TABLE 1.2.3c Alternative MPC-37P HEAT LOAD DATA (see Figure 1.2.1c)	
Number of Storage Cells:	37
Maximum Design Basis Heat Load (kW):	45
Maximum Quadrant Heat Load (kW):	11.25
Decay Heat Limit per Cell (kW):	See Figures 1.2.9a/b

Notes:

(1) See Chapter 4 for decay heat limits per cell when vacuum drying moderate or high burnup fuel.

~~(2) Decay heat limit per cell for cells containing damaged fuel or fuel debris is equal to the decay heat limit per cell of the region where the damaged fuel or fuel debris is permitted to be stored.~~

~~TABLE 1.2.3c~~

~~Not Used~~

TABLE 1.2.8b

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

2.1.6 Radiological Parameters for Design Basis SNF

The principal radiological design criteria for the HI-STORM FW System are the 10CFR72 §104 and §106 operator-controlled boundary dose rate limits, and the requirement to maintain operational dose rates as low as reasonably achievable (ALARA). The radiation dose is directly affected by the gamma and neutron source terms of the assembly, which is a function of the assembly type, and the burnup, enrichment and cooling time of the assemblies. Dose rates are further directly affected by the size and arrangement of the ISFSI, and the specifics of the loading operations. All these parameters are site-dependent, and the compliance with the regulatory dose rate requirements are performed in site-specific calculations. The evaluations here are therefore performed with reference fuel assemblies, and with parameters that result in reasonably conservative dose rates. The reference assemblies given in Table 1.0.4 are the predominant assemblies used in the industry.

The design basis dose rates can be met by a variety of burnup levels and cooling times. Table 2.1.1a provides the acceptable ranges of burnup, enrichment and cooling time for all of the authorized fuel assembly array/classes. Table 2.1.5 and Figures 2.1.3 and 2.1.4 provide the axial distribution for the radiological source terms for PWR and BWR fuel assemblies based on the axial burnup distribution. The axial burnup distributions are representative of fuel assemblies with the design basis burnup levels considered. These distributions are used for analyses only, and do not provide a criterion for fuel assembly acceptability for storage in the HI-STORM FW System.

Non-fuel hardware, as defined in the Glossary, has been evaluated and is also authorized for storage in the PWR MPCs as specified in Table 2.1.1a.

2.1.6.1 Radiological Parameters for Spent Fuel and Non-fuel Hardware in MPC-32ML, MPC-37 and MPC-89

MPC-32ML is authorized to store 16x16D spent fuel with burnup - cooling time combinations as given in Table 2.1.9. Spent fuel with burnup – cooling time combinations authorized for storage according to the alternative storage patterns shown in Figures 1.2.3 through 1.2.5 (MPC-37) and 1.2.6 through 1.2.7 (MPC-89) are given in Table 2.1.10. ~~Burnup and cooling time combinations in Table 2.1.10 also apply for 10x10J fuel loaded according to heat load regions shown in Table 1.2.4a.~~

The burnup and cooling time for every fuel assembly loaded into the MPC-32ML, MPC-37 and MPC-89 must satisfy the following equation:

$$Ct = A \cdot Bu^3 + B \cdot Bu^2 + C \cdot Bu + D$$

where,

Ct = Minimum cooling time (years),
Bu = Assembly-average burnup (MWd/mtU),

A, B, C, D = Polynomial coefficients listed in Table 2.1.9 or Table 2.1.10

Minimum cooling time must also meet limits specified in Tables 2.1.1a and 2.1.1b. If the calculated *Ct* is less than the cooling time limits in Tables 2.1.1a or 2.1.1b, the minimum cooling time in table is used.

For MPC-37 and MPC-89, the coefficients for above equation for the assembly in an individual cell depend on the heat load limit in that cell, Table 2.1.10 lists the coefficients for several heat load limit ranges. Note that the heat load limits are only used for the lookup of the coefficients in that table, and do not imply any equivalency. Specifically, meeting heat load limits is not a substitute for meeting burnup and cooling time limits, and vice versa.

Non-fuel hardware, as defined in the Glossary, has been evaluated and is also authorized for storage in the PWR MPCs as specified in Table 2.1.1b.

2.1.6.2 Radiological Parameters for Spent Fuel and Non-fuel Hardware in MPC-37P and MPC-44

MPC-37P is authorized to store CE15x15 spent fuel with burnup - cooling time combinations as given in Table 2.1.12. MPC-44 is authorized to store 14x14 spent fuel with burnup - cooling time combinations as given in Table 2.1.12.

The burnup and cooling time for every fuel assembly loaded into the MPC-37P and MPC-44 must satisfy the following equation:

$$Ct = A \cdot Bu^4 + B \cdot Bu^3 + C \cdot Bu^2 + D\, Bu + E$$

where,

Ct = Minimum cooling time (years),

Bu = Assembly-average burnup (MWd/mtU),

A, B, C, D, E = Polynomial coefficients listed in Table 2.1.12.

2.1.6.3 Alternative Radiological Parameters for Spent Fuel in the MPC-37 and MPC-37P

As an alternative to the radiological parameters for the MPC-37 and MPC-37P defined in Sections 2.1.6.1 and 2.1.6.2, it is permissible to use the parameters in Tables 2.1.13 and 2.1.14. These tables also define minimum cooling time as a function of burnup, but instead of specifying those through polynomials, the limits are directly specified in the tables. All assemblies in a single MPC must either meet the limits from Subsections 2.1.6.1 and 2.1.6.2, or the limits in those tables. A combination is not permitted.

2.1.6.4 Radiological Parameters for Assembly Class 10x10J loaded according to the Patterns in Tables 1.2.4a, 1.2.4.b or 1.2.4.c

For assembly class 10x10J loaded in the MPC-89 according to Table 1.2.4a the radiological parameters in Table 2.1.16 must be applied.

TABLE 2.1.10
BURNUP AND COOLING TIME FUEL QUALIFICATION REQUIREMENTS FOR MPC-37 AND MPC-89

Cell Decay Heat Load Limit (kW)	**Polynomial Coefficients, see Paragraph 2.1.6.1**			
	A	**B**	**C**	**D (Note 1)**
MPC-37				
≤ 0.85	1.68353E-13	-9.65193E-09	2.69692E-04	2.95915E-01
0.85 < decay heat ≤ 3.5	1.19409E-14	-1.53990E-09	9.56825E-05	-3.98326E-01
MPC-89 ~~(Note 2)~~				
≤ 0.32	1.65723E-13	-9.28339E-09	2.57533E-04	3.25897E-01
0.32 < decay heat ≤ 0.5	3.97779E-14	-2.80193E-09	1.36784E-04	3.04895E-01
0.5 < decay heat ≤ 0.75	1.44353E-14	-1.21525E-09	8.14851E-05	3.31914E-01
0.75 < decay heat ≤ 1.1	-7.45921E-15	1.09091E-09	-1.14219E-05	9.76224E-01
1.1 < decay heat ≤ 1.45	3.10800E-15	-7.92541E-11	1.56566E-05	6.47040E-01
1.45 < decay heat ≤ 1.6	-8.08081E-15	1.23810E-09	-3.48196E-05	1.11818E+00

Notes:

1. For BLEU fuel, coefficient D is increased by 1.

2. For calculation of the minimum cooling time for 10x10J fuel that is loaded in accordance with ~~Table 1.2.4a or~~ Table 1.2.4b, the~~an~~ assembly-average burnup must be increased by ~~10,000 MWd/mtU and~~ 5,000 MWd/mtU~~, respectively~~.

~~1.~~

TABLE 2.1.13
ALTERNATIVE BURNUP AND COOLING TIME FUEL QUALIFICATION REQUIREMENTS FOR THE MPC-37P

Cell Location (see Figure 2.1.1c)	Maximum Burnup, MWd/mtU	Minimum Cooling Time, Years
2-2, 2-4 through 2-9, 2-11	55000	1.6
	60000	3.5
2-1, 2-3, 2-10, 2-12	55000	1.8
	60000	3.5
3-4, 3-5, 3-12, 3-13	55000	2
	60000	6
3-2, 3-6 through 3-11, 3-15	45000	3.5
	50000	5
	55000	6
	60000	10
3-1, 3-3, 3-14, 3-16	50000	11
1-2, 1-4, 1-5, 1-6, 1-8	15000	3.5
	50000	5
	55000	10
	60000	13

Note: Cell Locations 1-1, 1-3, 1-7 and 1-9 need to remain empty

TABLE 2.1.14
ALTERNATIVE BURNUP AND COOLING TIME FUEL QUALIFICATION REQUIREMENTS FOR THE MPC-37

Cell Location (see Figure 2.1.1a)	Maximum Burnup, MWd/mtU	Minimum Cooling Time, Years
1-1 through 1-9	50000	5
	55000	6
	60000	10
2-1 through 2-12	55000	5
	60000	6
3-1 through 3-16	50000	3.5
	55000	5
	60000	6

TABLE 2.1.15
BURNUP AND COOLING TIME FUEL QUALIFICATION REQUIREMENTS FOR ASSEMBLY CLASS 10X10J LOADED ACCORDING TO TABLE 1.2.4A

Region	Maximum Burnup, MWd/mtU	Minimum Cooling Time, Years
2	5000	1.2
	10000	1.4
	20000	2.0
	30000	2.4
	40000	3.0
	50000	3.5
	60000	5.0
	70000	6.0
1,3	5000	1.8
	10000	2.2
	20000	2.8
	30000	3.5
	40000	5.0
	50000	7.0
	60000	9.0
	70000	13.0

10 CFR 72.104.
PWR fuel assemblies may contain burnable poison rod assemblies (BPRAs), with any number of full-length rods and thimble plug rodlets in the locations without a full-length rod, thimble plug devices (TPDs), control rod assemblies (CRAs) or axial power shaping rod assemblies (APSRs), neutron source assemblies (NSAs), guide tube anchors (GTAs), or similarly named devices. These non-fuel hardware devices are an integral yet removable part of PWR fuel assemblies and therefore the HI-STORM FW system has been designed to store PWR fuel assemblies with or without these devices. Since each device occupies the same location within a fuel assembly, a single PWR fuel assembly will not contain multiple devices, with the exception of instrument tube tie rods (ITTRs), which may be stored in the assembly along with other types of non-fuel hardware.

~~As described in Chapter 1(see Tables 1.2.3 and 1.2.4), the loading of fuel in all HI-STORM FW MPCs will follow specific heat load limitations.~~

In order to offer the user more flexibility in fuel storage, the HI-STORM FW System offers several ~~heat~~ loading patterns, each with two or more regions with different ~~heat load~~ limits. This is taken into consideration when calculating dose rates in this chapter. The regionalized storage patterns are guided by the considerations of minimizing occupational and site boundary dose to comply with ALARA principles.

Two different lids have been developed for the HI-STORM FW concrete overpack. The lid included in the initial application, referred to as “standard lid”, and a revised design with overall improved shielding performance, referred to as “XL lid”. Since by now essentially all installations utilize the “XL lid”, all dose rates provided for MPC-37 and MPC-89 in this chapter are for that lid design, with the only exception being some tables in Section 5.4 which contain selected results for the “standard lid” from previous versions of this chapter for reference. The shielding analysis of HI-STORM FW with MPC-32ML is performed using a “standard lid” design. All references to the “lid” are to be understood to refer to the “XL lid”, unless otherwise noted.

The sections that follow will demonstrate that the design of the HI-STORM FW dry cask storage system fulfills the following acceptance criteria outlined in the Standard Review Plan, NUREG-1536 [5.2.1]:

Acceptance Criteria

1. The minimum distance from each spent fuel handling and storage facility to the controlled area boundary must be at least 100 meters. The “controlled area” is defined in 10CFR72.3 as the area immediately surrounding an ISFSI or monitored retrievable storage (MRS) facility, for which the licensee exercises authority regarding its use and within which ISFSI operations are performed.

10CFR72 contains two sections that set down main dose rate requirements: §104 for normal and off-normal conditions, and §106 for accident conditions. The relationship of these requirements to the analyses in this Chapter 5, and the burnup and cooling times selected for the various analyses, are as follows:

- 10CFR72.104 specifies the dose limits from an ISFSI (and other operations) at a site boundary under normal and off-normal conditions. Compliance with §104 can therefore only be demonstrated on a site-specific basis, since it depends not only on the design of the cask system and the loaded fuel, but also on the ISFSI layout, the distance to the site boundary, and possibly other factors such as use of higher density concrete or the terrain around the ISFSI. The purpose of this chapter is therefore to present a general overview over the expected or maximum dose rates, next to the casks and at various distances, to aid the user in applying ALARA considerations and planning of the ISFSI.
- For the accident dose limit in 10CFR72.106 it is desirable to show compliance in this Chapter 5 on a generic basis, so that calculations on a site-by-site basis are not required[†]. To that extent, a burnup and cooling time calculation that maximizes the dose rate under accident conditions needs to be selected.

~~It is recognized that for a given heat load, an infinite number of burnup and cooling time combination could be selected, which would result in slightly different dose rate distributions around the cask. For a high burnup with a corresponding longer cooling time, dose locations with a high neutron contribution would show higher dose values, due to the non-linear relationship between burnup and neutron source term. At other locations dose rates are more dominated by contribution from the gamma sources. In these cases, short cooling time and lower burnup combinations with heat load comparable to the higher burnup and corresponding longer cooling time combinations would result in higher dose rates. However, in those cases, there would always be a compensatory effect, since for each dose location, higher neutron dose rates would be partly offset by lower gamma dose rates and vice versa. This is further complicated by the regionalized loading patterns qualified from a thermal perspective and shown in Figure 1.2.3 through Figure 1.2.5 for MPC-37 and Figures 1.2.6 and 1.2.7 for MPC-89. These contain cells with substantially different heat load limits, and hence substantially different ranges of burnup, enrichment and cooling time combinations. The approach to cover all those variations in a conservative way is outlined below.~~

To prescribe radiological limits for the fuel to be loaded, loading curves are defined in Tables 2.1.9 and 2.1.10, where a loading curve specifies the minimum cooling time as a function of fuel burnup. Different loading curves are defined for different regions or cell locations in the basket. These ~~my~~may be referenced by region or cell numbers, or by the decay heat limit of the cell or region. ~~the different heat load limits, so that the thermal and radiological requirements for the fuel in each cell are approximately aligned.~~ However, when using decay heat limits to reference celle location, this is done for easier reference, and is not intended to imply any

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[†] As it is discussed in Subsection 5.1.2, a site-specific shielding evaluation may be required for accident-condition of MPC-32ML.

equivalency between thermal and radiological limits. In other words, ~~it should be noted that~~ thermal and radiological limits for each assembly are ~~applied~~ completely independent from each other. The uniform and regionalized loading curves for the fuel to be loaded in the MPC-37, MPC-32ML, MPC-37P, MPC-44 or MPC-89 canisters are discussed in Subsection 5.2.7.

To determine dose rates consistent with both the uniform and regionalized ~~thermal~~ loading patterns, it is necessary to consider the ranges of burnup and cooling times from all loading curves. For that, 8 burnup values between 5 and 70 GWd/mtU are selected, and corresponding minimum required cooling times are established and used in the dose analyzes. The ~~heat~~ loading patterns in Figures 1.2.3 through 1.2.7 contain from 5 to 20 regions each, ~~i.e.~~i.e., from 5 to 20 principal locations with different ~~heat load~~ limits. Applying 8 burnup and cooling time combinations to each location would result up to 8^{20} = 1.15E+18 different burnup and cooling time loading arrangements per pattern. Analyzing and comparing those many arrangements would be excessive. Therefore, for the radiological evaluations, some ~~regions and~~ loading patterns (MPC-37) are condensed into fewer regions.~~combined using the highest heat load limit (source term) of each group. For MPC-37, the heat loads for each cell are based on the “Long” fuel heat loads in Figure 1.2.5a. The established bounding heat load limits are provided in Tables 5.0.3 and 5.0.4.~~

This then results in effectively only 2 or 5 regions to be independently varied for the considered bounding MPC-37 and MPC-89 patterns, and hence 8^2 = 64 or 8^5 = 32,768 different burnup and cooling time arrangements per pattern is to be analyzed, which is manageable. The selected burnup, enrichment and cooling time combinations for the uniform and regionalized loading patterns are listed in Tables 5.0.3, 5.0.4a, 5.0.4b, ~~and~~ 5.0.5, 5.0.6 and 5.0.7. For the MPC-37 and MPC-37P, there are additional alternative burnup and cooling time limit combinations defined in Tables 2.1.13 and 2.1.14. The dose rates in the various important locations are calculated for each of these combination arrangements and the maximum is determined for each dose rate location. It should be noted that this maximum can be from a different loading arrangement in different locations.

Based on this approach, the source terms used in the analyses of MPC-37, MPC-32ML, MPC-37P, MPC-44 or MPC-89 are reasonably bounding for all realistically expected assemblies. All dose rates in this chapter are developed using this approach, unless noted otherwise. Also, as discussed in Section 5.2, the design basis BPRA activities are considered for MPC-37, MPC-32ML and MPC-44~~32ML~~ in this chapter, unless noted otherwise.

All dose rates in Section 5.1 are developed using the approach discussed above. Some dose rates in Section 5.4 were retained from previous versions of the FSAR and that are based on a representative (while still conservative) uniform loading pattern, as discussed in that Section.

Table 5.1.17

MAXIMUM DOSE RATES ADJACENT TO HI-STORM FW VERSION E OVERPACK FOR NORMAL CONDITIONS
MPC-37P WITH CE15X15 FUEL
LOADING PATTERNS (SEE TABLE 5.0.7 AND TABLE 2.1.13)

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)**
1	559.8	3.3	13.7	17.3	594.0	656.3
2	360.0	2.6	0.1	2.1	364.8	402.2
3 (surface)	99.7	0.8	57.2	9.8	167.5	238.7
3 (overpack edge)	45.3	0.4	25.6	4.8	76.1	107.7
4 (center)	1.7	1.7	1.0	0.5	5.0	6.1
4 (mid)	1.4	1.4	1.1	0.4	4.3	5.5
4 (outer)	1.0	0.1	0.5	<0.1	1.6	2.3

Notes:

- Refer to Figure 5.1.1 for dose locations.
- Values (in units of mrem/hr) are rounded to the nearest tenths place~~integer where appropriate~~.
- Dose location 3 (surface) is at the surface of the outlet vent. Dose location 3 (overpack edge) is in front of the outlet vent, but 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 situated directly above the vertical section of the outlet vent. 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.
- ^{60}Co activities from BPRA at 1~~3~~ year cooling are used.
- These dose rates also bound CE 15x15 fuel loaded into the MPC-37 in accordance with Table 2.1.14

Table 5.1.18

MAXIMUM DOSE RATES AT ONE METER FROM HI-STORM FW VERSION E OVERPACK
FOR NORMAL CONDITIONS
MPC-37P WITH CE15X15 FUEL
LOADING PATTERNS (SEE TABLE 5.0.7 AND TABLE 2.1.13)

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)**
1	164.6	1.1	3.8	1.7	171.3	190.7
2	183.7	1.2	1.8	1.9	188.6	209.8
3	25.0	0.2	7.4	1.2	33.8	44.3
4 (center)	2.8	<0.1	1.2	<0.1	4.0	5.6

Notes:

- Refer to Figure 5.1.1 for dose locations.
- Values (in units of mrem/hr) are rounded to nearest tenths place~~integer where appropriate~~.
- 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.
- ^{60}Co activities from BPRA at 1~~3~~ year cooling are used.
- These dose rates also bound CE 15x15 fuel loaded into the MPC-37 in accordance with Table 2.1.14

Table 5.1.19

MAXIMUM DOSE RATES FROM THE HI-TRAC VW FOR NORMAL CONDITIONS
MPC-37P WITH CE15X15 FUEL
LOADING PATTERNS (SEE TABLE 5.0.7AND TABLE 2.1.13)

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-TRAC VW						
1	1594.4	21.7	698.5	53.6	2368.3	2719.1
2	4646.7	64.9	<0.1	115.7	4827.3	5901.4
3	46.4	6.4	477.6	8.0	538.3	1117.0
4	446.2	2.9	560.3	500.4	1509.8	2208.3
5	2879.5	4.0	2880.4	1608.7	7372.6	7674.8
ONE METER FROM THE HI-TRAC VW						
1	1063.8	7.5	90.7	18.4	1180.4	1430.2
2	2493.8	7.8	8.3	16.8	2526.7	3041.0
3	280.7	3.7	117.3	5.4	407.1	611.4
4	227.4	0.9	381.9	138.8	748.9	1164.9
5	1338.0	1.5	1252.0	541.7	3133.1	3300.6

Notes:

- Refer to Figure 5.1.2 for dose locations.
- Values (in units of mrem/hr) are rounded to the nearest tenths place~~integer~~.
- Dose rates are based on no water within the MPC, an empty annulus, and a water jacket full of water. For the majority of the duration that the HI-TRAC bottom lid is installed, the MPC cavity will be flooded with water. The water within the MPC greatly reduces the dose rate.
- Streaming may occur through the annulus. However, during handling/operations the annulus is filled with water and lead snakes are typically present to reduce the streaming effects. Further, operators are not present on top of the transfer cask.
- 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.
- ^{60}Co activities from BPRA at 1~~3~~ year cooling are used.
- Dose rates are calculated for a HI-TRAC with a lead thickness of 3" which is the version intended for loading the fuel.
- These dose rates also bound CE 15x15 fuel loaded into the MPC-37 in accordance with Table 2.1.14

14. Place HI-STORM FW in storage as follows:

Note:

Closing the mating device drawer while the MPC is in the HI-STORM will block air flow. The mating device drawer shall remain open, to the extent possible, such that the open air path is at least as large as the HI-STORM Lid vent openings until the mating device is to be removed from the HI-STORM. When the mating device drawer is closed for mating device removal, the process shall be completed in an expeditious manner.

a. Remove the mating device.

~~a.~~b. Inspect the HI-STORM FW lid studs and nuts or lid closure bolts for general condition. Replace worn or damaged components with new ones.

Note:

Unless the lift has redundant drop protection features (or equivalent safety factor) for the HI-STORM FW lid, the lid shall be kept less than 2 feet above the top surface of the overpack. This is performed to protect the MPC lid from a potential HI-STORM FW lid drop.

~~a.~~c. Install the HI-STORM FW lid~~–~~, and if the HI-STORM anchor blocks are not utilized for cask movement, install the lid studs and nuts or lid closure bolts to secure the lid in place~~and the lid studs and nuts or lid closure bolts~~*.

~~a.~~d. Remove the HI-STORM FW lid lifting device and, if necessary, install the hole plugs* in the empty lift holes. Store the lifting device in an approved plant storage location.

Warning:

HI-STORM FW dose rates are measured to ensure they are within expected values. Dose rates exceeding the expected values could indicate that fuel assemblies not meeting the CoC may have been loaded.

~~b.~~e. Perform the HI-STORM FW surface dose rate measurements in accordance with the Technical Specifications. Measured dose rates must be compared with calculated dose rates that are consistent with the calculated doses that demonstrate compliance with the dose limits of 10CFR72.104(a).

~~c.~~f. Secure HI-STORM FW to the transporter device as necessary.

Note:

The site-specific transport route conditions must satisfy the requirements of the Technical Specification.

g. Perform a transport route walkdown to ensure that the transport conditions are met.

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* Upon installation, studs, nuts, and threaded plugs shall be cleaned and inspected for damage or excessive thread wear (replaced if necessary) and coated with a light layer of Loctite N-5000 High Purity Anti-Seize (or equivalent).

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 UVH; all other components in Table 1.I.1.2, 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, without vents and MPC guides.

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 UVH is engineered to limit exposure of the overpack internal cavity to the external environment, thus reducing the probability of stress corrosion cracking (SCC) in the stainless steel canister while also serving as a low-dose MPC storage system~~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~~.

In all physical respects, the Storage system is essentially identical to its ventilated counterpart. Thus, like the ventilated HI-STORM FW overpack models, the Version UVH overpack is staged as a free standing 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 of the UVH listed in Table 1.I.1.1 are designated Important-to-safety (ITS). The ISFSI pad is NITS.

1.I.2 General Description

1.I.2.1 System Characteristics

The components of the Storage system are listed in Table 1.I.1.1. The description presented in Section 1.2 of the main FSAR remains applicable for the components listed in Table 1.I.1.1, 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 MPCs listed in Table 1.I.1.2.

1.I.2.1.1 MPCs:

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

1.I.2.1.2 Version UVH Overpack:

The HI-STORM FW Version UVH 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 installed on the cask body, with a weather-resistant metallic gasket (also referred to as a metallic seal in this FSAR) limiting exposure of the overpack internal cavity to the external environment~~providing an enclosed environment in the overpack~~. ~~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 an environmentally sequestered enclosure.~~ This ~~sealed~~ annular space is envisaged to hold the loaded *multi-purpose canister* in an upright orientation.

As its design configuration would suggest, "Version UVH" (UV is an abbreviation of **u**n**v**entilated, H stands for **h**igh density concrete) has a reduced heat load capacity compared to its ventilated counterpart. Because the only heat rejection pathway available to the Version UVH storage overpack is through natural convection and radiation to the ambient and a limited amount of conduction to the ISFSI pad, the annulus gas inside the overpack will be at an elevated temperature. Because heating of gas 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 gas surrounding the Canister serves to minimize the incidence of SCC under extended storage conditions. Preventing SCC is a principal objective of Version UVH.

The key distinguishing feature of Version UVH is that it has no inlet or outlet vents. Thus, there is no meaningful ventilation flow of gas around the MPC. Rather the cask is designed to reject the fuel's decay heat from the external surface of the Canister without the benefit of ventilation flow. Rejection of heat from the external surface of the Canister to the external surface of the overpack is facilitated by a combination of conduction and radiation modes of heat transmission. The inside diameter of the overpack has a tight clearance with the OD of the Canister which, under the design basis heat load, computes to an essentially vanishing value giving conduction a bigger role in heat dissipation. Radiation from the hot MPC surfaces to the cask's inner surfaces also plays an active heat dissipation role. Finally, the shielding concrete used in Version UVH is of high density rich in hematite class of aggregate which ensures a high thermal conductance across its mass. Heat rejection from the overpack to the ambient environment like all other HI-STORM overpack models, occurs through natural convection and radiation from the cask's exposed surfaces.

The Closure Lid for Version UVH is also a steel structural weldment with high density, high conductivity concrete installed inside its body to provide protection against sky shine. The Closure Lid is installed on the cask body by a set of equally spaced anchor bolts with a small clearance and an interposed gasket limiting exposure of the overpack internal cavity to the external environment ~~providing a barrier against intrusion of air in the overpack's annulus space~~ and thus protecting the MPC from the deleterious effect of airborne species that induce stress corrosion cracking (SCC) in stainless steel. ~~Precluding the incidence~~Reducing the probability of SCC in the MPC shell during extended period of storage by creating a still air environment around it is a principal benefit of Version UVH. The weight of the Closure Lid helps the sealing action of the gasket. In the event the air in the overpack annulus were to pressurize, the weight of the lid is counteracted allowing the air to escape. Thus, the overpack has a built-in protection against overpressure.

In addition to providing a barrier against ingress of aggressive species in the space around the MPC, Version UVH also accrues several salutary benefits, such as:

- Absence of vent openings eliminates a source of radiation to the environment emitted from the Canister.
- The overpack is rendered much more rugged against mechanical projectiles in absence of vent openings. The intermediate and penetrant Design Basis Missiles (see Table 2.I.2.1) cease to be a safety concern.
- The Version UVH overpack, made of steel and devoid of any vents, emulates a metal cask in respect of critical functions under accident conditions such as the Design Basis Fire. However, thanks to its larger footprint and greater mass, it is a far superior in respect of shielding capacity and seismic stability in comparison to any peer metal cask.
- The aging related deterioration of the paint on the cask's internal surface is substantially retarded because of the hot and dry environment in contact with it.
- The need for periodic inspection of the vent openings and associated LCOs in the CoC becomes inoperative eliminating this source of radiation dose to the site staff.

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

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

- 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 within the allowable range in Table 1.I.2.1~~(between 200 and 250 pcf)~~ to realize the level of dose reduction required.

Table 2.I.1.9

Burnup and Cooling Time Fuel Qualification Requirements for MPC-89

Cell Decay Heat Load Limit (kW)	**Polynomial Coefficients, see Subsection 2.I.1.2**				
	A	**B**	**C**	**D**	**E**
≤ 0.326	-1.83052e-18	+4.29713e-13	-2.19962e-08	+4.76650e-04	-7.28771e-01
0.326 < decay heat ≤ 0.652	+5.33388e-19	-6.36638e-14	+2.76988e-09	+6.09709e-06	+9.75025e-01

Note:

For calculation of the minimum cooling time for 10x10J fuel, the assembly-average burnup must be increased by 5,000 MWd/mtU.

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 UVH and standard length MPC-37 (PWR canister)

ii. Storage system containing Version UVH and standard length MPC-89 (BWR canister). Thermal evaluations of MPC-89 standard basket design in ventilated HI-STORM FW overpack (Chapter 4) bounds that with MPC-89CBS design [4.1.9]. The same conclusion can be extended to the placement of MPC-89CBS in HI-STORM FW UVH.

iii. Storage system containing Version UVH and MPC-44 CBS assembly (PWR canister).

iv. 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 UVH overpack that is placed in an array is somewhat disadvantaged. The impact of the neighboring casks on the temperatures is particularly exacerbated in the case of Version UVH overpack compared to the standard HI-STORM FW system because of its high dependence on radiative heat transfer into the ambient due to lack of ventilation of the MPC. Therefore, to determine the impact of cask proximity, an example evaluation is performed for a 2xN layout shown in Figure 4.I.4.1. The methodology for this analysis is largely same as that used in Section 4.I.4.1 with the following differences:

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The computed temperatures and pressures are presented in Table 4.I.4.1 and meet the respective limits specified in this FSAR.

The above methodology can be adopted for any site-specific arrangement.

4.I.4.6 Results & Safety Conclusions

The results from the most-bounding configuration, determined in Section 4.I.4.2, are presented in Table 4.I.4.1. This evaluation includes the impact of the neighboring casks. The MPC cavity and annulus

9.I.2 PROCEDURE FOR LOADING THE HI-STORM FW UVH 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 UVH system. The changes to operations when placing the HI-STORM FW UVH into storage are described below.

9.I.2.6 Placement of HI-STORM FW UVH 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. After Step 2, prior to Step 4:
    a. Inspect cask cavity and confirm to be visibly dry (free of standing water).
2. After Step 14.b, prior to Step 14.c:
    a. Before installing the Closure Lid on the cask body, the lid gasket is placed on the top of the cask's top ring.
    b. Remove drain assembly plugs to prevent pressurization of cavity during HI-STORM transfer operations.
3. Perform Step 14.c, taking care not to crush or otherwise damage the gasket. No pre-load should be applied at this time.

4. After Step 14.h:
    1. Tighten lid hex nuts to the point of contact with the washer. Then loosen nut to provide a nominal axial gap of 0.5".

Note:

The HI-STORM FW UVH cavity initial pressure is adjusted as necessary in accordance with Section 4.I.1.4.

    2. Reinstall the drain assembly plugs.

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

Table 9.I.2.1

Not Used

~~Table 9.I.2.1~~

~~HI-STORM FW SYSTEM ANCILLARY EQUIPMENT OPERATIONAL DESCRIPTION~~

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

CHAPTER 10.I[†]: ACCEPTANCE CRITERIA AND MAINTENANCE PROGRAM

10.I.0 INTRODUCTION

The acceptance and maintenance program associated with the use of the HI-STORM FW UVH system, described in Supplement 10.I, are like the maintenance and acceptance program for the standard HI-STORM FW system. The following sections describe the requirements that are, in any respect, unique to the HI-STORM FW UVH system and thus supplement the information presented in Chapter 10. Where practical, the section numbers used below directly reference the corresponding sections in Chapter 10. For example, Subsection 10.I.2 supplements the requirements described in Subsection 10.2. The guidance provided in this supplement shall be used along with the procedures provided in Chapter 10 to develop the site-specific maintenance program for the HI-STORM FW UVH.

10.I.1 ACCEPTANCE CRITERIA

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

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

10.I.1.2 Structural and Pressure Tests

The HI-STORM FW UVH 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 UVH 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 UVH. No additional materials testing is required for the HI-STORM FW UVH. The HI-STORM Lid seal will be manufactured from a metallic 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 UVH boundary. The function of the HI-STORM FW UVH seal is to limit exposure of the overpack internal cavity to the external environment~~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

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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 UVH 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 limit exposure of the overpack internal cavity to the external environment~~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.

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 UVH 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 UVH 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 event is~~s are~~:

i. Elevated Off-normal environmental temperature – The off-normal ambient condition case of -40°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.

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[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.~~