from the ISFSI at the site boundary compared to an aboveground cask. The calculated VVM dose rates are discussed in Supplement 5.I, which also discusses dose rates during site construction next to an operating ISFSI.

The dose rate calculations presented in Supplement 5.I conservatively use a lower density for the subgrade than is specified in Table 2.I.2. For dose rate calculation at a particular ISFSI, the spatial average of the actual subgrade density shall be used.

Burnup and cooling time limits listed in Table 2.1.28 and Table 2.1.29 are applicable to the HI-STORM 100U, except that the cooling time can be no less than 3 years, consistent with Chapter 5.I.

Criticality

The VVM does not perform any criticality control function. The MPCs provide criticality control for all design basis normal, off-normal and postulated accident conditions, as discussed in Chapter 6.

Confinement

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

Operations

MPC preparation for storage and onsite transport of the MPC in the HI-TRAC transfer cask is the same for the VVM as for the aboveground overpack designs. The cask transporter is used to move the loaded transfer cask to the ISFSI and to transfer the MPC into the VVM. Generic operating instructions for the use of the HI-STORM 100U System that parallel those for the aboveground overpack are provided in Supplement 8.I.

Acceptance Tests and Maintenance

The fabrication acceptance bases and maintenance program to be applied to the VVM are described in Supplement 9.I. Application of these requirements will assure that the VVM is fabricated and maintained in a manner that satisfies the design criteria defined in this FSAR.

Decommissioning

Decommissioning considerations for the HI-STORM 100U System, including the VVM, are addressed in Section 2.I.11.

2.I.1 SPENT FUEL TO BE STORED

There is no difference in the authorized contents of the HI-STORM 100U VVM and the aboveground HI-STORM systems. The information in Section 2.1 is applicable.

2.IV.1 Spent Fuel to be Stored

The Version UVH overpack is compatible with select MPC models. All fuel assembly array/classes and non-fuel hardware which are authorized for storage in these MPCs are authorized for storage in Version UVH. All fuel storage characteristics applicable to these MPCs remain unchanged for the Version UVH. See Table 2.IV.1.1 for additional information. Allowable storage locations for damaged fuel assemblies is shown in Table 2.IV.1.9.

2.IV.1.1 Design Heat Load

The permissible heat load is also reduced to accord with the diminished heat rejection capacity of the Version UVH overpack. Permissible heat loads based on MPC type are listed in Tables 2.IV.1.2 through 2.IV.1.5.

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

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

2.IV.1.2 Radiological Parameters for Spent Fuel and Non-Fuel Hardware

The MPC-32M and MPC-68M canisters are authorized to store spent fuel assemblies with the minimum cooling time as a function of the assembly burnup. Non-fuel hardware may be stored in the PWR fuel assemblies in MPC-32M as specified in Table 2.IV.1.6.

The burnup and cooling time for every fuel assembly loaded into the MPC 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 Tables 2.IV.1.7 and 2.IV.1.8.

The coefficients for the above equation for the fuel assembly in an individual cell depend on the region where the cell is located, with regions depicted in Figure 2.IV.1.1 for the MPC-32M, and Figure 2.IV.1.2 for the MPC-68M. ~~heat load limit in that cell. Tables 2.IV.1.7 and 2.IV.1.8 list the coefficients for several heat load limit ranges for the MPC-32M and MPC-68M baskets, respectively. 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 the heat load limits established in Section 2.IV.1.1 is not a substitute for meeting burnup and cooling time limits herein, and vice versa.~~

Table 2.IV.1.7

Burnup and Cooling Time Fuel Qualification Requirements for MPC-32M

~~Cell Decay Heat Load Limit (kW)~~ **Region No.** (see Figure 2.IV.1.1)	Polynomial Coefficients, see Subsection 2.IV.1.2			
	A	**B**	**C**	**D**
1 (Inner) ~~≤ 0.83~~	6.57083E-14	-4.02593E-09	1.47107E-04	8.01647E-01
2 (Outer) ~~0.83 < decay heat ≤ 3.26~~	1.70290e-14 ~~3.76103e-16~~	-2.35944e-09 ~~4.83486e-11~~	1.53526e-04 ~~1.74805e-05~~	-7.45236e-01 ~~6.53455e-01~~

Table 2.IV.1.8

Burnup and Cooling Time Fuel Qualification Requirements for MPC-68M

~~Cell Decay Heat Load Limit (kW)~~ **Region No.** (see Figure 2.IV.1.2)	Polynomial Coefficients, see Subsection 2.IV.1.2			
	A	**B**	**C**	**D**
1 (Inner) ~~≤ 0.382~~	9.44656e-14	-8.01992e-09	2.79524e-04	-4.10441e-01
2 (Outer) ~~0.382 < decay heat ≤ 1.625~~	5.58795e-15 ~~8.59250e-15~~	-5.13598e-10 ~~-1.40950e-09~~	5.81723e-05 ~~9.57523e-05~~	4.09393e-01 ~~-1.02585e+00~~

SUPPLEMENT 5.IV: SHIELDING EVALUATION OF THE HI-STORM 100 SYSTEM WITH VERSION UVH OVERPACK

5.IV.0 Introduction

This supplement provides shielding evaluation of the HI-STORM 100 System with the unventilated version of the overpack, wherein the overpack's inlet and outlet air passages have been removed resulting in a complete cessation of associated radiation streaming and ventilation in the space between the cask cavity and the stored multi-purpose canister (MPC) during the system's operation. The overpack model is referred to as HI-STORM 100 Version UVH. The principal components of the HI-STORM 100 System that are subject to certification for the HI-STORM 100 Version UVH remain unchanged from the versions previously qualified and certified in this FSAR. Specifically, the HI-STORM 100 Version UVH overpack is qualified to store all MPC model types listed in Table 2.IV.1.1. The following components are explicitly evaluated in this supplement:

- HI-STORM 100 Version UVH – an unventilated version of the HI-STORM 100 overpack made of high-density concrete, with characteristics described in Supplement 1.IV.

- HI-TRAC Version MS and MPC-32M. These are variations of the HI-TRAC and MPC-32 addressed in the main part of this chapter, with characteristics described in Supplement 1.II.

- MPC-68M. This is a variation of the MPC-68 canister addressed in the main part of this chapter, with characteristics described in Supplement 1.III.

Note that the HI-TRAC Version MS cask is only analyzed in this supplement because the content for the MPC-32M and MPC-68M canisters is different from those previously evaluated for these canisters. The design of the HI-TRAC transfer casks, and the canisters, is unchanged.

The shielding evaluation of the HI-STORM 100 Version UVH System fully follows the methodology described in Supplement 5.II. All shielding analyses in this supplement were performed with MCNP5-1.51 [5.IV.1], which is the same code as that used for the evaluation of the HI-STORM 100 System with MPC-32M and MPC-68M in Supplements 5.II and 5.III, respectively. The source terms were determined by the TRITON/ORIGAMI sequence from SCALE 6.2.1 [5.IV.2], consistent with the analyses documented in Supplement 5.II. The SCALE code uses the ENDF/B-VII.1 252-group cross-section library. MCNP use the default cross-section libraries provided with that code version. For that, primarily ENDF/B-VII.0 and ENDF/B-VI.8 are used for neutrons and photons, respectively, and ENDF/B-VI neutron cross-sections are also used for some natural elements.

The evaluation presented herein supplements those evaluations of the HI-STORM 100 System contained in the main body of Chapter 5 and Supplement 5.II of this FSAR, and information that remains applicable to HI-STORM 100 Version UVH is not repeated here, but referenced accordingly. 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.IV.1 through 5.IV.6 correspond to Sections 5.1 through 5.6.

5.IV.1 Discussion and Results

The most distinctive feature of the HI-STORM 100 storage system introduced via this supplement is the unventilated overpack called Version UVH. The principal shielding design of the HI-STORM 100 UVH overpack is identical to the overpack designs evaluated in the main body of this chapter and Supplement 5.II, with gamma shielding provided by the concrete and steel materials, and neutron shielding provided by the concrete. The other components, namely the MPCs listed in Table 2.IV.1.1 and the HI-TRAC transfer casks, remain unchanged from the versions previously qualified and certified in this FSAR.

~~All calculations in this supplement are performed for the MPC-32M and MPC-68M canisters with the unifom and regionalized loadings, informed by the loading patterns introduced in Section 2.IV.1. The following configurations are considered for the bounding dose analyses:~~

[PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10 CFR 2.390]

[PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10 CFR 2.390]

5.IV.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, and this is also applicable to the systems described in this supplement, since the principal designs are the same. Therefore, off-normal and normal conditions are identical for the purpose of the shielding evaluation.

For each dose rate location, the maximum possible dose rate over the entire range of qualified content for both uniform and regionalized loading patterns is determined and presented.

Table 5.IV.1.1 provides the maximum dose rates adjacent to and one meter from the HI-STORM 100 Version UVH overpack with MPC-32M during normal conditions.

Table 5.IV.1.2 presents the annual dose to an individual from a single HI-STORM 100 Version UVH 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.IV.1.3 provides dose rates adjacent to and one meter from the HI-TRAC Version MS transfer cask with MPC-32M. The dose rates correspond to the normal condition in which the MPC is dry and the HI-TRAC Version MS water jacket is filled with water. The dose rates in this table are calculated for the limiting content of MPC-32M, and shielding thickness of the HI-TRAC Version MS cask that lead to dose rates on the outside of the cask that are consistent with the dose rate limit set for that location. For dose rates under other conditions see Section 5.IV.4. ~~[PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10 CFR 2.390]~~

The analyses summarized in this supplement demonstrate that the HI-STORM 100 System, including the HI-STORM 100 Version UVH storage cask, the HI-TRAC transfer casks and the MPC-32M and MPC-68M canisters, are capable of meeting the 10CFR72.104 limits and support ALARA practices.

5.IV.1.2 Accident Conditions

The discussions in Subsection 5.1.2 remain fully applicable for the HI STORM 100 System components evaluated in this supplement, except that dose rates are re-calculated for the HI-TRAC Version MS cask with the MPC-32M with the most limiting content. Results for this case are summarized in Table 5.IV.1.4 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, but note that bounding content for normal and accident conditions may not be identical, since both are determined to maximize dose rates under the respective condition. Also note that the dose rates under normal conditions are different from those in Table 5.IV.1.3 since minimum shielding thicknesses are assumed here.

Overall, the results show that under bounding conditions, the requirements form 10CFR72.106 will always be met at 100 m from the ISFSI. Additional site-specific evaluations for accident conditions are therefore not required.

Table 5.IV.1.1

DOSE RATES ADJACENT TO AND AT ONE METER FROM HI-STORM 100 VERSION UVH OVERPACK 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 OVERPACK					
1	17.04~~19.55~~	3.89~~3.25~~	0.07~~0.07~~	21.01~~22.87~~	22.23~~24.00~~
2	50.40~~58.97~~	0.01~~0.00~~	0.51~~0.16~~	50.91~~59.13~~	54.70~~62.55~~
3	1.05~~0.45~~	0.66~~0.70~~	<0.01~~0.01~~	1.71~~1.17~~	2.46~~1.93~~
4	3.30~~2.39~~	0.33~~0.17~~	1.94~~1.89~~	5.57~~4.45~~	6.08~~4.91~~
ONE METER FROM OVERPACK					
1	10.73~~11.07~~	0.69~~0.54~~	0.10~~0.02~~	11.52~~11.63~~	12.02~~12.32~~
2	23.85~~25.17~~	0.10~~0.04~~	0.20~~0.06~~	24.16~~25.27~~	25.83~~26.25~~
3	3.75~~3.87~~	0.42~~0.25~~	0.02~~0.01~~	4.18~~4.13~~	4.88~~4.53~~
4	1.11~~0.76~~	0.24~~0.10~~	0.65~~0.53~~	2.00~~1.39~~	2.30~~1.70~~

[1] Refer to Figure 5.IV.3-1.

[2] Gammas generated by neutron capture are included with fuel gammas.

Table 5.IV.1.2

DOSE RATES FOR ARRAYS OF HI-STORM 100 VERSION UVH CONTAINING MPC-32M

Array Configuration	1 cask	2x2	2x3	2x4	2x5
Annual Dose (mrem/year)[1]	23.42~~18.31~~	15.58~~11.59~~	23.38~~17.38~~	12.04~~23.18~~	15.05~~11.39~~
Distance to Controlled Area Boundary (meters)[2]	200~~200~~	300~~300~~	300~~300~~	400~~300~~	400~~400~~

[1] 8760 hr. annual occupancy is assumed.

[2] Dose location is at the center of the long side of the array.

Table 5.IV.1.3

**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	289.07~~380.07~~	696.12~~677.38~~	558.52~~196.57~~	1543.71~~1254.02~~	1571.71~~1270.97~~
2	2459.42~~2920.91~~	1.03~~1.32~~	124.27~~246.89~~	2584.73~~3169.12~~	2876.50~~3406.81~~
3	9.56~~4.29~~	17.44~~5.86~~	33.07~~25.86~~	60.07~~36.01~~	75.35~~51.28~~
4	2843.40~~2781.88~~	1532.99~~1218.31~~	545.91~~167.11~~	4922.30~~4167.30~~	6442.64~~5036.62~~
5	993.44~~864.17~~	5944.17~~5414.03~~	3381.06~~1095.73~~	10318.67~~7373.94~~	10533.40~~7645.65~~
ONE METER FROM HI-TRAC					
1	233.54~~353.51~~	199.61~~157.92~~	144.91~~37.56~~	578.07~~548.98~~	616.84~~576.31~~
2	909.45~~944.27~~	5.55~~4.76~~	46.34~~74.96~~	961.33~~1023.99~~	1065.74~~1101.66~~
3	147.00~~139.33~~	43.07~~37.87~~	9.54~~13.15~~	199.61~~190.35~~	265.65~~224.61~~
4	359.84~~207.72~~	458.04~~370.69~~	179.19~~55.26~~	997.08~~633.67~~	1416.78~~1053.37~~

[1] Refer to Figure 5.II.3-4.

[2] Gammas generated by neutron capture are included with fuel gammas.

Table 5.IV.1.4

**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)	2696.234420.46	44.3037.56	4059.531768.08	6800.066226.09	7407.426678.55
2 (Normal Condition)	2945.213257.23	21.3818.72	55.0589.31	3021.643365.27	3420.373658.95
100 METERS FROM HI-TRAC					
2 (Accident Condition)	1.211.55	0.200.12	1.530.64	2.942.30	3.292.49

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

5.IV.2 Source Specification

The neutron and gamma source terms were calculated with the TRITON / ORIGAMI modules of the SCALE 6.2.1 code package [5.IV.2]. These source terms have already been used in the shielding evaluation of the HI-STORM 100S Version E System documented in Supplement 5.II of this FSAR. Unless otherwise noted in the following subsections, the discussions and conclusions in Section 5.II.2 remain applicable to the evaluations in this supplement.

5.IV.2.1 Design Basis Assembly

See Subsection 5.II.2.1.

5.IV.2.2 Fuel Specifications and Limits

The fuel specifications and limitations for the MPC-32M and MPC-68M canisters to be loaded into the HI-STORM 100 Version UVH System are addressed in this subsection.

5.IV.2.2.1 Burnup and Cooling Times

Burnup and cooling time limits are specified in Supplement 2.IV for each basket cell through a loading curve that defines the minimum cooling time as a function of the assembly burnup. The loading curves are informed by the permissible heat loads described in Section 2.IV.1. Specifically, Region 2 of both the MPC-32M and MPC-68M basket have a higher decay heat limit per cell than cells in Region 1. Consequently, cells in Region 2 are assigned a lower colling time limit than those in Region 1 for a given burnup, and these limits are used in the dose evaluations. However, decay heat limits and burnup and cooling time limits~~they~~ are completely independent loading criteria, in that meeting the heat load limit is no substitute for meeting the burnup and cooling time limits, and vice versa.

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The loading curves for the MPC-32M and MPC-68M canisters are provided in Table 2.IV.1.7 and Table 2.IV.1.8, respectively, using polynomial equation and corresponding polynomial coefficients. [PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10 CFR 2.390]

~~The configurations selected for shielding analyses of the HI-STORM 100 Version UVH System encompass all configurations permitted for the MPC-32M and MPC-68M canisters, i.e., uniform and regionalized.~~ All sets of burnup and cooling time combinations used in the analyses are presented in Tables 5.IV.2.1 and 5.IV.2.2~~, together with the basket configurations they apply to~~.

5.IV.2.2.2 Fuel Enrichment

As discussed in Paragraph 5.4.11.2 in the main part of this chapter, a conservatively low enrichment value is selected for each burnup based on industry information on more than 130,000 PWR and 185,000 BWR assemblies. The determined enrichment values provided in Table 5.4.20 are used in all dose analyzes presented in this supplement.

5.IV.2.3 Non-Fuel Hardware

See Subsection 5.II.2.3.

Table 5.IV.2.1

BURNUP, ENRICHMENT AND COOLING TIMES COMBINATIONS CONSIDERED FOR MPC-32M

Applicability	Burnup (MWd/mtU)	Enrichment (wt% ^{235}U)	Calculated Cooling Time[1] (years)	Cooling Time Assumed in Dose Analysis (years)
~~Uniform Loading~~Region 1	5000	1.1	1.44	1.4
	10000	1.1	1.94	1.8
	20000	1.6	2.66	2.6
	30000	2.4	3.37	3.0
	40000	3.0	4.45	4.0
	50000	3.6	6.31	6.0
	60000	3.9	9.33	9.0
	70000	4.2	13.9	13.0
~~Zone 2[2] for Regionalized Configuration~~Region 2	5000	1.1	<1~~0.74~~	1.0~~1.0~~
	10000	1.1	<1~~0.83~~	1.0~~1.0~~
	20000	1.6	1.52~~1.03~~	1.4~~1.0~~
	30000	2.4	2.20~~1.23~~	2.0~~1.2~~
	40000	3.0	2.71~~1.45~~	2.6~~1.4~~
	50000	3.6	3.16~~1.70~~	3.0~~1.6~~
	60000	3.9	3.65~~1.96~~	3.5~~1.8~~
	70000	4.2	4.28~~2.24~~	4.0~~2.2~~

[1] Cooling times are calculated following the methodology in Subsection 2.IV.1.2 using the coefficients in Tables 2.IV.1.7.
~~[2] [PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10 CFR 2.390]~~

Table 5.IV.2.2

BURNUP, ENRICHMENT AND COOLING TIMES COMBINATIONS CONSIDERED FOR MPC-68M

Applicability	Burnup (MWd/mtU)	Enrichment (wt% ^{235}U)	Calculated Cooling Time[1] (years)	Cooling Time Assumed in Dose Analysis (years)
~~Uniform Loading~~Region 1	5000	0.7	0.80	1.0
	10000	0.9	1.68	1.6
	20000	1.6	2.73	2.6
	30000	2.4	3.31	3.0
	40000	3.0	3.98	3.5
	50000	3.3	5.32	5.0
	60000	3.7	7.89	7.0
	70000	4.0	12.3	12.0
~~Zone 2[2] for Regionalized Configuration~~Region 2	5000	0.7	≤1~~0.58~~	1.0~~1.0~~
	10000	0.9	≤1~~0.20~~	1.0~~1.0~~
	20000	1.6	1.41~~0.39~~	1.4~~1.0~~
	30000	2.4	1.84~~0.81~~	1.8~~1.0~~
	40000	3.0	2.27~~1.10~~	2.2~~1.0~~
	50000	3.3	2.73~~1.31~~	2.6~~1.2~~
	60000	3.7	3.26~~1.50~~	3.0~~1.4~~
	70000	4.0	3.88~~1.72~~	3.5~~1.6~~

[1] Cooling times are calculated following the methodology in Subsection 2.IV.1.2 using the coefficients in Table 2.IV.1.8.
~~[2] [PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10 CFR 2.390]~~

~~[PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10 CFR 2.390]~~

~~**FIGURE 5.IV.2-1 ZONE NUMBERS IN THE MODEL OF THE MPC-32M BASKET**~~

[PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10 CFR 2.390]

FIGURE 5.IV.2-2 ZONE NUMBERS IN THE MODEL OF THE MPC-68M BASKET

5.IV.4 Shielding Evaluation

5.IV.4.1 General

In general, the same methodology is used as described in Section 5.II.4 for the dose rate calculations, unless otherwise noted in the following subsections. Modeling of the content for the MPC-32M and MPC-68M canisters is presented in detail in Section 5.IV.2.

Bounding results for HI-STORM 100 Version UVH are summarized in Section 5.IV.1, Tables 5.IV.1.1 and 5.IV.1.2. For HI-TRAC Version MS, results are presented in Section 5.IV.1, in Table 5.IV.1.3 for normal conditions and Table 5.IV.1.4 for accident conditions. Results for accident conditions are presented there for upper bound content, and lower bound shielding thicknesses, so they present an overall bounding condition, and no further information is needed. However, for normal conditions, as discussed in Section 5.IV.1, results are presented for upper bound content, but for shielding thicknesses that result in radial dose rates consistent with the dose limit selected for ALARA purposes. For illustrative purposes, additional calculations are performed for different assumptions on content or shielding thicknesses (see Table 5.II.3.1). Results for all calculations, showing only total dose rates for all relevant surface and 1 m dose locations, are summarized and compared in Table 5.IV.4.1. The following conditions are shown:

- Bounding content, thickness selected for compliance with the external dose rate limit. These are the results for the regionalized loading pattern from Section 5.IV.1;

- Minimum thickness, content adjusted to match external dose limit. This is presented as an example to show what content limits will result in dose rates matching the limit, even if the HI-TRAC Version MS with minimum shielding thicknesses is used. The same combinations as in Table 5.IV.2.1, but with the cooling times increased by 4 years, are used for this example;

- Bounding content and reference thicknesses, assuming a higher crane capacity;

- Bounding content and reference thicknesses, but the annulus between the transfer cask and MPC is flooded by water. This condition represents a typical configuration for most loading operations in the vicinity of the transfer cask.

The results and comparisons show that for HI-TRAC Version MS designed for higher crane capacities, the external dose rates can be significantly lower than those presented in Section 5.IV.1. However, for a combination of the bounding content and bounding shielding thicknesses, the external dose rates would be ~~unacceptably~~ very high, justifying the introduction of the dose limit.

Note that dose location 4, in the top of HI-TRAC Version MS, shows a high dose rate in almost all cases As already discussed in Subsection 5.II.4.1,~~. However,~~ this is present only in a very narrow area above the annulus between the MPC and HI-TRAC Version MS, and for the condition where both the MPC and annulus are empty, i.e., no longer filled with water. Under this condition there is essentially no need for any access to this narrow area, so this high dose rate is inconsequential from an operational dose perspective. For illustration, the results in Table 5.IV.4.1 show that the dose rate in the top of HI-TRAC Version MS is substantially reduced when the annulus between HI-TRAC Version MS and MPC is flooded.

~~As discussed in Subsection 5.IV.2.2, the HI-STORM 100 Version UVH System is qualified for the MPC-32M and MPC-68M canisters with the uniform and regionalized loading patterns. From a dose rate~~

versus distance perspective, all these are bounded by the dose rates presented for MPC-32M with the regionalized loading in this supplement, due to the high source term used for evaluating this configuration. To demonstrate that this is the case, a comparison is performed for the HI-STORM 100 Version UVH cask with both MPCs. The following content is modeled for those:

[PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10 CFR 2.390]

AThe comparison for the dose rates for the two MPCs is presented in Tables 5.IV.4.2 for HI-STORM 100 Version UVH.—, and in Table 5.IV.4.3 for the HI-TRAC Version MS with the lower bound shielding thickness. The tables show It confirms that the MPC-68M results are bounded by those for the MPC-32M for all dose locations. Hence only results for the MPC-32M are presented in Section 5.IV.1, and used for the studies presented in Table 5.IV.4.1. This also justifies evaluating just the MPC-32M for the doses at larger distances from the cask presented in Subsection 5.IV.4.2. by the analyses presented here, so both MPCs are equally qualified for the systems analyzed in this supplement. While the regionalized loading patterns generally produce the bounding results, the maximum dose rate at the top surface of the cask is generated by the uniform loading. Hence the maximum dose rate over the entire range of qualified content for both uniform and regionalized loading patterns is presented for each dose rate location in Section 5.IV.1. Additionally, Tables 5.IV.4.3 provides a comparison of the MPC-32M and MPC-68M canisters with the uniform loading in the HI-TRAC Version MS cask with the lower bound shielding thicknesses.

The principal design of the HI-TRAC Version MS cask is similar to the other HI-TRAC transfer casks previously qualified and certified in this FSAR and, as discussed in Section 5.IV.1, a dose rate limit is applied to the outer surface of the transfer cask, when loaded with the content defined in Supplement 2.IV. The conservative analyses for the limiting HI-TRAC Version MS transfer cask with the minimum thickness of the shielding materials are therefore used to qualify all otherthe HI-TRAC versions for the MPCs analyzed in this supplement.

5.IV.4.2 Site Boundary Evaluation

The dose from a single HI-STORM overpack loaded with an MPC and from various arrays of loaded HI-STORMs at distances equal to and greater than 100 meters is determined as discussed in Subsection 5.II.4.2. Results of the analyses are presented in Tables 5.IV.4.4 and 5.IV.4.5, for 100% occupancy (8760 hours), and using bounding source terms. Table 5.IV.4.4 shows the annual dose rate, by dose component, at 200 m. Table 5.IV.4.5 shows the annual dose values A, B and C for determining the dose from ISFSI arrays, for various distances.

Table 5.IV.4.1

TOTAL DOSE RATES AROUND THE HI-TRAC VERSION MS WITH THE MPC-32M FOR DIFFERENT CONTENT AND SHIELDING THICKNESS COMBINATIONS

Content/Shielding Configuration				
Content	Bounding	Adjusted	Bounding	Bounding
Shielding[1]	Adjusted	Minimum	Reference	Reference
Annulus[2]	Empty	Empty	Empty	Water
Dose Point[3] **Location**	**TOTAL DOSE RATES (mrem/hr)**[4]			
ADJACENT TO HI-TRAC				
1	1572~~1271~~	1026~~724~~	1629~~1310~~	1091~~1013~~
2	2877~~3407~~	3706~~3745~~	1553~~1815~~	1258~~1447~~
3	75~~44~~	136~~88~~	52~~27~~	24~~15~~
4	6443~~5037~~	4046~~2748~~	6451~~5059~~	2404~~1767~~
5	10533~~4597~~	6878~~2726~~	10607~~4587~~	9772~~4256~~
ONE METER FROM HI-TRAC				
1	617~~576~~	773~~618~~	449~~381~~	328~~317~~
2	1066~~1102~~	1317~~1194~~	585~~588~~	481~~495~~
3	266~~225~~	552~~366~~	143~~118~~	112~~94~~
4	1417~~906~~	987~~469~~	1416~~936~~	984~~389~~

[1] Refer to Table 5.II.3.1.

[2] Radial annulus between the HI-TRAC Version MS cask and MPC enclosure vessel.

[3] Refer to Figure 5.II.3-4.

[4] Values are rounded to nearest integer.

Table 5.IV.4.2

COMPARISON OF TOTAL DOSE RATES AROUND THE HI-STORM 100 VERSION UVH FOR DIFFERENT MPCs

MPC	MPC-32M		MPC-68M	
Content	Regionalized	Uniform	Regionalized	Uniform
Dose Point[1] Location	TOTAL DOSE RATES (mrem/hr)			
ADJACENT TO OVERPACK				
1	22.2		16.4	
2	54.7		49.1	
3	2.5		1.4	
4	6.1		2.7	
ONE METER FROM OVERPACK				
1	12.0		10.0	
2	25.8		22.9	
3	4.9		2.4	
4	2.3		1.1	

[1] Refer to Figure 5.IV.3-1.

Table 5.IV.4.3

COMPARISON OF TOTAL DOSE RATES AROUND THE HI-TRAC MS FOR DIFFERENT MPCs

MPC	MPC-32M	MPC-68M
~~Content~~	~~Uniform~~	~~Uniform~~
Dose Point[1] Location	TOTAL DOSE RATES (mrem/hr)[2]	
ADJACENT TO HI-TRAC		
1	1575~~847~~	1371~~798~~
2	8865~~4860~~	7230~~3964~~
3	183~~136~~	107~~74~~
4	6461~~4418~~	4135~~2801~~
5	10375~~7526~~	8175~~6521~~
ONE METER FROM HI-TRAC		
1	1490~~968~~	1135~~705~~
2	3420~~1824~~	2737~~1477~~
3	930~~674~~	519~~370~~
4	1429~~1066~~	793~~556~~

[1] Refer to Figure 5.II.3-4.

[2] Values are rounded to nearest integer.

Table 5.IV.4.4

ANNUAL DOSE AT 200 METERS FROM A SINGLE HI-STORM 100 VERSION UVH OVERPACK WITH MPC-32M[1]

Dose Component	Annual Dose (mrem/yr)
Fuel gammas[2]	21.47~~17.23~~
^{60}Co Gammas	0.44~~0.24~~
Neutrons	0.20~~0.05~~
BPRA	1.32~~0.79~~
Total	23.42~~18.31~~

[1] 8760 hour annual occupancy is assumed.

[2] Gammas generated by neutron capture are included with fuel gammas.

Table 5.IV.4.5

DOSE VALUES USED IN CALCULATING ANNUAL DOSE FROM VARIOUS HI-STORM 100 VERSION UVH ISFSI CONFIGURATIONS[1]

Distance	**A** **Side of Overpack** **(mrem/yr)**	**B** **Top of Overpack** **(mrem/yr)**	**C** **Side of Shielded Overpack** **(mrem/yr)**
100 meters	129.08~~97.36~~	14.34~~10.82~~	25.82~~19.47~~
200 meters	21.08~~16.48~~	2.34~~1.83~~	4.22~~3.30~~
300 meters	5.48~~4.07~~	0.61~~0.45~~	1.10~~0.81~~
400 meters	2.12~~1.60~~	0.24~~0.18~~	0.42~~0.32~~
500 meters	0.84~~0.69~~	0.09~~0.08~~	0.17~~0.14~~
600 meters	0.33~~0.26~~	0.04~~0.03~~	0.07~~0.05~~

[1] 8760 hour annual occupancy is assumed.