An important benefit of the inlet vent system employed in Version E is the ability it imputes to the canister to continue to reject its decay heat in the event of a flood event that blocks the flow of incoming air. Because blocking of the elevated inlet vent with flood water will partially wet the MPC, which has recirculating helium from internal thermo-siphon effects, an effective means for heat rejection to the surrounding flood water is established without any operator action.

c. Directing the inlet air flow towards the bottom of the MPC serves to slightly pre-heat the incoming air, alleviating the stress-corrosion risk to the lower portion of the MPC shell (where it is most vulnerable).

d. As a key design objective, while the air flow areas are enlarged to facilitate increased ventilation flow, the design ensures that the flow regime throughout the VVM will continue to be fully turbulent at the system's Design Basis Heat Load (DBHT).

e. The MPC sits on a thin stainless liner welded to the Bottom Plate so that it is not in direct contact with the carbon steel bottom plate of the overpack

f. The density of the shielding concrete (Appendix 1.D) in the overpack body and Top Lid has been increased to enhance dose attenuation (See Table 1.II.2.4.) [1.II.2]

g. The massive Top Lid, which is held in place by four large anchor bolts has been designed such that during the non-mechanistic tip-over event, the lid will impact the ISFSI pad independently of the cask body because of the large clearances around each bolt hole. This feature has the beneficial effect of ameliorating internal stresses in the cask from the tip-over event.

Table 1.II.2.5 provides the essential design data required for the safety analysis of Version E overpack cask in the subsequent chapters. Table 1.II.2.1 lists the sections from the main body of the FSAR used to evaluate the improved features of Version E as analyzed in the supplement II to each chapter.

1.II.2.2 Multi-Purpose Canister (MPC)

The MPC for all HI-STORM/HI-STAR systems consists of two principal components, namely (i) The Enclosure Vessel (EV) which is an all-welded pressure vessel of the highest ASME Code pedigree, and (ii) The Fuel Basket. MPC-32M, MPC-32 Version 1 and MPC-68 Version 1 utilize Enclosure Vessel Version 1 listed in section 1.II.5. For reference purposes, a listing of MPCs allowed for storage in the Version E is provided in Table 1.II.2.2. MPC-32M along with version 1 of MPC-32 and MPC-68 are the subject of the safety analysis in this Supplement II.

(i) MPC-32M: Certain design attributes of MPC-32M are summarized below, most of which it shares with all other MPC models:

a. Like all MPCs, MPC-32M will be handled by a set of Lift Cleats" (under "Special lifting devices" in the regulatory literature) that engages with tapped anchor locations (TALs) in the top lid. The lifting appurtenances of the Enclosure Vessel body must meet the stress margin criteria of NUREG-0612 and ANSI 3.61.

b. In all MPCs, the Enclosure Vessel is made from one of the previously approved stainless-steel alloy materials denoted as Alloy X in this FSAR (See Appendix 1.A).

c. Like MPC-68M (described in Supplement III), the gap between the Enclosure Vessel shell and the Fuel Basket is occupied by the so-called Basket Shims that surround the Fuel Baskets and are made of an aluminum alloy qualified for their thermal environment. As in MPC-68M, the basket body and the Basket Shims are non-Code and feature axial flow holes to facilitate helium recirculation.

Quadrant No. 4

Quadrant No. 1

	1 3.000	2 0.775	3 0.775	4 3.000	
5 3.000	6 0.825	7 1.025	8 1.025	9 0.825	10 3.000
11 0.775	12 1.025	13 1.400	14 1.400	15 1.025	16 0.775
17 0.775	18 1.025	19 1.400	20 1.400	21 1.025	22 0.775
23 3.000	24 0.825	25 1.025	26 1.025	27 0.825	28 3.000
	29 3.000	30 0.775	31 0.775	32 3.000	

Quadrant No. 3

Quadrant No. 2

Cell No. Heat Load (kW)

*Notes: 1. This figure provides per cell allowable heat loads for MPC-32M with all UNDAMAGED FUEL assemblies. Fuel Assembly and Non-Fuel Hardware must meet per cell allowable limit as well as the total and quadrant decay heat limit set forth in Table 2.II.1.5.
2. Location of DFCs/ DFIs, applicable cell heat load penalties and the soluble boron requirements are provided in Table 2.II.1.7.

Figure 2.II.1-2
Discrete Pattern A, Per Cell Allowable Heat Loads (kW) - MPC-32M

Quadrant No. 4 | Quadrant No. 1

	1 3.255	2 0.745	3 0.745	4 3.255	
5 3.255	6 0.375	7 0.990	8 0.990	9 0.375	10 3.255
11 0.745	12 0.990	13 1.275	14 1.275	15 0.990	16 0.745
17 0.745	18 0.990	19 1.275	20 1.275	21 0.990	22 0.745
23 3.255	24 0.375	25 0.990	26 0.990	27 0.375	28 3.255
	29 3.255	30 0.745	31 0.745	32 3.255	

Quadrant No. 3 | Quadrant No. 2

Cell No. Heat Load (kW)

Notes: 1. This figure provides per cell allowable heat loads for MPC-32M with all UNDAMAGED FUEL assemblies. Fuel Assembly and Non-Fuel Hardware must meet per cell allowable limit as well as the total and quadrant decay heat limit set forth in Table 2.II.1.5.
2. Location of DFCs/ DFIs, applicable cell heat load penalties and the soluble boron requirements are provided in Table 2.II.1.7.

Figure 2.II.1-3
Discrete Pattern B, Per Cell Allowable Heat Loads (kW) - MPC-32M

Table 2.II.2.10

MATERIALS AND COMPONENTS OF THE HI-STORM 100 SYSTEM

MPC Version 1 [1,2]

Primary Function	Component[3]	Safety Class[4]	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/ Coating	Contact Matl. (if dissimilar)
Confinement	Baseplate	Refer to Table 2.2.6	Refer to Table 2.2.6	Refer to Table 2.2.6	See Appendix 1.A	NA	Refer to Table 2.2.6
Confinement	Inner Shell	Refer to Table 2.2.6	Refer to Table 2.2.6	Refer to Table 2.2.6	See Appendix 1.A	NA	Refer to Table 2.2.6
Confinement	Lid	Refer to Table 2.2.6	Refer to Table 2.2.6	Refer to Table 2.2.6	See Appendix 1.A	NA	Refer to Table 2.2.6
Confinement	Closure Ring	Refer to Table 2.2.6	Refer to Table 2.2.6	Refer to Table 2.2.6	See Appendix 1.A	NA	Refer to Table 2.2.6
Shielding	Vent / Drain Block (Upper/Lower	Refer to Table 2.2.6	Refer to Table 2.2.6	Refer to Table 2.2.6	See Appendix 1.A	NA	Refer to Table 2.2.6
Confinement	Port Cover Plate	Refer to Table 2.2.6	Refer to Table 2.2.6	Refer to Table 2.2.6	See Appendix 1.A	NA	Refer to Table 2.2.6

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

Table 3.II.2.3: HI-TRAC Version MS Weight and Dimension Data		
Item	Data (in inch or pounds)	Comment
Ref radial width of lead in the cask's annulus	4"	The data in this table corresponds to the Licensing drawing where the cask cavity height is set by the "reference PWR fuel". The radial thickness of lead and water jacket cavity are as listed in this table. These shielding material thicknesses may be adjusted to optimize shielding within the constraint of the cask laydown space in the Fuel Building and the capacity of the cask crane. The tornado missile analysis in Section 3.II.4 uses the reference data from this table.
Minimum radial width of lead in the cask's annulus	2 3/4"	
Ref radial width of water jacket in the cask body	4 3/4"	
Minimum radial width of water jacket in the cask body	3 7/8"	
Weight of empty cask with bottom lid attached (empty water jacket)	120,000	
Weight of Water in HI-TRAC Water Jacket	8,100	
HI-TRAC weight with MPC in the pool, water jacket *full* without accounting for buoyancy effects	230,000	
HI-TRAC weight with MPC in the pool, water jacket *empty* without accounting for buoyancy effects	222,000	
HI-TRAC weight with "loaded, welded and prepped" MPC (Includes 5% adder for fabrication tolerances)	215,000	

Table 3.II.2.4: Weight Data on HI-STORM 100S Version E Overpack			
Ref. Concrete density	Weight of cask body with MPC in kips (including lid)	Weight of top lid in kips	Comments
175 pcf	336,100	29,000	The weight data corresponds to the Licensing drawing
225 pcf	392,100	34,000	

the HI-TRAC Version MS main outer shell.

- 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.

- 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 [3.II.24] shows 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 100S Version E or the HI-TRAC Version MS. Therefore, the small missile will dent, but not penetrate, the cask. Likewise, the 1-inch missile cannot enter the air inlet/outlet vents in the HI-STORM 100S Version E overpack. The penetration results for the small and intermediate missile are summarized in Table 3.II.4.11 per [3.II.24].

For the intermediate missile, the analyses documented in [3.II.24] 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 Version MS inner shell. Therefore, there will be no impairment to the Confinement Boundary due to tornado-borne missile strikes. Furthermore, since the HI-STORM 100S Version E and HI-TRAC Version MS 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.

(ii) Loading Case M-2; Vertical Free fall of Loaded cask:

Since the lifting devices and the cask appurtenances (lifting attachments on the cask) are designed to meet the sing-failure proof criteria as per section 2.II.2.7, the vertical free fall of the HI-STORM cask and the horizontal fall of the HI-TRAC is not credible. If the lifting devices fail to meet the single failure proof criteria as per section 2.II.2.7, the postulated drops shall be addressed as part of the 10CFR72.212 evaluations. Such site-specific evaluation (if warranted) shall use the identical structural (finite element) models or evaluation methodologies as discussed in the following.

(iii) Loading Case M-4; Non-Mechanistic Tip-Over:

As discussed in Section 2.II.2.2, the non-mechanistic tip-over event applies to a loaded HI-STORM Version E module that is not anchored (or otherwise constrained from overturning on the ISFSI pad). The cask tip-over is not postulated as an outcome of any environmental phenomenon or accident condition. The cask tip-over is a non-mechanistic event, which is analyzed to comply with the guidance in NUREG-1536 [2.1.5]. The objective of the analysis is to demonstrate that the plastic deformation in the fuel basket is limited to the value at which the criticality safety is maintained, retrieval of the fuel by normal means is assured, and that there is no significant loss of radiation shielding in the storage system.

The tip over event is an artificial construct wherein the HI-STORM 100S Version E overpack is assumed to be perched on its edge with its C.G. directly over the pivot point A (Figure 3.II.4.6)). 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.

Table 3.II.4.12: Maximum Local True Plastic Strain Results		
Part	**MPC-32M**	**Failure Strain**
Fuel Basket	9.798×10^{-2}	1.97×10^{-1}
MPC Enclosure Vessel	3.04×10^{-1}	1.05×10^{0}
Cask Overpack (without Lid)	1.097×10^{-1}	3.72×10^{-1}
Cask Lid Bolts	1.32×10^{-1}	6.1×10^{-1}

external surfaces by convection heat transfer. Consistent with HI-STORM 100 Chapter 4 analysis methodology the air flow in the HI-STORM 100/MPC annulus is simulated by the k-ω turbulence model with the transitional option enabled. The mesh adopted to simulate annulus heat transfer is equal to or better than thermal models supporting the main HI-STORM 100 FSAR. The grid has been standardized in all HI-STORM simulations to evaluate the thermal state of the HI-STORM 100 system under normal, off-normal and accident conditions of storage.

- In vertical storage, the fuel assembly is assumed to be positioned coaxially with respect to its storage cell (contact between the fuel and the storage cell walls, MPC and cask can be modelled in short term operations where the cask is handled horizontally).
- As reported in [4.II.1], the effect of crud resistance on fuel cladding surfaces has been previously evaluated and found to be negligible and is therefore, neglected in the thermal analyses
- The formalism to quantify the resistance to the flow of helium in the MPC described in subsection 4.4.1 of [4.II.1] is adopted herein without modification for MPC-32M as it features the standard cell opening as in certified MPC-32 canisters.
- Flow resistance of MPC-32/68 storage cells featuring enlarged cell opening adopt the HI-STORM FW formulation for evaluation of flow resistance in non-standard cell openings ([4.II.1], Subsection 4.4.1.7).
- Informed by the results of analysis reported in this FSAR the thermal model considers a single cask so long as the casks are arrayed in accordance with main HI-STORM FSAR Section 1.4 requirements. For a denser layout, a §72.48 guided evaluation will be necessary.

4.II.4.2 Test Model

The HI-STORM 100 thermal analysis is performed on the FLUENT [4.1.2] Computational Fluid Dynamics (CFD) program. As reported in the main body of this FSAR and sub-section 4.4.3 of [4.II.1], the FLUENT code has been extensively benchmarked and determined to provide uniformly conservative solutions. The proven conservatism of Fluent solutions has enabled the USNRC to waive the need for model tests in prior licensing reviews. Accordingly, this FSAR amendment does not envisage any physical model tests.

4.II.4.3 Maximum and Minimum Temperatures-Normal Storage

(a) MPC-32M

As defined in Section 4.II.3.4 MPC-32M is designed for storage under regionalized loading as a function of parameter X and under discrete loading patterns. To address regionalized loading two extreme scenarios under X=0.5 and X=3 are analyzed. Discrete loading is permitted under cell specific loading limits defined in Figures 2.II.1-2 and 2.II.1-3 subject to Table 2.II.1.5 quadrant and aggregate cask heat load limits. To reasonably bound discrete loading under cask aggregate and cell specific limits multiple loading scenarios are considered based on the following principles:

1. Relative Location of the Hottest Fuel Assembly: A bounding heat load pattern will have the

hottest fuel storage cell surrounded by high heat load fuel assembles.

2. Direction of Panel Gaps: A bounding loading scenario will have highest heat loads concentrated along the most restrictive in-plane direction i.e. parallel to the panel gaps.

Based on the above principles several loading scenarios are developed and evaluated for the cell specific patterns defined in Figures 2.II.1-2 and 2.II.1-3 and are archived in the supporting Calculation Package [4.II.7].

Table 4.II.4.1 provides the results of analyzed scenarios and peak fuel cladding temperatures (PCT) obtained under MPC-32M storage in the HI-STORM Version E to establish limiting heat load pattern for compliance with the criteria set down in Sub-section 4.II.3.7. Results showing margin to the limits are provided later in this section.

(b) MPC-32/68 Version 1

MPC-32/68 Version 1 canisters are allowed for storage in all previously licensed overpacks and in Version E introduced in this supplement. Thermal evaluation is addressed in the bounding Version B overpack.
MPC-32/68 Version 1 canisters are enhanced version of MPC-32 and MPC-68 canisters evaluated in HI-STORM 100 Chapter 4. This Supplement intends to demonstrate thermal design of Version 1 canisters is bounded by Chapter 4 licensing basis evaluations. For this purpose limiting MPC-32 canister evaluated in HI-STORM Chapter 4 is adopted for evaluation under the Version 1 design. As Version 1 design incorporates a slightly larger storage cell the thermal performance is reasonably judged to be similar albeit towards slightly lower temperatures because of reduced resistance to helium flow. This supports the conclusion MPC-32 Version 1 design bounds MPC-68 Version 1. The MPC-32 Version 1 canister under lower and upperbound regionalized heat load scenarios (X = 0.5 and X = 3) is evaluated herein.

4.II.4.3.1 Maximum Temperatures

(a) MPC-32M

The storage pattern that yields the highest peak cladding temperature is termed the "*Governing heat load*" case. As evaluated in Table 4.II.4.1 the limiting heat load scenario is adopted for licensing basis evaluations. The maximum computed fuel, canister and overpack component temperatures are tabulated in Table 4.II.4.2. The results support the conclusion that MPC-32M temperatures are bounded by previously certified MPC-32 (Table 4.4.6) and MPC-68M temperatures (Table 4.III.3a). The results are in compliance with Sub-section 4.II.3.7 limits.

(b) MPC-32/68 Version 1

Maximum fuel, canister and overpack component temperatures under limiting MPC-32 canister loaded to lower and upperbound regionalized heat load scenarios (X = 0.5 and X = 3) are tabulated in Table 4.II.4.5. The results support the conclusion that MPC-32/68 Version 1 canisters are bounded by licensing basis HI-STORM 100 Chapter 4 Tables 4.4.6 and 4.4.7 temperatures.

4.II.4.3.2 Minimum Temperatures

screens and DFCs use square shaped boxes for storing fuel these affect flow resistance and lateral dissipation of heat. For this reason DFIs and DFCs are limited to locating in the cold peripheral regions of the canister. In design space a suitable heat load penalty is defined in the specifications permitting DFI/DFC storage (Table 2.II.1.7) and evaluated in the supporting Calculation Package [4.II.7]. The results show the maximum fuel temperature obtained under DFI/DFC storage are essentially same as or bounded by temperatures computed under intact or undamaged fuel storage (See Table 4.II.4.1).

MPC-32/68 Version 1 canisters permit damaged fuel or fuel debris storage in DFCs (See Table 1.II.2.3). The number, location and heat load allowances for DFC storage are same as for previously certified MPC-32/68 canisters. As the thermal design of MPC-32/68 Version 1 canisters evaluated in this Supplement are bounded by previously certified canisters no additional thermal analyses are necessary to support DFC storage in Version 1 canisters.

4.II.4.7 Storage Under Sheltered Configuration

As stated in Section 1.II.2.1, the HI-STORM 100S Version E system is permitted for storage in a sheltered configuration. If the sheltered configuration is utilized for long term storage, site-specific evaluations shall be performed to demonstrate that the acceptance criteria are satisfied. The site-specific evaluation for a sheltered configuration shall be performed in two steps as described below.

Step I. Determination of Sink Temperatures:

1. In order to determine the sink temperatures, a simplified cask array model shall be used.
2. The licensing basis HI-STORM 100S Version E geometric model described in Section 4.II.4.1 shall be modified to exclude the MPC internals. The MPC internals including basket, shims, fuel assemblies, downcomer and plenum regions will be removed.
3. A uniform heat flux equivalent to the site-specific maximum decay heat load shall be applied on the MPC top and side surfaces exposed to air.
4. The annual average temperature of the storage site shall be adopted as the long-term storage ambient temperature.
5. Any geometric features around the HI-STORM overpack (e.g. structures or walls around the overpack) that could potentially impact the heat dissipation from the cask shall be modelled explicitly.
6. The CFD modelling methodology (including turbulence model, radiation model and discretization schemes) described in Section 4.II.4.1 shall be adopted for the evaluation of a sheltered configuration.

The following input parameters are obtained by post processing the results from the above model:

1. Average temperature of air entering the inlet vents.
2. Equivalent convection sink temperature for overpack side and lid top surfaces.
3. Equivalent radiation sink temperature for overpack side and lid top surfaces.

Step II. Detailed Thermal Analysis of HI-STORM 100 Version E:

The licensing basis HI-STORM 100S Version E model described in Section 4.II.4.1 is adopted and evaluations are performed for the input parameters obtained in Step I. Compliance against the acceptance criteria in Section 4.II.3.7 is established through this detailed evaluation.

Table 4.II.4.1 Fluent Thermal Simulations Under MPC-32M Normal Condition of Storage in HI-STORM 100 Version E

Case #	Thermal Analysis Case	Peak Cladding Temperature (°F)
1	Regionalized Loading[Note 1], X = 0.5	682
2	Regionalized Loading, X = 3	702
3	**Discrete Loading Pattern A, Figure 2.II.1-2**	**705**[Note 2,4]
4	Discrete Loading Pattern B, Figure 2.II.1-3	696 [Note 4]

Note 1: MPC-32M thermal evaluations support uniform storage parameter Q_d defined in Table 2.II.1.5.
Note 2: Limiting heat load case highlighted in bold.
Note 3: Bounded by MPC-32 in Table 4.4.6 and MPC-68M in Table 4.III.3a.
Note 4: The bounding results from several loading scenarios evaluated in the supporting Calculation Package [4.II.7] are presented here.

Table 4.II.4.2 Maximum Computed Temperatures in MPC-32M Under Normal Storage Condition in HI-STORM 100 Version E

Component	Temperature, °F
Fuel Cladding	705
MPC Basket	678
MPC Shell	480
MPC Lid	477
Inner Shell	334
Outer Shell	169
Lid Bottom Plate	318
Lid Top Plate	189
Overpack Body Concrete[Note 1]	232
Overpack Lid Concrete[Note 1]	252
Area Averaged Air outlet[Note 2]	208

Notes:
1. Section temperature defined as the through-thickness average temperature tabulated.
2. Reported herein for the option of temperature measurement surveillance of outlet ducts air temperature as set forth in the Technical Specifications.

7. Cycle 1 (Cooldown) – The MPC cavity is backfilled with helium to 1 atm absolute pressure. Fuel cooling under helium is evaluated to compute maximum permissible time τ_2 for fuel temperatures to decreases by 65°C (117°F).

8. Cycle 2 (Heatup) - The drying process switches to vacuum drying and time τ_3 required to reach 380°C (716°F).

9. Up to 9 additional cycles of heatup and cooldown drying using the times τ_3 and τ_2 computed above may be performed until the drying completion criteria are met.

If a total of 10 drying cycles fail to meet drying criteria then other competent means to dry fuel (such as FHD discussed below) must be used or MPC must be de-fueled.

The above methodology can be adopted for a subject Canister heat load to determine the allowable durations for cyclic drying. A representative calculation of cyclic vacuum drying is performed using the above methodology assuming the following:

i. Basket: MPC-32M
ii. Fuel Burnup: HBF
iii. Heat Load: Maximum Design Basis (Bounding Loading Scenario from Table 4.II.4.1).

The computed cycle times are tabulated in Table 4.II.5.5. The variation of peak fuel cladding temperature with time during the cyclic vacuum drying operation is presented in Figure 4.II.5.1.

(iii) Forced Helium Dehydration (FHD)

The FHD system, described in Appendix 2.B in the main body of the FSAR, provides concurrent fuel cooling during the moisture removal process through forced convective heat transfer. The attendant forced convection-aided heat transfer occurring during operation of the FHD system helps ensure that the fuel cladding temperature will remain below the applicable peak cladding temperature limit in Table 1.II.2.3. Therefore, under normal short-term operations, the FHD does not pose the risk of temperature or pressure exceedance.

(iv) Normal On-site Transfer

The thermal state of the MPC-32M inside the ventilated HI-TRAC transfer cask during on-site transport is evaluated using the previously described Fluent model (conservatively) assuming steady state conditions. The Governing heat load condition established in Section 4.II.4 is assumed. The acceptance criteria are:

- The peak cladding temperature remains below the limits for moderate and high burnup fuels (See Table 1.II.2.3)
- PCT result above supports NO supplemental cooling for safe onsite transport of moderate and high burnup fuel.
- The internal helium pressure is within the limit set down in Table 1.II.2.3.
- The pressure in the Water Jacket remains below its Design Pressure (Table 1.II.2.6).

MPC cavity near the MPC baseplate. Steam produced during the direct quenching process will be vented from the MPC cavity through the lid vent port. To maximize venting capacity, both vent port RVOA connections must remain open for the duration of the fuel unloading operations. As direct water quenching of hot fuel results in steam generation, it is necessary to limit the rate of water addition to avoid MPC over-pressurization. The rate of water introduction depends on the Canister's aggregate heat generation rate and shall be computed for the subject Canister to ensure that there is no excessive steam buildup in the Canister's cavity. An example calculation is documented in the Supporting Calculation Package [4.II.7]. This steam flow calculation using bounding assumptions (100% steam production and MPC at design pressure) show that the MPC is adequately protected up to a reflood rate of 2967 lb/hr. Limiting the water reflood rate to this amount or less would prevent exceeding the MPC design pressure.

Table 4.II.5.5 Permissible Time Limits for Multiple Vacuum Drying Cycles **Note-1,2**

Cycle	Time (hrs)
Cycle 1 – Heat-Up (Vacuum Drying)	8.8
Cycle 1 – Cooldown (Helium)	15
Cycle 2 – Heat-Up (Vacuum Drying)	2.8
Note 1: Allowable time limits for the maximum design basis heat load presented herein. Note 2: Allowable time limit for cycles beyond those presented in this table are the same as Cycle 1 (Helium) and Cycle 2 (Vacuum Drying).	

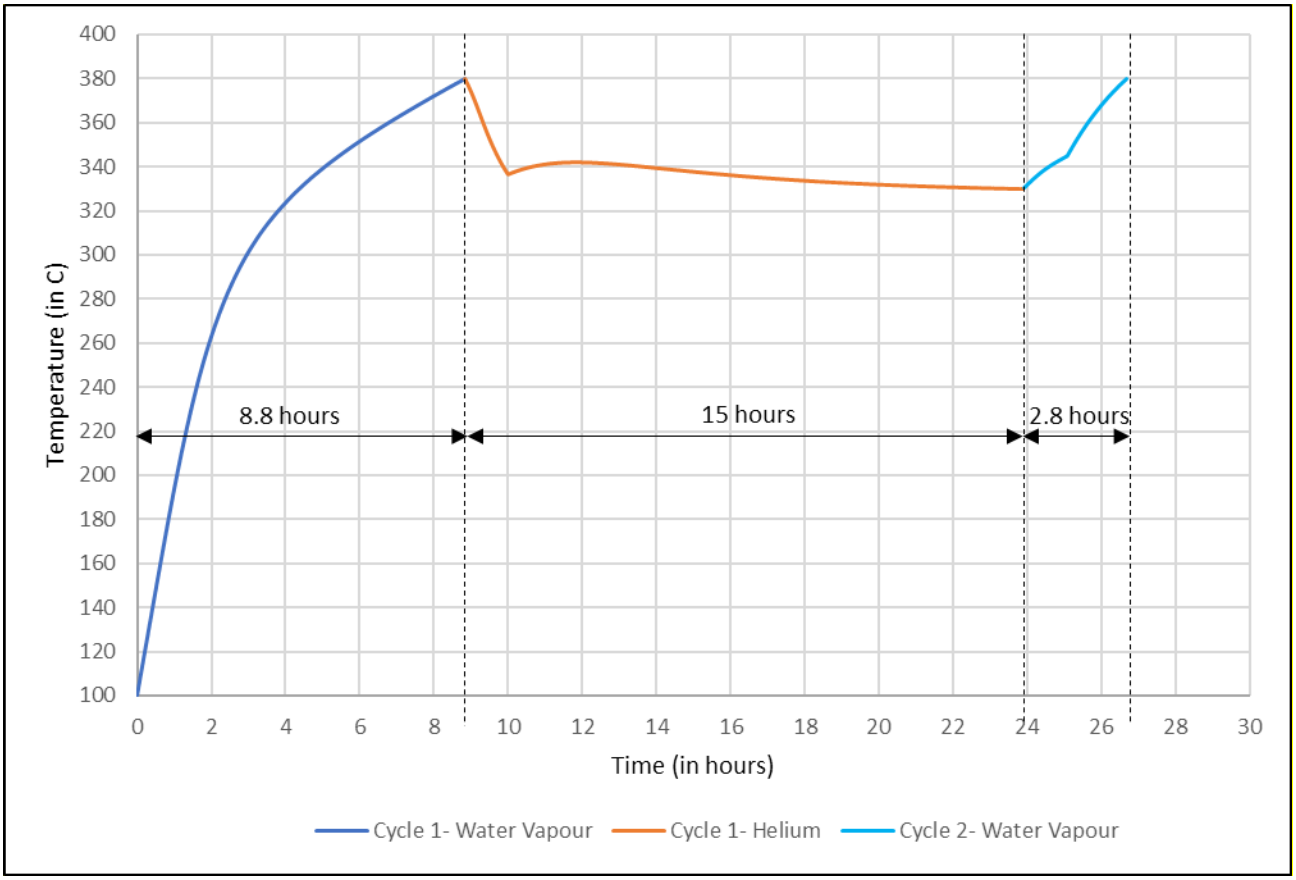

FIGURE 4.II.5.1: VARIATION OF PEAK CLADDING TEMPERATURE WITH TIME DURING CYCLIC VACUUM DRYING

SUPPLEMENT 5.II: SHIELDING EVALUATION

5.II.0 Introduction

This supplement is focused on providing a shielding evaluation of the HI-STORM 100 System with the following components: MPC-32 Version 1, MPC-68 Version 1, MPC-32M as well as the HI-STORM 100S Version E storage cask and the HI-TRAC Version MS transfer cask. The evaluation is performed pursuant to the guidelines in NUREG-1536.

MPC-32M is a new canister, that is the PWR counterpart of MPC-68M analyzed in Supplement 5.III. Also, slightly modified updates of the classical canisters, namely MPC-32 Version 1 and MPC-68 Version 1, are introduced in this supplement. The evaluation presented herein supplements the evaluations in the main body of Chapter 5 of this FSAR, and information in the main body of Chapter 5 that remains applicable is not repeated here. 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, i.e., Sections 5.II.1 through 5.II.6 correspond to Sections 5.1 through 5.6. Tables and figures in this supplement are labeled sequentially.

The design goal for the HI-STORM 100S Version E cask is to provide overall (not necessarily locally) the same or better performance as of the reference HI-STORM 100S Version B cask.

The same goal applies to the HI-TRAC Version MS cask, i.e. to provide overall (not necessarily locally) the same or better performance as of the reference 100-ton HI-TRAC casks, but assuming that a loaded weight above 100 t can be used and considered for HI-TRAC MS, something not possible for the 100-t HI-TRAC cask since the weight of that model is fixed. This addresses the specific advantage of HI-TRAC MS, where the weight and height of the system can be adjusted according to the site conditions to minimize dose rates, something not possible for the 100-t HI-TRAC cask. However, for the same loaded weight of 100 t, and the same length of an MPC, the HI-TRAC MS cask may have slightly higher dose rates in some locations than the 100-t HI-TRAC cask for the same fuel loading. In such a case, a comparative ALARA analysis should be performed to decide which of the models should be used, or if other actions would be preferable, such as plant modifications to allow a higher loaded weight. To support such a comparison and decision, Section 5.II.1 presents the dose rates for a loaded weight of HI-TRAC MS of about 100 t, the same weight as 100-t HI-TRAC, whereas Section 5.II.4 also provides the dose rates for HI-TRAC MS with a higher and more representative weight, including a comparison with values for the 100-t HI-TRAC cask.

Dose calculations are performed and values are presented considering the design basis fuel loading. Specifically, the design basis burnup-cooling time combinations for uniform loading patterns in Section 5.1 with the fuel enrichments in accordance with Table 5.2.24, as well as the design basis loading curves (which specify burnup and cooling time combinations for all/specific cells in the cask) for the uniform, regionalized and discrete loading patterns, presented in Table 2.II.1.6 for MPC-32M, have been evaluated.

In addition, in order to simplify fuel qualification procedures as well as present reasonably bounding dose rates for the HI-STORM 100S Version E and HI-TRAC Version MS casks, an additional approach is used to specify the MPC-32M basket content's burnup, enrichment and cooling time.

loading pattern that includes a maximum heat load limit among loading patterns in Figures 2.II.1-2 and 2.II.1-3 in each storage cell is analyzed in this supplement.

According to Subsection 2.1.9, for the ratio X = 0.5, the regionalized loading pattern can include the fuel assemblies with up to ~1.6 kW in the outer region and ~0.8 kW in the inner region of the basket. Alternatively, for the ratio X = 3, the outer and inner regions can include the fuel assemblies with up to ~0.6 kW and ~1.8 kW, respectively. However, such configurations are bounded by the burnup, enrichment and cooling time combinations, considered for the uniform and regionalized loading pattern in Table 5.II.2.5, because the source terms with much higher heat loads than 1.6 kW have been considered in the shielding analysis, while the configuration with 1.8 kW in the inner region is bounded due to self-shielding. Therefore, consistent with Section 5.1, the shielding calculations performed for the uniform and regionalized loading pattern in Table 5.II.2.5 are bounding for all acceptable uniform and regionalized loading burnup levels and cooling times per Subsection 2.1.9.

Overall, the loading curves, established in Table 2.II.1.6 and evaluated in this supplement, produce the burnup and cooling time combinations that correspond to higher heat loads than permitted in Subsection 2.1.9 and Figures 2.II.1-2 and 2.II.1-3, hence the calculated and reported dose rates are bounding with respect to the dose rates from the fuel assemblies that can actually be loaded according to the thermal requirements.

Based on this approach, the source terms used in the analyses of MPC-32M are reasonably bounding for all realistically expected assemblies. All MPC-32M dose rates in this supplement are developed using this approach, unless noted otherwise. Both the uniform/regionalized loading and discrete loading pattern in Table 5.II.2.5 are evaluated and the bounding results are reported. Also, as discussed in Section 5.II.4, the bounding BPRA activity at 1 year cooling time is considered for MPC-32M in this supplement.

5.II.1.1 Normal and Off-Normal Operations

As discussed in Subsection 5.1.1, none of the off-normal conditions have any impact on the shielding analysis. Therefore, off-normal and normal conditions are identical for the purpose of the shielding evaluation.

Tables 5.II.1.1 and 5.II.1.2 provide the maximum dose rates adjacent to and one meter from the HI-STORM 100S Version E overpack with MPC-32M during normal conditions, respectively.

Table 5.II.1.3 presents the annual dose to an individual from a single HI-STORM 100S Version E cask and various storage cask arrays, assuming an 8760 hour annual occupancy at the dose point location. The minimum distance required for the corresponding dose is also listed.

Table 5.II.1.4 provides dose rates adjacent to and one meter from the HI-TRAC Version MS with MPC-68M using the design basis loading pattern, in accordance with the analysis in the main part of Chapter 5. The dose rates correspond to the normal condition in which the MPC is dry and the HI-TRAC water jacket is filled with water.

Table 5.II.1.6 provides dose rates adjacent to and one meter from HI-TRAC Version MS with MPC-32M using the discrete loading pattern in Table 5.II.2.5b. Results in Table 5.II.1.6 show the theoretical and most extreme case of a combination of the minimum lead and water jacket thicknesses in HI-TRAC MS, and the highest possible source terms in MPC-32M based on the the loading curves in Table 2.II.1.6. As expected, this extreme combination results in extreme dose rates. It is presented here to clearly highlight the potential dose consequences emanating from the selection of the lead thickness in HI-TRAC MS combined with the selected content of the MPC-32M basket, so that such consequences can be

appropriately taken into consideration in the site-specific ALARA planning when selecting the HI-TRAC version and the content. Specifically, the comparisons for MPC-68M between the standard (reference) results in Table 5.II.4.4 and the minimum lead thickness results in Table 5.II.1.4 show the difference in dose rates around the HI-TRAC cask by over factor 5. It is therefore important, specifically when loading content that may approach the limits of the loading curves, that thicker than minimum lead lead is considered.

The analyses summarized in this supplement demonstrate that the design basis goal is met and the HI-STORM 100S Version E and HI-TRAC Version MS casks provide for the most part the better performance in comparison with the reference HI-STORM 100S Version B and 100-ton HI-TRAC casks, respectively. The presented dose rates are reasonably bounding for all and any combination of the design basis content, authorized in Chapter 2. Hence the HI-STORM 100 System, including the HI-STORM Version E storage cask, the HI-TRAC Version MS transfer cask and MPC-32M, are in compliance with the 10CFR72.104 limits and ALARA practices.

5.II.1.2 Accident Conditions

The safety information in Subsection 5.1.2 remains fully applicable for the HI STORM 100 System components evaluated in this supplement, except if the lead thickness of the customized HI-TRAC Version MS cask is less than the lead thickness of the reference 100-ton HI-TRAC analyzed in the main body of Chapter 5. For this specific case, the additional site-specific shielding evaluation shall be performed to confirm the shielding performance of HI-TRAC Version MS under accident conditions.

To illustrate the impact of the design basis accident, Tables 5.II.1.5 and 5.II.1.7 provide the dose rates for MPC-68M and MPC-32M, respectively, at 1 and 100 meters from the HI-TRAC Version MS cask with the lower bound lead and water jacket thicknesses under accident conditions. Consistent with Subsection 5.1.2, it is conservatively assumed that the neutron shield (water) is completely lost and replaced by a void under the accident condition. The normal condition dose rates are provided for reference. The burnup and cooling time combinations used in Table 5.II.1.5 (design basis uniform loading) and Table 5.II.1.7 (discrete loading pattern) were the combinations that resulted in the highest post-accident condition dose rates at the respective locations. Note that these burnup and cooling time combinations do not necessarily correspond to the burnup and cooling time combinations that result in the highest dose rate during normal conditions. Further note that the dose rate at the controlled area boundary (100 meters from the HI-TRAC Version MS cask) for the design basis uniform loading pattern presented in Table 5.II.1.5 is bounded by the 100-ton HI-TRAC results in Table 5.1.10, showing that the design goal for the HI-TRAC Version MS cask is met. Table 5.II.1.7 shows higher dose rates. In addition to the effect of the minimum lead thickness in HI-TRAC MS, and the highest possible source terms in the MPC, the reported high dose rates are partly caused by the loading pattern that is not azimuthally uniform, i.e. it has high source term assemblies only in certain locations, which create locally higher dose rates. The dose rate comparison between the 100-ton HI-TRAC (Table 5.1.10) and HI-TRAC Version MS (Table 5.II.1.7) casks at a distance of 100 meters indicates that the dose rate increase is not significant. For additional discussion of the loss of the neutron shield (water), please see Section 5.II.4.

Table 5.II.1.6

DOSE RATES FROM HI-TRAC VERSION MS FOR NORMAL CONDITIONS MPC-32M

Dose Point[1] Location	Fuel Gammas[2] (mrem/hr)	^{60}Co Gammas (mrem/hr)	Neutrons (mrem/hr)	Totals (mrem/hr)	Totals with BPRAs (mrem/hr)
ADJACENT TO HI-TRAC					
1	446.06	748.06	539.36	1733.48	1768.86
2	10727.52	3.48	480.55	11211.55	12267.08
3	41.13	78.79	23.70	143.61	202.51
4	3641.58	1702.07	398.05	5741.70	7275.12
5	1071.22	6385.27	4528.57	11985.06	12236.67
ONE METER FROM HI-TRAC					
1	1198.05	501.49	93.14	1792.68	1923.66
2	3652.37	30.07	162.06	3844.50	4243.24
3	571.00	243.96	30.83	845.79	1104.16
4	459.47	483.72	183.63	1126.82	1550.94

[1] Refer to Figures 5.II.3-4.
[2] Gammas generated by neutron capture are included with fuel gammas.

Table 5.II.1.7

**DOSE RATES FROM HI-TRAC VERSION MS
FOR ACCIDENT CONDITIONS
MPC-32M**

Dose Point[1] Location	Fuel Gammas[2] (mrem/hr)	^{60}Co Gammas (mrem/hr)	Neutrons (mrem/hr)	Totals (mrem/hr)	Totals with BPRAs (mrem/hr)
ONE METER FROM HI-TRAC					
2 (Accident Condition)	4551.12	49.33	3874.88	8475.32	9099.17
2 (Normal Condition)	3652.37	30.07	162.06	3844.50	4243.24
100 METERS FROM HI-TRAC					
2 (Accident Condition)	1.65	0.18	1.48	3.30	3.66

[1] Refer to Figures 5.II.3-4.
[2] Gammas generated by neutron capture are included with fuel gammas.

As discussed in Subsection 5.2.2, enrichments have a significant impact on neutron dose rates, with lower enrichments resulting in higher dose rates at the same burnup. For assemblies with higher burnups (which result in high neutron source terms) and/or locations that are more neutron dominated, the enrichment would therefore be important in order to present dose rates in a conservative way. However, it would be impractical and excessively conservative to perform all calculations at bounding low enrichment, since low enrichments are generally only found in lower burned assemblies. Therefore, a conservatively low enrichment value is selected based on the burnup. Specifically, based on industry information on more than 130,000 PWR assemblies, the fuel assemblies are distributed over different burnup range bins (0 5, 5-10 … 70-75 GWd/mtU). For instance, for a given burnup group of 5-10 GWd/mtU, the data array includes the enrichments for the fuel assemblies with the burnup from 5,000 MWd/mtU to 9,999 MWd/mtU. Then, in each burnup group, the array of enrichments is sorted from low to high, and the array index that precedes a fraction of 99% of the population is determined. The fuel enrichment under this array position represents the lower bound enrichment that conservatively bounds 99% of the fuel assembly population. For additional details the reader is referred to Reference [5.II.6]. The calculated and finally established lower bound enrichment values are provided in Figure 5.II.2-2, as well as summarized in Table 5.II.2.4.

Given that the considered baskets contain a relatively large number of available cells for fuel loading, selecting the minimum enrichment for all assemblies is considered reasonably conservative. The typical content of the basket would have most assemblies well above the lower bound enrichment assumed in the analyses, so even if a small number of assemblies would be below the assumed minimum, that would have a negligible effect or be essentially inconsequential for the dose rates around the cask. Furthermore, the site-specific shielding analysis shall consider actual or bounding fuel enrichment. Therefore, an explicit lower enrichment limit for the fuel assemblies is not considered necessary.

5.II.2.4 Non-Fuel Hardware

This subsection is only for non-fuel hardware to be loaded in MPC-32M. The non-fuel hardware in other canisters is discussed in Sections 5.2 and 5.4 of the main part of the chapter.

The same non-fuel hardware, discussed in Subsection 5.2.4, i.e. BPRAs, TPDs, CRAs, and APSRs, are permitted for storage in MPC-32M as an integral part of a PWR fuel assembly, following the requirements provided in Subsection 2.1.9 and Section 2.II.1.

Additionally, in order to qualify non-fuel hardware with the lower cooling time, the following conditions are considered:

- BPRA and TPD with the minimum cooling time of 1 year, independent of the burnup (i.e. up to 60 GWd/mtU and 225 GWd/mtU). Table 5.II.2.6 shows the ^{60}Co activities that were calculated for BPRAs and TPDs in each region of the fuel assembly (e.g. incore, plenum, top);
- CRA and APSR with the minimum cooling time of 2 years, independent of the burnup (i.e. up to 630 GWd/mtU). Tables 5.II.2.7 and 5.II.2.8 present the source terms, including decay heat, that were calculated for the CRAs and APSRs, respectively. As discussed in Paragraph 5.2.4.2, the only significant source from the activation of inconel or steel is Co-60 and the other significant source is from the activation of AgInCd (0.3-1.0 MeV);
- NSAs with the minimum cooling time of 1 year are also permitted for storage in MPC-32M. As discussed in Paragraph 5.2.7.1, the total activation of steel and inconel in NSAs (^{60}Co source) is bounded by the total activation of a BPRA, while the neutron source itself is either very short-lived, which results in a complete decay by the time of storage, or long-lived, where the cooling

- For both MPC-32M and MPC-68M baskets, no elevation of the fuel assemblies above the MPC baseplate is assumed. This is conservative since the bottom nozzle is located adjacent to the flow holes as well as closer to the bottom vent ducts and bottom cask surface;
- The MPC-32M baseplate can be made with the optionally increased thickness. Nonetheless, a baseplate with a lowest nominal thickness is conservatively considered in the calculations;
- Several simplifications are made in the model of the MPC-32M and/or MPC-68M basket shims. Specifically,
    - The rounding of the shim corners is neglected. Since the amount of extra material is roughly compensated by the amount of lost material due to these simplifications, a small (if any) net effect on results is expected;
    - The potential tiny gaps between the basket shims and basket/enclosure are not modeled since an insignificant impact on results is expected;
    - For MPC-32M, in the overlap of the peripheral shim walls and the basket corners (enriched with B_4C), the basket material is conservatively neglected (see Figure 5.II.3-2).

To ensure that the bounding dose rates are provided for HI-TRAC Version MS, the evaluations are performed for HI-TRAC Version MS with the lower bound lead and water jacket thicknesses, listed in Table 3.II.2.3. The results of the calculations for the HI-TRAC Version MS cask with the lower bound lead and water jacket thicknesses are provided in Tables 5.II.1.4 through 5.II.1.7 and 5.II.4.9. The results of the calculations for HI-TRAC Version MS with the reference dimensions are provided Tables 5.II.4.4 (for a discussion, see Section 5.II.4).

5.II.3.2 Regional Densities

In addition to the composition and densities of the various materials used in the HI-STORM 100 System shielding analyses and presented in Table 5.3.2, the shielding models of HI-STORM Version E and HI-TRAC Version MS casks employ the materials provided in Table 5.II.3.1.

The concrete density shown in Table 5.II.3.1 represents the minimum concrete density in the body and lid of HI-STORM Version E overpack.

Both the MPC-32M and MPC-68M baskets are manufactured using the Metamic-HT panels, made of aluminum and B_4C powder. The B_4C content of 9 wt% is conservatively used in the Metamic-HT fixed neutron absorber material.

$$\sigma_{\bar{k}}^2 = \frac{\sum_{i=1}^{n} k_i^2 - (\sum_{i=1}^{n} k_i)^2 / n}{n(n-1)} \quad (6.A.2)$$

$$\text{Bias} = (1 - \bar{k}) \pm K\sigma_{\bar{k}} \quad (6.A.3)$$

where k_i are the calculated reactivities for n critical experiments; $\sigma_{\bar{k}}$ is the unbiased estimator of the standard deviation of the mean (also called the standard error of the bias (mean)); and K is the one-sided multiplier for 95% probability at the 95% confidence level (NBS Handbook 91 [6.A.18]).

Formula 6.A.3 is based on the methodology of the National Bureau of Standards (now NIST) and is used to calculate the values presented on page 6.A-2. The first portion of the equation, $(1-\bar{k})$, is the actual bias which is added to the MCNP4a and KENO5a results. The second term, $K\sigma_{\bar{k}}$, which corresponds to σ_B in Section 6.4.3, is the uncertainty or standard error associated with the bias. The K values used were obtained from the National Bureau of Standards Handbook 91 and are for one-sided statistical tolerance limits for 95% probability at the 95% confidence level. The actual K values for the 56 critical experiments evaluated with MCNP4a and the 53 critical experiments evaluated with KENO5a are 2.04 and 2.05, respectively.

The larger of the calculational biases (truncated bias) was used to evaluate the maximum k_{eff} values for the cask designs.

6.A.1.1 Summary of Benchmark Calculations for the MCNP5-1.51 Code with the ENDF/B-VII Library

The same methodology as discussed in Section 6.A.1 is applied in the determination of the bias and standard error of the bias (95% probability at the 95% confidence level) for the MCNP5-1.51 Code with the ENDF/B-VII library.

In addition to the benchmark calculations shown in Table 6.A.1, an extended set of the critical experiments, which include Gd_2O_3 absorber, is considered to support the criticality calculations of BWR fuel with a partial gadolinium credit. These experiments are selected because they contain Gd_2O_3 rods, either mixed with UO_2 or not. Reasonable assurance that the MCNP5-1.51 Code with the ENDF/B-VII library is fully capable of analyzing systems which incorporate Gd_2O_3 rods is demonstrated with the extended set of the critical experiments for the following reasons:

- The average reactivity effect of the Gd_2O_3 rods in these experiments is approximately 1.8%, with a minimum of 1.2% and a maximum of 2.4%. Specifically, the effect of the Gd_2O_3 rods in the experiments is significant; and,
- If the Gd_2O_3 rods are replaced with fuel pins for the extended set of the critical experiments (all of which incorporate Gd_2O_3 rods), then essentially the same bias and bias uncertainty is produced.

All calculations are documented in Appendix C of [6.A.19].

For MCNP5-1.51 with the ENDF/B-VII library, the total bias (systematic error, or mean of the deviation from a k_{eff} of exactly 1.000) are shown in the table below for both the base set and extended set.

Calculational Bias of MCNP5-1.51 with the ENDF/B-VII Library		
	Total	Truncated
MCNP5-1.51 with the ENDF/B-VII Library (base set)	-0.0024 ± 0.0008	0.0004 ± 0.0003
MCNP5-1.51 with the ENDF/B-VII Library (extended set)	-0.0020 ± 0.0008	0.0004 ± 0.0002

For calculations made in this report using MCNP5-1.51 with the ENDF/B-VII library, the truncated biases and bias uncertainties from base set is the largest and therefore used to evaluate the maximum k_{eff} values.

6.A.2 Effect of Enrichment

The benchmark critical experiments include those with enrichments ranging from 2.46% to 5.74% and therefore span the enrichment range for the MPC designs. Figures 6.A.3 and 6.A.4 show the calculated k_{eff} values (Table 6.A.1) as a function of the fuel enrichment reported for the critical experiments. Linear regression analyses for these data confirms that there are no trends, as indicated by low values of the correlation coefficients (0.03 for MCNP4a and 0.38 for KENO5a). Thus, there are no corrections to the bias for the various enrichments.

As further confirmation of the absence of any trends with enrichment, the MPC-68 configuration was calculated with both MCNP4a and KENO5a for various enrichments. The cross-comparison

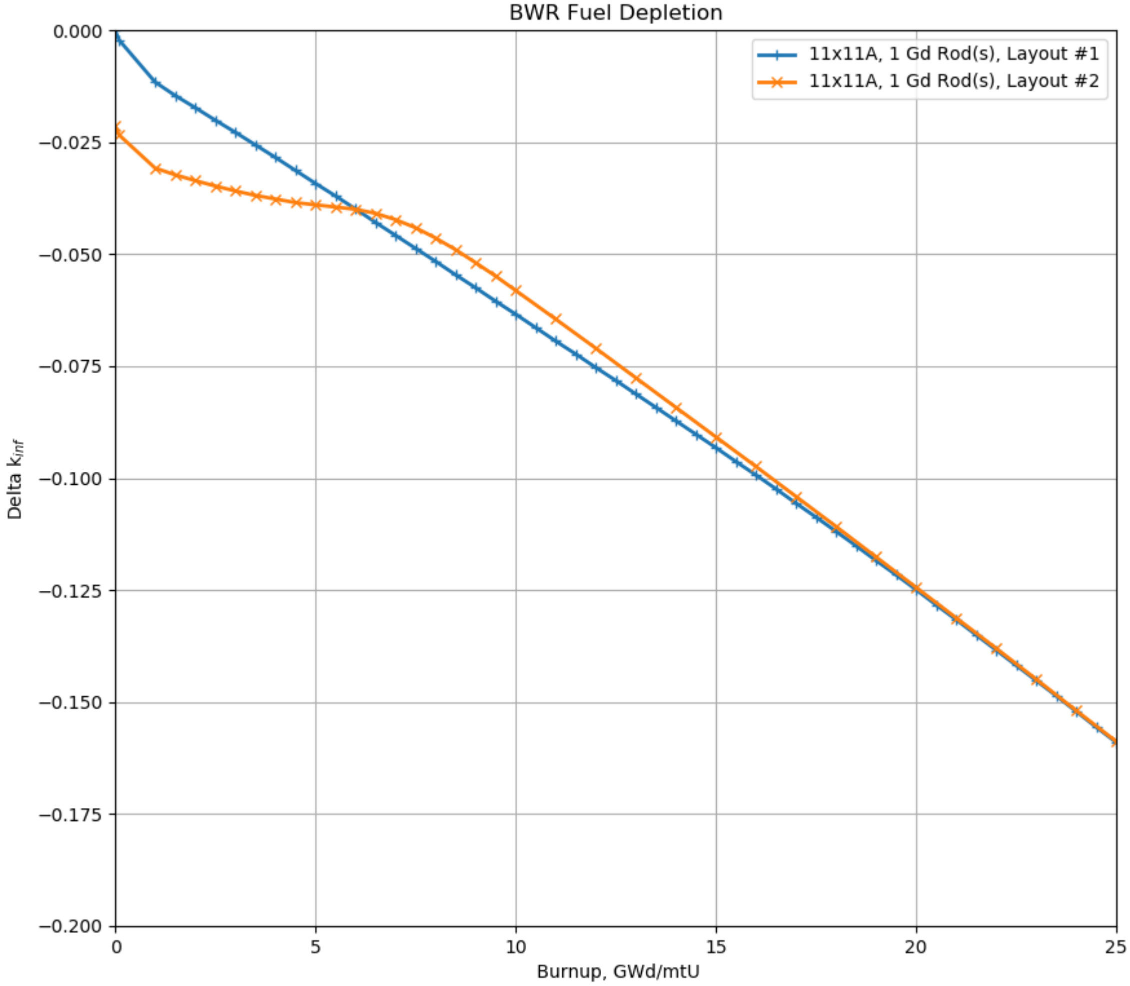

Figure 6.III.4.10 BWR FUEL REACTIVITY DIFFERENCES TO THE DESIGN BASIS CASE OF THE 11X11A FUEL ASSEMBLY CLASS AT FRESH FUEL CONDITIONS AS A FUNCTION OF FUEL BURNUP WITH PARTIAL GADOLINIUM CREDIT

SUPPLEMENT 7.II: CONFINEMENT

The main body of this chapter remains fully applicable for the HI-STORM 100 System using an MPC-32M, MPC-32 Version 1 or MPC-68 Version 1, except as indicated below since the MPC-32M, MPC-32 Version 1 and MPC-68 Version 1 fuel baskets are used with the MPC enclosure vessel version 1 is the confinement boundary of the system. Therefore, only sections that are modified by this supplement are included. If a section is not listed, the main body information applies. The drawing of the MPC enclosure vessel used with the MPC-32M, MPC-32 Version 1 and MPC-68 Version 1 baskets is contained in Section 1.II.5.

7.II.1.1 Confinement Vessel

Table 7.II.1.1 provides a summary of the design ratings for normal, off-normal and accident conditions for the MPC confinement vessel.

7.II.1.5 Damaged Fuel Container

The MPC-32M is designed to allow for the storage of specified damaged fuel assemblies and fuel debris in a specially designed damaged fuel container (DFC) or damaged fuel assemblies in damaged fuel isolators (DFIs). Section 2.II.1 specifies the fuel assembly characteristics for damaged fuel and fuel debris acceptable for loading in the MPC-32M. Fuel assemblies classified as damaged fuel or fuel debris as specified in Section 2.II.1 for MPC-32M have been evaluated.

The MPC-32 Version 1 and MPC-68 Version 1 are designed to allow for the storage of specified damaged fuel assemblies and fuel debris in a specially designed damaged fuel container (DFC). Section 2.1.9 specifies the fuel assembly characteristics for damaged fuel and fuel debris acceptable for loading in the MPC-32 Version 1 and MPC-68 Version 1. Fuel assemblies classified as damaged fuel or fuel debris as specified in Section 2.1.9 for MPC-32 or MPC-68 have been evaluated and are approved for storage in MPC-32 Version 1 and MPC-68 Version 1, respectively.

7.II.1.6 Design and Qualification of the MPC Lid-to-Shell Weld

Table 7.II.1.4 provides the matrix of ISG-18 criteria and how the Holtec MPC design and associated inspection, testing, and QA requirements meet each one.

SUPPLEMENT 10.II: RADIATION PROTECTION

10.II.0 Introduction

This supplement addresses certain variations of the HI-STORM 100 System, namely MPC-32 Version 1, MPC-68 Version 1, MPC-32M as well as the HI-STORM 100S Version E storage cask and the HI-TRAC Version MS transfer cask. These variations are based on the same design considerations and use the same operational features as those described in the main part of this chapter. Therefore, all principal and qualitative discussions in the main part of this chapter on radiation protection, ALARA and regulatory compliance are directly applicable to the design variations addressed here and are not repeated. This supplement therefore focusses on the areas that are different from the main part of the chapter, namely on areas where estimated doses or dose rates are different.

One notable difference in the shielding design and ALARA consideration is the variable shielding radial thickness of HI-TRAC Version MS, compared to the fixed dimensions for the 100-ton and 125-ton HI-TRACs in the main part of the chapter. This allows a shielding optimization of the HI-TRAC, based on the site-specific cask weight limits, that are not possible with the 100 or 125-ton HI-TRAC designs. Even a small increase of the HI-TRAC shielding weight can have a significant impact on the dose rates around the cask. Nevertheless, in order to present bounding results, all dose values presented in this supplement are based on HI-TRAC Version MS with the minimum shielding thickness, equivalent in weight to the 100-ton HI-TRAC.

10.II.1 Ensuring that Occupational Radiation Exposures are As-Low-As-Reasonably-Achievable (ALARA)

All discussions in Section 10.1 are directly applicable here, including the information in Table 10.1.1, except that HI-TRAC Version MS, as the HI-TRACs 100D and 125D casks, use a mating device and no transfer step. Table 10.II.1.1 provides the minimum requirements for use of the temporary shielding with the Version MS transfer cask indicating optional and required shielding.

10.II.2 Radiation Protection Design Features

As discussed in Section 10.II.0, the principal radiation protection design features are the same as discussed in Section 10.2.

10.II.3 Estimated On-Site Collective Dose Assessment

The principal designs and loading operation procedures for the HI-STORM 100S Version E and HI-TRAC Version MS casks are the same as for the reference HI-STORM 100S Version B and 100-ton HI-TRAC, evaluated in the main body of this chapter. However, the design details result in slightly different shielding performance. To highlight the potential impact of these differences, the operational exposures during the loading operations for HI-STORM Version E and HI-TRAC Version MS have been calculated for a direct comparison with Table 10.3.1b, and results are presented in Table 10.II.3.1.

For the review and comparison of the tables please note the following:

- The dose values in the main part of the report were established before any significant operational experience with the loading of the HI-STORM 100 systems was available. By now, there is a vast amount of operating experience available, indicating that operating doses are significantly lower than initially estimated. Nevertheless, information in Table 10.II.3.1 is determined to be consistent with that in Table 10.3.1b, in order to allow a comparison. For that, the focus should not be on the absolute doses calculated, but on the relative differences.

  The comparison show that, under identical conditions, operational dose from the HI-STORM Version E / HI-TRAC Version MS combination could be 50% higher than that from the HI-STORM 100 / HI-TRAC 100, and this should be taken into account in the site-specific ALARA considerations. However, this is based on the minimum shielding thickness in the HI-TRAC Version MS cask. As discussed in Section 10.II.0, HI-TRAC Version MS allows better shielding optimization based on site-specific conditions compared to HI-TRAC 100. Under more typical site-specific scenarios, the operational exposure of the HI-STORM Version E / HI-TRAC Version MS combination should be lower than that from the HI-STORM 100 / HI-TRAC 100 combination.

- Operational doses in Table 10.II.3.1 are determined for the same loading conditions that were used for Table 10.3.1b. However, there are loading conditions for the MPC-32M basket, that would result in higher dose rates then those, specifically if the content would approach the limits of the loading curves, as discussed in Subsection 5.II.1.1. In extreme cases, this could result in an overall operational dose value about 80% higher than that for the loading condition assumed in Table 10.II.3.1. This would need to be specifically considered in the site-specific ALARA evaluations for the HI-STORM system. As discussed above, an optimized HI-TRAC Version MS should be considered to offset such dose effects.

- As discussed in Section 10.3, the results indicated that there was only a small difference in the occupational exposure from using a mating device rather than transfer doors. Therefore, the use of the mating device for HI-TRAC Version MS does not result in occupational exposures significantly different than those presented in Table 10.II.3.1 for HI-TRAC Version MS with the transfer doors, and no adjustments have been made for this.

10.II.4 Estimated Collective Dose Assessment

The general discussions in Section 10.4 are directly applicable to the HI-STORM Version E and HI-TRAC Version MS casks, hence only differences in doses and dose rates are presented here.

Table 5.II.1.3 presents dose rates at various distances from sample ISFSI arrays for the design basis burnup and cooling time which results in the highest off-site dose for the combination of maximum burnup and minimum cooling times analyzed in Supplement 5.II. 10CFR72.106 [10.0.1] specifies that the minimum distance from the ISFSI to the controlled area boundary is 100 meters. Therefore this was the minimum distance analyzed in Supplement 5.II. As a summary of Supplement 5.II, Table 10.II.4.1 presents the annual dose results for a single overpack at 100 and 300 meters and a 2x5 array of the HI-STORM Version E casks at 500 meters. These annual doses are based on a full array of design basis fuel with the bounding source terms, as discussed in Section 5.II.1. In addition, 100% occupancy (8760 hours) is conservatively assumed. These results indicate that the calculated annual dose is less than the regulatory limit of 25 mrem/year at a distance of 300 meters for a single cask and at 500 meters for a 2x5 array of the HI-STORM Version E casks containing design basis fuel. These results are presented only as an illustration to demonstrate that HI-STORM Version E is in compliance with 10CFR72.104[10.0.1]. Neither the distances nor the array configurations become part of the Technical Specifications. Rather, users are required to perform a site specific analyses to demonstrate compliance with 10CFR72.104[10.0.1] contributors and 10CFR20[10.1.1].

An additional contributor to the controlled area boundary dose is the loaded HI-TRAC transfer cask, if HI-TRAC is to be used at the ISFSI outside of the fuel building. To highlight the potential impact of the HI-TRAC Version MS shielding performance to the controlled area boundary dose, the dose rates at 100, 200, and 300 meters have been calculated for a direct comparison with Table 10.4.2, and results for this are presented in Table 10.II.4.2. The dose rates are determined for the same loading conditions that were used for Table 10.4.2. As discussed in Section 10.II.3, an extreme case loading of MPC-32M, specifically if the content would approach the limits of the loading curves, could result in a higher dose rate than that for the loading condition assumed in Table 10.II.4.2 (up to 70%). This would need to be specifically considered in the site-specific ALARA evaluations and an optimized HI-TRAC Version MS cask should be considered to offset such dose effects. Based on the short duration that the loaded HI-TRAC is used outside at the ISFSI and the limited dose rate increase due to extreme HI-TRAC conditions, the ability of the HI-STORM 100 System to show compliance with 10CFR72.104 [10.0.1] when worst-case design basis fuel is loaded in all fuel cell locations would not be affected. However, users are required to perform a site specific analysis to demonstrate compliance with 10CFR72.104[10.0.1] and 10CFR20[10.1.1] taking into account the actual site boundary distance and fuel characteristics.

BASES (continued)

ACTIONS	A note has been added to the ACTIONS which states that, for this LCO, separate Condition entry is allowed for each MPC. This is acceptable since the Required Actions for each Condition provide appropriate compensatory measures for each MPC not meeting the LCO. Subsequent MPCs that do not meet the LCO are governed by subsequent Condition entry and application of associated Required Actions. A.1 and A.2 If the MPC cavity pressure limit is not met, actions must be taken to restore the parameters to within the limits before initiating or continuing re-flooding the MPC. Immediately is an appropriate Completion Time because it requires action to be initiated promptly and completed without delay, but does not establish any particular fixed time limit for completing the action. This offers the flexibility necessary for users to plan and implement any necessary work activities commensurate with the safety significance of the condition, which is governed by the MPC heat load.
SURVEILLANCE REQUIREMENTS	SR 3.1.3.1 The integrity of the MPC is dependent on controlling the internal MPC pressure. By controlling the MPC internal pressure prior to and during re-flooding the MPC there is sufficient steam venting capacity during MPC re-flooding. The LCO must be met on each SFSC before the initiation of MPC re-flooding operations to ensure the design and analysis basis are preserved. If the re-flood rate is limited to the bounding value given in FSAR Section 4.II.5 or calculated specifically for the MPC heat load then the MPC pressure must only be verified once prior to the re-flood. If verifying the MPC pressure using direct measurement only the SR requires checks prior to the re-flood and every hour during re-flood. The direct measurement schedule is sufficient to prevent overpressurization of the MPC cavity as the rate of pressure rise is relatively slow compared to increase in re-flood rate.

(continued)