1536. Pagination and numbering of sections, figures, and tables are consistent with the convention set down in Chapter 1, Section 1.0, herein. Finally, all terms-of-art used in this chapter are consistent with the terminology of the glossary (Table 1.0.1) and component nomenclature of the Bill-of-Materials (Section 1.5).

the MPC lid are designed in accordance with the requirements of ANSI N14.6 for critical lifts to facilitate vertical MPC transfer.

The MPC closure welds are partial penetration welds that are structurally qualified by analysis, as presented in Chapter 3. The MPC lid and closure ring welds are inspected by performing a liquid penetrant examination of the root pass and/or final weld surface (if more than one weld pass was required), in accordance with the drawings contained in Section 1.5. The integrity of the MPC lid weld is further verified by performing a volumetric (or multi-layer liquid penetrant) examination, and a Code pressure test.

The structural analysis of the MPC, in conjunction with the redundant closures and nondestructive examination, pressure testing, and helium leak testing (performed during MPC fabrication), provides assurance of canister closure integrity in lieu of the specific weld joint requirements of Section III, Subsection NB.

Compliance with the ASME Code as it is applied to the design and fabrication of the MPC and the associated justification are discussed in Section 2.2.4. The MPC is designed for all design basis normal, off-normal, and postulated accident conditions, as defined in Section 2.2. These design loadings include postulated drop accidents while in the cavity of the HI-STORM overpack or the HI-TRAC transfer cask. The load combinations for which the MPC is designed are defined in Section 2.2.7. The maximum allowable weight and dimensions of a fuel assembly to be stored in the MPC are limited in accordance with Section 2.1.5.

The structural analysis to evaluate the margin against fuel rod damage from buckling under the drop accident scenario remains unchanged considering ISG-11, Revision 3 because no credit for the tensile stresses in the fuel rods due to internal pressure is taken. Because recognition of the state of tensile axial stress in the fuel cladding permitted by ISG-11 Revision 3 increases the resistance under axial buckling, neglecting the internal pressure buckling analysis is conservative. Therefore, compliance with ISG-11 Revision 3 does not have material effect on the structural analyses summarized in Chapter 3 of this FSAR.

Thermal

The design and operation of the HI-STORM 100 System meets the intent of the review guidance contained in ISG-11, Revision 3 [2.0.8]. Specifically, the ISG-11 provisions that are explicitly invoked and satisfied are:

i. The thermal acceptance criteria for all commercial spent fuel (CSF) authorized by the USNRC for operation in a commercial reactor are unified into one set of requirements.

ii. The maximum value of the *calculated* temperature for all CSF (including ZR and stainless steel fuel cladding materials) under long-term normal conditions of storage must remain below 400ºC (752ºF). For short-term operations, including canister drying, helium backfill, and on-site cask transport operations, the fuel cladding temperature must not exceed 400ºC (752ºF) for high burnup fuel and 570ºC (1058ºF) for moderate burnup fuel.

iii. The maximum fuel cladding temperature as a result of an off-normal or accident event must not exceed 570ºC (1058ºF).

iv. For High Burnup Fuel (HBF), operating restrictions are imposed to limit the maximum temperature excursion during short-term operations to 65ºC (117ºF).

To achieve compliance with the above criteria, certain design and operational changes are necessary, as summarized below.

i. The peak fuel cladding temperature limit (PCT) for long term storage operations and short term operations is generally set at 400ºC (752ºF). However, for MPCs containing all moderate burnup fuel, the fuel cladding temperature limit for short-term operations is set at 570ºC (1058ºF) because fuel cladding stress is shown to be less than approximately 90 MPa per Reference [2.0.9]. Appropriate analyses have been performed as discussed in Chapter 4 and operating restrictions added to ensure these limits are met (see Section 4.5).

ii. For MPCs containing at least one high burnup fuel (HBF) assembly, the forced helium dehydration (FHD) method of MPC cavity drying must be used to meet the normal operations PCT limit and satisfy the 65ºC temperature excursion criterion for HBF.

iii. The off-normal and accident condition PCT limit remains unchanged (1058ºF).

~~iv. For high burnup fuel *above a threshold heat load*, the Supplemental Cooling System (SCS) is required to ensure fuel cladding temperatures remain below the applicable temperature limit (see Section 4.5). The design criteria for the SCS are provided in Appendix 2.C.~~

The MPC cavity is dried using either a vacuum drying system, or a forced helium dehydration system (see Appendix 2.B). The MPC is backfilled with 99.995% pure helium in accordance with the limits in Table 1.2.2 during canister sealing operations to promote heat transfer and prevent cladding degradation.

The *normal condition* design temperatures for the structural steel components of the MPC are based on the temperature limits provided in ASME Section II, Part D, tables referenced in ASME Section III, Subsection NB and NG, for those load conditions under which material properties are relied on for a structural load combination. The specific design temperatures for the components of the MPC are provided in Table 2.2.3.

The MPCs are designed for a bounding thermal source term, as described in Section 2.1.6. The maximum allowable fuel assembly heat load for each MPC is limited as specified in Section 2.1.9.

Each MPC model, except MPC-68F, allows for two fuel loading strategies. The first is uniform fuel loading, wherein any authorized fuel assembly may be stored in any fuel storage location *up to a maximum specific heat emission rate*, subject to other restrictions, such as location requirements for damaged fuel containers (DFCs) and fuel with integral non-fuel hardware (e.g., *APSR*~~control rod~~

~~assemblies~~). The second is regionalized fuel loading, wherein the basket is segregated into two regions. ~~. Region 1 is the inner region where fuel assemblies with higher heat emission rates may be stored and Region 2 is the outer region where fuel assemblies with lower heat emission rates are stored.~~ Regionalized loading allows for storage of fuel assemblies with higher heat emission rates ~~(in Region 1)~~ than would otherwise be authorized for ~~loading under a~~ uniform loading ~~strategy~~. Regionalized loading strategies must also comply with other requirements, such as those for DFCs and non-fuel hardware. Specific fuel assembly cooling time, burnup, and decay heat limits for regionalized loading are presented in Section 2.1.9. The two fuel loading regions are defined by fuel storage location number in Table 2.1.*27*~~13~~ (refer to Figures 1.2.2 through 1.2.4). For MPC-68F, only uniform loading is permitted.

Shielding

The allowable doses for an ISFSI using the HI-STORM 100 System are delineated in 10CFR72.104 and 72.106. Compliance with these regulations for any particular array of casks at an ISFSI is necessarily site-specific and is to be demonstrated by the licensee, as discussed in Chapters 5 and 12. Compliance with these regulations for a single cask and several representative cask arrays is demonstrated in Chapters 5 and 10.

The MPC provides axial shielding at the top and bottom ends to maintain occupational exposures ALARA during canister closure and handling operations. The occupational doses are controlled in accordance with plant-specific procedures and ALARA requirements (discussed in Chapter 10).

The MPCs are designed for design basis fuel as described in Sections 2.1.7 and 5.2. The radiological source term for the MPCs is limited based on the burnup and cooling times specified in Section 2.1.9. Calculated dose rates for each MPC are provided in Section 5.1. These dose rates are used to perform an occupational exposure evaluation, as discussed in Chapter 10.

Criticality

The MPCs provide criticality control for all design basis normal, off-normal, and postulated accident conditions, as discussed in Section 6.1. The effective neutron multiplication factor is limited to $k_{eff} <$ 0.95 for fresh unirradiated fuel with optimum water moderation and close reflection, including all biases, uncertainties, and MPC manufacturing tolerances.

Criticality control is maintained by the geometric spacing of the fuel assemblies, fixed borated neutron absorbing materials incorporated into the fuel basket assembly, and, for certain MPC models, soluble boron in the MPC water. The minimum specified boron concentration verified during neutron absorber manufacture is further reduced by 25% for criticality analysis for Boral-equipped MPCs and by 10% for METAMIC®-equipped MPCs. No credit is taken for burnup. The maximum allowable initial enrichment for fuel assemblies to be stored in each MPC is limited. Enrichment limits and soluble boron concentration requirements are delineated in Section 2.1.9 consistent with the criticality analysis described in Chapter 6.

Confinement

The MPC provides for confinement of all radioactive materials for all design basis normal, off-normal, and postulated accident conditions. As discussed in Section 7.1, the Holtec MPC design meets the guidance in Interim Staff Guidance 18 to classify confinement boundary leakage as non-credible. Therefore, no confinement dose analysis is performed. The confinement function of the MPC is verified through pressure testing, helium leak testing and weld examinations performed in accordance with the acceptance test program in Chapter 9.

Operations

There are no radioactive effluents that result from storage or transfer operations. Effluents generated during MPC loading are handled by the plant's radwaste system and procedures.

Generic operating procedures for the HI-STORM 100 System are provided in Chapter 8. Detailed operating procedures will be developed by the licensee based on Chapter 8, site-specific requirements that comply with the 10CFR50 Technical Specifications for the plant, and the HI-STORM 100 System CoC.

Acceptance Tests and Maintenance

The fabrication acceptance basis and maintenance program to be applied to the MPCs are described in Chapter 9. The operational controls and limits to be applied to the MPCs are discussed in Chapter 12. Application of these requirements will assure that the MPC is fabricated, operated, and maintained in a manner that satisfies the design criteria defined in this chapter.

Decommissioning

The MPCs are designed to be transportable in the HI-STAR overpack and are not required to be unloaded prior to shipment off-site. Decommissioning of the HI-STORM 100 System is addressed in Section 2.4.

2.0.2 HI-STORM Overpack Design Criteria

General

The HI-STORM overpack is designed for 40 years of service, while satisfying the requirements of 10CFR72. The adequacy of the overpack design for the design life is discussed in Section 3.4.11.

Structural

The HI-STORM overpack includes both concrete and structural steel components that are classified as important to safety.

The concrete material is defined as important to safety because of its importance to the shielding analysis. The primary function of the HI-STORM overpack concrete is shielding of the gamma and neutron radiation emitted by the spent nuclear fuel.

Unlike other concrete storage casks, the HI-STORM overpack concrete is enclosed in steel inner and outer shells connected to each other by four radial ribs, and top and bottom plates. Where typical concrete storage casks are reinforced by rebar, the HI-STORM overpack is supported by the inner and outer shells connected by four ribs. As the HI-STORM overpack concrete is not reinforced, the structural analysis of the overpack only credits the compressive strength of the concrete. Providing further conservatism, the structural analyses for normal conditions demonstrate that the allowable stress limits of the structural steel are met even with no credit for the strength of the concrete. During accident conditions (e.g., tornado missile, tip-over, end drop, and earthquake), only the compressive strength of the concrete is accounted for in the analysis to provide an appropriate simulation of the accident condition. Where applicable, the compressive strength of the concrete is calculated in accordance with *ACI-318.1-89 (92)*~~ACI-318-95~~ [2.0.1].

In recognition of the conservative assessment of the HI-STORM overpack concrete strength and the primary function of the concrete being shielding, the applicable requirements of ACI-349 [2.0.2] are invoked in the design and construction of the HI-STORM overpack concrete as clarified in Appendix 1.D.

Steel components of the storage overpack are designed and fabricated in accordance with the requirements of ASME Code, Section III, Subsection NF for Class 3 plate and shell components with certain NRC-approved alternatives.

The overpack is designed for all normal, off-normal, and design basis accident condition loadings, as defined in Section 2.2. At a minimum, the overpack must protect the MPC from deformation, provide continued adequate performance, and allow the retrieval of the MPC under all conditions. These design loadings include a postulated drop accident from the maximum allowable handling height, consistent with the analysis described in Section 3.4.9. The load combinations for which the overpack is designed are defined in Section 2.2.7. The physical characteristics of the MPCs for which the overpack is designed are defined in Chapter 1.

Thermal

The allowable long-term through-thickness section average temperature limit for the overpack concrete is established in accordance with Paragraph A.4.3 of Appendix A to ACI 349, which allows the use of elevated temperature limits if test data supporting the compressive strength is available and an evaluation to show no concrete deterioration provided. Appendix 1.D specifies the cement and aggregate requirements to allow the utilization of the 300°F temperature limit. For short term conditions the through-thickness section average concrete temperature limit of 350°F is specified in accordance with Paragraph A.4.2 of Appendix A to ACI 349. The allowable temperatures for the structural steel components are based on the maximum temperature for which material properties and allowable stresses are provided in Section II of the ASME Code. The specific allowable temperatures for the structural steel components of the overpack are provided in Table 2.2.3.

The overpack is designed for extreme cold conditions, as discussed in Section 2.2.2.2. The structural steel materials used for the storage cask that are susceptible to brittle fracture are discussed in Section 3.1.2.3.

The overpack is designed for the maximum allowable heat load for steady-state normal conditions, in accordance with Section 2.1.6. The thermal characteristics of the MPCs for which the overpack is designed are defined in Chapter 4.

Shielding

The off-site dose for normal operating conditions *to a real individual beyond*~~at~~ the controlled area boundary is limited by 10CFR72.104(a) to a maximum of 25 mrem/year whole body, 75 mrem/year thyroid, and 25 mrem/year for other critical organs, including contributions from all nuclear fuel cycle operations. Since these limits are dependent on plant operations as well as site-specific conditions (e.g., the ISFSI design and proximity to the controlled area boundary, and the number and arrangement of loaded storage casks on the ISFSI pad), the determination and comparison of ISFSI doses to this limit are necessarily site-specific. Dose rates for a single cask and a range of typical ISFSIs using the HI-STORM 100 System are provided in Chapter 5. The determination of site-specific ISFSI dose rates at the site boundary and demonstration of compliance with regulatory limits is to be performed by the licensee in accordance with 10CFR72.212.

The overpack is designed to limit the calculated surface dose rates on the cask for all MPCs as defined in Section 2.3.5. The overpack is also designed to maintain occupational exposures ALARA during MPC transfer operations, in accordance with 10CFR20. The calculated overpack dose rates are determined in Section 5.1. These dose rates are used to perform a generic occupational exposure estimate for MPC transfer operations and a dose assessment for a typical ISFSI, as described in Chapter 10.

Confinement

The overpack does not perform any confinement function. Confinement during storage is provided by the MPC and is addressed in Chapter 7. The overpack provides physical protection and biological shielding for the MPC confinement boundary during MPC dry storage operations.

Operations

There are no radioactive effluents that result from MPC transfer or storage operations using the overpack. Effluents generated during MPC loading and closure operations are handled by the plant's radwaste system and procedures under the licensee's 10CFR50 license.

Generic operating procedures for the HI-STORM 100 System are provided in Chapter 8. The licensee is required to develop detailed operating procedures based on Chapter 8, site-specific conditions and requirements that also comply with the applicable 10CFR50 technical specification requirements for the site, and the HI-STORM 100 System CoC.

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Acceptance Tests and Maintenance

The fabrication acceptance basis and maintenance program to be applied to the overpack are described in Chapter 9. The operational controls and limits to be applied to the overpack are contained in Chapter 12. Application of these requirements will assure that the overpack is fabricated, operated, and maintained in a manner that satisfies the design criteria defined in this chapter.

Decommissioning

Decommissioning considerations for the HI-STORM 100 System, including the overpack, are addressed in Section 2.4.

2.0.3 HI-TRAC Transfer Cask Design Criteria

General

The HI-TRAC transfer cask is designed for 40 years of service, while satisfying the requirements of 10CFR72. The adequacy of the HI-TRAC design for the design life is discussed in Section 3.4.11.

Structural

The HI-TRAC transfer cask includes both structural and non-structural biological shielding components that are classified as important to safety. The structural steel components of the HI-TRAC, with the exception of the lifting trunnions, are designed and fabricated in accordance with the applicable requirements of Section III, Subsection NF, of the ASME Code with certain NRC-approved alternatives, as discussed in Section 2.2.4. The lifting trunnions and associated attachments are designed in accordance with the requirements of NUREG-0612 and ANSI N14.6 for non-redundant lifting devices.

The HI-TRAC transfer cask is designed for all normal, off-normal, and design basis accident condition loadings, as defined in Section 2.2. At a minimum, the HI-TRAC transfer cask must protect the MPC from deformation, provide continued adequate performance, and allow the retrieval of the MPC under all conditions. These design loadings include a side drop from the maximum allowable handling height, consistent with the technical specifications. The load combinations for which the HI-TRAC is designed are defined in Section 2.2.7. The physical characteristics of each MPC for which the HI-TRAC is designed are defined in Chapter 1.

Thermal

The allowable temperatures for the HI-TRAC transfer cask structural steel components are based on the maximum temperature for material properties and allowable stress values provided in Section II of the ASME Code. The top lid*s* of the ~~HI-TRAC 100 and~~ HI-TRAC 125 *and 125D* incorporate Holtite-A shielding material. This material has a maximum allowable temperature in accordance

with the manufacturer's test data. The specific allowable temperatures for the structural steel and shielding components of the HI-TRAC are provided in Table 2.2.3. The HI-TRAC is designed for off-normal environmental cold conditions, as discussed in Section 2.2.2.2. The structural steel materials susceptible to brittle fracture are discussed in Section 3.1.2.3.

The HI-TRAC is designed for the maximum heat load analyzed for storage operations. ~~When the MPC contains any high burnup fuel assemblies *and has a decay heat load above a threshold value,* the Supplemental Cooling System (SCS) will be required for certain time periods while the MPC is inside the HI-TRAC transfer cask (see Section 4.5). The design criteria for the SCS are provided in Appendix 2.C.~~ The HI-TRAC water jacket maximum allowable temperature is a function of the internal pressure. To preclude over pressurization of the water jacket due to boiling of the neutron shield liquid (water), the maximum temperature of the water is limited to less than the saturation temperature at the shell design pressure. In addition, the water is precluded from freezing during off-normal cold conditions by limiting the minimum allowable temperature and adding ethylene glycol. The thermal characteristics of the fuel for each MPC for which the transfer cask is designed are defined in Section 2.1.6. The working area ambient temperature limit for loading operations is limited in accordance with the design criteria established for the transfer cask.

Shielding

The HI-TRAC transfer cask provides shielding to maintain occupational exposures ALARA in accordance with 10CFR20, while also maintaining the maximum load on the plant's crane hook to below either 125 tons or 100 tons, or less, depending on whether the *HI-TRAC 125 or* ~~125-ton or 100-ton~~ HI-TRAC *100* transfer cask is utilized. The HI-TRAC calculated dose rates are reported in Section 5.1. These dose rates are used to perform a generic occupational exposure estimate for MPC loading, closure, and transfer operations, as described in Chapter 10. A postulated HI-TRAC accident condition, which includes the loss of the liquid neutron shield (water), is also evaluated in Section 5.1.2. In addition, HI-TRAC dose rates are controlled in accordance with plant-specific procedures and ALARA requirements (discussed in Chapter 10).

The HI-TRAC 125 and 125D provide better shielding than the 100 ton HI-TRAC. Provided the licensee is capable of utilizing the 125 ton HI-TRAC, ALARA considerations would normally dictate that the 125 ton HI-TRAC should be used. However, sites may not be capable of utilizing the 125 ton HI-TRAC due to crane capacity limitations, floor loading limits, or other site-specific considerations. As with other dose reduction-based plant activities, individual users who cannot accommodate the 125 ton HI-TRAC should perform a cost-benefit analysis of the actions (e.g., modifications) which would be necessary to use the 125 ton HI-TRAC. The cost of the action(s) would be weighed against the value of the projected reduction in radiation exposure and a decision made based on each plant’s particular ALARA implementation philosophy.

The HI-TRAC provides a means to isolate the annular area between the MPC outer surface and the HI-TRAC inner surface to minimize the potential for surface contamination of the MPC by spent fuel pool water during wet loading operations. The HI-TRAC surfaces expected to require decontamination are coated. The maximum permissible surface contamination for the HI-TRAC is in

accordance with plant-specific procedures and ALARA requirements (discussed in Chapter 10).

Confinement

The HI-TRAC transfer cask does not perform any confinement function. Confinement during MPC transfer operations is provided by the MPC, and is addressed in Chapter 7. The HI-TRAC provides physical protection and biological shielding for the MPC confinement boundary during MPC closure and transfer operations.

Operations

There are no radioactive effluents that result from MPC transfer operations using HI-TRAC. Effluents generated during MPC loading and closure operations are handled by the plant's radwaste system and procedures.

Generic operating procedures for the HI-STORM 100 System are provided in Chapter 8. The licensee will develop detailed operating procedures based on Chapter 8, plant-specific requirements including the Part 50 Technical Specifications, and the HI-STORM 100 System CoC.

Acceptance Tests and Maintenance

The fabrication acceptance basis and maintenance program to be applied to the HI-TRAC Transfer Cask are described in Chapter 9. The operational controls and limits to be applied to the HI-TRAC are contained in Chapter 12. Application of these requirements will assure that the HI-TRAC is fabricated, operated, and maintained in a manner that satisfies the design criteria defined in this chapter.

Decommissioning

Decommissioning considerations for the HI-STORM 100 Systems, including the HI-TRAC Transfer Cask, are addressed in Section 2.4.

2.0.4 Principal Design Criteria for the ISFSI Pad

2.0.4.1 Design and Construction Criteria

In compliance with 10CFR72, Subpart F, “General Design Criteria”, the HI-STORM 100 cask system is classified as “important-to-safety” (ITS). This final safety analysis report (FSAR) explicitly recognizes the HI-STORM 100 System as an assemblage of equipment containing numerous ITS components. The reinforced concrete pad on which the cask is situated, however, is designated as a non-ITS structure. This is principally because, in most cases, cask systems for storing spent nuclear fuel on reinforced concrete pads are installed as free-standing structures. The lack of a physical connection between the cask and the pad permits the latter to be designated as not important-to-safety.

However, if the ZPAs at the surface of an ISFSI pad exceed the threshold limit for free-standing HI-STORM installation set forth in this FSAR, then the cask must be installed in an anchored configuration (HI-STORM 100A).

In contrast to an ISFSI containing free-standing casks, a constrained-cask installation relies on the structural capacity of the pad to ensure structural safety. The Part 72 regulations require consideration of natural phenomenon in the design. Since an ISFSI pad in an anchored cask installation participates in maintaining the stability of the cask during "natural phenomena" on the cask and pad, it is an ITS structure. The procedure suggested in Regulatory Guide 7.10 [2.0.4] and the associated NUREG [2.0.5] indicates that an ISFSI pad used to secure anchored casks should be classified as a Category C ITS structure.

Because tipover of a cask installed in an anchored configuration is not feasible, the pad does not need to be engineered to accommodate this non-mechanistic event. However, the permissible carry height for a loaded HI-STORM 100A overpack must be established for the specific ISFSI pad using the methodology described in this FSAR, if the load handling device is not designed in accordance with ANSI N 14.6 and does not have redundant drop protection design features. These requirements are specified in the CoC. However, to serve as an effective and reliable anchor, the pad must be made appropriately stiff and suitably secured to preclude pad uplift during a seismic event.

Because the geological conditions vary widely across the United States, it is not possible to, a'priori, define the detailed design of the pad. Accordingly, in this FSAR, the limiting requirements on the design and installation of the pad are provided. The user of the HI-STORM 100A System bears the responsibility to ensure that all requirements on the pad set forth in this FSAR are fulfilled by the pad design. Specifically, the ISFSI owner must ensure that:

- The pad design complies with the structural provisions of this report. In particular, the requirements of ACI-349-97 [2.0.2] with respect to embedments must be assured.

- The material of construction of the pad (viz., the additives used in the pad concrete), and the attachment system are compatible with the ambient environment at the ISFSI site.

- The pad is designed and constructed in accordance with a Part 72, Subpart G-compliant QA program.

- The design and manufacturing of the cask attachment system are consistent with the provisions of this report.

- Evaluations are performed (e.g., per 72.212) to demonstrate that the seismic and other inertial loadings at the site are enveloped by the respective bounding loadings defined in this report.

A complete listing of design and construction requirements for an ISFSI pad on which an anchored HI-STORM 100A will be deployed is provided in Appendix 2.A. A sample embedment design is

depicted in Figure 2.A.1.

2.0.4.2 Applicable Codes

Factored load combinations for ISFSI pad design are provided in NUREG-1536 [2.1.5], which is consistent with ACI-349-85. The factored loads applicable to the pad design consist of dead weight of the cask, thermal gradient loads, impact loads arising from handling and accident events, external missiles, and bounding environmental phenomena (such as earthquakes, wind, tornado, and flood). Codes ACI 360R-92, "Design of Slabs on Grade"; ACI 302.1R, "Guide for Concrete Floor and Slab Construction"; and ACI 224R-90, "Control of Cracking in Concrete Structures" should be used in the design and construction of the concrete pad, as applicable. The embedment design for the HI-STORM 100A (and 100SA) are the responsibility of the ISFSI owner and shall comply with Appendix B to ACI-349-97 as described in Appendix 2.A. A later Code edition may be used provided a written reconciliation is performed.

The factored load combinations presented in Table 3-1 of NUREG 1536 are reduced in the following to a bounding set of load combinations that are applied to demonstrate adherence to its acceptance criteria.

a. Definitions

D = dead load including the loading due to pre-stress in the anchor studs
L = live load
W = wind load
W_t = tornado load
T = thermal load
F = hydrological load
E = DBE seismic load
A = accident load
H = lateral soil pressure
T_a = accident thermal load
U_c= reinforced concrete available strength

Note that in the context of a complete ISFSI design, the DBE seismic load includes both the inertia load on the pad due to its self mass plus the interface loads transmitted to the pad to resist the inertia loads on the cask due to the loaded cask self mass. It is only these interface loads that are provided herein for possible use in the ISFSI structural analyses. The inertia load associated with the seismic excitation of the self mass of the slab needs to be considered in the ISFSI owner's assessment of overall ISFSI system stability in the presence of large uplift, overturning, and sliding forces at the base of the ISFSI pad. Such considerations are site specific and thus beyond the purview of this document.

b. Load Combinations for the Concrete Pad

The notation and acceptance criteria of NUREG-1536 apply.

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Normal Events

$U_c > 1.4D + 1.7L$

$U_c > 1.4D + 1.7 (L+H)$

Off-Normal Events

$U_c > 1.05D + 1.275 (L+H+T)$
$U_c > 1.05D + 1.275 (L+H+T+W)$

Accident-Level Events

$U_c > D+L+H+T+F$
$U_c > D+L+H+T_a$
$U_c > D+L+H+T+E$
$U_c > D+L+H+T+W_t$
$U_c > D+L+H+T+A$

In all of the above load combinations, the loaded cask weight is considered as a live load L on the pad. The structural analyses presented in Chapter 3 provide the interface loads contributing to “E”, “F” and “W_t”, which, for high-seismic sites, are the most significant loadings. The above set of load combinations can be reduced to a more limited set by recognizing that the thermal loads acting on the ISFSI slab are small because of the low decay heat loads from the cask. In addition, standard construction practices for slabs serve to ensure that extreme fluctuations in environmental temperatures are accommodated without extraordinary design measures. Therefore, all thermal loads are eliminated in the above combinations. Likewise, lateral soil pressure load “H” will also be bounded by "F" (hydrological) and "E" (earthquake) loads. Accident loads “A”, resulting from a tipover, have no significance for an anchored cask. The following three load combinations are therefore deemed sufficient for structural qualification of the ISFSI slab supporting an anchored cask system.

Normal Events

$U_c > 1.4D + 1.7 (L)$

Off-Normal Events

$U_c > 1.05D + 1.275 (L+F)$

Accident-Level Events

$U_c > D+L+E$ (or W_t)

c. Load Combination for the Anchor Studs

The attachment bolts are considered to be governed by the ASME Code, Section III, Subsection NF and Appendix F [2.0.7]. Therefore, applicable load combinations and allowable stress limits for the attachment bolts are as follows:

Event Class and Load Combination	Governing ASME Code Section III Article for Stress Limits
Normal Events D	NF-3322.1, 3324.6
Off-Normal Events D+F	NF-3322.1, 3324.6 with all stress limits increased by 1.33
Accident-Level Events D+E and D+W_t	Appendix F, Section F-1334, 1335

2.0.4.3 Limiting Design Parameters

Since the loaded HI-STORM overpack will be carried over the pad, the permissible lift height for the cask must be determined site-specifically to ensure the integrity of the storage system in the event of a handling accident (uncontrolled lowering of the load). To determine the acceptable lift height, it is necessary to set down the limiting ISFSI design parameters. The limiting design parameters for an anchored cask ISFSI pad and the anchor studs, as applicable, are tabulated in Table 2.0.4. The design of steel embedments in reinforced concrete structures is governed by Appendix B of ACI-349-97. Section B.5 in that appendix states that "anchorage design shall be controlled by the strength of embedment steel…". Therefore, limits on the strength of embedment steel and on the anchor studs must be set down not only for the purposes of quantifying structural margins for the design basis load combinations, but also for the use of the ISFSI pad designer to establish the appropriate embedment anchorage in the ISFSI pad.The anchored cask pad design parameters presented in Table 2.0.4 allow for a much stiffer pad than the pad for free-standing HI-STORMs (Table 2.2.9). This increased stiffness has the effect of reducing the allowable lift height. However, a lift height for a loaded HI-STORM 100 cask (free-standing or anchored) is not required to be established if the cask is being lifted with a lift device designed in accordance with ANSI N14.6 having redundant drop protection design features.

In summary, the requirements for the ISFSI pad for free-standing and anchored HI-STORM deployment are similar with a few differences. Table 2.0.5 summarizes their commonality and differences in a succinct manner with the basis for the difference fully explained.

2.0.4.4 Anchored Cask/ISFSI Interface

The contact surface between the baseplate of overpack and the top surface of the ISFSI pad defines the structural interface between the HI-STORM overpack and the ISFSI pad. When HI-STORM is deployed in an anchored configuration, the structural interface also includes the surface where the nuts on the anchor studs bear upon the sector lugs on the overpack baseplate. The anchor studs and their fastening arrangements into the ISFSI pad are outside of the structural boundary of the storage cask. While the details of the ISFSI pad design for the anchored configuration, like that for the free-standing geometry, must be custom engineered for each site, certain design and acceptance criteria are specified herein (Appendix 2.A) to ensure that the design and construction of the pad fully comports with the structural requirements of the HI-STORM System.

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Table 2.0.1
MPC DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
Design Life:			
Design	40 yrs.	-	Table 1.2.2
License	20 yrs.	10CFR72.42(a) and 10CFR72.236(g)	-
Structural:			
Design Codes:			
Enclosure Vessel	ASME Code, Section III, Subsection NB	10CFR72.24(c)(4)	Section 2.0.1
Fuel Basket	ASME Code, Section III, Subsection NG for core supports (NG-1121)	10CFR72.24(c)(4)	Section 2.0.1
MPC Fuel Basket Supports (Angled Plates)	ASME Code, Section III, Subsection NG for internal structures (NG-1122)	10CFR72.24(c)(4)	Section 2.0.1
MPC Lifting Points	ANSI N14.6/NUREG-0612	10CFR72.24(c)(4)	Section 1.2.1.4
Dead Weights[†]:			
Max. Loaded Canister (dry)	90,000 lb.	R.G. 3.61	Table 3.2.1
Empty Canister (dry)	42,000 lb. (MPC-24) 45,000 lb. (MPC-24E/EF) 39,000 lb. (MPC-68/68F/68FF) 36,000 lb. (MPC-32)	R.G. 3.61	Table 3.2.1
Design Cavity Pressures:			
Normal:	100 psig	ANSI/ANS 57.9	Section 2.2.1.3
Off-Normal:	110 psig	ANSI/ANS 57.9	Section 2.2.2.1
Accident (Internal)	200 psig	ANSI/ANS 57.9	Section 2.2.3.8

[†] Weights listed in this table are bounding weights. Actual weights will be less, and will vary based on as-built dimensions of the components, fuel type, and the presence of fuel spacers and non-fuel hardware.

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Table 2.0.1 (continued)
MPC DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
Accident (External)	60 psig	ANSI/ANS 57.9	Sections 2.2.3.6 and 2.2.3.10
Response and Degradation Limits	SNF assemblies confined in dry, inert environment	10CFR72.122(h)(l)	Section 2.0.1
Thermal:			
Maximum Design Temperatures:			
Structural Materials:			
Stainless Steel (Normal)	725° F	ASME Code Section II, Part D	Table 2.2.3
Stainless Steel (Accident)	~~950°~~ *-1200°* F	*See Subsection 2.2.2.3*~~ASME Code Section II, Part D~~	Table 2.2.3
Neutron Poison:			
Neutron Absorber (normal)	800° F	See Table 4.3.1 and *Sub*section 1.2.1.3.1	Table 2.2.3
Neutron Absorber (accident)	~~950°~~ *-1000°* F	See Table 4.3.1 and *Sub*section 1.2.1.3.1	Table 2.2.3
Canister Drying	≤ 3 torr for ≥ 30 minutes (VDS) ≤ 21°F exiting the demoisturizer for ≥ 30 minutes or a dew point of the MPC exit gas ≤ 22.9°F for ≥ 30 minutes(FHD)	NUREG-1536, ISG-11, Rev. 3	Section 4.5, Appendix 2.B
Canister Backfill Gas	Helium	-	Section 4.4
Canister Backfill	Varies (see Table 1.2.2)	Thermal Analysis	Section 4. 4
Fuel cladding temperature limit for long term storage conditions	752 °F (400 °C)	ISG-11, Rev. 3	Section 4.3

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Table 2.0.1 (continued)
MPC DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
Fuel cladding temperature limit for normal short-term operating conditions (e.g., MPC drying and onsite transport)	752 ^{o}F (400 ^{o}C), except certain MPCs containing all moderate burnup fuel (MBF) may use 1058°F (570°C) for normal short-term operating conditions	ISG-11, Rev. 3	Sections 4.3 and 4.5
Fuel cladding temperature limit for Off-Normal and Accident Events	1058° F (570 ^{o}C)	ISG-11, Rev. 3	Sections 2.0.1 and 4.3
Insolation	Protected by overpack or HI-TRAC	-	Section 4.3
Confinement:		10CFR72.128(a)(3) and 10CFR72.236(d) and (e)	
Closure Welds:			
Shell Seams and Shell-to-Baseplate	Full Penetration	-	Section 1.5 and Table 9.1.4
MPC Lid	Multi-pass Partial Penetration	10CFR72.236(e)	Section 1.5 and Table 9.1.4
MPC Closure Ring	Partial Penetration		
Port Covers	Partial Penetration		
NDE:			
Shell Seams and Shell-to-Baseplate	100% RT or UT	-	Table 9.1.4
MPC Lid	Root Pass and Final Surface 100% PT; Volumetric Inspection or 100% Surface PT each 3/8" of weld depth	-	Chapter 8 and Table 9.1.4
Closure Ring	Root Pass (if more than one pass is required) and Final Surface 100% PT	-	Chapter 8 and Table 9.1.4
Port Covers	Root Pass (if more than one pass is required) and Final Surface 100% PT	-	Chapter 8 and Table 9.1.4

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Table 2.0.1 (continued)
MPC DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
Leak Testing:			
Welds Tested	*MPC port covers to lid*	-	Section 9.1
Medium	Helium	-	Section 9.1
Max. Leak Rate	*"leaktight"per ANSI 14.5-1997*	-	Section 9.1
Monitoring System	None	10CFR72.128(a)(1)	Section 2.3.2.1
Pressure Testing:			
Minimum Test Pressure	125 psig (hydrostatic) 120 psig (pneumatic)	-	Sections 8.1 and 9.1
Welds Tested	MPC Lid-to-Shell, MPC Shell seams, MPC Shell-to-Baseplate	-	Sections 8.1 and 9.1
Medium	Water or helium	-	Section 8.1 and Chapter 9
Retrievability:			
Normal and Off-normal: Post (design basis) Accident	No Encroachment on Fuel Assemblies or Exceeding Fuel Assembly Deceleration Limits	10CFR72.122(f),(h)(1), & (l)	Sections 3.4, 3.5, and 3.1.2
Criticality:		10CFR72.124 & 10CFR72.236(c)	
Method of Control	Fixed Borated Neutron Absorber, Geometry, and Soluble Boron	-	Section 2.3.4
Min. ^{10}B Loading (Boral/METAMIC®)	0.0267/0.0223 g/cm^2 (MPC-24) 0.0372/0.0310 g/cm^2 (MPC-68, MPC-68FF, MPC-24E, MPC-24EF, MPC-32 and MPC-32F) 0.01 g/cm^2 (MPC-68F)	-	Sections 2.1.8 and 6.1
Minimum Soluble Boron	Varies (see Tables 2.1.14 and 2.1.16)	Criticality Analysis	Sections 2.1.9 and 6.1
Max. k_{eff}	0.95	-	Sections 6.1 and 2.3.4
Min. Burnup	0.0 GWd/MTU (fresh fuel)	-	Section 6.1

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Table 2.0.1 (continued)
MPC DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
Radiation Protection/Shielding:		10CFR72.126, & 10CFR72.128(a)(2)	
MPC: (normal/off-normal/accident)			
MPC Closure	ALARA	10CFR20	Sections 10.1, 10.2, & 10.3
MPC Transfer	ALARA	10CFR20	Sections 10.1, 10.2, & 10.3
Exterior of Shielding: (normal/off-normal/accident)			
Transfer Mode Position	See Table 2.0.3	10CFR20	Section 5.1.1
ISFSI Controlled Area Boundary	See Table 2.0.2	10CFR72.104 & 10CFR72.106	Section 5.1.1 and Chapter 10
Design Bases:		10CFR72.236(a)	
Spent Fuel Specification:			
Assemblies/Canister	Up to 24 (MPC-24, MPC-24E & MPC-24EF) Up to 32 (MPC-32 and MPC-32F) Up to 68 (MPC-68, MPC-68F, & MPC-68FF)	-	Table 1.2.1 and Section 2.1.9
Type of Cladding	ZR and Stainless Steel	-	Section 2.1.9
Fuel Condition	Intact, Damaged, and Debris	-	Sections 2.1.2, 2.1.3, and 2.1.9
PWR Fuel Assemblies:			
Type/Configuration	Various	-	Section 2.1.9
Max. Burnup	68,200 MWD/MTU	-	Sections 2.1.9 and 6.2

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Table 2.0.1 (continued)
MPC DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
Max. Enrichment	Varies by fuel design	-	Table 2.1.3 and Section 2.1.9
Max. Decay Heat/ MPC†:	~~28.74~~*36.9* kW	-	Section 4.4
Minimum Cooling Time:	3 years (Intact ZR Clad Fuel) 8 years (Intact SS Clad Fuel)	-	Section 2.19
Max. Fuel Assembly Weight: (including non-fuel hardware and DFC, as applicable)	*1,720 lb. for fuel assemblies that do not require fuel spacers, otherwise* 1,680 lb.	-	Section 2.1.9
Max. Fuel Assembly Length: (Unirradiated Nominal)	176.8 in.	-	Section 2.1.9
Max. Fuel Assembly Width (Unirradiated Nominal)	8.54 in.	-	Section 2.1.9
BWR Fuel Assemblies:			
Type	Various	-	Sections 2.1.9 and 6.2
Max. Burnup	65,000 MWD/MTU	-	Section 2.1.9
Max. Enrichment	Varies by fuel design	-	Section 2.1.9, Table 2.1.4
Max. Decay Heat/ MPC†:	~~28.19~~*36.9* kW	-	Section 4.4
Minimum Cooling Time:	3 years (Intact ZR Clad Fuel) 8 years (Intact SS Clad Fuel)		Section 2.1.9
Max. Fuel Assembly Weight:			
w/channels and DFC, as applicable	~~700 lb.~~ *730 lb.*	-	Section 2.1.9
Max. Fuel Assembly Length (Unirradiated Nominal)	176.5in.	-	Section 2.1.9
Max. Fuel Assembly Width (Unirradiated Nominal)	5.85 in.	-	Section 2.1.9
Normal Design Event Conditions:		10CFR72.122(b)(1)	
Ambient Temperatures	See Tables 2.0.2 and 2.0.3	ANSI/ANS 57.9	Section 2.2.1.4

† Section 2.1.9.1 describes the decay heat limits per assembly
† Section 2.1.9.1 describes the decay heat limits per assembly.

Table 2.0.1 (continued)
MPC DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
Handling:			Section 2.2.1.2
Handling Loads	115% of Dead Weight	CMAA #70	Section 2.2.1.2
Lifting Attachment Acceptance Criteria	1/10 Ultimate 1/6 Yield	NUREG-0612 ANSI N14.6	Section 3.4.3
Attachment/Component Interface Acceptance Criteria	1/3 Yield	Regulatory Guide 3.61	Section 3.4.3
Away from Attachment Acceptance Criteria	ASME Code Level A	ASME Code	Section 3.4.3
Wet/Dry Loading	Wet or Dry	-	Section 1.2.2.2
Transfer Orientation	Vertical	-	Section 1.2.2.2
Storage Orientation	Vertical	-	Section 1.2.2.2
Fuel Rod Rupture Releases:			
Source Term Release Fraction	1%	NUREG-1536	Sections 2.2.1.3
Fill Gases	100%	NUREG-1536	Sections 2.2.1.3
Fission Gases	30%	NUREG-1536	Sections 2.2.1.3
Snow and Ice	Protected by Overpack	ASCE 7-88	Section 2.2.1.6
Off-Normal Design Event Conditions:		10CFR72.122(b)(1)	
Ambient Temperature	See Tables 2.0.2 and 2.0.3	ANSI/ANS 57.9	Section 2.2.2.2
Leakage of One Seal	N/A	ISG-18	Sections 2.2.2.4 and 7.1
Partial Blockage of Overpack Air Inlets	~~Two~~ *50% of* Air Inlets Blocked	-	Section 2.2.2.5
Source Term Release Fraction:			
Fuel Rod Failures	10%	NUREG-1536	Sections 2.2.2.1
Fill Gases	100%	NUREG-1536	Sections 2.2.2.1
Fission Gases	30%	NUREG-1536	Sections 2.2.2.1
Design-Basis (Postulated) Accident Design Events and Conditions:		10CFR72.24(d)(2) & 10CFR72.94	
Tip Over	See Table 2.0.2	-	Section 2.2.3.2

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Table 2.0.1 (continued)
MPC DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
End Drop	See Table 2.0.2	-	Section 2.2.3.1
Side Drop	See Table 2.0.3	-	Section 2.2.3.1
Fire	See Tables 2.0.2 and 2.0.3	10CFR72.122(c)	Section 2.2.3.3
Fuel Rod Rupture Releases:			
Fuel Rod Failures (including non-fuel hardware)	100%	NUREG-1536	Sections 2.2.3.8
Fill Gases	100%	NUREG-1536	Sections 2.2.3.8
Fission Gases	30%	NUREG-1536	Sections 2.2.3.8
Particulates & Volatiles	See Table 7.3.1	-	Sections 2.2.3.9
Confinement Boundary Leakage	None	ISG-18 / *ANSI N14.5*	Sections 2.2.3.9 and 7.1
Explosive Overpressure	60 psig (external)	10CFR72.122(c)	Section 2.2.3.10
Airflow Blockage:			
Vent Blockage	100% of Overpack Air Inlets Blocked	10CFR72.128(a)(4)	Section 2.2.3.13
Partial Blockage of MPC Basket Vent Holes	Crud Depth (Table 2.2.8)	ESEERCO Project EP91-29	Section 2.2.3.4
Design Basis Natural Phenomenon Design Events and Conditions:		10CFR72.92 & 10CFR72.122(b)(2)	
Flood Water Depth	125 ft.	ANSI/ANS 57.9	Section 2.2.3.6
Seismic	See Table 2.0.2	10CFR72.102(f)	Section 2.2.3.7
Wind	Protected by Overpack	ASCE-7-88	Section 2.2.3.5
Tornado & Missiles	Protected by Overpack	RG 1.76 & NUREG-0800	Section 2.2.3.5
Burial Under Debris	Maximum Decay Heat Load	-	Section 2.2.3.12
Lightning	See Table 2.0.2	NFPA 78	Section 2.2.3.11
Extreme Environmental Temperature	See Table 2.0.2	-	Section 2.2.3.14

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Table 2.0.2
HI-STORM OVERPACK DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
Design Life:			
Design	40 yrs.	-	Section 2.0.2
License	20 yrs.	10CFR72.42(a) & 10CFR72.236(g)	
Structural:			
Design & Fabrication Codes:			
Concrete			
Design	ACI 349 as clarified in Appendix 1.D	10CFR72.24(c)(4)	Section 2.0.2 and Appendix 1.D
Fabrication	ACI 349 as clarified in Appendix 1.D	10CFR72.24(c)(4)	Section 2.0.2 and Appendix 1.D
Compressive Strength	*ACI 318.1-89 (92)*~~ACI 318-95~~ as clarified in Appendix 1.D	10CFR72.24(c)(4)	Section 2.0.2 and Appendix 1.D
Structural Steel			
Design	ASME Code Section III, Subsection NF	10CFR72.24(c)(4)	Section 2.0.2
Fabrication	ASME Code Section III, Subsection NF	10CFR72.24(c)(4)	Section 2.0.2
Dead Weights[†]:			
Max. Loaded MPC (Dry)	90,000 lb. (MPC- 32)	R.G. 3.61	Table 3.2.1
Max. Empty Overpack Assembled with Top Lid (150 pcf concrete/200pcf concrete)	270,000/320,000 lb.	R.G. 3.61	Table 3.2.1
Max. MPC/Overpack (150 pcf concrete/200pcf concrete)	360,000/410,000 lb.	R.G. 3.61	Table 3.2.1
Design Cavity Pressures	N/A	-	Section 2.2.1.3
Response and Degradation Limits	Protect MPC from deformation	10CFR72.122(b) 10CFR72.122(c)	Sections 2.0.2 and 3.1

[†] Weights listed in this table are bounding weights. Actual weights will be less, and will vary based on as-built dimensions of the components, fuel type, and the presence of fuel spacers and non-fuel hardware, as applicable.

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Table 2.0.2 (continued)
HI-STORM 100 OVERPACK DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
	Continued adequate performance of overpack	10CFR72.122(b) 10CFR72.122(c)	
	Retrieval of MPC	10CFR72.122(l)	
Thermal:			
Maximum Design Temperatures:			
Concrete			
Through-Thickness Section Average (Normal)	300° F	ACI 349, Appendix A (Paragraph A.4.3)	Section 2.0.2, and Tables 1.D.1 and 2.2.3
Through-Thickness Section Average (Off-*N*~~n~~ormal and Accident)	350° F	ACI 349 Appendix A (Paragraph A.4.2)	Section 2.0.2, and Tables 1.D.1 and 2.2.3
Steel Structure (other than lid top and bottom plates) Lid Top and Bottom Plates	350° F 450°F	ASME Code Section II, Part D	Table 2.2.3
Insolation:	Averaged Over 24 Hours	10CFR71.71	Section 4.4.1.1.8
Confinement:	None	10CFR72.128(a)(3) & 10CFR72.236(d) & (e)	N/A
Retrievability:			
Normal and Off-normal	No damage that precludes Retrieval of MPC or Exceeding Fuel Assembly Deceleration Limits	10CFR72.122(f),(h)(1), & (l)	Sections 3.5 and 3.4
Accident			Sections 3.5 and 3.4
Criticality:	Protection of MPC and Fuel Assemblies	10CFR72.124 & 10CFR72.236(c)	Section 6.1
Radiation Protection/Shielding:		10CFR72.126 & 10CFR72.128(a)(2)	
Overpack (Normal/Off-normal/Accident)			
Surface	ALARA	10CFR20	Chapters 5 and 10
Position	ALARA	10CFR20	Chapters 5 and 10

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Table 2.0.2 (continued)
HI-STORM 100 OVERPACK DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
Beyond Controlled Area During Normal Operation and Anticipated Occurrences	25 mrem/yr. to whole body 75 mrem/yr. to thyroid 25 mrem/yr. to any critical organ	10CFR72.104	Sections 5.1.1, 7.2, and 10.1
At Controlled Area Boundary from Design Basis Accident	5 rem TEDE or sum of DDE and CDE to any individual organ or tissue (other than lens of eye) $\leq$ 50 rem. 15 rem lens dose. 50 rem shallow dose to skin or extremity.	10CFR72.106	Sections 5.1.2, 7.3, and 10.1
Design Bases:			
Spent Fuel Specification	See Table 2.0.1	10CFR72.236(a)	Section 2.1.9
Normal Design Event Conditions:		10CFR72.122(b)(1)	
Ambient Outside Temperatures:			
Max. Yearly Average	80° F	ANSI/ANS 57.9	Section 2.2.1.4
Live Load[†]:		ANSI/ANS 57.9	-
Loaded Transfer Cask (max.)	250,000 lb. (HI-TRAC 125 w/transfer lid)	R.G. 3.61	Table 3.2.4 Section 2.2.1.2
Dry Loaded MPC (max.)	90,000 lb.	R.G. 3.61	Table 3.2.1 and Section 2.2.1.2
Handling:			Section 2.2.1.2
Handling Loads	115% of Dead Weight	CMAA #70	Section 2.2.1.2
Lifting Attachment Acceptance Criteria	1/10 Ultimate 1/6 Yield	NUREG-0612 ANSI N14.6	Section 3.4.3
Attachment/Component Interface Acceptance Criteria	1/3 Yield	Regulatory Guide 3.61	Section 3.4.3
Away from Attachment	ASME Code	ASME Code	Section 3.4.3

[†] Weights listed in this table are bounding weights. Actual weights will be less, and will vary based on as-built dimensions of the components, fuel type, and the presence of fuel spacers and non-fuel hardware, as applicable.

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Table 2.0.2 (continued)
HI-STORM 100 OVERPACK DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
Acceptance Criteria	Level A		
Minimum Temperature During Handling Operations	0° F	ANSI/ANS 57.9	Section 2.2.1.2
Snow and Ice Load	100 lb./ft^2	ASCE 7-88	Section 2.2.1.6
Wet/Dry Loading	Dry	-	Section 1.2.2.2
Storage Orientation	Vertical	-	Section 1.2.2.2
Off-Normal Design Event Conditions:		10CFR72.122(b)(1)	
Ambient Temperature			
Minimum	-40° F	ANSI/ANS 57.9	Section 2.2.2.2
Maximum	100° F	ANSI/ANS 57.9	Section 2.2.2.2
Partial Blockage of Air Inlets	*50% of* ~~Two~~ Air Inlet ~~Ducts~~ Blocked	-	Section 2.2.2.5
Design-Basis (Postulated) Accident Design Events and Conditions:		10CFR72.94	
Drop Cases:			
End	11 in.	-	Section 2.2.3.1
Tip-Over (Not applicable for HI-STORM 100A)	Assumed (Non-mechanistic)	-	Section 2.2.3.2
Fire:			
Duration	217 seconds	10CFR72.122(c)	Section 2.2.3.3
Temperature	$1,475^o$ F	10CFR72.122(c)	Section 2.2.3.3
Fuel Rod Rupture	See Table 2.0.1	-	Section 2.2.3.8
Air Flow Blockage:			
Vent Blockage	100% of Air Inlets Blocked	10CFR72.128(a)(4)	Section 2.2.3.13
Ambient Temperature	80° F	10CFR72.128(a)(4)	Section 2.2.3.13
Explosive Overpressure External Differential Pressure	10 psid instantaneous, 5 psid steady state	10 CFR 72.128(a)(4)	Table 2.2.1
Design-Basis Natural Phenomenon Design Events and Conditions:		10CFR72.92 & 10CFR72.122(b)(2)	
Flood			
Height	125 ft.	RG 1.59	Section 2.2.3.6
Velocity	15 ft/sec.	RG 1.59	Section 2.2.3.6

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Table 2.0.2 (continued)
HI-STORM 100 OVERPACK DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
Seismic			
Max. acceleration at top of ISFSI pad	Free Standing: $G_H + 0.53G_V \leq 0.53$ Anchored: $G_H \leq 2.12$, $G_V \leq 1.5$	10CFR72.102(f)	Section 3.4.7.1 Section 3.4.7.3
Tornado			
Wind			
Max. Wind Speed	360 mph	RG 1.76	Section 2.2.3.5
Pressure Drop	3.0 psi	RG 1.76	Section 2.2.3.5
Missiles			Section 2.2.3.5
Automobile			
Weight	1,800 kg	NUREG-0800	Table 2.2.5
Velocity	126 mph	NUREG-0800	Table 2.2.5
Rigid Solid Steel Cylinder			
Weight	125 kg	NUREG-0800	Table 2.2.5
Velocity	126 mph	NUREG-0800	Table 2.2.5
Diameter	8 in.	NUREG-0800	Table 2.2.5
Steel Sphere			
Weight	0.22 kg	NUREG-0800	Table 2.2.5
Velocity	126 mph	NUREG-0800	Table 2.2.5
Diameter	1 in.	NUREG-0800	Table 2.2.5
Burial Under Debris	Maximum Decay Heat Load	-	Section 2.2.3.12
Lightning	Resistance Heat-Up	NFPA 70 & 78	Section 2.2.3.11
Extreme Environmental Temperature	125° F	-	Section 2.2.3.14
Load Combinations:	See Table 2.2.14 and Table 3.1.5	ANSI/ANS 57.9 and NUREG-1536	Section 2.2.7

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TABLE 2.0.3
HI-TRAC TRANSFER CASK DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
Design Life:			
Design	40 yrs.	-	Section 2.0.3
License	20 yrs.	10CFR72.42(a) & 10CFR72.236(g)	
Structural:			
Design Codes:			
Structural Steel	ASME Code, Section III, Subsection NF	10CFR72.24(c)(4)	Section 2.0.3
Lifting Trunnions	NUREG-0612 & ANSI N14.6	10CFR72.24(c)(4)	Section 1.2.1.4
Dead Weights[†]:			
Max. Empty Cask:			
w/top lid and pool lid installed and water jacket filled	143,500 lb. (HI-TRAC 125) 102,000 lb. (HI-TRAC 100) 146,000 lb. (HI-TRAC 125D)	R.G. 3.61	Table 3.2.2
w/top lid and transfer lid installed and water jacket filled (N/A for HI-TRAC 125D)	155,000 lb. (HI-TRAC 125) 111,000 lb. (HI-TRAC 100)	R.G. 3.61	Table 3.2.2
Max. MPC/HI-TRAC with Yoke (in-pool lift):			
Water Jacket Empty	250,000 lb. (HI-TRAC 125 and 125D) 202,000 lb. (HI-TRAC 100)	R.G. 3.61	Table 3.2.4
Design Cavity Pressures:			
HI-TRAC Cavity	Hydrostatic	ANSI/ANS 57.9	Section 2.2.1.3
Water Jacket Cavity	60 psig (internal)	ANSI/ANS 57.9	Section 2.2.1.3
Response and Degradation Limits	Protect MPC from deformation	10CFR72.122(b) 10CFR72.122(c)	Section 2.0.3

[†] Weights listed in this table are bounding weights. Actual weights will be less, and will vary based on as-built dimensions of the components, fuel type, and the presence of fuel spacers and non-fuel hardware, as applicable.

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TABLE 2.0.3 (continued)
HI-TRAC TRANSFER CASK DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
	Continued adequate performance of HI-TRAC transfer cask	10CFR72.122(b) 10CFR72.122(c)	
	Retrieval of MPC	10CFR72.122(l)	
Thermal:			
Maximum Design Temperature			
Structural Materials	400° F	ASME Code Section II, Part D	Table 2.2.3
Shielding Materials			
Lead	350° F (max.)		Table 2.2.3
Liquid Neutron Shield	307° F (max.)	-	Table 2.2.3
Solid Neutron Shield	300° F (max.) (long term) 350°F (max.) (short term)	Test Data	Appendix 1.B and Table 2.2.3
Insolation:	Averaged Over 24 Hours	10CFR71.71	Section 4.5.1.1.3
Confinement:	None	10CFR72.128(a)(3) & 10CFR72.236(d) & (e)	N/A
Retrievability:			
Normal and Off-normal	No encroachment on MPC or Exceeding Fuel Assembly Deceleration Limits	10CFR72.122(f),(h)(1), & (l)	Sections 3.5 & 3.4
After Design-basis (Postulated) Accident			Section 3.5 & 3.4
Criticality:	Protection of MPC and Fuel Assemblies	10CFR72.124 & 10CFR72.236(c)	Section 6.1
Radiation Protection/Shielding:		10CFR72.126 & 10CFR72.128(a)(2)	
Transfer Cask (Normal/Off-normal/Accident)			
Surface	ALARA	10CFR20	Chapters 5 and 10
Position	ALARA	10CFR20	Chapters 5 and 10
Design Bases:			
Spent Fuel Specification	See Table 2.0.1	10CFR72.236(a)	Section 2.1
Normal Design Event Conditions:		10CFR72.122(b)(1)	
Ambient Temperature~~s~~:	*80 °F*	*ANSI/ANS 57.9*	*Section 2.2.1.4*

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TABLE 2.0.3 (continued)
HI-TRAC TRANSFER CASK DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
~~Lifetime Average~~	~~100° F~~	~~ANSI/ANS 57.9~~	~~Section 2.2.1.4~~
Live Load†			
Max. Loaded Canister			
Dry	90,000 lb.	R.G. 3.61	Table 3.2.1
Wet (including water in HI-TRAC annulus)	106,570 lb.	R.G. 3.61	Table 3.2.4
Handling:			Section 2.2.1.2
Handling Loads	115% of Dead Weight	CMAA #70	Section 2.2.1.2
Lifting Attachment Acceptance Criteria	1/10 Ultimate 1/6 Yield	NUREG-0612 ANSI N14.6	Section 3.4.3
Attachment/Component Interface Acceptance Criteria	1/3 Yield	Regulatory Guide 3.61	Section 3.4.3
Away from Attachment Acceptance Criteria	ASME Code Level A	ASME Code	Section 3.4.3
Minimum Temperature for Handling Operations	0° F	ANSI/ANS 57.9	Section 2.2.1.2
Wet/Dry Loading	Wet or Dry	-	Section 1.2.2.2
Transfer Orientation	Vertical	-	Section 1.2.2.2
Test Loads:			
Trunnions	300% of vertical design load	NUREG-0612 & ANSI N14.6	Section 9.1.2.1
~~**Off-Normal Design Event Conditions:**~~		~~10CFR72.122(b)(1)~~	
~~Ambient Temperature~~			
~~Minimum~~	~~0° F~~	~~ANSI/ANS 57.9~~	~~Section 2.2.2.2~~
~~Maximum~~	~~100° F~~	~~ANSI/ANS 57.9~~	~~Section 2.2.2.2~~
Design-Basis (Postulated) Accident Design Events and Conditions:		10CFR72.24(d)(2) & 10CFR72.94	
Side Drop	42 in.	-	Section 2.2.3.1

† Weights listed in this table are bounding weights. Actual weights will be less, and will vary based on as-built dimensions of the components, fuel type, and the presence of fuel spacers and non-fuel hardware, as applicable.

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TABLE 2.0.3 (continued)
HI-TRAC TRANSFER CASK DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
Fire			
Duration	4.8 minutes	10CFR72.122(c)	Section 2.2.3.3
Temperature	1,475^{o} F	10CFR72.122(c)	Section 2.2.3.3
Fuel Rod Rupture	See Table 2.0.1		Section 2.2.3.8
Design-Basis Natural Phenomenon Design Events and Conditions:		10CFR72.92 & 10CFR72.122(b)(2)	
Missiles			Section 2.2.3.5
Automobile			
Weight	1800 kg	NUREG-0800	Table 2.2.5
Velocity	126 mph	NUREG-0800	Table 2.2.5
Rigid Solid Steel Cylinder			
Weight	125 kg	NUREG-0800	Table 2.2.5
Velocity	126 mph	NUREG-0800	Table 2.2.5
Diameter	8 in.	NUREG-0800	Table 2.2.5
Steel Sphere			
Weight	0.22 kg	NUREG-0800	Table 2.2.5
Velocity	126 mph	NUREG-0800	Table 2.2.5
Diameter	1 in.	NUREG-0800	Table 2.2.5
Load Combinations:	See Table 2.2.14 and Table 3.1.5	ANSI/ANS-57.9 & NUREG-1536	Section 2.2.7

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TABLE 2.0.4
LIMITING DESIGN PARAMETERS FOR ISFSI PADS AND ANCHOR STUDS FOR HI-STORM 100A

Item	Maximum Permitted Value†	Minimum Permitted Value
ISFSI PAD		
Pad Thickness	---	48 inches
Subgrade Young's Modulus from Static Tests (needed if pad is not founded on rock)	---	10,000 psi
Concrete compressive strength at 28 days	---	4,000 psi
ANCHOR STUDS		
Yield Strength at Ambient Temperature	None	80,000 psi
Ultimate Strength at Ambient Temperature	None	125,000 psi
Initial Stud Tension	65 ksi	55 ksi

† Pad and anchor stud parameters to be determined site-specifically, except where noted.

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TABLE 2.0.5
ISFSI PAD REQUIREMENTS FOR FREE-STANDING AND ANCHORED HI-STORM INSTALLATION

Item	Free-Standing	Anchored	Comments
1. Interface between cask and ISFSI	Contact surface between cask and top surface of ISFSI pad	Same as free-standing with the addition of the bearing surface between the anchor stud nut and the overpack baseplate. (The interface between the anchor stud and the anchor receptacle is at the applicable threaded or bearing surface).	All components below the top surface of the ISFSI pad and in contact with the pad concrete are part of the pad design. A non-integral component such as the anchor stud is not part of the embedment even though it may be put in place when the ISFSI pad is formed. The embedment for the load transfer from the anchor studs to the concrete ISFSI pad shall be exclusively cast-in-place.
2. Applicable ACI Code	At the discretion of the ISFSI owner. ACI-318 and ACI-349 are available candidate codes.	ACI-349-97. A later edition of this Code may be used if a written reconciliation is performed.	ACI-349-97 recognizes increased structural role of the ISFSI pad in an anchored cask storage configuration and imposes requirements on embedment design.
3. Limitations on the pad design parameters	Per Table 2.2.9	Per Table 2.0.4	In free-standing cask storage, the non-mechanistic tipover requirement limits the stiffness of the pad. In the anchored storage configuration, increased pad stiffness is permitted; however, the permissible HI-STORM carry height is reduced.
4. HI-STORM Carry Height	11 inches (for ISFSI pad parameter Set A or Set B) or, otherwise, site-specific. Not applicable if the cask is lifted with a device designed in accordance with ANSI N14.6 and having redundant drop protection features.	Determined site-specifically. Not applicable if the cask is lifted with a device designed in accordance with ANSI N14.6 and having redundant drop protection features.	Appendix 3.A provides the technical basis for free-standing installation. Depending on the final ISFSI pad configuration (thickness, concrete strength, subgrade,etc.), and the method of transport, an allowable carry height may need to be established.

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TABLE 2.0.5 (continued)
ISFSI PAD REQUIREMENTS FOR FREE-STANDING AND ANCHORED HI-STORM INSTALLATION

Item	Free-Standing	Anchored	Comments
5. Maximum seismic input on the pad/cask contact surface. G_H is the vectorial sum of the two horizontal ZPAs and G_V is the vertical ZPA	$G_H + \mu G_V \leq \mu$	$G_H \leq 2.12$ AND $G_V \leq 1.5$	
6. Required minimum value of cask to pad static coefficient of friction (μ, must be confirmed by testing).	Greater than or equal to 0.53 (per Table 2.2.9).	Same as that for free-standing condition	
7. Applicable Wind and Large Missile Loads	Per Table 2.2.4, missile and wind loading different from the tabulated values, require 10CFR 72.48 evaluation	The maximum overturning moment at the base of the cask due to lateral missile and/or wind action must be less than 1×10^7 ft-lb.	The bases are provided in Section 3.4.8 for free-standing casks; the limit for anchored casks ensures that the anchorage system will have the same structural margins established for seismic loading.
8. Small and medium missiles (penetrant missile)	Per Table 2.2.5, missiles and wind loading different from the tabulated value, require 10CFR 72.48 evaluation.	Same as for free-standing cask construction.	
9. Design Loadings for the ISFSI Pad	Per load combinations in Section 2.0.4 using site-specific load.	Same as for free-standing cask.	

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2.2 HI-STORM 100 DESIGN CRITERIA

The HI-STORM 100 System is engineered for unprotected outside storage for the duration of its design life. Accordingly, the cask system is designed to withstand normal, off-normal, and environmental phenomena and accident conditions of storage. Normal conditions include the conditions that are expected to occur regularly or frequently in the course of normal operation. Off-normal conditions include those infrequent events that could reasonably be expected to occur during the lifetime of the cask system. Environmental phenomena and accident conditions include events that are postulated because their consideration establishes a conservative design basis.

Normal condition loads act in combination with all other loads (off-normal or environmental phenomena/accident). Off-normal condition loads and environmental phenomena and accident condition loads are not applied in combination. However, loads that occur as a result of the same phenomena are applied simultaneously. For example, the tornado winds loads are applied in combination with the tornado missile loads.

In the following subsections, the design criteria are established for normal, off-normal, and accident conditions for storage. Loads that require consideration under each condition are identified and the design criteria discussed. Based on consideration of the applicable requirements of the system, the following loads are identified:

Normal (Long-Term Storage) Condition: Dead Weight, Handling, Pressure, Temperature, Snow

Off-Normal Condition: Pressure, Temperature, Leakage of One Seal, Partial Blockage of Air Inlets, Off-Normal Handling of HI-TRAC.~~, Supplemental Cooling System Power Failure~~

Accident Condition: Handling Accident, Tip-Over, Fire, Partial Blockage of MPC Basket Vent Holes, Tornado, Flood, Earthquake, Fuel Rod Rupture, Confinement Boundary Leakage, Explosion, Lightning, Burial Under Debris, 100% Blockage of Air Inlets, Extreme Environmental Temperature. ~~Supplemental Cooling System Operational Failure~~

Short-Term Operations: This loading condition is defined to accord with ISG-11, Revision 3 guidance [2.0.8]. This includes those normal operational evolutions necessary to support fuel loading or unloading activities. These include, but are not limited to MPC cavity drying, helium backfill, MPC transfer, and on-site handling of a loaded HI-TRAC transfer cask.

Each of these conditions and the applicable loads are identified with applicable design criteria established. Design criteria are deemed to be satisfied if the specified allowable limits are not exceeded.

2.2.1 Normal Condition Design Criteria

2.2.1.1 Dead Weight

The HI-STORM 100 System must withstand the static loads due to the weights of each of its components, including the weight of the HI-TRAC with the loaded MPC atop the storage overpack.

2.2.1.2 Handling

The HI-STORM 100 System must withstand loads experienced during routine handling. Normal handling includes:

i. vertical lifting and transfer to the ISFSI of the HI-STORM overpack with loaded MPC
ii. lifting, upending/downending, and transfer to the ISFSI of the HI-TRAC with loaded MPC in the vertical or horizontal position
iii. lifting of the loaded MPC into and out of the HI-TRAC, HI-STORM, or HI-STAR overpack

The loads shall be increased by 15% to include any dynamic effects from the lifting operations as directed by CMAA #70 [2.2.16].

Handling operations of the loaded HI-TRAC transfer cask or HI-STORM overpack are limited to working area ambient temperatures greater than or equal to 0°F. This limitation is specified to ensure that a sufficient safety margin exists before brittle fracture might occur during handling operations. Subsection 3.1.2.3 provides the demonstration of the adequacy of the HI-TRAC transfer cask and the HI-STORM overpack for use during handling operations at a minimum service temperature of 0° F.

Lifting attachments and *special lifting* devices shall meet the requirements of ANSI N14.6[†] [2.2.3].

2.2.1.3 Pressure

The MPC internal pressure is dependent on the initial volume of cover gas (helium), the volume of fill gas in the fuel rods, the fraction of fission gas released from the fuel matrix, the number of fuel rods assumed to have ruptured, and temperature.

The normal condition MPC internal design pressure bounds the cumulative effects of the maximum fill gas volume, normal environmental ambient temperatures, the maximum MPC heat load, and an assumed 1% of the fuel rods ruptured with 100% of the fill gas and 30% of the significant radioactive gases (e.g., H^3, Kr, and Xe) released in accordance with NUREG-1536.

[†] Yield and ultimate strength values used in the stress compliance demonstration per ANSI N14.6 shall utilize confirmed material test data through either independent coupon testing or material suppliers= CMTR or COC, as appropriate. To ensure consistency between the design and fabrication of a lifting component, compliance with ANSI N14.6 in this FSAR implies that the guidelines of ASME Section III, Subsection NF for Class 3 structures are followed for material procurement and testing, fabrication, and for NDE during manufacturing.

Table 2.2.1 provides the design pressures for the HI-STORM 100 System.

For the storage of damaged fuel assemblies or fuel debris in a damaged fuel container, it is conservatively assumed that 100% of the fuel rods are ruptured with 100% of the rod fill gas and 30% of the significant radioactive gases (e.g., H^3, Kr, and Xe) released for both normal and off-normal conditions. For PWR assemblies stored with non-fuel hardware, it is assumed that 100% of the gasses in the non-fuel hardware (e.g., BPRAs) is also released. This condition is bounded by the pressure calculation for design basis intact fuel with 100% of the fuel rods ruptured in all of the fuel assemblies. It is shown in Chapter 4 that the accident condition design pressure is not exceeded with 100% of the fuel rods ruptured in all of the design basis fuel assemblies. Therefore, rupture of 100% of the fuel rods in the damaged fuel assemblies or fuel debris will not cause the MPC internal pressure to exceed the accident design pressure.

The MPC internal design pressure under accident conditions is discussed in Subsection 2.2.3.

The HI-STORM overpack and MPC external pressure is a function of environmental conditions which may produce a pressure loading. The normal and off-normal condition external design pressure is set at ambient standard pressure (1 atmosphere).

The HI-STORM overpack is not capable of retaining internal pressure due to its open design, and, therefore, no analysis is required or provided for the overpack internal pressure.

The HI-TRAC is not capable of retaining internal pressure due to its open design and, therefore, ambient and hydrostatic pressures are the only pressures experienced. Due to the thick steel walls of the HI-TRAC transfer cask, it is evident that the small hydrostatic pressure can be easily withstood; no analysis is required or provided for the HI-TRAC internal pressure. However, the HI-TRAC water jacket does experience internal pressure due to the heat-up of the water contained in the water jacket. Analysis is presented in Chapter 3 that demonstrates that the design pressure in Table 2.2.1 can be withstood by the water jacket and Chapter 4 demonstrates by analysis that the water jacket design pressure will not be exceeded. To provide an additional layer of safety, a pressure relief device set at the design pressure is provided, which ensures the pressure will not be exceeded.

2.2.1.4 Environmental Temperatures

To evaluate the long-term effects of ambient temperatures on the HI-STORM 100 System, an upper bound value on the annual average ambient temperatures for the continental United States is used. The normal temperature specified in Table 2.2.2 is bounding for all reactor sites in the contiguous United States. The "normal" temperature set forth in Table 2.2.2 is intended to ensure that it is greater than the annual average of ambient temperatures at any location in the continental United States. In the northern region of the U.S., the design basis "normal" temperature used in this FSAR will be exceeded only for brief periods, whereas in the southern U.S, it may be straddled daily in summer months. Inasmuch as the sole effect of the "normal" temperature is on the computed fuel cladding temperature to establish long-term fuel integrity, it should not lie below the time averaged

yearly mean for the ISFSI site. Previously licensed cask systems have employed lower "normal" temperatures (viz. 75° F in Docket 72-1007) by utilizing national meteorological data.

Likewise, within the thermal analysis, a conservatively assumed soil temperature of the value specified in Table 2.2.2 is utilized to bound the annual average soil temperatures for the continental United States. The 1987 ASHRAE Handbook (HVAC Systems and Applications) reports average earth temperatures, from 0 to 10 feet below grade, throughout the continental United States. The highest reported annual average value for the continental United States is 77° F for Key West, Florida. Therefore, this value is specified in Table 2.2.2 as the bounding soil temperature.

Confirmation of the site-specific annual average ambient temperature and soil temperature is to be performed by the licensee, in accordance with 10CFR72.212. The annual average temperature is combined with insolation in accordance with 10CFR71.71 averaged over 24 hours to establish the normal condition temperatures in the HI-STORM 100 System.

2.2.1.5 Design Temperatures

The ASME Boiler and Pressure Vessel Code (ASME Code) requires that the value of the vessel design temperature be established with appropriate consideration for the effect of heat generation internal or external to the vessel. The decay heat load from the spent nuclear fuel is the internal heat generation source for the HI-STORM 100 System. The ASME Code (Section III, Paragraph NCA-2142) requires the design temperature to be set at or above the maximum through thickness mean metal temperature of the pressure part under normal service (Level A) condition. Consistent with the terminology of NUREG-1536, we refer to this temperature as the "Design Temperature for Normal Conditions". Conservative calculations of the steady-state temperature field in the HI-STORM 100 System, under assumed environmental normal temperatures with the maximum decay heat load, result in HI-STORM component temperatures at or below the normal condition design temperatures for the HI-STORM 100 System defined in Table 2.2.3.

Maintaining fuel rod cladding integrity is also a design consideration. The fuel rod peak cladding temperature (PCT) limits for the long-term storage and short-term normal operating conditions meet the intent of the guidance in ISG-11, Revision 3 [2.0.8]. For moderate burnup fuel, the previously licensed PCT limit of 570°C (1058°F) may be used [2.0.9] (see also Section 4.5).

2.2.1.6 Snow and Ice

The HI-STORM 100 System must be capable of withstanding pressure loads due to snow and ice. ASCE 7-88 (formerly ANSI A58.1) [2.2.2] provides empirical formulas and tables to compute the effective design pressure on the overpack due to the accumulation of snow for the contiguous U.S. and Alaska. Typical calculated values for heated structures such as the HI-STORM 100 System range from 50 to 70 pounds per square foot. For conservatism, the snow pressure loading is set at a level in Table 2.2.8 which bounds the ASCE 7-88 recommendation.

2.2.2 Off-Normal Conditions Design Criteria

As the HI-STORM 100 System is passive, loss of power and instrumentation failures are not defined as off-normal conditions. The off-normal condition design criteria are defined in the following subsections.

A discussion of the effects of each off-normal condition is provided in Section 11.1. Section 11.1 also provides the corrective action for each off-normal condition. The location of the detailed analysis for each event is referenced in Section 11.1.

2.2.2.1 Pressure

The HI-STORM 100 System must withstand loads due to off-normal pressure. The off-normal condition MPC internal design pressure bounds the cumulative effects of the maximum fill gas volume, off-normal environmental ambient temperatures, the maximum MPC heat load, and an assumed 10% of the fuel rods ruptured with 100% of the fill gas and 30% of the significant radioactive gases (e.g., H^3, Kr, and Xe) released in accordance with NUREG-1536.

2.2.2.2 Environmental Temperatures

The HI-STORM 100 System must withstand off-normal environmental temperatures. The off-normal environmental temperatures are specified in Table 2.2.2. The lower bound temperature occurs with no solar loads and the upper bound temperature occurs with steady- state insolation. Each bounding temperature is assumed to persist for a duration sufficient to allow the system to reach steady-state temperatures.

Limits on the peaks in the time-varying ambient temperature at an ISFSI site is recognized in the FSAR in the specification of the off-normal temperatures. The lower bound off-normal temperature is defined as the minimum of the 72-hour average of the ambient temperature at an ISFSI site. Likewise, the upper bound off-normal temperature is defined by the maximum of 72-hour average of the ambient temperature. The lower and upper bound off-normal temperatures listed in Table 2.2.2 are intended to cover all ISFSI sites in the continent U.S. The 72-hour average of temperature used in the definition of the off-normal temperature recognizes the considerable thermal inertia of the HI-STORM 100 storage system which reduces the effect of undulations in instantaneous temperature on the internals of the multi-purpose canister.

2.2.2.3 Design Temperatures

In addition to the normal condition design temperatures, which apply to long-term storage and short term normal operating conditions (e.g., MPC drying operations and onsite transport operations), we also define an "off-normal/accident condition temperature" pursuant to the provisions of NUREG-1536 and Regulatory Guide 3.61. This is, in effect, the temperature which may exist during a transient event (examples of such instances are the overpack blocked air duct off-normal event and fire accident). The off-normal/accident design temperatures of Table 2.2.3 are set down to bound the maximax (maximum in time and space) value of the thru-thickness average temperature of the

structural or non-structural part, as applicable, during the transient event. These enveloping values, therefore, will bound the maximum temperature reached anywhere in the part, excluding skin effects during or immediately after, a transient event.

The off-normal/accident design temperatures for stainless steel and carbon steel components are chosen such that the material's ultimate tensile strength does not fall below 30% of its room temperature value, based on data in published references [2.2.12 and 2.2.13]. This ensures that the material will not fail due to creep rupture during these short duration transient events.

2.2.2.4 Leakage of One Seal

The MPC enclosure vessel is designed to have no credible leakage under all normal, off-normal, and hypothetical accident conditions of storage.

The confinement boundary is defined by the MPC shell, baseplate, MPC lid, port cover plates, closure ring, and associated welds. Most confinement boundary welds are inspected by radiography or ultrasonic examination. Field welds are examined by the liquid penetrant method on the root (if more than one weld pass is required) and final weld passes. In addition to liquid penetrant examination, the MPC lid-to-shell weld is pressure tested, and volumetrically examined or multi-pass liquid penetrant examined. The vent and drain port cover plates are subject to liquid penetrant examination *and helium leakage testing*. These inspection and testing techniques are performed to verify the integrity of the confinement boundary.

2.2.2.5 Partial Blockage of Air Inlets

The HI-STORM 100 System must withstand the partial blockage of the overpack air inlets. This event is ~~conservatively~~ defined *in Table 2.0.2 as 50%* ~~as a complete~~ blockage of ~~two (2) of~~ the four air inlets. Because the overpack air inlets and outlets are covered by ~~fine mesh steel~~ screens, located 90° apart, and inspected routinely (or alternatively, exit vent air temperature monitored), *significant blockage of*~~it is unlikely that~~ all vents ~~could become blocked~~ by blowing debris, animals, etc. *is very unlikely.*~~during normal and off-normal operations~~. ~~Two of the air inlets are conservatively assumed to be completely blocked~~ *To*~~to~~ demonstrate the inherent thermal stability of the HI-STORM 100 System *all four air inlets are assumed to be 50% blocked*.

2.2.2.6 Off-Normal HI-TRAC Handling

During upending and/or downending of the HI-TRAC 100 or HI-TRAC 125 transfer cask, the total lifted weight is distributed among both the upper lifting trunnions and the lower pocket trunnions. Each of the four trunnions on the HI-TRAC therefore supports approximately one-quarter of the total weight. This even distribution of the load would continue during the entire rotation operation. The HI-TRAC 125D transfer cask design does not include pocket trunnions. Therefore, the entire load is held by the lifting trunnions.

If the lifting device cables begin to "go slack" while upending or downending the HI-TRAC 100 or HI-TRAC 125, the eccentricity of the pocket trunnions would immediately cause the cask to pivot,

restoring tension on the cables. Nevertheless, the pocket trunnions are conservatively analyzed to support one-half of the total weight, doubling the load per trunnion. This condition is analyzed to demonstrate that the pocket trunnions in the standard HI-TRAC design possess sufficient strength to support the increased load under this off-normal condition.

2.2.3 Environmental Phenomena and Accident Condition Design Criteria

Environmental phenomena and accident condition design criteria are defined in the following subsections.

The minimum acceptance criteria for the evaluation of the accident conditions are that the MPC confinement boundary maintains radioactive material confinement, the MPC fuel basket structure maintains the fuel contents subcritical, the stored SNF can be retrieved by normal means, and the system provides adequate shielding.

A discussion of the effects of each environmental phenomenon and accident condition is provided in Section 11.2. The consequences of each accident or environmental phenomenon are evaluated against the requirements of 10CFR72.106 and 10CFR20. Section 11.2 also provides the corrective action for each event. The location of the detailed analysis for each event is referenced in Section 11.2.

2.2.3.1 Handling Accident

The HI-STORM 100 System must withstand loads due to a handling accident. Even though the loaded HI-STORM 100 System will be lifted in accordance with approved, written procedures and may use *special* lifting *devices*~~equipment~~ which complies with ANSI N14.6-1993 [2.2.3], certain drop events are considered herein to demonstrate the defense-in-depth features of the design.

The loaded HI-STORM overpack will be lifted so that the bottom of the cask is at a height less than the vertical lift limit (see Table 2.2.8) above the ground. For conservatism, the postulated drop event assumes that the loaded HI-STORM 100 overpack falls freely from the vertical lift limit height before impacting a thick reinforced concrete pad. The deceleration of the cask must be maintained below 45 g's. Additionally, the overpack must continue to suitably shield the radiation emitted from the loaded MPC. The use of *special* lifting devices designed in accordance with ANSI N14.6 having redundant drop protection features to lift the loaded overpack will eliminate the lift height limit. The lift height limit is dependent on the characteristics of the impacting surface which are specified in Table 2.2.9. For site-specific conditions, which are not encompassed by Table 2.2.9, the licensee shall evaluate the site-specific conditions to ensure that the drop accident loads do not exceed 45 g's. The methodology used in this alternative analysis shall be commensurate with the analyses in Appendix 3.A and shall be reviewed by the Certificate Holder.

The loaded HI-TRAC will be lifted so that the lowest point on the transfer cask (i.e., the bottom edge of the cask/lid assemblage) is at a height less than the calculated horizontal lift height limit (see Table 2.2.8) above the ground, when lifted horizontally outside of the reactor facility. For

conservatism, the postulated drop event assumes that the loaded HI-TRAC falls freely from the horizontal lift height limit before impact.

Analysis is provided that demonstrates that the HI-TRAC continues to suitably shield the radiation emitted from the loaded MPC, and that the HI-TRAC end plates (top lid and transfer lid for HI-TRAC 100 and HI-TRAC 125 and the top lid and pool lid for HI-TRAC 125D) remain attached. Furthermore, the HI-TRAC inner shell is demonstrated by analysis to not deform sufficiently to hinder retrieval of the MPC. The horizontal lift height limit is dependent on the characteristics of the impacting surface which are specified in Table 2.2.9. For site-specific conditions, which are not encompassed by Table 2.2.9, the licensee shall evaluate the site-specific conditions to ensure that the drop accident loads do not exceed 45 g's. The methodology used in this alternative analysis shall be commensurate with the methodology described in this FSAR and shall be reviewed by the Certificate Holder. The use of lifting devices designed in accordance with ANSI N14.6 having redundant drop protection features during horizontal lifting of the loaded HI-TRAC outside of the reactor facilities eliminate the need for a horizontal lift height limit.

The loaded HI-TRAC, when lifted in the vertical position outside of the Part 50 facility shall be lifted with devices designed in accordance with ANSI N14.6 and having redundant drop protection features unless a site-specific analysis has been performed to determine a lift height limit. For vertical lifts of HI-TRAC with suitably designed lift devices, a vertical drop is not a credible accident for the HI-TRAC transfer cask and no vertical lift height limit is required to be established. Likewise, while the loaded HI-TRAC is positioned atop the HI-STORM 100 overpack for transfer of the MPC into the overpack (outside the Part 50 facility), the lifting equipment will remain engaged with the lifting trunnions of the HI-TRAC transfer cask or suitable restraints will be provided to secure the HI-TRAC. This ensures that a tip-over or drop from atop the HI-STORM 100 overpack is not a credible accident for the HI-TRAC transfer cask. The design criteria and conditions of use for MPC transfer operations from the HI-TRAC transfer cask to the HI-STORM 100 overpack at a Cask Transfer Facility are specified in Subsection 2.3.3.1 of this FSAR.

The loaded MPC is lowered into the HI-STORM or HI-STAR overpack or raised from the overpack using the HI-TRAC transfer cask and a MPC lifting system designed in accordance with ANSI N14.6 and having redundant drop protection features. Therefore, the possibility of a loaded MPC falling freely from its highest elevation during the MPC transfer operations into the HI-STORM or HI-STAR overpacks is not credible.

The magnitude of loadings imparted to the HI-STORM 100 System due to drop events is heavily influenced by the compliance characteristics of the impacted surface. Two "pre-approved" concrete pad designs for storing the HI-STORM 100 System are presented in Table 2.2.9. Other ISFSI pad designs may be used provided the designs are reviewed by the Certificate Holder to ensure that impactive and impulsive loads under accident events such as cask drop and non-mechanistic tip-over are less than the design basis limits when analyzed using the methodologies established in this FSAR.

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2.2.3.2 Tip-Over

The free-standing HI-STORM 100 System is demonstrated by analysis to remain kinematically stable under the design basis environmental phenomena (tornado, earthquake, etc.). However, the HI-STORM 100 overpack and MPC shall also withstand impacts due to a hypothetical tip-over event. The structural integrity of a loaded HI-STORM 100 System after a tip-over onto a reinforced concrete pad is demonstrated by analysis. The cask tip-over is not postulated as an outcome of any environmental phenomenon or accident condition. The cask tip-over is a non-mechanistic event.

The ISFSI pad for deploying a free-standing HI-STORM overpack must possess sufficient structural stiffness to meet the strength limits set forth in the ACI Code selected by the ISFSI owner. At the same time, the pad must be sufficiently compliant such that the maximum deceleration under a tip-over event is below the limit set forth in Table 3.1.2 of this FSAR.

During original licensing for the HI-STORM 100 System, a single set of ISFSI pad and subgrade design parameters (now labeled Set A) was established. Experience has shown that achieving a maximum concrete compressive strength (at 28 days) of 4,200 psi can be difficult. Therefore, a second set of ISFSI pad and subgrade design parameters (labeled Set B) has been developed. The Set B ISFSI parameters include a thinner concrete pad and less stiff subgrade, which allow for a higher concrete compressive strength. Cask deceleration values for all design basis drop and tipover events with the HI-STORM 100, HI-STORM 100S, and HI-STORM 100S Version B overpacks have been verified to be less than or equal to the design limit of 45 g's for both sets of ISFSI pad parameters.

The original set and the new set (Set B) of acceptable ISFSI pad and subgrade design parameters are specified in Table 2.2.9. Users may design their ISFSI pads and subgrade in compliance with either parameter Set A or Set B. Alternatively, users may design their site-specific ISFSI pads and subgrade using any combination of design parameters resulting in a structurally competent pad that meets the provisions of ACI-318 and also limits the deceleration of the cask to less than or equal to 45 g's for the design basis drop and tip-over events for the HI-STORM 100, HI-STORM 100S, and HI-STORM 100S Version B overpacks. The structural analyses for site-specific ISFSI pad design shall be performed using methodologies consistent with those described in this FSAR, as applicable.

If the HI-STORM 100 System is deployed in an anchored configuration (HI-STORM 100A), then tip-over of the cask is structurally precluded along with the requirement of target compliance, which warrants setting specific limits on the concrete compressive strength and subgrade Young's Modulus. Rather, at the so-called high seismic sites (ZPAs greater than the limit set forth in the CoC for free standing casks), the ISFSI pad must be sufficiently rigid to hold the anchor studs and maintain the integrity of the fastening mechanism embedded in the pad during the postulated seismic event. The ISFSI pad must be designed to minimize a physical uplift during extreme environmental event (viz., tornado missile, DBE, etc.). The requirements on the ISFSI pad to render the cask anchoring function under long-term storage are provided in Section 2.0.4.

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2.2.3.3 Fire

The possibility of a fire accident near an ISFSI site is considered to be extremely remote due to the absence of significant combustible materials. The only credible concern is related to a transport vehicle fuel tank fire engulfing the loaded HI-STORM 100 overpack or HI-TRAC transfer cask while it is being moved to the ISFSI.

The HI-STORM 100 System must withstand temperatures due to a fire event. The HI-STORM overpack and HI-TRAC transfer cask fire accidents for storage are conservatively postulated to be the result of the spillage and ignition of 50 gallons of combustible transporter fuel. The HI-STORM overpack and HI-TRAC transfer cask surfaces are considered to receive an incident radiation and forced convection heat flux from the fire. Table 2.2.8 provides the fire durations for the HI-STORM overpack and HI-TRAC transfer cask based on the amount of flammable materials assumed. The temperature of fire is assumed to be 1475° F in accordance with 10CFR71.73.

The accident condition design temperatures for the HI-STORM 100 System, and the fuel rod cladding limits are specified in Table 2.2.3. The specified fuel cladding temperature limits are based on the temperature limits specified in ISG-11, Rev. 3 [2.0.9].

2.2.3.4 Partial Blockage of MPC Basket Vent Holes

The HI-STORM 100 System is designed to withstand reduction of flow area due to partial blockage of the MPC basket vent holes. As the MPC basket vent holes are internal to the confinement barrier, the only events that could partially block the vents are fuel cladding failure and debris associated with this failure, or the collection of crud at the base of the stored SNF assembly. The HI-STORM 100 System maintains the SNF in an inert environment with fuel rod cladding temperatures below accepted values (Table 2.2.3). Therefore, there is no credible mechanism for gross fuel cladding degradation during storage in the HI-STORM 100. For the storage of damaged BWR fuel assemblies or fuel debris, the assemblies and fuel debris will be placed in damaged fuel containers prior to placement in the MPC. The damaged fuel container is equipped with fine mesh screens which ensure that the damaged fuel and fuel debris will not escape to block the MPC basket vent holes. In addition, each MPC will be loaded once for long-term storage and, therefore, buildup of crud in the MPC due to numerous loadings is precluded. Using crud quantities reported in an Empire State Electric Energy Research Corporation Report [2.2.6], a layer of crud of conservative depth is assumed to partially block the MPC basket vent holes. The crud depths for the different MPCs are listed in Table 2.2.8.

2.2.3.5 Tornado

The HI-STORM 100 System must withstand pressures, wind loads, and missiles generated by a tornado. The prescribed design basis tornado and wind loads for the HI-STORM 100 System are consistent with NRC Regulatory Guide 1.76 [2.2.7], ANSI 57.9 [2.2.8], and ASCE 7-88 [2.2.2]. Table 2.2.4 provides the wind speeds and pressure drops which the HI-STORM 100 overpack must withstand while maintaining kinematic stability. The pressure drop is bounded by the accident condition MPC external design pressure.

The kinematic stability of the HI-STORM overpack, and continued integrity of the MPC confinement boundary, while within the storage overpack or HI-TRAC transfer cask, must be demonstrated under impact from tornado-generated missiles in conjunction with the wind loadings. Standard Review Plan (SRP) 3.5.1.4 of NUREG-0800 [2.2.9] stipulates that the postulated missiles include at least three objects: a massive high kinetic energy missile that deforms on impact (large missile); a rigid missile to test penetration resistance (penetrant missile); and a small rigid missile of a size sufficient to pass through any openings in the protective barriers (micro-missile). SRP 3.5.1.4 suggests an automobile for a large missile, a rigid solid steel cylinder for the penetrant missile, and a solid sphere for the small rigid missile, all impacting at 35% of the maximum horizontal wind speed of the design basis tornado. Table 2.2.5 provides the missile data used in the analysis, which is based on the above SRP guidelines. The effects of a large tornado missile are considered to bound the effects of a light general aviation airplane crashing on an ISFSI facility.

During horizontal handling of the loaded HI-TRAC transfer cask outside the Part 50 facility, tornado missile protection shall be provided to prevent tornado missiles from impacting either end of the HI-TRAC. The tornado missile protection shall be designed such that the large tornado missile cannot impact the bottom or top of the loaded HI-TRAC, while in the horizontal position. Also, the missile protection for the top of the HI-TRAC shall be designed to preclude the penetrant missile and micro-missile from passing through the penetration in the HI-TRAC top lid, while in the horizontal position. With the tornado missile protection in place, the impacting of a large tornado missile on either end of the loaded HI-TRAC or the penetrant missile or micro-missile entering the penetration of the top lid is not credible. Therefore, no analyses of these impacts are provided.

2.2.3.6 Flood

The HI-STORM 100 System must withstand pressure and water forces associated with a flood. Resultant loads on the HI-STORM 100 System consist of buoyancy effects, static pressure loads, and velocity pressure due to water velocity. The flood is assumed to deeply submerge the HI-STORM 100 System (see Table 2.2.8). The flood water depth is based on the hydrostatic pressure which is bounded by the MPC external pressure stated in Table 2.2.1.

It must be shown that the MPC does not collapse, buckle, or allow water in-leakage under the hydrostatic pressure from the flood.

The flood water is assumed to be nonstagnant. The maximum allowable flood water velocity is determined by calculating the equivalent pressure loading required to slide or tip over the HI-STORM 100 System. The design basis flood water velocity is stated in Table 2.2.8. Site-specific safety reviews by the licensee must confirm that flood parameters do not exceed the flood depth, slide, or tip-over forces.

If the flood water depth exceeds the elevation of the top of the HI-STORM overpack inlet vents, then the cooling air flow would be blocked. The flood water may also carry debris which may act to block the air inlets of the overpack. Blockage of the air inlets is addressed in Subsection 2.2.3.13.

Most reactor sites are hydrologically characterized as required by Paragraph 100.10(c) of 10CFR100 and further articulated in Reg. Guide 1.59, "Design Basis Floods for Nuclear Power Plants" and Reg. Guide 1.102, "Flood Protection for Nuclear Power Plants." It is assumed that a complete characterization of the ISFSIs hydrosphere including the effects of hurricanes, floods, seiches and tsunamis is available to enable a site-specific evaluation of the HI-STORM 100 System for kinematic stability. An evaluation for tsunamis† for certain coastal sites should also be performed to demonstrate that sliding or tip-over will not occur and that the maximum flood depth will not be exceeded.

Analysis for each site for such transient hydrological loadings must be made for that site. It is expected that the plant licensee will perform this evaluation under the provisions of 10CFR72.212.

2.2.3.7 Seismic Design Loadings

The HI-STORM 100 System must withstand loads arising due to a seismic event and must be shown not to tip over during a seismic event. Subsection 3.4.7 contains calculations based on conservative static "incipient tipping" calculations which demonstrate static stability. The calculations in Section 3.4.7 result in the values reported in Table 2.2.8, which provide the maximum horizontal zero period acceleration (ZPA) versus vertical acceleration multiplier above which static incipient tipping would occur. This conservatively assumes the peak acceleration values of each of the two horizontal earthquake components and the vertical component occur simultaneously. The maximum horizontal ZPA provided in Table 2.2.8 is the vector sum of two horizontal earthquakes.

For anchored casks, the limit on zero period accelerations is set by the structural capacity of the sector lugs and anchoring studs. Table 2.2.8 provides the limits for HI-STORM 100A for the maximum vector sum of two horizontal earthquake peak ZPAs along with the coincident limit on the vertical ZPA.

2.2.3.8 100% Fuel Rod Rupture

The HI-STORM 100 System must withstand loads due to 100% fuel rod rupture. For conservatism, 100 percent of the fuel rods are assumed to rupture with 100 percent of the fill gas and 30% of the significant radioactive gases (e.g., H^3, Kr, and Xe) released in accordance with NUREG-1536. All of the fill gas contained in non-fuel hardware, such as Burnable Poison Rod Assemblies (BPRAs) is also assumed to be released in analyzing this event.

2.2.3.9 Confinement Boundary Leakage

No credible scenario has been identified that would cause failure of the confinement system. Section 7.1 provides a discussion as to why leakage of any magnitude from the MPC is not credible, based on the materials and methods of fabrication and inspection.

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† A tsunami is an ocean wave from seismic or volcanic activity or from submarine landslides. A tsunami may be the result of nearby or distant events. A tsunami loading may exist in combination with wave splash and spray, storm surge and tides.

2.2.3.10 Explosion

The HI-STORM 100 System must withstand loads due to an explosion. The accident condition MPC external pressure and overpack pressure differential specified in Table 2.2.1 bounds all credible external explosion events. There are no credible internal explosive events since all materials are compatible with the various operating environments, as discussed in Section 3.4.1, or appropriate preventive measures are taken to preclude internal explosive events (see Section 1.2.1.3.1.1). The MPC is composed of stainless steel, neutron absorber material, and prior to CoC Amendment 2, possibly optional aluminum alloy 1100 heat conduction elements. For these materials, and considering the protective measures taken during loading and unloading operations there is no credible internal explosive event.

2.2.3.11 Lightning

The HI-STORM 100 System must withstand loads due to lightning. The effect of lightning on the HI-STORM 100 System is evaluated in Chapter 11.

2.2.3.12 Burial Under Debris

The HI-STORM 100 System must withstand burial under debris. Such debris may result from floods, wind storms, or mud slides. Mud slides, blowing debris from a tornado, or debris in flood water may result in duct blockage, which is addressed in Subsection 2.2.3.13. The thermal effects of burial under debris on the HI-STORM 100 System is evaluated in Chapter 11. Siting of the ISFSI pad shall ensure that the storage location is not located near shifting soil. Burial under debris is a highly unlikely accident, but is analyzed in this FSAR.

2.2.3.13 100% Blockage of Air Inlets

For conservatism, this accident is defined as a complete blockage of all four bottom air inlets. Such a blockage may be postulated to occur during accident events such as a flood or tornado with blowing debris. The HI-STORM 100 System must withstand the temperature rise as a result of 100% blockage of the air inlets and outlets. The fuel cladding temperature must be shown to remain below the off-normal/accident temperature limit specified in Table 2.2.3.

2.2.3.14 Extreme Environmental Temperature

The HI-STORM 100 System must withstand extreme environmental temperatures. The extreme accident level temperature is specified in Table 2.2.2. The extreme accident level temperature occurs with steady-state insolation. This temperature is assumed to persist for a duration sufficient to allow the system to reach steady-state temperatures. The HI-STORM overpack and MPC have a large thermal inertia. Therefore, this temperature is assumed to persist over three days (3-day average).

2.2.3.15 Bounding Hydraulic, Wind, and Missile Loads for HI-STORM 100A

In the anchored configuration, the HI-STORM 100A System is clearly capable of withstanding much greater lateral loads than a free-standing overpack. Coastal sites in many areas of the world, particularly the land mass around the Pacific Ocean, may be subject to severe fluid inertial loads. Several publications [2.2.10, 2.2.11] explain and quantify the nature and source of such environmental hazards.

It is recognized that a lateral fluid load may also be accompanied by an impact force from a fluid borne missile (debris). Rather than setting specific limits for these loads on an individual basis, a limit on the static overturning base moment on the anchorage is set. This bounding overturning moment is given in Table 2.2.8 and is set at a level that ensures that structural safety margins on the sector lugs and on the anchor studs are essentially equal to the structural safety margins of the same components under the combined effect of the net horizontal and vertical seismic load limits in Table 2.2.8.The ISFSI owner bears the responsibility to establish that the lateral hydraulic, wind, and missile loads at his ISFSI site do not yield net overturning moments, when acting separately or together, that exceed the limit value in Table 2.2.8. If loadings are increased above those values for free-standing casks, their potential effect on the other portions of the cask system must be considered.

2.2.4 Applicability of Governing Documents

The ASME Boiler and Pressure Vessel Code (ASME Code), 1995 Edition, with Addenda through 1997 [2.2.1], is the governing code for the structural design of the MPC, the metal structure of the HI-STORM 100 overpack, and the HI-TRAC transfer cask, except for Sections V and IX. The latest effective editions of ASME Section V and IX may be used, provided a written reconciliation of the later edition against the 1995 Edition, including addenda, is performed by the certificate holder. The MPC enclosure vessel and fuel basket are designed in accordance with Section III, Subsections NB Class 1 and NG Class 1, respectively. The metal structure of the overpack and the HI-TRAC transfer cask are designed in accordance with Section III, Subsection NF Class 3. The ASME Code is applied to each component consistent with the function of the component.

ACI 349 is the governing code for the plain concrete in the HI-STORM 100 overpack. ACI 318-95 is the applicable code utilized to determine the allowable compressive strength of the plain concrete credited during structural analysis. Appendix 1.D provides the sections of ACI 349 and ACI 318-95 applicable to the plain concrete.

Table 2.2.6 provides a summary of each structure, system and component (SSC) of the HI-STORM 100 System that is identified as important to safety, along with its function and governing Code. Some components perform multiple functions and in those cases, the most restrictive Code is applied. In accordance with NUREG/CR-6407, "Classification of Transportation Packaging and Dry Spent Fuel Storage System Components", and according to importance to safety, components of the HI-STORM 100 System are classified as A, B, C, or NITS (not important to safety) in Table 2.2.6. Section 13.1 provides the criteria used to classify each item. The classification of necessary auxiliary equipment is provided in Table 8.1.6.

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Table 2.2.7 lists the applicable governing Code for material procurement, design, fabrication and inspection of the components of the HI-STORM 100 System. The ASME Code section listed in the design column is the section used to define allowable stresses for structural analyses.

Table 2.2.15 lists the alternatives to the ASME Code for the HI-STORM 100 System and the justification for those alternatives.

The MPC enclosure vessel and certain fuel basket designs utilized in the HI-STORM 100 System are identical to the MPC components described in the SARs for the HI-STAR 100 System for storage (Docket 72-1008) and transport (Docket 71-9261). To avoid unnecessary repetition of the large numbers of stress analyses, this document refers to those SARs, as applicable, if the MPC loadings for storage in the HI-STORM 100 System do not exceed those computed in the HI-STAR documents. Many of the loadings in the HI-STAR applications envelope the HI-STORM loadings on the MPC, and, therefore, a complete re-analysis of the MPC is not provided in the FSAR. Certain individual MPC analyses may have been required to license a particular MPC fuel basket design for HI-STORM that was not previously licensed for HI-STAR. These unique analyses are summarized in the appropriate location in this FSAR.

Table 2.2.16 provides a summary comparison between the loading elements. Table 2.2.16 shows that most of the loadings remain unchanged and several are less than the HI-STAR loading conditions. In addition to the magnitude of the loadings experienced by the MPC, the application of the loading must also be considered. Therefore, it is evident from Table 2.2.16 that the MPC stress limits can be ascertained to be qualified a priori if the HI-STAR analyses and the thermal loadings under HI-STORM storage are not more severe compared to previously analyzed HI-STAR conditions. In the analysis of each of the normal, off-normal, and accident conditions, the effect on the MPC is evaluated and compared to the corresponding condition analyzed in the HI-STAR 100 System SARs [2.2.4 and 2.2.5]. If the HI-STORM loading is greater than the HI-STAR loading or the loading is applied differently, the analysis of its effect on the MPC is evaluated in Chapter 3.

2.2.5 Service Limits

In the ASME Code, plant and system operating conditions are commonly referred to as normal, upset, emergency, and faulted. Consistent with the terminology in NRC documents, this FSAR utilizes the terms normal, off-normal, and accident conditions.

The ASME Code defines four service conditions in addition to the Design Limits for nuclear components. They are referred to as Level A, Level B, Level C, and Level D service limits, respectively. Their definitions are provided in Paragraph NCA-2142.4 of the ASME Code. The four levels are used in this FSAR as follows:

a. Level A Service Limits: Level A Service Limits are used to establish allowables for normal condition load combinations.

b. Level B Service Limits: Level B Service Limits are used to establish allowables for off-normal condition load combinations.

c. Level C Service Limits: Level C Service Limits are not used.

d. Level D Service Limits: Level D Service Limits are used to establish allowables for accident condition load combinations.

The ASME Code service limits are used in the structural analyses for definition of allowable stresses and allowable stress intensities. Allowable stresses and stress intensities for structural analyses are tabulated in Chapter 3. These service limits are matched with normal, off-normal, and accident condition loads combinations in the following subsections.

The MPC confinement boundary is required to meet Section III, Class 1, Subsection NB stress intensity limits. Table 2.2.10 lists the stress intensity limits for the Levels A, B, C, and D service limits for Class 1 structures extracted from the ASME Code (1995 Edition). The limits for the MPC fuel basket, required to meet the stress intensity limits of Subsection NG of the ASME Code, are listed in Table 2.2.11. Table 2.2.12 lists allowable stress limits for the steel structure of the HI-STORM overpack and HI-TRAC which are analyzed to meet the stress limits of Subsection NF, Class 3. Only service levels A, B, and D requirements, normal, off-normal, and accident conditions, are applicable.

2.2.6 Loads

Subsections 2.2.1, 2.2.2, and 2.2.3 describe the design criteria for normal, off-normal, and accident conditions, respectively. Table 2.2.13 identifies the notation for the individual loads that require consideration. The individual loads listed in Table 2.2.13 are defined from the design criteria. Each load is assigned a symbol for subsequent use in the load combinations.

The loadings listed in Table 2.2.13 fall into two broad categories; namely, (i) those that primarily affect kinematic stability, and (ii) those that produce significant stresses. The loadings in the former category are principally applicable to the overpack. Tornado wind (W'), earthquake (E), and tornado-borne missile (M) are essentially loadings which can destabilize a cask. Analyses reported in Chapter 3 show that the HI-STORM 100 overpack structure will remain kinematically stable under these loadings. Additionally, for the missile impact case (M), analyses that demonstrate that the overpack structure remains unbreached by the postulated missiles are provided in Chapter 3.

Loadings in the second category produce global stresses that must be shown to comply with the stress intensity or stress limits, as applicable. The relevant loading combinations for the fuel basket, the MPC, the HI-TRAC and the HI-STORM overpack are different because of differences in their function. For example, the fuel basket does not experience a pressure loading because it is not a pressure vessel. The specific load combination for each component is specified in Subsection 2.2.7.

2.2.7 Load Combinations

To demonstrate compliance with the design requirements for normal, off-normal, and accident conditions of storage, the individual loads, identified in Table 2.2.13, are combined into load combinations. In the formation of the load combinations, it is recognized that the number of combinations requiring detailed analyses is reduced by defining bounding loads. Analyses performed using bounding loads serve to satisfy the requirements for analysis of a multitude of separately identified loads in combination.

For example, the values established for internal and external pressures (P_i and P_o) are defined such that they bound other surface-intensive loads, namely snow (S), tornado wind (W'), flood (F), and explosion (E^*). Thus, evaluation of pressure in a load combination established for a given storage condition enables many individual load effects to be included in a single load combination.

Table 2.2.14 identifies the combinations of the loads that are required to be considered in order to ensure compliance with the design criteria set forth in this chapter. Table 2.2.14 presents the load combinations in terms of the loads that must be considered together. A number of load combinations are established for each ASME Service Level. Within each loading case, there may be more than one analysis that is required to demonstrate compliance. Since the breakdown into specific analyses is most applicable to the structural evaluation, the identification of individual analyses with the applicable loads for each load combination is found in Chapter 3. Table 3.1.3 through 3.1.5 define the particular evaluations of loadings that demonstrate compliance with the load combinations of Table 2.2.14.

For structural analysis purposes, Table 2.2.14 serves as an intermediate classification table between the definition of the loads (Table 2.2.13 and Section 2.2) and the detailed analysis combinations (Tables 3.1.3 through 3.1.5).

Finally, it should be noted that the load combinations identified in NUREG-1536 are considered as applicable to the HI-STORM 100 System. The majority of load combinations in NUREG-1536 are directed toward reinforced concrete structures. Those load combinations applicable to steel structures are directed toward frame structures. As stated in NUREG-1536, Page 3-35 of Table 3-1, "Table 3-1 does not apply to the analysis of confinement casks and other components designed in accordance with Section III of the ASME B&PV Code." Since the HI-STORM 100 System is a metal shell structure, with concrete primarily employed as shielding, the load combinations of NUREG-1536 are interpreted within the confines and intent of the ASME Code.

2.2.8 Allowable Stresses

The stress intensity limits for the MPC confinement boundary for the design condition and the service conditions are provided in Table 2.2.10. The MPC confinement boundary stress intensity limits are obtained from ASME Code, Section III, Subsection NB. The stress intensity limits for the MPC fuel basket are presented in Table 2.2.11 (governed by Subsection NG of Section III). The steel structure of the overpack and the HI-TRAC meet the stress limits of Subsection NF of ASME Code, Section III for plate and shell components. Limits for the Level D condition are obtained from

Appendix F of ASME Code, Section III for the steel structure of the overpack. The ASME Code is not applicable to the HI-TRAC transfer cask for accident conditions, service level D conditions. The HI-TRAC transfer cask has been shown by analysis to not deform sufficiently to apply a load to the MPC, have any shell rupture, or have the top lid, pool lid, or transfer lid (as applicable) detach.

The following definitions of terms apply to the tables on stress intensity limits; these definitions are the same as those used throughout the ASME Code:

S_m: Value of Design Stress Intensity listed in ASME Code Section II, Part D, Tables 2A, 2B and 4

S_y: Minimum yield strength at temperature

S_u: Minimum ultimate strength at temperature

Table 2.2.1

DESIGN PRESSURES

Pressure Location	Condition	Pressure (psig)
MPC Internal Pressure	Normal	100
	Off-Normal	110
	Accident	200
MPC External Pressure	Normal	(0) Ambient
	Off-Normal	(0) Ambient
	Accident	60
Overpack External Pressure	Normal	(0) Ambient
	Off-Normal	(0) Ambient
	Accident	10 (differential pressure for 1 second maximum) or 5 (differential pressure steady state)
HI-TRAC Water Jacket	Normal	60
	Off-normal	60
	Accident	N/A (Under accident conditions, the water jacket is assumed to have lost all water thru the pressure relief valves)

Table 2.2.2

ENVIRONMENTAL TEMPERATURES

Condition	**Temperature (^{o}F)**	**Comments**
HI-STORM 100 Overpack		
Normal Ambient (Bounding Annual Average)	80	
Normal Soil Temperature (Bounding Annual Average)	77	
Off-Normal Ambient (3-Day Average)	-40 and 100	-40°F with no insolation 100°F with insolation
Extreme Accident Level Ambient (3-Day Average)	125	125°F with insolation starting at steady-state off-normal high environment temperature
HI-TRAC Transfer Cask		
Normal (Bounding Annual Average)	~~100~~*80*	
~~Off-Normal (3-Day Average)~~	~~0 and 100~~	~~0° F with no insolation~~ ~~100° F with insolation~~

Note:

1. Handling operations with the loaded HI-STORM overpack and HI-TRAC transfer cask are limited to working area ambient temperatures greater than or equal to 0°F as specified in Subsection 2.2.1.2.

Table 2.2.3
DESIGN TEMPERATURES

HI-STORM 100 Component	Long Term, Normal Condition Design Temperature Limits (^{o} F)	Off-Normal and Accident Condition Temperature Limits (^{o} F)
MPC shell	500	~~775~~*1200*
MPC basket	725	~~950~~*1200*
MPC Neutron Absorber	800	~~950~~*1000*
MPC lid	550	~~775~~*1200*
MPC closure ring	400	~~775~~*1200*
MPC baseplate	400	~~775~~*1200*
~~MPC Heat Conduction Elements~~	~~725~~	~~950~~
HI-TRAC inner shell	400	~~600~~*800*
HI-TRAC pool lid/transfer lid	350	~~700~~*800*
HI-TRAC top lid	400	~~700~~*800*
HI-TRAC top flange	400	700
HI-TRAC pool lid seals	350	N/A
HI-TRAC bottom lid bolts	350	~~700~~*800*
HI-TRAC bottom flange	350	~~700~~*800*
HI-TRAC top lid neutron shielding	300	350
HI-TRAC radial neutron shield	307	N/A
HI-TRAC radial lead gamma shield	350	600
Remainder of HI-TRAC	350	~~700~~*800*
Fuel Cladding	752	752 or 1058 (Short Term Operations)[~~†~~] 1058 (Off-~~n~~*N*ormal and Accident Conditions)
~~Overpack outer shell~~	~~350~~	~~600~~
Overpack concrete	300	350
~~Overpack inner shell~~	~~350~~	~~400~~
Overpack Lid Top and Bottom Plates	450	~~550~~800
Remainder of overpack steel structure	350	~~400~~800

~~†~~ Normal short term operations includes MPC drying and onsite transport per Reference [2.0.8]. The 1058°F temperature limit applies to MPCs containing all moderate burnup fuel as discussed in Reference [2.0.9]. The limit for MPCs containing one or more high burnup fuel assemblies is 752°F. See also Section 4.3.

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Table 2.2.4

TORNADO CHARACTERISTICS

Condition	Value
Rotational wind speed (mph)	290
Translational speed (mph)	70
Maximum wind speed (mph)	360
Pressure drop (psi)	3.0

Table 2.2.5

TORNADO-GENERATED MISSILES

Missile Description	Mass (kg)	Velocity (mph)
Automobile	1800	126
Rigid solid steel cylinder (8 in. diameter)	125	126
Solid sphere (1 in. diameter)	0.22	126

TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STORM 100 SYSTEM
MPC [1,2]

Primary Function	Component [3]	Safety Class [4]	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
Confinement	Shell	A	ASME Section III; Subsection NB	Alloy X [5]	See Appendix 1.A	NA	NA
Confinement	Baseplate	A	ASME Section III; Subsection NB	Alloy X	See Appendix 1.A	NA	NA
Confinement	Lid (One-piece design and top portion of optional two-piece design)	A	ASME Section III; Subsection NB	Alloy X	See Appendix 1.A	NA	NA
Confinement	Closure Ring	A	ASME Section III; Subsection NB	Alloy X	See Appendix 1.A	NA	NA
Confinement	Port Cover Plates	A	ASME Section III; Subsection NB	Alloy X	See Appendix 1.A	NA	NA
Criticality Control	Basket Cell Plates	A	ASME Section III; Subsection NG core support structures (NG-1121)	Alloy X	See Appendix 1.A	NA	NA
Criticality Control	Neutron Absorber	A	Non-code	NA	NA	NA	Aluminum/SS
Shielding	Drain and Vent Shield Block	C	Non-code	Alloy X	See Appendix 1.A	NA	NA
Shielding	Plugs for Drilled Holes	NITS	Non-code	SA 193B8 (or equivalent)	See Appendix 1.A	NA	NA

Notes:
1) There are no known residuals on finished component surfaces
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III.
3) Component nomenclature taken from Bill of Materials in Chapter 1.
4) A, B, and C denote important to safety classifications as described in the Holtec QA Program. NITS stands for Not Important to Safety.
5) For details on Alloy X material, see Appendix 1.A.
6) Must be Type 304, 304LN, 316, or 316 LN with tensile strength $\geq$ 75 ksi, yield strength $\geq$ 30 ksi and chemical properties per ASTM A554.

HOLTEC INTERNATIONAL COPYRIGHTED MATERIAL

TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STORM 100 SYSTEM
MPC [1,2]

Primary Function	Component [3]	Safety Class [4]	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
Shielding	Bottom portion of optional two-piece MPC lid design	B	Non-code	Alloy X	See Appendix 1.A	NA	NA
Structural Integrity	Upper Fuel Spacer Column	B	ASME Section III; Subsection NG (only for stress analysis)	Alloy X	See Appendix 1.A	NA	NA
Structural Integrity	Sheathing	A	Non-code	Alloy X	See Appendix 1.A	Aluminum/SS	NA
Structural Integrity	Shims	NITS	Non-code (shims welded directly to angle plate basket supports are ASME Section II)	Alloy X	See Appendix 1.A	NA	NA
Structural Integrity	Basket Supports (Angled Plates)	A	ASME Section III; Subsection NG internal structures (NG-1122)	Alloy X	See Appendix 1.A	NA	NA
Structural Form	Basket Supports (Flat Plates)	NITS	Non-Code	Alloy X	See Appendix 1.A	NA	NA
Structural Integrity	Lift Lug	C	NUREG-0612	Alloy X	See Appendix 1.A	NA	NA
Structural Integrity	Lift Lug Baseplate	C	Non-code	Alloy X	See Appendix 1.A	NA	NA
Structural Integrity	Upper Fuel Spacer Bolt	NITS	Non-code	A193-B8 (or equiv.)	Per ASME Section II	NA	NA

Notes:
1) There are no known residuals on finished component surfaces
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III.
3) Component nomenclature taken from Bill of Materials in Chapter 1.
4) A, B, and C denote important to safety classifications as described in the Holtec QA Program. NITS stands for Not Important to Safety.
5) For details on Alloy X material, see Appendix 1.A.
6) Must be Type 304, 304LN, 316, or 316 LN with tensile strength $\geq$ 75 ksi, yield strength $\geq$ 30 ksi and chemical properties per ASTM A554.

HOLTEC INTERNATIONAL COPYRIGHTED MATERIAL

TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STORM 100 SYSTEM
MPC [1,2]

Primary Function	Component [3]	Safety Class [4]	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
Structural Integrity	Upper Fuel Spacer End Plate	B	Non-code	Alloy X	See Appendix 1.A	NA	NA
Structural Integrity	Lower Fuel Spacer Column	B	ASME Section III; Subsection NG (only for stress analysis)	Stainless Steel. See Note 6	See Appendix 1.A	NA	NA
Structural Integrity	Lower Fuel Spacer End Plate	B	Non-code	Alloy X	See Appendix 1.A	NA	NA
Structural Integrity	Vent Shield Block Spacer	C	Non-code	Alloy X	See Appendix 1.A	NA	NA
Operations	Vent and Drain Tube	C	Non-code	S/S	Per ASME Section II	Thread area surface hardened	NA
Operations	Vent & Drain Cap	C	Non-code	S/S	Per ASME Section II	NA	NA
Operations	Vent & Drain Cap Seal Washer	NITS	Non-code	Aluminum	NA	NA	Aluminum/SS
Operations	Vent & Drain Cap Seal Washer Bolt	NITS	Non-code	Aluminum	NA	NA	NA
Operations	Reducer	NITS	Non-code	Alloy X	See Appendix 1.A	NA	NA
Operations	Drain Line	NITS	Non-code	Alloy X	See Appendix 1.A	NA	NA
Operations	Damaged Fuel Container	C	ASME Section III; Subsection NG	304 S/S except for locking spring,	See Appendix 1.A	NA	NA

Notes:
1) There are no known residuals on finished component surfaces
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III.
3) Component nomenclature taken from Bill of Materials in Chapter 1.
4) A, B, and C denote important to safety classifications as described in the Holtec QA Program. NITS stands for Not Important to Safety.
5) For details on Alloy X material, see Appendix 1.A.
6) Must be Type 304, 304LN, 316, or 316 LN with tensile strength $\geq$ 75 ksi, yield strength $\geq$ 30 ksi and chemical properties per ASTM A554.

HOLTEC INTERNATIONAL COPYRIGHTED MATERIAL

TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STORM 100 SYSTEM
MPC [1,2]

Primary Function	Component [3]	Safety Class [4]	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
				which may be any type of SS			
Operations	Drain Line Guide Tube	NITS	Non-code	S/S	NA	NA	NA

Notes:
1) There are no known residuals on finished component surfaces
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III.
3) Component nomenclature taken from Bill of Materials in Chapter 1.
4) A, B, and C denote important to safety classifications as described in the Holtec QA Program. NITS stands for Not Important to Safety.
5) For details on Alloy X material, see Appendix 1.A.
6) Must be Type 304, 304LN, 316, or 316 LN with tensile strength $\geq$ 75 ksi, yield strength $\geq$ 30 ksi and chemical properties per ASTM A554.

HOLTEC INTERNATIONAL COPYRIGHTED MATERIAL

TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STORM 100 SYSTEM OVERPACK [1,2]

Primary Function	Component [3]	Safety Class [4]	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
Shielding	Radial Shield	B	ACI 349, App. 1.D	Concrete	See Table 1.D.1	NA	NA
Shielding	Shield Block Ring (100)	B	See Note 6	SA516-70	See Table 3.3.2	See Note 5	NA
Shielding	Lid Shield Ring (100S and 100S Version B) and Shield Block Shell (100S)	B	ASME Section III; Subsection NF	SA516-70 or SA515-70 (SA515-70 not permitted for 100S Version B)	See Table 3.3.2	See Note 5	NA
Shielding	Shield Block Shell (100)	B	See Note 6	SA516-70 or SA515-70	See Table 3.3.2	See Note 5	NA
Shielding	Pedestal Shield	B	ACI 349, App. 1-D	Concrete	See Table 1.D.1	NA	NA
Shielding	Lid Shield	B	ACI 349, App. 1-D	Concrete	See Table 1.D.1	NA	NA
Shielding	Shield Shell (eliminated from design 6/01)	B	See Note 6	SA516-70	See Table 3.3.2	NA	NA
Shielding	Shield Block	B	ACI 349, App. 1-D	Concrete	See Table 1.D.1	NA	NA
Shielding	Gamma Shield Cross Plates & Tabs	C	Non-code	SA240-304	NA	NA	NA
Structural Integrity	Baseplate	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.3	See Note 5	NA

Notes:
1) There are no known residuals on finished component surfaces
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III.
3) Component nomenclature taken from Bills of Material and drawings in Chapter 1. All components are “as applicable” based in the overpack drawing/BOM unless otherwise noted.
4) A, B, and C denote important to safety classifications as described in the Holtec QA Program. NITS stands for Not Important to Safety.
5) All exposed steel surfaces (except threaded holes) to be painted with Thermaline 450 or equivalent to the extent practical.
6) Welds will meet AWS D1.1 requirements for prequalified welds, except that welder qualification and weld procedures of ASME Code Section IX may be substituted.

HOLTEC INTERNATIONAL COPYRIGHTED MATERIAL

TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STORM 100 SYSTEM OVERPACK [1,2]

Primary Function	Component [3]	Safety Class [4]	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
Structural Integrity	Outer Shell	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Inner Shell	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Concrete Form	Pedestal Shell	B	See Note 6	SA516-70	See Table 3.3.2	See Note 5	NA
Concrete Form	Pedestal Plate (100) Pedestal Baseplate (100S)	B	See Note 6	SA516-70 or SA515-70	See Table 3.3.2	See Table 3.3.2	NA
Structural Integrity	Lid Bottom Plate	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Lid Shell	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Inlet Vent Vertical & Horizontal Plates	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Thermal	Exit Vent Horizontal Plate (100)	B	See Note 6	SA516-70	See Table 3.3.2	See Note 5	NA
Thermal	Exit Vent Vertical/Side Plate	B	See Note 6	SA516-70 or SA515-70	See Table 3.3.2	See Note 5	NA
Thermal	Heat Shield	B	N/A	C/S	N/A	See Note 5	N/A
Thermal	Heat Shield Ring	B	N/A	C/S	N/A	See Note 5	N/A

Notes:
1) There are no known residuals on finished component surfaces
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III.
3) Component nomenclature taken from Bills of Material and drawings in Chapter 1. All components are “as applicable” based in the overpack drawing/BOM unless otherwise noted.
4) A, B, and C denote important to safety classifications as described in the Holtec QA Program. NITS stands for Not Important to Safety.
5) All exposed steel surfaces (except threaded holes) to be painted with Thermaline 450 or equivalent to the extent practical.
6) Welds will meet AWS D1.1 requirements for prequalified welds, except that welder qualification and weld procedures of ASME Code Section IX may be substituted.

HOLTEC INTERNATIONAL COPYRIGHTED MATERIAL

TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STORM 100 SYSTEM OVERPACK [1,2]

Primary Function	Component [3]	Safety Class [4]	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
Structural Integrity	Top Plate, including shear ring	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Lid Top (Cover) Plate, including shear ring	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Radial Plate	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Lid Stud & Nut	B	ASME Section II	SA564-630 or SA 193-B7 (stud) SA 194-2H (nut)	See Table 3.3.4	Threads to have cadmium coating (or similar lubricant for corrosion protection)	NA
Structural Integrity	100S Lid Washer	B	Non-Code	SA240-304	Per ASME Section II	NA	NA
Structural Integrity	Bolt Anchor Block	B	ASME Section III; Subsection NF ANSI N14.6	SA350-LF3, SA350-LF2, or SA203E	See Table 3.3.3	See Note 5	NA
Structural Integrity	Channel	B	ASME Section III; Subsection NF	SA516-70 (galvanized) or SA240-304	See Table 3.3.2 or Table 3.3.1	See Note 5	NA
Structural Integrity	Channel Mounts	B	ASME Section III; Subsection NF	A36 or equivalent	Per ASME Section II	See Note 5	NA

Notes:
1) There are no known residuals on finished component surfaces
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III.
3) Component nomenclature taken from Bills of Material and drawings in Chapter 1. All components are “as applicable” based in the overpack drawing/BOM unless otherwise noted.
4) A, B, and C denote important to safety classifications as described in the Holtec QA Program. NITS stands for Not Important to Safety.
5) All exposed steel surfaces (except threaded holes) to be painted with Thermaline 450 or equivalent to the extent practical.
6) Welds will meet AWS D1.1 requirements for prequalified welds, except that welder qualification and weld procedures of ASME Code Section IX may be substituted.

HOLTEC INTERNATIONAL COPYRIGHTED MATERIAL

TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STORM 100 SYSTEM OVERPACK [1,2]

Primary Function	Component [3]	Safety Class [4]	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
Shielding	Pedestal Platform	B	Non-Code	A36 or equivalent	NA	See Note 5	NA
Operations	Storage Marking Nameplate	NITS	Non-code	SA240-304	NA	NA	NA
Operations	Exit Vent Screen Sheet	NITS	Non-code	SA240-304	NA	NA	NA
Operations	Drain Pipe	NITS	Non-code	C/S or S/S	NA	See Note 5	NA
Operations	Exit & Inlet Screen Frame	NITS	Non-code	SA240-304	NA	NA	NA
Operations	Temperature Element & Associated Temperature Monitoring Equipment	C	Non-code	NA	NA	NA	NA
Operations	Screen	NITS	Non-code	Mesh Wire	NA	NA	NA
Operations	Paint	NITS	Non-code	Thermaline 450 or equivalent	NA	NA	NA
Structural Integrity	100S Version B Base Bottom Plate	B	ASME III; Subsection NF	SA516- 70	See Table 3.3.2	See Note 5	NA
Structural Integrity	100S Version B Base Spacer Block	B	Non-code	SA36	NA	See Note 5	NA
Shielding	100S Version B Base Shield Block	B	Non-code	SA36	NA	See Note 5	NA
Structural Integrity	100S Version B Base Top Plate	B	ASME III; Subsection NF	SA 516-70	See Table 3.3.2	See Note 5	NA

Notes:
1) There are no known residuals on finished component surfaces
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III.
3) Component nomenclature taken from Bills of Material and drawings in Chapter 1. All components are “as applicable” based in the overpack drawing/BOM unless otherwise noted.
4) A, B, and C denote important to safety classifications as described in the Holtec QA Program. NITS stands for Not Important to Safety.
5) All exposed steel surfaces (except threaded holes) to be painted with Thermaline 450 or equivalent to the extent practical.
6) Welds will meet AWS D1.1 requirements for prequalified welds, except that welder qualification and weld procedures of ASME Code Section IX may be substituted.

HOLTEC INTERNATIONAL COPYRIGHTED MATERIAL

TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STORM 100 SYSTEM OVERPACK [1,2]

Primary Function	Component [3]	Safety Class [4]	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
Structural Integrity	100S Version B Base MPC Support	B	Non-code	SA36	NA	See Note 5	NA
Shielding	100S Version B Lid Outer Ring	B	ASME III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Operations	100S Version B Lid Vent Duct	NITS	Non-code	Carbon Steel	NA	See Note 5	NA
Structural Integrity	100S Version B Lid Inner Ring	B	ASME III; Subsection NF	SA36	See Table 3.3.2	See Note 5	NA
Operations	100S Version B Lid Stud Pipe	NITS	Non-code	Carbon Steel	NA	See Note 5	NA
Operations	100S Version B Lid Stud Spacer	NITS	Non-code	Carbon Steel	NA	See Note 5	NA
Operations	100S Version B Lid Lift Block	B	ASME III; Subsection NF	SA36	See Table 3.3.2	See Note 5	NA
Shielding	100S Version B Lid Vent Shield	B	Non-code	SA36	NA	See Note 5	NA
Operations	100S Version B Lid Stud Washer	C	Non-code	Stainless Steel	NA	See Note 5	NA
Operations	100S Version B Lid Stud Cap	NITS	Non-code	PVC	NA	See Note 5	NA
Structural Integrity	100S Version B Radial Gusset	B	ASME III; Subsection NF	SA 516-70	NA	See Note 5	NA

Notes:
1) There are no known residuals on finished component surfaces
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III.
3) Component nomenclature taken from Bills of Material and drawings in Chapter 1. All components are “as applicable” based in the overpack drawing/BOM unless otherwise noted.
4) A, B, and C denote important to safety classifications as described in the Holtec QA Program. NITS stands for Not Important to Safety.
5) All exposed steel surfaces (except threaded holes) to be painted with Thermaline 450 or equivalent to the extent practical.
6) Welds will meet AWS D1.1 requirements for prequalified welds, except that welder qualification and weld procedures of ASME Code Section IX may be substituted.

HOLTEC INTERNATIONAL COPYRIGHTED MATERIAL

TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STORM 100 SYSTEM
HI-TRAC TRANSFER CASK [1,2]

Primary Function	Component [3]	Safety Class [4]	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
Shielding	Radial Lead Shield	B	Non-code	Lead	NA	NA	NA
Shielding	Pool Lid Lead Shield	B	Non-code	Lead	NA	NA	NA
Shielding	Top Lid Shielding	B	Non-code	Holtite	NA	NA	NA
Shielding	Plugs for Lifting Holes	NITS	Non-code	C/S or S/S	NA	NA	
Structural Integrity	Outer Shell	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Inner Shell	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Radial Ribs	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Water Jacket Enclosure Shell Panels (HI-TRAC 100 and 125)	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Water Jacket Enclosure Shell Panels (HI-TRAC 125D)	B	ASME Section III; Subsection NF	SA516-70 or SA515-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Water Jacket End Plate	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Top Flange	B	ASME Section III; Subsection NF	SA350-LF3	See Table 3.3.3	See Note 5	NA
Structural Integrity	Lower Water Jacket Shell	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA

Notes:
1) There are no known residuals on finished component surfaces
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III.
3) Component nomenclature taken from Bill of Materials in Chapter 1.
4) A, B, and C denote important to safety classifications as described in the Holtec QA Program. NITS stands for Not Important to Safety.
5) All external surfaces to be painted with Carboline 890. Top surface of doors to be painted with Thermaline 450.

HOLTEC INTERNATIONAL COPYRIGHTED MATERIAL

TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STORM 100 SYSTEM
HI-TRAC TRANSFER CASK [1,2]

Primary Function	Component [3]	Safety Class [4]	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
Structural Integrity	Bottom Flange	B	ASME Section III; Subsection NF	SA350-LF3 (SA516-70)	See Table 3.3.3 (Table 3.3.2)	See Note 5	NA
Structural Integrity	Pool Lid Outer Ring	B	ASME Section III; Subsection NF	SA516-70 or SA 203E or SA350-LF3	See Table 3.3.3	See Note 5	NA
Structural Integrity	Pool Lid Top Plate	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Top Lid Outer Ring	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Top Lid Inner Ring	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Top Lid Top Plate	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Top Lid Bottom Plate	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Fill Port Plugs	C	ASME Section III; Subsection NF	Carbon Steel	See Table 3.3.2	See Note 5	NA

Notes:
1) There are no known residuals on finished component surfaces
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III.
3) Component nomenclature taken from Bill of Materials in Chapter 1.
4) A, B, and C denote important to safety classifications as described in the Holtec QA Program. NITS stands for Not Important to Safety.
5) All external surfaces to be painted with Carboline 890. Top surface of doors to be painted with Thermaline 450.

HOLTEC INTERNATIONAL COPYRIGHTED MATERIAL

TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STORM 100 SYSTEM
HI-TRAC TRANSFER CASK [1,2]

Primary Function	Component [3]	Safety Class [4]	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
Structural Integrity	Pool Lid Bolt	B	ASME Section III; Subsection NF	SA193-B7	See Table 3.3.4	NA	NA
Structural Integrity	Lifting Trunnion Block	B	ASME Section III; Subsection NF	SA350-LF3	See Table 3.3.3	See Note 5	NA
Structural Integrity	Lifting Trunnion	A	ANSI N14.6	SB637 (N07718)	See Table 3.3.4	NA	NA
Structural Integrity	Pocket Trunnion (HI-TRAC 100 and HI-TRAC 125 only)	B	ASME Section III; Subsection NF ANSI N14.6	SA350-LF3	See Table 3.3.3	See Note 5	NA
Structural Integrity	Dowel Pins	B	ASME Section III; Subsection NF	SA564-630	See Table 3.3.4	NA	SA350-LF3
Structural Integrity	Water Jacket End Plate	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Pool Lid Bottom Plate	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Top Lid Lifting Block	C	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Bottom Flange Gussets (HI-TRAC 125D only)	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Operations	Top Lid Stud or bolt	B	ASME Section III; Subsection NF	SA193-B7	See Table 3.3.4	NA	NA

Notes:
1) There are no known residuals on finished component surfaces
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III.
3) Component nomenclature taken from Bill of Materials in Chapter 1.
4) A, B, and C denote important to safety classifications as described in the Holtec QA Program. NITS stands for Not Important to Safety.
5) All external surfaces to be painted with Carboline 890. Top surface of doors to be painted with Thermaline 450.

HOLTEC INTERNATIONAL COPYRIGHTED MATERIAL

TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STORM 100 SYSTEM
HI-TRAC TRANSFER CASK [1,2]

Primary Function	Component [3]	Safety Class [4]	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
Operations	Top Lid Nut	B	ASME Section III; Subsection NF	SA194-2H	NA	NA	NA
Operations	Pool Lid Gasket	NITS	Non-code	Elastomer	NA	NA	NA
Operations	Lifting Trunnion End Cap (HI-TRAC 100 and HI-TRAC 125 only)	C	Non-code	SA516-70	See Table 3.3.2	See Note 5	NA
Operations	End Cap Bolts (HI-TRAC 100 and HI-TRAC 125 only)	NITS	Non-code	SA193-B7	See Table 3.3.4	NA	NA
Operations	Drain Pipes	NITS	Non-code	SA106	NA	NA	NA
Operations	Drain Bolt	NITS	Non-code	SA193-B7	See Table 3.3.4	NA	NA
Operations	Couplings, Valves and Vent Plug	NITS	Non-code	Commercial	NA	NA	NA

Notes:
1) There are no known residuals on finished component surfaces
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III.
3) Component nomenclature taken from Bill of Materials in Chapter 1.
4) A, B, and C denote important to safety classifications as described in the Holtec QA Program. NITS stands for Not Important to Safety.
5) All external surfaces to be painted with Carboline 890. Top surface of doors to be painted with Thermaline 450.

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TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STORM 100 SYSTEM
HI-TRAC TRANSFER LID (HI-TRAC 100 and HI-TRAC 125 ONLY) (1,2)

Primary Function	Component (3)	Safety Class (4)	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
Shielding	Side Lead Shield	B	Non-code	Lead	NA	NA	NA
Shielding	Door Lead Shield	B	Non-code	Lead	NA	NA	
Shielding	Door Shielding	B	Non-code	Holtite	NA	NA	NA
Structural Integrity	Lid Top Plate	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Lid Bottom Plate	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Lid Intermediate Plate	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Lead Cover Plate	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Lead Cover Side Plate	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Door Top Plate	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Door Middle Plate	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Door Bottom Plate	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Door Wheel Housing	B	ASME Section III; Subsection NF	SA516-70 (SA350-LF3)	See Table 3.3.2 (Table 3.3.3)	See Note 5	NA
Structural Integrity	Door Interface Plate	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Door Side Plate	B	ASME Section III;	SA516-70	See Table 3.3.2	See Note 5	NA

Notes:
1) There are no known residuals on finished component surfaces
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III.
3) Component nomenclature taken from Bill of Materials in Chapter 1.
4) A, B, and C denote important to safety classifications as described in the Holtec QA Program. NITS stands for Not Important to Safety.
5) All external surfaces to be painted with Carboline 890. Top surface of doors to be painted with Thermaline 450.

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TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STORM 100 SYSTEM
HI-TRAC TRANSFER LID (HI-TRAC 100 and HI-TRAC 125 ONLY) (1,2)

Primary Function	Component (3)	Safety Class (4)	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
			Subsection NF				
Structural Integrity	Wheel Shaft	C	ASME Section III; Subsection NF	SA 193-B7	36 (yield)	See Note 5	NA
Structural Integrity	Lid Housing Stiffener	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Door Lock Bolt	B	ASME Section III; Subsection NB	SA193-B7	See Table 3.3.4	NA	NA
Structural Integrity	Door End Plate	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Structural Integrity	Lifting Lug and Pad	B	ASME Section III; Subsection NF	SA516-70	See Table 3.3.2	See Note 5	NA
Operations	Wheel Track	C	ASME Section III; Subsection NF	SA-36	36 (yield)	See Note 5	NA
Operations	Door Handle	NITS	Non-code	C/S or S/S	NA	See Note 5	NA
Operations	Door Wheels	NITS	Non-code	Forged Steel	NA	NA	NA
Operations	Door Stop Block	C	Non-code	SA516-70	See Table 3.3.2	See Note 5	NA
Operations	Door Stop Block Bolt	C	Non-code	SA193-B7	See Table 3.3.4	NA	NA

Notes:
1) There are no known residuals on finished component surfaces
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III.
3) Component nomenclature taken from Bill of Materials in Chapter 1.
4) A, B, and C denote important to safety classifications as described in the Holtec QA Program. NITS stands for Not Important to Safety.
5) All external surfaces to be painted with Carboline 890. Top surface of doors to be painted with Thermaline 450.

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Table 2.2.7

HI-STORM 100 ASME BOILER AND PRESSURE VESSEL CODE APPLICABILITY

HI-STORM 100 Component	Material Procurement	Design	Fabrication	Inspection
Overpack steel structure	Section II, Section III, Subsection NF, NF-2000	Section III, Subsection NF, NF-3200	Section III, Subsection NF, NF-4000	Section III, Subsection NF, NF-5350, NF-5360 and Section V
Anchor Studs for HI-STORM 100A	Section II, Section III, Subsection NF, NF-2000*	Section III, Subsection NF, NF- 3300	NA	NA
MPC confinement boundary	Section II, Section III, Subsection NB, NB-2000	Section III, Subsection NB, NB-3200	Section III, Subsection NB, NB-4000	Section III, Subsection NB, NB-5000 and Section V
MPC fuel basket	Section II, Section III, Subsection NG, NG-2000; core support structures (NG-1121)	Section III, Subsection NG, NG-3300 and NG-3200; core support structures (NG-1121)	Section III, Subsection NG, NG-4000; core support structures (NG-1121)	Section III, Subsection NG, NG-5000 and Section V; core support structures (NG-1121)
HI-TRAC Trunnions	Section II, Section III, Subsection NF, NF-2000	ANSI *N*14.6	Section III, Subsection NF, NF-4000	See Chapter 9
MPC basket supports (Angled Plates)	Section II, Section III, Subsection NG, NG-2000; internal structures (NG-1122)	Section III, Subsection NG, NG-3300 and NG-3200; internal structures (NG-1122)	Section III, Subsection NG, NG-4000; internal structures (NG-1122)	Section III, Subsection NG, NG-5000 and Section V; internal structures (NG-1122)
HI-TRAC steel structure	Section II, Section III, Subsection NF, NF-2000	Section III, Subsection NF, NF-3300	Section III, Subsection NF, NF-4000	Section III, Subsection NF, NF-5360 and Section V
Damaged fuel container	Section II, Section III, Subsection NG, NG-2000	Section III, Subsection NG, NG-3300 and NG-3200	Section III, Subsection NG, NG-4000	Section III, Subsection NG, NG-5000 and Section V
Overpack concrete	ACI 349 as specified by Appendix 1.D	ACI 349 and ACI 318.*1-89(92)*~~95~~ as specified by Appendix 1.D	ACI 349 as specified by Appendix 1.D	ACI 349 as specified by Appendix 1.D

* Except impact testing shall be determined based on service temperature and material type.

Table 2.2.8

ADDITIONAL DESIGN INPUT DATA FOR NORMAL, OFF-NORMAL, AND ACCIDENT CONDITIONS

Item	Condition	Value
Snow Pressure Loading (lb./ft^2)	Normal	100
Constriction of MPC Basket Vent Opening By Crud Settling (Depth of Crud, in.)	Accident	0.85 (MPC-68) 0.36 (MPC-24 and MPC-32)
Cask Environment During the Postulated Fire Event (Deg. F)	Accident	1475
HI-STORM Overpack Fire Duration (seconds)	Accident	217
HI-TRAC Transfer Cask Fire Duration (minutes)	Accident	4.8
Maximum submergence depth due to flood (ft)	Accident	125
Flood water velocity (ft/s)	Accident	15
Interaction Relation for Horizontal & Vertical acceleration for HI-STORM	Accident	$G_H + 0.53G_V = 0.53^{††}$ (HI-STORM 100, 100S, and 100S Version B) $G_H = 2.12$; $G_V = 1.5$ (HI-STORM 100A)
Net Overturning Moment at base of HI-STORM 100A (ft-lb)	Accident	18.7×10^6
HI-STORM 100 Overpack Vertical Lift Height Limit (in.)	Accident	$11^{†††}$ (HI-STORM 100 and 100S), OR By Users (HI-STORM 100A)
HI-TRAC Transfer Cask Horizontal Lift Height Limit (in.)	Accident	$42^{†††}$

†† See Subsection 3.4.7.1 for definition of G_H and G_V. The coefficient of friction may be increased above 0.53 based on testing described in Subsection 3.4.7.1

††† For ISFSI and subgrade design parameter Sets A and B. Users may also develop a site-specific lift height limit.

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Table 2.2.9

EXAMPLES OF ACCEPTABLE ISFSI PAD DESIGN PARAMETERS

PARAMETER	**PARAMETER SET "A"** †	**PARAMETER SET "B"**
Concrete thickness, t_p, (inches)	$\leq$ 36	$\leq$ 28
Concrete Compressive Strength (at 28 days), f_c', (psi)	$\leq$ 4,200	$\leq$ 6,000 psi
Reinforcement Top and Bottom (both directions)	Reinforcing bar shall be 60 ksi Yield Strength ASTM Material	Reinforcing bar shall be 60 ksi Yield Strength ASTM Material
Subgrade Effective Modulus of Elasticity†† (measured prior to ISFSI pad installation), E, (psi)	$\leq$ 28,000	$\leq$ 16,000

NOTE: A static coefficient of friction of $\geq$ 0.53 between the ISFSI pad and the bottom of the overpack shall be verified by test. The test procedure shall follow the guidelines included in the Sliding Analysis in Subsection 3.4.7.1.

† The characteristics of this pad are identical to the pad considered by Lawrence Livermore Laboratory (see Appendix 3.A).

†† An acceptable method of defining the soil effective modulus of elasticity applicable to the drop and tipover analysis is provided in Table 13 of NUREG/CR-6608 with soil classification in accordance with ASTM-D2487 Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System USCS) and density determination in accordance with ASTM-D1586 Standard Test Method for Penetration Test and Split/Barrel Sampling of Soils.

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Table 2.2.10
MPC CONFINEMENT BOUNDARY STRESS INTENSITY LIMITS
FOR DIFFERENT LOADING CONDITIONS (ELASTIC ANALYSIS PER NB-3220)†

STRESS CATEGORY	DESIGN	LEVELS A & B	LEVEL D††
Primary Membrane, P_m	S_m	N/A†††	AMIN ($2.4S_m$, $.7S_u$)
Local Membrane, P_L	$1.5S_m$	N/A	150% of P_m Limit
Membrane plus Primary Bending	$1.5S_m$	N/A	150% of P_m Limit
Primary Membrane plus Primary Bending	$1.5S_m$	N/A	150% of P_m Limit
Membrane plus Primary Bending plus Secondary	N/A	$3S_m$	N/A
Average Shear Stress††††	$0.6S_m$	$0.6S_m$	$0.42S_u$

† Stress combinations including F (peak stress) apply to fatigue evaluations only.
†† Governed by Appendix F, Paragraph F-1331 of the ASME Code, Section III.
††† No Specific stress limit applicable.
†††† Governed by NB-3227.2 or F-1331.1(d).

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Table 2.2.11

MPC BASKET STRESS INTENSITY LIMITS
FOR DIFFERENT LOADING CONDITIONS (ELASTIC ANALYSIS PER NG-3220)

STRESS CATEGORY	DESIGN	LEVELS A & B	LEVEL D†
Primary Membrane, P_m	S_m	S_m	AMIN ($2.4S_m$, $.7S_u$)††
Primary Membrane plus Primary Bending	$1.5S_m$	$1.5S_m$	150% of P_m Limit
Primary Membrane plus Primary Bending plus Secondary	N/A†††	$3S_m$	N/A

† Governed by Appendix F, Paragraph F-1331 of the ASME Code, Section III.
†† Governed by NB-3227.2 or F-1331.1(d).
††† No specific stress intensity limit applicable.

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Table 2.2.12
STRESS LIMITS FOR DIFFERENT
LOADING CONDITIONS FOR THE STEEL STRUCTURE OF THE OVERPACK AND HI-TRAC
(ELASTIC ANALYSIS PER NF-3260)

		SERVICE CONDITION	
STRESS CATEGORY	**DESIGN + LEVEL A**	**LEVEL B**	**LEVEL D**[†]
Primary Membrane, P_m	S	1.33S	AMAX (1.2S , $1.5S_m$) but < $.7S_u$
Primary Membrane, P_m, plus Primary Bending, P_b	1.5S	1.995S	150% of P_m
Shear Stress (Average)	0.6S	0.6S	$<0.42S_u$

Definitions:

S = Allowable Stress Value for Table 1A, ASME Section II, Part D.
S_m = Allowable Stress Intensity Value from Table 2A, ASME Section II, Part D
S_u = Ultimate Strength

[†] Governed by Appendix F, Paragraph F-1332 of the ASME Code, Section III.

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Table 2.2.13

NOTATION FOR DESIGN LOADINGS FOR NORMAL, OFF-NORMAL, AND ACCIDENT CONDITIONS

NORMAL CONDITION	
LOADING	**NOTATION**
Dead Weight	D
Handling Loads	H
Design Pressure (Internal)	P_i
Design Pressure (External)†	P_o
Snow	S
Operating Temperature	T
OFF-NORMAL CONDITION	
Loading	Notation
Off-Normal Pressure (Internal)	P_i
Off-Normal Pressure (External)†	P_o
Off-Normal Temperature	T’
Off-Normal HI-TRAC Handling	H’

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Table 2.2.13 (continued)

NOTATION FOR DESIGN LOADINGS FOR NORMAL, OFF-NORMAL, AND ACCIDENT CONDITIONS

ACCIDENT CONDITIONS	
LOADING	**NOTATION**
Handling Accident	H’
Earthquake	E
Fire	T^*
Tornado Missile	M
Tornado Wind	W’
Flood	F
Explosion	E^*
Accident Pressure (Internal)	P_i^*
Accident Pressure (External)	P_o^*

Table 2.2.14
APPLICABLE LOAD CASES AND COMBINATIONS FOR EACH CONDITION AND COMPONENT[†, ††]

CONDITION	LOADING CASE	MPC	OVERPACK	HI-TRAC
Design (ASME Code Pressure Compliance)	1	P_i, P_o	N/A	N/A
Normal (Level A)	1	D ,T , H , P_i	D , T , H	D , T[†††] , H, $P_{i\ (water\ jacket)}$
	2	D , T , H , P_o	N/A	N/A
Off-Normal (Level B)	1	D , T', H , P_i'	D , T' , H	N/A[†††] (H' pocket trunnion)
	2	D , T' , H , P_o	N/A	N/A
Accident (Level D)	1	D , T , P_i , H'	D , T , H'	D , T , H'
	2	D , T^* , P_i^*	N/A	N/A
	3	D , T , P_o^{*}[††††]	D , T , P_o^{*}[††††]	D , T , P_o^{*}[††††]
	4	N/A	D, T, (E, M, F, W')[†††††]	D, T, (M, W')[†††††]

[†] The loading notations are given in Table 2.2.13. Each symbol represents a loading type and may have different values for different components. The different loads are assumed to be additive and applied simultaneously.

[††] N/A stands for "Not Applicable."

[†††] T (normal condition) for the HI-TRAC is 100°F and $P_{i(water\ jacket)}$ is 60 psig and, therefore, there is no off-normal temperature or load combination because Load Case 1, Normal (Level A), is identical to Load Case 1, Off-Normal (Level B). Only the off-normal handling load on the pocket trunnion is analyzed separately.

[††††] P_o^* bounds the external pressure due to explosion.

[†††††] (E, M, F, W') means loads are considered separately in combination with D, T. E and F not applicable to HI-TRAC.

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Table 2.2.15

LIST OF ASME CODE ~~EXCEPTIONS~~*ALTERNATIVES* FOR HI-STORM 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	~~Exception~~*Alternative*, Justification & Compensatory Measures
MPC, MPC basket assembly, HI-STORM overpack steel structure, and HI-TRAC transfer cask steel structure.	Subsection NCA	General Requirements. Requires preparation of a Design Specification, Design Report, Overpressure Protection Report, Certification of Construction Report, Data Report, and other administrative controls for an ASME Code stamped vessel.	Because the MPC, overpack, and transfer cask are not ASME Code stamped vessels, none of the specifications, reports, certificates, or other general requirements specified by NCA are required. In lieu of a Design Specification and Design Report, the HI-STORM FSAR includes the design criteria, service conditions, and load combinations for the design and operation of the HI-STORM 100 System as well as the results of the stress analyses to demonstrate that applicable Code stress limits are met. Additionally, the fabricator is not required to have an ASME-certified QA program. All important-to-safety activities are governed by the NRC-approved Holtec QA program. Because the cask components are not certified to the Code, the terms “Certificate Holder” and “Inspector” are not germane to the manufacturing of NRC-certified cask components. To eliminate ambiguity, the responsibilities assigned to the Certificate Holder in the various articles of Subsections NB, NG, and NF of the Code, as applicable, shall be interpreted to apply to the NRC Certificate of Compliance (CoC) holder (and by extension, to the component fabricator) if the requirement must be fulfilled. The Code term “Inspector” means the QA/QC personnel of the CoC holder and its vendors assigned to oversee and inspect the manufacturing process.

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Table 2.2.15 (continued)

LIST OF ASME CODE *ALTERNATIVES*~~EXCEPTIONS~~ FOR HI-STORM 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	~~Exception~~*Alternative*, Justification & Compensatory Measures
MPC	NB-1100	Statement of requirements for Code stamping of components.	MPC enclosure vessel is designed and will be fabricated in accordance with ASME Code, Section III, Subsection NB to the maximum practical extent, but Code stamping is not required.
MPC basket supports and lift lugs	NB-1130	NB-1132.2(d) requires that the first connecting weld of a nonpressure-retaining structural attachment to a component shall be considered part of the component unless the weld is more than 2t from the pressure-retaining portion of the component, where t is the nominal thickness of the pressure-retaining material. NB-1132.2(e) requires that the first connecting weld of a welded nonstructural attachment to a component shall conform to NB-4430 if the connecting weld is within 2t from the pressure-retaining portion of the component.	The MPC basket supports (nonpressure-retaining structural attachment) and lift lugs (nonstructural attachments (relative to the function of lifting a loaded MPC) that are used exclusively for lifting an empty MPC) are welded to the inside of the pressure-retaining MPC shell, but are not designed in accordance with Subsection NB. The basket supports and associated attachment welds are designed to satisfy the stress limits of Subsection NG and the lift lugs and associated attachment welds are designed to satisfy the stress limits of Subsection NF, as a minimum. These attachments and their welds are shown by analysis to meet the respective stress limits for their service conditions. Likewise, non-structural items, such as shield plugs, spacers, etc. if used, can be attached to pressure-retaining parts in the same manner.

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Table 2.2.15 (continued)

LIST OF ASME CODE *ALTERNATIVES*~~EXCEPTIONS~~ FOR HI-STORM 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	~~Exception~~*Alternative*, Justification & Compensatory Measures
MPC	NB-2000	Requires materials to be supplied by ASME-approved material supplier.	Materials will be supplied by Holtec approved suppliers with Certified Material Test Reports (CMTRs) in accordance with NB-2000 requirements.
MPC, MPC basket assembly, HI-STORM overpack, and HI-TRAC transfer cask	NB-3100 NG-3100 NF-3100	Provides requirements for determining design loading conditions, such as pressure, temperature, and mechanical loads.	These requirements are not applicable. The HI-STORM FSAR, serving as the Design Specification, establishes the service conditions and load combinations for the storage system.
MPC	NB-3350	NB-3352.3 requires, for Category C joints, that the minimum dimensions of the welds and throat thickness shall be as shown in Figure NB-4243-1.	Due to MPC basket-to-shell interface requirements, the MPC shell-to-baseplate weld joint design (designated Category C) does not include a reinforcing fillet weld or a bevel in the MPC baseplate, which makes it different than any of the representative configurations depicted in Figure NB-4243-1. The transverse thickness of this weld is equal to the thickness of the adjoining shell (1/2 inch). The weld is designed as a full penetration weld that receives VT and RT or UT, as well as final surface PT examinations. Because the MPC shell design thickness is considerably larger than the minimum thickness required by the Code, a reinforcing fillet weld that would intrude into the MPC cavity space is not included. Not including this fillet weld provides for a higher quality radiographic examination of the full penetration weld. From the standpoint of stress analysis, the fillet weld serves to reduce the local bending stress (secondary stress) produced by the gross structural discontinuity defined by the flat plate/shell junction. In the MPC design, the shell and baseplate thicknesses are well beyond that required to meet their respective membrane stress intensity limits.

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Table 2.2.15 (continued)

LIST OF ASME CODE *ALTERNATIVES*~~EXCEPTIONS~~ FOR HI-STORM 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	~~Exception~~*Alternative*, Justification & Compensatory Measures
MPC, MPC basket assembly, HI-STORM overpack steel structure, and HI-TRAC transfer cask steel structure	NB-4120 NG-4120 NF-4120	NB-4121.2, NG-4121.2, and NF-4121.2 provide requirements for repetition of tensile or impact tests for material subjected to heat treatment during fabrication or installation.	In-shop operations of short duration that apply heat to a component, such as plasma cutting of plate stock, welding, machining, coating, and pouring of lead are not, unless explicitly stated by the Code, defined as heat treatment operations. For the steel parts in the HI-STORM 100 System components, the duration for which a part exceeds the off-normal temperature limit defined in Chapter 2 of the FSAR shall be limited to 24 hours in a particular manufacturing process (such as the HI-TRAC lead pouring process).
MPC, HI-STORM overpack steel structure, HI-TRAC transfer cask steel structure	NB-4220 NF-4220	Requires certain forming tolerances to be met for cylindrical, conical, or spherical shells of a vessel.	The cylindricity measurements on the rolled shells are not specifically recorded in the shop travelers, as would be the case for a Code-stamped pressure vessel. Rather, the requirements on inter-component clearances (such as the MPC-to-transfer cask) are guaranteed through fixture-controlled manufacturing. The fabrication specification and shop procedures ensure that all dimensional design objectives, including inter-component annular clearances are satisfied. The dimensions required to be met in fabrication are chosen to meet the functional requirements of the dry storage components. Thus, although the post-forming Code cylindricity requirements are not evaluated for compliance directly, they are indirectly satisfied (actually exceeded) in the final manufactured components.

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Table 2.2.15 (continued)

LIST OF ASME CODE *ALTERNATIVES*~~EXCEPTIONS~~ FOR HI-STORM 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	~~Exception~~*Alternative*, Justification & Compensatory Measures
MPC Lid and Closure Ring Welds	NB-4243	Full penetration welds required for Category C Joints (flat head to main shell per NB-3352.3)	MPC lid and closure ring are not full penetration welds. They are welded independently to provide a redundant seal. Additionally, a weld efficiency factor of 0.45 has been applied to the analyses of these welds.
MPC Closure Ring, Vent and Drain Cover Plate Welds	NB-5230	Radiographic (RT) or ultrasonic (UT) examination required.	Root (if more than one weld pass is required) and final liquid penetrant examination to be performed in accordance with NB-5245. The closure ring provides independent redundant closure for vent and drain cover plates. *Vent and drain port cover plate welds are helium leakage tested.*
MPC Lid to Shell Weld	NB-5230	Radiographic (RT) or ultrasonic (UT) examination required.	Only UT or multi-layer liquid penetrant (PT) examination is permitted. If PT examination alone is used, at a minimum, it will include the root and final weld layers and each approx. 3/8" of weld depth.
MPC Enclosure Vessel and Lid	NB-6111	All completed pressure retaining systems shall be pressure tested.	The MPC vessel is seal welded in the field following fuel assembly loading. The MPC vessel shall then be pressure tested as defined in Chapter 9. Accessibility for leakage inspections preclude a Code compliant pressure test. All MPC vessel welds (except closure ring and vent/drain cover plate) are inspected by volumetric examination, except the MPC lid-to-shell weld shall be verified by volumetric or multi-layer PT examination. If PT alone is used, at a minimum, it must include the root and final layers and each approximately 3/8 inch of weld depth. For either UT or PT, the maximum undetectable flaw size must be determined in accordance with ASME Section XI methods. The critical flaw size shall not cause the primary stress limits of NB-3000 to be exceeded. The inspection results, including relevant findings (indications) shall be made a permanent part of the user's

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Table 2.2.15 (continued)

LIST OF ASME CODE *ALTERNATIVES*~~EXCEPTIONS~~ FOR HI-STORM 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	~~Exception~~*Alternative*, Justification & Compensatory Measures
			records by video, photographic, of other means which provide an equivalent record of weld integrity. The video or photographic records should be taken during the final interpretation period described in ASME Section V, Article 6, T-676. The vent/drain cover plate and the closure ring welds are confirmed by liquid penetrant examination. The inspection of the weld must be performed by qualified personnel and shall meet the acceptance requirements of ASME Code Section III, NB-5350 for PT or NB-5332 for UT.
MPC Enclosure Vessel	NB-7000	Vessels are required to have overpressure protection.	No overpressure protection is provided. Function of MPC enclosure vessel is to contain radioactive contents under normal, off-normal, and accident conditions of storage. MPC vessel is designed to withstand maximum internal pressure considering 100% fuel rod failure and maximum accident temperatures.
MPC Enclosure Vessel	NB-8000	States requirements for nameplates, stamping and reports per NCA-8000.	The HI-STORM 100 System is to be marked and identified in accordance with 10CFR71 and 10CFR72 requirements. Code stamping is not required. QA data package to be in accordance with Holtec approved QA program.
MPC Basket Assembly	NG-2000	Requires materials to be supplied by ASME approved Material Supplier.	Materials will be supplied by Holtec approved supplier with CMTRs in accordance with NG-2000 requirements.

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Table 2.2.15 (continued)

LIST OF ASME CODE *ALTERNATIVES*~~EXCEPTIONS~~ FOR HI-STORM 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	~~Exception~~*Alternative*, Justification & Compensatory Measures
MPC Basket Assembly	NG-4420	NG-4427(a) requires a fillet weld in any single continuous weld may be less that the specified fillet weld dimension by not more than 1/16 inch, provided that the total undersize portion of the weld does not exceed 10 percent of the length of the weld. Individual undersize weld portions shall not exceed 2 inches in length.	Modify the Code requirement (intended for core support structures) with the following text prepared to accord with the geometry and stress analysis imperatives for the fuel basket: For the longitudinal MPC basket fillet welds, the following criteria apply: 1) The specified fillet weld throat dimension must be maintained over at least 92 percent of the total weld length. All regions of undersized weld must be less than 3 inches long and separated from each other by at least 9 inches. 2) Areas of undercuts and porosity beyond that allowed by the applicable ASME Code shall not exceed 1/2 inch in weld length. The total length of undercut and porosity over any 1-foot length shall not exceed 2 inches. 3) The total weld length in which items (1) and (2) apply shall not exceed a total of 10 percent of the overall weld length. The limited access of the MPC basket panel longitudinal fillet welds makes it difficult to perform effective repairs of these welds and creates the potential for causing additional damage to the basket assembly (e.g., to the neutron absorber and its sheathing) if repairs are attempted. The acceptance criteria provided in the foregoing have been established to comport with the objectives of the basket design and preserve the margins demonstrated in the supporting stress analysis. From the structural standpoint, the weld acceptance criteria are established to ensure that any departure from the ideal, continuous fillet weld seam would not alter the primary bending stresses on which the design of the fuel baskets is predicated. Stated differently, the permitted weld discontinuities are limited in size to ensure that they remain classifiable as local stress elevators (“peak stress”, F, in the ASME Code for which specific stress intensity limits do not apply).

Table 2.2.15 (continued)

LIST OF ASME CODE *ALTERNATIVES*~~EXCEPTIONS~~ FOR HI-STORM 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	~~Exception~~*Alternative*, Justification & Compensatory Measures
MPC Basket Assembly	NG-8000	States requirements for nameplates, stamping and reports per NCA-8000.	The HI-STORM 100 System is to be marked and identified in accordance with 10CFR71 and 10CFR72 requirements. No Code stamping is required. The MPC basket data package is to be in conformance with Holtec's QA program.
Overpack Steel Structure	NF-2000	Requires materials to be supplied by ASME approved Material Supplier.	Materials will be supplied by Holtec approved supplier with CMTRs in accordance with NF-2000 requirements.
HI-TRAC Steel Structure	NF-2000	Requires materials to be supplied by ASME approved Material Supplier.	Materials will be supplied by Holtec approved supplier with CMTRs in accordance with NF-2000 requirements.
Overpack Baseplate and Lid Top Plate	NF-4441	Requires special examinations or requirements for welds where a primary member thickness of 1" or greater is loaded to transmit loads in the through thickness direction.	The margins of safety in these welds under loads experienced during lifting operations or accident conditions are quite large. The overpack baseplate welds to the inner shell, pedestal shell, and radial plates are only loaded during lifting conditions and have large safety factors during lifting. Likewise, the top lid plate to lid shell weld has a large structural margin under the inertia loads imposed during a non-mechanistic tipover event.

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Table 2.2.15 (continued)

LIST OF ASME CODE *ALTERNATIVES*~~EXCEPTIONS~~ FOR HI-STORM 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	~~Exception~~*Alternative*, Justification & Compensatory Measures
Overpack Steel Structure	NF-3256 NF-3266	Provides requirements for welded joints.	Welds for which no structural credit is taken are identified as "Non-NF" welds in the design drawings by an "*". These non-structural welds are specified in accordance with the pre-qualified welds of AWS D1.1. These welds shall be made by welders and weld procedures qualified in accordance with AWS D1.1 or ASME Section IX. Welds for which structural credit is taken in the safety analyses shall meet the stress limits for NF-3256.2, but are not required to meet the joint configuration requirements specified in these Code articles. The geometry of the joint designs in the cask structures are based on the fabricability and accessibility of the joint, not generally contemplated by this Code section governing supports.
HI-STORM Overpack and HI-TRAC Transfer Cask	NF-3320 NF-4720	NF-3324.6 and NF-4720 provide requirements for bolting	These Code requirements are applicable to linear structures wherein bolted joints carry axial, shear, as well as rotational (torsional) loads. The overpack and transfer cask bolted connections in the structural load path are qualified by design based on the design loadings defined in the FSAR. Bolted joints in these components see no shear or torsional loads under normal storage conditions. Larger clearances between bolts and holes may be necessary to ensure shear interfaces located elsewhere in the structure engage prior to the bolts experiencing shear loadings (which occur only during side impact scenarios). Bolted joints that are subject to shear loads in accident conditions are qualified by appropriate stress analysis. Larger bolt-to-hole clearances help ensure more efficient operations in making these bolted connections, thereby minimizing time spent by operations personnel in a radiation area. Additionally, larger bolt-to-hole clearances allow interchangeability of the lids from one particular fabricated cask to another.

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Table 2.2.16

COMPARISON BETWEEN HI-STORM MPC LOADINGS WITH HI-STAR MPC LOADINGS[†]

Loading Condition	**Difference Between MPC Loadings Under HI-STAR and HI-STORM Conditions**
Dead Load	Unchanged
Design Internal Pressure (normal, off-normal, & accident)	Unchanged
Design External Pressure (normal, off-normal, & accident)	HI-STORM normal and off-normal external pressure is ambient which is less than the HI-STAR 40 psig. The accident external pressure is unchanged.
Thermal Gradient (normal, off-normal, & accident)	Determined by analysis in Chapters 3 and 4
Handling Load (normal)	Unchanged
Earthquake (accident)	Inertial loading increased less than 0.1g's (for free-standing overpack designs).
Handling Load (accident)	HI-STORM vertical and horizontal deceleration loadings are less than those in HI-STAR, but the HI-STORM cavity inner diameter is different and therefore the horizontal loading on the MPC is analyzed in Chapter 3.

[†] HI-STAR MPC loadings are those specified in HI-STAR SARs under Docket Numbers 71-9261 and 72-1008.

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Appendix 2.C

[Deleted]

~~The Supplemental Cooling System~~

~~2.C.1 Purpose~~

~~The Supplemental Cooling System (SCS) will be utilized, as necessary, to maintain the peak fuel cladding temperature below the limit set forth in Chapter 2 of the FSAR during normal short-term operations(as defined in Section 2.2).~~

~~2.C.2 General Description and Requirements~~

~~The SCS is a water circulation system for cooling the MPC inside the HI-TRAC transfer cask during on-site transport. The system consists of a skid-mounted coolant pump and an air-cooled heat exchanger. During normal SCS operation, heat is removed by water~~*~~a coolant~~* ~~from the HI-TRAC annulus and rejected to the heat sink (ambient air) across the air-cooler heat exchange surfaces. The SCS shall be designed to meet the following criteria:~~

~~(i)~~*~~If the system uses water as the coolant,~~ ~~T~~*~~the system~~ ~~pump is sized to limit the coolant temperature rise (from annulus inlet to outlet) to a reasonably low value (20ºF)~~ *~~to below 180°F under steady-state conditions~~ ~~and the air-cooled heat exchanger sized for the design basis heat load at an ambient air temperature of 100°F. The pump and air-cooler fan are powered by electric motors with a backup power supply for uninterrupted operation.~~

~~(ii)The closed loop cooling circuit~~*~~system~~ ~~will utilize a contamination-free fluid medium in contact with the external surfaces of the MPC and inside surfaces of the HI-TRAC transfer cask to minimize corrosion. Figure 2.C.1 shows a typical P&ID for a SCS.~~

~~(iii)The number of active components in the SCS will be minimized.~~

~~(iv)All passive components such as tubular heat exchangers, manually operated valves and fittings shall be designed to applicable standards (TEMA, ANSI).~~

~~2.C.3 Thermal/Hydraulic Design Criteria~~

~~(i)The heat dissipation capacity of the SCS shall be equal to or greater than the minimum necessary to ensure that the peak cladding temperature is below the ISG-11, Rev. 3 limit of 400°C (752°F). All heat transfer surfaces in~~ *~~any~~* ~~heat exchangers shall be assumed to be fouled to the maximum limits specified in a widely used heat exchange equipment standard such as the Standards of Tubular Exchanger Manufacturers Association.~~

(ii)The coolant utilized to extract heat from the MPC shall be *either* high purity water *or air*. Anti-freeze may be used to prevent water from freezing if warranted by operating conditions.

2.C.4 Mechanical Requirements

(i)All pressure boundaries (as defined in the ASME Boiler and Pressure Vessel Code, Section VIII Division 1) shall have pressure ratings that are greater than the maximum system operating pressure by at least 15 psi.

(ii)All ASME Code components shall comply with Section VIII Division 1 of the ASME Boiler and Pressure Vessel Code.

(iii)Prohibited Materials

The following materials will not be in contact with the system coolant in the SCS.

- Lead
- Mercury
- Sulfur
- Saran
- Silastic L8-53
- Cadmium
- Tin
- Antimony
- Bismuth
- Mischmetal
- Neoprene or similar gasket materials made of halogen containing elastomers
- Phosphorus
- Zinc
- Copper and Copper Alloys
- Rubber-bonded asbestos
- Nylon
- Magnesium oxide (e.g., insulation)
- Materials that contain halogens in amounts exceeding 75 ppm

(iv)All gasketed and packed joints shall have a minimum design pressure rating of the pump shut-off pressure plus 15 psi. *Not Used.*

(v)The SCS skid shall be equipped with appropriate lifting lugs to permit its handling by the plant's lifting devices in full compliance with NUREG-0612 provisions.

2.C.5 Regulatory Requirements

The SCS is classified as Important-to-Safety Category B.

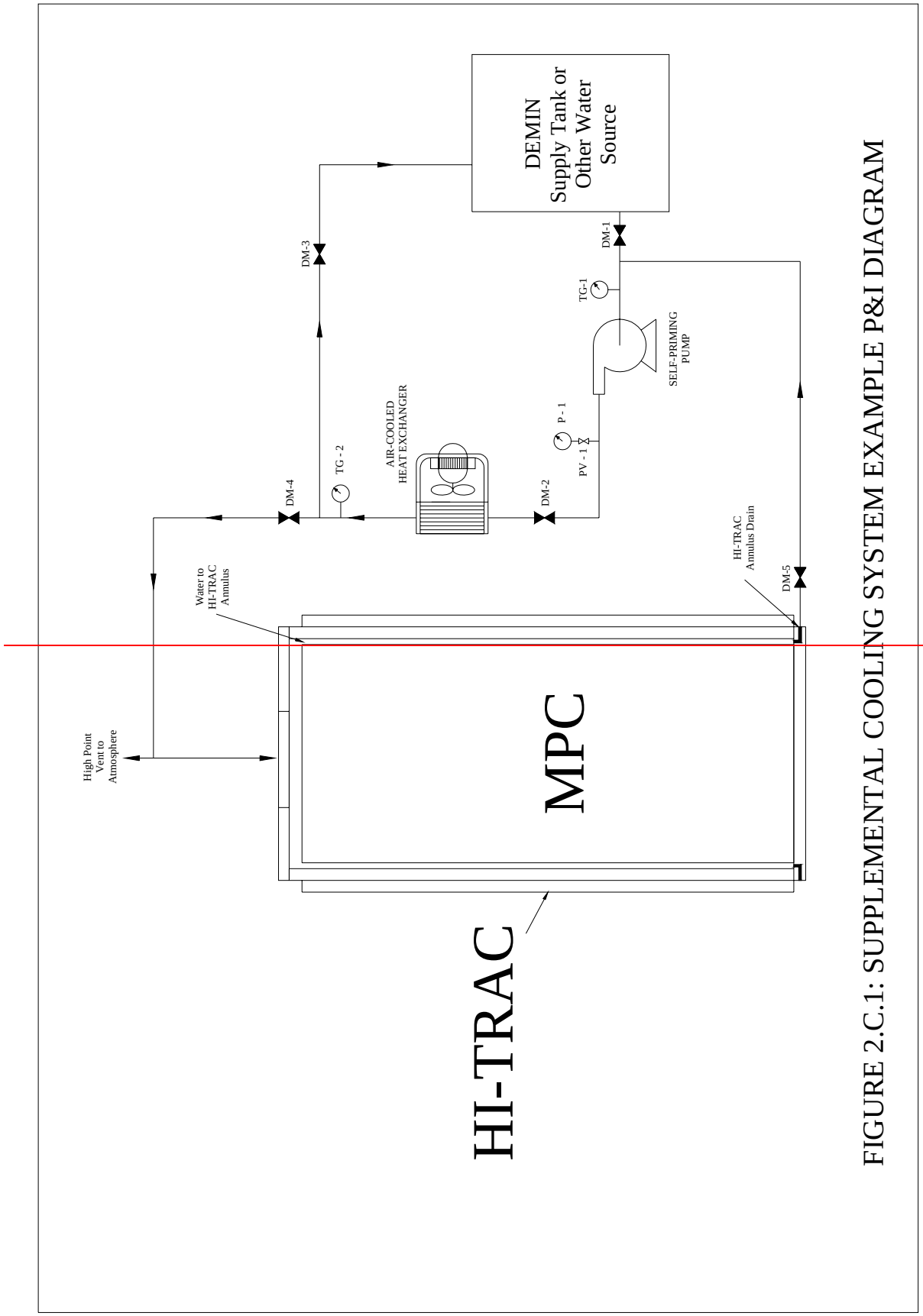

FIGURE 2.C.1: SUPPLEMENTAL COOLING SYSTEM EXAMPLE P&I DIAGRAM

4.1 DISCUSSION

The HI-STORM FSAR seeks to establish complete compliance with the provisions of ISG-11 [4.1.4]. For this purpose the HI-STORM normal storage fuel cladding temperatures are required to meet the 752°F (400°C) temperature limit for all CSF (See Section 4.3). Additionally, when the MPCs are deployed for storing High Burnup Fuel (HBF) further restrictions during certain fuel loading activities (vacuum drying) are set forth to preclude fuel temperatures from exceeding the normal temperature limits. To ensure explicit compliance, a specific term "short term operations" is defined in Chapter 2 to cover all fuel loading activities. ISG-11 fuel cladding temperature limits are applied for short-term operations (see Table 4.3.1).

Potential thermally challenging states for the spent fuel arise if the fuel drying process utilizes the pressure reduction process (i.e., vacuum drying). ~~or when the loaded MPC is inside the HI-TRAC transfer cask. In the latter state, the rate of heat rejection from the MPC is somewhat less compared to the normal storage condition when the MPC is inside the ventilated overpack. Heat dissipation within the MPC is, however, similar to HI-STORM storage as the principal HI-TRAC transfer cask operations with pressurized helium (FHD drying, on-site transport and HI-STORM overpack transfer) are performed in the vertical orientation which preserves MPC thermosiphon action. In the aggregate, the fuel cladding temperatures in the HI-TRAC are modestly higher than the HI-STORM storage temperatures.~~ The short-term evolutions that may be thermally limiting and warrant analysis are:

- *i. Vacuum Drying*
- *ii. Loaded MPC in HI-TRAC in the Vertical Orientation*

The threshold MPC heat generation rate at which the HI-STORM peak cladding temperature reaches a steady state equilibrium value approaching the normal storage peak clad temperature limit is computed in this chapter. Likewise, the MPC heat generation rates that produce the steady state equilibrium temperature approaching the normal storage peak clad temperature limit for the MPC in HI-TRAC are computed in this chapter. These computed heat generation rates directly bear upon the compliance of the system with ISG-11 [4.1.4] and are, accordingly, adopted in the system Technical Specifications for high burnup fuel (HBF).

The aboveground HI-STORM system consists of a sealed MPC situated inside a vertically-oriented, ventilated storage overpack. Air inlet and outlet ducts that allow for air cooling of the stored MPC are located at the bottom and top, respectively, of the cylindrical overpack. The SNF assemblies reside inside the MPC, which is sealed with a welded lid to form the confinement boundary. The MPC contains a stainless-steel honeycomb fuel basket structure with square-shaped compartments of appropriate dimensions to allow insertion of the fuel assemblies prior to welding of the MPC lid and closure ring. Each fuel basket panel, with the exception of exterior panels on the MPC-68 and MPC-32, is equipped with a thermal neutron absorber panel sandwiched between an Alloy X steel sheathing plate and the fuel basket panel, along the entire length of the active fuel region. The MPC is backfilled with helium up to the design-basis initial fill level (Table 1.2.2). This provides a stable, inert environment for long-term storage of the SNF. Heat is rejected from the SNF in the HI-STORM System to the environment by passive heat transport mechanisms only.

The helium backfill gas plays an important role in the MPC's thermal performance. The helium fills all the spaces between solid components and provides an improved conduction medium (compared to air) for dissipating decay heat in the MPC. Within the MPC the pressurized helium environment sustains a closed loop thermosiphon action, removing SNF heat by an upward flow of helium through the storage cells. This MPC internal convection heat dissipation mechanism is illustrated in Figure 4.1.1. On the outside of the MPC a ducted overpack construction with a vertical annulus facilitates an upward flow of air by buoyancy forces. The annulus ventilation flow cools the hot MPC surfaces and safely transports heat to the outside environment. The annulus ventilation cooling mechanism is illustrated in Figure 4.1.2. To ensure that the helium gas is retained and is not diluted by lower conductivity air, the MPC confinement boundary is designed and fabricated in accordance with ~~*to comply with the provisions of*~~ *the ASME B&PV Code Section III, Subsection NB* ~~*(to the maximum extent practical),*~~ *as an all-seal-welded pressure vessel with redundant closures. It is demonstrated in Section 11.1.3 that the failure of one field-welded pressure boundary seal will not result in a breach of the pressure boundary. The helium gas is therefore assumed to be retained in an undiluted state, and may be credited in the thermal analyses.*

An important thermal design criterion imposed on the HI-STORM System is to limit the maximum fuel cladding temperature to within design basis limits (Table 4.3.1) for long-term storage of design basis SNF assemblies. An equally important requirement is to minimize temperature gradients in the MPC so as to minimize thermal stresses. In order to meet these design objectives, the MPC baskets are designed to possess certain distinctive characteristics, which are summarized in the following.

The MPC design minimizes resistance to heat transfer within the basket and basket periphery regions. This is ensured by an uninterrupted panel-to-panel connectivity realized in the all-welded honeycomb basket structure. The MPC design incorporates top and bottom plenums with interconnected downcomer paths. The top plenum is formed by the gap between the bottom of the MPC lid and the top of the honeycomb fuel basket, and by elongated semicircular holes in each basket cell wall. The bottom plenum is formed by large elongated semicircular holes at the base of all cell walls. The MPC basket is designed to eliminate structural discontinuities (i.e., gaps) which introduce added thermal resistances to heat flow. Consequently, temperature gradients are minimized in the design, which results in lower thermal stresses within the basket. Low thermal stresses are also ensured by an MPC design that permits unrestrained axial and radial growth of the basket. The possibility of stresses due to restraint on basket periphery thermal growth is eliminated by providing adequate basket-to-canister shell gaps to allow for basket thermal growth during all operational modes.

The MPCs design maximum decay heat loads for storage of zircaloy clad fuel are listed in Table 4.0.1. Storage of stainless steel clad fuel is permitted for a low decay heat limit set forth in Chapter 2 (Tables 2.1.17 through 2.1.24). Storage of zircaloy clad fuel with stainless steel clad fuel in an MPC is permitted. In this scenario, the zircaloy clad fuel must meet the lower decay heat limits for stainless steel clad fuel. The axial heat distribution in each fuel assembly is conservatively *assumed* to be non-uniformly distributed with peaking in the active fuel mid-height region~~*follow the burnup profiles set forth in*~~ *(See axial burnup Table 2.1.11).*

The HI-STORM System (i.e., HI-STORM overpack, HI-TRAC transfer cask and MPC) is evaluated under normal storage (HI-STORM overpack), during off-normal and accident events and during short term operations in a HI-TRAC. Results of HI-STORM thermal analysis during normal (long-term) storage are obtained and reported in Section 4.4. Results of off-normal and accident events are reported in Section 4.6. Results of HI-TRAC short term operations (fuel loading, vacuum drying) are reported in Section 4.5.

~~*The HI-STORM thermal analysis is performed on the FLUENT [4.1.2] Computational Fluid Dynamics (CFD) program. To ensure a high degree of confidence in the HI-STORM thermal evaluations, the modeling of principal heat dissipation mechanisms – MPC internal convection and annulus ventilation cooling (See Figures 4.1.1 and 4.1.2) – are benchmarked using data from tests conducted with casks loaded with irradiated SNF. The benchmark work is archived in QA validated Holtec reports identified in Table 4.1.1. Additionally, in Section 4.4, a benchmarking study of the porous media model used to represent the hydraulic resistances of a fuel storage cell, is provided.*~~

~~*Table 4.1.1*~~

~~*Benchmarking of HI-STORM Thermal Models*~~

~~***Benchmark Model***~~	~~***Tested Cask***~~	~~***Test Reference***~~	~~***Holtec Benchmark Report***~~
~~*MPC Internal Convection*~~	~~*TN-24P*~~	~~*EPRI [4.1.3]*~~	~~*HI-992252 [4.1.5]*~~
~~*Overpack Ventilation Cooling*~~	~~*VSC-17*~~	~~*EPRI [4.1.7]*~~	~~*HI-2043258 [4.1.6]*~~

4.4 THERMAL EVALUATION FOR NORMAL CONDITIONS OF STORAGE

~~Under long-term storage conditions, t~~The HI-STORM System (i.e., HI-STORM overpack, HI-TRAC transfer cask and MPC) thermal evaluation is performed in accordance with the guidelines of NUREG-1536 [4.4.1] and ISG-11 [4.1.4]~~with the MPC cavity backfilled with helium~~. To ensure a high level of confidence in the thermal evaluation, 3-Dimensional models of the MPC, HI-STORM overpack and HI-TRAC transfer cask are constructed to evaluate fuel integrity under normal (long-term storage), off-normal and accident conditions and in the HI-TRAC transfer cask under short-term operation and hypothetical accidents. The thermal models incorporate an array of conservatisms to ensure robustly bounding thermal solutions. The principal features of these models are described in this section for HI-STORM and Section 4.5 for HI-TRAC. Thermal analysis results for the long-term storage scenarios are obtained and reported in this section.

4.4.1 Overview of the Thermal Model

The MPC basket design consists of four distinct geometries to hold 24 or 32 PWR, or 68 BWR fuel assemblies. The basket is a matrix of interconnected square compartments designed to hold the fuel assemblies in a vertical position under long term storage conditions. The basket is a honeycomb structure of stainless steel (Alloy X) plates with full-length edge-welded intersections to form an integral basket configuration. All individual cell walls, except outer periphery cell walls in the MPC-68 and MPC-32, are provided with neutron absorber plates sandwiched between the box wall and a stainless steel sheathing plate over the full length of the active fuel region. The neutron absorber plates used in all MPCs are made of an aluminum-based, boron carbide-containing material to provide criticality control, while maximizing heat conduction capabilities.

Thermal analysis of the HI-STORM System is performed for an array of limiting heat load scenarios defined in Chapter 2 for uniform and regionalized fuel loading (wherein each fuel assembly in a region is assumed to be generating heat at the maximum permissible rate). While the assumption of limiting heat generation in each storage cell imputes a certain symmetry to the cask thermal problem, it grossly overstates the total heat duty of the system in most casks because it is unlikely that any basket would be loaded with fuel emitting heat at their limiting values (see for example a fuel loading scenario discussed in Section 2.1). The principal attributes of the thermal model are described in the following:

i. While the rate of heat conduction through metals is a relatively weak function of temperature, radiation heat exchange is a highly nonlinear function of surface temperatures.

ii. Heat generation in the MPC is axially non-uniform due to non-uniform axial burnup profiles in the fuel assemblies.

iii. Inasmuch as the transfer of heat occurs from inside the basket region to the outside, the temperature field in the MPC is spatially distributed with the maximum values reached in the central core region.

~~*The design basis decay heat for long-term normal storage is specified in Table 2.2.26. The decay heat is conservatively considered to be non-uniformly distributed over the active fuel length based on the axial burnup distributions specified in Chapter 2 (Table 2.1.11).*~~

~~*The thermal model of the HI-STORM in this FSAR actually consists of two distinct models – a design-basis 3-D model and a confirmatory axisymmetric model. The 3-D model has been prepared that simulates each storage cell and seeks to represent the helium flow in each cell, upper and lower plenum and downcomer regions in a rigorous manner. The axisymmetric model replaces the fuel basket and the stored SNF by a porous cylinder having equivalent thermal-hydraulic properties. Because the 3-D model is very large and computationally intensive, the necessity to construct a computationally efficient model to perform miscellaneous analyses remains. In what follows, both the 3-D model and a computationally efficient axisymmetric model are described. The results from both the models are compared for all MPC types to benchmark the axisymmetric model, which is subsequently used to perform secondary qualifying analyses. The principal storage condition (namely, long-term normal storage) is evaluated using both the 3-D and axisymmetric models, with the 3-D model being the design basis. Shorter-term conditions like on-site transfer operations and off-normal and accident conditions are evaluated using the conservative axisymmetric models.*~~

~~*Certain aspects of the thermal simulation are common to both 3-D and axisymmetric models. For example, the composite wall of the basket consisting of a sandwich of Alloy X panel, the neutron absorber, and the Alloy X sheathing can be replaced by a single orthotropic metal whose conductivities in the three principal directions are equivalent to those of the sandwich. Further details on equivalent representation of the monometallic wall for the sandwich and other regions of the MPC are provided later in this subsection.*~~

4.4.1.1 Description of the 3-D Thermal Model ~~(Design-Basis Model)~~

i. Introduction~~Overview~~

The interior of the MPC is a 3-D array of square shaped cells inside an irregularly shaped basket outline confined inside the cylindrical space of the MPC cavity. To ensure an adequate representation of these features, a 3-D geometric model of the MPC is constructed using the FLUENT CFD code pre-processor [4.1.2]. Other than representing the composite cell walls (made up of Alloy X panels, neutron absorber panels and Alloy X sheathing) by a homogeneous panel with equivalent orthotropic (thru-thickness and parallel plates direction) thermal conductivities, the 3-D model requires no idealizations of the fuel basket structure. Further, since it is ~~clearly~~ impractical to model every fuel rod in every stored fuel assembly explicitly, the cross section bounded by the inside of the storage cell (inside of the fuel channel in the case of BWR MPCs), which surrounds the assemblage of fuel rods and the interstitial helium gas (also called the "rodded region"), is replaced with an "equivalent" square homogeneous section characterized by an effective thermal conductivity. Homogenization of the storage cell cross-section is illustrated in Figure 4.4.1. As the effective conductivity of the rodded region includes radiation heat transfer the conductivities will be a strong function of temperature because radiation heat transfer (a major component of the heat transport between the fuel rods and the surrounding basket cell metal) rises as the fourth power of

absolute temperature. Therefore, in effect, the effective conductivity of the equivalent square section (depending on the coincident temperature) will be different throughout the basket. For thermal-hydraulic simulation, each fuel assembly in its storage cell is represented by an equivalent porous medium. For BWR fuel, the presence of the fuel channel divides the storage cell space into two distinct axial flow regions, namely, the in-channel (rodded) region and the square prismatic annulus region (in the case of PWR fuel this modeling complication does not exist).

ii. Details of the 3-D Model

The 3-D model implemented to analyze the HI-STORM system has the following key attributes:

a. As mentioned above, the composite walls in the fuel basket consisting of the Alloy X structural panels, the aluminum-based neutron absorber, and the Alloy X sheathing, are represented by an orthotropic homogeneous panel of equivalent thermal conductivity in the three principal directions. The in-plane and thru-thickness thermal conductivities of the composite wall are computed using a standard procedure for such shapes with certain conservatisms, as described below.

During fabrication, a uniform normal pressure is applied to each "Box Wall - Neutron Absorber - Sheathing" sandwich in the assembly fixture during welding of the sheathing periphery on the box wall. This ensures adequate surface-to-surface contact between the neutron absorber and the adjacent Alloy X surfaces. The mean coefficient of linear expansion of the neutron absorber is higher than the thermal expansion coefficients of the basket and sheathing materials. Consequently, basket heat-up from the stored SNF will further ensure a tight fit of the neutron absorber plate in the sheathing-to-box pocket. Nevertheless the possible presence of small microscopic gaps due to less than perfect surface-to-surface contact requires consideration of an interfacial contact resistance between the neutron absorber and box-sheathing surfaces. In the thermal analysis a 2 mil neutron absorber to pocket gap has been used. This is conservative as the sandwich is engineered to ensure an essentially no-gap fitup and assembly of the neutron-absorber panels. Furthermore, no credit is taken for radiative heat exchange across the neutron absorber to sheathing or neutron absorber to box wall gaps.

~~Quite obviously,~~ The heat conduction properties of the~~a~~ composite "Box Wall - Neutron Absorber - Sheathing" sandwich panels in the two principal basket cross sectional directions (i.e., thru-thickness and parallel plates direction) are unequal. In the thru-thickness direction, heat is transported across layers of sheathing, helium-gap, neutron absorber and box wall resistances that are essentially in series. Heat conduction in the parallel plates direction, in contrast, is through an array of essentially parallel resistances comprised of these several layers listed above. In this manner the composite walls of the fuel basket storage cells are replaced with a solid wall of equivalent through thickness and parallel plates direction conductivities. Table 4.4.1 provides the values of the conductivities as a function of temperature for the different MPC types. ~~These values are used in the axisymmetric model as well.~~

b. In the case of a BWR CSF, the fuel bundle and the small surrounding spaces inside the fuel "channel" are replaced by an equivalent porous media having the flow impedance properties computed using a conservatively articulated 3-D CFD model ~~documented in~~ [4.4.2]. The space between the BWR fuel channel and the storage cell is represented as an open flow annulus. The fuel channel is also explicitly modeled. The porous medium within the channel space is also referred to as the "rodded region". The fuel assembly is assumed to be positioned coaxially with respect to its storage cell. The 3-D model of an MPC-68 storage cell occupied with channeled BWR fuel is shown in Figure 4.4.4.

In the case of the PWR CSF, the porous medium extends to the entire cross-section of the storage cell. As described in [4.4.2], the CFD model for both the BWR and PWR case is prepared for the Design Basis fuel in comprehensive detail, which includes grid straps, BWR water rods and PWR guide and instrument tubes (assumed to be plugged for conservatism).

c. Every MPC fuel storage cell is assumed to be occupied by design basis PWR or BWR fuel assemblies specified in Chapter 2 (Table 2.1.5). The in-plane thermal conductivity of the design basis fuel assemblies are obtained using ANSYS [4.1.1] finite element models of an array of fuel rods enclosed by a square box. Radiation heat transfer from solid surfaces (cladding and box walls) are enabled in these models. Using these models the effective conduction-radiation conductivities are obtained and reported in Table 4.4.2. For heat transfer in the axial direction an area weighted mean of cladding and helium conductivities are computed (see Table 4.4.2). Axial conduction heat transfer in the fuel pellets and radiation heat dissipation in the axial direction are conservatively ignored. Thus, the thermal conductivity of the rodded region, like the porous media simulation for helium flow, is represented by a 3-D continuum having effective planar and axial conductivities.

d. The internals of the MPC, including the basket cross section, bottom mouse holes, top plenum, and circumferentially irregular downcomer are modeled explicitly. For simplicity, the mouse holes are modeled as rectangular openings with understated flow area.

e. The inlet and outlet vents in the HI-STORM overpack are modeled explicitly to incorporate any effects of non-axisymmetry of inlet air passages on the system's thermal performance.

f. The air flow in the HI-STORM/MPC annulus is simulated by a k-ω turbulence model with the transitional option enabled.

The 3-D model described above is illustrated in the cross section for the MPC-68 in Figure 4.4.3. A closeup of the fuel cell spaces which explicitly include the channel-to-cell gap in the 3-D model is shown in Figure 4.4.4. The principal 3-D modeling conservatisms are listed below:

1) *The storage cell spaces are loaded with design basis fuel having the highest axial flow resistance (See Table 2.1.5).*
2) *Each storage cell is generating heat at it's limiting value under uniform or regionalized storage scenarios* as defined in Chapter 2, Section 2.1.
3) *Axial dissipation of heat by the fuel pellets is neglected.*

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4) *Axial dissipation of heat by radiation in the fuel bundle is neglected.*
5) *The fuel assembly channel length for BWR fuel is overstated.*
6) *The most severe environmental factors for long-term normal storage - ambient temperature of 80°F and 10CFR71 insolation levels - were coincidentally imposed on the system.*
7) *The absorbtivity of the external surfaces of the HI-STORM is conservatively assumed to be unity.*
8) *To understate MPC internal convection heat transfer, the helium pressure is understated.*
9) *No credit is taken for contact between fuel assemblies and the MPC basket wall or between the MPC basket and the basket supports.*
10) *Heat dissipation by fuel basket peripheral supports is neglected.*
11) *Fuel basket and MPC shell emissivities are understated (see Table 4.2.4).*
12) *The k-ω model used for simulating the HI-STORM annulus flow yields uniformly conservative results [4.1.6].*

The effect of crud resistance on fuel cladding surfaces has been evaluated and found to be negligible. The evaluation assumes a thick crud layer (130 μm) with a bounding low conductivity (conductivity of helium). The crud resistance increases the clad temperature by a very small amount (~0.1°F). Accordingly this effect is neglected in the thermal evaluations.

4.4.1.2 Fuel Assembly 3-Zone Flow Resistance Model~~Equivalent Resistance to Axial Flow of Helium in the Rodded Region~~

The HI-STORM System is evaluated for storage of bounding PWR (W-17x17) and BWR (GE-10x10) fuel assemblies. During fuel storage helium enters the MPC fuel cells from the bottom plenum and flows upwards through the open spaces in the fuel storage cells and exits in the top plenum. Because of the low flow velocities the helium flow in the fuel storage cells and MPC spaces is in the deep laminar regime (Re < 100). The bottom and top plenums are essentially open spaces engineered in the fuel basket ends to facilitate helium circulation. In the case of BWR fuel storage, a channel enveloping the fuel bundle divides the flow in two parallel paths. One flow path is through the in-channel or rodded region of the storage cell and the other flow path is in the square annulus area outside the channel. ~~Due to the fact that the fuel assemblies are constructed with a large number of rods an explicit modeling of fuel assemblies in a global thermal model of the HI-STORM System is not practical.~~ In the global thermal modeling of the HI-STORM System the following approach is adopted:

(i) In BWR fueled MPCs an explicit channel-to-cell gap is modeled.
(ii) The fuel assembly enclosed in a square envelope (fuel channel for BWR fuel or fuel storage cell for PWR fuel) is replaced by porous media with equivalent flow resistance.

The above modeling approach is illustrated in Figure 4.4.4.

In the FLUENT program, porous media flow resistance is modeled as follows:

$$\Delta P = D\mu VL \qquad \text{(Eq. 1)}$$

where ΔP is the hydraulic pressure loss, D is the flow resistance coefficient, μ is the fluid viscosity, V is the superficial fluid velocity and L is the porous media length. In the HI-STORM thermal models the fuel storage cell length between the bottom and top plenums[1] is replaced by porous media. As discussed below the porous media length is partitioned in three zones with discrete flow resistances.

To characterize the flow resistance of fuel assemblies inside square envelopes (fuel channel for BWR fuel or fuel storage cell for PWR fuel) 3D models of W-17x17 and GE-10x10 fuel assemblies are constructed using the FLUENT CFD program. These models are embedded with several pessimistic assumptions to overstate flow resistance. These are:

(a) Water rods (BWR fuel) and guide tubes (PWR fuel) are assumed to be completely blocked
(b) Fuel rods assumed to be full length
(c) Channel length (BWR fuel) overstated
(d) Bounding grid thickness used
(e) Bottom fittings resistance overstated
(f) Bottom nozzle lateral flow holes (BWR fuel) assumed to be blocked

Using the 3D fuel assembly models flow solutions under an impressed pressure differential between the two extremities of the fuel storage cell are computed at reference conditions (7 atmosphere absolute pressure and 450°F temperature). The results of the 3D flow solutions are post-processed as described next and equivalent porous media flow resistances obtained.

Because of the narrow flow passages in the bare rods and gridded regions of the fuel assembly the flow resistance of the fueled length to axial helium flow is greater than the flow resistance from the fuel assembly ends (bottom nozzle, top fitting, handle etc.). This physical fact is duly recognized by defining three distinct axial zones as follows:

Zone 1: Length below the active fuel region
Zone 2: Active fuel region
Zone 3: Length above the active fuel region

In the 3-Zone flow resistance modeling, the flow resistance of each zone is characterized by post-processing the 3D fuel flow model solutions. For this purpose two approaches to flow resistance characterization are adopted. The first approach is the pressure drop method. This method is suitable when a zone is characterized by irregular geometries and the objective is to obtain a lumped resistance to duplicate the pressure drop. The second method is the shear stress method, which is suitable for flow zones characterized by regular geometries. For the 3-Zone flow resistance

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1 These are the mousehole openings at the ends of the fuel basket to facilitate helium circulation. The mouseholes are explicitly included in the 3D thermal models with an understated flow area.

modeling the pressure drop method is adopted for the inactive regions (Zone 1 and Zone 3). The flow resistance coefficients are computed by post-processing the fuel assemblies 3D model flow solutions as follows:

Step 1: Obtain the helium volumetric flow Q under the impressed pressure differential.

Step 2: Compute helium superficial velocity, V = Q/A where A is the square envelope cross-sectional area.

Step 3: Obtain the individual Zone 1 and Zone 3 lengths (L_1 and L_3) and pressure drops (ΔP_1 and ΔP_3) from the FLUENT solutions.

Step 4: Compute Zone 1 and Zone 3 resistance coefficients D_1 and D_3 using Eq. 1, V, L_1, L_3, ΔP_1 and ΔP_3 from above steps.

The shear stress method is suitable for the active fuel region (Zone 2) as this region is characterized by an ordered array of entities (rods and grids). This method uses area averaged wall shear stresses post-processed from the active region (Zone 2) of the fuel assembly. Using hydraulic flow principles the wall shear stresses are mapped to flow resistance coefficients. To account for geometric discontinuities the active fuel region is sliced in a suitable number of constant geometry (bare rods and grids) sub-regions. Based on the fuel bundle layout, a total of 17 slices are identified for GE-10x10 fuel and 20 slices for W-17x17 fuel. In each sub-region an area averaged shear stress over all wetted surfaces (fuel rods, non-fuel rods, square envelope and grids) is post-processed and flow resistance coefficients of each slice are computed. The flow resistance of Zone 2 is obtained by computing the length-weighted average of the slice resistance coefficients.
~~*The axial flow through the rodded region under an impressed pressure differential between the two extremeties of the rodded space is computed in the deep laminar range (Reynolds numbers < 100). In this manner, a relationship between the pressure drop (ΔP) and axial flow is obtained for helium at reference conditions (7 atmospheres pressure and 450°F temperature) and the flow resistance parameters for input in the porous media simulation in the system 3-D model are obtained. This 3-D pressure vs. flow characterization of the rodded region by the porous media does not utilize any empirical loss correlations and forms a rigorously evaluated building block for the 3-D CFD model of the system.*~~

~~*4.4.1.3 Axisymmetric Model*~~

~~*The axisymmetric model requires several simplifications. In the most important step, the planar section of the MPC is homogenized. With each storage cell replaced with an equivalent solid square, the MPC cross section consists of a metallic gridwork (basket cell walls with each square cell space containing a solid storage cell square of effective thermal conductivity, which is a function of temperature) circumscribed by a circular ring (MPC shell). There are four distinct materials in this section, namely the homogenized storage cell squares, the Alloy X structural materials in the MPC (including neutron absorber sheathing), neutron absorber and helium gas. Each of the four constituent materials in this section has a different conductivity. It is emphasized that the conductivity of the homogenized storage cells is a strong function of temperature.*~~

~~*In the axisymmetric model, the required simplification is carried out by replacing the thermally heterogeneous fuel basket section mentioned above by an equivalent conduction-only region, using a finite element procedure. Because the rate of transport of heat within the fuel basket is influenced by radiation, which is a temperature-dependent effect, the equivalent conductivity of the fuel basket region must also be computed as a function of temperature. Also, it is recognized that the MPC section consists of two discrete regions, namely, the basket region and the peripheral region. The peripheral region is the space between the peripheral storage cells and the MPC shell. This is a helium filled space surrounded by Alloy X plates. Accordingly, as illustrated in Figure 4.4.2 for MPC-68, the MPC cross-section is replaced with two homogenized regions with temperature-dependent conductivities. In particular, the effective conductivity of the storage cells is subsumed into the equivalent conductivity of the basket cross section, as described before.*~~

~~*As illustrated in Figure 4.4.2 an MPC fuel basket is composed of a welded gridwork of Alloy X-neutron absorber-sheathing sandwich panels to form an array of square shaped cells on a square pitch. The basket cell spaces are occupied by irradiated SNF. The two principal components of a loaded fuel basket – sandwich panels and SNF – have unequal conduction properties in the planar and axial directions. The fuel basket thermal modeling duly recognizes these differences by characterizing the effective conductivities in the two (planar and axial) directions. For computing the planar fuel basket conductivity, ANSYS finite element models of the PWR and BWR fuel baskets are employed. The principal inputs to the models are the design basis fuel planar conductivities and the sandwich panel conductivities discussed previously. The results of fuel basket modeling are presented in Table 4.4.3.*~~

~~*The fuel basket axial conductivity is computed by an area weighted sum of cladding, helium, neutron absorber and Alloy X (box wall and sheathing) conductivities. This evaluation employs the design basis fuel and neglects fuel pellets axial conduction and axial dissipation of heat by radiation .*~~

~~*Finally, HI-STORM is simulated as a radially symmetric structure having annular vents at the bottom and top with a buoyancy-induced flow in the annular space surrounding the heat generating MPC cylinder. The annular vents in the HI-STORM model are porous media spaces having effective inlet and outlet ducts flow resistances.*~~

~~*Internal circulation of helium in the sealed MPC is modeled as flow in a porous media in the fuel basket region containing the SNF (including top and bottom plenums). The basket-to-MPC shell clearance space is modeled as a helium filled radial gap to include the downcomer flow in the thermal model. The downcomer region, as illustrated in Figure 4.4.2, consists of an azimuthally varying gap formed by the square-celled basket outline and the cylindrical MPC shell. At the locations of closest approach a differential expansion gap (see Subsection 4.4.6) is engineered to allow free thermal expansion of the basket. At the widest locations, the gaps are on the order of the storage cell opening (~6" for BWR and ~9" for PWR MPCs). It is heuristically evident that heat dissipation by conduction is maximum at the closest approach locations (low thermal resistance path) and that convective heat transfer is highest at the widest gap locations (large downcomer flow). In the axisymmetric thermal model, a radial gap that is large compared to the basket-to-shell clearance and small compared to the cell opening is used. As a relatively large gap penalizes heat*~~

~~*dissipation by conduction and a small gap throttles convective flow, the use of a single gap in the FLUENT model understates both conduction and convection heat transfer in the downcomer region.*~~

~~*To summarize, a loaded MPC standing upright on the ISFSI pad in a HI-STORM overpack is replaced with a right circular cylinder with spatially varying temperature-dependent conductivity. Heat is generated within the basket space in this cylinder in the manner of the prescribed axial burnup distribution (see Table 2.2.11). In addition, heat is deposited from insolation on the external surface of the overpack. Under steady state conditions the total heat due to internal generation and insolation is dissipated from the outer cask surfaces by natural convection, annulus ventilation cooling and thermal radiation to the ambient environment.*~~

~~*The table below provides a summary of the principal simplifications to the 3-D model that results in the computationally efficient axisymmetric model (which is also the supporting legacy model for early HI-STORM CoCs).*~~

~~*Comparison of 3-D and 2-D Model Attributes*~~		
	~~*Design-Basis 3-D Model*~~	~~*2-D Model*~~
~~*a.*~~	~~*The storage cell and cavity along with SNF is modeled as a porous medium for helium axial flow. In the case of BWR fuel, the porous medium idealization is limited to the fuel channel/SNF space; the annular space between the fuel channel and cell walls is explicitly modeled.*~~	~~*The storage cell/cavity space is simulated by an equivalent porous medium for both PWR and BWR SNF. This model is subsumed in the fuel basket model (see item (c) below.*~~
~~*b.*~~	~~*The composite cell walls of the fuel basket (Alloy X-neutron absorber-sheathing sandwich) are replaced by thermally equivalent orthotropic solid panels.*~~	~~*Same as the 3-D model*~~
~~*c.*~~	~~*The fuel basket panels in (b) above are explicitly modeled.*~~	~~*The basket structure along with the SNF is replaced by an equivalent cylindrical body of equivalent temperature-dependent conductivity.*~~
~~*d.*~~	~~*The MPC shell and baseplate modeled explicitly.*~~	~~*Same as the 3-D model*~~
~~*e.*~~	~~*The "mouseholes" in the storage cell walls for helium circulation modeled explicitly.*~~	~~*Equivalent openings for axisymmetric helium circulation are provided in the model.*~~

~~Comparison of 3-D and 2-D Model Attributes~~		
	~~Design-Basis 3-D Model~~	~~2-D Model~~
~~f.~~	~~The downcomer region (prismatic annulus of irregular cross section) is modeled explicitly.~~	~~The downcomer annulus region is defined by the space between the basked cylinder in (c) and the MPC shell. The width of the downcomer is conservatively set to ensure that the helium circulation rate will approach the actual from below.~~
~~g.~~	~~The HI-STORM inlet and outlet ducts are explicitly modeled.~~	~~The inlet and outlet ducts are simulated by equivalent flow resistance axisymmetric inlet and outlet passages.~~

~~It is evident from the foregoing that the 2-D model involves considerable simplifications. Therefore, to ensure that its use in production runs will not produce unconservative results, a number of comparison 3-D runs using identical input data were carried out, as discussed later in this section.~~

4.4.2 [deleted]~~Comparison of Axisymmetric and 3-D Thermal Models~~

~~To compare the axisymmetric thermal model described in Subsection 4.4.1.3 with the rigorous 3-D thermal model, fuel storage scenarios under uniform and regionalized fuel loading in a HI-STORM are run and thermal solutions using both (3-D and axisymmetric models) obtained. The results are compared in Table 4.4.4. As can be seen, the two models (3-D and axisymmetric) provide results that are in reasonable accord with each other.~~

4.4.3 Test Model

~~The 3-D CFD modeling of the HI-STORM system with the conservatisms noted in the foregoing provides a high level of assurance that the predictions of the peak cladding temperature will be conservative. Prior to the 3-D model, all analyses were performed using a simpler 2-D model which had been benchmarked [4.1.5] with full-scale cask test data [4.1.3], as well as with PNNL's COBRA-SFS modeling of the HI-STORM System. All licensing basis thermal evaluations of the HI-STORM system through CoC Revision 2 were performed exclusively using the axisymmetric model described above.~~

~~The 3-D model eliminates virtually all of the simplifications of the 2-D model and utilizes proven codes, namely, the FLUENT CFD code and the industry standard ANSYS modeling package, to foster maximum confidence. Further, as discussed throughout this chapter and specifically in Subsection 4.4.1, the analysis incorporates significant conservatisms so as to compute fuel cladding temperatures in a bounding manner. Furthermore, compliance with specified limits of operation is demonstrated with adequate margins. In addition, experimental verification of thermal performance in the form of data from numerous previously loaded HI-STORMs has been compared with the~~

~~predictions of the FLUENT CFD solutions and reported to the USNRC.~~ *The HI-STORM thermal analysis is performed on the FLUENT [4.1.2] Computational Fluid Dynamics (CFD) program. To ensure a high degree of confidence in the HI-STORM thermal evaluations, the FLUENT code is benchmarked using data from tests conducted with casks loaded with irradiated SNF ([4.1.3],[4.1.7]). The benchmark work is archived in QA validated Holtec reports ([4.1.5],[4.1.6]).These evaluations show that the FLUENT solutions are conservative in all cases. In view of these considerations, additional experimental verification of the thermal design is* ~~therefore~~ *not necessary* ~~at this time~~.

4.4.4 Maximum and Minimum Temperatures

4.4.4.1 Maximum Temperatures

The 3-D model from the previous subsection is used to determine temperature distributions under long-term normal storage conditions for an array of cases covering PWR and BWR fuel storage in uniform and regionalized loading configurations. For this purpose one bounding MPC design in each of the two fuel classes – MPC-68 for BWR and MPC-32 for PWR – are analyzed and results obtained and summarized in this subsection. For a bounding evaluation the MPCs are assumed to be emplaced in a limiting overpack (HI-STORM 100S Version B).

~~*For storage of PWR fuel two MPC designs, namely the MPC-24/24E and MPC-32 are available. Employing 3-D HI-STORM models fuel storage in both MPC-24 and MPC-32 canisters are evaluated. From the 3-D runs the peak cladding temperatures obtained in the MPC-24 are lower than the MPC-32 results by a substantial amount (~50°F). Thus, the MPC-32 is the bounding PWR-style fuel basket design. Accordingly HI-STORM thermal evaluations for PWR fuel storage employ the MPC-32 design. Results reported for this design bound the MPC-24/24E designs with additional margins.*~~

The HI-STORM 100S Version B is the limiting overpack by virtue of the inlet and outlet vents design. Compared to two other overpack designs (i.e., HI-STORM 100 and HI-STORM 100S), the HI-STORM 100S Version B has smaller inlet and outlet vents. Thus Version B vent airflow resistances are bounding. Also, the HI-STORM 100S Version B is the shortest of the overpacks. This reduces the chimney height which minimizes the driving head for air flow. Because the HI-STORM 100S Version B will have the least cooling air flow, it will yield bounding results.

A cross-reference of HI-STORM thermal analyses is provided in Table 4.4.5. Under regionalized loading, an array of runs covering a range of regionalized storage configurations specified in Chapter 2 (X=0.5 to X=3) are analyzed. The results are graphed in Figures 4.4.6 and 4.4.7 for PWR and BWR fuel storage respectively. Based on this array of runs the fuel storage condition corresponding to X = 0.5 is determined to be limiting for both PWR and BWR MPCs. Accordingly HI-STORM MPC and overpack temperatures are reported for this storage condition in Tables 4.4.6 and 4.4.7.

It should be noted that the 3-D FLUENT cask model incorporates the effective conductivity of the fuel assembly submodel ~~*and that the axisymmetric FLUENT cask model incorporates the effective*~~

~~conductivity results of the fuel basket submodel, which in turn incorporates the effective conductivity results of the fuel assembly submode~~l. Therefore the FLUENT models report the peak temperature in the fuel storage cells ~~every part of the system. In a dry storage cask, the hottest components are the fuel assemblies.~~ Thus, as the fuel assembly models include the fuel pellets, the FLUENT calculated peak temperatures are actually peak pellet centerline temperatures which bound the peak cladding temperatures with a margin.

The following observations can be derived by inspecting the temperature field obtained from the thermal models:

- *The fuel cladding temperatures are below the regulatory limit (ISG-11 [4.1.4]) under all storage scenarios (uniform and regionalized) in all MPCs.*
- *The maximum temperature of the basket structural materials are within their design limits.*
- *The maximum temperature of the neutron absorbers are below their design limits.*
- *The maximum temperatures of the MPC pressure boundary materials are below their design limits.*
- *The maximum temperatures of concrete is within the guidance of the governing ACI Code (see Table 4.3.1).*

The above observations lead us to conclude that the temperature field in the HI-STORM System with a loaded MPC containing heat emitting SNF complies with all regulatory temperature limits. In other words, the thermal environment in the HI-STORM System is in compliance with Chapter 2 Design Criteria.

4.4.4.2 <u>Minimum Temperatures</u>

In Table 2.2.2 of this report, the minimum ambient temperature condition for the HI-STORM storage overpack and MPC is specified to be -40 °F. If, conservatively, a zero decay heat load with no solar input is applied to the stored fuel assemblies, then every component of the system at steady state would be at a temperature of -40 °F. Low service temperature (-40°F) evaluation of the HI-STORM is provided in Chapter 3. All HI-STORM storage overpack and MPC materials of construction will satisfactorily perform their intended function in the storage mode at this minimum temperature condition.

4.4.4.3 <u>Effects of Elevation</u>

The reduced ambient pressure at site elevations significantly above the sea level will act to reduce the ventilation air mass flow, resulting in a net elevation of the peak cladding temperature. However, the ambient temperature (i.e., temperature of the feed air entering the overpack) also drops with the increase in elevation. Because the peak cladding temperature also depends on the feed air temperature (the effect is one-for-one within a small range, i.e., 1 °F drop in the feed air

temperature results in ~1 °F drop in the peak cladding temperature), the adverse ambient pressure effect of increased elevation is partially offset by the ambient air temperature decrease. The table below illustrates the variation of air pressure and corresponding ambient temperature as a function of elevation.

Elevation (ft)	*Pressure (psia)*	*Ambient Temperature Reduction versus Sea Level*
Sea Level (0)	*14.70*	*0°F*
2000	*13.66*	*7.1°F*
4000	*12.69*	*14.3°F*

A survey of the elevation of nuclear plants in the U.S. shows that nuclear plants are situated near about sea level or elevated slightly (~1000 ft). The effect of the elevation on peak fuel cladding temperatures is evaluated by performing calculations for a HI-STORM 100 System situated at an elevation of 1500 feet. At this elevation the ambient temperature would decrease by approximately 5°F (See Table above). *The peak cladding temperatures are calculated for a bounding configuration (non-uniform storage at X = 0.5), and* conservatively assuming ~~*neglecting the*~~ *no reduction in ambient temperature* ~~*that accompanies an increase in elevation*~~[2]~~*,*~~ *using the* ~~*axisymmetric*~~ *3D model described in Subsection 4.4.1.1*~~*3*~~ *and compared to the sea level conditions. The results are given in the following table.*

MPC Design	*PCT at Sea Level*	*PCT at 1500 feet*
MPC-68 BWR	*711.4*~~*728.1*~~*°F*	*723.8*~~*737.7*~~*°F*
MPC-32 PWR	*697.1*~~*720.0*~~*°F*	*718.2*~~*732.4*~~*°F*

These results show that the PCT, including the effects of site elevation, continues to be well below the regulatory cladding temperature limit of 752°F. In light of the above evaluation, it is not necessary to place any ISFSI elevation constraints for HI-STORM deployment at elevations up to 1500 feet. If, however, an ISFSI is sited at an elevation greater than 1500 feet, the effect of altitude on the PCT shall be quantified as part of the 10 CFR 72.212 evaluation for the site using the site ambient conditions.

4.4.5 Maximum Internal Pressure

4.4.5.1 MPC Helium Backfill Pressure

The quantity of helium emplaced in the MPC cavity shall be sufficient to produce an operating pressure of 7 atmospheres (absolute) during normal storage at reference conditions (See Table 4.0.1). Thermal analyses performed on the different MPC designs indicate that this operating

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~~*2 An elevation of 1500 feet would be accompanied by an ambient temperature decrease of approximately 5 °F, which would decrease cask system temperatures. Thus, actual PCT would be on the order of 5 °F lower than reported above.*~~

pressure requires a certain minimum helium backfill pressure (P_b) specified at a reference temperature (70ºF). The minimum backfill pressure for each MPC type is provided in Table 4.4.11. A theoretical upper limit on the helium backfill pressure also exists and is defined by the design pressure of the MPC vessel (Table 2.2.1). The upper limit of P_b is also reported in Table 4.4.11. To bound the minimum and maximum backfill pressures listed in Table 4.4.11 with a margin, a helium backfill specification is set forth in Table 4.4.12.

Two methods are available for ensuring that the appropriate quantity of helium has been placed in an MPC:

i. By pressure measurement
ii. By measurement of helium backfill volume (in standard cubic feet)

The direct pressure measurement approach is more convenient if the FHD method of MPC drying is used. In this case, a certain quantity of helium is already in the MPC. Because the helium is mixed inside the MPC during the FHD operation, the temperature of the helium gas at the MPC's exit, along with the pressure provides a reliable means to compute the inventory of helium using pressure and temperature gages. A shortfall or excess of helium is adjusted by a calculated raising or lowering of the MPC pressure such that the reference MPC backfill pressure is within the P_b specifications.

When vacuum drying is used as the method for MPC drying, then it is more convenient to fill the MPC by introducing a known quantity of helium (in standard cubic feet) by measuring the quantity of helium introduced using a calibrated mass flow meter or other measuring apparatus. The required quantity of helium is computed by the product of net free volume and helium specific volume at the reference temperature (70°F) and a target pressure that lies in the mid-range of the P_b specifications.

The net free volume of the MPC is obtained by subtracting B from A, where

A = MPC cavity volume in the absence of contents (fuel and non-fuel hardware) computed from nominal design dimensions

B = Total volume of the contents (fuel including DFCs, if used) based on nominal design dimensions

Using commercially available mass flow totalizers or other appropriate measuring devices, an MPC cavity is filled with the computed quantity of helium.

4.4.5.2 <u>MPC Pressure Calculations</u>

The MPC is initially filled with dry helium after fuel loading and drying prior to installing the MPC closure ring. During normal storage, the gas temperature within the MPC rises to its maximum operating basis temperature. The gas pressure inside the MPC will also increase with rising temperature. The pressure rise is determined using the ideal gas law.

Table 4.4.8 presents a summary of the minimum MPC free volumes determined for each MPC type (MPC-24, MPC-68, MPC-32, and MPC-24E). The MPC maximum gas pressure is computed for a postulated release of fission product gases from fuel rods into this free space. For these scenarios, the amounts of each of the release gas constituents in the MPC cavity are summed and the resulting total pressures determined from the ideal gas law. Based on fission gases release fractions (NUREG 1536 criteria [4.4.1]), rods' net free volume and initial fill gas pressure, maximum gas pressures with 1% (normal), 10% (off-normal) and 100% (accident condition) rod rupture are given in Table 4.4.9. The maximum computed gas pressures reported in Table 4.4.9 are all below the MPC internal design pressures for normal, off-normal and accident conditions specified in Table 2.2.1.

Evaluation of Non-Fuel Hardware

The inclusion of PWR non-fuel hardware (BPRA control elements and thimble plugs) to the PWR baskets influences the MPC internal pressure through two distinct effects. The presence of non-fuel hardware increases the effective basket conductivity, thus enhancing heat dissipation and lowering fuel temperatures as well as the temperature of the gas filling the space between fuel rods. The gas volume displaced by the mass of non-fuel hardware lowers the cavity free volume. These two effects, namely, temperature lowering and free volume reduction, have opposing influence on the MPC cavity pressure. The first effect lowers gas pressure while the second effect raises it. In the HI-STORM thermal analysis, the computed temperature field (with non-fuel hardware excluded) has been determined to provide a conservatively bounding temperature field for the PWR baskets (MPC-24, MPC-24E, and MPC-32). The MPC cavity free space is computed based on volume displacement by the heaviest fuel (bounding weight) with non-fuel hardware included. This approach ensures conservative bounding pressures.

During in-core irradiation of BPRAs, neutron capture by the B-10 isotope in the neutron absorbing material produces helium. Two different forms of the neutron absorbing material are used in BPRAs: Borosilicate glass and B_4C in a refractory solid matrix (Al_2O_3). Borosilicate glass (primarily a constituent of Westinghouse BPRAs) is used in the shape of hollow pyrex glass tubes sealed within steel rods and supported on the inside by a thin-walled steel liner. To accommodate helium diffusion from the glass rod into the rod internal space, a relatively high void volume (~40%) is engineered in this type of rod design. The rod internal pressure is thus designed to remain below reactor operation conditions (2,300 psia and approximately 600 °F coolant temperature). The B_4C-Al_2O_3 neutron absorber material is principally used in B&W and CE fuel BPRA designs. The relatively low temperature of the poison material in BPRA rods (relative to fuel pellets) favor the entrapment of helium atoms in the solid matrix.

Several BPRA designs are used in PWR fuel that differ in the number, diameter, and length of poison rods. The older Westinghouse fuel (W-14x14 and W-15x15) has used 6, 12, 16, and 20 rods per assembly BPRAs and the later (W-17x17) fuel uses up to 24 rods per BPRA. The BPRA rods in the older fuel are much larger than the later fuel and, therefore, the B-10 isotope inventory in the 20-rod BPRAs bounds the newer W-17x17 fuel. Based on bounding BPRA rods internal pressure, a large hypothetical quantity of helium (7.2 g-moles/BPRA) is assumed to be available for release into

the MPC cavity from each fuel assembly in the PWR baskets. The MPC cavity pressures (including helium from BPRAs) are summarized in Table 4.4.9.

4.4.6 Engineered Clearances to Eliminate Thermal Interferences

Thermal stress in a structural component is the resultant sum of two factors, namely: (i) restraint of free end expansion and (ii) non-uniform temperature distribution. To minimize thermal stresses in load bearing members, the HI-STORM System is engineered with adequate gaps to permit free thermal expansion of the fuel basket and MPC in axial and radial directions. In this subsection, differential thermal expansion calculations are performed to demonstrate that engineered gaps in the HI-STORM System are adequate to accommodate thermal expansion of the fuel basket and MPC.

The HI-STORM System is engineered with gaps for the fuel basket and MPC to expand thermally without restraint of free end expansion. Differential thermal expansion of the following gaps are evaluated:

a. *Fuel Basket-to-MPC Radial Gap*
b. *Fuel Basket to MPC Axial Gap*
c. *MPC-to-Overpack Radial Gap*
d. *MPC-to-Overpack Axial Gap*

To demonstrate that the fuel basket and MPC are free to expand without restraint, it is required to show that differential thermal expansion from fuel heatup is less than the as-built gaps that exist in the HI-STORM System. For this purpose a suitably bounding temperature profile (T(r)) for the fuel basket is established in Figure 4.4.5 wherein the center temperature (TC) is set at the limit (752 ℉) for fuel cladding (conservatively bounding assumption) and the basket periphery (TP) conservatively postulated at an upperbound of 610~~600~~ ℉ (see Table 4.4.6 for the maximum fuel and basket periphery temperatures). To maximize the fuel basket differential thermal expansion, the basket periphery-to-MPC shell temperature difference is conservatively maximized (ΔT = 175 ℉). From the bounding temperature profile T(r) and ΔT, the mean fuel basket temperature (T1) and MPC shell temperature (T2) are computed as follows:

$$T1 = \frac{\int_0^1 rT(r)dr}{\int_0^1 rdr} = 676°F$$

$$T2 = TP - \Delta T = 425°F$$

The differential radial growth of the fuel basket (Y1) from an initial reference temperature (To = 70 ℉) is computed as:

$$Y1 = R \times \left[A1 \times (T1 - To) - A2 \times (T2 - To)\right]$$

where:

R = Basket radius (conservatively assumed to be the MPC radius)

A1, A2 = Coefficients of thermal expansion for fuel basket and MPC shell at T1 and T2 respectively for Alloy X (Chapter 1 and Table 3.3.1)

For computing the relative axial growth of the fuel basket in the MPC, bounding temperatures for the fuel basket (TC) and MPC shell temperature T2 utilized above are adopted. The differential expansion is computed by a formula similar to the one for radial growth after replacing R with basket height (H), which is conservatively assumed to be that of the MPC cavity.

For computing the radial and axial MPC-to-overpack differential expansions, the MPC shell is postulated at its design temperature (Chapter 2, Table 2.2.3) and thermal expansion of the overpack is ignored. Even with the conservative computation of the differential expansions in the manner of the foregoing, it is evident from the data compiled in Table 4.4.10 that the differential expansions are a fraction of their respective gaps.

4.4.7 Evaluation of System Performance for Normal Conditions of Storage

The HI-STORM System thermal analysis is based on a detailed and complete heat transfer model that conservatively accounts for all modes of heat transfer in various portions of the MPC and overpack. The thermal model incorporates conservative features that render the results for long-term storage to be extremely conservative.

Temperature distribution results obtained from this highly conservative thermal model show that the maximum fuel cladding temperature limits are met with adequate margins. Expected margins during normal storage will be much greater due to the conservative assumptions incorporated in the analysis. The long-term impact of decay heat induced temperature levels on the HI-STORM System structural and neutron shielding materials is considered to be negligible. The maximum local MPC basket temperature level is below the recommended limits for structural materials in terms of susceptibility to stress, corrosion and creep-induced degradation. Furthermore, stresses induced due to imposed temperature gradients are within Code limits (See Structural Evaluation Chapter 3). Therefore, it is concluded that the HI-STORM System thermal design is in compliance with 10CFR72 requirements.

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Table 4.4.1

EFFECTIVE CONDUCTIVITY OF THE COMPOSITE FUEL BASKET WALLS
(Btu/hr-ft-°F)

	MPC-32		MPC-24/MPC-24E*		MPC-68	
Temperature (°F)	Thru-Thickness Direction	Parallel Plates Direction	Thru-Thickness Direction	Parallel Plates Direction	Thru-Thickness Direction	Parallel Plates Direction
200	6.000	14.65	5.676 4.800**	13.85 11.17**	5.544	12.06
450	7.260	16.12	6.864 5.808**	15.32 12.54**	6.708	13.45
700	8.316	17.20	7.884 6.672**	16.44 13.62**	7.680	14.52

* Lowerbound values reported.
** Effective conductivities of basket peripheral panels.

Table 4.4.2

LIMITING EFFECTIVE CONDUCTIVITIES OF THE RODDED REGION
(Btu/hr-ft-°F)

	PWR Fuel		BWR FUEL	
Temperature (°F)	Planar	Axial	Planar	Axial
200	0.257	0.753	0.282	0.897
450	0.406	0.833	0.425	0.988
700	0.604	0.934	0.606	1.104

Table 4.4.3

[deleted]

~~*MPC BASKET EFFECTIVE THERMAL CONDUCTIVITIES*~~

~~*(Btu/hr-ft-°F)*~~

	~~*MPC-32*~~		~~*MPC-24/MPC-24E**~~		~~*MPC-68*~~	
~~*Temperature (°F)*~~	~~*Planar*~~	~~*Axial***~~	~~*Planar*~~	~~*Axial***~~	~~*Planar*~~	~~*Axial***~~
~~*200*~~	~~*1.061*~~	~~*1.773*~~	~~*1.143*~~	~~*2.427*~~	~~*1.073*~~	~~*2.186*~~
~~*450*~~	~~*1.324*~~	~~*1.933*~~	~~*1.554*~~	~~*2.666*~~	~~*1.307*~~	~~*2.379*~~
~~*700*~~	~~*1.603*~~	~~*2.079*~~	~~*2.047*~~	~~*2.870*~~	~~*1.550*~~	~~*2.548*~~

~~** Lowerbound values reported.*~~

~~*** Conductivities are conservatively understated.*~~

Table 4.4.4

[deleted]

~~*COMPARISON OF 3-D AND AXISYMMETRIC MODEL SOLUTIONS*~~

~~*Regionalized Loading Parameter (X)*~~	~~*Peak Clad Temperature, °F*~~		
	~~*Axisymmetric Solution*~~	~~*3-D Solution*~~	~~*Relative Conservatism in the Axisymmetric Model, °F*~~
~~*MPC-68*~~			
~~*0.5*~~	~~*728*~~	~~*688*~~	~~*40*~~
~~*1*~~	~~*719*~~	~~*683*~~	~~*36*~~
~~*2*~~	~~*708*~~	~~*670*~~	~~*38*~~
~~*3*~~	~~*700*~~	~~*671*~~	~~*29*~~
~~*MPC-32*~~			
~~*0.5*~~	~~*720*~~	~~*710*~~	~~*10*~~
~~*1*~~	~~*715*~~	~~*706*~~	~~*9*~~
~~*2*~~	~~*716*~~	~~*704*~~	~~*12*~~
~~*3*~~	~~*713*~~	~~*702*~~	~~*11*~~

Table 4.4.5

MATRIX OF HI-STORM SYSTEM THERMAL EVALUATIONS

Scenario	*Description*	*Ultimate Heat Sink*	*Analysis Type*	*Principal Input Parameters*	*Results in FSAR Subsection*
1	*Long Term Normal*	*Ambient*	*SS*	N_T, Q_D, *ST, SC,* I_O	*4.4.4*
2	*Off-Normal Environment*	*Ambient*	*SS(B)*	O_T, Q_D, *ST, SC,* I_O	*4.6.1*
3	*Extreme Environment*	*Ambient*	*SS(B)*	E_T, Q_D, *ST, SC,* I_O	*4.6.2*
4	*Partial Ducts Blockage*	*Ambient*	*SS(B)*	N_T, Q_D, *ST, SC,* $I_{1/2}$	*4.6.1*
5	*All Inlets Ducts Blocked*	*Overpack*	*TA*	N_T, Q_D, *ST, SC,* I_C	*4.6.2*
6	*Fire Accident*	*Overpack*	*TA*	Q_D, *F*	*4.6.2*
7	*Burial Under Debris*	*Overpack*	*AH*	Q_D	*4.6.2*

Legend:

N_T - Maximum Annual Average (Normal) Temperature (80°F)
O_T - Off-Normal Temperature (100°F)
E_T - Extreme Hot Temperature (125°F)
Q_D - Design Basis Maximum Heat Load
SS - Steady State
SS(B) - Bounding Steady State
TA - Transient Analysis
AH - Adiabatic Heating

I_O - All Inlet Ducts Open
$I_{1/2}$ - Half of Inlet Ducts Open
I_C - All Inlet Ducts Closed

ST - Insolation Heating (Top)
SC - Insolation Heating (Curved)
F - Fire Heating (1475°F)

Table 4.4.6

MAXIMUM MPC TEMPERATURES FOR LONG-TERM NORMAL STORAGE CONDITION[3]

Component	*Temperature, °F*	
	MPC-32	*MPC-68*
Fuel Cladding	***711***	*697*
MPC Basket	***708***	*692*
Basket Periphery	***604***	*566*
MPC Shell	***469***	*452*

Table 4.4.7

BOUNDING HI-STORM OVERPACK TEMPERATURES FOR LONG-TERM NORMAL STORAGE[4]

Component	*Local Section Temperature*[5]*, °F*
Inner shell	*322*
Outer shell	*174*
Lid bottom plate	*302*
Lid top plate	*190*
Overpack Body Concrete	*248*
Overpack Lid Concrete	*246*
Area Averaged Air outlet[6]	*235*

3 *The temperatures reported in this table* for the bounding fuel storage configuration (regionalized storage~~all~~ *at X = 0.5) are below the design temperatures specified in Chapter 2, Table 2.2.3.* Results of the bounding canister (MPC-32) are highlighted in bold.

4 *The temperatures reported in this table (all for MPC-32 at X = 0.5) are below the design temperatures specified in Chapter 2, Table 2.2.3.*

5 *Section temperature is defined as the through-thickness average temperature.*

6 *Reported herein for the option of temperature measurement surveillance of outlet ducts air temperature as set forth in the Technical Specifications.*

Table 4.4.8

SUMMARY OF MPC FREE VOLUME CALCULATIONS

Item	*Volume (MPC-24) [ft^3]*	*Volume (MPC-24E) [ft^3]*	*Volume (MPC-32) [ft^3]*	*Volume (MPC-68) [ft^3]*
Cavity Volume	*367.9*	*367.9*	*367.9*	*367.3*
Basket Metal Volume	*44.3*	*51.4*	*24.9*	*34.8*
Bounding Fuel Assemblies Volume	*78.8*	*78.8*	*105.0*	*93.0*
Basket Supports and Fuel Spacers Volume	*6.1*	*6.1*	*9.0*	*11.3*
*Net Free Volume**	*238.7 (6,759 liters)*	*231.6 (6,558 liters)*	*229 (6,484 liters)*	*228.2 (6,462 liters)*

** Net free volumes are obtained by subtracting basket, fuel, supports and spacers metal volume from cavity volume. The free volumes used for MPC internal pressure calculations are conservatively understated.*

Table 4.4.9

*SUMMARY OF MPC INTERNAL PRESSURES UNDER LONG-TERM STORAGE**

Condition	*MPC-24*** (psig)*	*MPC-24E*** (psig)*	*MPC-32 (psig)*	*MPC-68 (psig)*
*Initial backfill** (at 70°F)*	*48.5*	*48.5*	*48.5*	*48.5*
Normal:				
intact rods	*99.0*	*99.0*	*99.0*	*96.8*
1% rods rupture	*100.0*	*99.7*	*99.7*	*97.2*
Off-Normal (10% rods rupture)	*106.0*	*106.2*	*108.7*	*101.2*
Accident (100% rods rupture)	*169.3*	*171.5*	*196.4*	*141.1*

** Per NUREG-1536, pressure analyses with ruptured fuel rods (including BPRA rods for PWR fuel) is performed with release of 100% of the ruptured fuel rod fill gas and 30% of the significant radioactive gaseous fission products.*

*** Conservatively assumed at the Tech. Spec. maximum value (See Table 4.4.12).*

**** Pressure calculations use the bounding MPC-32 temperature field.*

Table 4.4.10

SUMMARY OF HI-STORM DIFFERENTIAL THERMAL EXPANSIONS

Gap Description	*Cold Gap U (in)*	*Differential Expansion V (in)*	*Is Free Expansion Criterion Satisfied (i.e., U > V)*
Fuel Basket-to-MPC Radial Gap	*0.1875*	*0.095~~6~~*	*Yes*
Fuel Basket-to-MPC Axial Gap	*1.25*	*0.487~~99~~*	*Yes*
MPC-to-Overpack Radial Gap	*0.5*	*0.139*	*Yes*
MPC-to-Overpack Minimum Axial Gap	*1.0*	*0.771*	*Yes*

Table 4.4.11

THEORETICAL LIMITS OF MPC HELIUM BACKFILL PRESSURE***

MPC	*Minimum Backfill Pressure (psig)*	*Maximum Backfill Pressure (psig)*
MPC-32/24/24E	*44.1*	*49.1*
MPC-68	*45.2*	*50.3*

** The helium backfill pressures are set forth in the Technical Specifications with a margin (See Table 4.4.12).*

*** The pressures tabulated herein are at a reference gas temperature of 70°F.*

Table 4.4.12

MPC HELIUM BACKFILL PRESSURE SPECIFICATIONS

Item	*Specification*
Minimum Pressure	*45.5 psig @ 70°F Reference Temperature*
Maximum Pressure	*48.5 psig @ 70°F Reference Temperature*

FIGURE 4.4.2

Deleted

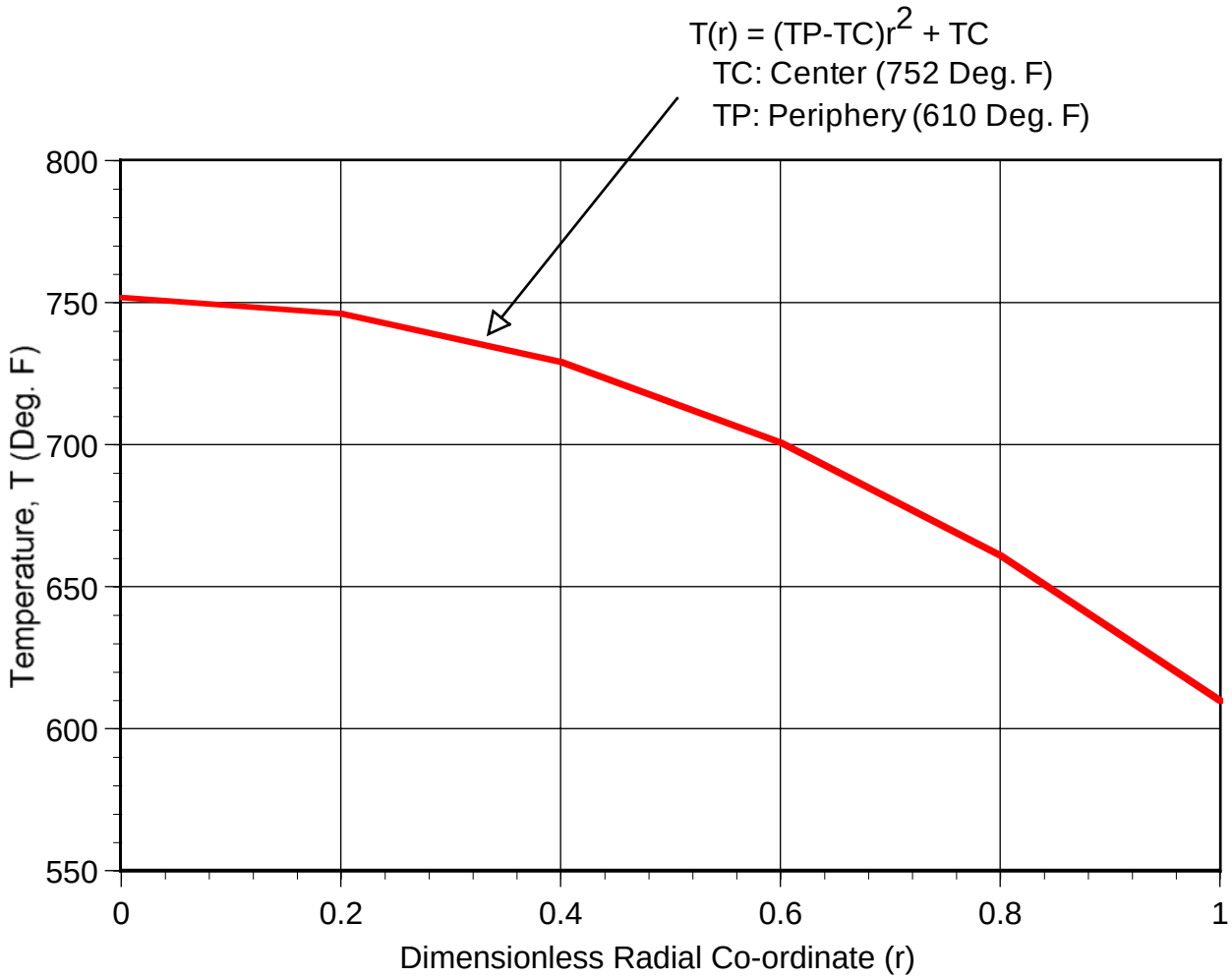

FIGURE 4.4.5: BOUNDING BASKET TEMPERATURE PROFILE FOR DIFFERENTIAL EXPANSION

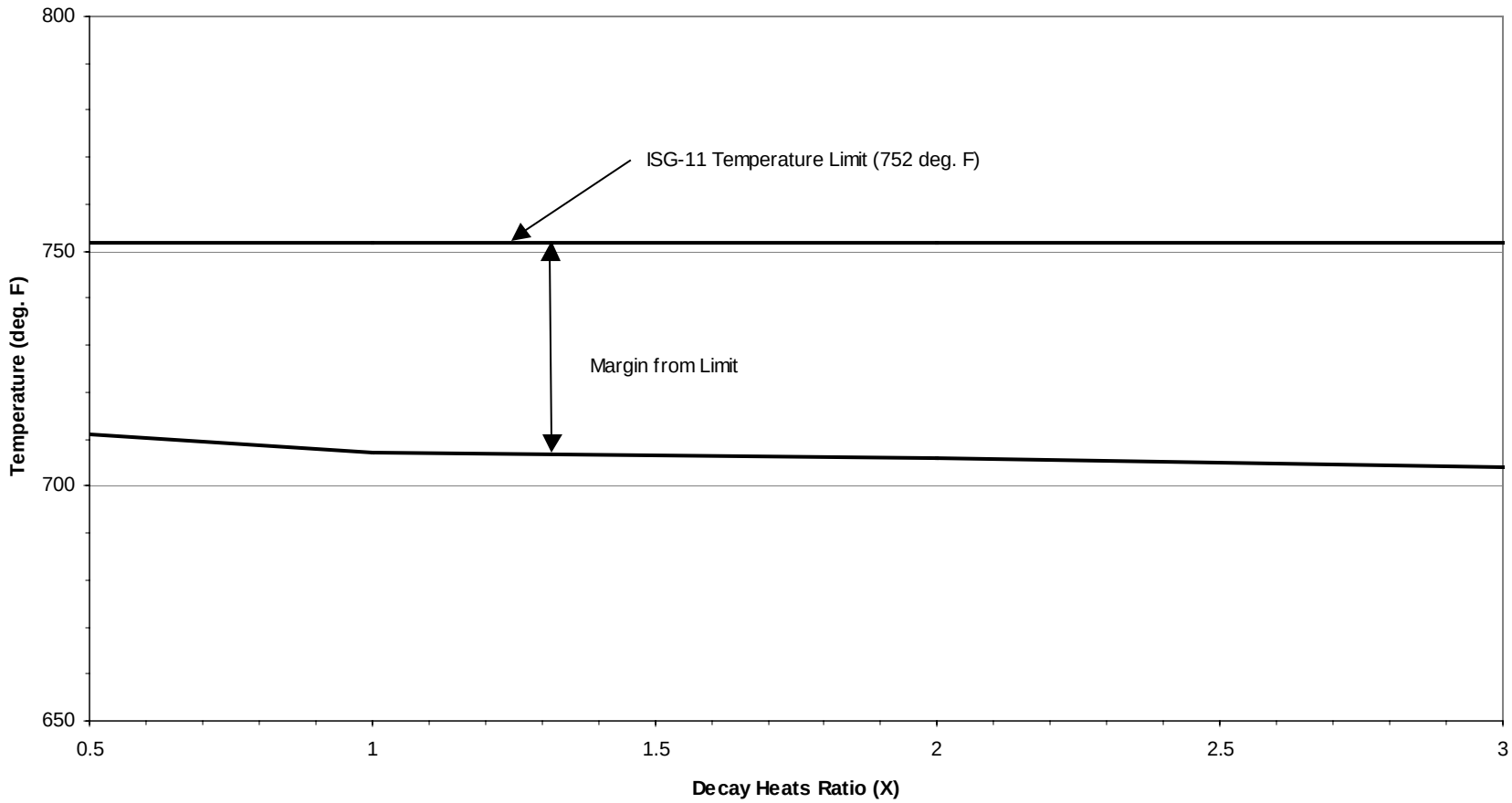

FIGURE 4.4.6: PEAK CLADDING TEMPERATURE VARIATION IN REGIONALIZED STORAGE (MPC 32)

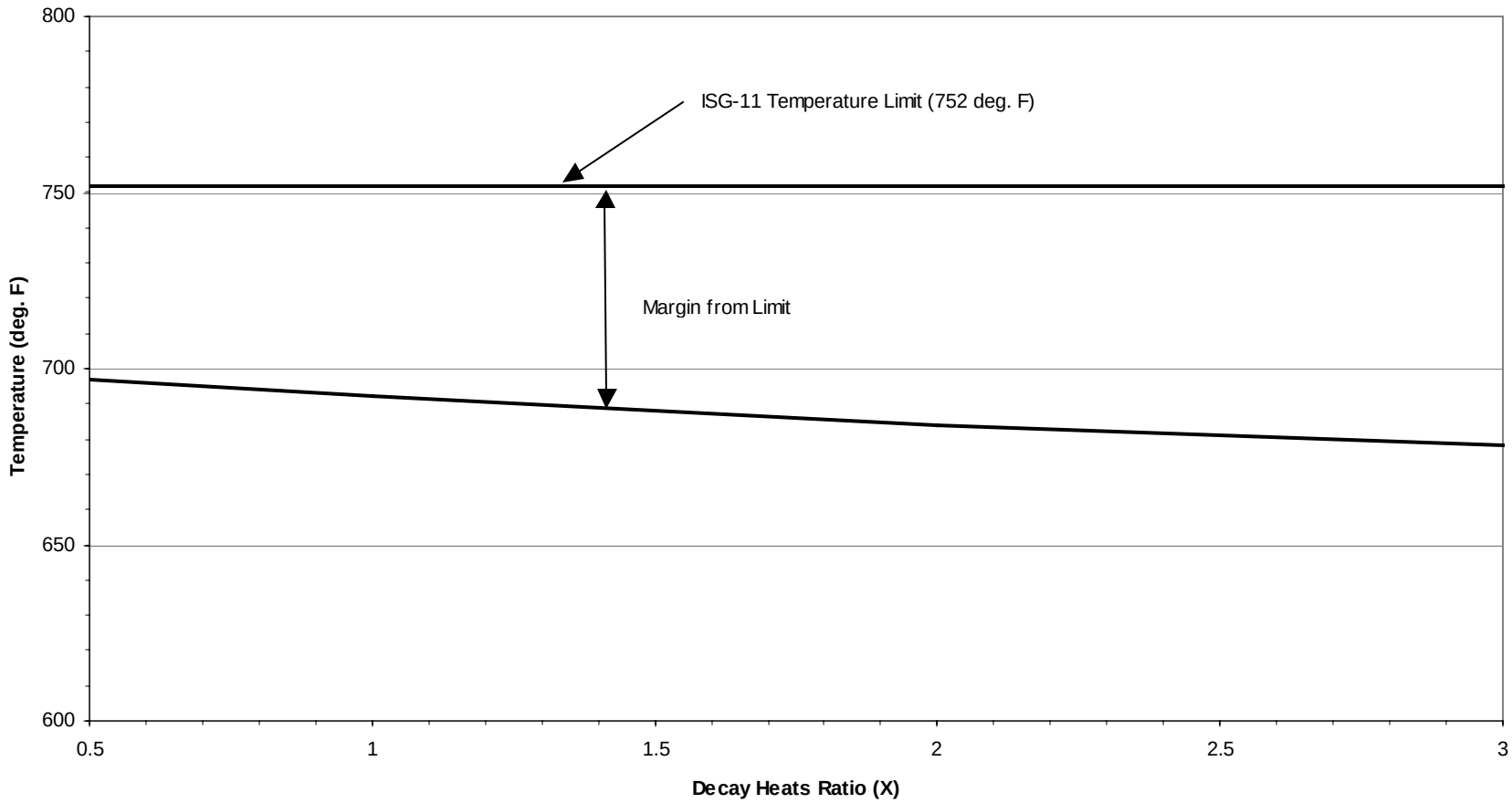

FIGURE 4.4.7: PEAK CLADDING TEMPERATURE VARIATION IN REGIONALIZED STORAGE (MPC-68)

4.5 THERMAL EVALUATION OF SHORT TERM OPERATIONS

Prior to placement in a HI-STORM overpack, an MPC must be loaded with fuel, outfitted with closures, dewatered, dried, backfilled with helium and transported to the HI-STORM module. In the unlikely event that the fuel needs to be returned to the spent fuel pool, these steps must be performed in reverse. Finally, if required, transfer of a loaded MPC between HI-STORM overpacks or between a HI-STAR transport overpack and a HI-STORM storage overpack must be carried out in an assuredly safe manner. All of the above operations, henceforth referred to as "short term operations", are short duration events that would likely occur no more than once or twice for an individual MPC.

The device central to all of the above operations is the HI-TRAC transfer cask that, as stated in Chapter 1, is available in two anatomically similar weight ratings (100- and 125-ton). The HI-TRAC transfer cask is a short-term host for the MPC; therefore it is necessary to establish that, during all thermally challenging operation events involving either the 100-ton or 125-ton HI-TRAC, the permissible temperature limits presented in Section 4.3 are not exceeded. The following discrete thermal scenarios, all of short duration, involving the HI-TRAC transfer cask have been identified as warranting thermal analysis.

i. Post-Loading Wet Transfer Operations
ii. MPC Cavity Vacuum Drying
iii. Normal Onsite Transport in a Vertical Orientation
iv. MPC Cooldown and Reflood for Unloading Operations

Onsite transport of the MPC occurs with the HI-TRAC in the vertical orientation, which preserves the thermosiphon action within the MPC. To avoid excessive temperatures, transport with the HI-TRAC in the horizontal condition is generally not permitted. However, it is recognized that an occasional downending of a HI-TRAC may become necessary to clear an obstruction such as a low egress bay door opening. In such a case the operational imperative for HI-TRAC downending must be ascertained and the permissible duration of horizontal configuration must be established on a site-specific basis and compliance with the thermal limits of ISG-11 [4.1.4] must be demonstrated as a part of the site-specific safety evaluation.

To ensure a bounding evaluation for the array of fuel storage configurations permitted in Section 2.1, the~~a~~ limiting storage condition is evaluated in this section. As evaluated in Table 4.4.6 ~~T~~the limiting storage condition[1] is ~~determined in Table 4.4.4 to be~~ design heat load in an MPC-32~~68 (based on the bounding axisymmetric thermal model)~~ under regionalized fuel loading at X = 0.5.~~with regionalization parameter X = 0.5.~~

1 *Limiting fuel storage condition is defined as the fuel loading scenario that yields the highest computed fuel temperatures. From the array of analyses presented on Section 4.4, it is found that the highest clad temperatures co-incidentally occur with the highest permitted MPC heat load (i.e. for X = 0.5). Therefore the limiting scenario also yields the highest confinement boundary and HI-TRAC overpack temperatures.*

~~*The fuel handling operations listed above place a certain level of constraint on the dissipation of heat from the MPC relative to the normal storage condition. Consequently, for some scenarios, it is necessary to provide additional cooling when certain threshold heat loads are exceeded. For such situations, the Supplemental Cooling System (SCS) is required to provide additional cooling during short-term operations. The SCS is required by the CoC for any MPC carrying one or more high burnup fuel assemblies when the MPC heat load is in excess of a conservatively postulated threshold (Q* = 25 kW). For compliance with this specification, the MPC heat load is computed based on the discussion provided in Section 2.1 for uniform loading. In accordance with Section 2.1, the MPC heat load (Q) is computed by multiplying the number of fuel storage cells by the decay heat of the most emissive assembly loaded for storage. The SCS is required when Q exceeds Q*. The specific design of an SCS must accord with site-specific needs and resources, including the availability of plant utilities. However, a set of specifications to ensure that the performance objectives of the SCS are satisfied by plant-specific designs are set forth in Appendix 2.C.*~~

The short term operations listed above are described and evaluated in the following subsections. A map of HI-TRAC thermal evaluations is provided in Table 4.5.1.

4.5.1 HI-TRAC Thermal Model

The HI-TRAC transfer cask is used to load and unload the HI-STORM concrete storage overpack, including onsite transport of the MPCs from the loading facility to an ISFSI. Section views of the HI-TRAC have been presented in Chapter 1. Within a loaded HI-TRAC, heat generated in the MPC is transported from the contained fuel assemblies to the MPC shell in the manner described in Section 4.4. From the outer surface of the MPC to the ambient air, heat is transported through the HI-TRAC overpack by a combination of conduction, thermal radiation and natural convection. For evaluation of a loaded canister during short-term operations (including vacuum drying) ~~*T*~~*the* 3-Dimensional ~~*axi-symmetric*~~ *thermal model of the MPC described in Section 4.4 is adopted.*~~*used for modeling the MPC is described in Section 4.4 and adopted for evaluation of short-term operations in a HI-TRAC overpack.*~~ *Thermal modeling of the HI-TRAC* ~~*transfer*~~ *overpack is provided in the following.* ~~*this subsection.*~~

Two HI-TRAC transfer cask designs, namely, the 125-ton and the 100-ton versions, are developed for onsite handling and transport, as discussed in Chapter 1. The two designs are principally different in terms of lead thickness and the thickness of the heat dissipating ribs (radial connectors) in the water jacket region. The analytical model developed for HI-TRAC thermal characterization conservatively accounts for these differences by applying the higher shell thickness and thinner radial connectors' thickness to the model. In this manner, the HI-TRAC overpack resistance to heat transfer is overestimated, resulting in higher predicted MPC internals and fuel cladding temperature levels.

The 100-ton and 125-ton HI-TRAC designs incorporate 2.5 inch and 4.5 inch annular lead spaces, respectively, formed between a 3/4-inch thick steel inner shell and a 1-inch thick steel outer shell. To ensure that lead forms a heat conduction continuum in the HI-TRAC body, ~~*solid*~~ *lead in the form of bricks or plates are not utilized in Holtec transfer casks. Rather, lead is poured in a molten state.*

The interior steel surfaces are cleaned, sandblasted and fluxed in preparation for the molten lead that will be poured in the annular cavity. The appropriate surface preparation technique is essential to ensure that molten lead sticks to the steel surfaces, which will form a metal to lead bond upon solidification during the lead pour process. ~~The molten lead is poured to fill the annular cavity. The molten lead in the immediate vicinity of the steel surfaces, upon cooling by the inner and outer shells, solidifies forming a melt-solid interface.~~ The ~~initial~~ formation ~~of a gap-free interfacial bond~~of gap-free interfacial bonds between the solidified lead and steel surfaces initiates a process of lead crystallization from the molten pool onto the solid surfaces. Static pressure from the column of molten lead further aids in retaining the solidified lead layer to the steel surfaces. The melt-solid interface growth occurs by freezing of successive layers of molten lead as the heat of fusion is dissipated by the solidified metal and steel structure enclosing it. This growth stops when all the molten lead is used up and the annulus is filled with a solid lead plug. The shop fabrication procedures, developed in conjunction with the manufacture of the HI-TRAC transfer casks contain detailed step-by-step instructions devised to eliminate the incidence of annular gaps in the lead space of the HI-TRAC. Accordingly the HI-TRAC transfer cask lead spaces are treated in the thermal models as continuous media.

Transport of heat within HI-TRAC occurs through multiple concentric layers of air, steel and shielding materials. From the surface of the enclosure shell heat is rejected to the atmosphere by natural convection and radiation.

A small diametral air gap exists between the outer surface of the MPC and the inner surface of the HI-TRAC overpack. Heat is transported across this gap by the parallel mechanisms of conduction and thermal radiation. Assuming that the MPC is centered and does not contact the transfer overpack walls conservatively minimizes heat transport across this gap. Thermal expansion would act to minimize this gap. At operating conditions, this gap would be quite small. For the purposes of evaluating heat transport across this gap, however, it is conservatively assumed that the gap is reduced to one-half of its nominal value. Heat is transported through the cylindrical wall of the HI-TRAC ~~transfer~~ overpack by conduction through successive layers of steel, lead and steel. A water jacket, which provides neutron shielding for the HI-TRAC overpack, surrounds the cylindrical steel wall. The water jacket is essentially an array of carbon steel radial ribs with welded, connecting enclosure plates. Heat is dissipated by conduction and natural convection in the water cavities and by conduction in the radial ribs. Heat is passively rejected to the ambient from the outer surface of the HI-TRAC transfer overpack by natural convection and thermal radiation.

The HI-TRAC bottom is conservatively modeled as an insulated surface. The HI-TRAC top lid and sides are modeled as insolation heated surfaces cooled by convection and radiation. Insolation on exposed surfaces is conservatively based on 12-hour insolation inputs from 10CFR71 averaged on a 24-hour basis.

4.5.1.1 Effective Thermal Conductivity of Water Jacket

The HI-TRAC water jacket is composed of an array of radial ribs equispaced along the circumference of the HI-TRAC. Enclosure plates are welded to these ribs, creating an array of water

compartments. Holes in the radial ribs connect all the individual compartments in the water jacket. The annular region between the HI-TRAC outer shell and the enclosure shell is an array of steel ribs and water spaces.

The effective radial thermal conductivity of this array of steel ribs and water spaces is determined by combining the heat transfer resistance of individual components (steel ribs and water spaces) in a parallel network. A bounding calculation is assured by using a minimum available metal thickness (product of number of radial ribs and rib thickness) for radial heat transfer.

The water in the jacket is free to move under the effects of buoyancy forces. The effect of this water motion on heat transfer is characterized by the Nusselt number (Nu), which can be defined as follows for a vertical enclosure [4.5.1]:

$$Nu = 0.046 \times Ra^{1/3}$$

where Ra is the Rayleigh number. For a conservatively determined Rayleigh number, based on the radial width of the water space, the Nusselt number for the water in the water jacket is approximately 79. This value is used as a multiplier on the thermal conductivity of water in the water jacket to reflect the effects of water motion on heat transfer in this region.

4.5.1.1.2 <u>*Heat Rejection from Overpack Exterior Surfaces*</u>

The following relationship is used for modeling heat loss from exposed cask surfaces:

$$q_s = 0.19\,(T_s - T_A)^{4/3} + 0.1714\varepsilon\,[(\frac{T_s + 460}{100})^4 - (\frac{T_A + 460}{100})^4]$$

where:

T_S = *cask surface temperatures (°F)*
T_A = *ambient atmospheric temperature (°F)*
q_s = *surface heat flux (Btu/ft^2×hr)*
ε = *surface emissivity*

The second term in this equation the Stefan-Boltzmann formula for thermal radiation from an exposed surface to ambient. The first term is the natural convection heat transfer correlation recommended by Jacob and Hawkins [4.2.9]. This correlation is appropriate for turbulent natural convection from vertical surfaces, such as the vertical overpack wall. Although the ambient air is conservatively assumed to be quiescent, the natural convection is nevertheless turbulent.

Turbulent natural convection correlations are suitable for use when the product of the Grashof and Prandtl (Gr×Pr) numbers exceeds 10^9. This product can be expressed as $L^3 \times \Delta T \times Z$, where L is the characteristic length, ΔT is the surface-to-ambient temperature difference, and Z is a function of the surface temperature. The characteristic length of a vertically oriented HI-TRAC is its height of approximately 17 feet. The value of Z, conservatively taken at a surface temperature of 340°F, is

2.6×10^5. Solving for the value of ΔT that satisfies the equivalence $L^3\times\Delta T\times Z = 10^9$ yields ΔT = 0.78°F. The natural convection will be turbulent, therefore, provided the surface to air temperature difference is greater than or equal to 0.78°F.

4.5.1.3 Determination of Solar Heat Input

The thermal evaluations use the 10CFR71 specified 12-hour insolation as a 24-hour averaged heat flux on exposed HI-TRAC surfaces. This is appropriate, as the HI-TRAC cask possesses a considerable thermal inertia that precludes it from reaching steady state during a 12-hour insolation period.

4.5.2 Maximum Time Limit During Wet Transfer Operations

In accordance with NUREG-1536, water inside the MPC cavity during wet transfer operations is not permitted to boil. Consequently, uncontrolled pressures in the de-watering, purging, and recharging system that may result from two-phase conditions are completely avoided. This requirement is accomplished by imposing a limit on the maximum allowable time duration for fuel to be submerged in water after a loaded HI-TRAC cask is removed from the pool and prior to the start of vacuum drying operations.

Fuel loading operations are typically conducted with the HI-TRAC and it's contents (water filled MPC) submerged in pool water. Under these conditions, the HI-TRAC is essentially at the pool water temperature. When the HI-TRAC transfer cask and the loaded MPC under water-flooded conditions is removed from the pool, the water, fuel, MPC and HI-TRAC metal absorb the decay heat emitted by the fuel assemblies. This results in a slow temperature rise of the HI-TRAC with time, starting from an initial (pool water) temperature. The rate of temperature rise is limited by the thermal inertia of the HI-TRAC system. To enable a bounding heat-up rate determination, the following conservative assumptions are utilized:

i. Heat loss by natural convection and radiation from the exposed HI-TRAC surfaces to ambient air is neglected (i.e., an adiabatic heat-up calculation is performed).

ii. Design maximum decay heat input from the loaded fuel assemblies is assumed.

iii. The smaller of the two (i.e., 100-ton and 125-ton) HI-TRAC transfer cask designs is credited in the analysis. The 100-ton design has a significantly smaller quantity of metal mass, which will result in a higher rate of temperature rise.

iv. The water mass in the MPC cavity is understated.

Table 4.5.2 summarizes the weights and thermal inertias of several components in the loaded HI-TRAC transfer cask. The rate of temperature rise of the HI-TRAC transfer cask and contents during an adiabatic heat-up is governed by the following equation:

$$\frac{dT}{dt} = \frac{Q}{C_h}$$

where:

- Q = *conservatively bounding heat load (Btu/hr) [38 kW = 1.3x10^5 Btu/hr]*
- C_h = *thermal inertia of a loaded HI-TRAC (Btu/°F)*
- T = *temperature of the HI-TRAC cask (°F)*
- t = *time after HI-TRAC transfer cask is removed from the pool (hr)*

A bounding heat-up rate for the HI-TRAC transfer cask contents is determined to be equal to 4.99°F/hr. From this adiabatic rate of temperature rise estimate, the maximum allowable time duration (t_{max}) for fuel to be submerged in water is determined as follows:

$$t_{max} = \frac{T_{boil} - T_{initial}}{(dT/dt)}$$

where:

- T_{boil} = *boiling temperature of water (equal to 212°F at the water surface in the MPC cavity)*
- $T_{initial}$ = *initial HI-TRAC temperature when the transfer cask is removed from the pool*

Table 4.5.3 provides a summary of t_{max} at several representative initial temperatures.

As set forth in the HI-STORM operating procedures, in the unlikely event that the maximum allowable time provided in Table 4.5.3 is found to be insufficient to complete all wet transfer operations, a forced water circulation shall be initiated and maintained to remove the decay heat from the MPC cavity. In this case, relatively cooler water will enter via the MPC lid drain port connection and heated water will exit from the vent port. The minimum water flow rate required to maintain the MPC cavity water temperature below boiling with an adequate subcooling margin is determined as follows:

$$M_W = \frac{Q}{C_{pW}\,(T_{max} - T_{in})}$$

where:

- M_W = *minimum water flow rate (lb/hr)*
- C_{pw} = *water heat capacity (Btu/lb-°F)*
- T_{max} = *maximum MPC cavity water mass temperature*
- T_{in} = *temperature of pool water supply to MPC*

With the MPC cavity water temperature limited to 150°F, MPC inlet water maximum temperature equal to 125°F and at the design basis maximum heat load, the water flow rate is determined to be 5210 lb/hr (10.5 gpm).

4.5.3 MPC Temperatures During Moisture Removal Operations

4.5.3.1 Vacuum Drying Operation

The initial loading of SNF in the MPC requires that the water within the MPC be drained and replaced with helium. For MPCs containing moderate burnup fuel assemblies only, this operation may be carried out using the conventional vacuum drying approach. In this method, removal of the last traces of residual moisture from the MPC cavity is accomplished by evacuating the MPC for a short time after draining the MPC. Vacuum drying of MPCs containing any high burnup fuel assemblies is not permitted. High burnup fuel drying is performed by a forced flow helium drying process as described in Appendix 2.B.

Prior to the start of the MPC draining operation, both the HI-TRAC annulus and the MPC are full of water. The presence of water in the HI-TRAC annulus ensures adequate fuel cooling even under high vacuum (~1 torr) for extended durations. As the heat generating active fuel length is uncovered during MPC draining operation, the fuel and basket mass will undergo a gradual heat up from the initially cold conditions when the heated surfaces were submerged under water.

Vacuum drying is evaluated assuming the MPC space is filled with water vapor at a very low pressure (1 torr) and bounding steady state temperatures have reached. For allowing vacuum drying of MBF without time limit restrictions MPC dependent threshold heat load are specified below:

MPC-24/24E: 29 kW
MPC-32: 26 kW
MPC-68: 26 kW

For compliance with the threshold heat loads specified above the MPC heat load, Q is computed based on the discussion in Section 2.1 for uniform loading. In accordance with this section Q is computed by multiplying the number of fuel storage cells by the decay heat of the most emissive assembly loaded in the MPC. For ~~total~~ MPC decay heat loads up to the threshold heat loads, vacuum drying of the MPC is permitted with the annular gap between the MPC and the HI-TRAC filled with water. The presence of water in this annular gap will maintain the MPC shell temperature approximately equal to the saturation temperature of the annulus water. In the vacuum drying thermal analysis a bounding MPC shell temperature (232°F) is conservatively assumed. 3-Dimensional ~~Axisymmetric~~ FLUENT thermal models ~~of the PWR and BWR MPCs~~ described previously in Section 4.4 (~~MPC-24/24E, MPC-32 and MPC-68~~) are constructed for the MPC-24/24E, MPC-32 and MPC-68 canisters. ~~, employing t~~The following ~~bounding~~ assumptions are conservatively applied to the thermal models:

i. Bounding steady-state condition.

ii. The MPC shell is postulated to be at a bounding maximum temperature of 232°F.

iii. The top surface of the MPC is cooled to the ambient in still air.

iv. The bottom surface of the MPC is insulated.

~~An axisymmetric FLUENT thermal model of the MPC is constructed for vacuum drying of moderate burnup fuel[2].~~ Each MPC is analyzed at its respective threshold heat load defined previously and fuel cladding temperatures below prescribed limit for MBF (Table 4.3.1) confirmed.

4.5.3.2 Forced Helium Dehydration

To reduce moisture to trace levels in the MPC using a Forced Helium Dehydration (FHD) system, a closed loop dehumidification system consisting of a condenser, a demoisturizer, a compressor, and a pre-heater is utilized to extract moisture from the MPC cavity through repeated displacement of its contained helium, accompanied by vigorous flow turbulation. A vapor pressure of 3 torr or less is assured by verifying that the helium temperature exiting the demoisturizer is maintained at or below the psychrometric threshold of 21°F for a minimum of 30 minutes. See Appendix 2.B for detailed discussion of the design criteria and operation of the FHD system.

The FHD system provides concurrent fuel cooling during the moisture removal process through forced convective heat transfer. The attendant forced convection-aided heat transfer occurring during operation of the FHD system ensures that the fuel cladding temperature will remain below the applicable peak cladding temperature limit for normal conditions of storage, which is well below the high burnup cladding temperature limit 752°F (400°C) for all combinations of SNF type, burnup, decay heat, and cooling time. Because the FHD operation induces a state of forced convection heat transfer in the MPC, (in contrast to the quiescent mode of natural convection in long term storage), it is readily concluded that the peak fuel cladding temperature under the latter condition will be greater than that during the FHD operation phase. In the event that the FHD system malfunctions, the forced convection state will degenerate to natural convection, which corresponds to the conditions of normal onsite transport. As a result, the peak fuel cladding temperatures will approximate the values reached during normal onsite transport as described elsewhere in this chapter.

4.5.4 Maximum Temperatures Under Onsite Transport Conditions

A 3-Dimensional~~n axisymmetric~~ FLUENT thermal model of an MPC inside a HI-TRAC transfer cask was constructed to evaluate temperature distributions for onsite transport. A bounding steady-state analysis of the HI-TRAC transfer cask has been performed for a limiting fuel storage configuration

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~~2 Vacuum drying of high burnup fuel is not permitted. MPCs containing one or more HBF assemblies shall be de-moisturized using the FHD drying method.~~

(X = 0.5, MPC-32~~68~~). While the duration of onsite transport may be short enough to preclude the MPC and HI-TRAC from reaching steady-state, a steady-state analysis is conservative.

The maximum HI-TRAC onsite transport temperatures are reported in Table 4.5.4. The results satisfy the temperature limits for both *moderate burnup fuel and high burnup fuel (see Table 4.3.1).* In other words, the HI-TRAC thermal design satisfies the ISG 11 [4.1.4] fuel cladding temperature limits in still air with air in the HI-TRAC annulus. This simplifies ISFSI operations as the fuel temperatures limits are met without the need for either auxiliary cooling or additional operator actions (e.g. filling the annulus with water). ~~*For high burnup fuel (HBF) the maximum computed fuel cladding temperature reported in Table 4.5.4 is greater than the temperature limit of 752 °F for HBF. Consequently, it is necessary to utilize the SCS described at the beginning of this section and specified in Appendix 2.C during onsite transfer of an MPC with a greater than threshold heat load and containing one or more HBF assemblies. As stated earlier, the exact design and operation of the SCS is necessarily site-specific. The design is required to satisfy the design and operational requirements of Appendix 2.C to ensure compliance with ISG-11 [4.1.4] temperature limits.*~~

4.5.5 Cask Cooldown and Reflood Analysis During Fuel Unloading Operation

NUREG-1536 requires an evaluation of cask cooldown and reflooding to support fuel unloading from a dry condition. Past industry experience generally supports cooldown of cask internals and fuel from hot storage conditions by direct water quenching. For high heat load MPCs, the extremely rapid cooldown rates to which the hot MPC internals and the fuel cladding can be subjected during water injection may, however, result in high thermal stresses. Additionally, water injection may also result in some steam generation. To limit the fuel cladding from thermal strains from direct water quenching, the MPCs may be cooled using appropriate means prior to the introduction of water in the MPC cavity space.

Because of the continuous gravity driven circulation of helium in the MPC which results in heated helium gas in sweeping contact with the underside of the top lid and the inner cylindrical surface of the enclosure vessel, utilizing an external cooling means to remove heat from the MPC is quite effective. The external cooling process can be completely non-intrusive such as extracting heat from the outer surface of the enclosure vessel using chilled water. Extraction of heat from the external surfaces of an MPC is very effective largely because of the thermosiphon induced internal transport of heat to the peripheral regions of the MPC. The non-intrusive means of heat removal is preferable to an intrusive process wherein helium is extracted and cooled using a closed loop system such as a Forced Helium Dehydrator (Appendix 2.B), because it eliminates the potential for any radioactive crud to exit the MPC during the cooldown process. Because the optimal method for MPC cooldown is heavily dependent on the location and availability of utilities at a particular nuclear plant, mandating a specific cooldown method cannot be prescribed in this FSAR. Simplified calculations are presented in the following to illustrate the feasibility and efficacy of utilizing an intrusive system such as a recirculating helium cooldown system.

Under a closed-loop forced helium circulation condition, the helium gas is cooled, via an external chiller. The chilled helium is then introduced into the MPC cavity from connections at the top of the MPC lid. The helium gas enters the MPC basket and moves through the fuel basket cells, removing heat from the fuel assemblies and MPC internals. The heated helium gas exits the MPC from the lid connection to the helium recirculation and cooling system. Because of the turbulation and mixing of the helium contents in the MPC cavity by the forced circulation, the MPC exiting temperature is a reliable measure of the thermal condition inside the MPC cavity. The objective of the cooldown system is to lower the bulk helium temperature in the MPC cavity to below the normal boiling temperature of water (212°F). For this purpose, the rate of helium circulation shall be sufficient to ensure that the helium exit gas temperature is below this threshold limit with a margin.

An example calculation for the required helium circulation rate is provided below to limit the helium temperature to 200°F. The calculation assumes no heat loss from the MPC boundaries and a conservatively bounding heat load (38 kW (1.3x10^5 Btu/hr)). Under these assumptions, the MPC helium is heated adiabatically by the MPC decay heat from a given inlet temperature (T_1) to a temperature (T_2). The required circulation rate to limit T_2 to 200°F is computed as follows:

$$m = \frac{Q_d}{C_p(T_2 - T_1)}$$

where:

Q_d = Design maximum decay heat load (Btu/hr)
m = Minimum helium circulation rate (lb/hr)
Cp = Heat capacity of helium (1.24 Btu/lb-^{o}F (Table 4.2.5))
T_1 = Helium supply temperature (assumed 15°F in this example)

Substituting the values for the parameters in the equation above, m is computed as 567 lb/hr.

4.5.6 <u>Maximum Internal Pressure</u>

After fuel loading and vacuum drying, but prior to installing the MPC closure ring, the MPC is initially filled with helium. During handling and on-site transfer operations in the HI-TRAC transfer cask, the gas temperature within the MPC rises to its maximum operating temperature as determined based on the thermal analysis methodology described previously. The gas pressure inside the MPC will also increase with rising temperature. The pressure rise is determined based on the ideal gas law. The maximum MPC internal pressure is determined using a bounding set of assumptions, namely:

a) Limiting fuel storage condition
b) Steady state maximum temperatures have reached
c) HI-TRAC in a 80°F quiescent ambient temperature
d) HI-TRAC annulus is filled with a stationary air column
e) Exposed surfaces of cask heated by insolation
f) MPC backfilled with helium to Technical Specification maximum level

Under the adverse set of conditions defined above the maximum MPC pressure is computed and compared with the short term (off-normal) pressure limit specified in Table 2.2.1. The computed result (See Table 4.5.4) meets the pressure limit with a margin.

4.5.7 Evaluation of HI-TRAC Performance for Short Term Operations

The HI-TRAC transfer cask thermal analysis is based on a detailed heat transfer model that conservatively accounts for all modes of heat transfer in various portions of the MPC and HI-TRAC. The thermal model incorporates several conservative features, which are listed below:

i. A constant solar flux is imposed in the thermal model. A bounding solar absorbtivity of 1.0 is applied to all insolation surfaces.

*ii. The MPC is considered to be concentrically aligned within the cask cavity. This is a worst-case scenario since any eccentricity ~~will~~ improve**s** conductive heat transport in this region.*

iii. No credit is considered for cooling of the HI-TRAC baseplate while in contact with a supporting surface. An insulated boundary condition is applied in the thermal model on the bottom baseplate face.

Temperature distribution results (Tables 4.5.4) obtained from this conservative thermal model show that the fuel cladding and cask component temperature limits (Table 2.2.3) are met with adequate margins ~~for MBF~~. ~~For HBF, supplemental cooling is specified to comply with the applicable temperature limits. Expected margins during HI-TRAC operations will be larger due to the many conservative assumptions incorporated in the analysis.~~ The coincident ~~Corresponding~~ MPC internal pressure is computed and reported Table 4.5.4. The pressure is ~~remains~~ below the MPC short-term condition design pressure (Table 2.2.1). The maximum local neutron shield temperature is lower than design limits. Therefore, it is concluded that the HI-TRAC transfer cask thermal design is adequate to maintain fuel cladding integrity for short-term onsite handling and transfer operations.

The water in the water jacket of the HI-TRAC provides necessary neutron shielding. During normal handling and onsite transfer operations this shielding water is contained within the water jacket, which is designed for an elevated internal pressure. It is recalled that the water jacket is equipped with pressure relief valves set at 60 psig and 65 psig. This set pressure elevates the saturation pressure and temperature inside the water jacket, thereby precluding boiling in the water jacket under normal conditions. Under normal handling and onsite transfer operations, the bulk temperature inside the water jacket reported in Table 4.5.4 is less than the coincident saturation temperature at 60 psig (307°F), so the shielding water remains in its liquid state. The bulk temperature is determined via a conservative analysis, presented earlier, for a limiting fuel storage configuration.

During a hypothetical fire accident ~~conditions~~ these relief valves allow venting of steam to prevent overpressurizing the water jacket. In this manner, a portion of the fire heat flux input to the HI-TRAC outer surfaces is expended in vaporizing water in the water jacket, thereby mitigating the magnitude of the heat input to the MPC during a fire.

During vacuum drying operations, the annular gap between the MPC and the HI-TRAC is filled with water. The saturation temperature of the annulus water bounds the maximum temperatures of all HI-TRAC components, which are located radially outside the water-filled annulus. As previously stated (see Subsection 4.5.3) the maximum annulus water temperature is 232°F, so the HI-TRAC water jacket temperature will be less than the 307°F saturation temperature.

Table 4.5.1

MATRIX OF HI-TRAC TRANSFER THERMAL EVALUATIONS

Scenario	***Description***	***Ultimate Heat Sink***	***Analysis Type***	***Principal Input Parameters***	***Results in FSAR Subsection***
1	*Onsite Transport*	*Ambient*	*SS(B)*	Q_D, *ST, SC*	*4.5.4*
3	*Vacuum*	*HI-TRAC Annulus Water*	*SS(B)*	Q_D	*4.5.3*
3	*Wet Transfer Operation*	*Cavity Water and Cask Internals*	*AH*	Q_D	*4.5.2*
4	*Fuel Unloading*	*Helium Circulation*	*TA*	Q_D	*4.5.5*
5	*Fire Accident*	*Jacket Water, Cask Internals*	*TA*	Q_D, *F*	*4.6.2*
6	*Jacket Water Loss Accident*	*Ambient*	*SS(B)*	O_T, Q_D, *ST, SC*	*4.6.2*

Legend:

Q_D - Design Basis Maximum Heat Load
ST - Insolation Heating (Top Surface)
SC - Insolation Heating (Curved Surfaces)
F - Fire Heating (1475°F)
SS(B) – Bounding Steady State
TA - Transient Analysis
AH - Adiabatic Heating

Table 4.5.2

HI-TRAC TRANSFER CASK LOWERBOUND WEIGHTS AND THERMAL INERTIAS

Component	***Weight (lbs)***	***Heat Capacity (Btu/lb-°F)***	***Thermal Inertia (Btu/°F)***
Water Jacket	*7,000*	*1.0*	*7,000*
Lead	*52,000*	*0.031*	*1,612*
Carbon Steel	*40,000*	*0.1*	*4,000*
Alloy-X MPC (empty)	*39,000*	*0.12*	*4,680*
Fuel	*40,000*	*0.056*	*2,240*
*MPC Cavity Water**	*6,500*	*1.0*	*6,500*
			26,032 (Total)

* *Conservative lower bound water mass.*

Table 4.5.3

MAXIMUM ALLOWABLE TIME FOR WET TRANSFER OPERATIONS

Initial Temperature (°F)	***Time Duration (hr)***
115	*19.4*
120	*18.4*
125	*17.4*
130	*16.4*
135	*15.4*
140	*14.4*
145	*13.4*
150	*12.4*

Table 4.5.4

HI-TRAC ONSITE TRANSPORT MAXIMUM TEMPERATURES AND PRESSURES

Component	***Temperature [°F]****
Fuel Cladding	~~*777***~~*687*
MPC Basket	~~*764*~~*683*
Basket Periphery	~~*601*~~*590*
MPC Outer Shell Surface	~~*507*~~*446*
HI-TRAC Inner Shell	~~*386*~~*342*
HI-TRAC Enclosure Shell	~~*269*~~*276*
Water Jacket Bulk Water	~~*252*~~*253*
Axial Neutron Shield	~~*328*~~*328*
Pressure (psig)	
MPC	~~*106.8*~~*99.4*
** The reported temperatures are below the HI-TRAC short-term temperature limits (Table 2.2.3).* ~~*** The reported temperature exceeds the allowable temperature limit for HBF fuel. The Supplemental Cooling System described in Appendix 2.C is required for greater than threshold heat load MPCs containing one or more HBF assemblies. (See threshold heat load discussion near the beginning of Section 4.5.)*~~	

4.6 OFF-NORMAL AND ACCIDENT EVENTS[1]

In accordance with NUREG 1536 the HI-STORM 100 System is evaluated for the effects of off-normal and accident events. The design basis off-normal and accident events are defined in Chapter 2. For each event, the cause of the event, means of detection, consequences, and corrective actions are discussed and evaluated in Chapter 11. To support the Chapter 11 evaluations, thermal analyses of limiting off-normal and accident events are provided in the following.

To ensure a bounding evaluation for the array of fuel storage configurations permitted in Section 2.1, a limiting storage condition is evaluated in this section. The limiting storage condition is previously determined in the Section 4.5 and adopted herein for all off-normal and accident evaluations.

4.6.1 Off-Normal Events

4.6.1.1 Off-Normal Pressure

This event is defined as a combination of (a) maximum helium backfill pressure (Table 4.4.12), (b) 10% fuel rods rupture, and (c) limiting fuel storage configuration. The principal objective of the analysis is to demonstrate that the MPC off-normal design pressure (Table 2.2.1) is not exceeded. The MPC off-normal pressures are reported in Table 4.4.9. The result[2] *is confirmed to be below the off-normal design pressure (Table 2.2.1).*

4.6.1.2 Off-Normal Environmental Temperature

This event is defined by a time averaged ambient temperature of 100°F for a 3-day period (Table 2.2.2). The results of this event (maximum temperatures and pressures) are provided in Table 4.6.1 and 4.6.2. The results are below the off-normal condition temperature and pressure limits (Tables 2.2.1 and 2.2.3). ~~*consequences of this event are bounded by the "Off-Normal Pressure" event evaluated earlier in this subsection.*~~

4.6.1.3 Partial Blockage of Air Inlets

The HI-STORM 100 System is designed with debris screens installed on the inlet and outlet openings. These screens ensure the air passages are protected from entry and blockage by foreign objects. As required by the design criteria presented in Chapter 2, it is postulated that the HI-STORM ~~*two of the four*~~ *air inlet vents*~~*ducts*~~ are 50% blocked ~~*in the aboveground HI-STORM overpack are blocked*~~*. The resulting decrease in flow area increases the flow resistance of the inlet ducts. The effect of the increased flow resistance on fuel temperature is analyzed for the normal*

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1 *A new standalone Section 4.6 is added in CoC Amendment 3 to address thermal analysis of off-normal and accident events. The results are evaluated in Chapter 11.*

2 *Pressures relative to 1 atm absolute pressure (i.e. gauge pressures) are reported throughout this section.*

ambient temperature (Table 2.2.2) and a limiting fuel storage configuration. The computed temperatures are reported in Table 4.6.1 and the corresponding MPC internal pressure in Table 4.6.2. The results are confirmed to be below the temperature limits (Table 2.2.3) and pressure limit (Table 2.2.1) for off-normal conditions.

4.6.2 Accident Events

4.6.2.1 Fire Accidents

Although the probability of a fire accident affecting a HI-STORM 100 System during storage operations is low due to the lack of combustible materials at an ISFSI, a conservative fire event has been assumed and analyzed. The only credible concern is a fire from an on-site transport vehicle fuel tank. Under a postulated fuel tank fire, the outer layers of HI-TRAC or HI-STORM overpacks are heated for the duration of fire by the incident thermal radiation and forced convection heat fluxes. The amount of fuel in the on-site transporter is limited to a volume of 50 gallons.

(a) HI-STORM Fire

The fuel tank fire is conservatively assumed to surround the HI-STORM Overpack. Accordingly, all exposed overpack surfaces are heated by radiation and convection heat transfer from the fire. Based on NUREG-1536 and 10 CFR 71 guidelines [4.6.1], the following fire parameters are assumed:

1. *The average emissivity coefficient must be at least 0.9. During the entire duration of the fire, the painted outer surfaces of the overpack are assumed to remain intact, with an emissivity of 0.85. It is conservative to assume that the flame emissivity is 1.0, the limiting maximum value corresponding to a perfect blackbody emitter. With a flame emissivity conservatively assumed to be 1.0 and a painted surface emissivity of 0.85, the effective emissivity coefficient is 0.85. Because the minimum required value of 0.9 is greater than the actual value of 0.85, use of an average emissivity coefficient of 0.9 is conservative.*

2. *The average flame temperature must be at least 1475 °F (800 °C). Open pool fires typically involve the entrainment of large amounts of air, resulting in lower average flame temperatures. Additionally, the same temperature is applied to all exposed cask surfaces, which is very conservative considering the size of the HI-STORM cask. It is therefore conservative to use the 1475 °F (800°C) temperature.*

3. *The fuel source must extend horizontally at least 1 m (40 in), but may not extend more than 3 m (10 ft), beyond the external surface of the cask. Use of the minimum ring width of 1 meter yields a deeper pool for a fixed quantity of combustible fuel, thereby conservatively maximizing the fire duration.*

4. *The convection coefficient must be that value which may be demonstrated to exist if the cask were exposed to the fire specified. Based upon results of large pool fire thermal measurements [4.6.2], a conservative forced convection heat transfer coefficient of 4.5*

Btu/(hr×ft^2×°F) is applied to exposed overpack surfaces during the short-duration fire.

Based on the 50 gallon fuel volume, the overpack outer diameter and the 1 m fuel ring width [4.6.1], the fuel ring surrounding the overpack covers 147.6 ft^2 and has a depth of 0.54 in. From this depth and a constant fuel consumption rate of 0.15 in/min, the fire duration is calculated to be 3.62 minutes. The fuel consumption rate of 0.15 in/min is a lowerbound value from a Sandia National Laboratories report [4.6.2]. Use of a lowerbound fuel consumption rate conservatively maximizes the duration of the fire.

To evaluate the impact of fire heating of the HI-STORM overpack, a thermal ~~two-dimensional, axisymmetric~~ model of the overpack cylinder was constructed using the ANSYS computer code. ~~developed with an~~ The initial temperature of the overpack was conservatively assumed to be the ~~corresponding to~~ maximum temperature field during storage (Table 4.4.7).~~normal storage conditions and design heat load~~. In this model the outer surface and top surface of the overpack were subjected for the duration of fire (3.62 minutes) to the fire conditions defined in this subsection. In the post-fire phase, the ~~overpack cools to an~~ ambient conditions~~temperature~~ preceding the fire were restored. The transient study was~~is~~ conducted for a period of 5 hours, which is sufficient to allow temperatures in the overpack to reach their maximum values and begin to recede.

Due to the severity of the fire condition radiative heat flux, heat flux from incident solar radiation is negligible and is not included. Furthermore, the smoke plume from the fire would block most of the solar radiation. It is recognized that the ventilation air in contact with the inner surface of the HI-STORM Overpack with design-basis decay heat and normal ambient temperature conditions varies between 80°F at the bottom and 220°F at the top of the overpack. It is further recognized that the inlet and outlet ducts occupy a miniscule fraction of area of the cylindrical surface of the massive HI-STORM Overpack. Due to the short duration of the fire event and the relative isolation of the ventilation passages from the outside environment, the ventilation air is expected to experience little intrusion of the fire combustion products. As a result of these considerations, it is conservative to assume that the air in the HI-STORM Overpack ventilation passages is held constant at a substantially elevated temperature (300°F) during the entire duration of the fire event.

The thermal transient response of the storage overpack is determined using the ANSYS finite element program. Time-histories for points in the storage overpack are monitored for the duration of the fire and the subsequent post-fire equilibrium phase.

Heat input to the HI-STORM Overpack while it is subjected to the fire is from a combination of an incident radiation and convective heat fluxes to all external surfaces. This can be expressed by the following equation:

$$q_F = h_{fc}(T_A - T_S) + \sigma\varepsilon[(T_A + C)^4 - (T_S + C)^4]$$

where:

q_F *=Surface Heat Input Flux (Btu/ft^2-hr)*
h_{fc} *= Forced Convection Heat Transfer Coefficient (4.5 Btu/ft^2-hr-°F)*
σ *= Stefan-Boltzmann Constant*

T_A = Fire Temperature (1475°F)
C= Conversion Constant (460 (°F to °R))
T_S = Surface Temperature (°F)
ε = Average Emissivity (0.90 per 10 CFR 71.73)

The forced convection heat transfer coefficient is based on the results of large pool fire thermal measurements [4.6.2].

After the fire event, the ambient temperature is restored and the storage overpack cools down (post-fire temperature relaxation). Heat loss from the outer surfaces of the storage overpack is determined by the following equation:

$$q_S = h_S(T_S - T_A) + \sigma\varepsilon[(T_S + C)^4 - (T_A + C)^4]$$

where:

q_S =Surface Heat Loss Flux (W/m^2 (Btu/ft^2-hr))
h_S = Natural Convection Heat Transfer Coefficient (Btu/ft^2-hr-°F)
T_S = Surface Temperature (°F))
T_A = Ambient Temperature (°F)
σ = Stefan-Boltzmann Constant
ε = Surface Emissivity
C= Conversion Constant (460 (°F to °R))

In the post-fire temperature relaxation phase, h_s is obtained using literature correlations for natural convection heat transfer from heated surfaces [4.2.9].

During the fire the overpack external shell temperatures are substantially elevated (~550°F) and an outer layer of concrete approximately 1 inch thick reaches temperatures in excess of short term temperature limit. This condition is addressed specifically in NUREG-1536 (4.0,V,5.b), which states that:

> *"The NRC accepts that concrete temperatures may exceed the temperature criteria of ACI 349 for accidents if the temperatures result from a fire."*

These results demonstrate that the fire accident event analyzed in a most conservative manner is determined to have a minor affect on the HI-STORM Overpack. Localized regions of concrete are exposed to temperatures in excess of accident temperature limit. The bulk of concrete remains below the short term temperature limit. The temperatures of steel structures are within the allowable temperature limits.

Having evaluated the effects of the fire on the overpack, we now evaluate the effects on the MPC and contained fuel assemblies. Guidance for the evaluation of the MPC and its internals during a fire event is provided by NUREG-1536 (4.0,V,5.b), which states:

"For a fire of very short duration (i.e., less than 10 percent of the thermal time constant of the cask body), the NRC finds it acceptable to calculate the fuel temperature increase by assuming that the cask inner wall is adiabatic. The fuel temperature increase should then be determined by dividing the decay energy released during the fire by the thermal capacity of the basket-fuel assembly combination."

The time constant of the cask body (i.e., the overpack) can be determined using the formula:

$$\tau = \frac{c_p \times \rho \times L_c^2}{k}$$

where:

c_p = *Overpack Specific Heat Capacity (Btu/lb-°F)*
ρ = *Overpack Density (lb/ft^3)*
L_c = *Overpack Characteristic Length (ft)*
k = *Overpack Thermal Conductivity (Btu/ft-hr-°F)*

The concrete contributes the majority of the overpack mass and volume, so we will use the specific heat capacity (0.156 Btu/lb-°F), density (142 lb/ft^3) and thermal conductivity (1.05 Btu/ft-hr-°F) of concrete for the time constant calculation. The characteristic length of a hollow cylinder is its wall thickness. The characteristic length for the HI-STORM Overpack is therefore 29.5 in, or approximately 2.46 ft. Substituting into the equation, the overpack time constant is determined as:

$$\tau = \frac{0.156 \times 142 \times 2.46^2}{1.05} = 128\, hrs$$

One-tenth of this time constant is approximately 12.8 hours (768 minutes), substantially longer than the fire duration of 3.62 minutes, so the MPC is evaluated by considering the MPC canister as an adiabatic boundary. The fuel temperature rise is computed next.

Table 4.5.2 lists lower-bound thermal inertia values for the MPC and the contained fuel assemblies. Applying a conservative upperbound decay heat load (38 kW (1.3x10^5 Btu/hr)) and adiabatic heating for the 3.62 minutes fire, the fuel temperature rise computes as:

$$\Delta T_{fuel} = \frac{\text{Decay heat} \times \text{Time duration}}{(\text{MPC} + \text{Fuel})\ \text{heat capacities}} = \frac{1.3 \times 10^5\ \text{Btu/hr} \times (3.62/60)hr}{(2240 + 4680)\ \text{Btu/}^{\circ}F} = 1.1^{\circ}F$$

This is a very small increase in fuel temperature. Consequently, the impact on the MPC internal helium pressure will be quite small. Based on a conservative analysis of the HI-STORM 100 System response to a hypothetical fire event, it is concluded that the fire event does not adversely affect the temperature of the MPC or contained fuel. We conclude that the ability of the HI-STORM 100

System to cool the spent nuclear fuel within design temperature limits during and after fire is not compromised.

(b) HI-TRAC Fire

In this subsection the fuel cladding and MPC pressure boundary integrity under an exposure to a short duration fire event is demonstrated. The HI-TRAC is initially (before fire) assumed to have a design basis decay heat and has reached steady-state (maximum) temperatures. The analysis assumes a fire from a 50 gallon transporter fuel tank spill. The fuel spill is assumed to surround the HI-TRAC in a 1 m wide ring. The fire parameters are same as that assumed for the HI-STORM fire. Based on the fuel spill defined above the HI-TRAC fire duration is computed as 4.8 minutes.

From the HI-TRAC fire analysis, a bounding MPC temperature rise rate is determined. The total temperature rise (ΔT) is obtained by the product of the rate of temperature rise and fire duration reported above. In this manner the final MPC (fuel and MPC contents) temperature is computed. The MPC pressures are also computed using the MPC temperature rise (ΔT) and Ideal Gas Law. The temperatures and pressures are reported in Table 4.6.7. The results are confirmed to be below the accident temperature and pressure limits (Tables 2.2.3 and 2.2.1).

4.6.2.2 Jacket Water Loss

In this subsection, the fuel cladding and MPC boundary integrity is evaluated for a postulated loss of water from the HI-TRAC water jacket. The HI-TRAC is equipped with an array of water compartments filled with water. For a bounding analysis, all water compartments are assumed to lose their water and be replaced with air. As an additional measure of conservatism, the air in the water jacket is assumed to be motionless (i.e. natural convection neglected) and radiation heat transfer in the water jacket spaces ignored. The HI-TRAC is assumed to have the maximum thermal payload (design heat load) and assumed to have reached steady state (maximum) temperatures. Under these assumed set of adverse conditions, the maximum temperatures are computed using the 3-Dimensional HI-TRAC thermal model described in Section 4.5 *and reported in Table 4.6.3. The results of jacket water loss evaluation confirm that the cladding, MPC and HI-TRAC component temperatures are below the limits prescribed in Chapter 2 (Table 2.2.3). The co-incident MPC pressure is also computed and compared with the MPC accident design pressure (Table 2.2.1). The result (Table 4.6.2) is confirmed to be below the limit.*

4.6.2.3 Extreme Environmental Temperatures

To evaluate the effect of extreme weather conditions, an extreme ambient temperature (Table 2.2.2) is postulated to persist for a 3-day period. For a conservatively bounding evaluation the extreme temperature is assumed to last for a sufficient duration to allow the HI-STORM 100 System to reach steady state conditions. Because of the large mass of the HI-STORM 100 System, with its corresponding large thermal inertia and the limited duration for the extreme temperature, this assumption is conservative. Starting from a baseline condition evaluated in Section 4.4 (normal ambient temperature and limiting fuel storage configuration) the temperatures of the HI-STORM

100 System are conservatively assumed to rise by the difference between the extreme and normal ambient temperatures (45°F). The HI-STORM extreme ambient temperatures computed in this manner are reported in Table 4.6.4. The co-incident MPC pressure is also computed (Table 4.6.2) and compared with the accident design pressure (Table 2.2.1). The result is confirmed to be below the accident limit.

4.6.2.4 100% Blockage of Air Inlets

This event is defined as a complete blockage of all four bottom inlets. The immediate consequence of a complete blockage of the air inlets is that the normal circulation of air for cooling the MPC is stopped. An amount of heat will continue to be removed by localized air circulation patterns in the overpack annulus and outlet ducts, and the MPC will continue to radiate heat to the relatively cooler storage overpack. As the temperatures of the MPC and its contents rise, the rate of heat rejection will increase correspondingly. Under this condition, the temperatures of the overpack, the MPC and the stored fuel assemblies will rise as a function of time.

As a result of the considerable inertia of the storage overpack, a significant temperature rise is possible if the inlets are substantially blocked for extended durations. This accident condition is, however, a short duration event that is identified and corrected through scheduled periodic surveillance. Nevertheless, this event is conservatively analyzed assuming a substantial duration of blockage. The event is analyzed using the FLUENT CFD code. The HI-STORM thermal~~CFD~~ model is the same 3-Dimensional model *~~as that~~ constructed for normal storage conditions (see Section 4.4) except for the bottom inlet ducts, which are assumed to be impervious to air. Using this model, a transient thermal solution of the HI-STORM 100 System starting from normal storage conditions is obtained. The results of the blocked ducts transient analysis are presented in Table 4.6.5 and confirmed to be below the accident temperature limits (Table 2.2.3). The co-incident MPC pressure is also computed and compared with the accident design pressure (Table 2.2.1). The result (Table 4.6.2) is confirmed to be below the limit.*

4.6.2.5 Burial Under Debris

Burial of the HI-STORM 100 System under debris is not a credible accident. During storage at the ISFSI there are no structures over the casks. Minimum regulatory distances from the ISFSI to the nearest ISFSI security fence precludes the close proximity of substantial amount of vegetation. There is no credible mechanism for the HI-STORM 100 System to become completely buried under debris. However, for conservatism, complete burial under debris is considered.

To demonstrate the inherent safety of the HI-STORM 100 System, a bounding analysis that considers the debris to act as a perfect insulator is considered. Under this scenario, the contents of the HI-STORM 100 System will undergo a transient heat up under adiabatic conditions. The minimum available time ($\Delta\tau$) for the fuel cladding to reach the accident limit depends on the following: (i) thermal inertia of the cask, (ii) the cask initial conditions, (iii) the spent nuclear fuel decay heat generation and (iv) the margin between the initial cladding temperature and the accident

temperature limit. To obtain a lowerbound on $\Delta\tau$, the HI-STORM 100 Overpack thermal inertia (item i) is understated, the cask initial temperature (item ii) is maximized, decay heat overstated (item iii) and the cladding temperature margin (item iv) is understated. A set of conservatively postulated input parameters for items (i) through (iv) are summarized in Table 4.6.6. Using these parameters $\Delta\tau$ is computed as follows:

$$\Delta\tau = \frac{m \times c_p \times \Delta T}{Q}$$

where:

$\Delta\tau$ = *Allowable burial time (hr)*
m = *Mass of HI-STORM System (lb)*
c_p = *Specific heat capacity (Btu/lb-^{o}F)*
ΔT = *Permissible temperature rise (^{o}F)*
Q = *Decay heat load (Btu/hr)*

Substituting the parameters in Table 4.6.6, a substantial burial time (34.6 hrs) is obtained. The co-incident MPC pressure is also computed and compared with the accident design pressure (Table 2.2.1). The result (Table 4.6.2) is confirmed to be below the limit.

Table 4.6.1
OFF-NORMAL CONDITION MAXIMUM
HI-STORM TEMPERATURES[3]

Location[4]	***Off-Normal Ambient Temperature***[5] ***(°F)***	***Partial Inlet Ducts Blockage (°F)***
Fuel Cladding	*731*	~~751~~725
MPC Basket	*728*	~~734~~721
MPC Shell	*489*	~~514~~478
Overpack Inner Shell	*342*	~~386~~339
Lid Concrete Bottom Plate	*322*	~~408~~321
Lid Concrete Section Temperature	*266*	~~291~~260

Table 4.6.2
OFF-NORMAL AND ACCIDENT CONDITION MAXIMUM MPC PRESSURES

Condition	***Pressure (psig)***
Off-Normal Conditions	
Off-Normal Ambient	*101.4*
Partial Blockage of Inlet Ducts	~~103.1~~100.4
Accident Conditions	
Extreme Ambient Temperature	104.4
100% Blockage of Air Inlets	~~121.4~~118.1
Burial Under Debris	134.8
HI-TRAC Jacket Water Loss	~~118.8~~ 112.2

[3] *The temperatures reported in this table are below the off-normal temperature limits specified in Chapter 2, Table 2.2.3.*
[4] *Temperatures of limiting components reported.*
[5] *Obtained by adding the off-normal-to-normal ambient temperature difference of 20°F (11.1°C) to normal condition HI-STORM temperatures reported in Section 4.4.*

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Table 4.6.3
HI-TRAC JACKET WATER LOSS ACCIDENT MAXIMUM TEMPERATURES

Component	***Temperature (^oF)***
Fuel Cladding	~~898~~824
MPC Basket	~~885~~820
MPC Shell	~~594~~526
HI-TRAC Inner Shell	~~499~~463
HI-TRAC Enclosure Shell	~~280~~281

Table 4.6.4
EXTREME ENVIRONMENTAL CONDITION MAXIMUM HI-STORM TEMPERATURES

Component	***Temperature[6] (^oF)***
Fuel Cladding	*756*
MPC Basket	*753*
MPC Shell	*514*
Overpack Inner Shell	*367*
Lid Concrete Bottom Plate	*347*
Lid Concrete Section Temperature	*291*

6 *Obtained by adding the extreme ambient to normal temperature difference (45°F) to normal condition temperatures reported in Section 4.4.*

Table 4.6.5

~~SUMMARY OF HI-STORM 100~~ 32-HOURS BLOCKED INLET DUCTS MAXIMUM HI-STORM TEMPERATURES~~THERMAL ANALYSIS~~

Component	~~**Initial Temperatures (°F)**~~	~~**Peak**~~ **Temperatures@32 hrs (°F)**
Fuel Cladding	~~728~~	~~916~~890
MPC Basket	~~711~~	~~904~~884
MPC Shell	~~490~~	~~630~~583
Overpack Inner Shell	~~356~~	~~533~~480
Lid Concrete Bottom Plate	~~389~~	~~416~~433
Lid Concrete Section Temperature	~~279~~	~~311~~328

Table 4.6.6

SUMMARY OF INPUTS FOR BURIAL UNDER DEBRIS ANALYSIS

Thermal Inertia Inputs:	
M (Lowerbound HI-STORM 100 Weight)	*150000 lb*
Cp (Carbon steel heat capacity)[7]	*0.1 Btu/lb-°F*
Cask initial temperature[8]	*728 °F*
Q (Decay heat)	*1.3×10^5 Btu/hr*
ΔT (clad temperature margin)[9]	*300 °F*

[7] *Carbon steel has the lowest heat capacity among the principal materials employed in MPC and overpack construction (carbon steel, stainless steel and concrete).*

[8] *Conservatively overstated.*

[9] *The clad temperature margin is conservatively understated in this table.*

Table 4.6.7

HI-TRAC FIRE ACCIDENT MAXIMUM TEMPERATURES AND PRESSURES

Component	***Initial Temperature (^oF)***	***Bounding Temperature Rise (^oF)***	***Peak Temperature (^oF)***
Fuel Cladding	~~777~~687	*27*	~~804~~714
MPC Shell	~~507~~446	*27*	~~534~~473
Pressures (psig)			
Component	*Initial*	*Pressure Rise*	*Peak Pressure*
MPC	~~106.8~~99.4	3.2	~~110.1~~102.6

8.1 PROCEDURE FOR LOADING THE HI-STORM 100 SYSTEM IN THE SPENT FUEL POOL

8.1.1 Overview of Loading Operations:

The HI-STORM 100 System is used to load, transfer and store spent fuel. Specific steps are performed to prepare the HI-STORM 100 System for fuel loading, to load the fuel, to prepare the system for storage and to place it in storage at an ISFSI. The MPC transfer may be performed in the cask receiving area, at the ISFSI, or any other location deemed appropriate by the user. HI-TRAC and/or HI-STORM may be transferred between the ISFSI and the fuel loading facility using a specially designed transporter, heavy haul transfer trailer, or any other load handling equipment designed for such applications as long as the lift height restrictions are met (lift height restrictions apply only to suspended forms of transport). Users shall develop detailed written procedures to control on-site transport operations. Section 8.1.2 provides the general procedures for rigging and handling of the HI-STORM overpack and HI-TRAC transfer cask. Figure 8.1.1 shows a general flow diagram of the HI-STORM loading operations.

Refer to the boxes of Figure 8.1.2 for the following description. At the start of loading operations, an empty MPC is upended (Box 1). The empty MPC is raised and inserted into HI-TRAC (Box 2). The annulus is filled with plant demineralized water† and the MPC is filled with either spent fuel pool water or plant demineralized water (borated as required) (Box 3). An inflatable seal is installed in the upper end of the annulus between the MPC and HI-TRAC to prevent spent fuel pool water from contaminating the exterior surface of the MPC. HI-TRAC and the MPC are then raised and lowered into the spent fuel pool for fuel loading using the lift yoke (Box 4). Pre-selected assemblies are loaded into the MPC and a visual verification of the assembly identification is performed (Box 5).

While still underwater, a thickly shielded lid (the MPC lid) is installed using either slings attached to the lift yoke or the optional Lid Retention System (Box 6). The lift yoke remotely engages to the HI-TRAC lifting trunnions to lift the HI-TRAC and loaded MPC close to the spent fuel pool surface (Box 7). When radiation dose rate measurements confirm that it is safe to remove the HI-TRAC from the spent fuel pool, the cask is removed from the spent fuel pool. If the Lid Retention System is being used, the HI-TRAC top lid bolts are installed to secure the MPC lid for the transfer to the cask preparation area. The lift yoke and HI-TRAC are sprayed with demineralized water to help remove contamination as they are removed from the spent fuel pool.

HI-TRAC is placed in the designated preparation area and the Lift Yoke and Lid Retention System (if utilized) are removed. The next phase of decontamination is then performed. The top surfaces of the MPC lid and the upper flange of HI-TRAC are decontaminated. The Temporary Shield Ring (if utilized) is installed and filled with water and the neutron shield jacket is filled with water (if drained). The inflatable annulus seal is removed, and the annulus shield (if utilized) is installed. The Temporary Shield Ring provides additional personnel shielding around the top of the HI-TRAC during MPC closure operations. The annulus shield provides additional personnel shielding at the top of the annulus and also prevents small items from being dropped into the annulus. Dose rates are measured at the MPC lid to ensure that the dose rates are within

† Users may substitute domestic water in each step where demineralized water is specified.

expected values.

The MPC water level is lowered slightly, the MPC is vented, and the MPC lid is seal welded using the automated welding system (Box 8). Visual examinations are performed on the tack welds. Liquid penetrant (PT) examinations are performed on the root and final passes. An ultrasonic or multi-layer PT examination is performed on the MPC Lid-to-Shell weld to ensure that the weld is satisfactory. As an alternative to volumetric examination of the MPC lid-to-shell weld, a multi-layer PT is performed including one intermediate examination after approximately every three-eighth inch of weld depth. The water level is raised to the top of the MPC and a hydrostatic test followed by an additional liquid penetrant examination is performed on the MPC Lid-to-Shell weld to verify structural integrity. To calculate the helium backfill requirements for the MPC (if the backfill is based upon helium mass or volume measurements), the free volume inside the MPC must first be determined. This free volume may be determined by measuring the volume of water displaced or any other suitable means.

Depending upon the burn-up of the fuel to be loaded in the MPC, moisture is removed from the MPC using either a vacuum drying system or forced helium dehydration system. For MPCs without high burn-up fuel, the vacuum drying system may be connected to the MPC and used to remove all liquid water from the MPC in a stepped evacuation process (Box 9). A stepped evacuation process is used to preclude the formation of ice in the MPC and vacuum drying system lines. The internal pressure is reduced to below 3 torr and held for 30 minutes to ensure that all liquid water is removed.

For high-burn-up fuel, or as an alternative for MPCs without high burn-up fuel, a forced helium dehydration system is utilized to remove residual moisture from the MPC. Gas is circulated through the MPC to evaporate and remove moisture. The residual moisture is condensed until no additional moisture remains in the MPC. The temperature of the gas exiting the system demoisturizer is maintained below 21 ^{o}F for a minimum of 30 minutes to ensure that all liquid water is removed

Following MPC moisture removal, the MPC is backfilled with a predetermined amount of helium gas. ~~If the MPC contains high burn-up fuel, then a Supplemental Cooling System (SCS) (if required) is connected to the HI-TRAC annulus prior to helium backfill and is used to circulate coolant to maintain fuel cladding temperatures below ISG-11 Rev. 3 limits (See Figure 2.C.1).~~ The helium backfill ensures adequate heat transfer during storage, and provides an inert atmosphere for long-term fuel integrity. Cover plates are installed and seal welded over the MPC vent and drain ports with liquid penetrant examinations performed on the root and final passes (for multi-pass welds) (Box 10). *The cover plate welds are helium leakage tested to confirm that they meet the established leakage rate criteria.*

The MPC closure ring is then placed on the MPC and dose rates are measured at the MPC lid to ensure that the dose rates are within expected values. The closure ring is aligned, tacked in place and seal welded providing redundant closure of the MPC confinement boundary closure welds. Tack welds are visually examined, and the root and final welds are inspected using the liquid penetrant examination technique to ensure weld integrity.

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The annulus shield (if utilized) is removed and the remaining water in the annulus is drained. The Temporary Shield Ring (if utilized) is drained and removed. The MPC lid and accessible areas of the top of the MPC shell are smeared for removable contamination and HI-TRAC dose rates are measured. HI-TRAC top lid[3] is installed and the bolts are torqued (Box 11). The MPC lift cleats are installed on the MPC lid. The MPC lift cleats are the primary lifting point on the MPC. MPC slings are installed between the MPC lift cleats and the lift yoke (Box 12).

If the HI-TRAC 125 is being used, the transfer lid is attached to the HI-TRAC as follows. The HI-TRAC is positioned above the transfer slide to prepare for bottom lid replacement. The transfer slide consists of an adjustable-height rolling carriage and a pair of channel tracks. The transfer slide supports the transfer step which is used to position the two lids at the same elevation and creates a tight seam between the two lids to eliminate radiation streaming. The overhead crane is shut down to prevent inadvertent operation. The transfer slide carriage is raised to support the pool lid while the bottom lid bolts are removed. The transfer slide then lowers the pool lid and replaces the pool lid with the transfer lid. The carriage is raised and the bottom lid bolts are replaced. The MPC lift cleats and slings support the MPC during the transfer operations. Following the transfer, the MPC slings are disconnected and HI-TRAC is positioned for MPC transfer into HI-STORM.

MPC transfer may be performed inside or outside the fuel building (Box 13). Similarly, HI-TRAC and HI-STORM may be transferred to the ISFSI in several different ways (Box 14 and 15). The empty HI-STORM overpack is inspected and positioned with the lid removed. Vent duct shield inserts[1] are installed in the HI-STORM exit vent ducts. The vent duct shield inserts prevent radiation streaming from the HI-STORM Overpack as the MPC is lowered past the exit vents. If the HI-TRAC 125D is used, the mating device is positioned on top of the HI-STORM. The HI-TRAC is placed on top of HI-STORM. An alignment device (or mating device in the case of HI-TRAC 125D) helps guide HI-TRAC during this operation[2]. The MPC may be lowered using the MPC downloader, the main crane hook or other similar devices. The MPC downloader (if used) may be attached to the HI-TRAC lid or mounted to the overhead lifting device. The MPC slings are attached to the MPC lift cleats.

~~If used, the SCS will be disconnected from the HI-TRAC and the HI-TRAC annulus drained, prior to transfer of the MPC from the HI-TRAC to the HI-STORM.~~ If the transfer doors are used (i.e. not the HI-TRAC 125D), the MPC is raised slightly, the transfer lid door locking pins are removed and the doors are opened. If the HI-TRAC 125D is used, the pool lid is removed and the mating device drawer is opened. Optional trim plates may be installed on the top and bottom of both doors (or drawer for HI-TRAC 125D) and secured using hand clamps. The trim plates eliminate radiation streaming above and below the doors (drawer). The MPC is lowered into HI-STORM. Following verification that the MPC is fully lowered, the MPC slings are disconnected from the lifting device and lowered onto the MPC lid. The trim plates are removed, the doors (or drawer) are closed. The empty HI-TRAC must be removed with the doors open when the HI-

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1 Vent duct shield inserts are only used on the HI-STORM 100.

2 The alignment guide may be configured in many different ways to accommodate the specific sites. See Table 8.1.6.

3 Users with the optional HI-TRAC Lid Spacer shall modify steps in their procedures to install and remove the spacer together with top lid

STORM 100S is used to prevent interference with the lift cleats and slings. HI-TRAC is removed from on top of HI-STORM. The MPC slings and MPC lift cleats are removed. Hole plugs are installed in the empty MPC lifting holes to fill the voids left by the lift cleat bolts. The alignment device (or mating device with pool lid for HI-TRAC 125D) and vent duct shield inserts (if used) are removed, and the HI-STORM lid is installed. The exit vent gamma shield cross plates, temperature elements (if used) and vent screens are installed. The HI-STORM lid studs and nuts are installed. The HI-STORM is secured to the transporter (as applicable) and moved to the ISFSI pad. The HI-STORM Overpack and HI-TRAC transfer cask may be moved using a number of methods as long as the lifting equipment requirements are met. For sites with high seismic conditions, the HI-STORM 100A is anchored to the ISFSI. Once located at the storage pad, the inlet vent gamma shield cross plates are installed and the shielding effectiveness test is performed. Finally, the temperature elements and their instrument connections are installed (if used), and the air temperature rise testing (if required) is performed to ensure that the system is functioning within its design parameters.

8.1.2 HI-TRAC and HI-STORM Receiving and Handling Operations

Note:
HI-TRAC may be received and handled in several different configurations and may be transported on-site in a horizontal or vertical orientation. This section provides general guidance for HI-TRAC and HI-STORM handling. Site-specific procedures shall specify the required operational sequences based on the handling configuration at the sites.

1. Vertical Handling of HI-TRAC:
   a. Verify that the lift yoke load test certifications are current.
   b. Visually inspect the lifting device (lift yoke or lift links) and the lifting trunnions for gouges, cracks, deformation or other indications of damage. Replace or repair damaged components as necessary.
   c. Engage the lift yoke to the lifting trunnions. See Figure 8.1.3.
   d. Apply lifting tension to the lift yoke and verify proper engagement of the lift yoke.

Note:
Refer to the site's heavy load handling procedures for lift height, load path, floor loading and other applicable load handling requirements.

Warning:
When lifting the loaded HI-TRAC with only the pool lid, the HI-TRAC should be carried as low as practicable. This minimizes the dose rates due to radiation scattering from the floor. Personnel should remain clear of the area and the HI-TRAC should be placed in position as soon as practicable.

   e. Raise HI-TRAC and position it accordingly.

2. Upending of HI-TRAC in the Transfer Frame:
   a. Position HI-TRAC under the lifting device. Refer to Step 1, above.

b. If necessary, remove the missile shield from the HI-TRAC Transfer Frame. See Figure 8.1.4.

c. Verify that the lift yoke load test certifications are current.

d. Visually inspect the lift yoke and the lifting trunnions for gouges, cracks, deformation or other indications of damage. Repair or replace damaged components as necessary.

e. Deleted.

f. Engage the lift yoke to the lifting trunnions. See Figure 8.1.3.

g. Apply lifting tension to the lift yoke and verify proper engagement of the lift yoke.

h. Slowly rotate HI-TRAC to the vertical position keeping all rigging as close to vertical as practicable. See Figure 8.1.4.

i. If used, lift the pocket trunnions clear of the Transfer Frame rotation trunnions.

3. Downending of HI-TRAC in the Transfer Frame:

ALARA Warning:
A loaded HI-TRAC should only be downended with the transfer lid or other auxiliary shielding installed.

a. Position the Transfer Frame under the lifting device.

b. Verify that the lift yoke load test certifications are current.

c. Visually inspect the lift yoke and the lifting trunnions for gouges, cracks, deformation or other indications of damage. Repair or replace damaged components as necessary.

d. Deleted.

e. Deleted.

f. Engage the lift yoke to the lifting trunnions. See Figure 8.1.3.

g. Apply lifting tension to the lift yoke and verify proper lift yoke engagement.

h. Position the pocket trunnions to receive the Transfer Frame rotation trunnions. See Figure 8.1.4 (Not used for HI-TRAC 125D).

i. Slowly rotate HI-TRAC to the horizontal position keeping all rigging as close to vertical as practicable.

j. Disengage the lift yoke.

4. Horizontal Handling of HI-TRAC in the Transfer Frame:

a. Verify that the Transfer Frame is secured to the transport vehicle as necessary.

b. Downend HI-TRAC on the Transfer Frame per Step 3, if necessary.

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c. If necessary, install the HI-TRAC missile Shield on the HI-STAR 100 Transfer Frame (See Figure 8.1.4).

5. Vertical Handling of HI-STORM:

Note:
The HI-STORM 100 Overpack may be lifted with a special lifting device that engages the overpack anchor blocks with threaded studs and connects to a cask transporter, crane, or similar equipment. The device is designed in accordance with ANSI N14.6.

a. Visually inspect the HI-STORM lifting device for gouges, cracks, deformation or other indications of damage.

b. Visually inspect the transporter lifting attachments for gouges, cracks, deformation or other indications of damage.

c. If necessary, attach the transporter's lifting device to the transporter and HI-STORM..

d. Raise and position HI-STORM accordingly. See Figure 8.1.5.

6. Empty MPC Installation in HI-TRAC:

Note:
To avoid side loading the MPC lift lugs, the MPC must be upended in the MPC Upending Frame (or equivalent). See Figure 8.1.6.

a. If necessary, rinse off any road dirt with water. Remove any foreign objects from the MPC internals.

b. If necessary, upend the MPC as follows:

1. Visually inspect the MPC Upending Frame for gouges, cracks, deformation or other indications of damage. Repair or replace damaged components as necessary.

2. Install the MPC on the Upending Frame. Make sure that the banding straps are secure around the MPC shell. See Figure 8.1.6.

3. Inspect the Upending Frame slings in accordance with the site's lifting equipment inspection procedures. Rig the slings around the bar in a choker configuration to the outside of the cleats. See Figure 8.1.6.

4. Attach the MPC upper end slings of the Upending Frame to the main overhead lifting device. Attach the bottom-end slings to a secondary lifting device (or a chain fall attached to the primary lifting device) (See Figure 8.1.6).

5. Raise the MPC in the Upending Frame.

Warning:
The Upending Frame corner should be kept close to the ground during the upending process.

6. Slowly lift the upper end of the Upending Frame while lowering the bottom end of the Upending Frame.

7. When the MPC approaches the vertical orientation, tension on the lower slings may be released.

8. Place the MPC in a vertical orientation.

9. Disconnect the MPC straps and disconnect the rigging.

c. Install the MPC in HI-TRAC as follows:

1. Install the four-point lift sling to the lift lugs inside the MPC. See Figure 8.1.7.

2. Raise and place the MPC inside HI-TRAC.

Note:
An alignment punch mark is provided on HI-TRAC and the top edge of the MPC. Similar marks are provided on the MPC lid and closure ring. See Figure 8.1.8.

3. Rotate the MPC so the alignment marks agree and seat the MPC inside HI-TRAC. Disconnect the MPC rigging or the MPC lift rig.

8.1.3 HI-TRAC and MPC Receipt Inspection and Loading Preparation

Note:

Receipt inspection, installation of the empty MPC in the HI-TRAC, and lower fuel spacer installation may occur at any location or be performed at any time prior to complete submersion in the spent fuel pool as long as appropriate steps are taken to prevent contaminating the exterior of the MPC or interior of the HI-TRAC.

ALARA Note:
A bottom protective cover may be attached to HI-TRAC pool lid bottom. This will help prevent imbedding contaminated particles in HI-TRAC bottom surface and ease the decontamination effort.

1. Place HI-TRAC in the cask receiving area. Perform appropriate contamination and security surveillances, as required.

2. If necessary, remove HI-TRAC Top Lid by removing the top lid bolts and using the lift sling. See Figure 8.1.9 for rigging.

   a. Rinse off any road dirt with water. Inspect all cavity locations for foreign objects. Remove any foreign objects.

   b. Perform a radiological survey of the inside of HI-TRAC to verify there is no residual contamination from previous uses of the cask.

3. Disconnect the rigging.

4. Store the Top Lid and bolts in a site-approved location.

5. If necessary, configure HI-TRAC with the pool lid as follows:

ALARA Warning:
The bottom lid replacement as described below may be performed only on an empty HI-TRAC.

a. Inspect the seal on the pool lid for cuts, cracks, gaps and general condition. Replace the seal if necessary.

b. Remove the bottom lid bolts and store them temporarily.

c. Raise the empty HI-TRAC and position it on top of the pool lid.

d. Inspect the pool lid bolts for general condition. Replace worn or damaged bolts with new bolts.

e. Install the pool lid bolts. See Table 8.1.5 for torque requirements.

f. If necessary, thread the drain connector pipe to the pool lid.

g. Store the HI-TRAC Transfer Lid in a site-approved location.

6. At the site's discretion, perform an MPC receipt inspection and cleanliness inspection in accordance with a site-specific inspection checklist.

7. Install the MPC inside HI-TRAC and place HI-TRAC in the designated preparation area. See Section 8.1.2.

Note:
Upper fuel spacers are fuel-type specific. Not all fuel types require fuel spacers. Upper fuel spacer installation may occur any time prior to MPC lid installation.

8. Install the upper fuel spacers in the MPC lid as follows:

Warning:
Never work under a suspended load.

a. Position the MPC lid on supports to allow access to the underside of the MPC lid.

b. Thread the fuel spacers into the holes provided on the underside of the MPC lid. See Figure 8.1.10 and Table 8.1.5 for torque requirements.

c. Install threaded plugs in the MPC lid where and when spacers will not be installed, if necessary. See Table 8.1.5 for torque requirements.

9. At the user's discretion perform an MPC lid and closure ring fit test:

Note:
It may be necessary to perform the MPC installation and inspection in a location that has sufficient crane clearance to perform the operation.

a. Visually inspect the MPC lid rigging (See Figure 8.1.9).

b. At the user's discretion, raise the MPC lid such that the drain line can be installed. Install the drain line to the underside of the MPC lid. See Figure 8.1.11.

Note:
The MPC Shell is relatively flexible compared to the MPC Lid and may create areas of local contact that impede Lid insertion in the Shell. Grinding of the MPC Lid below the minimum diameter on the drawing is permitted to alleviate interference with the MPC Shell in areas of localized contact. If the amount of material removed from the surface exceeds 1/8", the surface shall be examined by a liquid penetrant method (NB-2546). The weld prep for the Lid-to-Shell weld shall be maintained after grinding.

c. Align the MPC lid and lift yoke so the drain line will be positioned in the MPC drain location. See Figure 8.1.12. Install the MPC lid. Verify that the MPC lid fit and weld prep are in accordance with the design drawings.

ALARA Note:
The closure ring is installed by hand. Some grinding may be required on the closure ring to adjust the fit.

d. Install, align and fit-up the closure ring.

e. Verify that closure ring fit and weld prep are in accordance with the fabrication drawings or the approved design drawings.

f. Remove the closure ring, vent and drain port cover plates and the MPC lid. Disconnect the drain line. Store these components in an approved plant storage location.

10. At the user's discretion, perform an MPC vent and drain port cover plate fit test and verify that the weld prep is in accordance with the approved fabrication drawings.

Note:
Fuel spacers are fuel-type specific. Not all fuel types require fuel spacers. Lower fuel spacers are set in the MPC cells manually. No restraining devices are used.

11. Install lower fuel spacers in the MPC (if necessary). See Figure 8.1.10.

12. Fill the MPC and annulus as follows:

a. Fill the annulus with plant demineralized water to just below the inflatable seal seating surface.

Caution:
Do not use any sharp tools or instruments to install the inflatable seal. Some air in the inflatable seal helps in the installation.

b. Manually insert the inflatable annulus seal around the MPC. See Figure 8.1.13.

c. Ensure that the seal is uniformly positioned in the annulus area.

d. Inflate the seal.

e. Visually inspect the seal to ensure that it is properly seated in the annulus. Deflate, adjust and inflate the seal as necessary. Replace the seal as necessary.

ALARA Note:
Bolt plugs, placed in, or waterproof tape over empty bolt holes, reduce the time required for decontamination.

13. At the user's discretion, install HI-TRAC top lid bolt plugs and/or apply waterproof tape over any empty bolt holes.

ALARA Note:
Keeping the water level below the top of the MPC prevents splashing during handling.

14. Fill the MPC with either demineralized water or spent fuel pool water to approximately 12 inches below the top of the MPC shell. Refer to Tables 2.1.14 and 2.1.16 for boron concentration requirements.

15. If necessary for plant crane capacity limitations, drain the water from the neutron shield jacket. See Tables 8.1.1 through 8.1.4 as applicable.

16. Place HI-TRAC in the spent fuel pool as follows:

ALARA Note:
The term "Spent Fuel Pool" is used generically to refer to the users designated cask loading location. The optional Annulus Overpressure System is used to provide further protection against MPC external shell contamination during in-pool operations.

a. If used, fill the Annulus Overpressure System lines and reservoir with demineralized water and close the reservoir valve. Attach the Annulus Overpressure System to the HI-TRAC. See Figure 8.1.14.

b. Verify spent fuel pool for boron concentration requirements in accordance with Tables 2.1.14 and 2.1.16.

c. Engage the lift yoke to HI-TRAC lifting trunnions and position HI-TRAC over the cask loading area with the basket aligned to the orientation of the spent fuel racks.

ALARA Note:
Wetting the components that enter the spent fuel pool may reduce the amount of decontamination work to be performed later.

d. Wet the surfaces of HI-TRAC and lift yoke with plant demineralized water while slowly lowering HI-TRAC into the spent fuel pool.

e. When the top of the HI-TRAC reaches the elevation of the reservoir, open the Annulus Overpressure System reservoir valve. Maintain the reservoir water level at approximately 3/4 full the entire time the cask is in the spent fuel pool.

f. Place HI-TRAC on the floor of the cask loading area and disengage the lift yoke. Visually verify that the lift yoke is fully disengaged. Remove the lift yoke from the spent fuel pool while spraying the crane cables and yoke with plant demineralized water.

g. Observe the annulus seal for signs of air leakage. If leakage is observed (by the steady flow of bubbles emanating from one or more discrete locations) then immediately remove the HI-TRAC from the spent fuel pool and repair or replace the seal.

8.1.4 MPC Fuel Loading

Note:
An underwater camera or other suitable viewing device may be used for monitoring underwater operations.
Note:
When loading MPCs requiring soluble boron, the boron concentration of the water shall be checked in accordance with Tables 2.1.14 and 2.1.16 before and during operations with fuel and water in the MPC.

1. Perform a fuel assembly selection verification using plant fuel records to ensure that only fuel assemblies that meet all the conditions for loading as specified in Section 2.1.9 have been selected for loading into the MPC.
2. Load the pre-selected fuel assemblies into the MPC in accordance with the approved fuel loading pattern.
3. Perform a post-loading visual verification of the assembly identification to confirm that the serial numbers match the approved fuel loading pattern.

8.1.5 MPC Closure

Note:
The user may elect to use the Lid Retention System (See Figure 8.1.15) to assist in the installation of the MPC lid and lift yoke, and to provide the means to secure the MPC lid in the event of a drop accident during loaded cask handling operations outside of the spent fuel pool. The user is responsible for evaluating the additional weight imposed on the cask, lift yoke, crane and floor prior to use. See Tables 8.1.1 through 8.1.4 as applicable. The following guidance describes installation of the MPC lid using the lift yoke. The MPC lid may also be installed separately. Depending on facility configuration, users may elect to perform MPC closure operations with the HI-TRAC partially submerged in the spent fuel pool. If opted, operations involving removal of the HI-TRAC from the spent fuel pool shall be sequenced accordingly.

1. Remove the HI-TRAC from the spent fuel pool as follows:
   a. Visually inspect the MPC lid rigging or Lid Retention System in accordance with site-approved rigging procedures. Attach the MPC lid to the lift yoke so that MPC lid, drain line and trunnions will be in relative alignment. Raise the MPC lid and adjust the rigging so the MPC lid hangs level as necessary.
   b. Install the drain line to the underside of the MPC lid. See Figure 8.1.17.

c. Align the MPC lid and lift yoke so the drain line will be positioned in the MPC drain location and the cask trunnions will also engage. See Figure 8.1.11 and 8.1.17.

ALARA Note:
Pre-wetting the components that enter the spent fuel pool may reduce the amount of decontamination work to be performed later.

d. Slowly lower the MPC lid into the pool and insert the drain line into the drain access location and visually verify that the drain line is correctly oriented. See Figure 8.1.12.

e. Lower the MPC lid while monitoring for any hang-up of the drain line. If the drain line becomes kinked or disfigured for any reason, remove the MPC lid and replace the drain line.

Note:
The outer diameter of the MPC lid will seat flush with the top edge of the MPC shell when properly installed. Once the MPC lid is installed, the HI-TRAC /MPC removal from the spent fuel pool should proceed in a continuous manner to minimize the rise in MPC water temperature.

f. Seat the MPC lid in the MPC and visually verify that the lid is properly installed.

g. Engage the lift yoke to HI-TRAC lifting trunnions.

h. Apply a slight tension to the lift yoke and visually verify proper engagement of the lift yoke to the lifting trunnions.

ALARA Note:
Activated debris may have settled on the top face of HI-TRAC and MPC during fuel loading. The cask top surface should be kept under water until a preliminary dose rate scan clears the cask for removal. Users are responsible for any water dilution considerations.

i. Raise HI-TRAC until the MPC lid is just below the surface of the spent fuel pool. Survey the area above the cask lid to check for hot particles. Remove any activated or highly radioactive particles from HI-TRAC or MPC.

j. Visually verify that the MPC lid is properly seated. Lower HI-TRAC, reinstall the lid, and repeat as necessary.

k. Install the Lid Retention System bolts if the lid retention system is used.

l. Continue to raise the HI-TRAC under the direction of the plant's radiological control personnel. Continue rinsing the surfaces with demineralized water. When the top of the HI-TRAC reaches the same elevation as the reservoir, close the Annulus Overpressure System reservoir valve (if used). See Figure 8.1.14.

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Caution:

Users are required to take necessary actions to prevent boiling of the water in the MPC. This may be accomplished by performing a site-specific analysis to identify a time limitation to ensure that water boiling will not occur in the MPC prior to the initiation of draining operations. Chapter 4 of the FSAR provides some sample time limits for the time to initiation of draining for various spent fuel pool water temperatures using design basis heat loads. These time limits may be adopted if the user chooses not to perform a site-specific analysis. If time limitations are imposed, users shall have appropriate procedures and equipment to take action. One course of action involves initiating an MPC water flush for a certain duration and flow rate. Any site-specific analysis shall identify the methods to respond should it become likely that the imposed time limit could be exceeded. Refer to Tables 2.1.14 and 2.1.16 for boron concentration requirements whenever water is added to the loaded MPC.

m. Remove HI-TRAC from the spent fuel pool while spraying the surfaces with plant demineralized water. Record the time.

ALARA Note:

Decontamination of HI-TRAC bottom should be performed using remote cleaning methods, covering or other methods to minimize personnel exposure. The bottom lid decontamination may be deferred to a convenient and practical time and location. Any initial decontamination should only be sufficient to preclude spread of contamination within the fuel building.

n. Decontaminate HI-TRAC bottom and HI-TRAC exterior surfaces including the pool lid bottom. Remove the bottom protective cover, if used.

o. If used, disconnect the Annulus Overpressure System from the HI-TRAC See Figure 8.1.14.

p. Set HI-TRAC in the designated cask preparation area.

Note:

If the transfer cask is expected to be operated in an environment below 32 ^{o}F, the water jacket shall be filled with an ethylene glycol solution (25% ethylene glycol). Otherwise, the jacket shall be filled with demineralized water. Depending on weight limitations, the neutron shield jacket may remain filled (with pure water or 25% ethylene glycol solution, as required). Users shall evaluate the cask weights to ensure that cask trunnion, lifting devices and equipment load limitations are not exceeded.

q. If previously drained, fill the neutron shield jacket with plant demineralized water or an ethylene glycol solution (25% ethylene glycol) as necessary.

r. Disconnect the lifting slings or Lid Retention System (if used) from the MPC lid and disengage the lift yoke. Decontaminate and store these items in an approved storage location.

Warning:

MPC lid dose rates are measured to ensure that dose rates are within expected values. Dose rates exceeding the expected values could indicate that fuel assemblies not meeting the CoC may have been loaded.

s. Measure the dose rates at the MPC lid and verify that the combined gamma and neutron dose is below expected values.

t. Perform decontamination and a dose rate/contamination survey of HI-TRAC.

u. Prepare the MPC annulus for MPC lid welding as follows:

ALARA Note:
If the Temporary Shield Ring is not used, some form of gamma shielding (e.g., lead bricks or blankets) should be placed in the trunnion recess areas of the HI-TRAC water jacket to eliminate the localized hot spot.

v. Decontaminate the area around the HI-TRAC top flange and install the Temporary Shield Ring, (if used). See Figure 8.1.18.

ALARA Note:
The water in the HI-TRAC-to-MPC annulus provides personnel shielding. The level should be checked periodically and refilled accordingly.

w. Attach the drain line to the HI-TRAC drain port and lower the annulus water level approximately 6 inches.

2. Prepare for MPC lid welding as follows:

Note:
The following steps use two identical Removable Valve Operating Assemblies (RVOAs) (See Figure 8.1.16) to engage the MPC vent and drain ports. The MPC vent and drain ports are equipped with metal-to-metal seals to minimize leakage during drying, and to withstand the long-term effects of temperature and radiation. The RVOAs allow the vent and drain ports to be operated like valves and prevent the need to hot tap into the penetrations during unloading operations. The RVOAs are purposely not installed until the cask is removed from the spent fuel pool to reduce the amount of decontamination.

Note:
The vent and drain ports are opened by pushing the RVOA handle down to engage the square nut on the cap and turning the handle fully in the counter-clockwise direction. The handle will not turn once the port is fully open. Similarly, the vent and drain ports are closed by turning the handle fully in the clockwise direction. The ports are closed when the handle cannot be turned further.

Note:
Steps involving preparation for welding may occur in parallel as long as precautions are taken to prevent contamination of the annulus.

a. Clean the vent and drain ports to remove any dirt. Install the RVOAs (See Figure 8.1.16) to the vent and drain ports leaving caps open.

ALARA Warning:
Personnel should remain clear of the drain hoses any time water is being pumped or purged from the MPC. Assembly crud, suspended in the water, may create a radiation hazard to workers. Controlling the amount of water pumped from the MPC prior to welding keeps the fuel assembly cladding covered with water yet still allows room for thermal expansion.

Caution:
Personnel shall ensure that the water level is not lowered below the top of the fuel cladding to avoid exposing the fuel to atmosphere to prevent oxidation and potential fuel damage.

b. Attach the water pump to the drain port (See Figure 8.1.19) and lower the water level to keep moisture away from the weld region.

c. Disconnect the water pump.

d. Carefully decontaminate the MPC lid top surface and the shell area above the inflatable seal

e. Deflate and remove the inflatable annulus seal.

ALARA Note:
The MPC exterior shell survey is performed to evaluate the performance of the inflatable annulus seal. Indications of contamination could require the MPC to be unloaded. In the event that the MPC shell is contaminated, users must decontaminate the annulus. If the contamination cannot be reduced to acceptable levels, the MPC must be returned to the spent fuel pool and unloaded. The MPC may then be removed and the external shell decontaminated.

f. Survey the MPC lid top surfaces and the accessible areas of the top three inches of the MPC.

ALARA Note:
The annulus shield is used to prevent objects from being dropped into the annulus and helps reduce dose rates directly above the annulus region. The annulus shield is hand installed and requires no tools.

g. Install the annulus shield. See Figure 8.1.13.

3. Weld the MPC lid as follows:

ALARA Warning:
Grinding of MPC welds may create the potential for contamination. All grinding activities shall be performed under the direction of radiation protection personnel.

ALARA Warning:
It may be necessary to rotate or reposition the MPC lid slightly to achieve uniform weld gap and lid alignment. A punch mark is located on the outer edge of the MPC lid and shell. These marks are aligned with the alignment mark on the top edge of the HI-TRAC Transfer Cask (See Figure 8.1.8). If necessary, the MPC lid lift should be performed using a hand operated chain fall to closely control the lift to allow rotation and repositioning by hand. If the chain fall is hung from the crane hook, the crane should be tagged out of service to prevent inadvertent use during this operation. Continuous radiation monitoring is recommended.

a. If necessary center the lid in the MPC shell using a hand-operated chain fall.

Note:
The MPC is equipped with lid shims that serve to close the gap in the joint for MPC lid closure weld.

b. As necessary, install the MPC lid shims around the MPC lid to make the weld gap uniform.

ALARA Note:
The AWS Baseplate shield is used to further reduce the dose rates to the operators working around the top cask surfaces.

c. Install the Automated Welding System baseplate shield. See Figure 8.1.9 for rigging.

d. If used, install the Automated Welding System Robot.

Note:
It may be necessary to remove the RVOAs to allow access for the automated welding system. In this event, the vent and drain port caps should be opened to allow for thermal expansion of the MPC water.

Note:

Combustible gas monitoring as described in Step 3e and the associated Caution block are required by the HI-STORM 100 CoC (CoC Appendix B, Section 3.8) and may not be deleted without prior NRC approval via CoC amendment.

Caution:

Oxidation of Boral panels contained in the MPC may create hydrogen gas while the MPC is filled with water. Appropriate monitoring for combustible gas concentrations shall be performed prior to, and during MPC lid welding operations. The space below the MPC lid shall be exhausted or purged with inert gas prior to, and during MPC lid welding operations to provide additional assurance that flammable gas concentrations will not develop in this space.

e. Perform combustible gas monitoring and exhaust or purge the space under the MPC lid with an inert gas to ensure that there is no combustible mixture present in the welding area.

f. Perform the MPC lid-to-shell weld and NDE with approved procedures (See 9.1 and Table 2.2.15).

g. Deleted.

h. Deleted.

i. Deleted.

j. Deleted.

4. Perform hydrostatic testing as follows:

ALARA Note:
Testing is performed before the MPC is drained for ALARA reasons. A weld repair is a lower dose activity if water remains inside the MPC.

a. Attach the drain line to the vent port and route the drain line to the spent fuel pool or the plant liquid radwaste system. See Figure 8.1.20 for the hydrostatic test arrangement.

ALARA Warning:
Water flowing from the MPC may carry activated particles and fuel particles. Apply appropriate ALARA practices around the drain line.

b. Fill the MPC with either spent fuel pool water or plant demineralized water until water is observed flowing out of the vent port drain hose. Refer to Tables 2.1.14 and 2.1.16 for boron concentration requirements.

c. Perform a hydrostatic test of the MPC as follows:

1. Close the drain valve and pressurize the MPC to 125 +5/-0 psig.

2. Close the inlet valve and monitor the pressure for a minimum of 10 minutes. The pressure shall not drop during the performance of the test.

3. Following the 10-minute hold period, visually examine the MPC lid-to-shell weld for leakage of water. The acceptance criteria is no observable water leakage.

d. Release the MPC internal pressure, disconnect the water fill line and drain line from the vent and drain port RVOAs leaving the vent and drain port caps open.

1. Repeat the liquid penetrant examination on the MPC lid final pass.

e. Repair any weld defects in accordance with the site's approved weld repair procedures. Re-perform the Ultrasonic (if necessary), PT, and Hydrostatic tests if weld repair is performed.

5. Drain the MPC as follows:

a. Attach the drain line to the vent port and route the drain line to the spent fuel pool or the plant liquid radwaste system. See Figure 8.1.20.

ALARA Warning:
Water flowing from the MPC may carry activated particles and fuel particles. Apply appropriate ALARA practices around the drain line.

b. Attach the water fill line to the drain port and fill the MPC with either spent fuel pool water or plant demineralized water until water is observed flowing out of the drain line.

c. Disconnect the water fill and drain lines from the MPC leaving the vent port valve open to allow for thermal expansion of the MPC water.

ALARA Warning:
Dose rates will rise as water is drained from the MPC. Continuous dose rate monitoring is recommended.

d. Attach a regulated helium or nitrogen supply to the vent port.

e. Attach a drain line to the drain port shown on Figure 8.1.21.

f. Deleted

g. Verify the correct pressure on the gas supply.

h. Open the gas supply valve and record the time at the start of MPC draining.

Note:
An optional warming pad may be placed under the HI-TRAC Transfer Cask to replace the heat lost during the evaporation process of MPC drying. This may be used at the user's discretion for older and colder fuel assemblies to reduce vacuum drying times.

i. Start the warming pad, if used.

Note:
Users may continue to purge the MPC to remove as much water as possible.

j. Drain the water out of the MPC until water ceases to flow out of the drain line. Shut the gas supply valve. See Figure 8.1.21.

k. Deleted.

l. Disconnect the gas supply line from the MPC.

m. Disconnect the drain line from the MPC.

Note:
Vacuum drying or moisture removal using FHD (for high burn-up fuel) is performed to remove moisture and oxidizing gasses from the MPC. This ensures a suitable environment for long-term storage of spent fuel assemblies and ensures that the MPC pressure remains within design limits. The vacuum drying process described herein reduces the MPC internal pressure in stages. Dropping the internal pressure too quickly may cause the formation of ice in the fittings. Ice formation could result in incomplete removal of moisture from the MPC. The moisture removal process limits bulk MPC temperatures by continuously circulating gas through the MPC. Section 8.1.5 Steps 6a through o are used for the vacuum drying method of drying and backfill. Section 8.1.5 Steps 7a through i are used for the FHD method of drying and backfill.

6. Dry and Backfill the MPC as follows (Vacuum Drying Method):

   a. Attach the drying system (VDS) to the vent and drain port RVOAs. See Figure 8.1.22a. Other equipment configurations that achieve the same results may also be used.

Note:
The vacuum drying system may be configured with an optional fore-line condenser. Other equipment configurations that achieve the same results may be used.

Note:
To prevent freezing of water, the MPC internal pressure should be lowered in incremental steps. The vacuum drying system pressure will remain at about 30 torr until most of the liquid water has been removed from the MPC.

   b. Open the VDS suction valve and reduce the MPC pressure to below 3 torr.

   c. Shut the VDS valves and verify a stable MPC pressure on the vacuum gage.

Note:
The MPC pressure may rise due to the presence of water in the MPC. The dryness test may need to be repeated several times until all the water has been removed. Leaks in the vacuum drying system, damage to the vacuum pump, and improper vacuum gauge calibration may cause repeated failure of the dryness verification test. These conditions should be checked as part of the corrective actions if repeated failure of the dryness verification test is occurring.

   d. Perform the MPC drying pressure test in accordance with the technical specifications.

~~**Caution:**~~
~~Limitations for the at-vacuum duration are evaluated and established on a canister basis to ensure that acceptable cladding temperatures are not exceeded although a time limit of less than 2 hours at vacuum will bound any MPC.~~

   e. Close the vent and drain port valves.

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f. Disconnect the VDS from the MPC.

g. Stop the warming pad, if used.

h. Close the drain port RVOA cap and remove the drain port RVOA.

Note:
Helium backfill shall be in accordance with the Technical Specification using 99.995% (minimum) purity. Other equipment configurations that achieve the same results may be used.

i. Set the helium bottle regulator pressure to the appropriate pressure.

j. Purge the Helium Backfill System to remove oxygen from the lines.

k. Attach the Helium Backfill System to the vent port as shown on Figure 8.1.23 and open the vent port.

l. Slowly open the helium supply valve while monitoring the pressure rise in the MPC.

Note:
If helium bottles need to be replaced, the bottle valve needs to be closed and the entire regulator assembly transferred to the new bottle.

m. Carefully backfill the MPC in accordance with the technical specifications

n. Disconnect the helium backfill system from the MPC.

o. Close the vent port RVOA and disconnect the vent port RVOA.

7. Dry and Backfill the MPC as follows (FHD Method)::

Note:
Helium backfill shall be in accordance with the Technical Specification using 99.995% (minimum) purity. When using the FHD system to perform the MPC helium backfill, the FHD system shall be evacuated or purged and the system operated with 99.995% (minimum) purity helium.

a. Attach the moisture removal system to the vent and drain port RVOAs. See Figure 8.1.22b. Other equipment configurations that achieve the same results may also be used.

b. Circulate the drying gas through the MPC while monitoring the circulating gas for moisture. Collect and remove the moisture from the system as necessary.

c. Continue the monitoring and moisture removal until LCO 3.1.1 is met for MPC dryness.

d. Continue operation of the FHD system with the demoisturizer on.

e. While monitoring the temperatures into and out of the MPC, adjust the helium pressure in the MPC to provide a fill pressure as required by the technical specifications.

f. Open the FHD bypass line and Close the vent and drain port RVOAs.

g. Close the vent and drain port RVOAs.

h. Shutdown the FHD system and disconnect it from the RVOAs.

i. Remove the vent and drain port RVOAs.

8. Weld the vent and drain port cover plates as follows:

Note:
The process provided herein may be modified to perform actions in parallel.

a. Wipe the inside area of the vent and drain port recesses to dry and clean the surfaces.

b. Place the cover plate over the vent port recess.

c. Weld the cover plate.

Note:
ASME Boiler and Pressure Vessel Code [8.1.3], Section V, Article 6 provides the liquid penetrant inspection methods. The acceptance standards for liquid penetrant examination shall be in accordance with ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, Article NB-5350 as specified on the Design Drawings. ASME Code, Section III, Subsection NB, Article NB-4450 provides acceptable requirements for weld repair. NDE personnel shall be qualified per the requirements of Section V of the Code or site-specific program.

d. Perform NDE on the cover plate with approved procedures (See 9.1 and Table 2.2.15)

e. Repair and weld defects in accordance with the site's approved code weld repair procedures.

f. ~~Deleted~~*Perform a helium leakage rate test on the cover plate welds. (See 9.1 and Table 2.2.15). Acceptance Criteria are defined in Technical Specification LCO 3.1.1.*

g. ~~Deleted~~*Repair any weld defects in accordance with the site's approved code weld repair procedures.*

h. Deleted.

i. Repeat for the drain port cover plate.

9. Weld the MPC closure ring as follows:

ALARA Note:
The closure ring is installed by hand. No tools are required. Localized grinding to achieve the desired fit and weld prep is allowed.

a. Install and align the closure ring. See Figure 8.1.8.

b. Weld the closure ring to the MPC shell and the MPC lid, and perform NDE with approved procedures (See 9.1 and Table 2.2.15).

c. Deleted.

d. Deleted.

e. Deleted.

f. Deleted.

g. Deleted.

h. Deleted.

i. Deleted.

j. If necessary, remove the AWS. See Figure 8.1.7 for rigging.

8.1.6 Preparation for Storage

ALARA Warning:
Dose rates will rise around the top of the annulus as water is drained from the annulus. Apply appropriate ALARA practices.
Caution:
Limitations for the handling an MPC containing high burn-up fuel in a HI-TRAC are evaluated and established on a canister basis to ensure that acceptable cladding temperatures are not exceeded. Refer to FSAR Section 4.5 for guidance.

1. Remove the annulus shield (if used) and store it in an approved plant storage location

2. ~~If use of the SCS is not required, a~~*A*ttach a drain line to the HI-TRAC and drain the remaining water from the annulus to the spent fuel pool or the plant liquid radwaste system.

3. Install HI-TRAC top lid as follows:

Warning:
When traversing the MPC with the HI-TRAC top lid using non-single-failure proof (or equivalent safety factors), the lid shall be kept less than 2 feet above the top surface of the MPC. This is performed to protect the MPC lid from a potential lid drop.

   a. Install HI-TRAC top lid. Inspect the bolts for general condition. Replace worn or damaged bolts with new bolts.

   b. Install and torque the top lid bolts. See Table 8.1.5 for torque requirements.

   c. Inspect the lift cleat bolts for general condition. Replace worn or damaged bolts with new bolts.

   d. Install the MPC lift cleats and MPC slings. See Figure 8.1.24 and 8.1.25. See Table 8.1.5 for torque requirements.

   e. Drain and remove the Temporary Shield Ring, if used.

4. Replace the pool lid with the transfer lid as follows (Not required for HI-TRAC 125D):

ALARA Note:
The transfer slide is used to perform the bottom lid replacement and eliminate the possibility of directly exposing the bottom of the MPC. The transfer slide consists of the guide rails, rollers, transfer step and carriage. The transfer slide carriage and jacks are powered and operated by remote control. The carriage consists of short-stroke hydraulic jacks that raise the carriage to support the weight of the bottom lid. The transfer step produces a tight level seam between the transfer lid and the pool lid to minimize radiation streaming. The transfer slide jacks do not have sufficient lift capability to support the entire weight of the HI-TRAC. This was selected specifically to limit floor loads. Users should designate a specific area that has sufficient room and support for performing this operation.

Note:
The following steps are performed to pretension the MPC slings.

a. Lower the lift yoke and attach the MPC slings to the lift yoke. See Figure 8.1.25.

b. Raise the lift yoke and engage the lift yoke to the HI-TRAC lifting trunnions.

c. If necessary, position the transfer step and transfer lid adjacent to one another on the transfer slide carriage. See Figure 8.1.26. See Figure 8.1.9 for transfer step rigging.

d. Deleted.

e. Position HI-TRAC with the pool lid centered over the transfer step approximately one inch above the transfer step.

f. Raise the transfer slide carriage so the transfer step is supporting the pool lid bottom. Remove the bottom lid bolts and store them temporarily.

ALARA Warning:
Clear all personnel away from the immediate operations area. The transfer slide carriage and jacks are remotely operated. The carriage has fine adjustment features to allow precise positioning of the lids.

g. Lower the transfer carriage and position the transfer lid under HI-TRAC.

h. Raise the transfer slide carriage to place the transfer lid against the HI-TRAC bottom lid bolting flange.

i. Inspect the transfer lid bolts for general condition. Replace worn or damaged bolts with new bolts.

j. Install the transfer lid bolts. See Table 8.1.5 for torque requirements.

k. Raise and remove the HI-TRAC from the transfer slide.

l. Disconnect the MPC slings and store them in an approved plant storage location.

Note:
HI-STORM receipt inspection and preparation may be performed independent of procedural sequence.

5. Perform a HI-STORM receipt inspection and cleanliness inspection in accordance with a site-approved inspection checklist, if required. See Figure 8.1.27 for HI-STORM lid rigging.

Note:

MPC transfer may be performed in the truck bay area, at the ISFSI, or any other location deemed appropriate by the licensee. The following steps describe the general transfer operations (See Figure 8.1.28). The HI-STORM may be positioned on an air pad, roller skid in the cask receiving area or at the ISFSI. The HI-STORM or HI-TRAC may be transferred to the ISFSI using a heavy haul transfer trailer, special transporter or other equipment specifically designed for such a function (See Figure 8.1.29) as long as the HI-TRAC and HI-STORM lifting requirements are not exceeded. The licensee is responsible for assessing and controlling floor loading conditions during the MPC transfer operations. Installation of the lid, vent screen, and other components may vary according to the cask movement methods and location of MPC transfer.

8.1.7 Placement of HI-STORM into Storage

1. Position an empty HI-STORM module at the designated MPC transfer location. The HI-STORM may be positioned on the ground, on a de-energized air pad, on a roller skid, on a flatbed trailer or other special device designed for such purposes. If necessary, remove the exit vent screens and gamma shield cross plates, temperature elements and the HI-STORM lid. See Figure 8.1.28 for some of the various MPC transfer options.

   a. Rinse off any road dirt with water. Inspect all cavity locations for foreign objects. Remove any foreign objects.

   b. Transfer the HI-TRAC to the MPC transfer location.

2. De-energize the air pad or chock the vehicle wheels to prevent movement of the HI-STORM during MPC transfer and to maintain level, as required.

ALARA Note:

The HI-STORM vent duct shield inserts eliminate the streaming path created when the MPC is transferred past the exit vent ducts. Vent duct shield inserts are not used with the HI-STORM 100S.

3. Install the alignment device (or mating device for HI-TRAC 125D) and if necessary, install the HI-STORM vent duct shield inserts. See Figure 8.1.30.

~~**Caution:**~~

~~For MPCs with high burn-up fuel requiring supplemental cooling, the time to complete the transfer may be limited to prevent fuel cladding temperatures in excess of ISG-11 Rev. 3 limits. (See Section 4.5) All preparatory work related to the transfer should be completed prior to terminating the supplemental cooling operations.~~

4. *Deleted.*~~If used, discontinue the supplemental cooling operations and disconnect the SCS. Drain water from the HI-TRAC annulus to an appropriate plant discharge point.~~

5. Position HI-TRAC above HI-STORM. See Figure 8.1.28.

6. Align HI-TRAC over HI-STORM (See Figure 8.1.31) and mate the overpacks.
7. If necessary, attach the MPC Downloader. See Figure 8.1.32.
8. Attach the MPC slings to the MPC lift cleats.
9. Raise the MPC slightly to remove the weight of the MPC from the transfer lid doors (or pool lid for HI-TRAC 125D and mating device)
10. If using the HI-TRAC 125D, unbolt the pool lid from the HI-TRAC.
11. Remove the transfer lid door (or mating device drawer) locking pins and open the doors (or drawer).

ALARA Warning:
MPC trim plates are used to eliminate the streaming path above and below the doors (or drawer). If trim plates are not used, personnel should remain clear of the immediate door area during MPC downloading since there may be some radiation streaming during MPC raising and lowering operations.

12. At the user's discretion, install trim plates to cover the gap above and below the door/drawer. The trim plates may be secured using hand clamps or any other method deemed suitable by the user. See Figure 8.1.33.
13. Lower the MPC into HI-STORM.
14. Disconnect the slings from the MPC lifting device and lower them onto the MPC lid.
15. Remove the trim plates (if used), and close the doors (or mating device drawer)

ALARA Warning:
Personnel should remain clear (to the maximum extent practicable) of the HI-STORM annulus when HI-TRAC is removed due to radiation streaming.

Note:
It may be necessary, due to site-specific circumstances, to move HI-STORM from under the empty HI-TRAC to install the HI-STORM lid, while inside the Part 50 facility. In these cases, users shall evaluate the specifics of their movements within the requirements of their Part 50 license.

16. Remove HI-TRAC from on top of HI-STORM.
17. Remove the MPC lift cleats and MPC slings and install hole plugs in the empty MPC bolt holes. See Table 8.1.5 for torque requirements.
18. Place HI-STORM in storage as follows:
    a. Remove the alignment device (mating device with HI-TRAC pool lid for HI-TRAC 125D) and vent duct shield inserts (if used). See Figure 8.1.30.
    b. Inspect the HI-STORM lid studs and nuts for general condition. Replace worn or damaged components with new ones.
    c. If used, inspect the HI-STORM 100A anchor components for general condition. Replace worn or damaged components with new ones.

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d. Deleted.

Warning:
Unless the lift is single failure proof (or equivalent safety factor) for the HI-STORM Lid, the lid shall be kept less than 2 feet above the top surface of the overpack. This is performed to protect the MPC lid from a potential HI-STORM 100 lid drop.

Note:
Shims may be used on the HI-STORM 100 lid studs. If used, the shims shall be positioned to ensure a radial gap of less than 1/8 inch around each stud. The method of cask movement will determine the most effective sequence for vent screen, lid, temperature element, and vent gamma shield cross plate installation.

e. Install the HI-STORM lid and the lid studs and nuts. See Table 8.1.5 for bolting requirements. Install the HI-STORM 100 lid stud shims if necessary. See Figure 8.1.27 for rigging.

f. Install the HI-STORM exit vent gamma shield cross plates, temperature elements (if used) and vent screens. See Table 8.1.5 for torque requirements. See Figure 8.1.34a and 8.1.34b.

g. Remove the HI-STORM lid lifting device and install the hole plugs in the empty holes. Store the lifting device in an approved plant storage location. See Table 8.1.5 for torque requirements.

h. Secure HI-STORM to the transporter device as necessary.

19. Perform a transport route walkdown to ensure that the cask transport conditions are met.

20. Transfer the HI-STORM to its designated storage location at the appropriate pitch. See Figure 8.1.35.

Note:
Any jacking system shall have the provisions to ensure uniform loading of all four jacks during the lifting operation.

a. If air pads were used, insert the HI-STORM lifting jacks and raise HI-STORM. See Figure 8.1.36. Remove the air pad.

b. Lower and remove the HI-STORM lifting jacks, if used.

c. For HI-STORM 100A overpack (anchored), perform the following:

1. Inspect the anchor stud receptacles and verify that they are clean and ready for receipt of the anchor hardware.

2. Align the overpack over the anchor location.

3. Lower the overpack to the ground while adjusting for alignment.

4. Install the anchor connecting hardware (See Table 8.1.5 for torque requirements).

21. Install the HI-STORM inlet vent gamma shield cross plates and vent screens. See Table 8.1.5 for torque requirements. See Figure 8.1.34.

22. Perform shielding effectiveness testing.

23. Perform an air temperature rise test as follows for the first HI-STORM 100 System placed in service:

Note:
The air temperature rise test shall be performed between 5 and 7 days after installation of the HI-STORM 100 lid to allow thermal conditions to stabilize. The purpose of this test is to confirm the initial performance of the HI-STORM 100 ventilation system.

a. Measure the inlet air (or screen surface) temperature at the center of each of the four vent screens. Determine the average inlet air (or surface screen) temperature.

b. Measure the outlet air (or screen surface) temperature at the center of each of the four vent screens. Determine the average outlet air (or surface screen) temperature.

c. Determine the average air temperature rise by subtracting the results of the average inlet screen temperature from the average outlet screen temperature.

d. Report the results to the certificate holder.

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Table 8.1.1
ESTIMATED HANDLING WEIGHTS OF HI-STORM 100 SYSTEM COMPONENTS
125-TON HI-TRAC**

Component	MPC-24 (Lbs.)	MPC-32 (Lbs.)	MPC-68 (Lbs.)	Case† Applicability					
				1	2	3	4	5	6
Empty HI-STORM 100 overpack (without lid)††	245,040	245,040	245,040					1	
HI-STORM 100 lid (without rigging)	23,963	23,963	23,963					1	
Empty HI-STORM 100S (Short) overpack (without lid)††	275,000	275,000	275,000					1	
Empty HI-STORM 100S (Tall) overpack (without lid) ††	290,000	290,000	290,000					1	
HI-STORM 100S lid (without rigging. Add 1,000 lbs for 100S Version B Lid)	28,000	28,000	28,000					1	
Empty MPC (without lid or closure ring including drain line)	29,845	24,503	29,302	1	1	1	1	1	1
MPC lid (without fuel spacers or drain line)	9,677	9,677	10,194	1	1	1	1	1	1
MPC Closure Ring	145	145	145			1	1	1	1
Fuel (design basis)	~~40,320~~ *41,280*	~~53,760~~ *55,040*	~~47,600~~ *49,640*	1	1	1	1	1	1
Damaged Fuel Container (Dresden 1)	0	0	150						
Damaged Fuel Container (Humboldt Bay)	0	0	120						
MPC water (with fuel in MPC)	17,630	17,630	16,957	1	1				
Annulus Water	256	256	256	1	1				
HI-TRAC Lift Yoke (with slings)	4,200	4,200	4,200	1	1	1			
Annulus Seal	50	50	50	1	1				
Lid Retention System	2,300	2,300	2,300						
Transfer frame	6,700	6,700	6,700						1
Mating Device	15,000	15,000	15,000						
Empty HI-TRAC 125 (without Top Lid, neutron shield jacket water, or bottom lids)	117,803	117,803	117,803	1	1	1			1
Empty HI-TRAC 125D (without Top Lid, neutron shield jacket water, or bottom lids)	122,400	122,400	122,400	1	1	1			1
HI-TRAC 125 Top Lid	2,745	2,745	2,745			1			1
HI-TRAC 125D Top Lid	2,645	2,645	2,645			1			1
Optional HI-TRAC Lid Spacer (weight lbs/in thickness)	400	400	400						
HI-TRAC 125/125D Pool Lid(with bolts)	11,900	11,900	11,900	1	1				
HI-TRAC Transfer Lid (with bolts) (125 Only)	23,437	23,437	23,437			1			1
HI-TRAC 125 Neutron Shield Jacket Water	8,281	8,281	8,281		1	1			1
HI-TRAC 125 D Neutron Shield Jacket Water	9,000	9,000	9,000		1	1			1
MPC Stays (total of 2)	200	200	200						
MPC Lift Cleat	480	480	480			1	1		1

** Actual component weights are dependant upon as-built dimensions. The values provided herein are estimated. FSAR analyses use bounding values provided elsewhere. Users are responsible for ensuring lifted loads meet site capabilities and requirements.

† See Table 8.1.2 for a description of each load handling case.

†† Short refers to both 100S-232 and 100S Version B-219. Tall refers to both 100S-243 and 100S Version B-229. Weights are based on 200 lb/cf concrete. Add an additional 1955 lbs. for the HI-STORM 100A overpack.

TABLE 8.1.2
ESTIMATED HANDLING WEIGHTS
125-TON HI-TRAC**

Caution:
The maximum weight supported by the 125-Ton HI-TRAC lifting trunnions cannot exceed 250,000 lbs. Users must take actions to ensure that this limit is not exceeded.

Note:
The weight of the fuel spacers and the damaged fuel container are less than the weight of the design basis fuel assembly for each MPC and are therefore not included in the maximum handling weight calculations. Fuel spacers are determined to be the maximum combination weight of fuel + spacer. Users should determine their specific handling weights based on the MPC contents and the expected handling modes.

Case No.	Load Handling Evolution	Weight (lbs)		
		MPC-24	MPC-32	MPC-68
1	Loaded HI-TRAC 125 removal from spent fuel pool (neutron tank empty)	*232,641* ~~231,700~~	*241,059* ~~239,700~~	*240,302* ~~238,200~~
2	Loaded HI-TRAC 125 removal from spent fuel pool (neutron tank full)	*240,992* ~~239,900~~	*249,340* ~~248,000~~	*248,583* ~~246,500~~
3	Loaded HI-TRAC 125 During Movement through Hatchway	*237,893* ~~236,900~~	*246,311* ~~244,700~~	*246,227* ~~244,100~~
1A	Loaded HI-TRAC 125D removal from spent fuel pool (neutron tank empty)	*237,238* ~~236,400~~	*245,656* ~~244,500~~	*244,899* ~~243,000~~
2A	Loaded HI-TRAC 125D removal from spent fuel pool (neutron tank full)	*246,238* ~~245,400~~	*254,656* ~~253,500~~	*253,899* ~~252,000~~
3A	Loaded HI-TRAC 125D During Movement through Hatchway	*231,572* ~~230,900~~	*239,990* ~~238,700~~	*239,906* ~~238,100~~
4	MPC during transfer operations	*81,427* ~~80,467~~	*89,595* ~~88,315~~	*89,761* ~~87,721~~
5A	Loaded HI-STORM 100 in storage (See Second Note to Table 8.1.1)	*349,950* ~~348,990~~	*358,368* ~~357,088~~	*358,284* ~~356,244~~
5B	Loaded HI-STORM 100S (Short) in storage (See Second Note to Table 8.1.1)	*383,947* ~~380,500~~	*392,365* ~~388,600~~	*392,281* ~~387,800~~
5C	Loaded HI-STORM 100S (Tall) in storage (See Second Note to Table 8.1.1)	*398,947* ~~395,500~~	*407,365* ~~403,600~~	*407,281* ~~402,800~~
6	Loaded HI-TRAC and transfer frame during on site handling	*240,393* ~~239,434~~	*248,811* ~~247,282~~	*248,727* ~~246,688~~

** Actual component weights are dependant upon as-built dimensions. The values provided herein are estimated. FSAR analyses use bounding values provided elsewhere. Users are responsible for ensuring lifted loads meet site capabilities and requirements.

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Table 8.1.3
ESTIMATED HANDLING WEIGHTS OF HI-STORM 100 SYSTEM COMPONENTS100-TON HI-TRAC**

Component	MPC-24 (Lbs.)	MPC-32 (Lbs.)	MPC-68 (Lbs.)	Case† Applicability					
				1	2	3	4	5	6
Empty HI-STORM 100 overpack (without lid)††	245,040	245,040	245,040					1	
HI-STORM 100 lid (without rigging)	23,963	23,963	23,963					1	
Empty HI-STORM 100S (Short) overpack (without lid)††	275,000	275,000	275,000					1	
Empty HI-STORM 100S (Tall) overpack (without lid)††	290,000	290,000	290,000					1	
HI-STORM 100S lid (without rigging, add 1,000 lbs for 100S Version B Lid)	28,000	28,000	28,000						
Empty MPC (without lid or closure ring including drain line)	29,845	24,503	29,302	1	1	1	1	1	1
MPC lid (without fuel spacers or drain line)	9,677	9,677	10,194	1	1	1	1	1	1
MPC Closure Ring	145	145	145			1	1	1	1
Fuel (design basis)	~~40,320~~ *41,280*	~~53,760~~ *55,040*	~~47,600~~ *49,640*	1	1	1	1	1	1
Damaged Fuel Container (Dresden 1)	0	0	150						
Damaged Fuel Container (Humboldt Bay)	0	0	120						
MPC water (with fuel in MPC)	17,630	17,630	16,957	1	1				
Annulus Water	256	256	256	1	1				
HI-TRAC Lift Yoke (with slings)	3,200	3,200	3,200	1	1	1			
Annulus Seal	50	50	50	1	1				
Lid Retention System	2,300	2,300	2,300						
Transfer frame	6,700	6,700	6,700						1
Empty HI-TRAC (without Top Lid, neutron shield jacket water, or bottom lids)	84,003	84,003	84,003	1	1	1			1
HI-TRAC Top Lid	1,189	1,189	1,189			1			1
HI-TRAC Pool Lid	7,863	7,863	7,863	1	1				
HI-TRAC Transfer Lid	16,686	16,686	16,686			1			1
HI-TRAC Neutron Shield Jacket Water	7,583	7,583	7,583		1	1			1
MPC Stays (total of 2)	200	200	200						
MPC Lift Cleat	480	480	480				1		1

** Actual component weights are dependant upon as-built dimensions. The values provided herein are estimated. FSAR analyses use bounding values provided elsewhere. Users are responsible for ensuring lifted loads meet site capabilities and requirements.

† See Table 8.1.4 for a description of each load handling case.

†† Short refers to both 100S-232 and 100S Version B-219. Tall refers to both 100S-243 and 100S Version B-229. Weights are based on 200 lb/cf concrete. Add an additional 1955 lbs. for the HI-STORM 100A overpack.

Table 8.1.4
ESTIMATED HANDLING WEIGHTS
100-TON HI-TRAC**

Caution:
The maximum weight supported by the 100-Ton HI-TRAC lifting trunnions cannot exceed 200,000 lbs. Users must take actions to ensure that this limit is not exceeded.

Note:
The weight of the fuel spacers and the damaged fuel container are less than the weight of the design basis fuel assembly and therefore not included in the maximum handling weight calculations. Fuel spacers are determined to be the maximum combination weight of fuel + spacer. Users should determine the handling weights based on the contents to be loaded and the expected mode of operations.

Case No.	Load Handling Evolution	Weight (lbs)		
		MPC-24	MPC-32	MPC-68
1	Loaded HI-TRAC removal from spent fuel pool (neutron tank empty)	*193,804* ~~192,844~~	*202,222* ~~200,942~~	*201,465* ~~199,425~~
2	Loaded HI-TRAC removal from spent fuel pool (neutron tank full)	*201,387* ~~200,427~~	*209,805* ~~208,525~~	*209,048* ~~207,008~~
3	Loaded HI-TRAC During Movement through Hatchway	*194,088* ~~192,647~~	*202,506* ~~200,745~~	*202,422* ~~199,901~~
4	MPC during transfer operations	*81,427* ~~80,467~~	*89,845* ~~88,565~~	*89,761* ~~87,721~~
5A	Loaded HI-STORM 100 in storage (See Second Note to Table 8.1.1)	*349,950* ~~348,990~~	*358,368* ~~357,088~~	*358,284* ~~356,244~~
5B	Loaded HI-STORM 100S (Short) in storage (See Second Note to Table 8.1.1)	*383,947* ~~380,500~~	*392,365* ~~388,600~~	*392,281* ~~387,800~~
5C	Loaded HI-STORM 100S (Tall) in storage (See Second Note to Table 8.1.1)	*398,947* ~~395,500~~	*407,365* ~~403,600~~	*407,281* ~~402,800~~
6	Loaded HI-TRAC and transfer frame during on site handling	*197,588* ~~196,627~~	*206,006* ~~204,725~~	*205,922* ~~203,881~~

** Actual component weights are dependant upon as-built dimensions. The values provided herein are estimated. FSAR analyses use bounding values provided elsewhere. Users are responsible for ensuring lifted loads meet site capabilities and requirements.

Table 8.1.5
HI-STORM 100 SYSTEM TORQUE REQUIREMENTS

Fastener†	**Torque (ft-lbs)** ††	**Pattern**†††
HI-TRAC Top Lid Bolts†	Hand tight	None
HI-TRAC Pool Lid Bolts (36 Bolt Lid)†	58 ft-lbs	Figure 8.1.37
HI-TRAC Pool Lid Bolts (16 Bolt Lid)†	110 ft-lbs	Figure 8.1.37
100-Ton HI-TRAC Transfer Lid Bolts†	203 ft-lbs	Figure 8.1.37
125-Ton HI-TRAC Transfer Lid Bolts†	270 ft-lbs	Figure 8.1.37
MPC Lift Cleats Stud Nuts†	793 ft-lbs	None
MPC Lift Hole Plugs†	Hand tight	None
Threaded Fuel Spacers	Hand Tight	None
HI-STORM Lid Nuts †	100 ft-lbs	None
HI-STORM 100S Lid Nuts† (Temporary and Permanent Lids, Including Version B)	Hand Tight	None
Door Locking Pins	Hand Tight + 1/8 to 1/2 turn	None
HI-STORM 100 Vent Screen/Temperature Element Screws	Hand Tight	None
HI-STORM 100A Anchor Studs	55- 65 ksi tension applied by bolt tensioner (no initial torque)	None

† Studs and nuts shall be cleaned and inspected for damage or excessive thread wear (replace if necessary) and coated with a light layer of Fel-Pro Chemical Products, N-5000, Nuclear Grade Lubricant (or equivalent).

†† Unless specifically specified, torques have a +/- 5% tolerance.

††† No de-torquing pattern is needed.

Table 8.1.6
HI-STORM 100 SYSTEM ANCILLARY EQUIPMENT OPERATIONAL DESCRIPTION

Equipment	Important To Safety Classification	Reference Figure†	Description
Air Pads/Rollers	Not Important To Safety	8.1.29	Used for HI-STORM or HI-TRAC cask positioning. May be used in conjunction with the cask transporter or other HI-STORM 100 or HI-TRAC lifting device.
Annulus Overpressure System	Not Important To Safety	8.1.14	The Annulus Overpressure System is used for protection against spent fuel pool water contamination of the external MPC shell and baseplate surfaces by providing a slight annulus overpressure during in-pool operations.
Annulus Shield	Not Important To Safety	8.1.13	A shield that is placed at the top of the HI-TRAC annulus to provide supplemental shielding to the operators performing cask loading and closure operations.
Automated Welding System	Not Important To Safety	8.1.2b	Used for remote field welding of the MPC.
AWS Baseplate Shield	Not Important To Safety	8.1.2b	Provides supplemental shielding to the operators during the cask closure operations.
Bottom Lid Transfer Slide (Not used with HI-TRAC 125D)	Not Important To Safety	8.1.26	Used to simultaneously replace the pool lid with the transfer lid under the suspended HI-TRAC and MPC. Used in conjunction with the bottom lid transfer step.
Cask Transporter	Not Important to Safety unless site-specific conditions require transfer cask or overpack handling outside drop analysis basis.	8.1.29a and 8.1.29b	Used for handling of the HI-STORM 100 Overpack and/or the HI-TRAC Transfer Cask around the site. The cask transporter may take the form of heavy haul transfer trailer, special transporter or other equipment specifically designed for such a function.
Cool-Down System	Not Important To Safety	8.3.4	A closed-loop forced ventilation cooling system used to gas-cool the MPC fuel assemblies down to a temperature at which water can be introduced without the risk of uncontrolled pressure transients in the MPC due to flashing or thermally shocking the fuel assemblies. The cool-down system is attached between the MPC drain and vent ports. The cool-down system is used only for unloading operations.

† Figures are representative and may not depict all configurations for all users.

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Table 8.1.6
HI-STORM 100 SYSTEM ANCILLARY EQUIPMENT OPERATIONAL DESCRIPTION
(Continued)

Equipment	Important To Safety Classification	Reference Figure†	Description
Lid and empty component lifting rigging	Not Important To Safety, Rigging shall be provided in accordance with NUREG 0612	8.1.9	Used for rigging such components such as the HI-TRAC top lid, pool lid, MPC lid, transfer lid, AWS, HI-STORM Lid and auxiliary shielding and the empty MPC.
Helium Backfill System	Not Important To Safety	8.1.23	Used for controlled insertion of helium into the MPC for leakage testing, blowdown and placement into storage.
HI-STORM 100 Lifting Jacks	Not Important To Safety	8.1.36	Jack system used for lifting the HI-STORM overpack to provide clearance for inserting or removing a device for transportation. .
Alignment Device	Not Important To Safety	8.1.31	Guides HI-TRAC into place on top of HI-STORM for MPC transfers. (Not used for HI-TRAC 125D)
HI-STORM Lifting Devices	Determined site-specifically based on type, location, and height of lift being performed. Lifting devices shall be provided in accordance with ANSI N14.6.	Not shown.	A special lifting device used for connecting the crane (or other primary lifting device) to the HI-STORM 100 for cask handling. Does not include the crane hook (or other primary lifting device) device.
HI-STORM Vent Duct Shield Inserts	Important to Safety Category C .	8.1.30	Used for prevention of radiation streaming from the HI-STORM 100 exit vents during MPC transfers to and from HI-STORM. Not used with the HI-STORM 100S.
HI-TRAC Lid Spacer	Spacer Ring is Not-Important-To-Safety, Studs or bolts are I Important to Safety Category B	Not Shown	Optional ancillary which is used during MPC transfer operations to increase the clearance between the top of the MPC and the underside of the HI-TRAC top lid. Longer threaded studs (or bolts), supplied with the lid spacer, replace the standard threaded studs (or bolts) supplied with the HI-TRAC. The HI-TRAC lid spacer may ONLY be used when the HI-TRAC is handled in the vertical orientation or if HI-TRAC transfer lid is NOT used. The height of the spacer shall be limited to ensure that the weights and C.G. heights in a loaded HI-TRAC with the spacer do not exceed the bounding values found in Section 3.2 of the FSAR.
HI-TRAC Lift Yoke/Lifting Links	Determined site-specifically based on type and location, and height of lift being performed. Lift yoke and lifting devices for loaded HI-TRAC handling shall be provided in accordance with ANSI N14.6.	8.1.3	Used for connecting the crane (or other primary lifting device) to the HI-TRAC for cask handling. Does not include the crane hook (or other primary lifting device).

† Figures are representative and may not depict all configurations for all users.

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Table 8.1.6
HI-STORM 100 SYSTEM ANCILLARY EQUIPMENT OPERATIONAL DESCRIPTION
(Continued)

Equipment	Important To Safety Classification	Reference Figure†	Description
HI-TRAC transfer frame	Not Important To Safety	8.1.4	A steel frame used to support HI-TRAC during delivery, on-site movement and upending/downending operations.
Cask Primary Lifting Device (Cask Transfer Facility)	Important to Safety. Quality classification of subcomponents determined site-specifically.	8.1.28 and 8.1.32	Optional auxiliary (Non-Part 50) cask lifting device(s) used for cask upending and downending and HI-TRAC raising for positioning on top of HI-STORM to allow MPC transfer. The device may consist of a crane, lifting platform, gantry system or any other suitable device used for such purpose.
Inflatable Annulus Seal	Not Important To Safety	8.1.13	Used to prevent spent fuel pool water from contaminating the external MPC shell and baseplate surfaces during in-pool operations.
Lid Retention System	Important to Safety Status determined by each licensee. MPC lid lifting portions of the Lid Retention System shall meet the requirements of ANSI N14.6.	8.1.15, 8.1.17	Optional. The Lid Retention System secures the MPC lid in place during cask handling operations between the pool and decontamination pad.
MPC Lift Cleats	Important To Safety – Category A. MPC Lift Cleats shall be provided in accordance with of ANSI N14.6.	8.1.24	MPC lift cleats consist of the cleats and attachment hardware. The cleats are supplied as solid steel components that contain no weds. The MPC lift cleats are used to secure the MPC inside HI-TRAC during bottom lid replacement and support the MPC during MPC transfer from HI-TRAC into HI-STORM and vice versa. The ITS classification of the lifting device attached to the cleats may be lower than the cleat itself, as determined site-specifically.
Hydrostatic Test System	Not Important to Safety	8.1.20	Used to pressure test the MPC lid-to-shell weld.
MPC Downloader	Important To Safety status determined site-specifically. MPC Downloader Shall meet the requirements of CoC, Appendix B, Section 3.5 .	8.1.28 and 8.1.32	A lifting device used to help raise and lower the MPC during MPC transfer operations to limit the lift force of the MPC against the top lid of HI-TRAC. The MPC downloader may take several forms depending on the location of MPC transfer and may be used in conjunction with other lifting devices.

† Figures are representative and may not depict all configurations for all users.

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Table 8.1.6
HI-STORM 100 SYSTEM ANCILLARY EQUIPMENT OPERATIONAL DESCRIPTION
(Continued)

Equipment	Important To Safety Classification	Reference Figure[†]	Description
Deleted			
Deleted			
Mating Device	Important-To-Safety – Category B	8.1.31	Used to mate HI-TRAC 125D to HI-ST)RM during transfer operations. Includes sliding drawer for use in removing HI-TRAC pool lid.
MPC Support Slings	Important To Safety – Category A – Rigging shall be provided in accordance with NUREG 0612.	8.1.25	Used to secure the MPC to the lift yoke during HI-TRAC bottom lid replacement operations. Attaches between the MPC lift cleats and the lift yoke. Can be configured for different crane hook configuration.
MPC Upending Frame	Not Important to Safety	8.1.6	A steel frame used to evenly support the MPC during upending operations. and control the upending process.
~~Supplemental Cooling System~~	~~Important to Safety – Category B~~	~~2.C.1~~	~~A system used to circulate water or other coolant through the HI-TRAC annulus in order to maintain fuel cladding temperatures below ISG-11 Rev. 3 limits during operations with the MPC in the HI-TRAC. Required only for MPC containing high burn-up fuel as determined in accordance with Section 4.5.~~
MSLD (Helium Leakage Detector)~~Deleted~~	*Not Important to Safety*	*Not shown*	*Used for helium leakage testing of the MPC cover plate welds.*
Deleted			
Temporary Shield Ring	Not Important To Safety	8.1.18	A water-filled tank that fits on the cask neutron shield around the upper forging and provides supplemental shielding to personnel performing cask loading and closure operations.
Vacuum Drying (Moisture Removal) System	Not Important To Safety	8.1.22a	Used for removal of residual moisture from the MPC following water draining.
Forced Helium Dehydration System	Not Important To Safety	8.1.22b	Used for removal of residual moisture from the MPC following water draining.
Vent and Drain RVOAs	Not Important To Safety	8.1.16	Used to access the vent and drain ports. The vent and drain RVOAs allow the vent and drain ports to be operated like valves and prevent the need to hot tap into the penetrations during unloading operation.
Deleted			
Weld Removal	Not Important To Safety	8.3.2b	Semi-automated weld removal system used for removal of the MPC field weld to support

[†] Figures are representative and may not depict all configurations for all users.

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System			unloading operations.

Table 8.1.7
HI-STORM 100 SYSTEM INSTRUMENTATION SUMMARY FOR LOADING AND UNLOADING OPERATIONS†

Instrument	Function
Contamination Survey Instruments	Monitors fixed and non-fixed contamination levels.
Dose Rate Monitors/Survey Equipment	Monitors dose rate and contamination levels and ensures proper function of shielding. Ensures assembly debris is not inadvertently removed from the spent fuel pool during overpack removal.
Flow Rate Monitor	Monitors fluid flow rate during various loading and unloading operations.
Helium Mass Spectrometer Leakage Detector (MSLD) ~~Deleted~~	*Ensures leakage rates of welds are within acceptable limits*
Deleted	Ensures leakage rates of welds are within acceptance criteria.
Deleted	
Volumetric Examination Testing Rig	Used to assess the integrity of the MPC lid-to-shell weld.
Pressure Gauges	Ensures correct pressure during loading and unloading operations.
Temperature Gauges	Monitors the state of gas and water temperatures during closure and unloading operations.
Deleted	
Temperature Surface Pyrometer	For HI-STORM vent operability testing.
Vacuum Gages	Used for vacuum drying operations and to prepare an MPC evacuated sample bottle for MPC gas sampling for unloading operations.
Deleted	
Deleted	
Moisture Monitoring Instruments	Used to monitor the MPC moisture levels as part of the moisture removal system.

† All instruments require calibration. See figures at the end of this section for additional instruments, controllers and piping diagrams.

Table 8.1.8
HI-STORM 100 SYSTEM OVERPACK INSPECTION CHECKLIST

Note:
This checklist provides the basis for establishing a site-specific inspection checklist for the HI-STORM 100 overpack. Specific findings shall be brought to the attention of the appropriate site organizations for assessment, evaluation and potential corrective action prior to use.

HI-STORM 100 Overpack Lid:

1. Lid studs and nuts shall be inspected for general condition.
2. The painted surfaces shall be inspected for corrosion and chipped, cracked or blistered paint.
3. All lid surfaces shall be relatively free of dents, scratches, gouges or other damage.
4. The lid shall be inspected for the presence or availability of studs and nuts and hole plugs.
5. Lid lifting device/ holes shall be inspected for dirt and debris and thread condition.
6. Lid bolt holes shall be inspected for general condition.

HI-STORM 100 Main Body:

1. Lid bolt holes shall be inspected for dirt, debris, and thread condition.
2. Vents shall be free from obstructions.
3. Vent screens shall be available, intact, and free of holes and tears in the fabric.
4. The interior cavity shall be free of debris, litter, tools, and equipment.
5. Painted surfaces shall be inspected for corrosion, and chipped, cracked or blistered paint.
6. The nameplate shall be inspected for presence, legibility, and general condition and conformance to Quality Assurance records package.
7. Anchor hardware, if used, shall be checked for general condition.

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Table 8.1.9
MPC INSPECTION CHECKLIST

Note:
This checklist provides the basis for establishing a site-specific inspection checklist for MPC. Specific findings shall be brought to the attention of the appropriate site organizations for assessment, evaluation and potential corrective action prior to use.

MPC Lid and Closure Ring:

1. The MPC lid and closure ring surfaces shall be relatively free of dents, gouges or other shipping damage.
2. The drain line shall be inspected for straightness, thread condition, and blockage.
3. Vent and Drain attachments shall be inspected for availability, thread condition operability and general condition.
4. Upper fuel spacers (if used) shall be inspected for availability and general condition. Plugs shall be available for non-used spacer locations.
5. Lower fuel spacers (if used) shall be inspected for availability and general condition.
6. Drain and vent port cover plates shall be inspected for availability and general condition.
7. Serial numbers shall be inspected for readability.

MPC Main Body:

1. All visible MPC body surfaces shall be inspected for dents, gouges or other shipping damage.
2. Fuel cell openings shall be inspected for debris, dents and general condition.
3. Lift lugs shall be inspected for general condition.
4. Verify proper MPC basket type for contents.

Table 8.1.10
HI-TRAC TRANSFER CASK INSPECTION CHECKLIST

Note:
This checklist provides the basis for establishing a site-specific inspection checklist for the HI-TRAC Transfer Cask. Specific findings shall be brought to the attention of the appropriate site organizations for assessment, evaluation and potential corrective action prior to use.

HI-TRAC Top Lid:

1. The painted surfaces shall be inspected for corrosion and chipped, cracked or blistered paint.
2. All Top Lid surfaces shall be relatively free of dents, scratches, gouges or other damage.

HI-TRAC Main Body:

1. The painted surfaces shall be inspected for corrosion, chipped, cracked or blistered paint.
2. The Top Lid bolt holes shall be inspected for dirt, debris and thread damage.
3. The Top Lid lift holes shall be inspected for thread condition.
4. Lifting trunnions shall be inspected for deformation, cracks, end plate damage, corrosion, excessive galling, damage to the locking plate, presence or availability of locking plate and end plate retention bolts.
5. Pocket trunnion, if used, recesses shall be inspected for indications of overstressing (i.e., cracks, deformation, and excessive wear).
6. Annulus inflatable seal groove shall be inspected for cleanliness, scratches, dents, gouges, sharp corners, burrs or any other condition that may damage the inflatable seal.
7. The nameplate shall be inspected for presence and general condition.
8. The neutron shield jacket shall be inspected for leaks.
9. Neutron shield jacket pressure relief valve shall be inspected for presence, and general condition.
10. The neutron shield jacket fill and drain plugs shall be inspected for presence, leaks, and general condition.
11. Bottom lid flange surface shall be clean and free of large scratches and gouges.

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Table 8.1.10 (Continued)
HI-TRAC OVERPACK INSPECTION CHECKLIST

HI-TRAC Transfer Lid (Not used with HI-TRAC 125D):

1. The doors shall be inspected for smooth actuation.
2. The threads shall be inspected for general condition.
3. The bolts shall be inspected for indications of overstressing (i.e., cracks, deformation, thread damage, excessive wear) and replaced as necessary.
4. Door locking pins shall be inspected for indications of overstressing (i.e., cracks, and deformation, thread damage, excessive wear) and replaced as necessary.
5. Painted surfaces shall be inspected for corrosion and chipped, cracked or blistered paint.
6. Lifting holes shall be inspected for thread damage.

HI-TRAC Pool Lid:

1. Seal shall be inspected for cracks, breaks, cuts, excessive wear, flattening, and general condition.
2. Drain line shall be inspected for blockage and thread condition.
3. The lifting holes shall be inspected for thread damage.
4. The bolts shall be inspected for indications of overstressing (i.e., cracks and deformation, thread damage, and excessive wear).
5. Painted surfaces shall be inspected for corrosion and chipped, cracked or blistered paint.
6. Threads shall be inspected for indications of damage.

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8.3 PROCEDURE FOR UNLOADING THE HI-STORM 100 SYSTEM IN THE SPENT FUEL POOL

8.3.1 Overview of HI-STORM 100 System Unloading Operations

ALARA Note:
The procedure described below uses the weld removal system to remove the welds necessary to enable the MPC lid to be removed. Users may opt to remove some or all of the welds using hand operated equipment. The decision should be based on dose rates, accessibility, degree of weld removal, and available tooling and equipment.

The HI-STORM 100 System unloading procedures describe the general actions necessary to prepare the MPC for unloading, cool the stored fuel assemblies in the MPC, flood the MPC cavity, remove the lid welds, unload the spent fuel assemblies, and recover the HI-TRAC and empty MPC. Special precautions are outlined to ensure personnel safety during the unloading operations, and to prevent the risk of MPC over pressurization and thermal shock to the stored spent fuel assemblies. Figure 8.3.1 shows a flow diagram of the HI-STORM unloading operations. Figure 8.3.2 illustrates the major HI-STORM unloading operations.

Refer to the boxes of Figure 8.3.2 for the following description. The MPC is recovered from HI-STORM either at the ISFSI or the fuel building using the same methodologies as described in Section 8.1 (Box 1). The HI-STORM lid is removed, the vent duct shield inserts are installed, the alignment device (or mating device with pool lid for HI-TRAC 125D) is positioned, and the MPC lift cleats are attached to the MPC. The exit vent screens and gamma shield cross plates are removed as necessary. MPC slings are attached to the MPC lift cleat and positioned on the MPC lid. HI-TRAC is positioned on top of HI-STORM (Box 2) and the slings are brought through the HI-TRAC top lid. The MPC is raised into HI-TRAC, the HI-TRAC doors (or mating device drawer) are closed and the locking pins are installed. If the mating device and HI-TRAC 125D are used, the pool lid is bolted to the HI-TRAC. The HI-TRAC is removed from on top of HI-STORM. If the HI-TRAC 125D is not used, the HI-TRAC is positioned in the transfer slide and the transfer lid is replaced with the pool lid (Box 3) using the same methodology as with the loading operations.

~~If the MPC contains high burn-up fuel, a Supplemental Cooling System (SCS) (if required) is connected to the HI-TRAC annulus following transfer from the HI-STORM to the HI-TRAC and used to circulate coolant to maintain fuel cladding temperatures below ISG-11 Rev. 3 limits.~~ HI-TRAC and its enclosed MPC are returned to the designated preparation area and the MPC slings and MPC lift cleats are removed. The temporary shield ring is installed on the HI-TRAC upper section and filled with plant demineralized water. The HI-TRAC top lid is removed[1] (Box 4) and a water flush is performed on the annulus. Water is fed into the annulus through the drain port and allowed to cool the MPC shell. After a predetermined period (based on the fuel conditions), cover the annulus and HI-TRAC top surfaces to protect them from debris produced when removing the MPC lid. The weld removal system is installed (Box 7) and the MPC vent and drain ports are accessed (Box 5). The vent RVOA is attached to the vent port and an evacuated sample bottle is connected. The vent port is slightly opened to allow the sample bottle

[1] Users with the optional HI-TRAC Lid Spacer shall modify steps in their procedures to install and remove the spacer together with top lid.

to obtain a gas sample from inside the MPC. A gas sample is performed to assess the condition of the fuel assembly cladding. A vent line is attached to the vent port and the MPC is vented to the fuel building ventilation system or spent fuel pool as determined by the site's radiation protection personnel. The MPC is cooled using the cool-down system to reduce the MPC internal temperature to allow water flooding (Box 6). The cool-down process gradually reduces the cladding temperature to a point where the MPC may be flooded with water without thermally shocking the fuel assemblies or over-pressurizing the MPC from the formation of steam. Following the fuel cool-down, *and* the MPC is filled with water (borated as required)~~ and the supplemental cooling is terminated (if used)~~. The weld removal system then removes the MPC lid-to-shell weld. The weld removal system is removed with the MPC lid left in place (Box 7).

The top surfaces of the HI-TRAC and MPC are cleared of metal shavings. The inflatable annulus seal is installed and pressurized. The MPC lid is rigged to the lift yoke or lid retention system and the lift yoke is engaged to HI-TRAC lifting trunnions. If weight limitations require, the neutron shield jacket is drained of water. HI-TRAC is placed in the spent fuel pool and the MPC lid is removed (Boxes 8 and 9). All fuel assemblies are returned to the spent fuel storage racks and the MPC fuel cells are vacuumed to remove any assembly debris and crud (Box 10). HI-TRAC and MPC are returned to the designated preparation area (Box 11) where the MPC water is pumped back into the spent fuel pool or liquid radwaste facility. The annulus water is drained and the MPC and overpack are decontaminated (Box 12 and 13).

8.3.2 HI-STORM Recovery from Storage

Note:
The MPC transfer may be performed using the MPC downloader or the overhead crane.

1. Recover the MPC from HI-STORM as follows:

    a. If necessary, perform a transport route walkdown to ensure that the cask transport conditions are met.

    b. Transfer HI-STORM to the fuel building or site designated location for the MPC transfer.

    c. Position HI-STORM under the lifting device.

    d. Remove the HI-STORM lid nuts, washers and studs.

    e. Remove the HI-STORM lid lifting hole plugs and install the lid lifting sling. See Figure 8.1.27.

Note:
The specific sequence for vent screen, temperature element, and gamma shield cross plate removal may vary based on the mode(s) or transport.

    f. Remove the HI-STORM exit vent screens, temperature elements and gamma shield cross plates. See Figure 8.1.34a and b.

Warning:
Unless the lift is single-failure proof (or equivalent safety factor) for the HI-STORM lid, the lid shall be kept less than 2 feet above the top surface of the overpack. This is performed to protect the MPC lid from a potential HI-STORM 100 lid drop.

g. Remove the HI-STORM lid. See Figure 8.1.27.

h. Install the alignment device (or mating device with pool lid for HI-TRAC 125D) and vent duct shield inserts (HI-STORM 100 only). See Figure 8.1.30.

i. Deleted.

j. Remove the MPC lift cleat hole plugs and install the MPC lift cleats and MPC slings to the MPC lid. See Table 8.1.5 for torque requirements.

k. If necessary, install the top lid on HI-TRAC. See Figure 8.1.9 for rigging. See Table 8.1.5 for torque requirements.

l. Deleted.

2. If necessary, configure HI-TRAC with the transfer lid (Not required for HI-TRAC 125D):

ALARA Warning:
The bottom lid replacement as described below may only be performed on an empty (i.e., no MPC) HI-TRAC.

a. Position HI-TRAC vertically adjacent to the transfer lid. See Section 8.1.2.

b. Remove the bottom lid bolts and plates and store them temporarily.

c. Raise the empty HI-TRAC and position it on top of the transfer lid.

d. Inspect the pool lid bolts for general condition. Replace worn or damaged bolts with new bolts.

e. Install the transfer lid bolts. See Table 8.1.5 for torque requirements.

3. At the site's discretion, perform a HI-TRAC receipt inspection and cleanliness inspection in accordance with a site-specific inspection checklist.

Note:
If the HI-TRAC is expected to be operated in an environment below 32 ^{o}F, the water jacket shall be filled with an ethylene glycol solution (25% ethylene glycol). Otherwise, the jacket shall be filled with demineralized water.

4. If previously drained, fill the neutron shield jacket with plant demineralized water or an ethylene glycol solution (25% ethylene glycol) as necessary. Ensure that the fill and drain plugs are installed.

5. Engage the lift yoke to the HI-TRAC lifting trunnions.

6. Align HI-TRAC over HI-STORM and mate the overpacks. See Figure 8.1.31.

7. If necessary, install the MPC downloader.

8. Remove the transfer lid (or mating device) locking pins and open the doors (mating device drawer).

9. At the user's discretion, install trim plates to cover the gap above and below the door (drawer for 125D). The trim plates may be secured using hand clamps or any other method deemed suitable by the user. See Figure 8.1.33.

10. Attach the ends of the MPC sling to the lifting device or MPC downloader. See Figure 8.1.32.

ALARA Warning:
If trim plates are not used, personnel should remain clear of the immediate door area during MPC downloading since there may be some radiation streaming during MPC raising and lowering operations.

~~**Caution:**~~
~~Limitations for the handling an MPC containing high burn-up fuel in a HI-TRAC are evaluated and established on a canister basis to ensure that acceptable cladding temperatures are not exceeded. Refer to FSAR Section 4.5 for guidance. For MPCs containing high burn-up fuel, the Supplemental Cooling System (SCS) (if required) is used to prevent fuel cladding temperatures from exceeding ISG-11 Rev. 3 limits. Operation of the SCS typically begins as soon as the MPC is placed in the HI-TRAC and continues until MPC cool-down and re-flooding operations have commenced. Staging and check-out of the SCS shall be completed prior to transferring the MPC to the HI-TRAC to minimize the time required to begin its operation.~~

11. Raise the MPC into HI-TRAC.

12. Verify the MPC is in the full-up position.

13. Close the HI-TRAC doors (or mating device drawer) and install the door locking pins.

14. For the HI-TRAC 125D, bolt the pool lid to the HI-TRAC. See Table 8.1.5 for torque requirements.

15. Lower the MPC onto the transfer lid doors (or pool lid for 125D).

16. Disconnect the slings from the MPC lift cleats.

~~**Note:**~~
~~For the HI-TRAC 100 and HI-TRAC 125, operation of the SCS may need to be postponed until the pool lid is in place on the HI-TRAC. In any event, supplemental cooling shall begin before time limits established by the canister thermal evaluation are exceeded.~~

~~**Warning:**~~
~~At the start of SCS operations, the annulus fill water may flash to steam due to high MPC shell temperatures. Users may select the location and means of filling the annulus. Water addition should be preformed in a slow and controlled manner until water steam generation has ceased.~~

17. *Deleted.*~~If required, attach the SCS to the HI-TRAC annulus and begin circulating coolant. (See Figure 2.C.1). Continue operation of the SCS until MPC cool-down and re-flooding operations have commenced.~~

18. If necessary, remove the MPC downloader from the top of HI-TRAC.

19. Remove HI-TRAC from the top of HI-STORM.

8.3.3 Preparation for Unloading:

1. Replace the transfer lid with the pool lid as follows (Not required for HI-TRAC 125D):

   a. Lower the lift yoke and attach the MPC slings between the lift cleats and the lift yoke. See Figure 8.1.25.

   b. Engage the lift yoke to the HI-TRAC lifting trunnions.

   c. Deleted.

   d. Raise HI-TRAC and position the transfer lid approximately one inch above the transfer step. See Figure 8.1.26.

   e. Raise the transfer slide carriage so the transfer carriage is supporting the transfer lid bottom. Remove the transfer lid bolts and store them temporarily.

ALARA Warning:
Clear all personnel away from the immediate operations area. The transfer slide carriage and jacks are remotely operated. The carriage has fine adjustment features to allow precise positioning of the lids.

   f. Lower the transfer carriage and position the pool lid under HI-TRAC.

   g. Raise the transfer slide carriage to place the pool lid against the HI-TRAC bottom lid bolting flange.

   h. Inspect the bottom lid bolts for general condition. Replace worn or damaged bolts with new bolts.

   i. Install the pool lid bolts. See Table 8.1.5 for torque requirements.

   j. *Deleted.*~~If required, attach the SCS to the HI-TRAC annulus and begin circulating coolant. (See Figure 2.C.1) Continue operation of the SCS until MPC cool-down and re-flooding operations have commenced.~~

   k. Raise and remove the HI-TRAC from the transfer slide.

   l. Disconnect the MPC slings and lift cleats.

   m. Deleted.

   n. Deleted.

2. Place HI-TRAC in the designated preparation area.

Warning:
Unless the lift is single-failure proof (or equivalent safety factor) the HI-TRAC top lid, the top lid shall be kept less than 2 feet above the top surface of the MPC. This is performed to protect the MPC lid from a potential lid drop.

3. Prepare for MPC cool-down as follows:

a. Remove the top lid bolts and remove HI-TRAC top lid. See Figure 8.1.9 for rigging.

Warning:
At the start of annulus filling, the annulus fill water may flash to steam due to high MPC shell temperatures. Users may select the location and means of performing the annulus flush. Users may also elect the source of water and method for collecting the water flowing from the annulus. Water addition should be preformed in a slow and controlled manner until water steam generation has ceased. Water flush should be performed for a minimum of 33 hours at a flow rate of 10 GPM or as specified for the particular heat load of the MPC.~~. Annulus filling is only required if the SCS is not used.~~

b. If necessary, perform annulus flush by injecting water into the HI-TRAC drain port and allowing the water to cool the MPC shell and lid.

4. If necessary, set the annulus water level to approximately 4 inches below the top of the MPC shell and install the annulus shield. Cover the annulus and HI-TRAC top surfaces to protect them from debris produced when removing the MPC lid.

5. Access the MPC as follows:

ALARA Note:
The following procedures describe weld removal using a machine tool head. Other methods may also be used. The metal shavings may need to be periodically vacuumed.

ALARA Warning:
Weld removal may create an airborne radiation condition. Weld removal must be performed under the direction of the user's Radiation Protection organization.

a. Install bolt plugs and/or waterproof tape from HI-TRAC top bolt holes.

b. Using the marked locations of the vent and drain ports, core drill the closure ring and vent and drain port cover plates.

6. Remove the closure ring section and the vent and drain port cover plates.

ALARA Note:
The MPC vent and drain ports are equipped with metal-to-metal seals to minimize leakage and withstand the long-term effects of temperature and radiation. The vent and drain port design prevents the need to hot tap into the penetrations during unloading operation and eliminate the risk of a pressurized release of gas from the MPC.

7. Take an MPC gas sample as follows:

Note:
Users may select alternate methods of obtaining a gas sample.

a. Attach the RVOAs (See Figure 8.1.16).

b. Attach a sample bottle to the vent port RVOA as shown on Figure 8.3.3.

c. Using the vacuum drying system, evacuate the RVOA and Sample Bottle.

d. Slowly open the vent port cap using the RVOA and gather a gas sample from the MPC internal atmosphere.

e. Close the vent port cap and disconnect the sample bottle.

ALARA Note:
The gas sample analysis is performed to determine the condition of the fuel cladding in the MPC. The gas sample may indicate that fuel with damaged cladding is present in the MPC. The results of the gas sample test may affect personnel protection and how the gas is processed during MPC depressurization.

f. Turn the sample bottle over to the site's Radiation Protection or Chemistry Department for analysis.

g. Deleted.

8. Fill the MPC cavity with water as follows:

Caution:
The MPC interior shall be filled with helium or another suitable inert gas to avoid exposing the fuel to oxidizing agents while at elevated temperatures. Exposing fuel at elevated temperatures to oxidizing agents can lead to deleterious oxidation of the fuel.

a. Configure the cool-down system as shown on Figure 8.3.4.

b. Verify that the helium gas pressure regulator is set to the appropriate pressure.

c. Open the helium gas supply valve to purge the gas lines of air.

d. Deleted.

e. If necessary, slowly open the helium supply valve and increase the Cool-Down System pressure. Close the helium supply valve.

f. Start the gas coolers.

g. Open the vent and drain port caps using the RVOAs.

h. Start the blower and monitor the gas exit temperature. Continue the fuel cool-down operations until the gas exit temperature meets the requirements.

Note:
Water filling should commence immediately at the completion of fuel cool-down operations to prevent fuel assembly heat-up. Prepare the water fill line and the vent line in advance of water filling.

i. Prepare the MPC fill and vent lines as shown on Figure 8.1.20. Route the vent port line several feet below the spent fuel pool surface or to the radwaste gas facility. Turn off the blower and disconnect the gas lines to the vent and drain port RVOAs. Attach the vent line to the MPC vent port and slowly open the vent line valve to depressurize the MPC.

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Note:
When unloading MPCs requiring soluble boron, the boron concentration of the water shall be checked in accordance with Tables 2.1.14 and 2.1.16 before and during operations with fuel and water in the MPC.

j. Attach the water fill line to the MPC drain port and slowly open the water supply valve and establish a pressure less than 90 psi. (Refer to Tables 2.1.14 and 2.1.16 for boron concentration requirements). Fill the MPC until bubbling from the vent line has terminated. Close the water supply valve on completion.

k. *Deleted.*~~If used, cease operation of the SCS and remove the system from the HI-TRAC.~~

Caution:

Oxidation of Boral panels contained in the MPC may create hydrogen gas while the MPC is filled with water. Appropriate monitoring for combustible gas concentrations shall be performed prior to, and during MPC lid cutting operations. The space below the MPC lid shall be exhausted or purged with inert gas prior to, and during MPC lid cutting operations to provide additional assurance that flammable gas concentrations will not develop in this space.

l. Disconnect both lines from the drain and vent ports leaving the drain port cap open to allow for thermal expansion of the water during MPC lid weld removal.

m. Connect a combustible gas monitor to the MPC vent port and check for combustible gas concentrations prior to and periodically during weld removal activities. Purge or evacuate the gas space under the lid as necessary

n. Remove the MPC lid-to-shell weld using the weld removal system. See Figure 8.1.9 for rigging.

o. Vacuum the top surfaces of the MPC and HI-TRAC to remove any metal shavings.

9. Install the inflatable annulus seal as follows:

Caution:
Do not use any sharp tools or instruments to install the inflatable seal.

a. Remove the annulus shield.

b. Manually insert the inflatable seal around the MPC. See Figure 8.1.13.

c. Ensure that the seal is uniformly positioned in the annulus area.

d. Inflate the seal

e. Visually inspect the seal to ensure that it is properly seated in the annulus. Deflate, adjust and inflate the seal as necessary.

10. Place HI-TRAC in the spent fuel pool as follows:

a. If necessary for plant weight limitations, drain the water from the neutron shield jacket.

b. Engage the lift yoke to HI-TRAC lifting trunnions, remove the MPC lid lifting hole plugs and attach the MPC lid slings or lid retention system to the MPC lid.

c. If the lid retention system is used, inspect the lid bolts for general condition. Replace worn or damaged bolts with new bolts.

d. Install the lid retention system bolts if the lid retention system is used.

ALARA Note:
The optional Annulus Overpressure System is used to provide further protection against MPC external shell contamination during in-pool operations.

e. If used, fill the annulus overpressure system lines and reservoir with demineralized water and close the reservoir valve. Attach the annulus overpressure system to the HI-TRAC. See Figure 8.1.14.

f. Position HI-TRAC over the cask loading area with the basket aligned to the orientation of the spent fuel racks.

ALARA Note:
Wetting the components that enter the spent fuel pool may reduce the amount of decontamination work to be performed later.

g. Wet the surfaces of HI-TRAC and lift yoke with plant demineralized water while slowly lowering HI-TRAC into the spent fuel pool.

h. When the top of the HI-TRAC reaches the elevation of the reservoir, open the annulus overpressure system reservoir valve. Maintain the reservoir water level at approximately 3/4 full the entire time the cask is in the spent fuel pool.

i. If the lid retention system is used, remove the lid retention bolts when the top of HI-TRAC is accessible from the operating floor.

j. Place HI-TRAC on the floor of the cask loading area and disengage the lift yoke. Visually verify that the lift yoke is fully disengaged.

k. Apply slight tension to the lift yoke and visually verify proper disengagement of the lift yoke from the trunnions.

l. Remove the lift yoke, MPC lid and drain line from the pool in accordance with directions from the site's Radiation Protection personnel. Spray the equipment with demineralized water as they are removed from the pool.

m. Disconnect the drain line from the MPC lid.

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n. Store the MPC lid components in an approved location. Disengage the lift yoke from MPC lid. Remove any upper fuel spacers using the same process as was used in the installation.

o. Disconnect the lid retention system if used.

8.3.4 MPC Unloading

1. Remove the spent fuel assemblies from the MPC using applicable site procedures.

2. Vacuum the cells of the MPC to remove any debris or corrosion products.

3. Inspect the open cells for presence of any remaining items. Remove them as appropriate.

8.3.5 Post-Unloading Operations

1. Remove HI-TRAC and the unloaded MPC from the spent fuel pool as follows:

a. Engage the lift yoke to the top trunnions.

b. Apply slight tension to the lift yoke and visually verify proper engagement of the lift yoke to the trunnions.

c. Raise HI-TRAC until HI-TRAC flange is at the surface of the spent fuel pool.

ALARA Warning:
Activated debris may have settled on the top face of HI-TRAC during fuel unloading.

d. Measure the dose rates at the top of HI-TRAC in accordance with plant radiological procedures and flush or wash the top surfaces to remove any highly-radioactive particles.

e. Raise the top of HI-TRAC and MPC to the level of the spent fuel pool deck.

f. Close the annulus overpressure system reservoir valve.

g. Using a water pump, lower the water level in the MPC approximately 12 inches to prevent splashing during cask movement.

ALARA Note:
To reduce contamination of HI-TRAC, the surfaces of HI-TRAC and lift yoke should be kept wet until decontamination can begin.

h. Remove HI-TRAC from the spent fuel pool while spraying the surfaces with plant demineralized water.

i. Disconnect the annulus overpressure system from the HI-TRAC via the quick disconnect.

j. Place HI-TRAC in the designated preparation area.

k. Disengage the lift yoke.

l. Perform decontamination on HI-TRAC and the lift yoke.

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2. Carefully decontaminate the area above the inflatable seal. Deflate, remove, and store the seal in an approved plant storage location.
3. Using a water pump, pump the remaining water in the MPC to the spent fuel pool or liquid radwaste system.
4. Drain the water in the annulus area by connecting the drain line to the HI-TRAC drain connector.
5. Remove the MPC from HI-TRAC and decontaminate the MPC as necessary.
6. Decontaminate HI-TRAC.
7. Remove the bolt plugs and/or waterproof tape from HI-TRAC top bolt holes.
8. Return any HI-STORM 100 equipment to storage as necessary.

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CHAPTER 11[†]: ACCIDENT ANALYSIS

This chapter presents the evaluation of the HI-STORM 100 System for the effects of off-normal and postulated accident conditions. The design basis off-normal and postulated accident events, including those resulting from mechanistic and non-mechanistic causes as well as those caused by natural phenomena, are identified in Subsections 2.2.2 and 2.2.3. For each postulated event, the event cause, means of detection, consequences, and corrective action are discussed and evaluated. As applicable, the evaluation of consequences includes structural, thermal, shielding, criticality, confinement, and radiation protection evaluations for the effects of each design event.

The structural, thermal, shielding, criticality, and confinement features and performance of the HI-STORM 100 System are discussed in Chapters 3, 4, 5, 6, and 7. The evaluations provided in this chapter are based on the design features and evaluations described therein.

Chapter 11 is in full compliance with NUREG-1536; no exceptions are taken.

11.1 OFF-NORMAL CONDITIONS

Off-normal operations, as defined in accordance with ANSI/ANS-57.9, are those conditions, which, although not occurring regularly, are expected to occur no more than once a year. In this section, design events pertaining to off-normal operation for expected operational occurrences are considered. The off-normal conditions are listed in Subsection 2.2.2.

The following off-normal operation events have been considered in the design of the HI-STORM 100:

Off-Normal Pressure
Off-Normal Environmental Temperature
Leakage of One MPC Seal Weld
Partial Blockage of Air Inlets
Off-Normal Handling of HI-TRAC Transfer Cask
Malfunction of FHD System
~~*SCS Power Failure*~~
Off-Normal Loads[‡]

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† *This chapter has been prepared in the format and section organization set forth in Regulatory Guide 3.61. However, the material content of this chapter also fulfills the requirements of NUREG-1536. Pagination and numbering of sections, figures, and tables are consistent with the convention set down in Chapter 1, Section 1.0, herein. Finally, all terms-of-art used in this chapter are consistent with the terminology of the glossary (Table 1.0.1). This chapter has been substantially revised in support of LAR#3 to enhance clarity of presentation and evaluation of results. Because of extensive editing a clean chapter is issued with this amendment.*

‡ *Off-normal load combinations are defined in Chapter 2, Table 2.2.14 and evaluated in Chapter 3, Section 3.4.*

For each event, the postulated cause of the event, detection of the event, analysis of the event effects and consequences, corrective actions, and radiological impact from the event are presented.

The results of the evaluations performed herein demonstrate that the HI-STORM 100 System can withstand the effects of off-normal events without affecting function, and are in compliance with the applicable acceptance criteria. The following subsections present the evaluation of the HI-STORM 100 System for the design basis off-normal conditions that demonstrate that the requirements of 10CFR72.122 are satisfied, and that the corresponding radiation doses satisfy the requirements of 10CFR72.104(a) and 10CFR20.

11.1.1 Off-Normal Pressures

The sole pressure boundary in the HI-STORM 100 System is the MPC enclosure vessel. The off-normal pressure condition is specified in Subsection 2.2.2. The off-normal pressure for the MPC internal cavity is a function of the initial helium fill pressure and the temperature reached within the MPC cavity under normal storage. The MPC internal pressure is evaluated with 10% of the fuel rods ruptured and 100% of the rods fill gas and 30% of the fission gases released to the cavity.

11.1.1.1 Postulated Cause of Off-Normal Pressure

After fuel assembly loading, the MPC is drained, dried, and backfilled with an inert gas (helium) to assure long-term fuel cladding integrity during dry storage. Therefore, the probability of failure of intact fuel rods in dry storage is low. Nonetheless, the event is postulated and evaluated.

11.1.1.2 Detection of Off-Normal Pressure

The HI-STORM 100 System is designed to withstand the MPC off-normal internal pressure without any effects on its ability to meet its safety requirements. There is no requirement for detection of off-normal pressure and, therefore, no monitoring is required.

11.1.1.3 Analysis of Effects and Consequences of Off-Normal Pressure

The MPC off normal internal pressure is reported in Subsection 4.6.1 for the following conditions: limiting fuel storage scenario, tech. spec. maximum helium backfill and 10% rod rupture with 100% of rod fill gas and 30% of gaseous fission products released into the MPC cavity. The analysis shows that the MPC pressure remains below the design MPC internal pressure (Table 2.2.1).

It should be noted that this bounding temperature rise does not take any credit for the increase in thermosiphon action that would accompany the pressure increase that results from both the temperature rise and the addition of the gaseous fission products to the MPC cavity. As any such increase in thermosiphon action would decrease the temperature rise, the calculated pressure is higher than would actually occur.

Structural

The structural evaluation of the MPC enclosure vessel for off-normal internal pressure conditions is discussed in Section 3.4. The stresses resulting from the off-normal pressure are confirmed to be bounded by the applicable pressure boundary stress limits.

Thermal

The MPC internal pressure for off-normal conditions is reported in Subsection 4.6.1. The design basis internal pressure for off-normal conditions used in the structural evaluation (Table 2.2.1) bounds the off-normal condition pressure. .

Shielding

There is no effect on the shielding performance of the system as a result of this off-normal event.

Criticality

There is no effect on the criticality control features of the system as a result of this off-normal event.

Confinement

There is no effect on the confinement function of the MPC as a result of this off-normal event. As discussed in the structural evaluation above, all stresses remain within allowable values, assuring confinement boundary integrity.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this off-normal event.

Based on this evaluation, it is concluded that the off-normal pressure does not affect the safe operation of the HI-STORM 100 System.

11.1.1.4 Corrective Action for Off-Normal Pressure

The HI-STORM 100 System is designed to withstand the off-normal pressure without any effects on its ability to maintain safe storage conditions. There is no corrective action requirement for off-normal pressure.

11.1.1.5 Radiological Impact of Off-Normal Pressure

The event of off-normal pressure has no radiological impact because the confinement barrier and shielding integrity are not affected.

11.1.2 Off-Normal Environmental Temperatures

The HI-STORM 100 System is designed for use at any site in the United States. Off-normal environmental temperatures of -40 to 100°F (HI-STORM overpack) and 0 to 100°F (HI-TRAC transfer cask) have been conservatively selected to bound off-normal temperatures at these sites. The off-normal temperature range affects the entire HI-STORM 100 System and must be evaluated against the allowable component design temperatures. The off-normal temperatures are evaluated against the off-normal condition temperature limits listed in Table 2.2.3.

11.1.2.1 Postulated Cause of Off-Normal Environmental Temperatures

The off-normal environmental temperature is postulated as a constant ambient temperature caused by extreme weather conditions. To determine the effects of the off-normal temperatures, it is conservatively assumed that these temperatures persist for a sufficient duration to allow the HI-STORM 100 System to achieve thermal equilibrium. Because of the large mass of the HI-STORM 100 System with its corresponding large thermal inertia and the limited duration for the off-normal temperatures, this assumption is conservative.

11.1.2.2 Detection of Off-Normal Environmental Temperatures

The HI-STORM 100 System is designed to withstand the off-normal environmental temperatures without any effects on its ability to maintain safe storage conditions. There is no requirement for detection of off-normal environmental temperatures for the HI-STORM overpack and MPC. Chapter 2 provides operational limitations to the use of the HI-TRAC transfer cask at temperatures of ≤32°F and prohibits use of the HI-TRAC transfer cask below 0°F.

11.1.2.3 Analysis of Effects and Consequences of Off-Normal Environmental Temperatures

The off-normal event considers an environmental temperature of 100°F with insolation for a duration sufficient to reach thermal equilibrium. The evaluation is performed for a limiting fuel storage configuration. The Off-Normal ambient temperature condition is evaluated in Subsection 4.6.1. The results are in compliance with off-normal temperature and pressure limits in Tables 2.2.1 and 2.2.3.

The off-normal event considering an environmental temperature of -40°F and no solar insolation for a duration sufficient to reach thermal equilibrium is evaluated with respect to material design temperatures of the HI-STORM overpack. The HI-STORM overpack and MPC are conservatively assumed to reach -40°F throughout the structure. The minimum off-normal environmental temperature specified for the HI-TRAC transfer cask is 0°F and the HI-TRAC is conservatively assumed to reach 0°F throughout the structure. For ambient temperatures from 0° to 32°F, antifreeze must be added to the demineralized water in the water jacket to prevent freezing. Chapter 3, Subsection 3.1.2, details the structural analysis and testing performed to assure prevention of brittle fracture failure of the HI-STORM 100 System.

Structural

The effect on the MPC for the upper off-normal thermal conditions (i.e., 100 °F) is an increase in the internal pressure. As shown in Subsection 4.6.1, the resultant pressure is below the off-normal design pressure (Table 2.2.1). The effect of the lower off-normal thermal conditions (i.e., -40 °F) requires an evaluation of the potential for brittle fracture. Such an evaluation is presented in Subsection 3.1.2.

Thermal

The resulting off-normal system and fuel assembly cladding temperatures for the hot conditions are provided in Subsection 4.6.1 for the HI-STORM overpack and MPC. As can be seen from this table, all temperatures for the off-normal environmental temperatures event are within the allowable values for off-normal conditions listed in Table 2.2.3.

Shielding

There is no effect on the shielding performance of the system as a result of this off-normal event.

Criticality

There is no effect on the criticality control features of the system as a result of this off-normal event.

Confinement

There is no effect on the confinement function of the MPC as a result of this off-normal event.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this off-normal event.

Based on this evaluation, it is concluded that the specified off-normal environmental temperatures do not affect the safe operation of the HI-STORM 100 System.

11.1.2.4 Corrective Action for Off-Normal Environmental Temperatures

The HI-STORM 100 System is designed to withstand the off-normal environmental temperatures without any effects on its ability to maintain safe storage conditions. There are no corrective actions required for off-normal environmental temperatures.

11.1.2.5 Radiological Impact of Off-Normal Environmental Temperatures

Off-normal environmental temperatures have no radiological impact, as the confinement barrier and shielding integrity are not affected.

11.1.3 Leakage of One Seal

The HI-STORM 100 System has a reliable welded boundary to contain radioactive fission products within the confinement boundary. The radioactivity confinement boundary is defined by the MPC shell, baseplate, MPC lid, vent and drain port cover plates, and associated welds. The closure ring provides a redundant welded closure to the release of radioactive material from the MPC cavity through the field-welded MPC lid closures. Confinement boundary welds are inspected by radiography or ultrasonic examination except for field welds that are examined by the liquid penetrant method on the root (for multi-pass welds) and final pass, at a minimum. Field welds are performed on the MPC lid, the MPC vent and drain port covers, and the MPC closure ring. The welds on the vent and drain port cover plates are leakage tested. Additionally, the MPC lid weld is subjected to a pressure test to verify its integrity.

Section 7.1 provides a discussion as to how the MPC design, welding, testing and inspection requirements meet the guidance of ISG-18 such that leakage from the confinement boundary may be considered non-credible.

11.1.3.1 Postulated Cause of Leakage of One Seal in the Confinement Boundary

There is no credible cause for the leakage of one seal in the confinement boundary. The conditions analyzed in Chapter 3 shows that the confinement boundary components are maintained within their Code-allowable stress limits under all normal and off-normal storage conditions. The MPC lid-to-shell weld meets the requirements of ISG-18, such that leakage from the confinement boundary is not considered credible. Therefore, there is no event that could cause leakage of one seal in the confinement boundary.

11.1.3.2 Detection of Leakage of One Seal in the Confinement Boundary

The HI-STORM 100 System is designed such that leakage of one ~~field weld~~ seal in the confinement boundary is not considered a credible scenario. Therefore, there is no requirement to detect leakage from one seal.

11.1.3.3 Corrective Action for Leakage of One Seal in the Confinement Boundary

There is no corrective action required for the failure of one weld in the closure system of the confinement boundary. Leakage of one weld in the confinement boundary closure system is not a credible event.

11.1.3.4 Radiological Impact of Leakage of One Seal in the Confinement Boundary

The off-normal event of the failure of one weld in the confinement boundary closure system has no radiological impact because leakage from the confinement barrier is not credible.

11.1.4 Partial Blockage of Air Inlets

The HI-STORM 100 System is designed with debris screens on the inlet and outlet air ducts. These screens ensure the air ducts are protected from the incursion of foreign objects. There are four air inlet ducts 90° apart and it is highly unlikely that blowing debris during normal or off-normal operation could block all air inlet ducts. As required by the design criteria presented in Chapter 2, it is conservatively assumed that two of the four air inlet ducts are blocked. The blocked air inlet ducts are assumed to be completely blocked with an ambient temperature of 80°F (Table 2.2.2), full solar insolation, and maximum SNF decay heat values. This condition is analyzed to demonstrate the inherent thermal stability of the HI-STORM 100 System.

11.1.4.1 Postulated Cause of Partial Blockage of Air Inlets

It is conservatively assumed that the blocked air inlet ducts are completely blocked, although screens prevent foreign objects from entering the ducts. The screens are either inspected periodically or the outlet duct air temperature is monitored. It is, however, possible that blowing debris may block two air inlet ducts of the overpack.

11.1.4.2 Detection of Partial Blockage of Air Inlets

The detection of the partial blockage of air inlet ducts will occur during the routine visual inspection of the screens or temperature monitoring of the outlet duct air. The frequency of inspection is based on an assumed complete blockage of all four air inlet ducts. There is no inspection requirement as a result of the postulated two inlet duct blockage, because the complete blockage of all four air inlet ducts is bounding.

11.1.4.3 Analysis of Effects and Consequences of Partial Blockage of Air Inlets

Structural

There are no structural consequences as a result of this off-normal event.

Thermal

The thermal analysis for the two air inlet ducts blocked off-normal condition is performed in Subsection 4.6.1. The analysis demonstrates that under bounding (steady-state) conditions, no system components exceed the off-normal temperature limits in Table 2.2.3.

Shielding

There is no effect on the shielding performance of the system as a result of this off-normal event.

Criticality

There is no effect on the criticality control features of the system as a result of this off-normal event.

Confinement

There is no effect on the confinement function of the MPC as a result of this off-normal event.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this off-normal event.

Based on this evaluation, it is concluded that the specified off-normal partial blockage of air inlet ducts event does not affect the safe operation of the HI-STORM 100 System.

11.1.4.4 Corrective Action for Partial Blockage of Air Inlets

The corrective action for the partial blockage of air inlet ducts is the removal, cleaning, and replacement of the affected mesh screens. After clearing of the blockage, the storage module temperatures will return to the normal temperatures reported in Chapter 4. Partial blockage of air inlet ducts does not affect the HI-STORM 100 System's ability to operate safely.

Periodic inspection of the HI-STORM overpack air duct screens is required. Alternatively, the outlet duct air temperature is monitored. The frequency of inspection is based on an assumed blockage of all four air inlet ducts analyzed in Section 11.2.

11.1.4.5 Radiological Impact of Partial Blockage of Air Inlets

The off-normal event of partial blockage of the air inlet ducts has no radiological impact because the confinement barrier is not breached and shielding is not affected.

11.1.5 Off-Normal Handling of HI-TRAC

During upending and/or downending of the HI-TRAC transfer cask, the total lifted weight is distributed among both the upper lifting trunnions and the lower pocket trunnions. Each of the four trunnions on the HI-TRAC therefore supports approximately one-quarter of the total weight. This even distribution of the load would continue during the entire rotation operation.

If the lifting device is allowed to "go slack", the total weight would be applied to the lower pocket trunnions only. Under this off-normal condition, the pocket trunnions would each be required to

support one-half of the total weight, doubling the load per trunnion. This condition is analyzed to demonstrate that the pocket trunnions possess sufficient strength to support the increased load under this off-normal condition.

This off-normal condition does not apply to the HI-TRAC 125D, which does not have lower pocket trunnions. Upending and downending of the HI-TRAC 125D is performed using an L-frame.

11.1.5.1 Postulated Cause of Off-Normal Handling of HI-TRAC

If the cable of the crane handling the HI-TRAC is inclined from the vertical, it would possible to unload the upper lifting trunnions such that the lower pocket trunnions are supporting the total cask weight and the lifting trunnions are only preventing cask rotation.

11.1.5.2 Detection of Off-Normal Handling of HI-TRAC

Handling procedures and standard rigging practice call for maintaining the crane cable in a vertical position by keeping the crane trolley centered over the lifting trunnions. In such an orientation it is not possible to completely unload the lifting trunnions without inducing rotation. If the crane cable were inclined from the vertical, however, the possibility of unloading the lifting trunnions would exist. It is therefore possible to detect the potential for this off-normal condition by monitoring the incline of the crane cable with respect to the vertical.

11.1.5.3 Analysis of Effects and Consequences of Off-Normal Handling of HI-TRAC

If the upper lifting trunnions are unloaded, the lower pocket trunnions will support the total weight of the loaded HI-TRAC. The analysis of the pocket trunnions to support the applied load of one-half of the total weight is provided in Subsection 3.4.4. The consequence of off-normal handling of the HI-TRAC is that the pocket trunnions safely support the applied load.

Structural

The stress evaluations of the lower pocket trunnions are discussed in Subsection 3.4.4. All stresses are within the allowable values.

Thermal

There is no effect on the thermal performance of the system as a result of this off-normal event.

Shielding

There is no effect on the shielding performance of the system as a result of this off-normal event.

Criticality

There is no effect on the criticality control features of the system as a result of this off-normal event.

Confinement

There is no effect on the confinement function of the MPC as a result of this off-normal event.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this off-normal event.

Based on this evaluation, it is concluded that the specified off-normal handling of the HI-TRAC does not affect the safe operation of the system.

11.1.5.4 Corrective Action for Off-Normal Handling of HI-TRAC

The HI-TRAC transfer casks are designed to withstand the off-normal handling condition without any adverse effects. There are no corrective actions required for off-normal handling of HI-TRAC other than to attempt to maintain the crane cable vertical during HI-TRAC upending or downending.

11.1.5.5 Radiological Consequences of Off-Normal Handling of HI-TRAC

The off-normal event of off-normal handling of HI-TRAC has no radiological impact because the confinement barrier is not breached and shielding is not affected.

11.1.6 Malfunction of FHD System

The FHD system is a forced helium circulation device used to effectuate moisture removal from loaded MPCs. For circulating helium, the FHD system is equipped with active components requiring external power for normal operation.

11.1.6.1 Postulated Cause of FHD Malfunction

Likely causes of FHD malfunction are (i) a loss of external power to the FHD System and (ii) an active component trip. In both cases a stoppage of forced helium circulation occurs. Such a circulation stoppage does not result in any helium leakage from the MPC or the FHD itself.

11.1.6.2 Detection of FHD Malfunction

The FHD System is monitored during its operation. An FHD malfunction is detected by operator response to control panel visual displays and alarms.

11.1.6.3 Analysis of Effects and Consequences of FHD Malfunction

Structural

The FHD System is required to be equipped with safety relief devices§ to prevent the MPC structural boundary pressures from exceeding the design limits. Consequently there is no adverse effect.

Thermal

Malfunction of the FHD System is categorized as an off-normal condition, for which the applicable peak cladding temperature limit is 1058°F (Table 2.2.3). The FHD System malfunction event is evaluated assuming the following bounding conditions:

1) *Steady state maximum temperatures have been reached*
2) *Design basis heat load*
3) *Standing column of air in the annulus*
4) *MPCs backfilled with the minimum helium pressure required by the Technical Specifications*

It is noted that operator action may be required to raise the helium regulator set point to ensure that condition 4 above is satisfied. These conditions are the same as for the normal on-site transfer in a vertically oriented HI-TRAC, discussed in Section 4.5. The steady state results are provided in Table 4.5.4. The results demonstrate that the peak fuel cladding temperatures remain below the limit in the event of a prolonged unavailability of the FHD system.

Shielding

There is no effect on the shielding performance of the system as a result of this off-normal event.

Criticality

There is no effect on the criticality control of the system as a result of this off-normal event.

Confinement

There is no effect on the confinement function of the MPC as a result of this off-normal event. As discussed in the structural evaluation above, the structural boundary pressures cannot exceed the design limits.

§ *The relief pressure is below the off-normal design pressure (Table 2.2.1) to prevent MPC overpressure and above 7 atm to enable MPC pressurization for adequate heat transfer.*

Radiation Protection

As there is no adverse effect on the shielding or confinement functions, there is no effect on occupational or public exposures as a result of this off-normal event.

Based on this evaluation, it is concluded that the FHD malfunction does not affect the safe operation of the HI-STORM 100 System.

11.1.6.4 Corrective Action for FHD Malfunction

The HI-STORM 100 System is designed to withstand the FHD malfunction without an adverse effect on its safety functions. Consequently no corrective action is required.

11.1.6.5 Radiological Impact of FHD Malfunction

The event has no radiological impact because the confinement barrier and shielding integrity are not affected.

11.1.7 deleted~~SCS Power Failure~~

~~*The SCS system is a forced fluid circulation device used to provide supplemental HI-TRAC cooling. For fluid circulation, the SCS system is equipped with active components requiring power for normal operation.*~~

~~*11.1.7.1 Postulated Cause of SCS Power Failure*~~

~~*The SCS is normally operated from an external source of power such as from site utilities or a feed from a heavy haul vehicle carrying the HI-TRAC. Occasional interruption in power supply is possible.*~~

~~*11.1.7.2 Detection of SCS Power Failure*~~

~~*The HI-STORM 100 System is designed to withstand a power failure without affecting its ability to meet safety requirements. Consequently SCS monitoring and failure detection is not required.*~~

~~*11.1.7.3 Analysis of Effects and Consequences of SCS Power Failure*~~

~~*The SCS System is required to be equipped with a backup power supply (See SCS specifications in Chapter 2, Appendix 2.C). This ensures uninterrupted operation of the SCS following a power failure. Consequently, a power failure does not effect SCS operation.*~~

~~*Structural*~~

~~*There is no effect on the structural integrity.*~~

~~*Thermal*~~

~~*There is no effect on thermal performance.*~~

~~*Shielding*~~

~~*There is no effect on the shielding performance.*~~

~~*Criticality*~~

~~*There is no effect on the criticality control.*~~

~~*Confinement*~~

~~*There is no effect on the confinement function.*~~

~~*Radiation Protection*~~

~~*As there is no effect on the shielding or confinement functions, there is no effect on occupational or public exposures.*~~

~~*Based on this evaluation, it is concluded that the SCS failure does not affect the safe operation of the HI-STORM 100 System.*~~

~~*11.1.7.4 Corrective Action for SCS Power Failure*~~

~~*The HI-STORM 100 System is designed to withstand a power failure without an adverse effect on its normal operation. Consequently no corrective action is required.*~~

~~*11.1.7.5 Radiological Impact of SCS Power Failure*~~

~~*The event has no radiological impact because the confinement barrier and shielding integrity are not affected.*~~

11.2 ACCIDENTS

Accidents, in accordance with ANSI/ANS-57.9, are either infrequent events that could reasonably be expected to occur during the lifetime of the HI-STORM 100 System or events postulated because their consequences may affect the public health and safety. Subsection 2.2.3 defines the design basis accidents considered. By analyzing for these design basis events, safety margins inherently provided in the HI-STORM 100 System design can be quantified.

The results of the evaluations performed herein demonstrate that the HI-STORM 100 System can withstand the effects of all credible and hypothetical accident conditions and natural phenomena without affecting safety function, and are in compliance with the acceptable criteria. The following sections present the evaluation of the design basis postulated accident conditions and natural phenomena which demonstrate that the requirements of 10CFR72.122 are satisfied, and that the corresponding radiation doses satisfy the requirements of 10CFR72.106(b) and 10CFR20.

The load combinations evaluated for postulated accident conditions are defined in Table 2.2.14. The load combinations include normal loads with the accident loads. The accident load combination evaluations are provided in Section 3.4.

11.2.1 HI-TRAC Transfer Cask Handling Accident

11.2.1.1 Cause of HI-TRAC Transfer Cask Handling Accident

During the operation of the HI-STORM 100 System, the loaded HI-TRAC transfer cask is transported to the ISFSI in a vertical position. Unless the lifting device is designed in accordance with the criteria specified in Subsection 2.3.3, the height of the loaded overpack above the ground shall be limited to below the handling height limit determined in Chapter 3 to limit the inertia loading on the cask in a horizontal drop to less than 45g's. Although a handling accident is remote, a cask drop from the horizontal handling height limit is credible only if the lifting device is not designed in accordance with the criteria specified in Subsection 2.3.3. A vertical drop of the loaded HI-TRAC transfer cask is not a credible accident as the loaded HI-TRAC shall be transported and handled in the vertical orientation by devices designed in accordance with the criteria specified in Subsection 2.3.3 and a horizontal drop is precluded as HI-TRAC is transported in the vertical orientation. Nevertheless, for defense-in-depth a drop from a horizontal orientation is postulated and structural consequences evaluated. .

11.2.1.2 HI-TRAC Transfer Cask Handling Accident Analysis

The handling accident analysis evaluates the effects of dropping the loaded HI-TRAC in the horizontal position. The analysis of the handling accident is provided in Chapter 3. The analysis shows that the HI-TRAC meets all structural requirements and there is no adverse effect on the confinement, thermal or subcriticality performance of the contained MPC. Limited localized damage to the HI-TRAC water jacket shell and loss of the water in the water jacket may occur as a result of the handling accident. The HI-TRAC top lid and transfer lid housing (pool lid for the HI-TRAC 125D) are demonstrated to remain attached by withstanding the maximum deceleration. The

transfer lid doors (not applicable to HI-TRAC 125D) are also shown to remain closed during the drop. Limiting the inertia loading to 60g's or less ensures the fuel cladding remains intact based on dynamic impact effects on spent fuel assemblies in the literature [11.2.1]. Therefore, demonstrating that the 45g limit for the HI-TRAC transfer cask is met ensures that the fuel cladding remains intact.

Structural

The structural evaluation of the MPC for 45g's is provided in Section 3.4. As discussed in Section 3.4, the MPC stresses as a result of the HI-TRAC side drop, 45g loading, are all within allowable values.

As discussed above, the water jacket enclosure shell could be punctured which results in a loss of the water within the water jacket. Additionally, the HI-TRAC top lid, transfer lid (pool lid for the HI-TRAC 125D), and transfer lid doors (not applicable to HI-TRAC 125D) are shown to remain in position under the 45g loading. Analysis of the lead in the HI-TRAC is performed in Appendix 3.F and it is shown that there is no appreciable change in the lead shielding.

Thermal

The loss of the water in the water jacket causes the temperatures to increase due to a reduction in the thermal conductivity through the HI-TRAC water jacket. An analysis of the MPC in the HI-TRAC transfer cask temperatures with no water in the water jacket is presented in Subsection 4.6.2. The analysis results are below the short-term allowable fuel cladding and material temperatures limits for accident conditions.

Shielding

The assumed loss of the water in the water jacket results in an increase in the radiation dose rates at locations adjacent to the water jacket. The shielding analysis results presented in Chapter 5 demonstrate that the requirements of 10CFR72.106 are not exceeded. As the structural analysis demonstrates that the HI-TRAC top lid, transfer lid (pool lid for the HI-TRAC 125D), and transfer lid doors (not applicable to HI-TRAC 125D) remain in place, there is no change in the dose rates at the top and bottom of the HI-TRAC.

Criticality

There is no effect on the criticality control features of the system as a result of this accident event.

Confinement

There is no effect on the confinement function of the MPC as a result of this accident event. As discussed in the structural evaluation above, all stresses remain within allowable values, assuring confinement boundary integrity.

Radiation Protection

There is no degradation in the confinement capabilities of the MPC, as discussed above. There are increases in the local dose rates adjacent to the water jacket. The dose rates are provided in Chapter 5. Immediately after the drop accident a radiological inspection of the HI-TRAC will be performed and temporary shielding shall be installed to limit exposure . Based on a minimum distance to the controlled area boundary of 100 meters, the 10CFR72.106 dose rate requirements at the controlled area boundary (5 Rem limit) are not exceeded.

11.2.1.3 HI-TRAC Transfer Cask Handling Accident Dose Calculations

The handling accident could cause localized damage to the HI-TRAC water jacket shell and loss of the water in the water jacket as the neutron shield impacts the ground.

When the water jacket is impacted, the HI-TRAC transfer cask surface dose rate could increase. The HI-TRAC's post-accident shielding analysis presented in Chapter 5 assumes complete loss of the water in the water jacket and bounds the dose rates anticipated for the handling accident.

If the water jacket of the loaded HI-TRAC is damaged beyond immediate repair and the MPC is not damaged, the loaded HI-TRAC may be unloaded into a HI-STORM overpack, a HI-STAR overpack, or unloaded in the fuel pool. If the MPC is damaged, the loaded HI-TRAC must be returned to the fuel pool for unloading. Depending on the damage to the HI-TRAC and the current location in the loading or unloading sequence, personnel exposure is minimized by continuing to load the MPC into a HI-STORM or HI-STAR overpack. Once the MPC is placed in the HI-STORM or HI-STAR overpack, the dose rates are greatly reduced. The highest personnel exposure will result from returning the loaded HI-TRAC to the fuel pool to unload the MPC.

The analysis of the handling accident presented in Section 3.4 shows that the MPC confinement barrier will not be compromised and, therefore, there will be no release of radioactive material from the confinement vessel. Any possible rupture of the fuel cladding will have no effect on the site boundary dose rates because the magnitude of the radiation source has not changed.

11.2.1.4 HI-TRAC Transfer Cask Handling Accident Corrective Action

Following a handling accident, the ISFSI operator shall first perform a radiological and visual inspection to determine the extent of the damage to the HI-TRAC transfer cask and MPC to the maximum practical extent. As appropriate, place temporary shielding around the HI-TRAC to reduce radiation dose rates. Special handling procedures will be developed and approved by the ISFSI operator to lift and upright the HI-TRAC. Upon uprighting, the portion of the overpack not previously accessible shall be radiologically and visually inspected. If damage to the water jacket is limited to a local penetration or crushing, local repairs can be performed to the shell and the water replaced. If damage to the water jacket is extensive, the damage shall be repaired and re-tested in accordance with Chapter 9, following removal of the MPC.

If upon inspection of the damaged HI-TRAC transfer cask and MPC, damage of the MPC is observed, the loaded HI-TRAC transfer cask will be returned to the facility for fuel unloading in accordance with Chapter 8. The handling accident will not affect the ability to unload the MPC using normal means as the structural analysis of the 60g loading (HI-STAR Docket Numbers 71-9261 and 72-1008) shows that there will be no gross deformation of the MPC basket. After unloading, the structural damage of the HI-TRAC and MPC shall be assessed and a determination shall be made if repairs will enable the equipment to return to service. Subsequent to the repairs, the equipment shall be inspected and appropriate tests shall be performed to certify the equipment for service. If the equipment cannot be repaired and returned to service, the equipment shall be disposed of in accordance with the appropriate regulations.

11.2.2 HI-STORM Overpack Handling Accident

11.2.2.1 Cause of HI-STORM Overpack Handling Accident

During the operation of the HI-STORM 100 System, the loaded HI-STORM overpack is lifted in the vertical orientation. The height of the loaded overpack above the ground shall be limited to below the vertical handling height limit determined in Chapter 3, unless the lifting device is designed in accordance with the criteria specified in Subsection 2.3.3. This vertical handling height limit will maintain the inertial loading on the cask in a vertical drop to 45g's or less. Although a handling accident is remote, a drop from the vertical handling height limit is a credible accident if the lifting device is not designed in accordance with the criteria specified in Subsection 2.3.3.

11.2.2.2 HI-STORM Overpack Handling Accident Analysis

The handling accident analysis evaluates the effects of dropping the loaded overpack in the vertical orientation. The analysis of the handling accident is provided in Chapter 3. The analysis shows that the HI-STORM 100 System meets all structural requirements and there are no adverse effects on the structural, confinement, thermal or subcriticality performance of the HI-STORM 100 System. Limiting the inertia loading to 60g's or less ensures the fuel cladding remains intact based on dynamic impact effects on spent fuel assemblies in the literature [11.2.1].

Structural

The structural evaluation of the MPC under a 60g vertical load is presented in the HI-STAR FSAR and SAR [11.2.3 and 11.2.4] and it is demonstrated therein that the stresses are within allowable limits. The structural analysis of the HI-STORM overpack is presented in Section 3.4. The structural analysis of the overpack shows that the concrete shield attached to the underside of the overpack lid remains attached and air inlet ducts do not collapse.

Thermal

As the structural analysis demonstrates that there is no adverse effect to the MPC or overpack, there is no effect on the thermal performance of the system as a result of this event.

Shielding

As the structural analysis demonstrates that there is no adverse effect to the MPC or overpack, there is no effect on the shielding performance of the system as a result of this event.

Criticality

There is no adverse effect on the criticality control features of the system as a result of this event.

Confinement

There is no adverse effect on the confinement function of the MPC as a result of this event. As discussed in the structural evaluation above, all stresses remain within allowable values, assuring confinement boundary integrity.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this event.

Based on this evaluation, it is concluded that the vertical drop of the HI-STORM Overpack with the MPC inside does not affect the safe operation of the HI-STORM 100 System.

11.2.2.3 HI-STORM Overpack Handling Accident Dose Calculations

The vertical drop handling accident of the loaded HI-STORM overpack will not cause any change of the shielding or breach of the MPC confinement boundary. Any possible rupture of the fuel cladding will have no affect on the site boundary dose rates because the magnitude of the radiation source has not changed. Therefore, the dose calculations are equivalent to the normal condition dose rates.

11.2.2.4 HI-STORM Overpack Handling Accident Corrective Action

Following a handling accident, the ISFSI operator shall first perform a radiological and visual inspection to determine the extent of the damage to the overpack. Special handling procedures, as required, will be developed and approved by the ISFSI operator.

If upon inspection of the MPC, structural damage of the MPC is observed, the MPC is to be returned to the facility for fuel unloading in accordance with Chapter 8. After unloading, the structural damage of the MPC shall be assessed and a determination shall be made if repairs will enable the MPC to return to service. Likewise, the HI-STORM overpack shall be thoroughly inspected and a determination shall be made if repairs will enable the HI-STORM overpack to return to service. Subsequent to the repairs, the equipment shall be inspected and appropriate tests shall be performed to certify the HI-STORM 100 System for service. If the equipment cannot be repaired and returned to service, the equipment shall be disposed of in accordance with the appropriate regulations.

11.2.3 Tip-Over

11.2.3.1 Cause of Tip-Over

The analysis of the HI-STORM 100 System has shown that the overpack does not tip over as a result of the accidents (i.e., tornado missiles, flood water velocity, and seismic activity) analyzed in this section. It is highly unlikely that the overpack will tip-over during on-site movement because of the required low handling height or the use of a lifting device designed in accordance with the criteria specified in Subsection 2.3.3. The tip-over accident is stipulated as a non-mechanistic accident.

For the anchored HI-STORM designs (HI-STORM 100A and 100SA), a tip-over accident is not possible. As described in Chapter 2 of this FSAR, these system designs are not evaluated for the hypothetical tip-over. As such, the remainder of this accident discussion applies only to the non-anchored designs (i.e., the 100 and 100S designs only).

11.2.3.2 Tip-Over Analysis

The tip-over accident analysis evaluates the effects of the loaded overpack tipping-over onto a reinforced concrete pad. The tip-over analysis is provided in Section 3.4. The structural analysis provided in Appendix 3.A demonstrates that the resultant deceleration loading on the MPC as a result of the tip-over accident is less than the design basis 45g's. The analysis shows that the HI-STORM 100 System meets all structural requirements and there is no adverse effect on the structural, confinement, thermal, or subcriticality performance of the MPC. However, the side impact will cause some localized damage to the concrete and outer shell of the overpack in the radial area of impact.

Structural

The structural evaluation of the MPC presented in Section 3.4 demonstrates that under a 45g loading the stresses are well within the allowable values. Analysis presented in Chapter 3 shows that the concrete shields attached to the underside and top of the overpack lid remains attached. As a result of the tip-over accident there will be localized crushing of the concrete in the area of impact.

Thermal

The thermal analysis of the overpack and MPC is based on vertical storage. The thermal consequences of this accident while the overpack is in the horizontal orientation are bounded by the burial under debris accident evaluated in Subsection 4.6.2. Damage to the overpack will be limited as discussed above. As the structural analysis demonstrates that there is no significant change in the MPC or overpack, once the overpack and MPC are returned to their vertical orientation there is no effect on the thermal performance of the system.

Shielding

The effect on the shielding performance of the system as a result of this event is two-fold. First, there may be a localized decrease in the shielding thickness of the concrete in the body of the overpack. Second, the bottom of the overpack, which is normally facing the ground and not accessible, will now be facing the horizon. This orientation will increase the off-site dose rate. However, the dose rate limits of 10CFR72.106 are not exceeded.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event. As discussed in the structural evaluation above, all stresses remain within allowable values, assuring confinement boundary integrity.

Radiation Protection

There is no effect on occupational or public exposures from radionuclide release as a result of this accident event since the confinement boundary integrity of the MPC remains intact.

Immediately after the tip-over accident a radiological inspection of the HI-STORM will be performed and temporary shielding shall be installed to limit exposure from direct radiation. Based on a minimum distance to the controlled area boundary of 100 meters, the 10CFR72.106 dose rate requirements at the controlled area boundary (5 Rem limit) are not exceeded.

Based on this evaluation, it is concluded that the accident does not affect the safe operation of the HI-STORM 100 System.

11.2.3.3 Tip-Over Dose Calculations

The analysis of the tip-over accident has shown that the MPC confinement barrier will not be compromised and, therefore, there will be no release of radioactivity or increase in site-boundary dose rates from release of radioactivity.

The tip-over accident could cause localized damage to the radial concrete shield and outer steel shell where the overpack impacts the surface. The overpack surface dose rate in the affected area could increase due to the damage. However, there should be no noticeable increase in the ISFSI site or boundary dose rate as a result of the localized damage on the side of the overpack.

The tip-over accident will also cause a re-orientation of the bottom of the overpack. As a result, radiation leaving the bottom of the overpack, which would normally be directed into the ISFSI pad, will be directed towards the horizon and the controlled area boundary. The dose rate at 100 meters

from the bottom of the overpack, the minimum distance to the controlled area boundary, was calculated for the HI-STORM 100S Version B with an MPC-24 for an assumed accident duration of 30 days. The burnup and cooling time of the fuel was 60,000 MWD/MTU and 3 years which is consistent with the off-site dose analysis reported in Chapter 10, Table 10.4.1. This combination of overpack, MPC, burnup and cooling time is the same as that used in Chapters 5 and 10 for off-site dose calculations. The results presented below demonstrate that the regulatory requirements of 10CFR72.106 are easily met.

Distance	*Dose Rate (mrem/hr)*	*Accident Duration*	*Total Dose (mrem)*	*10CFR72.106 Limit (mrem)*
100 meters	*2.36*	*720 hours or 30 days*	*1699.2*	*5000*

11.2.3.4 *Tip-Over Accident Corrective Action*

Following a tip-over accident, the ISFSI operator shall first perform a radiological and visual inspection to determine the extent of the damage to the overpack. Special handling procedures, including the use of temporary shielding, will be developed and approved by the ISFSI operator.

If upon inspection of the MPC, structural damage of the MPC is observed, the structural damage shall be assessed and a determination shall be made if repairs will enable the MPC to return to service. If determined necessary, the MPC shall be returned to the facility for fuel unloading or transferred to either a HI-STAR or HI-STORM overpack in accordance with Chapter 8 for a duration that is determined to be appropriate. Likewise, the HI-STORM overpack shall be thoroughly inspected and a determination shall be made if repairs are required and will enable the HI-STORM overpack to return to service. Subsequent to the repairs, the equipment shall be inspected and appropriate tests shall be performed to certify the HI-STORM 100 System for service. If the equipment cannot be repaired and returned to service, the equipment shall be disposed of in accordance with the appropriate regulations.

11.2.4 *Fire Accident*

11.2.4.1 *Cause of Fire*

Although the probability of a fire accident affecting a HI-STORM 100 System during storage operations is low, a conservative fire has been assumed and analyzed. The analysis shows that the HI-STORM 100 System continues to perform its structural, confinement, thermal, and subcriticality functions.

11.2.4.2 Fire Analysis

11.2.4.2.1 Fire Analysis for HI-STORM Overpack

The possibility of a fire accident near an ISFSI is considered to be extremely remote due to an absence of combustible materials within the ISFSI and adjacent to the overpacks. The only credible concern is related to a transport vehicle fuel tank fire, causing the outer layers of the storage overpack to be heated by the incident thermal radiation and forced convection heat fluxes. The amount of combustible fuel in the on-site transporter is limited to a volume of 50 gallons.

Structural

As discussed in Section 3.4, there are no structural consequences as a result of the fire accident condition.

Thermal

Based on a conservative analysis discussed in Subsection 4.6.2, of the HI-STORM 100 System response to a hypothetical fire event, it is concluded that the fire event does not significantly affect the temperature of the MPC or contained fuel. Furthermore, the ability of the HI-STORM 100 System to cool the spent nuclear fuel within temperature limits (Table 2.2.3) during and after fire is not compromised.

Shielding

With respect to concrete damage from a fire, NUREG-1536 (4.0,V,5.b) states: "the loss of a small amount of shielding material is not expected to cause a storage system to exceed the regulatory requirements in 10 CFR 72.106 and, therefore, need not be estimated or evaluated in the SAR." Less than one-inch of the concrete (~4% of the overpack radial concrete thickness) exceeds the short-term temperature limit.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event.

Radiation Protection

Since there is a very localized reduction in shielding and no effect on the confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this accident event.

Based on this evaluation, it is concluded that the overpack fire accident does not affect the safe operation of the HI-STORM 100 System.

11.2.4.2.2 Fire Analysis for HI-TRAC Transfer Cask

To demonstrate the fuel cladding and MPC pressure boundary integrity under an exposure to a hypothetical short duration fire event during on-site handling operations, a fire accident analysis of the loaded 100-ton HI-TRAC is performed. This analysis, because of the lower mass of the 100-ton HI-TRAC, bounds the effects for the 125-ton HI-TRAC.

Structural

As discussed in Section 3.4, there are no adverse structural consequences as a result of the fire accident condition.

Thermal

As discussed in Subsection 4.6.2, the MPC internal pressure and fuel temperature increases as a result of the fire accident. The fire accident MPC internal pressure and peak fuel cladding temperature are substantially less than the accident limits for MPC internal pressure and maximum cladding temperature (Tables 2.2.1 and 2.2.3).

The thermal analysis of the MPC in the HI-TRAC transfer cask under a fire accident is performed in Subsection 4.6.2. As can be concluded from the analysis, the temperatures for fuel cladding and components are below the accident temperature limits.

Shielding

The assumed loss of all the water in the water jacket results in an increase in the radiation dose rates at locations adjacent to the water jacket. The assumed loss of all the Holtite in the 125-ton HI-TRAC lids results in an increase in the radiation dose rates at locations adjacent to the lids. The shielding evaluation presented in Chapter 5 demonstrates that the requirements of 10CFR72.106 are not exceeded.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event, since the internal pressure does not exceed the accident condition design pressure and the MPC confinement boundary temperatures do not exceed the short-term allowable temperature limits.

Radiation Protection

There is no degradation in confinement capabilities of the MPC, as discussed above. Increases in the local dose rates adjacent to the water jacket are evaluated in Chapter 5. . Immediately after the fire accident a radiological inspection of the HI-TRAC shall be performed and temporary shielding shall be installed to limit exposure. .

11.2.4.3 Fire Dose Calculations

The complete loss of the HI-TRAC neutron shield along with the water jacket shell is assumed in the shielding analysis for the post-accident analysis of the loaded HI-TRAC in Chapter 5 and bounds the determined fire accident consequences. The loaded HI-TRAC following a fire accident meets the accident dose rate requirement of 10CFR72.106.

The elevated temperatures experienced by the HI-STORM overpack concrete shield is limited to the outermost layer. Therefore, overall reduction in neutron shielding capabilities is quite small. . The slight increase in the neutron dose rate as a result of the concrete in the outer inch reaching elevated temperatures will not significantly increase the site boundary dose rate, due to the limited amount of the concrete shielding with reduced effectiveness and low site boundary dose rates. The loaded HI-STORM overpack following a fire accident meets the accident dose rate requirement of 10CFR72.106.

The analysis of the fire accident shows that the MPC confinement boundary is not compromised and therefore, there is no release of airborne radioactive materials.

11.2.4.4 Fire Accident Corrective Actions

Upon detection of a fire adjacent to a loaded HI-TRAC or HI-STORM overpack, the ISFSI operator shall take the appropriate immediate actions necessary to extinguish the fire. Fire fighting personnel should take appropriate radiological precautions, particularly with the HI-TRAC as the water jacket pressure relief valves may open with resulting water loss and increase in radiation doses. Following the termination of the fire, a visual and radiological inspection of the equipment shall be performed.

As appropriate, install temporary shielding around the HI-TRAC. Specific attention shall be taken during the inspection of the water jacket of the HI-TRAC. If damage to the HI-TRAC is limited to the loss of water in the water jacket due to the pressure increase, the water may be replaced . If damage to the HI-TRAC water jacket or HI-TRAC body is widespread and/or radiological conditions require, the HI-TRAC shall be unloaded in accordance with Chapter 8, prior to repair.

If damage to the HI-STORM storage overpack as the result of a fire event is widespread and/or as radiological conditions require, the MPC shall be removed from the HI-STORM overpack in accordance with Chapter 8. However, the thermal analysis described herein demonstrates that only the outermost layer of the radial concrete exceeds its design temperature. The HI-STORM overpack may be returned to service if there is no significant increase in the measured dose rates (i.e., the overpack's shielding effectiveness is confirmed) and if the visual inspection is satisfactory.

11.2.5 Partial Blockage of MPC Basket Vent Holes

Each MPC basket fuel cell wall has elongated vent holes at the bottom and top. The partial blockage of the MPC basket vent holes analyzes the effects on the HI-STORM 100 System due to the restriction of the vent openings.

11.2.5.1 Cause of Partial Blockage of MPC Basket Vent Holes

After the MPC is loaded with spent nuclear fuel, the MPC cavity is drained, dried, and backfilled with helium. There are only two possible sources of material that could block the MPC basket vent holes. These are the fuel cladding/fuel pellets and crud. Due to the maintenance of relatively low cladding temperatures during storage, it is not credible that the fuel cladding would rupture, and that fuel cladding and fuel pellets would fall to block the basket vent holes. It is conceivable that a percentage of the crud deposited on the fuel rods may fall off of the fuel assembly and deposit at the bottom of the MPC.

Helium in the MPC cavity provides an inert atmosphere for storage of the fuel. The HI-STORM 100 System maintains the peak fuel cladding temperature below the required long-term storage limits. All credible accidents do not cause the fuel assembly to experience an inertia loading greater than 60g's. Therefore, there is no mechanism for the extensive rupture of spent fuel rod cladding.

Crud can be made up of two types of layers, loosely adherent and tightly adherent. The SNF assembly movement from the fuel racks to the MPC may cause a portion of the loosely adherent crud to fall away. The tightly adherent crud is not removed during ordinary fuel handling operations. The MPC basket vent holes that act as the bottom plenum for the MPC internal thermosiphon are of an elongated, semi-circular design to ensure that the flow passages will remain open under a hypothetical shedding of the crud on the fuel rods. For conservatism, only the minimum semi-circular hole area is credited in the thermal models (i.e., the elongated portion of the hole is completely neglected).

The amount of crud on fuel assemblies varies greatly from plant to plant. Typically, BWR plants have more crud than PWR plants. Based on the maximum expected crud volume per fuel assembly provided in reference [11.2.2], and the area at the base of the MPC basket fuel storage cell, the maximum depth of crud at the bottom of the MPC-68 was determined. For the PWR-style MPC designs , 90% of the maximum crud volume was used to determine the crud depth. The maximum crud depths for each of the MPCs is listed in Table 2.2.8. The maximum amount of crud was assumed to be present on all fuel assemblies within the MPC. Both the tightly and loosely adherent crud was conservatively assumed to fall off of the fuel assembly. As can be seen by the values listed in the table, the maximum amount of crud depth does not block the MPC basket vent holes as the crud accumulation depth is less than the elongation of the vent holes. Therefore, the available vent holes area is greater than that used in the thermal models.

11.2.5.2 Partial Blockage of MPC Basket Vent Hole Analysis

The partial blockage of the MPC basket vent holes has no affect on the structural, confinement and thermal analysis of the MPC. There is no affect on the shielding analysis other than a slight increase of the gamma radiation dose rate at the base of the MPC due to the accumulation of crud. As the MPC basket vent holes are not completely blocked, preferential flooding of the MPC fuel basket is not possible, and, therefore, the criticality analyses are not affected.

Structural

There are no structural consequences as a result of this event.

Thermal

There is no effect on the thermal performance of the system as a result of this event.

Shielding

There is no effect on the shielding performance of the system as a result of this accident event.

Criticality

There is no effect on the criticality control features of the system as a result of this accident event.

Confinement

There is no effect on the confinement function of the MPC as a result of this accident event.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this accident event.

Based on this evaluation, it is concluded that the partial blockage of MPC vent holes does not affect the safe operation of the HI-STORM 100 System.

11.2.5.3 Partial Blockage of MPC Basket Vent Holes Dose Calculations

Partial blockage of basket vent holes will not result in a compromise of the confinement boundary. Therefore, there will be no effect on the site boundary dose rates because the magnitude of the radiation source has not changed. There will be no radioactive material release.

11.2.5.4 Partial Blockage of MPC Basket Vent Holes Corrective Action

There are no consequences that exceed normal storage conditions. No corrective action is required for the partial blockage of the MPC basket vent holes.

11.2.6 Tornado

11.2.6.1 Cause of Tornado

The HI-STORM 100 System will be stored on an unsheltered ISFSI concrete pad and subject to environmental conditions. Additionally, the transfer of the MPC from the HI-TRAC transfer cask to the overpack may be performed at the unsheltered ISFSI concrete pad. It is possible that the HI-STORM System (storage overpack and HI-TRAC transfer cask) may experience the extreme environmental conditions of a tornado.

11.2.6.2 Tornado Analysis

The tornado accident has two effects on the HI-STORM 100 System. The tornado winds and/or tornado missile attempt to tip-over the loaded overpack or HI-TRAC transfer cask. The pressure loading of the high velocity winds and/or the impact of the large tornado missiles act to apply an overturning moment. The second effect is tornado missiles propelled by high velocity winds, which attempt to penetrate the storage overpack or HI-TRAC transfer cask.

During handling operations at the ISFSI pad, the loaded HI-TRAC transfer cask, while in the vertical orientation, shall be attached to a lifting device designed in accordance with the requirements specified in Subsection 2.3.3. Therefore, it is not credible that the tornado missile and/or wind could tip-over the loaded HI-TRAC while being handled in the vertical orientation. During handling of the loaded HI-TRAC in the horizontal orientation, it is possible that the tornado missile and/or wind may cause the rollover of the loaded HI-TRAC on the transport vehicle unless the lifting device is designed in accordance with the requirements specified in Subsection 2.3.3. The horizontal drop handling accident for the loaded HI-TRAC, Subsection 11.2.1, evaluates the consequences of the loaded HI-TRAC falling from the horizontal handling height limit and consequently this bounds the effect of the roll-over of the loaded HI-TRAC on the transport vehicle.

Structural

Section 3.4 provides the analysis of the pressure loading which attempts to tip-over the storage overpack and the analysis of the effects of the different types of tornado missiles. These analyses show that the loaded storage overpack does not tip-over as a result of the tornado winds and/or tornado missiles.

Analyses provided in Section 3.4 also shows that the tornado missiles do not penetrate the storage overpack or HI-TRAC transfer cask to impact the MPC. The result of the tornado missile impact on the storage overpack or HI-TRAC transfer cask is limited to damage of the shielding.

Thermal

The thermal consequences are evaluated in Subsection 11.2.1.

Shielding

The loss of the water in the water jacket results in an increase in the radiation dose rates at locations adjacent to the water jacket. The shielding analysis results presented in Chapter 5 demonstrate that the requirements of 10CFR72.106 are not exceeded.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event.

Radiation Protection

There is no degradation in confinement capabilities of the MPC, since the tornado missiles do not impact the MPC, as discussed above. Increases in the local dose rates as a result of the loss of water in the HI-TRAC water jacket are evaluated in Chapter 5. Immediately after the tornado accident a radiological inspection of the HI-TRAC shall be performed and temporary shielding shall be installed to limit the exposure to the public.

11.2.6.3 Tornado Dose Calculations

The tornado winds do not tip-over the loaded storage overpack; damage the shielding materials of the overpack or HI-TRAC; or damage the MPC confinement boundary. There is no affect on the radiation dose as a result of the tornado winds. A tornado missile may cause localized damage in the concrete radial shielding of the storage overpack. However, the damage will have a negligible effect on the site boundary dose. A tornado missile may penetrate the HI-TRAC water jacket shell causing the loss of the neutron shielding (water). The effects of the tornado missile damage on the loaded HI-TRAC transfer cask is bounded by the post-accident dose assessment performed in Chapter 5, which conservatively assumes complete loss of the water in the water jacket and the water jacket shell.

11.2.6.4 Tornado Accident Corrective Action

Following exposure of the HI-STORM 100 System to a tornado, the ISFSI operator shall perform a visual and radiological inspection of the overpack and/or HI-TRAC transfer cask. Damage sustained by the overpack outer shell, concrete, or vent screens shall be inspected and repaired. Damage sustained by the HI-TRAC shall be inspected and repaired.

11.2.7 Flood

11.2.7.1 Cause of Flood

The HI-STORM 100 System will be located on an unsheltered ISFSI concrete pad. Therefore, it is possible for the storage area to be flooded. The potential sources for the flood water could be unusually high water from a river or stream, a dam break, a seismic event, or a hurricane.

11.2.7.2 Flood Analysis

Structural

The flood accident affects the HI-STORM 100 overpack structural analysis in two ways. The flood water velocity acts to apply an overturning moment, which attempts to tip-over the loaded overpack. The flood affects the MPC by applying an external pressure.

Section 3.4 provides the analysis of the flood water applying an overturning moment. The results of the analysis show that the loaded overpack does not tip over if the flood velocity does not exceed the value stated in Table 2.2.8.

The structural evaluation of the MPC for the accident condition external pressure (Table 2.2.1) is presented in Section 3.4 and the resulting stresses from this event are shown to be well within the allowable values.

Thermal

For a flood of sufficient magnitude to allow the water to come into contact with the MPC, there is no adverse effect on the thermal performance of the system. The thermal consequence of such a flood is an increase in the rejection of the decay heat. Because the storage overpack is ventilated, water from a large flood will enter the annulus between the MPC and the overpack. The water would provide cooling that exceeds that available in the air filled annulus, due to water's higher thermal conductivity.

A smart flood condition that blocks the air flow but is not sufficient to allow water to come into contact with the MPC is bounded by the 100% inlet ducts blocked condition evaluated in Subsection 11.2.13.

Shielding

There is no effect on the shielding performance of the system as a result of this event. The flood water provides additional shielding that reduces radiation doses.

Criticality

There is no effect on the criticality control features of the system as a result of this event. The criticality analysis is unaffected because under the flooding condition water does not enter the MPC cavity and therefore the reactivity would be less than the loading condition in the fuel pool, which is presented in Section 6.1.

Confinement

There is no effect on the confinement function of the MPC as a result of this event. As discussed in the structural evaluation above, all stresses remain within allowable values, assuring confinement boundary integrity.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this event.

Based on this evaluation, it is concluded that the flood accident does not affect the safe operation of the HI-STORM 100 System.

11.2.7.3 Flood Dose Calculations

Since the flood accident produces no leakage of radioactive material and no reduction in shielding effectiveness, there are no adverse radiological consequences.

11.2.7.4 Flood Accident Corrective Action

As shown in the analysis of the flood accident, the HI-STORM 100 System sustains no damage as a result of the flood. At the completion of the flood, exposed surfaces may need debris and adherent foreign matter removal.

11.2.8 Earthquake

11.2.8.1 Cause of Earthquake

The HI-STORM 100 System may be employed at any reactor or ISFSI facility in the United States. It is possible that during the use of the HI-STORM 100 System, the ISFSI may experience an earthquake.

11.2.8.2 Earthquake Analysis

The earthquake accident analysis evaluates the effects of a seismic event on the loaded HI-STORM 100 System. The objective is to determine the stability limits of the HI-STORM 100 System. Based on a static stability criteria, it is shown in Chapter 3 that the HI-STORM 100 System is qualified to seismic activity less than or equal to the values specified in Table 2.2.8. The analyses in Chapter 3 show that the HI-STORM 100 System will not tip over under the conditions evaluated. The seismic activity has no adverse thermal, criticality, confinement, or shielding consequences.

Some ISFSI sites will have earthquakes that exceed the seismic activity specified in Table 2.2.8. For these high-seismic sites, anchored HI-STORM designs (the HI-STORM 100A and 100SA) have been

developed. The design of these anchored systems is such that seismic loads cannot result in tip-over or lateral displacement. Chapter 3 provides a detailed discussion of the anchored systems design.

Structural

The sole structural effect of the earthquake is an inertial loading of less than 1g. This loading is bounded by the tip-over analysis presented in Subsection 11.2.3, which analyzes a deceleration of 45g's and demonstrates that the MPC allowable stress criteria are met.

Thermal

There is no effect on the thermal performance of the system as a result of this event.

Shielding

There is no effect on the shielding performance of the system as a result of this event.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this event.

Based on this evaluation, it is concluded that the earthquake does not affect the safe operation of the HI-STORM 100 System.

11.2.8.3 Earthquake Dose Calculations

Structural analysis of the earthquake accident shows that the loaded overpack will not tip over as a result of the specified seismic activity. If the overpack were to tip over, the resultant damage would be equal to that experienced by the tip-over accident analyzed in Subsection 11.2.3. Since the loaded overpack does not tip-over, there is no increase in radiation dose rates or release of radioactivity.

11.2.8.4 Earthquake Accident Corrective Action

Following the earthquake accident, the ISFSI operator shall perform a visual and radiological inspection of the overpacks in storage to determine if any of the overpacks have tipped-over. In the unlikely event of a tip-over, the corrective actions shall be in accordance with Subsection 11.2.3.4.

11.2.9 100% Fuel Rod Rupture

This accident event postulates that all the fuel rods rupture and that the appropriate quantities of fission product gases and fill gas are released from the fuel rods into the MPC cavity.

11.2.9.1 Cause of 100% Fuel Rod Rupture

Through all credible accident conditions, the HI-STORM 100 System maintains the spent nuclear fuel in an inert environment while maintaining the peak fuel cladding temperature below the required short-term temperature limits, thereby providing assurance of fuel cladding integrity. There is no credible cause for 100% fuel rod rupture. This accident is postulated to evaluate the MPC confinement barrier for the maximum possible internal pressure based on the non-mechanistic failure of 100% of the fuel rods.

11.2.9.2 100% Fuel Rod Rupture Analysis

The 100% fuel rod rupture accident has no thermal, structural, criticality or shielding consequences. The event does not change the reactivity of the stored fuel, the magnitude of the radiation source, which is being shielded, the shielding capability, or the criticality control features of the HI-STORM 100 System. The determination of the maximum accident pressure is provided in Chapter 4. The MPC design basis internal pressure bounds the pressure developed assuming 100% fuel rod rupture. The structural analysis provided in Chapter 3 evaluates the MPC confinement boundary under the accident condition design internal pressure.

Structural

The structural evaluation of the MPC for the accident condition internal pressure presented in Section 3.4 demonstrates that the MPC stresses are well within the allowable values.

Thermal

The MPC internal pressure for the 100% fuel rod rupture condition is presented in Table 4.4.9. As can be seen from the values, the design basis accident condition MPC internal pressure (Table 2.2.1) used in the structural evaluation bounds the calculated value.

Shielding

There is no effect on the shielding performance of the system as a result of this event.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event. As discussed in the structural evaluation above, all stresses remain within allowable values, assuring confinement boundary integrity.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this event.

Based on this evaluation, it is concluded that the non-mechanistic 100% fuel rod rupture accident does not affect the safe operation of the HI-STORM 100 System.

11.2.9.3 100% Fuel Rod Rupture Dose Calculations

The MPC confinement boundary maintains its integrity. There is no effect on the shielding effectiveness, and the magnitude of the radiation source is unchanged. However, the radiation source could redistribute within the sealed MPC cavity causing a slight change in the radiation dose rates at certain locations. Therefore, there is no release of radioactive material or significant increase in radiation dose rates.

11.2.9.4 100% Fuel Rod Rupture Accident Corrective Action

As shown in the analysis of the 100% fuel rod rupture accident, the MPC confinement boundary is not damaged. The HI-STORM 100 System is designed to withstand this accident and continue performing the safe storage of spent nuclear fuel under normal storage conditions. No corrective actions are required.

11.2.10 Confinement Boundary Leakage

The MPC uses redundant confinement closures to assure that there is no release of radioactive materials for postulated storage accident conditions. The analyses presented in Chapter 3 and this chapter demonstrate that the MPC remains intact during all postulated accident conditions. The discussion contained in Chapter 7 demonstrates that MPC is designed, welded, tested and inspected to meet the guidance of ISG-18 such that leakage from the confinement boundary is considered non-credible.

11.2.10.1 Cause of Confinement Boundary Leakage

There is no credible cause for confinement boundary leakage. The accidents analyzed in this chapter show that the MPC confinement boundary withstands all credible accidents. There are no man-made or natural phenomena that could cause failure of the confinement boundary restricting radioactive material release. Additionally, because the MPC satisfies the criteria specified in Interim Staff Guidance (ISG) 18, there is no credible leakage that would occur from the confinement boundary.

11.2.10.3 Confinement Boundary Leakage Accident Corrective Action

The HI-STORM 100 System is designed to withstand this accident and continue performing the safe storage of spent nuclear fuel. No corrective actions are required.

11.2.11 Explosion

11.2.11.1 Cause of Explosion

An explosion within the bounds of an ISFSI is improbable since there are no explosive materials within the site boundary. An explosion as a result of combustion of the fuel contained in cask transport vehicle is possible. As the fuel available for the explosion is limited in quantity the effects of an explosion on a reinforced structure are minimal. Explosions postulated to occur within or beyond the ISFSI boundary would require a site hazards evaluation under the provisions of 72.212 regulations by individual cask users.

11.2.11.2 Explosion Analysis

Any credible explosion accident is bounded by the accident external design pressure (Table 2.2.1) analyzed as a result of the flood accident water depth in Subsection 11.2.7 and the tornado missile accident of Subsection 11.2.6, because explosive materials are not stored within close proximity to the casks. The bounding analysis shows that the MPC and the Overpack can withstand the effects of substantial accident external pressures without collapse or rupture.

Structural

The structural evaluations for the MPC accident condition external pressure and overpack pressure differential are presented in Section 3.4 and demonstrate that all stresses are within allowable values.

Thermal

There is no effect on the thermal performance of the system as a result of this event.

Shielding

There is no effect on the shielding performance of the system as a result of this event.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event. As discussed in the structural evaluation above, all stresses remain within allowable values, assuring confinement boundary integrity.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this event.

Based on this evaluation, it is concluded that the explosion accident does not affect the safe operation of the HI-STORM 100 System.

11.2.11.3 Explosion Dose Calculations

The bounding external pressure load has no effect on the HI-STORM 100 overpack and MPC. Therefore, no effect on the shielding, criticality, thermal or confinement capabilities of the HI-STORM 100 System is experienced as a result of the explosion pressure load. The effects of explosion generated missiles on the HI-STORM 100 System structure is bounded by the analysis of tornado generated missiles.

11.2.11.4 Explosion Accident Corrective Action

The explosive overpressure caused by the explosion is bounded by the external pressure exerted by the flood accident. The external pressure from the flood is shown not to damage the HI-STORM 100 System. Following an explosion, the ISFSI operator shall perform a visual and radiological inspection of the overpack. If the outer shell or concrete is damaged as a result of explosion generated missiles, the concrete material may be replaced and the outer shell repaired.

11.2.12 Lightning

11.2.12.1 Cause of Lightning

The HI-STORM 100 System will be stored on an unsheltered ISFSI concrete pad. There is the potential for lightning to strike the overpack. This analysis evaluates the effects of lightning striking the overpack.

11.2.12.2 Lightning Analysis

The HI-STORM 100 System is a large metal/concrete cask stored in an unsheltered ISFSI. As such, it may be subject to lightning strikes. When the HI-STORM 100 System is hit with lightning, the lightning will discharge through the steel shell of the overpack to the ground. Lightning strikes have high currents, but their duration is short (i.e., less than a second). The overpack outer shell is composed of conductive carbon steel and, as such, will provide a direct path to ground.

The MPC provides the confinement boundary for the spent nuclear fuel. The effects of a lightning strike will be limited to the overpack. The lightning current will discharge into the overpack and directly into the ground. Therefore, the MPC will be unaffected.

Structural

There is no structural consequence as a result of this event.

Thermal

There is no effect on the thermal performance of the system as a result of this event.

Shielding

There is no effect on the shielding performance of the system as a result of this event.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this event.

Based on this evaluation, it is concluded that the lightning accident does not affect the safe operation of the HI-STORM 100 System.

11.2.12.3 Lightning Dose Calculations

An evaluation of lightning strikes demonstrates that the effect of a lightning strike has no effect on the confinement boundary or shielding materials. Therefore, no further analysis is necessary.

11.2.12.4 Lightning Accident Corrective Action

The HI-STORM 100 System will not sustain any damage from the lightning accident. There is no surveillance or corrective action required.

11.2.13 100% Blockage of Air Inlets

11.2.13.1 Cause of 100% Blockage of Air Inlets

This event is defined as a complete blockage of all four bottom inlets. Such blockage of the inlets may be postulated to occur as a result of a flood, blizzard snow accumulation, tornado debris, or volcanic activity.

11.2.13.2 100% Blockage of Air Inlets Analysis

The immediate consequence of a complete blockage of the air inlet ducts is that the normal circulation of air for cooling the MPC is stopped. An amount of heat will continue to be removed by localized air circulation patterns in the overpack annulus and outlet ducts, and the MPC will continue to radiate heat to the relatively cooler storage overpack. As the temperatures of the MPC and its contents rise, the rate of heat rejection will increase correspondingly. Under this condition, the temperatures of the overpack, the MPC and the stored fuel assemblies will rise as a function of time.

As a result of the large mass, and correspondingly large thermal capacity of the storage overpack, it is expected that a significant temperature rise is only possible if the blocked condition is allowed to persist for a number of days. This accident condition is, however, a short duration event that will be identified and corrected by scheduled periodic surveillance at the ISFSI site.

Structural

There are no structural consequences as a result of this event.

Thermal

A thermal analysis is performed in Subsection 4.6.2 to determine the effect of a complete blockage of all inlets for an extended duration. For this event, both the fuel cladding and component temperatures remain below their short-term temperature limits. The MPC internal pressure for this event is evaluated in Subsection 4.6.2 and is bounded by the design basis internal pressure for accident conditions (Table 2.2.1).

Shielding

There is no effect on the shielding performance of the system as a result of this event, since the concrete temperatures do not exceed the short-term condition design temperature provided in Table 2.2.3.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this event.

Based on this evaluation, it is concluded that the 100% blockage of air inlets accident does not affect the safe operation of the HI-STORM 100 System, if the blockage is removed in the specified time period.

11.2.13.3 100% Blockage of Air Inlets Dose Calculations

As shown in the analysis of the 100% blockage of air inlets accident, the shielding capabilities of the HI-STORM 100 System are unchanged because the peak concrete temperature does not exceed its short-term condition design temperature. The elevated temperatures will not cause the breach of the confinement system and the short term fuel cladding temperature limit is not exceeded. Therefore, there is no radiological impact.

11.2.13.4 100% Blockage of Air Inlets Accident Corrective Action

Analysis of the 100% blockage of air inlet accident shows that the temperatures for cask system components and fuel cladding are within the accident temperature limits if the blockage is cleared within 32 hours. Upon detection of the complete blockage of the air inlet ducts, the ISFSI operator shall assign personnel to clear the blockage with mechanical and manual means as necessary. After clearing the overpack ducts, the overpack shall be visually and radiologically inspected for any damage. If exit air temperature monitoring is performed in lieu of direct visual inspections, the difference between the ambient air temperature and the exit air temperature will be the basis for assurance that the temperature limits are not exceeded.

For an accident event that completely blocks the inlet or outlet air ducts for greater than the analyzed duration, a site-specific evaluation or analysis may be performed to demonstrate adequate heat removal for the duration of the event. Adequate heat removal is defined as the minimum rate of heat dissipation that ensures cladding temperatures limits are met and structural integrity of the MPC and Overpack is not compromised. For those events where an evaluation or analysis is not performed or is not successful in showing that cladding temperatures remain below their short term temperature limits, the site's emergency plan shall include provisions to address removal of the material blocking the air inlet ducts and to provide alternate means of cooling prior to exceeding the time when the fuel cladding temperature reaches its short-term temperature limit. Alternate means of cooling could include, for example, spraying water into the air outlet ducts using pumps or fire-hoses or blowing air into the air outlet ducts using fans, to directly cool the MPC.

11.2.14 Burial Under Debris

11.2.14.1 Cause of Burial Under Debris

Burial of the HI-STORM System under debris is not a credible accident. During storage at the ISFSI, there are no structures over the casks. The minimum regulatory distance(s) from the ISFSI to the nearest site boundary and the controlled area around the ISFSI concrete pad precludes the close proximity of substantial amounts of vegetation.

There is no credible mechanism for the HI-STORM System to become completely buried under debris. However, for conservatism, complete burial under debris is considered. Blockage of the HI-STORM overpack air inlet ducts has already been considered in Subsection 11.2.13.

11.2.14.2 Burial Under Debris Analysis

Burial of the HI-STORM System does not impose a condition that would have more severe consequences for criticality, confinement, shielding, and structural analyses than that performed for the other accidents analyzed. The debris would provide additional shielding to reduce radiation doses. The accident external pressure encountered during the flood bounds any credible pressure loading caused by the burial under debris.

Burial under debris can affect thermal performance because the debris acts as an insulator and heat sink. This will cause the HI-STORM System and fuel cladding temperatures to increase. A thermal analysis has been performed to determine the time for the fuel cladding temperatures to reach the short term accident condition temperature limit during a burial under debris accident.

Structural

The structural evaluation of the MPC enclosure vessel for accident internal pressure conditions bounds the pressure calculated herein. Therefore, the resulting stresses from this event are well within the allowable values, as demonstrated in Section 3.4.

Thermal

The fuel cladding and MPC integrity is evaluated in Subsection 4.6.2. The evaluation demonstrates that the fuel cladding and confinement function of the MPC are not compromised.

Shielding

There is no effect on the shielding performance of the system as a result of this event.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event. As discussed in the structural evaluation above, all stresses remain within allowable values, assuring confinement boundary integrity.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this event.

Based on this evaluation, it is concluded that the burial under debris accident does not affect the safe operation of the HI-STORM 100 System, if the debris is removed within the specified time. The 24-hour minimum duct inspection interval ensures that a burial under debris condition will be detected long before the allowable burial time is reached.

11.2.14.3 Burial Under Debris Dose Calculations

As discussed in burial under debris analysis, the shielding is enhanced while the HI-STORM System is covered.

The elevated temperatures will not cause the breach of the confinement system and the short term fuel cladding temperature limit is not exceeded. Therefore, there is no radiological impact.

11.2.14.4 Burial Under Debris Accident Corrective Action

Analysis of the burial under debris accident shows that the fuel cladding peak temperatures are not exceeded even for an extended duration of burial. Upon detection of the burial under debris accident, the ISFSI operator shall assign personnel to remove the debris with mechanical and manual means as necessary. After uncovering the storage overpack, the storage overpack shall be visually and radiologically inspected for any damage. The loaded MPC shall be removed from the storage overpack with the HI-TRAC transfer cask to allow complete inspection of the overpack air inlets and outlets, and annulus. Removal of obstructions to the air flow path shall be performed prior to the re-insertion of the MPC. The site's emergency action plan shall include provisions for the performance of this corrective action.

11.2.15 Extreme Environmental Temperature

11.2.15.1 Cause of Extreme Environmental Temperature

The extreme environmental temperature is postulated as a constant ambient temperature caused by extreme weather conditions. To determine the effects of the extreme temperature, it is conservatively assumed that the temperature persists for a sufficient duration to allow the HI-STORM 100 System to achieve thermal equilibrium. Because of the large mass of the HI-STORM 100 System, with its

corresponding large thermal inertia and the limited duration for the extreme temperature, this assumption is conservative.

11.2.15.2 Extreme Environmental Temperature Analysis

The accident condition considering an extreme environmental temperature (Table 2.2.2) for a duration sufficient to reach thermal equilibrium is evaluated with respect to accident condition design temperatures listed in Table 2.2.3.

Structural

The structural evaluation of the MPC enclosure vessel for accident condition internal pressure bounds the pressure resulting from this event. Therefore, the resulting stresses from this event are bounded by that of the accident condition and are well within the allowable values, as discussed in Section 3.4.

Thermal

The resulting temperatures for the system and fuel assembly cladding are provided in evaluation performed in Subsection 4.6.2. As concluded from this evaluation, all temperatures are within the short-term accident condition allowable values specified in Table 2.2.3.

Shielding

There is no effect on the shielding performance of the system as a result of this event, since the concrete temperature does not exceed the short-term temperature limit specified in Table 2.2.3.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event. As discussed in the structural evaluation above, all stresses remain within allowable values, assuring confinement boundary integrity.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this event.

Based on this evaluation, it is concluded that the extreme environment temperature accident does not affect the safe operation of the HI-STORM 100 System.

11.2.15.3 Extreme Environmental Temperature Dose Calculations

The extreme environmental temperature will not cause the concrete to exceed its normal design temperature. Therefore, there will be no degradation of the concrete's shielding effectiveness. The elevated temperatures will not cause a breach of the confinement system and the short-term fuel cladding temperature is not exceeded. Therefore, there is no radiological impact on the HI-STORM 100 System for the extreme environmental temperature and the dose calculations are equivalent to the normal condition dose rates.

11.2.15.4 Extreme Environmental Temperature Corrective Action

There are no consequences of this accident that require corrective action.

11.2.16 deleted~~Supplemental Cooling System (SCS) Failure~~

~~The SCS system is a forced fluid circulation device used to provide supplemental HI-TRAC cooling. For fluid circulation, the SCS system is equipped with active components requiring power for normal operation. Although an SCS System failure is highly unlikely, for defense-in-depth an accident condition that renders it inoperable for an extended duration is postulated herein.~~

~~11.2.16.1 Cause of SCS Failure~~

~~Possible causes of SCS failure are: (a) Simultaneous loss of external and backup power, or (b) Complete loss of annulus water from an uncontrolled leak or line break.~~

~~11.2.16.2 Analysis of Effects and Consequences of SCS Failure~~

~~Structural~~

~~See discussion under thermal evaluation below.~~

~~Thermal~~

~~In the event of a SCS failure due to (a), the following sequence of events occur:~~

~~The annulus water temperature rises to reach it's boiling temperature (~212°F).~~
~~A progressive reduction of water level and dryout of the annulus.~~

~~In the event of an SCS failure due to (b), a rapid water loss occurs and annulus is replaced with air. For the condition of a vertically oriented HI-TRAC with air in the annulus, the maximum steady-state temperatures are below the accident temperature limits for fuel cladding and components (see Subsection 4.5.4).~~

~~Shielding~~

~~*There is no adverse effect on the shielding effectiveness of the system.*~~

~~*Criticality*~~

~~*There is no adverse effect on the criticality control of the system.*~~

~~*Confinement*~~

~~*There is no adverse effect on the confinement function of the MPC. As discussed in the evaluations above, the structural boundary pressures are within design limits.*~~

~~*Radiation Protection*~~

~~*As there is no adverse effect on the shielding or confinement functions, there is no effect on occupational or public exposures as a result of this off-normal event.*~~

~~*Based on this evaluation, it is concluded that the SCS failure does not affect the safe operation of the HI-STORM 100 System.*~~

~~*11.2.16.3 SCS Failure Dose Calculations*~~

~~*The event has no radiological impact because the confinement barrier and shielding integrity are not affected.*~~

~~*11.2.16.4 SCS Failure Corrective Action*~~

~~*In the vertical orientation the HI-TRAC is designed to withstand an SCS failure without an adverse effect on its safety functions.*~~

12.1 PROPOSED OPERATING CONTROLS AND LIMITS

12.1.1 NUREG-1536 (Standard Review Plan) Acceptance Criteria

12.1.1.1 This portion of the FSAR establishes the commitments regarding the HI-STORM 100 System and its use. Other 10CFR72 [12.1.2] and 10CFR20 [12.1.3] requirements in addition to the Technical Specifications may apply. The conditions for a general license holder found in 10CFR72.212 [12.1.2] shall be met by the licensee prior to loading spent fuel into the HI-STORM 100 System. The general license conditions governed by 10CFR72 [12.1.2] are not repeated with these Technical Specifications. Licensees are required to comply with all commitments and requirements.

12.1.1.2 The Technical Specifications provided in Appendix A to CoC 72-1014 and the authorized contents and design features provided in Appendix B to CoC 72-1014 are primarily established to maintain subcriticality, confinement boundary and intact fuel cladding integrity, shielding and radiological protection, heat removal capability, and structural integrity under normal, off-normal and accident conditions. Table 12.1.1 addresses each of these conditions respectively and identifies the appropriate Technical Specification(s) designed to control the condition. Table 12.1.2 provides the list of Technical Specifications for the HI-STORM 100 System.

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Table 12.1.1

HI-STORM 100 SYSTEM CONTROLS

Condition to be Controlled	**Applicable Technical Specifications**†
Criticality Control	3.3.1 Boron Concentration
Confinement Boundary and Intact Fuel Cladding Integrity	3.1.1 Multi-Purpose Canister (MPC) ~~3.1.4 Supplemental Cooling System~~
Shielding and Radiological Protection	3.1.1 Multi-Purpose Canister (MPC) 3.1.3 Fuel Cool-Down 3.2.2 TRANSFER CASK Surface Contamination *5.4 Radioactive Effluent Control Program* 5.7 Radiation Protection Program
Heat Removal Capability	3.1.1 Multi-Purpose Canister (MPC) 3.1.2 SFSC Heat Removal System ~~3.1.4 Supplemental Cooling System~~
Structural Integrity	~~3.5 Cask Transfer Facility (CTF)~~ 5.5 Cask Transport Evaluation Program

† Technical Specifications are located in Appendix A to CoC 72-1014. Authorized contents are specified in FSAR Section 2.1.9

Table 12.1.2

HI-STORM 100 SYSTEM TECHNICAL SPECIFICATIONS

NUMBER	TECHNICAL SPECIFICATION
1.0	USE AND APPLICATION 1.1 Definitions 1.2 Logical Connectors 1.3 Completion Times 1.4 Frequency
2.0	Not Used
3.0	LIMITING CONDITION FOR OPERATION (LCO) APPLICABILITY SURVEILLANCE REQUIREMENT (SR) APPLICABILITY
3.1.1	Multi-Purpose Canister (MPC)
3.1.2	SFSC Heat Removal System
3.1.3	Fuel Cool-Down
3.1.4	*Deleted*~~Supplemental Cooling System~~
3.2.1	Deleted
3.2.2	TRANSFER CASK Surface Contamination
3.2.3	Deleted
3.3.1	Boron Concentration
Table 3-1	MPC Cavity Drying Limits
Table 3-2	MPC Helium Backfill Limits
4.0	Not Used
5.0	ADMINSTRATIVE CONTROLS~~ AND PROGRAMS~~
5.1	Deleted
5.2	Deleted
5.3	Deleted
5.4	Radioactive Effluent Control Program
5.5	Cask Transport Evaluation Program
5.6	Deleted
5.7	Radiation Protection Program
Table 5-1	TRANSFER CASK and OVERPACK Lifting Requirements

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12.2 DEVELOPMENT OF OPERATING CONTROLS AND LIMITS

This section provides a discussion of the operating controls and limits, and training requirements for the HI-STORM 100 System to assure long-term performance consistent with the conditions analyzed in this FSAR.

12.2.1 Training Modules

Training modules are to be developed under the licensee's training program to require a comprehensive, site-specific training, assessment, and qualification (including periodic re-qualification) program for the operation and maintenance of the HI-STORM 100 Spent Fuel Storage Cask (SFSC) System and the Independent Spent Fuel Storage Installation (ISFSI). The training modules shall include the following elements, at a minimum:

1. HI-STORM 100 System Design (overview);

2. ISFSI Facility Design (overview);

3. Systems, Structures, and Components Important to Safety (overview);

4. HI-STORM 100 System Final Safety Analysis Report (overview);

5. NRC Safety Evaluation Report (overview);

6. Certificate of Compliance conditions;

7. HI-STORM 100 Technical Specifications, Approved Contents, Design Features and other Conditions for Use;

8. HI-STORM 100 Regulatory Requirements (e.g., 10CFR72.48, 10CFR72, Subpart K, 10CFR20, 10CFR73);

9. Required instrumentation and use;

10. Operating Experience Reviews

11. HI-STORM 100 System and ISFSI Procedures, including

    - Procedural overview
    - Fuel qualification and loading
    - MPC /HI-TRAC/overpack rigging and handling, including safe load pathways
    - MPC welding operations
    - HI-TRAC/overpack closure
    - Auxiliary equipment operation and maintenance (e.g., draining, moisture removal, helium backfilling, ~~supplemental cooling,~~ and cooldown)

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- MPC/HI-TRAC/overpack pre-operational and in-service inspections and tests
- Transfer and securing of the loaded HI-TRAC/overpack onto the transport vehicle
- Transfer and offloading of the HI-TRAC/overpack
- Preparation of MPC/HI-TRAC/overpack for fuel unloading
- Unloading fuel from the MPC/HI-TRAC/overpack
- Surveillance
- Radiation protection
- Maintenance
- Security
- Off-normal and accident conditions, responses, and corrective actions

12.2.2 Dry Run Training

A dry run training exercise of the loading, closure, handling, and transfer of the HI-STORM 100 System shall be conducted by the licensee prior to the first use of the system to load spent fuel assemblies. The dry run shall include, but is not limited to the following:

1. Receipt inspection of HI-STORM 100 System components.

2. Moving the HI-STORM 100 MPC/HI-TRAC into the spent fuel pool.

3. Preparation of the HI-STORM 100 System for fuel loading.

4. Selection and verification of specific fuel assemblies to ensure type conformance.

5. Locating specific assemblies and placing assemblies into the MPC (using a dummy fuel assembly), including appropriate independent verification.

6. Remote installation of the MPC lid and removal of the MPC/HI-TRAC from the spent fuel pool.

7. Replacing the HI-TRAC pool lid with the transfer lid (HI-TRAC 100 and 125 only).

8. MPC welding, NDE inspections, pressure testing, draining, moisture removal, and helium backfilling (for which a mockup may be used).

9. HI-TRAC upending/downending on the horizontal transfer trailer or other transfer device, as applicable to the site's cask handling arrangement.

10. Placement of the HI-STORM 100 System at the ISFSI.

11. HI-STORM 100 System unloading, including cooling fuel assemblies, flooding the MPC cavity, and removing MPC welds (for which a mock-up may be used).

~~12. Installation and operation of the Supplemental Cooling System.~~

12.2.3 Functional and Operating Limits, Monitoring Instruments, and Limiting Control Settings

The controls and limits apply to operating parameters and conditions which are observable, detectable, and/or measurable. The HI-STORM 100 System is completely passive during storage and requires no monitoring instruments. The user may choose to implement a temperature monitoring system to verify operability of the overpack heat removal system in accordance with Technical Specification Limiting Condition for Operation (LCO) 3.1.2.

12.2.4 Limiting Conditions for Operation

Limiting Conditions for Operation specify the minimum capability or level of performance that is required to assure that the HI-STORM 100 System can fulfill its safety functions.

12.2.5 Equipment

The HI-STORM 100 System and its components have been analyzed for specified normal, off-normal, and accident conditions, including extreme environmental conditions. Analysis has shown in this FSAR that no credible condition or event prevents the HI-STORM 100 System from meeting its safety function. As a result, there is no threat to public health and safety from any postulated accident condition or analyzed event. When all equipment is loaded, tested, and placed into storage in accordance with procedures developed for the ISFSI, no failure of the system to perform its safety function is expected to occur.

12.2.6 Surveillance Requirements

The analyses provided in this FSAR show that the HI-STORM 100 System fulfills its safety functions, provided that the Technical Specifications and the Authorized Contents described in Section 2.1.9 are met. Surveillance requirements during loading, unloading, and storage operations are provided in the Technical Specifications.

12.2.7 Design Features

This section describes HI-STORM 100 System design features that are Important to Safety. These features require design controls and fabrication controls. The design features, detailed in this FSAR and in Appendix B to CoC 72-1014, are established in specifications and drawings which are controlled through the quality assurance program. Fabrication controls and inspections to assure that the HI-STORM 100 System is fabricated in accordance with the design drawings and the requirements of this FSAR are described in Chapter 9.

12.2.8 MPC

a. Basket material composition, properties, dimensions, and tolerances for criticality control.

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b. Canister material mechanical properties for structural integrity of the confinement boundary.

c. Canister and basket material thermal properties and dimensions for heat transfer control.

d. Canister and basket material composition and dimensions for dose rate control.

12.2.9 HI-STORM Overpack

a HI-STORM overpack material mechanical properties and dimensions for structural integrity to provide protection of the MPC and shielding of the spent nuclear fuel assemblies during loading, unloading and handling operations.

b. HI-STORM overpack material thermal properties and dimensions for heat transfer control.

c. HI-STORM overpack material composition and dimensions for dose rate control.

12.2.10 Verifying Compliance with Fuel Assembly Decay Heat, Burnup, and Cooling Time Limits

The~~is~~ example*s below* execute~~s~~ the methodology and equations described in Section 2.1.9.1 for determining allowable decay heat, burnup, and cooling time for the approved cask contents. ~~In this example a demonstration of the use of burnup versus cooling time tables for regionalized fuel loading is provided. In this example it will be assumed that the MPC-32 is being loaded with array/class 16x16A fuel in a regionalized loading pattern.~~

~~Step 1: Determine the maximum allowable assembly decay heat load for each region.~~

~~$q_{Region\ 1} = 1.131$ kW~~
~~$q_{Region\ 2} = 0.600$ kW~~

~~Step 2: Develop a burnup versus cooling time table. Since this table is enrichment dependent, it is permitted and advisable to create multiple tables for different enrichments. In this example, two enrichments will be used: 3.1 and 4.185. Tables 12.2.1 and 12.2.2 show the burnup versus cooling time tables calculated for these enrichments for Region 1 and Region 2 using Equation 2.1.9.3.~~

~~Table 12.2.3 provides three hypothetical fuel assemblies in the 16x16A array/class that will be evaluated for acceptability for loading in the MPC-32 example above. The decay heat values in Table 12.2.3 are calculated by the user. The other information is taken from the fuel assembly and reactor operating records.~~

~~Fuel Assembly Number 1 is not acceptable for storage because its enrichment is lower than that used to determine the allowable burnups in Table 12.2.1 and 12.1.2. The solution is to develop~~

~~another table using an enrichment of 3.0 wt.% ^{235}U or less to determine this fuel assembly's suitability for loading in this MPC-32.~~

~~Fuel Assembly Number 2 is not acceptable for loading unless a unique maximum allowable burnup for a cooling time of 4.6 years is calculated by linear interpolation between the values in Table 12.2.1 for 4 years and 5 years of cooling. Linear interpolation yields a maximum burnup of 39,843 MWD/MTU (rounded down from 39,843.4), making Fuel Assembly Number 2 acceptable for loading only in Region 1 due to decay heat limitations.~~

~~Fuel Assembly Number 3 is acceptable for loading based on the higher allowable burnups in Table 12.2.2, which were calculated using a higher minimum enrichment that those in Table 12.2.1, which is still below the actual initial enrichment of Fuel Assembly Number 3. Due to its relatively low total decay heat of 0.5 kW (fuel: 0.4, non-fuel hardware: 0.1), Fuel Assembly Number 3 may be stored in Region 1 or Region 2.~~

Example 1

In this example, a demonstration of the use of burnup versus cooling time tables for regionalized fuel loading is provided. In this example it will be assumed that the MPC-32 is being loaded with array/class 16x16A fuel in a regionalized loading pattern.

Step 1: Pick a value of X between 0.5 and 3. For this example X will be 2.8.

Step 2: Calculate $q_{Region2}$ as described in Section 2.1.9.1.2:

$$q_{Region2} = (2 \times 34)/[(1 + (2.8)^{0.2075}) \times ((12 \times 2.8) + 20)] = 0.5668\ kW^{\dagger}$$

Step 3: Calculate $q_{Region1}$ as described in Section 2.1.9.1.2:

$$q_{Region1} = X \times q_{Region2} = 2.8 \times 0.5668 = 1.5871\ kW$$

Step 4: Develop a burnup versus cooling time table. Since this table is enrichment dependent, it is permitted and advisable to create multiple tables for different enrichments. In this example, two enrichments will be used: 3.1 and 4.185. Tables 12.2.1 and 12.2.2 show the burnup versus cooling time tables calculated for these enrichments for Region 1 and Region 2 as described in Section 2.1.9.1.3.

Table 12.2.3 provides three hypothetical fuel assemblies in the 16x16A array/class that will be evaluated for acceptability for loading in the MPC-32 example above. The decay heat values in Table 12.2.3 are calculated by the user. The other information is taken from the fuel assembly and reactor operating records.

Fuel Assembly Number 1 is not acceptable for storage because its enrichment is lower than that used to determine the allowable burnups in Table 12.2.1 and 12.1.2. The solution is to develop

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† *Results are arbitrarily rounded to four decimal places.*

another table using an enrichment of 3.0 wt.% ^{235}U or less to determine this fuel assembly's suitability for loading in this MPC-32.

Fuel Assembly Number 2 is not acceptable for loading unless a unique maximum allowable burnup for a cooling time of 3.3 years is calculated by linear interpolation between the values in Table 12.2.1 for 3 years and 4 years of cooling. Linear interpolation yields a maximum burnup of 36,497 MWD/MTU (rounded down from 36,497.2), making Fuel Assembly Number 2 acceptable for loading only in Region 1 due to decay heat limitations.

Fuel Assembly Number 3 is acceptable for loading based on the higher allowable burnups in Table 12.2.2, which were calculated using a higher minimum enrichment that those in Table 12.2.1, which is still below the actual initial enrichment of Fuel Assembly Number 3. Due to its relatively low total decay heat of 0.5 kW (fuel: 0.4, non-fuel hardware: 0.1), Fuel Assembly Number 3 may be stored in Region 1 or Region 2.

<u>Example 2</u>

In this example, each fuel assembly in Table 12.2.3 will be evaluated to determine whether it may be stored in the same hypothetical MPC-32 in a regionalized storage pattern. Assuming the same value 'X', the same maximum fuel storage location decay heats are calculated. The equation in Section 2.1.9.1.3 is executed for each fuel assembly using its exact initial enrichment to determine its maximum allowable burnup. Linear interpolation is used to further refine the maximum allowable burnup value between cooling times, if necessary.

Fuel Assembly Number 1: The calculated allowable burnup for 3.0 wt.% ^{235}U and a decay heat value of 1.5871 kW ($q_{region1}$) is 44,905 MWD/MTU at 4 years minimum cooling. Its decay heat is too high for loading in Region 2. Comparing the fuel assembly burnup and total decay heat of the contents[†] (fuel (1.01 kW) plus non-fuel hardware (0.5 kW)) to the calculated limits indicates that the fuel assembly, including the non-fuel hardware, is acceptable for storage in Region 1.

Fuel Assembly Number 2: The calculated allowable burnup for 3.2 wt.% ^{235}U and a decay heat value of 1.5871 kW ($q_{region1}$) is 32,989 MWD/MTU for 3 years cooling and 45,382 MWD/MTU for 4 years cooling. Linearly interpolating between these values for a cooling time of 3.3 years yields a maximum allowable burnup of 36,706 MWD/MTU and, therefore, the assembly is acceptable for storage in Region 1. This fuel assembly's decay heat is also too high for loading in Region 2.

Fuel Assembly Number 3: The calculated allowable maximum burnup for 4.3 wt.% ^{235}U and a decay heat value of 0.5668 ($q_{Region2}$) is 41,693 MWD/MTU for 18 years cooling. Comparing the fuel assembly burnup and total decay heat of the contents (fuel plus non-fuel hardware) against the calculated limits indicates that the fuel assembly and non-fuel hardware are acceptable for storage. Therefore, the assembly is acceptable for storage in Region 2. This fuel assembly would also be acceptable for loading in Region 1 (this conclusion is inferred, but not demonstrated).

[†] *The assumption is made that the non-fuel hardware meets burnup and cooling time limits in Table 2.1.25.*

Table 12.2.1

EXAMPLE BURNUP VERSUS COOLING TIME LIMITS FOR REGIONALIZED LOADING
(MPC-32, Array/Class 16x16A, *X = 2.8,* and Enrichment = 3.1 wt.% ^{235}U)
($q_{Region\ 1}$ = *1.5871*~~1.131~~ kW, $q_{Region\ 2}$ = 0.*5668*~~600~~ kW)

MINIMUM COOLING TIME (years)	**MAXIMUM ALLOWABLE BURNUP IN REGION 1 (MWD/MTU)**	**MAXIMUM ALLOWABLE BURNUP IN REGION 2 (MWD/MTU)**
≥3	~~24432~~*32791*	~~12303~~*10896*
≥4	~~35110~~*45145*	~~19318~~*17370*
≥5	~~42999~~*53769*	~~24991~~*22697*
≥6	~~48530~~*59699*	~~29209~~*26615*
≥7	~~52394~~*63971*	~~32135~~*29386*
≥8	~~55322~~*67343*	~~34318~~*31437*
≥9	~~57636~~*68200*	~~36005~~*33000*
≥10	~~59584~~*68200*	~~37395~~*34271*
≥11	~~61262~~*68200*	~~38552~~*35384*
≥12	~~62786~~*68200*	~~39584~~*36322*
≥13	~~64206~~*68200*	~~40507~~*37189*
≥14	~~65551~~*68200*	~~41368~~*37980*
≥15	~~66881~~*68200*	~~42200~~*38773*
≥16	~~68184~~*68200*	~~42998~~*39512*
≥17	68200	~~43769~~*40234*
≥18	68200	~~44538~~*40908*
≥19	68200	~~45292~~*41620*
≥20	68200	~~46055~~*42324*

Table 12.2.2

EXAMPLE BURNUP VERSUS COOLING TIME LIMITS FOR REGIONALIZED LOADING
(MPC-32, Array/Class 16x16A, *X = 2.8,* and Enrichment =4.185 wt.% ^{235}U)
($q_{Region\ 1}$ = 1.*5871*~~131~~ kW, $q_{Region\ 2}$ = 0.*5668*~~600~~ kW)

MINIMUM COOLING TIME (years)	**MAXIMUM ALLOWABLE BURNUP IN REGION 1 (MWD/MTU)**	**MAXIMUM ALLOWABLE BURNUP IN REGION 2 (MWD/MTU)**
≥3	~~2581~~*34797*	~~1263~~*11101*
≥4	~~3690~~*47590*	~~1996~~*17870*
≥5	~~4496~~*56438*	~~2570~~*23272*
≥6	~~5060~~*62533*	~~2991~~*0*~~7~~*157*
≥7	~~5456~~*66963*	~~3283~~*0*~~9~~*9907*
≥8	~~5759~~*68200*	~~3502~~*0*~~1~~*1935*
≥9	~~5998~~*68200*	~~3671~~*0*~~3~~*3510*
≥10	~~6201~~*68200*	~~3813~~*2*~~4~~*4785*
≥11	~~6376~~*68200*	~~3932~~*1*~~3~~*5927*
≥12	~~6535~~*68200*	~~4037~~*2*~~6~~*6894*
≥13	~~6682~~*68200*	~~4133~~*0*~~3~~*7790*
≥14	68200	~~4222~~*43*~~8~~*8593*
≥15	68200	~~4308~~*39419*
≥16	68200	~~4391~~*40191*
≥17	68200	~~4469~~*40937*
≥18	68200	~~4549~~*41643*
≥19	68200	~~4627~~*42363*
≥20	68200	~~4706~~*43094*

Table 12.2.3

SAMPLE CONTENTS TO DETERMINE ACCEPTABILITY FOR STORAGE
(Array/Class 16x16A)

FUEL ASSEMBLY NUMBER	ENRICHMENT (wt. % ^{235}U)	FUEL ASSEMBLY BURNUP (MWD/MTU)	FUEL ASSEMBLY COOLING TIME (years)	FUEL ASSEMBLY DECAY HEAT (kW)	NON-FUEL HARDWARE STORED WITH ASSEMBLY	NFH DECAY HEAT (kW)
1	3.0	37100	4.7	~~0.7~~*1.01*	BPRA	0.5~~3~~
2	3.2	~~38812~~*35250*	~~4.6~~*3.3*	~~0.9~~*1.45*	NA	NA
3	4.3	~~41976~~*41276*	18.2	0.4	BPRA	0.1

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B 3.1 SFSC Integrity

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~~BASES~~

~~BACKGROUND~~ ~~The Supplemental Cooling System (SCS) is an active, water cooling system that provides augmented heat removal from the MPC to ensure fuel cladding temperatures remain below the applicable limit during onsite transport operations in the TRANSFER CASK. The system is required for all MPCs meeting the burnup, heat load, and TRANSFER CASK orientation combinations specified in the Applicability of the LCO.~~

~~APPLICABLE SAFETY ANALYSIS~~ ~~The thermal analyses of the MPC inside the TRANSFER CASK take credit for the operation of the SCS under certain conditions to ensure that the spent fuel cladding temperature remains below the applicable limit. FSAR Section 4.5 describes these analyses in more detail. For MPCs containing all moderate burnup fuel (≤ 45,000 MWD/MTU), SCS operation is not required, because the fuel cladding temperature cannot exceed the limit of 1058°F for moderate burnup fuel (Refs. 2 and 3).~~

~~For high burnup fuel, the fuel cladding temperature limit is 400°C (752°F) during onsite transportation. For MPCs containing one or more high burnup fuel assemblies, the SCS has been credited in the thermal analysis in order to meet the lower fuel cladding temperature limit.~~

~~(continued)~~

~~BASES~~

~~LCO~~ ~~The Supplemental Cooling System must be operable if the MPC/TRANSFER cask assemblage meets one of the following conditions in the Applicability portion of the LCO in order to preserve the assumptions made in the thermal analysis.~~

~~APPLICABILITY~~ ~~The LCO is applicable within 4 hours after completion of MPC drying operations in accordance with LCO 3.1.1 or within 4 hours of transferring the MPC into the TRANSFER CASK if the MPC is to be unloaded, and the following conditions are met:~~

~~MPCs having one or more fuel assemblies with an average burnup greater than 45,000 MWD/MTU.25~~

~~ACTIONS~~ ~~A.1~~

~~If the SCS has been determined to be inoperable, the thermal analysis shows that the fuel cladding temperature would not exceed the short term temperature limit applicable to an off-normal condition, even with no water in the TRANSFER CASK-to-MPC annulus. Actions should be taken to restore the SCS to operable status in a timely manner. Because the thermal analysis is a steady-state analysis, there is an indefinite period of time available to make repairs to the SCS. However, it is prudent to require the actions to be completed in a reasonably short period of time. A Completion Time of 7 days is considered appropriate and a reasonable amount of time to plan the work, obtain needed parts, and execute the work in a controlled manner.~~

~~(continued)~~

~~BASES~~

~~ACTIONS (continued)~~

~~B.1~~

~~If, after 7 days, the SCS cannot be restored to operable status, actions should be taken to remove the fuel assemblies from the MPC and place them back into the spent fuel pool storage racks. Thirty days is considered a reasonable time frame given that the MPC will be adequately cooled while this action is being planned and implemented, and certain equipment for this infrequent evolution (e.g., weld cutting machine) may take some time to acquire.~~

~~SURVEILLANCE REQUIREMENTS~~

~~SR 3.1.4.1~~

~~The long-term integrity of the stored fuel is dependent on the ability of the SFSC to reject heat from the MPC to the environment, including during short-term evolutions such as on-site transportation in the TRANSFER CASK. The SCS is required to ensure adequate fuel cooling in certain cases. The SCS should be verified to be operable every two hours. This would involve verification that the water flow rate and temperatures are within expected ranges and the pump and air cooler are operating as expected. This is a reasonable Frequency given the typical oversight occurring during the on-site transportation evolution, the duration of the evolution, and the simple equipment involved.~~

~~REFERENCES~~

~~1. FSAR Section 4.5~~
~~2. NRC Interim Staff Guidance 11, Rev. 3~~
~~3. NRC Memorandum, C. Brown to M.W. Hodges, January 29, 2004~~