[2.2.7] Regulatory Guide 1.76, "Design Basis Tornado ~~and Tornado Missiles~~ for Nuclear Power Plants," United States Nuclear Regulatory Commission, ~~March 2007~~April 1974.

[2.2.8] ANSI/ANS 57.9-1992, "Design Criteria for an Independent Spent Fuel Storage Installation (Dry Type)", American Nuclear Society, LaGrange Park, IL, May 1992.

[2.2.9] NUREG-0800, "Standard Review Plan," United States Nuclear Regulatory Commission, Washington, DC, April 1996

[2.2.10] ASME Boiler & Pressure Vessel Code, Section III, Subsection NB. "Class 1 Components," American Society of Mechanical Engineers, New York, NY, 2007

[2.2.11] Holtec Proprietary Position Paper DS-331, "Structural Acceptance Criteria for the Metamic-HT Fuel Basket", (USNRC Docket No. 71-9325).

[2.3.1] ISG-2, "Fuel Retrievability", Revision 0, USNRC, Washington DC

$$\Delta_r = \frac{\phi D}{100} = \frac{(2.0)(140in)}{100} = 2.8in$$

$$\Delta_v = \frac{\Psi H}{100} = \frac{(\pm 3.0)(207.75in)}{100} = \pm 6.23in \text{ (CG height relative to H/2)}$$

~~The C.G. information provided above shall be used in designing the lifting and handling ancillary for the HI-STORM FW cask components. In addition, t~~The maximum CG height per Table 3.2.7 shall be used for the stability analysis of the HI-STORM FW under DBE conditions unless a more accurate CG height is calculated on a site-specific basis. Using the weight data in the previously mentioned tables, Table 3.2.8 has been constructed to provide the bounding weights for structural analyses so that every load case is analyzed using the most conservative data (to *minimize the computed safety margins*). The weight data in Table 3.2.8 is used in all structural analyses in this chapter.

Table 3.2.8

BOUNDING WEIGHTS FOR STRUCTURAL ANALYSES
(Height from Tables 3.2.1 and 3.2.2)

	Case	Purpose	Assumed Weight (Kilo-pounds)
1.	Loaded HI-STORM FW on the pad containing maximum length/weight fuel and 200 lb/cubic feet concrete – maximum possible weight scenario	Sizing and analysis of lifting and handling locations and cask stability analysis under overturning loads such as flood and earthquake	425.7
2.	Loaded HI-STORM FW on the pad with 150 lb concrete, shortest length MPC	Stability analysis under missile strike	285.7
3.	Loaded HI-TRAC VW with maximum length fuel and maximum lead and water shielding	Analysis for NUREG-0612 compliance of lifting and handling locations (TALs and Trunnions)	270.0 NOTE 1
4a.	50% Loaded HI-TRAC VW (tallest cask) ~~with shortest length MPC and minimum lead and water shielding~~	Stability analysis under missile strike	~~183.5~~200.2 NOTE 2~~1~~
4b.	50% Loaded HI-TRAC VW (shortest and lightest cask)		158.5 NOTE 2
5.	Loaded MPC containing maximum length/weight fuel – maximum possible weight scenario	Analysis for NUREG-0612 compliance of lifting and handling locations (TALs)	116.4

NOTE 1: The listed weight conservatively bounds all HI-TRAC VW versions (maximum or minimum loaded weight, as applicable).
NOTE 2: For users with lighter loaded cask weight, a site-specific tornado wind and missile evaluation shall be performed for stability; stability analysis assumes that center of mass of stored fuel assemblies lies close to the cask centerline axis.

performed by solving the 1-DOF equation of motion for the cask angular rotation, which is same methodology used in the HI-STORM 100 FSAR (Docket No. 72-1014). Specifically, the solution of the post-impact dynamics problem is obtained by solving the following equation of motion:

$$I_r \alpha = \left(-W_c \frac{a}{2}\right) + F_{max}\left(\frac{L}{2}\right)$$

where:

I_r = cask moment of inertia about the pivot point
α = angular acceleration of the cask
W_c = lower bound weight of the cask
a/2 = restoring moment arm = ~~diameter~~ radius of cask at its base (see Figure 3.4.7) at time zero~~, moment arm updated with changing angle~~
F_{max} = force on the cask due to tornado wind/instantaneous pressure drop
L/2 = overturning moment arm = half-height of the cask (see Figure 3.4.7) at time zero~~, moment arm updated with changing angle~~

In the above equation, α, a, and L are time dependent variables. The impacting missile enters into the above through the post-strike angular velocity of the cask, which is the relevant initial condition for the cask equation of motion. The solution gives the post-impact position of the cask centroid as a function of time, which indicates whether the cask remains stable.

The following assumptions are made in the analysis:

i. The cask is assumed to be a rigid solid cylinder, with uniform mass distribution. This assumption implies that the cask sustains no plastic deformation (i.e. no absorption of energy through plastic deformation of the cask occurs).

ii. The angle of incidence of the missile is assumed to be the worst case of a~~pure~~ perfect horizontal impact at the maximum horizontal missile velocity and the angle that maximizes overturning moment arm ~~of the cask~~ (see Figure 3.4.7) with the missile traveling at a reduced velocity corresponding to the inclined angle~~.such that its overturning effect on the cask is maximized (see Figure 3.4.7)~~.

iii. The analysis considers the maximum height cask and the minimum height cask (with their corresponding weights) per Tables 3.2.1 and 3.2.2. The missile is assumed to strike at the highest point of the cask (see Figure 3.4.7), again maximizing the overturning effect.

iv. The cask is assumed to pivot about a point at the bottom of the base plate opposite the location of missile impact and the application of wind force in order to conservatively maximize the propensity for overturning (see Figure 3.4.7).

v. Inelastic impact is assumed, with the missile velocity reduced to zero after impact. This assumption conservatively lets the missile impart the maximum amount of angular momentum to the cask, and it is in agreement with missile impact tests conducted by EPRI [3.4.14].

vi. The analysis is performed using the minimum loaded HI-STORM FW weight and 50% loaded HI-TRAC VW weight per Table 3.2.8. A lighter cask will tend to rotate further after the missile strike. The weight of the missile is not included in the total post-impact weight.

vii. Planar motion of the cask is assumed; any loads from out-of-plane wind forces are neglected.

viii. The drag coefficient for a cylinder in turbulent cross flow is used.

ix. The missile and wind loads are assumed to be perfectly aligned in direction.

The results for the post-impact response of the HI-STORM FW overpack and the HI-TRAC VW transfer cask are summarized in Table 3.4.5. The table shows that both casks remain in a vertical upright position (i.e., no overturning) in the aftermath of a large missile impact. The complete details of the tornado wind and large missile impact analyses for the HI-STORM FW overpack and the HI-TRAC VW transfer cask are provided in ~~Appendix 3.A~~[3.4.15].

The results for the post-impact response of the HI-TRAC VW Versions V and V2 transfer casks are summarized in Tables 3.4.5A and 3.4.5B, respectively. The table shows that the cask remains in a vertical upright position (i.e., no overturning) in the aftermath of a large missile impact. The complete details of the tornado wind and large impact analyses for the HI-TRAC VW Versions V and V2 transfer casks are provided in [3.4.15].

<u>Sliding Analysis</u>

A conservative calculation of the extent of sliding of the HI-STORM FW overpack and the HI-TRAC VW cask due to the impact of a large missile (Table 2.2.5) and tornado wind (Table 2.2.4) is obtained using a common formulation as explained below. A more realistic impact simulation using LS-DYNA, with less bounding assumptions, has been used in Subsection 3.4.4.1.4 to qualify the HI-STORM overpack for a non-mechanistic tip over event. While it is not necessary for demonstrating adequate safety margins for this problem, an LS-DYNA analysis could also be used to calculate the sliding potential of the HI-STORM FW and HI-TRAC VW for a large missile impact. In what follows, both HI-STORM FW and HI-TRAC VW are identified by the generic term "cask".

The principal assumptions that render these calculations for sliding conservative are:

i. The weight of the cask used in the analysis is assumed to be the lowest per Table 3.2.8.

ii. The cask is assumed to absorb the energy of impact purely by sliding. In other words, none of the impact energy is dissipated by the noise from the impact, from local plastic between HI-STORM FW overpacks and the minimum distance of the overpack to the edge of the pad are calculated. The above table demonstrates the HI-STORM FW overpack will not collide with another overpack, and the overpack will not slide off the pad due to the combined effects of a large tornado missile impact and high wind.

No generic limits for sliding are established for HI-TRAC VW and HI-TRAC VW Versions V and V2 transfer casks. Therefore, the sliding result for the HI-TRAC VW and the HI-TRAC VW Versions V and V2 transfer casks in Table 3.4.16 are strictly informational.

b. Small and Intermediate Missiles

The small and intermediate missiles (Table 2.2.5) are analyzed to determine the extent to which they will penetrate the HI-STORM FW overpack or the HI-TRAC VW and cause potential damage to the MPC Enclosure Vessel. Classical energy balance methods are used to compute the depth of penetration at the following impact locations:

- on the HI-STORM FW outer shell (with concrete backing)
- on the HI-STORM FW lid top plate (with concrete backing)
- on the HI-TRAC VW outer shell (with lead backing)
- on the top surface of the MPC upper lid

The MPC upper lid is analyzed for a direct missile impact because, when the MPC is placed inside the HI-TRAC VW, the MPC lid is theoretically accessible to a vertically downward directed small or intermediate missile.

The following assumptions are made in the analysis:

i. The intermediate missile and the small missile are assumed to be unyielding, and hence the entire initial kinetic energy is assumed to be absorbed by local yielding and denting of the cask surface.

ii. No credit is taken for the missile resistance offered by the HI-TRAC VW water jacket shell. It is assumed a priori that the small and intermediate missiles will penetrate the water jacket shell (with no energy loss). Therefore, in the analysis 100% of the missile impact energy is applied directly to the HI-TRAC VW outer shell.

iii. For missile strikes on the side and top lid of the overpack, the analysis credits the structural resistance in compression offered by the concrete material that backs the outer shell and the lid.

iv. The resistance from the concrete is conservatively assumed to act over an area equal to the target area of impact. In other words, no diffusion of the load is assumed to occur through the concrete.

The analyses documented in ~~Appendix 3.B~~[3.4.15] show that the depth of penetration of the small missile is less than the thinnest section of material on the exterior surface of the HI-STORM FW or the HI-TRAC VW. Therefore, the small missile will dent, but not penetrate, the cask. The 1-inch missile can enter the air inlet/outlet vents in the HI-STORM FW overpack, but geometry prevents a direct impact with the MPC.

For the intermediate missile, the analyses documented in ~~Appendix 3.B~~[3.4.15] show that there will be no penetration through the concrete surrounding the inner shell of the storage overpack or penetration of the top lid. Likewise, the intermediate missile will not penetrate the lead surrounding the HI-TRAC VW inner shell. Therefore, there will be no impairment to the Confinement Boundary due to tornado-borne missile strikes. Furthermore, since the HI-STORM FW and HI-TRAC VW inner shells are not compromised by the missile strike, there will be no permanent deformation of the inner shells and ready retrievability of the MPC will be assured.

The penetration results for the small and intermediate missile are summarized in Table 3.4.6.

The calculations for HI-TRAC VW Versions V and V2 transfer casks are performed in [3.4.15] following the same approach used for HI-TRAC VW transfer cask, and the conclusions are identical to those for impacts from small and intermediate missiles on HI-TRAC VW. The penetration results for HI-TRAC VW Versions V and V2 transfer casks due to impacts from small and intermediate results are summarized in Tables 3.4.6A and 3.4.6B, respectively.

3.4.4.1.4 <u>Load Case 4: Non-Mechanistic Tipover</u>

The non-mechanistic tipover event, as described in Subsection 2.2.3(b), is site-dependent only to the extent that the stiffness of the target (ISFSI pad) affects the severity of the impact impulse. To bound the majority of ISFSI pad sites, the tipover analyses are performed using a stiff target foundation, which is defined in Table 2.2.9. The objectives of the analyses are to demonstrate that the plastic deformation in the fuel basket is sufficiently limited to permit the stored SNF to be retrieved by normal means and that there is no significant loss of radiation shielding in the storage system. Furthermore, the maximum lateral deflection of the lateral surface of the fuel basket is within the limit assumed in the criticality analyses (Chapter 6), and therefore, the lateral deflection does not have an adverse effect on criticality safety.

The tipover event is an artificial construct wherein the HI-STORM FW overpack is assumed to be perched on its edge with its C.G. directly over the pivot point A (Figure 3.4.8). In this orientation, the overpack begins its downward rotation with zero initial velocity. Towards the end of the tip-over, the overpack is horizontal with its downward velocity ranging from zero at the pivot point (point A) to a maximum at the farthest point of impact. The angular velocity at the instant of impact defines the downward velocity distribution along the contact line.

In the following, an explicit expression for calculating the angular velocity of the cask at the instant when it impacts on the ISFSI pad is derived. Referring to Figure 3.4.8, let r be the length AC where C is the cask centroid. Therefore, The detailed evaluation of the MPC shell under accident external pressure is provided in ~~Appendix 3.C~~Supplement 4 of [3.4.13]. It is concluded that positive safety margins exist so that elastic or plastic instability of the maximum height MPC shell does not occur under the applied pressure.

3.4.4.1.8 Load Case 8: Non-Mechanistic Heat-Up of the HI-TRAC VW Water Jacket

Even though the analyses presented in Chapter 4 indicate that the temperature of water in the water jacket shall not reach boiling and the rupture disks will not open, it is (non-mechanistically) assumed that the hydraulic pressure in the water jacket reaches the relief devices' set point. The objective of this analysis is to demonstrate that the stresses in the water jacket and its welds shall be below the limits set down in an appropriate reference ASME Boiler and Pressure Vessel Code (Section II Class 3) for the Level D service condition. The accident pressure inside the water jacket is given in Table 2.2.1.

The HI-TRAC VW water jacket is analyzed using classical strength-of-materials. Specifically, the unsupported span of the water jacket shell between radial ribs is treated as a curved beam, with clamped ends, under a uniformly distributed radial pressure. The force and moment reactions at the ends of the curved beam for this type of loading are calculated using the formula for Case 5j of Table 18 in [3.4.16]. The primary membrane plus bending stress is then calculated using the formula for Case 1 of Table 16 in [3.4.16]. Figure 3.4.35 depicts the curved beam model that is used to analyze the water jacket shell and defines the key input variables. The input values that are used in the calculations are provided in Table 3.4.12.

The bottom flange, which serves as the base of the water jacket, is conservatively analyzed as an annular plate clamped at the water jacket inside diameter and simply supported at the water jacket outside diameter. The maximum bending stress in the bottom flange is calculated using the following formula from [3.4.18, Art. 23]:

$$\sigma_{max} = k \frac{q \cdot a^2}{h^2}$$

where q is the internal pressure inside the water jacket (= 73.65 psi), a is the outside radius of the water jacket (= 47.5 in), and h is the thickness of the bottom flange (= 2.0 in). The analyzed pressure accounts for the accident internal pressure inside the water jacket (Table 2.2.1) plus the hydrostatic pressure at the base of the water jacket. The value of k is dependent on the diameter ratio of the annular plate and the boundary conditions. Per Table 5 of [3.4.18], k is equal to 0.122 for a bounding diameter ratio of 1.25 and simply supported-clamped boundary conditions (Case 4). Therefore, the maximum bending stress in the bottom flange is:

$$\sigma_{max} = 5{,}068 \text{ psi}$$

Per Table 3.1.6, the allowable primary membrane plus bending stress intensity for SA-516 Gr. 70 material (at 400ºF) is 58,500 psi, which means the factor of safety is greater than 10.

Table 3.4.5

CASK ROTATIONS DUE TO LARGE MISSILE IMPACT

Event	Calculated Value (deg)	Allowable Limit (deg)	Safety Factor
Missile Impact plus Tornado Wind on HI-STORM FW	3.834.27	29.830.3	7.916.98
Missile Impact plus Pressure Drop on HI-STORM FW	4.374.80	29.830.3	6.936.21
Missile Impact plus Tornado Wind on HI-TRAC VW (standard version)	14.8815.74	23.19	1.561.4750
Missile Impact plus Pressure Drop on HI-TRAC VW (standard version)	12.6612.29	23.19	1.831.8992

Table 3.4.5A

CASK ROTATIONS DUE TO LARGE MISSILE IMPACT – HI-TRAC VW VERSION V

Event	Calculated Value (deg)	Allowable Limit (deg)	Safety Factor
Missile Impact plus Tornado Wind on HI-TRAC VW Version V	15.0034	23.21	1.515
Missile Impact plus Pressure Drop on HI-TRAC VW Version V	12.749.60	23.21	1.822.42

Table 3.4.5B

CASK ROTATIONS DUE TO LARGE MISSILE IMPACT – HI-TRAC VW VERSION V2

Event	Calculated Value (deg)	Allowable Limit (deg)	Safety Factor
Missile Impact plus Tornado Wind on HI-TRAC VW Version V2	16.439.15	21.24	1.292.32
Missile Impact plus Pressure Drop on HI-TRAC VW VersionV2	13.557.76	21.24	1.572.74

as tornado-borne missiles (large, intermediate, or small) have also been analyzed to evaluate their potential for reaching and breaching the Confinement Boundary. Analyses presented in Section 3.4 ~~and supplemented by Appendices 3.A and 3.B~~ show that the integrity of the Confinement Boundary is preserved under all design basis projectile impact scenarios.

- The information on structural design included in this FSAR complies with the requirements of 10CFR72.120 and 10CFR72.122.

- The structural design features in the HI-STORM FW system are in compliance with the specific requirements of 10CFR72.236(e), (f), (g), (h), (i), (j), (k), and (m).

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[3.4.19] "Mechanical Testing and Evaluation", ASM Handbook, Volume 8, 2000.

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[3.4.27] ANSYS 14.0, ANSYS, Inc., 2011.

[3.4.28] ANSYS 15.0, SAS IP, Inc., 2013.

[3.4.29] ANSYS 17.1, SAS IP, Inc., 2016.

[3.4.30] Holtec Report HI-2200503, Analysis of the Non-Mechanistic Tipover Event of the Loaded HI-STORM FW Version E Storage Cask, Latest Revision.

[3.6.1] Visual Nastran 2004, MSC Software, 2004.

<u>(b) HI-TRAC VW Fire</u>

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 VW is initially (before fire) assumed to be loaded to 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, as discussed in Subsection 4.6.2.1(a) is assumed to surround the HI-TRAC VW in a 1 m wide ring. The fire parameters are same as that assumed for the HI-STORM FW fire discussed in this preceding subsection. In this analysis, the HI-TRAC VW and its contents are conservatively postulated to undergo a transient heat-up as a lumped mass from the decay heat and heat input from the fire.

Based on the specified 50 gallon fuel volume, HI-TRAC VW cylinder diameter (7.9 ft) and the 1 m fuel ring width, the fuel ring area is 115.2 ft^2 and has a depth of 0.696 in. From this depth and the fuel consumption rate of 0.15 in/min, the fire duration τ_f is calculated to be 4.64 minutes (279 seconds). The fuel consumption rate of 0.15 in/min is a lowerbound value from Sandia Report [4.6.1]. Use of a lowerbound fuel consumption rate conservatively maximizes the duration of the fire.

From the HI-TRAC VW fire analysis, a bounding rate of temperature rise 2.722^{o}F per minute is determined. Therefore, the total temperature rise is computed as the product of the rate of temperature rise and τ_f is 12.6^{o}F. Because the cladding temperature at the start of fire is substantially below the accident temperature limit, the fuel cladding temperature limit during HI-TRAC VW fire is not exceeded. To confirm that the MPC pressure remains below the design accident pressure (Table 2.2.1) the MPC pressure resulting from fire temperature rise is computed using the Ideal Gas Law. The result (see Table 4.6.7) is below the pressure limit (see Table 2.2.1).

An alternate method using the FLUENT thermal model described in Section 4.5 can be adopted to evaluate HI-TRAC site-specific fire accident event. Principal modeling steps and acceptance criteria are defined in Table 4.6.11. This approach is consistent with that approved in HI-STORM 100 FSAR [4.1.8].

4.6.2.2 Jacket Water Loss

In this subsection, the fuel cladding and MPC boundary integrity is evaluated under a postulated (non-mechanistic) loss of water from the HI-TRAC VW water jacket. For a bounding analysis, all water compartments are assumed to lose their water and be replaced with air. The HI-TRAC VW 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 and reported in Table 4.6.3. The results of jacket water loss evaluation confirm that the cladding, MPC and HI-TRAC VW 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 4.6.7) shows a positive margin of safety.

Table 4.6.11

PRINCIPAL SITE-SPECIFIC HI-TRAC FIRE ACCIDENT MODELING STEPS

Step 1: Site Specific Conditions	<u>Heat Loads</u> Site Specific heat load map. <u>Ambient Temperature</u> – Short Term Operations temperature defined in Chapter 2. <u>Fire Accident</u> – Compute fire duration τ_f based on site specific fuel quantity in accordance with methodology defined in Sub-Section 4.6.2.1(b).
Step 2: FLUENT Thermal Model	Incorporate HI-TRAC thermal methodologies defined in Section 4.5.2. Use the licensing basis HI-TRAC thermal model presented in [4.1.9]. Apply heat loads and ambient temperature defined in Step 1 and obtain baseline initial temperature field.
Step 3: Fire Transient Solution	Apply fire parameters defined by fire temperature, fire emissivity and convection heat transfer coefficient specified in Sub-Section 4.6.2.1(a) to FLUENT Model and compute time dependent HI-TRAC temperature field starting from initial temperature field obtained in Step 2 up to end of fire τ_f.
Step 4: Post-Fire Solution	Restore ambient temperature conditions as defined in Sub-Section 4.6.2.1(a). Compute time dependent temperature field under cooldown of HI-TRAC cask by natural convection and radiation. Continue solution until all component and fuel temperatures reach their maximum and begin to recede.
Step 5: Post-Process Results	Post-process FLUENT solution and evaluate compliance of maximum fuel, basket, MPC confinement boundary and HI-TRAC enclosure shell temperatures with Chapter 2 accident temperature limits. Compute maximum MPC pressure in accordance with Sub-Section 4.4.5 methodology and evaluate compliance with Chapter 2 accident pressure limits.

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 in accordance with Technical Specification requirements to ensure that all liquid water is removed.

Following MPC moisture removal, by VDS or FHD, 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 (for multi-pass welds). The cover plate welds are then leak tested. In the case where the optional redundant port covers are used, the leak test is omitted. The leak test is replaced with welding of the primary port cover with liquid penetrant examination performed on the final pass. Followed by welding of the redundant port cover with liquid penetrant examination performed on the root and final passes.

The MPC closure ring is then placed on the MPC and 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.

The annulus shield (if utilized) is removed and the remaining water in the annulus is drained. The MPC lid and accessible areas of the top of the MPC shell are smeared for removable contamination. HI-TRAC VW surface dose rates are measured in accordance with the technical specifications. The MPC lift attachments are installed on the MPC lid. The MPC lift attachments are the primary lifting point on the MPC. MPC slings are installed between the MPC lift attachments and the lift yoke.

MPC transfer may be performed inside or outside the fuel building. The empty HI-STORM FW overpack is inspected and positioned with the lid removed. Next, the mating device is positioned on top of the HI-STORM FW and HI-TRAC VW is placed on top of it. The mating device assists in the removal of the HI-TRAC VW bottom lid and helps guide the HI-TRAC VW during its placement on the HI-STORM FW. The MPC slings are attached to the MPC lift attachments. The MPC is transferred using a suitable load handling device.

Next, the HI-TRAC VW bottom lid is removed and the mating device drawer is opened. The MPC is transferred into HI-STORM FW. Following verification that the MPC is fully lowered, the MPC slings are disconnected from the lifting device and lowered onto the MPC lid. Next, the HI-TRAC VW is removed from the top of HI-STORM FW[5]. The MPC slings and MPC lift attachments are removed. Plugs are installed in the empty MPC lifting holes to fill the voids left by the lift attachment bolts. Next, the mating device is removed. The HI-STORM FW lid, along with the temperature elements (if used), and vent screens may be installed at anytime after the mating device is removed. The HI-STORM FW is secured to the transporter (as applicable) and

5 The empty HI-TRAC VW may be removed from the mating device with its bottom lid installed or removed.

gases. 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 purged with inert gas prior to, and during MPC lid welding operations, including welding, grinding, and other hot work, to provide additional assurance that flammable gas concentrations will not develop in this space.

c. Perform combustible gas monitoring and purge the space under the MPC lid with an inert gas to ensure that there is no combustible mixture present in the welding area.

Note:
MPC closure welding procedures dictate the performance requirements and acceptance requirements of the weld examinations.

d. Perform the MPC lid-to-shell weld and NDE in accordance with the licensing drawings using approved procedures. Repair any weld defects in accordance with the applicable code and re-perform the NDE until the weld meets the required acceptance criteria.

4. Perform MPC lid-to-shell weld pressure testing in accordance with site-approved procedures.

5. ~~Repeat the liquid penetrant examination on the final pass of the MPC lid-to-shell weld.~~Examine MPC for leakage.

a. In the event of leakage, ~~R~~repair any weld defects in accordance with the applicable code requirements and re-perform the NDE in accordance with approved procedures.

6. Drain the MPC and terminate time-to-boil monitoring and boron sampling program, where required.

ALARA Warning:
For operations involving HI-TRAC VW Version V2, the HI-TRAC VW shall be installed in the NSC prior to draining the water from the loaded MPC. The NSC contains Holtite-A shielding material to provide neutron shielding following drainage of water from the MPC.

Note:
Detailed procedures for MPC drying are provided on a site-specific basis. The following summarize those procedures.

7. Dry and backfill the MPC (Vacuum Drying Method).

Note:
During drying activities, the annulus between the MPC and the HI-TRAC VW must be maintained full of water. Water lost due to evaporation or boiling must be replaced to maintain the water level.

e. Fill the annulus between the MPC and HI-TRAC VW with clean water. The water level must be within 6” of the top of the MPC.

i. Shutdown the FHD system and disconnect it from the RVOAs.

j. Remove the vent and drain port RVOAs.

9. Weld the vent and drain port cover plates and perform NDE in accordance with the licensing drawings using approved procedures. Repair any weld defects in accordance with the applicable code and re-perform the NDE until the weld meets the required acceptance criteria. If the optional redundant port covers have been used, proceeding Step 10 shall be omitted.

10. Perform a leakage test of the MPC vent port cover plate and drain port cover plate in accordance with the following and site-approved procedures:

a. If necessary, remove the cover plate set screws.

b. Flush the cavity with helium to remove the air and immediately install the set screws recessed approximately ¼ inch below the top of the cover plate.

c. Plug weld the recess above each set screw to complete the penetration closure welding in accordance with the licensing drawings using approved procedures. Repair any weld defects in accordance with the applicable code and re-perform the NDE until the weld meets the required acceptance criteria.

d. Flush the area around the vent and drain cover plates with compressed air or nitrogen to remove any residual helium gas.

e. Perform a helium leakage rate test of vent and drain cover plate welds in accordance with the Mass Spectrometer Leak Detector (MSLD) manufacturer's instructions and leakage test methods and procedures of ANSI N14.5 [9.1.2]. The MPC Helium Leak Rate acceptance criterion is provided in LCO 3.1.1.

11. Weld the MPC closure ring as follows:

a. Install and align the closure ring.

b. Weld the closure ring to the MPC shell and the MPC lid, and perform NDE in accordance with the licensing drawings using approved procedures. Repair any weld defects in accordance with the applicable code and re-perform the NDE until the weld meets the required acceptance criteria.

c. If necessary, remove the AWS.

9.2.5 Preparation for Storage

10.1.2.2 Pressure Testing

10.1.2.2.1 HI-TRAC Transfer Cask Water Jacket

All HI-TRAC transfer cask water jackets shall be hydrostatically tested in accordance with written and approved procedures. The water jacket fill port will be used for filling the cavity with water and the vent port for venting the cavity. The approved test procedure shall clearly define the test equipment arrangement.

The hydrostatic test shall be performed after the water jacket has been welded together. The test pressure gage installed on the water jacket shall have an upper limit of approximately twice that of the test pressure. The hydrostatic test pressure shall be maintained for ten minutes. During this time period, the pressure gage shall not fall below the applicable minimum test pressure. At the end of ten minutes, and while the pressure is being maintained at the minimum pressure, weld joints shall be visually examined for leakage. If a leak is discovered, the cavity shall be emptied and an examination to determine the cause of the leakage shall be made. Repairs and retest shall be performed until the hydrostatic test criteria are met.

After completion of the hydrostatic testing, the water jacket exterior surfaces shall be visually examined for cracking or deformation. Evidence of cracking or deformation shall be cause for rejection, or repair and retest, as applicable. Unacceptable areas shall require repair and re-examination per the applicable ASME Code. The HI-TRAC water jacket hydrostatic test shall be repeated until all examinations are found to be acceptable.

Test results shall be documented. The documentation shall become part of the final quality documentation package.

10.1.2.2.2 MPC Confinement Boundary

Pressure testing (hydrostatic or pneumatic) of the MPC Confinement Boundary shall be performed to verify the lid-to-shell field weld in accordance with the requirements of the ASME Code Section III, Subsection NB, Article NB-6000 and applicable sub-articles, when field welding of the MPC lid-to-shell weld is completed. If hydrostatic testing is used, the MPC shall be pressure tested to 125% of design pressure. If pneumatic testing is used, the MPC shall be pressure tested to 120% of design pressure. The calibrated test pressure gage installed on the MPC Confinement Boundary shall have an upper limit of approximately twice that of the test pressure. The MPC vent and drain ports will be used for pressurizing the MPC cavity. Water shall be pumped into the MPC drain port until water only is flowing from the MPC vent port. The MPC vent port is then closed and the pressure is increased to the test pressure. While the MPC is under pressure, the MPC lid-to-shell weld shall be examined for leakage. If any leaks are observed, the pressure shall be released and the weld shall be repaired in accordance with the requirements of ASME Code, Section III, Subsection NB. Following completion of the required hold period at the test pressure, the pressure shall be released. ~~and the surface of the MPC lid-to-shell weld shall be re-examined by liquid penetrant examination in accordance with ASME~~

~~Code, Section III, Subsection NB, Article NB-5350 acceptance criteria. Any evidence of cracking or deformation shall be cause for rejection, or repair and retest, as applicable.~~

If a leak is discovered, the test pressure shall be reduced, the MPC cavity water level lowered, if applicable, the MPC cavity vented, and the weld shall be examined to determine the cause of the leakage and/or cracking. Repairs to the weld shall be performed in accordance with written and approved procedures prepared in accordance with the ASME Code, Section III, Article NB-4450.

The MPC confinement boundary pressure test shall be repeated until all required examinations are found to be acceptable. Test results shall be documented and maintained as part of the loaded MPC quality documentation package.

10.1.3 Materials Testing

The majority of materials used in the HI-TRAC transfer cask and a portion of the material in the HI-STORM overpack are ferritic steels. ASME Code, Section II and Section III require that certain materials be tested in order to assure that these materials are not subject to brittle fracture failures. Certain versions of the HI-TRAC include Holtite neutron shielding material.

Materials of the HI-TRAC transfer cask and HI-STORM overpack, as required, shall be Charpy V-notch tested in accordance with ASME Section IIA and/or ASME Section III, Subsection NF, Articles NF-2300, and NF-2430. The materials to be tested are identified in Table 3.1.9 and applicable weld materials. Table 3.1.9 provides the test temperatures and test acceptance criteria to be used when performing the material testing specified above.

For Holtite neutron shielding material, each manufactured lot of material shall be tested to verify the material composition (aluminum and hydrogen), boron concentration, and neutron shield density (or specific gravity) meet the requirements specified in Table 1.2.5. Appendix 1.B of HI-STORM 100 System FSAR [1.1.3] provides the Holtite-A material properties germane to its function as a neutron shield. A manufactured lot is defined as the total amount of material used to make any number of mixed batches comprised of constituent ingredients from the same lot/batch identification numbers supplied by the constituent manufacturer. Testing shall be performed in accordance with written and approved procedures and/or standards. Material composition, boron concentration, and density (or specific gravity) data for each manufactured lot of neutron shield material shall become part of the quality documentation package. The procedures shall ensure that mix ratios and mixing methods are controlled in order to achieve proper material composition, boron concentration and distribution, and that pours are controlled in order to prevent gaps from occurring in the material. Samples of each manufactured lot of neutron shield material shall be maintained by Holtec International as part of the quality record documentation package.

The concrete utilized in the construction of the HI-STORM overpack shall be mixed, poured, and tested as set down in Chapter 1.D of the HI-STORM 100 FSAR (Docket 72-1014) [10.1.6] in accordance with written and approved procedures. Testing shall verify the compressive strength

10.1.4 Leakage Testing

Leakage testing shall be performed in accordance with written and approved procedures and the leakage test methods and procedures of ANSI N14.5 [10.1.5], as follows.

Helium leakage testing of the MPC base metals (shell, baseplate, and MPC lid) and MPC shell to baseplate and shell to shell welds is performed on the unloaded MPC. The acceptance criterion is “leaktight” as defined in ANSI N14.5. Shop leakage tests of the base metals and enclosure welds may be performed using automated leak test equipment to minimize the need for operator actions and interpretations. Automated leak test equipment design and computer software programs shall be reviewed and approved by a Level III Leak Test specialist qualified in accordance with ANSI N14.5. Maintenance and calibration of the equipment and testing of the software shall be performed by individuals qualified in accordance with ANSI.N14.5 using written procedures produced under the licensee’s quality program. The placement of the MPC components in the test equipment and recording of the test data in the documentation package for the equipment shall be performed by personnel trained and qualified in accordance with the licensee’s quality program. The helium leakage test of the vent and drain port cover plate welds shall be performed using a helium mass spectrometer leak detector (MSLD). If a leakage rate exceeding the acceptance criterion is detected, then the area of leakage shall be determined and the area repaired per ASME Code Section III, Subsection NB, Article NB-4450 requirements. Re-testing shall be performed until the leakage rate acceptance criterion is met.

Leakage testing of the field welded MPC lid-to-shell weld and closure ring welds are not required. Leak testing results for the MPC shall be documented and shall become part of the quality record documentation package.

Leakage testing of the vent and drain port cover plate welds shall be performed after welding of the cover plates and subsequent NDE. For instances where redundant port covers have been installed, leakage testing is not required. The description and procedures for these field leakage tests are provided in Chapter 9 of this FSAR and the acceptance criteria are defined in the Technical Specifications for the HI-STORM FW system.

10.1.5 Component Tests

10.1.5.1 Valves, Pressure Relief Devices, and Fluid Transport Devices

There are no fluid transport devices associated with the HI-STORM FW system. The only valve-like components in the HI-STORM FW system are the specially designed caps installed in the MPC lid for the drain and vent ports. These caps are recessed inside the MPC lid and covered by the fully-welded vent and drain port cover plates. No credit is taken for the caps' ability to confine helium or radioactivity. After completion of drying and backfill operations, the drain and vent port cover plates are welded in place on the MPC lid and are liquid penetrant examined and leakage tested to verify the MPC Confinement Boundary.

Table 10.1.4
HI-STORM FW MPC NDE REQUIREMENTS

Weld Location	NDE Requirement	Applicable Code	Acceptance Criteria (Applicable Code)
Shell longitudinal seam	RT PT (surface)	ASME Section V, Article 2 (RT) ASME Section V, Article 6 (PT)	RT: ASME Section III, Subsection NB, Article NB-5320 PT: ASME Section III, Subsection NB, Article NB-5350
Shell circumferential seam	RT PT (surface)	ASME Section V, Article 2 (RT) ASME Section V, Article 6 (PT)	RT: ASME Section III, Subsection NB, Article NB-5320 PT: ASME Section III, Subsection NB, Article NB-5350
Baseplate-to-shell	RT PT (surface)	ASME Section V, Article 2 (RT) ASME Section V, Article 6 (PT)	RT: ASME Section III, Subsection NB, Article NB-5320 PT: ASME Section III, Subsection NB, Article NB-5350
Lid-to-shell	PT (root and final pass) and multi-layer PT. PT (surface following pressure test)	ASME Section V, Article 6 (PT)	PT: ASME Section III, Subsection NB, Article NB-5350
Closure ring-to-shell	PT (final pass)	ASME Section V, Article 6 (PT)	PT: ASME Section III, Subsection NB, Article NB-5350
Closure ring-to-lid	PT (final pass)	ASME Section V, Article 6 (PT)	PT: ASME Section III, Subsection NB, Article NB-5350
Closure ring radial welds	PT (final pass)	ASME Section V, Article 6 (PT)	PT: ASME Section III, Subsection NB, Article NB-5350
Port cover plates-to-lid Port cover plates-to-lid (when in conjunction with redundant port cover plate)	PT (root and final pass) PT (final pass)	ASME Section V, Article 6 (PT) ASME Section V, Article 6 (PT)	PT: ASME Section III, Subsection NB, Article NB-5350 PT : Clean White
Redundant Port cover plates to lid	PT (root and final pass)	ASME Section V, Article 6 (PT	PT: ASME Section III, Subsection NB, Article NB-5350
Lift lug and lift lug baseplate	PT (surface)	ASME Section V, Article 6 (PT)	PT: ASME Section III, Subsection NB, Article NB-5350
Vent and drain port cover plate plug welds	PT (surface)	ASME Section V, Article 6 (PT)	PT: ASME Section III, Subsection NB, Article NB-5350

CHAPTER 1.I; GENERAL DESCRIPTION: HI-STORM FW SYSTEM WITH UNVENTILATED OVERPACK

1.I.0 General Information:

Supplement 1.I to the HI-STORM FSAR is a supplement to the existing HI-STORM FW FSAR for the Unventilated Version of the system. Each individual chapter that requires additional safety analysis to qualify the addition of a new overpack model also has its own supplement. Specifically, this supplement to the HI-STORM FW FSAR is limited to the safety analysis of a simplified version of the HI-STORM FW system (hereafter abbreviated as "the *Storage System*") wherein the overpack's inlet and outlet air passages have been removed resulting in a complete cessation of ventilation in the space between the cask cavity and the stored multi-purpose canister (MPC) during the system's operation. The overpack model is referred to as HI-STORM FW Version UV (the annex UV is an abbreviation of **u**n-**v**entilated) or simply as "Version UV." Figure 1.I.1.1 shows a cut-away view of the Storage system with the MPC and Closure Lid slightly raised for clarity.

This supplement contains the necessary information and analyses to support the amendment to the certificate-of-compliance issued to the HI-STORM FW Canister Storage system in docket # 72-1032 to serve as a spent nuclear fuel (SNF) dry storage cask under the provisions of 10 CFR 72 [1.0.1][1]. This supplement, prepared pursuant to 10 CFR 72.230, describes the basis for NRC approval and CoC amendment on the HI-STORM FW System under 10 CFR 72, Subpart L to safely store spent nuclear fuel (SNF) at an Independent Spent Fuel Storage Installation (ISFSI) under the general license authorized under 10 CFR 72, Subpart K.

The purpose of this chapter is to provide a general description of the design features and storage capabilities of the storage system containing the Version UV overpack and any of the MPCs certified for storage in the HI-STORM FW system. This supplement introduces no new MPC or transfer cask; the only new equipment introduced is the unvented overpack which is illustrated in the Licensing drawing package in Section 1.I.5. This supplement is also suitable for incorporation into a site-specific Safety Analysis Report, which may be submitted by an applicant for a site-specific 10 CFR 72 license to store SNF at an ISFSI or a facility that is similar in objective and scope.

For completeness, Table 1.I.0.1 provides the principal components of the HI-STORM FW System containing the Version UV overpack that are subject to certification. An MPC (containing either PWR or BWR fuel) is placed inside the HI-STORM FW Version UV overpack for extended storage. The overpack provides shielding and environmental protection to the MPC. The HI-TRAC VW transfer cask, used in every HI-STORM FW model, is used for MPC transfer and also provides shielding and protection while the MPC is being prepared for storage.

Supplement I is comprised of a number of chapters where safety-relevant information on the HI-STORM FW system containing the Version UV overpack is needed. There are, however, several chapters that are not affected by Version UV and are therefore omitted. The unaffected chapters are listed in Table 1.I.0.2 along with the rationale for their omission.

Because of the extensive nexus between the SSCs introduced in this Supplement and those previously documented in this FSAR, even the chapters that require fresh safety evaluation material have sections

[1] Reference to a section, table, Figure or Reference without a Roman Numeral in it means it is in the main report.

within them that do not. Those sections are identified at the beginning of each chapter and the rationale for their omission is given. For this chapter, Table 1.I.0.3 lists the sections that do not require any change.

All chapters in this supplement are identified as n.I, where n is the chapter number in the main report which it supplements. Likewise, sections within a chapter are denoted by n.I.m, where m is the section number in the main chapter to which it applies. Thus, n.I.m.p represents the sequential sub-section p within section n.I.m.

All tables and figures within each chapter are numbered sequentially. Thus, Table n.I.1.1 represents the first table in Section n.I.1

Thus, the presence of I in the reference to a section, table, reference or figure clearly identifies it to belong to Supplement I.

All tables and figures called out in a Section can be found at the end of that Section.

Table 1.I.0.1 Principal Components Subject to Certification Associated with the Version UV in the HI-STORM FW System			
Component I.D.	**Characteristic**	**Function**	**Comment**
MPC-37(Certified in Rev 0 of the CoC)	Storage for 37 PWR fuel assemblies	Provide confinement to the its contents under normal, off-normal and accident conditions and during Part 72 Short Term operations	All MPC Fuel Baskets are made of Metamic-HT.
MPC-89 (certified in Rev 0 of the CoC)	Storage for 89 BWR fuel assemblies		
HI-TRAC VW(certified in Rev 0 of the CoC), HI-TRAC VW Version V (certified in Rev 5 of the CoC), HI-TRAC VW Version V2 (certified in Rev 5 of the CoC)	Variable weight transfer cask available in unventilated and ventilated versions	The transfer cask is indispensable to execute Short Term operations.	Version UV is configured to utilize the same HI-TRAC models as other “FW” overpack models.

Table 1.I.0.2; HI-STORM FW FSAR Chapters Unaffected by the Inclusion of Version UV		
Chapter number	**Title**	**Reason for omission**
6	Criticality Evaluation	No new MPC is introduced in this supplement; therefore, there is no change in the criticality safety of the storage system
7	Confinement	There is no change in the MPC confinement system. Therefore, the assertion made in Chapter 7 with regard to the leak tightness of the Confinement system apply.
8	Materials evaluation	No new material is introduced in this Supplement I.
11	Radiation Protection	The radiation protection attributes of the Storage system are improved in the unvented Storage system because the elimination of the inlet and outlet air passages eliminates associated streaming of radiation during both the MPC loading operations and on-the-pad storage. Therefore, the safety conclusions reached in Chapter 11 are applicable in an even greater measure.
14	Quality Assurance Program	The quality assurance program remains unchanged.

Table 1.I.0.3; Sections in Chapter 1 of the FSAR that Remain Applicable to the Safety Evaluation in Supplement I		
Section number	**Title**	**Reason for omission**
1.I.3	Agents and subcontractors	The information in Section 1.3 does not require any correction
1.I.4	Generic cask arrays	The information in Section 1.4 remains applicable

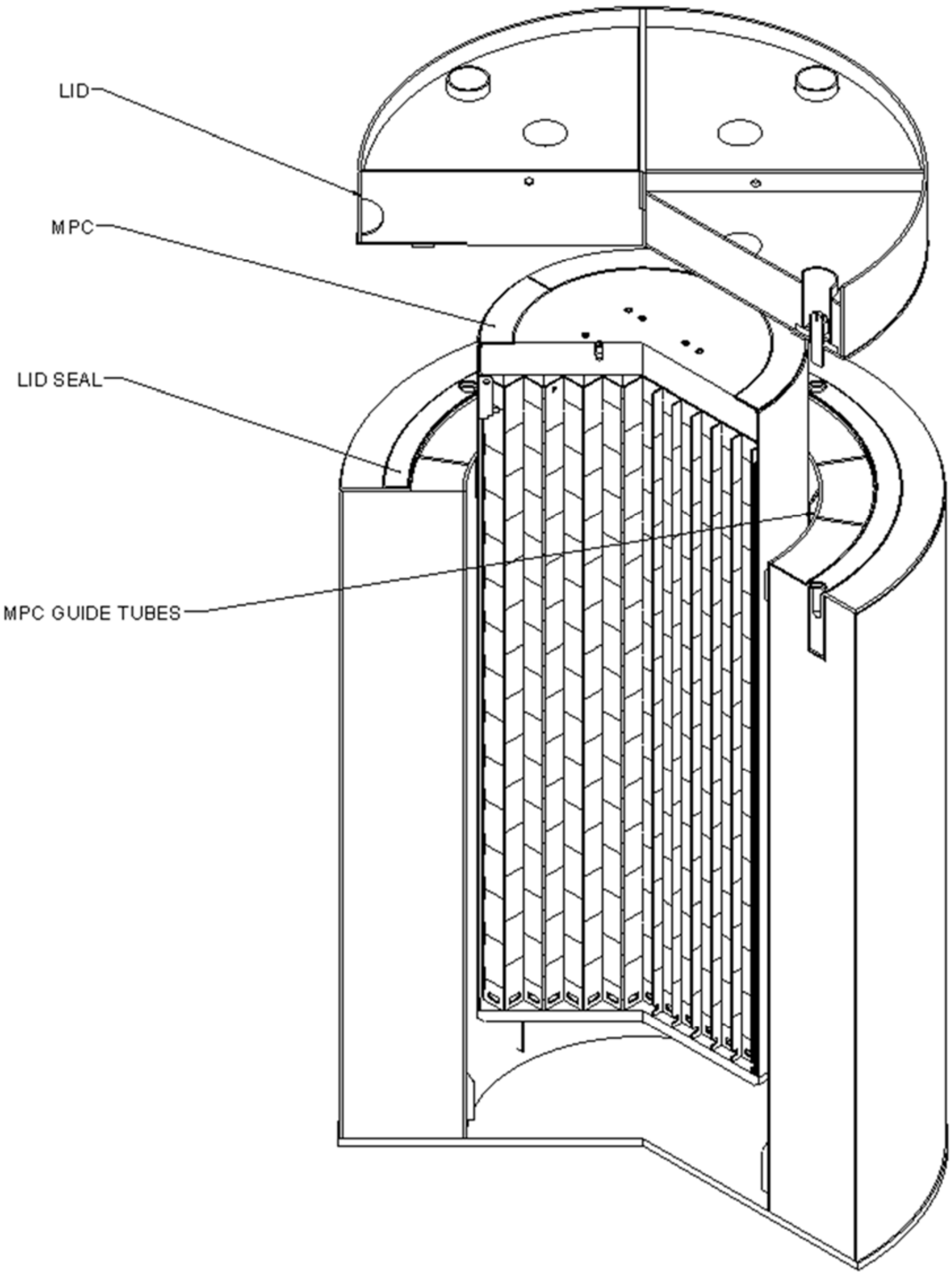


Figure 1.I.1.1 HI-STORM FW Storage System with Version UV Overpack in cut-away View

1.I.1 Introduction to the Storage System

The HI-STORM FW storage system considered in this supplement is differentiated by the unventilated overpack called Version UV; all other components, namely the MPCs and the HI-TRAC VW transfer cask remain unchanged. To fix ideas, wherever the ventilated HI-STORM FW system is referenced in this Supplement I, it refers to the latest version, namely Version E analyzed and qualified in the main report.

Because the Storage system does not rely on ventilation action, its heat rejection capacity is rather modest, governed by the natural convection and radiation from the external surfaces of the overpack. To quantify the heat removal rate, a quiescent condition (no wind) is assumed in the thermal analysis summarized in Chapter 4.I.

Version UV is expected to serve as a low-dose MPC storage system wherein the external environment around the Canister is sought to be controlled, such as to protect from stress corrosion cracking. Because the vent-free overpack serves as a secondary confinement, it can also be used to store an MPC suspected of an impending loss of confinement.

In all physical respects, the Storage system is identical to its ventilated counterpart. Thus, like the ventilated HI-STORM FW overpack models, the Version UV overpack can be staged in a free standing or anchored configuration on a sheltered or unsheltered pad. Other key characteristics of the Storage system that it shares with other HI-STORM FW systems are:

- Because the cask is not used to load fuel in the pool, the storage system does not run the risk of being infected with the pool's contamination.

- The Canister, designed and qualified to be *leak-tight*, is a compact "*waste package*" which can be readily retrieved and transported off-site in a suitably certified transport cask.

- The MPC confinement boundary, deemed to be leak-tight pursuant to ISG-18, provides an incomparably greater protection against leakage than a gasketed metal cask with a bare basket.

- All SSCs listed in Table 1.I.1 are designated Important-to-safety (ITS). The ISFSI pad is NITS unless it is used to anchor the cask in which case it is also ITS.

1.I.2 General Description

1.I.2.1 System Characteristics

The components of the Storage system are listed in Table 1.I.0.1. The description presented in Section 1.2 of the main FSAR remains applicable with only the storage overpack being different. The overpack, illustrated in the licensing drawing in Section 1.I.5, is sized to store the designated reference PWR MPC (MPC-37) listed in Table 1.I.1.

1.I.2.1.1 MPCs:

There no change in the MPCs described in Subsection 1.2.1.1 of this FSAR. This supplement introduces no new MPCs or amends any MPC design.

1.I.2.1.2 Version UV Overpack:

The HI-STORM FW Version UV overpack is made from a dual shell steel weldment filled with shielding concrete. Structurally, it emulates a classic metal cask wherein all inlet and outlet vents have been eliminated and the Closure Lid is fastened to the cask body with a weather-resistant elastomeric gasket. Absence of the inlet and outlet air passages and the all-welded steel internal boundary of the overpack enclosed by a steel buttressed and gasketed Closure lid renders the cask's internal space into a pressure-retaining enclosure. This pneumatically sealed space is envisaged to hold the loaded *multi-purpose canister* such as MPC-89 or MPC-37 in an upright orientation.

As its design configuration would suggest, "Version UV" (UV is an abbreviation of **u**n**v**entilated) has a considerably reduced heat load capacity compared to its ventilated counterpart. Because the only heat rejection pathway available to the Version UV storage system is through natural convection to the ambient and a limited conduction to the ISFSI pad, the annulus air inside the overpack will be at an elevated temperature. Because heating of air reduces its relative humidity and a high humidity content is necessary (but not sufficient) to induce stress corrosion cracking (SCC) in the stainless steel confinement boundary of the MPC, increasing the temperature of the air surrounding the Canister serves to minimize the incidence of SCC under extended storage conditions. Preventing SCC is a principal objective of Version UV.

The air pressure in the sealed space of the overpack will rise with its absolute temperature roughly in accordance with the perfect gas law. The annulus air is replaced with a non-oxidizing gas to further protect the MPC from stress corrosion cracking, such as nitrogen, without any adverse effect on the system's performance. The initial fill pressure in the annulus is shown on the licensing drawing in Section 1.I.5 which, as the calculations in Supplement 4.I indicate, ensures that the annulus pressure will remain sub-atmospheric at all times.

However, to provide pressure relief in the hypothetical condition where the inside pressure in the cask rises above the ambient pressure, the Closure Lid bolts are installed with a small axial clearance such that the Lid can heave and relieve the increased gas pressure. There is no credible scenario, however, where such a condition of overpressure has been postulated to develop.

The reference dimensions listed in Table 1.I.3 are used to size the Version UV overpack for different MPC types along with the licensing drawing in Section 1.I.5 in this chapter.

Because of the main heat rejection path in Version UV is conduction through the cask body, a large number of "*connector plates*" are used to join the inner and outer shells. Likewise, the Closure lid features extensive physical connectivity between its bottom and top surfaces.

By virtue of the thermosiphon effect inside the MPC, its Top Lid is the hottest part of the Canister's surface. The hot MPC lid rejects heat to the cask's Closure Lid by direct radiation and convection whose top surface is ideally situated (hot surface looking up) to promote convection of heat to the ambient. From a personnel safety standpoint, having the hottest surface of the cask located at the very top of the cask (away from the reach of surveillance personnel) is a salutary operational feature.

In summary, Version UV overpack emulates a conventional metal cask but provides significantly improved radiation shielding because of its thick concrete filled steel weldment construction. Its other notable characteristics are:

- There is no real restriction on the gap between the MPC and cask's internal surface. Therefore, canisters of different outer diameters can be loaded in the same Version UV overpack.

- There is considerable flexibility relative to the height of the cask's internal cavity as well. The cavity should be tall enough to accommodate the tallest MPC that will be stored at the site.

- The density of the shielding concrete can be set at the value needed to realize the level of dose reduction required.

1.I.2.1.3 Transfer Cask

No new transfer cask design is proposed in this supplement and existing design described in Subsection 1.2.1.3 is not modified.

1.I.2.1.4 Shielding and Neutron Absorber Materials:

There is no change in the materials employed in the HI-STORM FW system with Version UV overpack.

1.I.2.1.5 Shielding Materials:

There is no change in the shielding materials used in the HI-STORM FW system as described in Subsection 1.2.1.4 in the main report.

1.I.2.1.6 Lifting Devices:

There is no change in the specification for the Lifting Devices described in the HI-STORM FW system as described in subsection 1.2.1.5 in the main report.

1.I.2.2 Operational Features:

The operational features remain fully applicable except that, as stated in Chapter 9.I, before installing the Closure Lid on the Storage overpack, a gasket to inhibit exchange of the gas inside and outside of the cask is placed on the interface between the cask body and the Closure Lid.

1.I.2.2.3 Identification of Subjects for Safety and Reliability Analysis

1.I.2.2.3.1 Criticality Prevention

There is no change in the MPCs, and their Fuel Baskets proposed in this Supplement. Therefore, there is no change in the criticality safety characteristics of the Storage system.

1.I.2.2.3.2 Chemical Safety

As stated in 1.2.2.3.2, there are no chemical safety hazards associated with operations of the Storage system. A detailed evaluation is provided in Section 3.4.

1.I.2.2.3.3 Operation Shutdown Modes

The Storage system is totally passive and consequently, operation shutdown modes are unnecessary.

1.I. 2.2.3.4 Instrumentation

As stated in 1.2.2.3.4, the HI-STORM FW MPC, which is seal welded, non-destructively examined, and pressure tested, confines the radioactive contents. The Storage system is completely passive 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 surface temperature of the cask and the temperature of the annulus air.

1.I.2.2.3.5 Maintenance Technique

As stated in 1.2.2.3.5, because of its passive nature, the Storage system requires minimal maintenance over its lifetime. No special maintenance program is required. The maintenance program consists of protecting the overpack from external corrosion and periodic replacement of the Closure Lid gasket.

1.I.2.3 Cask Contents:

The same fuel types allowed in the main chapter, subsection 1.2.3 are allowed for storage in the HI-STORM UV system. However, additional restrictions on heat load apply, and are listed in Tables 1.I.2.1 through 1.I.2.4.

For PWR fuel with a longer active fuel length than the reference fuel, the maximum total heat load, maximum section heat load limits, and specific heat load limits in each cell, may be increased by the ratio SQRT(L/144), where L is the active length of the fuel in inches

For PWR fuel with a shorter active fuel length than the reference fuel, the maximum total heat load, maximum section heat load limits, and specific heat load limits in each cell, shall be reduced linearly by the ratio L/144, where L is the active fuel length of the fuel in inches.

For BWR fuel with a longer active fuel length than the reference fuel, the maximum total heat load, maximum section heat load limits, and specific heat load limits in each cell, may be increased by the ratio SQRT(L/150), where L is the active length of the fuel in inches

For BWR fuel with a shorter active fuel length than the reference fuel, the maximum total heat load, maximum section heat load limits, and specific heat load limits in each cell, shall be reduced linearly by the ration L/150, where L is the active fuel length of the fuel in inches.

TABLE 1.I.2.1 HI-STORM FW UV MPC-37 HEAT LOAD DATA			
Number of Regions: 3			
Number of Storage Cells: 37			
Maximum Total Heat Load (kW): 24			
Maximum Section Heat Load (kW): 3 (Note 1)			
Region No.	Decay Heat Limit per Cell, kW (Note 2)	Number of Cells per Region	Decay Heat Limit per Region, kW
1	0.648	9	5.832
2	0.648	12	7.776
3	0.648	16	10.368
Note 1: Figure 1.I.2-1 identifies the cell locations in each section. Note 2: Maximum total heat load, maximum quadrant heat load and specific cell heat load limits may need to be adjusted in accordance with Section 1.I.2.3. Note 3: This pattern can be modified to develop regionalized patterns in accordance with the requirements in Table 1.I.2.2.			

TABLE 1.I.2.2
HI-STORM FW UV MPC-37 REQUIREMENTS ON DEVELOPING REGIONALIZED HEAT LOAD PATTERNS (See Figure 1.I.2-1)

1. Pattern-specific total heat load must be equal to 24 kW
2. Section Heat Load must be equal to 3 kW, calculated per Figure 1.I.2-1, and pattern must be $1/8^{th}$ symmetric
3. Maximum Allowable Decay Heat per Cell in Region 1 is 0.648 kW
4. Maximum Allowable Decay Heat per Cell in Region 2 is 1.296 kW
5. Maximum Allowable Decay Heat per Cell in Region 3 is 1.944 kW
6. Pattern-specific Decay Heat in a storage cell may need to be adjusted to meet items 1 and 2
7. Pattern-specific decay heat for any storage cell in Region 1 may be determined by reducing the allowable in Region 1 of Table 1.I.2.1 by Δ and pattern-specific decay heat for any storage cell in Regions 2 and 3 may be determined by increasing the allowable in Region 2 and/or Region 3 of Table 1.I.2.1 by the same Δ.
8. Pattern-specific decay heat for any storage cell in Region 2 may be determined by reducing the allowable in Region 2 of Table 1.I.2.1 by θ and pattern-specific decay heat for any storage cell in Region 3 may be determined by increasing the allowable in Region 3 of Table 1.I.2.1 by the same θ. This θ may not be added to other cells in Region 2.
9. Items 1 through 8 need to be scaled in accordance with Section 1.I.2.3 for non-standard active fuel lengths.

General Note – The limits developed for the patterns are maximums, and any assembly with a heat load less than those limits can be loaded in the applicable cell, provided it meets all other CoC requirements.

TABLE 1.I.2.3 HI-STORM FW UV MPC-89 HEAT LOAD DATA			
Number of Regions: 3			
Number of Storage Cells: 89			
Maximum Total Heat Load (kW): 24			
Maximum Section Heat Load (kW): 3 (Note 1)			
Region No.	Decay Heat Limit per Cell, kW (Note 2)	Number of Cells per Region	Decay Heat Limit per Region, kW
1	0.269	9	2.421
2	0.269	40	10.76
3	0.269	40	10.76

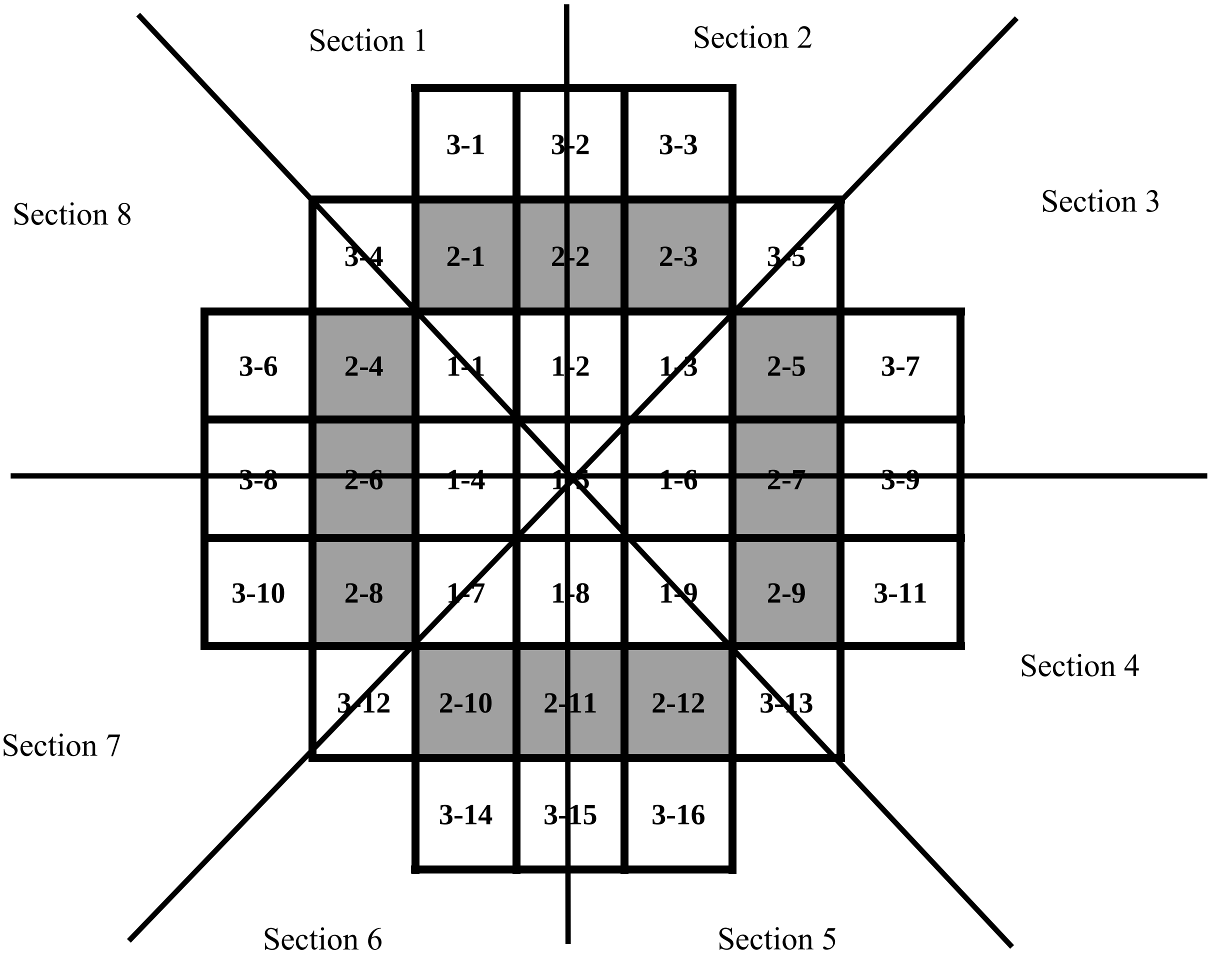
Note 1: Figure 1.I.2-2 identifies the cell locations in each section.
Note 2: Maximum total heat load, maximum section heat load and specific cell heat load limits may need to be adjusted in accordance with Section 1.I.2.3
Note 3: This pattern can be modified to develop regionalized patterns in accordance with the requirements in Table 1.I.2.4.

TABLE 1.I.2.4
HI-STORM FW UV MPC-89 HEAT LOAD DATA REQUIREMENTS ON DEVELOPING REGIONALIZED HEAT LOAD PATTERNS (See Figure 1.I.2-2)

1. Pattern-specific total heat load must be equal to 24 kW
2. Section Heat Load must be equal to 3 kW, calculated per Figure 1.I.2-2, and pattern must be 1/8th symmetric
3. Maximum Allowable Decay Heat per Cell in Region 1 is 0.269 kW
4. Maximum Allowable Decay Heat per Cell in Region 2 is 0.538 kW
5. Maximum Allowable Decay Heat per Cell in Region 3 is 0.807 kW
6. Pattern-specific Decay Heat in a storage cell may need to be adjusted to meet items 1 and 2
7. Pattern-specific decay heat for any storage cell in Region 1 may be determined by reducing the allowable in Region 1 of Table 1.I.2.3 by Δ and pattern-specific decay heat for any storage cell in Regions 2 and 3 may be determined by increasing the allowable in Region 2 and/or Region 3 of Table 1.I.2.3 by the same Δ.
8. Pattern-specific decay heat for any storage cell in Region 2 may be determined by reducing the allowable in Region 2 of Table 1.I.2.3 by θ and pattern-specific decay heat for any storage cell in Region 3 may be determined by increasing the allowable in Region 3 of Table 1.I.2.3 by the same θ. This θ may not be added to other cells in Region 2.
9. Items 1 through 8 need to be scaled in accordance with Section 1.I.2.3 for non-standard active fuel lengths.

General Note – The limits developed for the patterns are maximums, and any assembly with a heat load less than those limits can be loaded in the applicable cell, provided it meets all other CoC requirements.

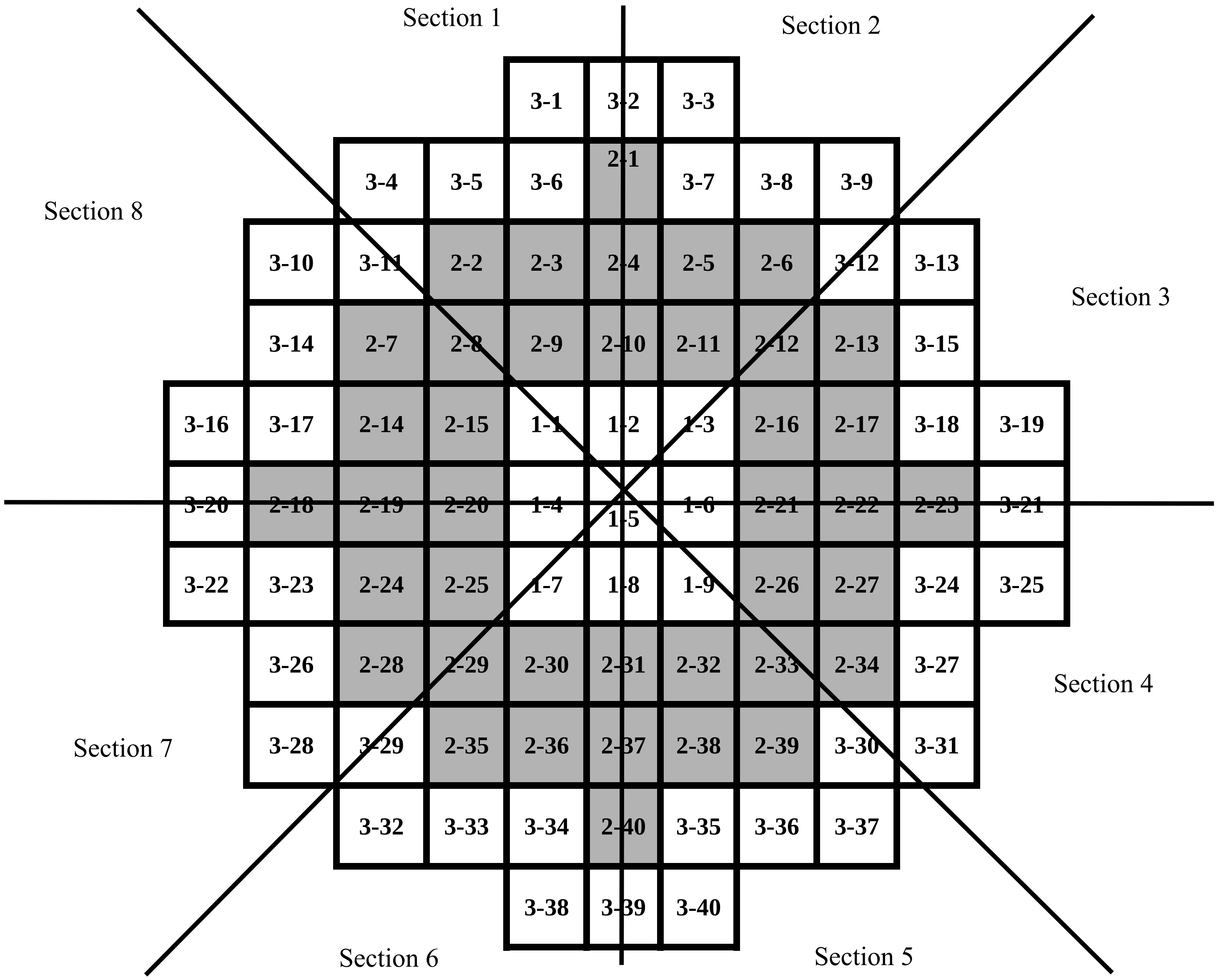
Figure 1.I.2-1 – MPC-37 Cell and Section Identification



To calculate the per section heat load, the following apply, where Q represents the heat load in the identified cell in kW.

Section 1: $Q_{3-1} + Q_{2-1} + ½Q_{3-2} + ½Q_{3-4} + ½Q_{2-2} + ½Q_{1-1} + ½Q_{1-2} + 1/8Q_{1-5}$
Section 2: $Q_{3-3} + Q_{2-3} + ½Q_{3-2} + ½Q_{3-5} + ½Q_{2-2} + ½Q_{1-3} + ½Q_{1-2} + 1/8Q_{1-5}$
Section 3: $Q_{2-5} + Q_{3-7} + ½Q_{1-6} + ½Q_{3-5} + ½Q_{2-7} + ½Q_{1-3} + ½Q_{3-9} + 1/8Q_{1-5}$
Section 4: $Q_{2-9} + Q_{3-11} + ½Q_{1-6} + ½Q_{1-9} + ½Q_{2-7} + ½Q_{3-13} + ½Q_{3-9} + 1/8Q_{1-5}$
Section 5: $Q_{2-12} + Q_{3-16} + ½Q_{1-8} + ½Q_{1-9} + ½Q_{2-11} + ½Q_{3-13} + ½Q_{3-15} + 1/8Q_{1-5}$
Section 6: $Q_{2-10} + Q_{3-14} + ½Q_{1-8} + ½Q_{1-7} + ½Q_{2-11} + ½Q_{3-12} + ½Q_{3-15} + 1/8Q_{1-5}$
Section 7: $Q_{2-8} + Q_{3-10} + ½Q_{1-4} + ½Q_{1-7} + ½Q_{2-6} + ½Q_{3-12} + ½Q_{3-8} + 1/8Q_{1-5}$
Section 8: $Q_{2-4} + Q_{3-6} + ½Q_{1-4} + ½Q_{1-1} + ½Q_{2-6} + ½Q_{3-4} + ½Q_{3-8} + 1/8Q_{1-5}$

Figure 1.I.2-2 – MPC-89 Cell and Section Identification



To calculate the per section heat load, the following apply, where Q represents the heat load in the identified cell in kW.

Section 1: $Q_{3-1} + Q_{3-4} + Q_{3-5} + Q_{3-6} + Q_{2-2} + Q_{2-3} + Q_{2-9} + \frac{1}{2}Q_{3-2} + \frac{1}{2}Q_{2-1} + \frac{1}{2}Q_{2-4} + \frac{1}{2}Q_{2-10} + \frac{1}{2}Q_{1-2} + \frac{1}{2}Q_{1-1} + \frac{1}{2}Q_{2-8} + \frac{1}{2}Q_{2-11} + 1/8Q_{1-5}$

Section 2: $Q_{3-3} + Q_{3-7} + Q_{3-8} + Q_{3-9} + Q_{2-5} + Q_{2-6} + Q_{2-11} + \frac{1}{2}Q_{3-2} + \frac{1}{2}Q_{2-1} + \frac{1}{2}Q_{2-4} + \frac{1}{2}Q_{2-10} + \frac{1}{2}Q_{1-2} + \frac{1}{2}Q_{1-3} + \frac{1}{2}Q_{2-12} + \frac{1}{2}Q_{3-12} + 1/8Q_{1-5}$

Section 3: $Q_{3-13} + Q_{2-13} + Q_{3-15} + Q_{2-16} + Q_{2-17} + Q_{3-18} + Q_{3-19} + \frac{1}{2}Q_{1-6} + \frac{1}{2}Q_{2-21} + \frac{1}{2}Q_{2-22} + \frac{1}{2}Q_{2-23} + \frac{1}{2}Q_{3-21} + \frac{1}{2}Q_{1-3} + \frac{1}{2}Q_{2-12} + \frac{1}{2}Q_{3-12} + 1/8Q_{1-5}$

Section 4: $Q_{2-26} + Q_{2-27} + Q_{3-24} + Q_{3-25} + Q_{2-34} + Q_{3-27} + Q_{3-31} + \frac{1}{2}Q_{1-6} + \frac{1}{2}Q_{2-21} + \frac{1}{2}Q_{2-22} + \frac{1}{2}Q_{2-23} + \frac{1}{2}Q_{3-21} + \frac{1}{2}Q_{1-9} + \frac{1}{2}Q_{2-33} + \frac{1}{2}Q_{3-30} + 1/8Q_{1-5}$

Section 5: $Q_{2-32} + Q_{2-38} + Q_{2-39} + Q_{3-35} + Q_{2-36} + Q_{3-37} + Q_{3-40} + \frac{1}{2}Q_{1-8} + \frac{1}{2}Q_{2-31} + \frac{1}{2}Q_{2-37} + \frac{1}{2}Q_{2-40} + \frac{1}{2}Q_{3-39} + \frac{1}{2}Q_{1-9} + \frac{1}{2}Q_{2-33} + \frac{1}{2}Q_{3-30} + 1/8Q_{1-5}$

Section 6: $Q_{2-30} + Q_{2-35} + Q_{2-36} + Q_{3-32} + Q_{2-33} + Q_{3-34} + Q_{3-38} + \frac{1}{2}Q_{1-8} + \frac{1}{2}Q_{2-31} + \frac{1}{2}Q_{2-37} + \frac{1}{2}Q_{2-40} + \frac{1}{2}Q_{3-39} + \frac{1}{2}Q_{1-7} + \frac{1}{2}Q_{2-29} + \frac{1}{2}Q_{3-29} + 1/8Q_{1-5}$

Section 7: $Q_{2-25} + Q_{2-24} + Q_{3-23} + Q_{3-22} + Q_{2-28} + Q_{3-26} + Q_{3-28} + \frac{1}{2}Q_{1-4} + \frac{1}{2}Q_{2-20} + \frac{1}{2}Q_{2-19} + \frac{1}{2}Q_{2-18} + \frac{1}{2}Q_{3-20} + \frac{1}{2}Q_{1-7} + \frac{1}{2}Q_{2-29} + \frac{1}{2}Q_{3-29} + 1/8Q_{1-5}$

Section 8: $Q_{2-15} + Q_{2-14} + Q_{3-17} + Q_{3-16} + Q_{2-7} + Q_{3-14} + Q_{3-10} + \frac{1}{2}Q_{1-4} + \frac{1}{2}Q_{2-20} + \frac{1}{2}Q_{2-19} + \frac{1}{2}Q_{2-18} + \frac{1}{2}Q_{3-20} + \frac{1}{2}Q_{1-1} + \frac{1}{2}Q_{2-8} + \frac{1}{2}Q_{3-11} + 1/8Q_{1-5}$

1.I.5 Licensing Drawings:

The licensing drawing package for “Version UV” is provided in this section. The Licensing drawing package in this section shows explicit dimensions for the Storage system containing MPC-37 to store standard PWR (Westinghouse) fuel. For other MPC types in Table 1.I.0.1, the relational dimensional data in Table 1.I.5.1 can be used to establish the design dimensions.

Drawing Number	Title	Revision
11897	HI-STORM FW Version UV Licensing Drawing	0

[PROPRIETARY DRAWINGS WITHHELD PER 10CFR2.390]

CHAPTER 2.I: PRINCIPAL DESIGN CRITERIA

2.I.0 Introduction:

The principal design criteria for the Version UV equipped HI-STORM FW Canister storage system is unchanged in all respects except for those relating to its function related to environment control. The Version UV overpack does not have any open penetrations such as air vents in the classical design to permit ventilation of the ambient air. Rather the all open vents are eliminated, and the Closure Lid is installed with a concentric gasket which inhibits the exchange of the gas inside the cask with the ambient air. The air in the cask cavity space is replaced with a non-oxidizing gas and filled to a sub-atmospheric pressure, to ensure that the internal pressure during operating conditions will always remain below the external ambient pressure precluding any release of the cavity gas into the ambient. The Closure Lid is however emplaced on the cask body with a set of large body bolts which are installed with a small axial clearance to allow any significant increase in internal gas pressure above the ambient, under hypothetical scenarios, to be relieved once it overcomes the counteracting lid's weight. A simple force equilibrium shows that a pressure rise of 5 psi in the cask cavity is not possible to sustain even under the scenario of maximum density concrete installed in the cask's lid. However, the structural evaluations are performed by conservatively assuming that the internal pressure is not relieved under hypothetical accident conditions.

The loadings associated with Version UV must include internal pressure and external pressure which are not present in the ventilated cask. For all other Design Basis Loadings, Version UV cask body is the same as the standard FW or Version E cask body. In this chapter, the Design pressures appropriate to Version UV are defined and the overpack loadings are re-visited to ensure that the safety analyses presented in other chapters are comprehensive.

2.I.1 Spent Fuel to be Stored

There is no change in the permitted used fuel in the Storage system as a result of the introduction of Version UV. However, the permissible heat load is reduced to accord with the diminished heat rejection capacity of Version UV. This is considered in Chapter 4.I, and described in Chapter 1.I.

2.I.2 Design Loadings:

The Design Basis Loads (DBLs) applicable to the Version UV overpack are summarized in Table 2.I.2.1 wherein the justification for their admissibility is also provided obviating the need for a structural evaluation in Chapter 3.I.

a) Loadings unique to Version UV by virtue of its vent-less design arise from the potential for the internal pressure in the cavity to fall below the initial fill pressure under extreme cold conditions. To bound all potential pressure variations, the Design Basis Internal Pressure (DBIP) in the cask cavity is set equal to *full vacuum* on the lower end and a bounding value on the upper end in Table 2.I.2.2.

b) Accident External Pressure: A state of external pressure may arise if the cask is submerged by flood waters or is exposed to pressure wave from an explosive device. The Accident External Pressure (AEP) for this condition is set down at a value which is based on the site-specific loadings being used at numerous operating ISFSIs (Table 2.I.2.2).

   A §72.48 analysis would be necessary to modify the external pressure if the design basis value used in this FSAR is not bounding or the pressure wave must be simulated as a dynamic load.

c) Accident Internal Pressure: The internal gas pressure in the Version UV cask cavity may rise under hypothetical accident conditions. To envelope the potential pressure variations, the Accident Internal Pressure (AIP) in the cask cavity is set to a bounding value in Table 2.I.2.2.

d) Acceptance criterion: It is necessary to demonstrate that the dual wall cask shell structure, cask’s Base Plate and its Closure Lid can withstand all loadings without exceeding the stress limits set forth in Section III Subsection NF of the ASME Code.

Table 2.I.2.1; Evaluation of the Design Basis Loadings for the Version UV Storage Cask			
Applicable Loading Case from Tables 2.2.6, 2.2.7 and 2.2.13	**Load Case Description**	**Subsection in the main report where the loading is explained**	**Safety Consideration and Conclusion**
AD	Moving Floodwaters Moving Floodwater with loaded HI-STORM on the pad	2.2.3	Determine the flood velocity that will not overturn the overpack. Because the weight of the loaded cask is slightly greater than the benchmark overpack (HI-STORM FW Version E) due to removal of the vent openings, the resistance to overturning will be slightly greater. Therefore, the admissible flood water velocity based on Version E is conservative.
AE	Design Basis Earthquake (DBE) Loaded HI-STORMs arrayed on the ISFSI pad subject to ISFSI's DBE	2.2.3	This case involves determining the maximum magnitude of the earthquake that meets the acceptance criteria of 2.2.3(g). Because the outer diameter (OD) and height of the CG of Version UV cask are essentially identical to the reference cask analyzed in Chapter 3, the discussion in Subparagraph 3.4.4.1.2 is applicable to Version UV cask.
AC	Strike by a Tornado-borne Missile A large, medium or small tornado missile strikes a loaded HI-STORM on the ISFSI pad or a loaded HI-TRAC	2.2.3	This criterion requires that the acceptance criteria of 2.2.3(e) be met. The Design Basis Tornado missiles are evidently satisfied by Version UV because it is structurally identical to the reference cask (Version E) except for the absence of vent penetrations which is a positive structural advantage for Version UV.
AA	Non-Mechanistic Tip-Over A loaded HI-STORM is assumed to tip over and strike the pad.	2.2.3	Version UV's response to the tip-over event will be identical to the cask analyzed in Chapter 3 to the acceptance criteria of 2.2.3(b). Therefore, a new tip-over analysis is not required. Since the Version UV lid design is different from those analyzed in Chapter 3, a separate lid evaluation is performed in Chapter 3.I using bounding decelerations.
HC	Handling of Cask	2.2.3	The methodology for evaluating the handling loads remains applicable. The lifting analysis of Version E cask using bounding lifted weight in Table 3.2.8 remains applicable for Version UV cask. Site specific verification of the handling loads is required under the plant's §72.212 mandated by the system's CoC.
NA	Snow Load	2.2.1	The Design Basis snow load in Chapter 3 is used to evaluate the Version UV Closure Lid in Chapter 3.I.

Table 2.I.2.2; Design Basis Pressure Loadings applicable to the Version UV Canister Storage Cask		
Loading	**Value, psig**	**Comment**
Design Basis Minimum Internal Pressure	-14.7	Corresponds to full vacuum
Design Basis Maximum Internal Pressure	5	Bounding internal pressure under normal conditions.
Accident External Pressure	60	Bounding steady state pressure assumed to act on all external surfaces of the overpack
Accident Internal Pressure	10	Bounding internal pressure under hypothetical conditions

2.I.3 Safety Protection Systems

There is no change in the safety protection systems described in Section 2.3 required by the introduction of the Version UV overpack.

2.I.4 Decommissioning Considerations

The decommissioning considerations described in Section 2.4 remain applicable.

2.I.5 Safety Conclusions

The evaluations in this supplement show that:

- The loadings specified in Chapter 2 for the classical HI-STORM FW ventilated overpacks that are also applicable to the unvented Version UV overpack are satisfied by it without additional analysis.
- Additional loadings - internal and external pressures have been identified for Version UV that warrant analysis to demonstrate safety compliance with the acceptance criteria in this supplement.
- Version UV Closure Lid requires analyses to demonstrate safety compliance with the acceptance criteria in main FSAR.
- All other components of the Storage system are unaffected by the choice of the version of the overpack employed in the Storage system.

CHAPTER 3.I: STRUCTURAL EVALUATION

3.I.0 Overview

This chapter contains the structural safety analysis of the HI-STORM FW storage system containing the Version UV overpack (hereafter referred to as the *Storage System* for brevity) illustrated in Figure 1.I.1.1 and in the Licensing drawing package in Section 1.I.5. The structural evaluation for Version UV under pressure loading, as discussed in Chapter 2.I, is the only distinct loading case compared to standard FW and FW Version E overpacks. All of the other loading scenarios for Version UV overpack are either bounded by the standard FW or FW Version E overpack or reperformed as described in Section 3.I.3.

3.I.1 Structural Design

The design information provided in Section 3.1 remains applicable except that the storage cask has no inlet or outlet vents and the space between the cask cavity and the MPC is sub-atmospheric. To support the state of a partially de-pressurized cask cavity space, the interface between the Closure Lid and the cask body is equipped with a weather-resistant polymeric gasket.

The absence of vents confers additional structural resistance to Version UV to certain mechanical loadings such as the Design Basis penetrant missiles considered in Subsection 3.4.3 of this report. Indeed, as the evaluation narrative in Table 2.I.2.1 demonstrates, from the structural standpoint, the Version UV either equals or exceeds the safety margins established for the system components in the main FSAR. Any additional evaluations to demonstrate structural integrity of various components are discussed in Section 3.I.3.

As this chapter envisages no change to the MPCs or their contents or to the HI-TRAC transfer casks, all safety information on them in Chapter 3 remains fully applicable. The only new calculations for MPC are limited to two new cases for containment boundary pressure and temperature evaluation as the temperature distribution on the MPC containment boundary is different from those used in Subsection 3.4.3 evaluations. The safety evaluation of the Design Basis Loadings (DBLs) for Version UV overpack is limited to ensuring that the overpack's response remains acceptable under the design criteria unique to Version UV, which, as stated in Section 2.I.2, consists of the Design Basis internal and external pressure loadings. In addition, since the Version UV overpack lid is different from those designs evaluated in Subsections 3.4.3 and 3.4.4, a separate lid evaluation is performed under all applicable loading as described in Section 3.I.3.

3.I.2 Structural Model

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The cask lid is secured to the body using four large anchor bolts similar to the standard FW design, and it has shielding concrete to keep the top and bottom plates and outer shell from deflecting into the space occupied by the concrete. In addition, there are diagonal stiffener plates through the thickness of the lid to reinforce the structure and to provide interfacing lift points for handling of the lid.

3.I.3 Safety Analyses

As discussed in Chapter 2.I and Section 3.I.1, three separate evaluations are performed to demonstrate structural integrity of HI-STORM FW Version UV Storage System, namely,

a) Evaluation of MPC containment boundary under normal and off-normal conditions using pressure limits from Table 2.2.1 and temperature profiles from thermal analyses supporting Chapter 4.I.

b) Evaluation of Version UV cask under internal and external pressure loads.

c) Evaluation of Version UV closure lid under lifting, snow load and non-mechanistic tip-over conditions.

3.I.3.1 MPC Containment Boundary Evaluation

Using the ANSYS finite element model of MPC described in Paragraph 3.4.3.2, two separate analyses are added to demonstrate structural integrity in Supplement 1 of [3.4.13] as described below.

i) The long-term normal condition internal pressure limit in Table 2.2.1 is applied to MPC lid, shell and baseplate along with temperature contour obtained from normal condition thermal analysis in Chapter 4.I. The primary and secondary stresses in MPC lid, shell and baseplate are then compared against ASME NB Level A stress limits obtained at bounding temperatures. It is demonstrated in Supplement 1 of [3.4.13] that all safety factors are greater than 1.0.

ii) The off-normal condition internal pressure limit in Table 2.2.1 is applied to MPC lid, shell and baseplate along with temperature contour obtained from off-normal condition thermal analysis in Chapter 4.I. The primary and secondary stresses in MPC lid, shell and baseplate are then compared against ASME NB Level B stress limits obtained at bounding temperatures. It is demonstrated in Supplement 1 of [3.4.13] that all safety factors are greater than 1.0.

3.I.3.2 HI-STORM FW Version UV Cask Pressure Loading

A 3-D finite element model of the HI-STORM FW Version UV overpack is constructed in ANSYS [3.4.29] as shown in Supplement 43 of [3.4.13]. All plate and shell components are modeled using ANSYS solid shell elements (SOLSH190) and concrete is modeled using ANSYS solid element (SOLID65).

Five pressure loading cases (three normal and two accident) are evaluated in Supplement 43 of [3.4.13] to envelope all design basis internal and external pressure loadings in Table 2.I.2.2.

The primary membrane and membrane plus bending stresses in Version UV overpack shells, base plate and lid are compared against ASME NF Level A (under design pressure loading) and Level D (under accident pressure loadings) stress limits obtained at bounding temperatures. It is demonstrated in Supplement 43 of [3.4.13] that all safety factors are greater than 1.0. In addition, it is demonstrated that outer shell of overpack does not collapse or buckle under the accident external pressure loading.

3.I.3.3 HI-STORM FW Version UV Cask Closure Lid

The Version UV closure lid is evaluated under the following load conditions in Supplement 44 of [3.4.13] using the same methodology and acceptance criteria used to evaluate standard, XL, domed and Version E closure lids in Subsections 3.4.3 and 3.4.4.

i) Lid lifting: It is demonstrated in Supplement 44 of [3.4.13] that the stresses in lid lifting points are less than NUREG-0612 and Regulatory Guide 3.61 stress limits obtained at bounding temperatures for the heaviest lid (bounded by heaviest lid weight in Table 3.2.5). Also, the primary stresses in the remainder of lid structure, including welds, are shown to be less than ASME Code Subsection NF Level A stress limits obtained at bounding temperature.

ii) Snow load: It is demonstrated in Supplement 44 of [3.4.13] that under a bounding snow load, applied as pressure on top surface of closure lid, all primary stresses in the lid structure are less than ASME Code Subsection NF Level A stress limits obtained at bounding temperature.

iii) Non-mechanistic tipover: The Version UV cask tipover analysis is bounded by that of Version E [3.4.30] because of identical cask body design except for vents in Version E design. However, since the Version UV lid design is different from that of Version E lid, a separate lid evaluation is performed in Supplement 44 of [3.4.13] using the bounding decelerations from Version E cask tipover analysis [3.4.30]. It is demonstrated in Supplement 44 of [3.4.13] that all primary stresses in the lid structure are less than ASME Code Appendix F Level D stress limits obtained at bounding temperature.

3.I.4 Safety Conclusions

The structural analysis of the Version UV storage cask under the loading condition unique to it, described in Section 3.I.1, demonstrates that the stresses in all cask components, namely the buttressed base plate, the dual shell structure and the closure lid weldments are below the ASME Code limits with significant margins. The structural analysis of the HI-STORM Version UV closure lid demonstrates that the stresses in lid components are below the stress limits in ASME Code under all loading conditions. In addition, the MPC confinement boundary continues to satisfy the established acceptance criteria under temperature profiles unique to Version UV Storage System under all loading conditions.

The structural safety of the Storage System under all loadings germane to the ventilated cask model has been previously established in Table 2.I.2.2. Therefore, the Version UV overpack has been proven to meet all structural criteria applicable to the HI-STORM FW Canister Storage System in this FSAR.

CHAPTER 4.I: THERMAL EVALUATION

4.I.0 Overview

In this supplement to Chapter 4, the thermal compliance of the HI-STORM FW system containing the Version UV overpack to the ISG-11 Rev 3[4.1.4] and other limits specified in Chapter 2 is considered. In particular, the thermal acceptance criteria provide specific limits on the permissible maximum cladding temperature in the stored commercial spent fuel (CSF) and other Confinement Boundary components in the MPC, and on the maximum permissible pressure in the MPC confinement space under certain operating scenarios. Specifically, the requirements are:

i. The fuel cladding temperature must meet the temperature limit under normal, off-normal, and accident conditions appropriate to its burnup level and condition of storage or handling set forth in Table 4.3.1[1].

ii. The maximum internal pressure of the MPC and the air annulus should remain within their design pressures for normal, off-normal, and accident conditions set forth in Table 2.2.1.

iii. The temperatures of the cask materials shall remain below their allowable limits set forth in Table 2.2.3 under all scenarios.

As discussed in Section 1.I.1, Version UV is characterized by a hermetically sealed storage cavity space which encloses the MPC. Therefore, the sole path for the rejection of the spent fuel decay heat to the ambient air is by convection and radiation from the cask's external surface (i.e., no assist from ventilation of the MPC unlike the standard HI-STORM FW system). The heat from the canister surfaces is delivered to the overpack's inside surface primarily by radiation, with conduction and convection playing a less important role. [

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The safety evaluation of the Storage system is, therefore, carried out through a detailed 3-D Computational Fluid Dynamics (CFD) analysis of the Storage system on the QA validated Code, Fluent (which has been used in all thermal safety analyses in all Holtec dockets, including all analyses documented in Chapter 4 of this FSAR), using a set of conservative assumptions that seek to overstate the computed temperatures, summarized in this supplement.

[1] All table references without a Roman numeral in the second place indicate that they are in the main report (i.e., not in a supplement)

4.I.1 Discussion

The MPC is completely surrounded by the overpack, and the transmission of MPC's decay heat occurs mainly by radiation, and to a smaller degree, by convection and conduction across the annulus gap. Therefore, the size of the annular gap between the MPC and the cask cylinder is an important parameter. In addition, the outer diameter of the cask is also important because it determines the external surface area for rejection of heat to the environment.

4.I.1.1 Allowable Heat Load Patterns

The selection of the location in the basket where a fuel assembly of a specific fuel heat load has the most pronounced effect on the peak fuel cladding temperature. Because individual fuel batches for fuel loading have different composition of specific heat loads, it is necessary to provide flexibility in the heat load pattern such that one CoC covers as many batches as possible. To that end, the approach of multi-region storage is generalized using the following strategy based on heuristic reasoning coupled with bounding pattern evaluations.

The definitions of the storage regions are the same as those described in Section 1.2 of the main SAR. The uniform heat load pattern, i.e. the maximum allowable decay heat load is the same (say, q) for all the n cells, is designated as Pattern-0. Thus, the aggregate heat load Q_0 is given by

$$Q_0 = n.q$$

Q_0 is defined in Table 4.I.1.1.

Any site-specific regionalized heat load pattern is subject to the following constraints:

1. The total heat load should be equal to Q_0.

2. The heat load pattern should exhibit 1/8th symmetry as defined in Figures 1.I.2-1 (MPC-37) and 1.I.2-2 (MPC-89). Thus, the total decay heat in any of the eight sections is equal to $Q_0/8$.

3. The maximum allowable decay heat per cell in the region r is limited by the following expression:

$$q_r = r.q$$

4. Decay heat for any storage cell in Region 1 may be determined by reducing the allowable in Region 1 of Pattern-0 by Δ and decay heat for any storage cell in Region 2 and 3 may be determined by increasing the allowable in Region 2 and/or Region 3 of Pattern-0 by the same Δ.

5. Decay heat for any storage cell in Region 2 may be determined by reducing the allowable in Region 2 of Pattern-0 by θ and decay heat for any storage cell in Region 3 may be determined by increasing the allowable in Region 3 of Pattern-0 by the same θ.

The validity of the above generalized multi-region storage strategy within the confines of the above rules is demonstrated by parametric analyses for the bounding heat load patterns. Details of the methodology to identify these bounding heat load patterns are given in Section 4.I.1.3.

4.I.1.2 Fuel-length Dependent Allowance of Heat Loads

All the analyses identified in the above manner are performed for standard length PWR and BWR fuels. The maximum allowable heat load per storage cell determined using the aforementioned process, is therefore, applicable for fuels with standard and longer active length fuels.

For fuel with shorter active fuel lengths than the standard active length defined in Table 4.I.1.2, the maximum storage cell-specific allowable heat loads are determined using the following scaling formula:

$$q_i = \frac{L}{L_{std}} * q_0, \qquad \text{where,}$$

q_i is maximum allowable cell-wise heat load,

L is the active length of the fuel,

L_{std} is the active length of the standard-length fuel used in the corresponding analysis for PWR or BWR in this supplement listed in Table 4.I.1.2, and

q_0 is maximum allowable heat load for the corresponding cell in the standard-length analysis based on the rules prescribed in Section 4.I.1.1.

Similarly, for fuel with a longer active fuel length than the standard active length defined in Table 4.I.1.2, the maximum storage cell-specific allowable heat loads are determined using the following scaling formula:

$$q_i = \sqrt{\frac{L}{L_{std}}} * q_0$$

4.I.1.3 Identification of Heat Load Patterns for Parametric Analyses

To demonstrate the validity of the generalized multi-region storage strategy described in the preceding section, the following procedure is used to identify the bounding patterns:

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Therefore, following this strategy, several regionalized patterns for MPC-37 and MPC-89 are identified and evaluated using 3-D Computational Fluid Dynamics (CFD) models (Section 4.I.4.2).

4.I.1.4 Backfill Pressure Limits

The minimum and maximum initial helium backfill pressures for MPCs stored in Version UV system are listed in Table 4.I.1.3. The air annulus between the MPC and the Version UV overpack is backfilled such that the operating pressure under normal long-term storage conditions is approximately 1 atmosphere. The theoretical backfill pressure for air annulus is listed in Table 4.I.1.3.

TABLE 4.I.1.1
TOTAL MAXIMUM ALLOWABLE HEAT LOADS FOR PWR AND BWR FUELS

MPC Type (Fuel Type)	Maximum Allowable Heat Load
MPC-37 (PWR)	24 kW
MPC-89 (BWR)	24 kW

TABLE 4.I.1.2
STANDARD ACTIVE FUEL LENGTHS USED IN THE THERMAL ANALYSES FOR PWR AND BWR FUELS

MPC Type (Fuel Type)	Active Fuel Length (in)
MPC-37 (PWR)	144
MPC-89 (BWR)	150

Table 4.I.1.3
THEORETICAL LIMITS OF BACKFILL PRESSURE FOR MPC HELIUM AND ANNULUS AIR

Condition	MPC Helium Backfill Pressure Limits (psig)	Annulus Air Fill Pressure Limits (psig)
MPC-37	42.0 – 45.5	-5.58 – -4.94
MPC-89	42.5 – 46.5	-5.56 – -4.94

Note-1: Initial backfill pressures of both helium and air are specified at a reference temperature of 70°F (21°C).

4.I.2 Thermal Properties of Materials

The Storage system uses no new materials; therefore, the property data in Section 4.2 are applicable without change.

4.I.3 Specifications for Components

All applicable material temperature limits in Section 4.3 of the FSAR continue to apply to the HI-STORM FW Version UV system.

4.I.4 Thermal Model and Evaluation of Normal Conditions of Storage

4.I.4.1 Thermal Model

The Storage system consists of the MPC standing upright on the cask's baseplate and the surrounding cask made of steel and plain concrete. The MPC thermal model is identical to that described in Section 4.4.1 of the main SAR. Since the analyses in this supplement employ standard active fuel length, accordingly, effective fuel properties of standard length PWR and BWR fuels are used. Taking advantage of the symmetry in MPC fuel loading pattern resulting from the patterns identified in Section 4.I.1.3, a quarter symmetric model of both the MPC and the overpack is employed.

The following methodology is employed to render the computed peak cladding temperature into an upper-bound of the value that would obtain in practice:

[

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4.I.4.2 Limiting MPC Configurations

Screening calculations are performed for various patterns identified in [4.I.1]. These patterns are derived following the rules specified in Section 4.I.1.1. The results from the most-bounding heat load patterns are presented in Section 4.I.4.6.

4.I.4.3 Test Model

The rationale for not requiring an experimental test model provided in Section 4.3 remains applicable in its entirety.

4.I.4.4 Normal Condition of Storage

The steady state thermal analysis to determine compliance with the temperature limits corresponding to the normal condition of storage consists of several discrete analyses, namely:

i. Storage system containing Version UV and standard length MPC-37 (PWR canister)

ii. Storage system containing Version UV and standard length MPC-89 (BWR canister).

iii. Parametric analysis to demonstrate the validity of the Generalized Multi-Region (GMR) storage model explained in Section 4.I.1.3.

4.I.4.5 Impact of Neighboring Casks

As described in Section 4.4.2 of the main SAR, heat dissipation through the Version UV overpack that is placed in an array is somewhat disadvantaged. To determine the impact of this, a site-specific evaluation shall be performed using the following methodology:

[

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The computed temperatures and pressures shall meet the respective limits specified in this FSAR.

4.I.4.6 Results & Safety Conclusions

The component temperatures and MPC cavity pressure for the bounding pattern evaluations for MPC-37 and MPC-89 are summarized in Tables 4.I.4.1 and 4.I.4.2 respectively. It can be seen from the results that under the licensing-basis heat load:

i. The storage system containing the Version UV satisfies the ISG-11 Rev. 3 fuel cladding and other temperature limits set down in this FSAR.

ii. The pressures inside the overpack and the MPC are below their respective design-basis limits (Chapter 2).

iii. The Closure Lid is protected from lifting under the increased pressure at the Design Basis heat load and accident condition of storage by a large margin (ratio of threshold pressure at Lid lift divided by the actual absolute pressure). (While lifting of the Lid is not a safety event, the analyses demonstrate that the selection of the initial fill pressure for the overpack cavity is appropriate.)

Table 4.I.4.1
[Proprietary Information Withheld in Accordance with 10 CFR 2.390]

Table 4.I.4.2 [Proprietary Information Withheld in Accordance with 10 CFR 2.390]		
-		

4.I.5 Thermal Evaluation for Short Term Operations

Short-term operations use HI-TRAC and not Version UV overpack. Since the maximum heat loads qualified for MPC-37 and MPC-89 in Version UV system are significantly lower than those qualified for use in the standard HI-STORM FW version, no separate evaluations are needed for MPCs qualified for use in Version UV. Thermal evaluations presented in Section 4.5 of the main chapter remain bounding.

4.I.6 Off-Normal and Accident Events

4.I.6.1 Off-Normal Conditions

The most bounding fuel temperatures for Version UV with MPC-37 and MPC-89 are bounded by the corresponding MPC-37 and MPC-89 HI-STORM FW evaluations under normal conditions of storage. Although maximum temperatures of some components, such as MPC baseplate, are higher for Version UV analyses compared to those for standard HI-STORM FW, due to the temperature limits for individual MPC and overpack components being much higher for off-normal conditions compared to the normal storage limits, separate evaluations do not need to be performed for Version UV system.

4.I.6.2 Accident Conditions

(a) Fire Accident

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Following the above methodology, the maximum temperature and pressure rise of the MPC internals due to a hypothetical fire event is given in Table 4.I.6.1. It can be seen that even with the conservative assumptions, the PCT and the MPC component temperatures remain well below their respective accident temperature limits for the hypothetical design basis fire scenario.

It is understood that for site-specific evaluations, there is a possibility of variability in the volume of combustibles which are not bounded by those used for the design basis fire event. In such cases, a site-specific evaluation may be performed to demonstrate the safety of the Version UV system and the MPC internals.

Alternately, a CFD evaluation of the fire accident condition following the methodology presented in Section 4.6.2.1 of the main SAR can be performed for the HI-STORM UV thermal model.

(b) Jacket Water Loss Accident

A description of the jacket water loss accident is presented in Section 4.6.2.2 of the main FSAR.

The maximum allowable heat load of the MPCs qualified for use in HI-STORM FW Version UV system is significantly lower than those qualified for use in the standard HI-STORM FW version. Therefore, the component temperatures and MPC cavity pressure under jacket water loss accident condition for the MPCs qualified for use in HI-STORM Version UV will be bounded by those presented in Section 4.6.2.2 of the main report, and thus, will be acceptable.

(c) Extreme Environment Temperatures

Following the methodology presented in Section 4.6.2.3 of the main FSAR, to evaluate the effect of extreme weather conditions, an extreme ambient temperature (Table 2.2.2 of the main FSAR) is postulated to persist for a 3-day period. Starting from the baseline condition evaluated in Section 4.I.4.4 (normal ambient temperature and limiting fuel storage configuration) the temperatures of the HI-STORM FW system are conservatively assumed to rise by the difference between the extreme and normal ambient temperatures (45^{o}F). The MPC component extreme ambient temperatures computed in this manner are reported in Table 4.I.6.2. The co-incident MPC pressure is also computed (Table 4.I.6.2) and compared with the accident design pressure (Table 2.2.1), which shows a positive safety margin. The result is confirmed to be below the accident limit.

(d) Burial Under Debris

At the storage site, no structures are permitted over the casks. Minimum regulatory distances from the storage site to the nearest site boundary precludes close proximity of vegetation. There is no credible mechanism for the Version UV System to become completely buried under debris. However, for conservatism, a complete burial under debris scenario is considered.
Since the standard HI-STORM FW is primarily cooled by ventilation while the Version UV system is not, a burial-under-debris accident will have a much more significant impact on the temperatures for the standard version. A standard HI-STORM FW without ventilation is thermally equivalent to the Version UV system. Since the maximum allowable heat load for Version UV system is significantly lower than that for the standard version, therefore, the evaluation for the standard version bounds that for Version UV. Therefore, the time limits applicable for MPC-37 in standard HI-STORM FW under the burial-under-debris accident scenario can be conservatively applied to Version UV system.

(f) Flood Accident

Many ISFSIs are located in flood plains susceptible to floods. However, since the Version UV system is hermetically sealed, the event of flood water entering the internals of the system is not credible. In addition, the heat rejection of the Version UV system to water is far more efficient than to air, and therefore, the results during normal long-term storage conditions bound those during an event of flood.

TABLE 4.I.6.1 [Proprietary Information Withheld in Accordance with 10 CFR 2.390]	

TABLE 4.I.6.2

[Proprietary Information Withheld in Accordance with 10 CFR 2.390]

4.I.7 Regulatory Compliance

The statements on compliance of the vented storage system to the regulatory requirements of 10CFR72 presented in Section 4.7 remain applicable to the unvented system without limitation.

4.I.8 References

[4.I.1] Thermal Analysis of HI-STORM FW UV System, “HI-2200191, Revision 0.

SUPPLEMENT 5.I

SHIELDING EVALUATION OF THE HI-STORM FW SYSTEM WITH UNVENTILATED OVERPACK

5.I.0 INTRODUCTION

This supplement presents the shielding safety evaluation of a version of the HI-STORM FW system, Version UV, wherein the overpack's inlet and outlet air passages have been removed resulting in a complete cessation of ventilation in the space between the cask cavity and the stored multi-purpose canister (MPC) during the system's operation.

The evaluation presented herein supplements those evaluations of the HI-STORM FW overpacks contained in the main body of Chapter 5 of this FSAR, and information in the main body of Chapter 5 that remains applicable to the Version UV is not repeated in this supplement. To aid the reader, the sections in this supplement are numbered in the same fashion as the corresponding sections in the main body of this chapter, e.g., Section 5.I.1 correspond to Sections 5.1. Table 5.I.0.1 lists those sections that do not require any change and that are therefore omitted from this supplement.

TABLE 5.I.0.1

SECTIONS IN CHAPTER 5 OF THE FSAR THAT REMAIN APPLICABLE TO THE SAFETY EVALUATION IN SUPPLEMENT 5.I

Section number	Title	Reason for omission
5.I.2	Source specification	The information in Section 5.2 remains applicable
5.I.5	Regulatory Compliance	The information in Section 5.5 remains applicable
5.I.6	References	The information in Section 5.6 remains applicable, no new references are required

5.I.1 DISCUSSION AND RESULTS

The HI-STORM FW UV system differs from the HI-STORM FW system evaluated in the main body of this chapter only in the use of an unventilated storage overpack. All MPCs and HI-TRAC transfer casks are identical between the systems. All calculations in this supplement are performed with limiting heat load patterns for the MPC-37 and MCNP-89.

The principal shielding design of the HI-STORM FW UV is identical to that of the overpack designs evaluated in the main body of this chapter, with gamma shielding provided by the concrete and the steel of the module, and neutron shielding provided by the module concrete.

The shielding analyses were performed with MCNP5 [5.1.1], which is the same code used for the analyses presented in the main body of this chapter. The source terms methodology is developed in the main part of the report.

The zircaloy clad fuel assemblies used for calculating the dose rates presented in this supplement are Westinghouse (W) 17x17 and the General Electric (GE) 10x10, for PWR and BWR fuel types, respectively. The same fuel assemblies are considered in the main part of the report.

The thermal limitations are specified in Supplement 4.I using an approach that provides flexibility in loading the system. For that, three concentric regions are utilized in both the MPC-37 and the MPC-89, as was used before (see Figures 1.2.1 and 1.2.2), individual cell heat load limits are defined for each region, but also a total heat load limit for the entire basket, with a value lower than the total sum of the individual cell limits. The limits for the cells are set highest for the cells on the periphery (Region 3 in Figures 1.2.1 and 1.2.2), second-highest for the intermediate region (Region 2 in Figures 1.2.1 and 1.2.2), and lowest in the center of the basket (Region 1 in Figures 1.2.1 and 1.2.2).

The dose rate evaluations presented in the main section of Chapter 5 show that dose rates around both the HI-STORM and the HI-TRAC are principally gamma dominated. This is directly applicable to the HI-STORM FW Version UV, since it uses the same principal shielding design as the models analyzed in the main section of this chapter, and also to the HI-TRAC versions that are used to load the Version UV, since these are the same as those used for any other HI-STORM version. Due to the high gamma dose absorption of the fuel assemblies, that means that the dose rates on the radial cask surfaces, and at any distances, are dominated by the source terms in the assemblies on the periphery of the basket. The bounding case from a dose perspective is therefore a condition where the cells on the periphery of the basket (Region 3) are loaded with the assemblies of the highest permitted heat loads for those cells, since highest heat loads correspond to highest source terms. Following the total heat load restriction for the entire basket, this means that cells further inwards (Region 2 and Region 1) can only be loaded at a lower heat loads than otherwise permitted for these regions. It is therefore appropriate to also reduce the source terms for these regions, otherwise calculated dose rates would be unrealistic, i.e. impossible to be reached even theoretically based on the permitted heat load distribution. A review of the heat load distribution specified and qualified in Supplement 4.I shows that, for both the MPC-37 and the MPC-89, if all cells in Region 3 would be loaded up to their specified cell heat load limits, the maximum basket heat load would already be exceeded. A conservative bounding case for the dose evaluations is therefore a hypothetical condition where all (or almost all) cells on the periphery (Region 3) are loaded with assemblies corresponding to the highest source terms, and no source terms are assigned to any cells in inner parts of the basket (Region 1 and Region 2). The heat loads in Region 3 that were selected to inform the source terms for the bounding dose analyses are as follows:

- MPC-37: Region 3 has 16 assemblies, out of those, 12 are assumed at a heat load of 2.2 kW, and the remaining 4 at 0.85 kW, with a total of 29.8 kW. The 4 assemblies with the lower heat load are those with only a single side facing the periphery, while the other 12 are those with two sides facing the periphery. This will maximize the effect of the assemblies with higher heat loads.

- MPC-89: Region 3 has 29 assemblies, and they are assumed at a heat load of 1.1 kW, with a total of 31.9 kW.

All other cells in the baskets are assigned no source term in the analyses. To be clear, the bounding source terms are just informed by the heat loads but are not a substitute for any heat load limits. As presented in Section 5.2.7, source terms informed by heat load limits are then specified as a group of burnup and cooling time combinations, termed loading curves. For the limit of 0.85 kW for the MPC-37, the loading curve shown in Table 5.0.3 is used, whereas for the limit of 1.1 kW in the MPC-89, the loading curve shown in Table 5.0.4b is used. For the limit of 2.2 kW in the MPC-37, a new loading curve was generated, shown in Table 5.I.1.1. This table is developed using the same approach that Tables 5.0.3 and 5.0.4 in the main section of this Chapter were prepared, namely using a polynomial function to conservatively represent the results of the source term evaluations that calculate heat loads.

While it is clear that placing assemblies with the highest source terms on the periphery is a bounding condition for the radial dose rates, it may not be bounding for the top and bottom of the cask (dose locations 4 and 5 in Figure 5.1.2). For these dose locations, a loading with the maximum source at and near the center of the basket may be more conservative. The limiting case for those locations is where all assemblies in Region 1 are at their heat load limit, and hence source term limit. This is the uniform loading where all assemblies have the same heat load, since this uniform heat load is the limit for the assemblies in Region 1. This uniform loading is analyzed as a second case, and for each dose location, the higher value, either form the uniform case, or from the case with the maximum source on the periphery, is reported in this chapter.

To assure that dose rates from any actual loading are bounded by the values presented here, loading curves for each of the three regions of each basket are specified to define the acceptable content, informed by the heat load limits of the regions.

Additional limitations on the content may stem from the dose rate limits set for the outer surfaces of the HI-TRAC and HI-STORM based on ALARA considerations. For the Version UV, these dose rate limits are identical to those for the systems and configurations evaluated in the main part of this chapter. Hence while some of the dose rates calculated here, based on the bounding configurations discussed above, are higher than those in the main part of this chapter and higher than those limits in some cases, the overall radiological performance limit of the system evaluated here is identical to that in the main part of this chapter, and therefore does not require any new considerations. Dose rates presented here that exceed the ALARA based dose rate limits are therefore for illustrative purposes, based on assumed extreme conditions. No attempt was made to determine the combinations of conditions (cask and content parameters) that would satisfy those dose limits, since this would result in unnecessary complications of analyses and/or loading restrictions. Also, since the overall radiological performance is not different from that described in the main chapter, the presentation of results is somewhat abbreviated. Specifically, results for the new Version UV overpack are presented in this Section 5.I.1, whereas results for the HI-TRAC VW, which is identical to the model analyzed in the main part of this Chapter and only analyzed for the different content, is just summarized in Section 5.I.4, in comparison to the results from the main part of this chapter.

All dose rates in this supplement are evaluated using the approach discussed above, either based on the bounding heat load distribution with the maximum heat load on the periphery, and/or based on a uniform loading of the basket. Also, as discussed in Section 5.2 in the main part of the report, the design basis BPRA activity is considered for MPC-37 in this supplement.

5.I.1.1 Normal and Off-Normal Operations

Tables 5.I.1.2 and 5.I.1.3 provide the dose rates adjacent to and one meter from the HI-STORM FW UV overpack during normal conditions when loaded with the MPC-37 and MPC-89.

Table 5.I.1.4 presents the annual dose to an individual from a single HI-STORM FW UV cask and various storage cask arrays, assuming an 8760 hour annual occupancy at the dose point location for the MPC-89, which is more limiting than the MPC-37. The minimum distance required for the corresponding dose is also listed. It is noted that these data are provided for illustrative purposes only. A detailed site-specific evaluation of dose at the controlled area boundary must be performed for each ISFSI in accordance with 10CFR72.212.

Figure 5.I.1.1 identifies the locations of the dose points referenced in the dose rate summary tables for the HI-STORM FW UV overpack.

5.I.1.2 Accident Conditions

The design basis accidents analyzed in Chapter 11 have a negligible effect on the HI-STORM FW UV overpack, but a larger effect on the HI-TRAC, and results for this is presented in Section 5.I.4.

Table 5.I.1.1

BURNUP, ENRICHMENT, COOLING TIME COMBINATIONS FOR THE MPC-37 LOADING PATTERNS

Burnup (MWd/mtU)	**Enrichment (wt.% ^{235}U)**	**Cooling Time (years)**	**Decay Heat Limit (kW)**
5000	1.1	1.0	2.2
10000	1.1	1.0	
20000	1.6	1.4	
30000	2.4	2.0	
40000	3.0	2.4	
50000	3.6	3.0	
60000	3.9	3.5	
70000	4.5	4.5	

Table 5.I.1.2

MAXIMUM DOSE RATES FROM THE HI-STORM FW UV OVERPACK
FOR NORMAL CONDITIONS MPC-37
BOUNDING LOADING CONFIGURATION

Dose Point Location	**Fuel Gammas (mrem/hr)**	**(n,γ) Gammas (mrem/hr)**	**^{60}Co Gammas (mrem/hr)**	**Neutrons (mrem/hr)**	**Totals (mrem/hr)**	**Totals with BPRAs (mrem/hr)**
ADJACENT TO THE HI-STORM FW UV						
1	320.2	<0.1	1.1	<0.1	321.5	356.7
2	349.0	0.1	<0.1	0.1	349.3	387.7
3	3.2	<0.1	10.1	<0.1	13.3	30.3
4 (center)	<0.1	0.8	0.1	1.0	2.0	2.8
4 (mid)	21.5	<0.1	4.0	<0.1	25.6	34.0
4 (outer)	38.8	<0.1	7.8	<0.1	46.6	61.3
ONE METER FROM THE HI-STORM FW UV						
1	132.3	<0.1	1.5	<0.1	133.8	148.1
2	166.1	<0.1	0.3	<0.1	166.5	184.7
3	14.1	<0.1	1.7	<0.1	15.9	19.8
4	8.3	<0.1	2.0	<0.1	10.3	13.9

Notes:

- Refer to Figure 5.I.1.1 for dose locations.
- Values are rounded to nearest integer where appropriate.
- Dose location 3 (overpack edge) is located radially above the overpack outer diameter.
- Dose location 4 (center) is at the center of the top surface of the top lid. Dose location 4 (mid) is in the middle of the top surface of the top lid. Dose location 4 (outer) is extended along the top plane of the top lid, located radially above the overpack outer diameter.
- The “Fuel Gammas” category includes gammas from the spent fuel, ^{60}Co from the spacer grids, and ^{60}Co from the BPRAs in the active fuel region.

Table 5.I.1.3

MAXIMUM DOSE RATES FROM THE HI-STORM FW UV OVERPACK FOR NORMAL CONDITIONS MPC-89 BOUNDING LOADING CONFIGURATION

Dose Point Location	**Fuel Gammas (mrem/hr)**	**(n,γ) Gammas (mrem/hr)**	**^{60}Co Gammas (mrem/hr)**	**Neutrons (mrem/hr)**	**Totals (mrem/hr)**
ADJACENT TO THE HI-STORM FW UV					
1	373.3	<0.1	2.3	<0.1	375.8
2	461.3	0.1	<0.1	0.2	461.6
3	0.9	<0.1	10.1	<0.1	11.1
4 (center)	<0.1	0.5	<0.1	0.5	1.0
4 (mid)	12.8	0.5	7.4	0.4	21.2
4 (outer)	19.6	<0.1	12.9	<0.1	32.6
ONE METER FROM THE HI-STORM FW UV					
1	152.4	<0.1	2.6	<0.1	155.1
2	217.2	<0.1	0.3	<0.1	217.7
3	17.1	<0.1	2.6	<0.1	19.7
4	3.7	0.2	3.3	<0.1	7.2

Notes:

- Refer to Figure 5.I.1.1 for dose locations.
- Values are rounded to nearest integer where appropriate.
- Dose location 3 (overpack edge) is located radially above the overpack outer diameter.
- Dose location 4 (center) is at the center of the top surface of the top lid. Dose location 4 (mid) is in the middle of the top surface of the top lid. Dose location 4 (outer) is extended along the top plane of the top lid, located radially above the overpack outer diameter.
- The “Fuel Gammas” category includes gammas from the spent fuel and ^{60}Co from the spacer grids.

Table 5.I.1.4

DOSE RATES FOR ARRAYS OF HI-STORM FWs Version UV

Array Configuration	**1 cask**	**2x2**	**2x3**	**2x4**	**2x5**
BOUNDING LOADING CONFIGURATION					
Annual Dose (mrem/year)	16.6	17.9	10.1	13.5	16.8
Distance to Controlled Area Boundary (meters)	400	500	600	600	600

Notes:
- Values are rounded to nearest integer.
- 8760 hour annual occupancy is assumed.
- Dose location is at the center of the long side of the array.

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Figure 5.I.1.1

5.I.3 MODEL SPECIFICATIONS

The shielding analysis of the HI-STORM FW UV system was performed with MCNP5 [5.1.1], which is the same code used for the analyses presented in the main part of this chapter. A sample input file for MCNP is provided in Appendix 5.I.A.

Section 1.I.5 provides the drawings that describe the HI-STORM FW UV system. These drawings, using nominal dimensions, were used to create the MCNP models used in the radiation transport calculations. Modeling deviations from these drawings are discussed below. Figures 5.I.3.1 and 5.I.3.2 show cross sectional views of the HI-STORM FW UV overpack, MPCs, and basket cells as they are modeled in MCNP. Figures 5.I.3.1 and 5.I.3.2 were created in VISED and are drawn to scale.

Composition and densities of the various materials used in the HI-STORM FW UV system and HI-TRAC shielding analyses are given in Section 5.3.2 in the main part of the report.

Since the HI-STORM FW UV model uses principally the same MPC model as the calculations in the main body of this chapter, all figures, conservative modeling approximations, and modeling differences for the MPC shown in Section 5.3 are applicable to the calculations in this supplement. The differences between models and drawings for the module are listed and discussed here.

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Figure 5.I.3.1
HI-STORM FW UV OVERPACK WITH MPC-37 CROSS SECTIONAL VIEW AS MODELED IN MCNP†

† This figure is drawn to scale using VISED.

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Figure 5.I.3.2

HI-STORM FW UV OVERPACK WITH MPC-89 CROSS SECTIONAL VIEW AS MODELED IN MCNP†

† This figure is drawn to scale using VISED.

5.I.4 SHIELDING EVALUATION

MCNP was used to calculate doses at the various desired locations. MCNP calculates neutron or photon flux and these values can be converted into dose using dose response functions. MCNP and the calculational approach used in this supplement in the same way as in the main part of this chapter in calculating the results presented in Section 5.I.1 and this section 5.I.4. An example of an MCNP input file, for the HI-STORM FW Version UV, is listed in Appendix 5.I.A.

As discussed in Section 5.I.1, detailed results for the HI-STORM FW Version UV overpack are presented in that section 5.I.1, while this section 5.I.4 presents comparative results for the HI-TRAC VW, which is identical in design to that in the main part of this chapter, only with the content based on the thermal limitations set for the HI-STORM FW Version UV.

Table 5.I.4.1 provides dose rates for normal conditions around the HI-TRAC VW. Maximum total dose rates are presented for both the MPC-37 and the MPC-89, together with corresponding values from the main part of this chapter. In the same fashion, Table 5.I.4.2 presents accident dose rates around the cask, and Table 5.I.4.3 presents accident dose rates for a distance of 100 m.

The results in Table 5.I.4.3 show that the dose as a result of the design basis accident does not exceed 5 rems at the controlled area boundary for the assumed duration of the accident.

Note that all results presented here are for worst case limiting content and the minimum shielding thickness of the HI-TRAC. This results in very high calculated dose rates, which are presented here for illustration purposes, and are not considered to be representative of actual loading conditions where both the shielding thickness and the loading content should be governed by ALARA considerations.

Table 5.I.4.1

MAXIMUM TOTAL DOSE RATES FOR THE HI-TRAC VW
FOR NORMAL CONDITIONS

Dose Point Location	**MPC-37 Table 5.1.1**	**MPC-37 Bounding for Version UV**	**MPC-89 Table 5.1.2b**	**MPC-89 Bounding for Version UV**
ADJACENT TO THE HI-TRAC VW				
1	2333.2	3014.8	2993.3	3399.4
2	4736.8	7394.6	5898.2	12233.9
3	860.8	765.6	751.6	533.0
4	1604.3	1415.8	888.4	527.8
5	3897.4	3191.6	4063.3	2339.8
ONE METER FROM THE HI-TRAC VW				
1	1163.1	1585.8	1154.8	2081.6
2	2399.6	3351.3	2663.6	5588.5
3	557.8	539.3	572.5	662.4
4	878.5	754.2	484.2	299.9
5	2257.4	1628.5	2038.1	1221.0

Notes:
- Refer to Figure 5.1.2 for dose point locations.
- Values are rounded to nearest integer.

Table 5.I.4.2

MAXIMUM TOTAL DOSE RATES FOR THE HI-TRAC VW
FOR ACCIDENT CONDITIONS

Dose Point Location	MPC-37 Table 5.1.4a	MPC-37 Bounding for Version UV	MPC-89 Table 5.1.4c	MPC-89 Bounding for Version UV
1 meter from HI-TRAC VW				
2 (Accident Condition)	4580.3	6020.6	6711.4	11131.4
2 (Normal Condition)	2399.6	3351.3	2663.6	5588.5
100 meters from HI-TRAC VW				
2 (Accident Condition)	0.8	3.2	3.5	5.2

Notes:

- Refer to Figure 5.1.2 for dose point locations.
- Values are rounded to nearest integer.

Table 5.I.4.3 MAXIMUM DOSE FROM HI-TRAC VW WITH MPC-89 FOR ACCIDENT CONDITIONS AT 100 METERS					
Content	**Dose Rate (rem/hr)**	**Accident Duration (days)**	**Total Dose (rem)**	**Regulatory Limit (rem)**	**Time to Reach Regulatory Limit (days)**
From Table 5.1.9	3.5E-03	30	2.52	5	59
Bounding for Version UV	5.2E-3	30	3.7	5	40.5

Notes:
- Refer to Figure 5.1.2 for dose locations.
- Values are rounded to nearest integer where appropriate.
- Dose rates used to evaluate " Total Dose (rem)" are from Table 5.I.4.2
- Regulatory Limit is from 10CFR72.106.

APPENDIX 5.I.A

[PROPRIETARY APPENDIX WITHHELD PER 10 CFR 2.390]

CHAPTER 9.I: OPERATING PROCEDURES

9.I.0 INTRODUCTION

The operations associated with the use of the HI-STORM FW UV system, described in Supplement 1.I, are like the operations for the standard HI-STORM FW system. The following sections describe those operations that are, in any respect, unique to the HI-STORM FW UV system and thus supplement the information presented in Chapter 9. Where practical, the section numbers used below directly references the corresponding section in Chapter 9. For example, Subsection 9.I.2.6 supplements the operations described in Subsection 9.2.6. The guidance provided in this supplement shall be used along with the operations procedures provided in Chapter 9 to develop the site-specific operating procedures for the HI-STORM FW UV.

9.I.1 TECHNICAL AND SAFETY BASIS FOR LOADING AND UNLOADING PROCEDURES

The Technical and Safety Basis for loading and unloading the HI-STORM FW identified in Section 9.1 of Chapter 9 are applicable to the HI-STORM FW UV.

9.I.2 PROCEDURE FOR LOADING THE HI-STORM FW SYSTEM IN THE SPENT FUEL POOL

The procedures presented within Subsections 9.2.1 through 9.2.5 of Chapter 9 are identical for the HI-STORM FW UV system. The changes to operations when placing the HI-STORM FW UV into storage are described below.

9.I.2.6 Placement of HI-STORM FW into Storage

The following instructions shall be incorporated to the cask operations as additional steps to the generic guidance in Section 9.2.6 on loading operations for unventilated cask models in Chapter 9:

1. Before installing the Closure Lid on the cask body, the lid gasket is placed on the top of the cask's top ring.

2. Inspect cask cavity and confirm to be visibly dry (free of standing water).

3. Place cask lid on top of the gasket.

4. Continue with the steps of Subsection 9.2.6 of Chapter 9 for conducting the required surface dose rate measurements in accordance with the Technical Specification and movement of the overpack to its storage location on the ISFSI pad.

5. After the cask is placed in its storage location on the ISFSI pad, install lid studs, washers, and hex nuts onto the cask.

6. Tighten lid hex nuts to the point of contact with the washer. Then loosen nut 1 ½" turns to provide a nominal axial gap.

7. Evacuate air in the MPC/HI-STORM FW UV annulus and replace with dry nitrogen (or another non-oxidizing gas) using couplings provided in the small penetrations in the cask body. The target fill pressure of the non-oxidizing fill gas shall be as indicated on Table 4.I.1.3.

Table 9.I.2.1

HI-STORM FW SYSTEM ANCILLARY EQUIPMENT OPERATIONAL DESCRIPTION

Equipment	Important To Safety Classification	Description
HI-STORM UV Annulus Evacuation System	Not Important To Safety	Used to evacuate air from the HI-STORM UV annulus space.
Nitrogen (or another non-oxidizing gas) Backfill System	Not Important To Safety	Used for controlled insertion of nitrogen into the HI-STORM UV for placement into storage.

Table 9.2.2

HI-STORM FW SYSTEM INSTRUMENTATION SUMMARY FOR LOADING AND UNLOADING OPERATIONS†

Instrument	Function
Pressure Gauges	Ensures correct pressure during HI-STORM backfill operations.

† All instruments require calibration.

Table 9.I.2.3 HI-STORM FW UV SYSTEM OVERPACK INSPECTION CHECKLIST
Note: This checklist provides a supplement to the main table 9.2.3 as a basis for establishing additional steps to a site-specific inspection checklist for the HI-STORM FW UV 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 FW UV Overpack Lid:

1. Lid sealing surfaces shall be cleaned and inspected for corrosion, scratches, and gouges.
2. Lid seal shall be inspected for cuts, abrasions, or other damage which may affect is function.

9.I.3 ISFSI OPERATIONS

The HI-STORM FW UV system heat removal system is a totally passive system. Maintenance on the HI-STORM FW UV system is typically limited to cleaning and touch-up painting of the overpacks. The HI-STORM FW UV system does not have vents which require surveillance. In the unlikely event of significant damage to the HI-STORM FW UV, the situation may warrant removal of the MPC, and repair or replacement of the damaged HI-STORM FW UV overpack. The procedures in Section 9.2 should be used to reposition a HI-STORM FW UV overpack for minor repairs and maintenance. In extreme cases, Section 9.I.4 provides guidance in addition to Section 9.4 of Chapter 9 for unloading the MPC from the HI-STORM FW UV.

9.I.4 PROCEDURE FOR UNLOADING THE HI-STORM FW FUEL IN THE SPENT FUEL POOL

The HI-STORM FW UV system unloading procedures shall be identical to main chapter section 9.4.1. 9.4.3 and 9.4.4. Additional steps for section 9.4.2 are included below for the removal of the HI-STORM UV lid.

9.I.4.2 HI-STORM FW UV Recovery from Storage

1. Prior to recovering the MPC from HI-STORM FW UV, the following step shall be performed:

   Vent HI-STORM FW UV to atmospheric pressure, such that the interior pressure is equal to ambient pressure.

CHAPTER 10.I†: ACCEPTANCE CRITERIA AND MAINTENANCE PROGRAM

10.I.0 INTRODUCTION

As the addition of the unventilated overpack through Supplement # I does not involve the introduction of any new structural or shielding materials, MPCs or transfer cask to the Storage system, no change to such areas which cover a great bulk of Chapter 10 is necessary. Any additional tests, inspections, and maintenance activities are identified in the following sections.

10.I.1 ACCEPTANCE CRITERIA

10.I.1.1 Fabrication and Nondestructive Examination (NDE)

The HI-STORM FW UV does not introduce any new fabrication or NDE requirements.

10.I.1.2 Structural and Pressure Tests

The HI-STORM FW UV does not introduce any new structural or pressure test beyond what is presented in Subsection 10.1.2. Pressure testing of the HI-STORM FW UV Body is not required due to low operating pressure.

10.I.1.3 Materials Testing

There are no new structural and shielding materials used for the HI-STORM FW UV. No additional materials testing is required for the HI-STORM FW UV. The HI-STORM Lid seal will be manufactured from an elastomeric material that is demonstrated to have good radiation resistance such that degradation over the service life of the cask is not a concern.

10.I.1.4 Leakage Testing

There is no leakage test required for the HI-STORM FW UV boundary. The function of the HI-STORM FW UV seal is to provide a barrier against deleterious effects of the environment, not as a pressure boundary. The only requirement is that the gasket is inspected to ensure that it is intact and new before the lid is installed

10.I.1.5 Component Tests

10.I.1.5.1 Valves, Pressure Relief Devices, and Fluid Transport Devices

There are no additional valves or pressure relief devices introduced for the HI-STORM FW UV System. Excess pressure is released from the boundary by the HI-STORM lid momentarily lifting from the body and then re-seating.

10.I.1.5.2 Seals and Gaskets

The Lid to Cask body in the unventilated overpack features a gasket to isolate the environment in the cask's cavity space from ambient air. The gasket does not perform a safety significant function and thus no additional testing is required

10.I.1.6 Shielding Integrity

There are no new tests or inspections required for shielding integrity.

10.I.1.7 Thermal Acceptance Tests

There are no new tests or inspections required for thermal acceptance.

10.I.1.8 Cask Identification

There are no new marking requirements.

10.I.2 MAINTENANCE PROGRAM

As the addition of the unventilated overpack through Supplement # I does not involve the introduction of any new structural or shielding materials, MPCs or transfer cask to the Storage system, only minimal changes to the Maintenance activities outlined in Section 10.2 of Chapter 10 are required. Any additional tests, inspections, and maintenance activities are identified in the following Subsections.

10.I.2.1 Structural and Pressure Parts

No additional maintenance for structural and pressure parts is required for the HI-STORM FW UV.

10.I.2.2 Leakage Tests

Leakage tests are not a requirement for the storage maintenance program.

The unventilated Storage system lid gasket requires the additional maintenance step of replacement anytime the joint is completely disassembled. A new gasket shall be used upon re-assembly.

10.I.2.3 Subsystem Maintenance

The HI-STORM FW UV does not have vents and will not have the option a monitoring system which must be maintained.

10.I.2.4 Pressure Relief Devices

There is no additional pressure relief device introduced for the HI-STORM FW UV System which must be maintained.

10.I.2.5 Shielding

There are no additional shielding maintenance requirements for the HI-STORM FW UV.

10.2.6 Thermal

The HI-STORM FW UV does not include air vents. As a result, surveillance or monitoring is not required during storage operations.

Table 10.I.2.1 HI-STORM SYSTEM MAINTENANCE PROGRAM SCHEDULE	
Task	**Frequency**
HI-STORM UV Lid Seal Replacement	In the event the HI-STORM lid is completely disassembled from the body.

10.I.3 REGULATORY COMPLIANCE

There are no additional requirements for the HI-STORM FW UV.

CHAPTER 12.I: OFF-NORMAL AND ACCIDENT EVENTS

12.I.0 Introduction

In this chapter, the off-normal and accident events germane to the HI-STORM FW UV system are considered. Because no new MPC or transfer cask are introduced in Chapter I, the off-normal and accident events applicable to them remain unchanged and therefore, are not required to be evaluated herein. Furthermore, events resulting from vent openings in the overpack are also not applicable for the ventless UV overpack. Finally, a survey of the regulatory literature shows that the unvented overpack does not introduce any new off-normal or accident event of safety consequence[1]. Therefore, the number of events that merit consideration in this chapter is vastly reduced. Those events that are applicable to the unvented overpack are evaluated in the following.

[1] The case of leakage of the gasket in the overpack is included even though it is not a safety significant event.

12.I.1 Off-Normal Conditions

The applicable off-normal events are:

i. Elevated Off-normal environmental temperature – The off-normal ambient condition case of -40^{o}F is important only for consideration of protection against brittle fracture for which the Storage System has been qualified in Chapter 3 and so stated in Chapter 12. This conclusion remains valid because the type of materials used and their thicknesses have not been changed in Chapter I.

ii. Leakage of the Lid to overpack seal.

12.I.1.1[1] Off-Normal Environmental Temperature

The elevated off-normal temperature condition is evaluated against the off-normal condition temperature limit for the Storage system components listed in Table 2.2.3 of the main chapter.

12.I.1.1.1 Postulated Cause of Off-Normal Environmental Temperature

The off-normal environmental temperature is postulated as a constant ambient temperature caused by extreme weather conditions. As in the main chapter, to determine the effects of the off-normal environmental temperature, it is conservatively assumed that these temperatures persist for a sufficient duration to allow the Storage System to achieve thermal equilibrium. Because of the large mass of the Storage System with its corresponding large thermal inertia and the limited duration for the off-normal temperatures, this assumption is conservative.

12.I.1.1.2 Detection of Off-Normal Environmental Temperature

The analysis in Chapter 4.I shows that the Storage System is designed to withstand the off-normal environmental temperatures without any effects on its ability to maintain safe storage conditions. Therefore, there is no safety imperative for detection of off-normal environmental temperatures.

12.I.1.1.3 Analysis of Effects and Consequences of Off-Normal Environmental Temperature

- Structural: The rise in the ambient temperature will cause an increase in the cask cavity pressure which, as calculations in Chapter 4.I show, will reduce the extent of sub-atmospheric condition inside the cask which directly reduces the stress in the cask structure. However, conservatively bounding pressures under normal conditions are used in structural evaluation of cask in Chapter 3.I which envelope the off-normal ambient temperature condition with regards to the state of stress in the cask structure.

- Thermal: Thermal analysis summarized in Chapter 4.I shows that temperature of all components remains below their respective limits.

[1] The numbering of the events follows that in the main chapter with the Roman numeral I inserted to indicate that it is a part of the chapter.

- 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 rendered by the Storage System's MPC as a result of this off-normal event.

- Radiation Protection: Since there is no degradation in shielding or confinement capabilities of the Storage System, there is no effect on occupational or public exposures as a result of this off-normal event.

12.I.1.1.4 Corrective Action

Because elevated ambient temperature is a natural event and does not impair the compliance of the Storage system with the acceptance criteria set forth in Chapter 2 and Chapter 2.I, no remedial action is required.

12.I.1.1.5 Radiological Impact:

There is no radiological impact from the elevated ambient temperature on the Storage System.

Based on the above evaluation, it is concluded that the elevated off-normal temperature event does not affect the safe operation of the Storage System.

12.I.1.2 Leakage of One Seal

12.I.1.2.1 Postulated cause

Long term exposure to varying weather conditions can degrade the polymeric gasket resulting in air in-leakage in the cask and causing its sub-atmospheric cavity pressure to begin approaching the ambient.

12.I.1.2.2 Detection of leakage

Air in-leakage does not impact the safety function of the cask; therefore, there is no safety-driven imperative to detect leakage. However, monitoring of the pressure in the cask's cavity provides the means to infer air leakage into the cask

12.I.1.2.3 Effects and consequences of seal failure

MPCs are designed to be exposed to ambient air. Therefore, there is no adverse impact on the Storage System if the pressure inside the cask cavity were to rise all the way up to the ambient, as explained below:

- Structural: The rise in the cask cavity pressure to the ambient reduces the extent of sub-atmospheric condition inside the cask which directly reduces the stress in the cask structure. Hence, intrusion of air into the cask cavity would ameliorate the state of stress in the cask structure. In addition, conservatively bounding pressures under normal conditions are used in structural evaluation of cask in Chapter 3.I which envelope the off-normal condition with regards to the state of stress in the cask structure.

- Thermal: The thermal performance of the Storage System will be slightly improved because the increased mass of cavity gas caused by the air in-leakage will augment the natural convection effect which is only second to radiation in terms of heat transmission. However, because the safety analysis in Chapter 4.I uses the conductivity of air, there is no reduction in the computed thermal margin due to in-leakage of air.

- 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 rendered by the Storage System's MPC as a result of this off-normal event.

- Radiation Protection: Since there is no degradation in shielding or confinement capabilities of the Storage System, there is no effect on occupational or public exposures as a result of this off-normal event.

12.I.1.2.4 Corrective Action:

While the loss of seal does not affect the System's safety function, replacement of gasket shall be carried out upon discovery to restore the non-oxidizing gas environment inside the cask.

12.I.1.2.5 Radiological Impact:

There is no radiological impact from the in-leakage of air in the cask's cavity.

Based on the above evaluation, it is concluded that the off-normal event resulting in the loss of seal effectiveness does not affect the safe operation of the Storage System.

12.I.2 Accident Events

The accident events germane to the introduction of the unvented overpack in the Storage System excerpted from Table 12.2.1 are summarized in Table 12.I.2 where those requiring a detailed evaluation are shown in italicized text.

12.I.2.1 Design Basis Fire

The fire accident under on-the-pad storage is conservatively postulated in Subsection 4.6.2 of the main report. The acceptance criteria for the fire accident are provided in Subsection 2.2.3.

12.I.2.4.1 Postulated cause:

Fire in the cask transporter visiting the ISFSI pad is a probable cause for fire.

12.I.2.4.2 Detection:

The fire at the ISFSI equipped with smoke detectors is easy to detect.

12.I.2.4.3 Analysis of effects and consequences:

The thermal model described in Section 4.I is utilized to quantify the effect of the Design Basis Fire. The transport vehicle fuel tank fire has been analyzed to evaluate the outer layers of the storage overpack heated by the incident thermal radiation and forced convection heat fluxes and to evaluate fuel cladding and MPC temperatures.

- *Structural*: There are no structural consequences as a result of the fire accident condition since the accident temperature limit of the concrete is not exceeded and all component temperatures remain within applicable temperature limits (Table 2.2.3). The accident condition pressure evaluations for cask in Chapter 3.I bound the fire accident condition. The MPC structural boundary remains within accident condition internal pressure and temperature limits.

- *Thermal*: Based on a conservative analysis discussed in Chapter 4.I, it is concluded that the fire event does not significantly affect the temperature of the MPC or contained fuel. Furthermore, the ability of the Storage System to maintain cooling of the spent nuclear fuel within the ISG-11 Rev 3 temperature limits (Table 2.2.3) during and after fire is not compromised.

- *Shielding*: Because the shielding concrete remains below its accident temperature limit, there is no adverse effect on the shielding function 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 since the structural integrity of the confinement boundary is unaffected.

- *Radiation Protection*: Since there is minimal reduction, if any, in the cask's shielding capacity 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 the above evaluation, it is concluded that the overpack fire accident does not affect the safe operation of the Storage System.

TABLE 12.I.1

ACCIDENT CONDITION EVENTS

Event	Location in the main report	Comment (Cases that are italicized have been determined to require complete evaluation which is provided in the subsections above)
Overpack handling accident	12.2.2	The unvented overpack has the same handling characteristics as the vented type. Therefore, the discussion in subsection 12.2.2 applies.
Non-mechanistic tip-over	12.2.3	The unvented overpack has the same lateral impact characteristics as the vented type. Therefore, the discussion in subsection 12.2.3 applies
Design Basis Fire	*12.2.4*	*This condition requires additional evaluation because the unvented overpack is thermally more conductive and hence more responsive to fire.*
Tornado borne missiles	12.2.6	The unvented overpack has improved tornado missile resistance in the absence of vent openings. Therefore, the safety justification in subsection 12.2.6 applies.
Design Basis Flood	12.2.7	A vulnerability in the vented models, the unvented overpack does not suffer from a deleterious scenario such as “smart flood”. Furthermore, the heat rejection rate to the flood waters will be greater. Therefore, a flood event does not challenge the safety performance of the Storage System containing an unvented overpack.
Earthquake	12.2.8	The discussion and approach to deal with earthquake in Chapters 2, 3 and 12 applies to the unvented overpack-bearing storage system without any modification.
Explosion	12.2.11	The discussion and approach to deal with an explosion event, discussed in subsection 12.2.11, applies to the unvented overpack-bearing storage system. In addition, the discussion in Section 2.I.2 regarding AEP is applicable.
Lightning	12.2.12	As discussed in subsection 12.2.12, lightning is an inconsequential event to the Storage System.
Burial-under-debris	12.2.14	Since the standard HI-STORM FW is primarily cooled by ventilation while the Version UV system is not, a burial-under-debris accident will have a much more significant impact on the temperatures for the standard version. A standard HI-STORM FW without ventilation is thermally equivalent to the Version UV system. Since the maximum allowable heat load for Version UV system is significantly lower than that for the standard version, therefore, the evaluation for the standard version bounds that for Version UV
Extreme Environmental Temperature	12.2.15	The consideration of elevated off-normal temperature in subsection 12.I.1.1 in the foregoing applies without any change to the accident condition case.