Table 3.2.2

LIMITING PARAMETERS

	Item	PWR	BWR
1.	Minimum fuel assembly length, inch	150	171
2.	Maximum fuel assembly length, inch	199.2	181.5[3]
3.	Nominal thickness of the lead cylinder in the lowest weight HI-TRAC VW, inch	2.75 (MPC-37) 3.25 (MPC-32ML)	2.50
4.	Maximum nominal thickness of the lead cylinder, inch	4.25	4.25
5.	Nominal (radial) thickness of the water in the external jacket, inch	4.75	4.75

[3] Maximum fuel assembly length for the BWR fuel assembly refers to the maximum fuel assembly length plus an additional 5" to account for a Damage Fuel Container (DFC).

5.1.1 Normal and Off-Normal Operations

Chapter 12 discusses the potential off-normal conditions and their effect on the HI-STORM FW system. 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.

The 10CFR72.104 criteria for radioactive materials in effluents and direct radiation during normal operations are:

1. During normal operations and anticipated occurrences, the annual dose equivalent to any real individual who is located beyond the controlled area, must not exceed 25 mrem to the whole body, 75 mrem to the thyroid and 25 mrem to any other critical organ.

2. Operational restrictions must be established to meet as low as reasonably achievable (ALARA) objectives for radioactive materials in effluents and direct radiation.

10CFR20 Subparts C and D specify additional requirements for occupational dose limits and radiation dose limits for individual members of the public. Chapter 11 specifically addresses these regulations.

In accordance with ALARA practices, design objective dose rates are established for the HI-STORM FW system and presented in Table 2.3.2.

Figure 5.1.1 identifies the locations of the dose points referenced in the dose rate summary tables for the HI-STORM FW overpack. Dose Point #2 is located on the side of the cask at the axial mid-height. Dose Points #1 and #3 are the locations of the inlet and outlet air ducts, respectively. The dose values reported for these locations (adjacent and 1 meter) were averaged over the duct opening. Dose Point #4 is the dose location on the overpack lid. The dose values reported at the locations shown on Figure 5.1.1 are averaged over a region that is approximately 1 foot in width.

Figure 5.1.2 identifies the location of the dose points for the HI-TRAC VW transfer cask. Dose Point Locations #1 and #3 are situated below and above the water jacket, respectively. Dose Point #4 is the dose location on the HI-TRAC VW lid and dose rates below the HI-TRAC VW are estimated with Dose Point #5. Dose Point Location #2 is situated on the side of the cask at the axial mid-height.

The total dose rates presented are presented for two cases: with and without BPRAs. The dose from the BPRAs was conservatively assumed to be the maximum calculated in Subsection 5.2.4.

Tables 5.1.1 ~~and~~, 5.1.2 provides dose rates adjacent to and one meter from the HI-TRAC VW during normal conditions for the MPC-37 ~~and~~, MPC-89 and MPC-32ML. The dose rates listed in Table 5.1.1 correspond to the normal condition in which the MPC is dry and the HI-TRAC water

jacket is filled with water. It should be noted that the minimum lead thickness of HI-TRAC VW with MPC-32ML is more than that of HI-TRAC with MPC-37.

Tables 5.1.5 ~~and~~, 5.1.6 and 5.1.10 provide the design basis dose rates adjacent to the HI-STORM FW overpack during normal conditions for the MPC-37 ~~and~~, MPC-89 and MPC-32ML. Tables 5.1.7 ~~and~~, 5.1.8 and 5.1.11 provide the design basis dose rates at one meter from the HI-STORM FW overpack containing the MPC-37, ~~and~~ MPC-89 and MPC-32ML, respectively.

~~It should be noted that since adjacent and 1-m dose rates of HI-STORM FW with MPC-32ML are comparable with those with MPC-37, it is concluded that the dose rates around the HI-TRAC VW with MPC-32ML are also comparable with those with MPC-37. Also, the lead thickness of the HI-TRAC VW varies from one plant to another plant. Thus, no additional shielding calculation is performed in this chapter for HI-TRAC VW with MPC-32ML.~~

The dose to any real individual at or beyond the controlled area boundary is required to be below 25 mrem per year. The minimum distance to the controlled area boundary is 100 meters from the ISFSI. Table 5.1.3 presents the annual dose to an individual from a single HI-STORM FW 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. It is noted that these data are provided for illustrative purposes only. A detailed site-specific evaluation of dose at the controlled area boundary must be performed for each ISFSI in accordance with 10CFR72.212. The site-specific evaluation will consider dose from other portions of the facility and will consider the actual conditions of the fuel being stored (burnup and cooling time).

Figure 5.1.3 is an annual dose versus distance graph for the HI-STORM FW cask array configurations provided in Table 5.1.3. Figure 5.1.4 is an annual dose versus distance graph for the HI-STORM FW cask array configurations provided in Table 5.4.11. These ~~is~~ curves, which ~~is~~ are based on an 8760 hour occupancy, ~~is~~ are provided for illustrative purposes only and will be re-evaluated on a site-specific basis.

Subsection 5.2.3 discusses the BPRAs, TPDs, CRAs and APSRs that are permitted for storage in the HI-STORM FW system. Subsection 5.4.4 discusses the increase in dose rate as a result of adding non-fuel hardware in the MPCs.

The analyses summarized in this section demonstrate that the HI-STORM FW system is in compliance with the radiation and exposure objectives of 10CFR72.106. Since only representative dose rate values for normal conditions are presented in this chapter, compliance with 10CFR72.104 is not being evaluated. This will be performed as part of the site specific evaluations.

Table 5.1.12

MAXIMUM DOSE RATES FROM THE HI-TRAC VW FOR NORMAL CONDITIONS
MPC-32MLWITH 16X16D FUEL
LOADING PATTERNS (SEE TABLE 5.0.3)

Dose Point Location	Fuel Gammas (mrem/hr)	(n,γ) Gammas (mrem/hr)	^{60}Co Gammas (mrem/hr)	Neutrons (mrem/hr)	Totals (mrem/hr)	Totals with BPRAs (mrem/hr)
ADJACENT TO THE HI-TRAC VW						
1	5	4	41	86	136	136
2	1627	14	<1	25	1666	1666
3	67	3	329	3	402	606
4	74	1	364	156	595	858
5	318	1	1887	527	2734	2734
ONE METER FROM THE HI-TRAC VW						
1	190	4	154	8	356	356
2	723	5	7	10	745	746
3	95	1	63	1	160	198
4	236	<1	229	25	490	634
5	168	<1	1028	133	1329	1329

Notes:

- Refer to Figure 5.1.2 for dose locations.
- Values are rounded to nearest integer.
- Dose rates are based on no water within the MPC, an empty annulus, and a water jacket full of water. For the majority of the duration that the HI-TRAC bottom lid is installed, the MPC cavity will be flooded with water. The water within the MPC greatly reduces the dose rate.
- Streaming may occur through the annulus. However, during handling/operations the annulus is filled with water and lead snakes are typically present to reduce the streaming effects. Further, operators are not present on top of the transfer cask.
- The "Fuel Gammas" category includes gammas from the spent fuel, ^{60}Co from the spacer grids, and ^{60}Co from the BPRAs in the active fuel region.

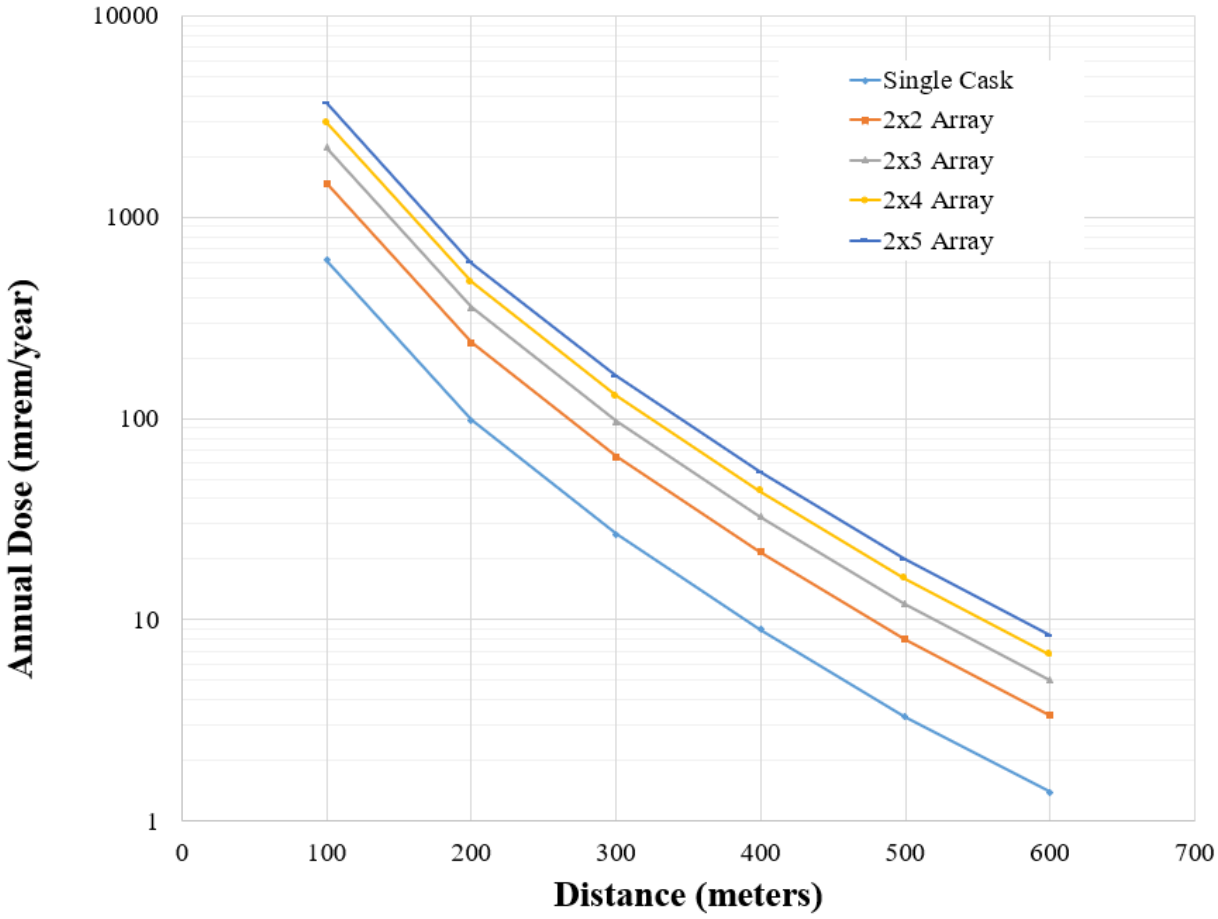

Figure 5.1.4

MAXIMUM ANNUAL DOSE VERSUS DISTANCE FOR VARIOUS CONFIGURATIONS OF THE MPC-32ML FOR BOUNDING UNIFORM PATTERNS (SEE TABLE 5.0.3) (8760-HOUR OCCUPANCY ASSUMED)

indicate the dose rate on the radial surfaces of the overpack due to the storage of these devices is less than the dose rate from BPRAs (the increase in dose rate on the radial surface due to CRAs and APSRs are virtually negligible). For the surface dose rate at the bottom, the value for the CRA is comparable to or higher than the value from the BPRA. The increase in the bottom dose rates due to the presence of CRAs is on the order of 10-15% (based on bounding configuration 1 in [5.2.17]). The dose rate out the top of the overpack is essentially 0. The latter is due to the fact that CRAs and APSRs do not achieve significant activation in the upper portion of the devices due to the manner in which they are utilized during normal reactor operations. In contrast, the dose rate out the bottom of the overpack is substantial due to these devices. However, these dose rates occur in an area (below the pool lid and transfer doors) which is not normally occupied.

While the evaluations described above are based on conservative assumptions, the conclusions can vary slightly depending on the number of CRAs and their operating conditions.

5.4.5 Effect of Uncertainties

The design basis calculations presented in this chapter are based on a range of conservative assumptions, but do not explicitly account for uncertainties in the methodologies, codes and input parameters, that is, it is assumed that the effect of uncertainties is small compared to the numerous conservatisms in the analyses. To show that this assumption is valid, calculations have previously been performed as "best estimate" calculations and with estimated uncertainties added [5.4.9]. In all scenarios considered (e.g., evaluation of conservatisms in modeling assumptions, uncertainties associated with MCNP as well as the depletion analysis (including input parameters), etc.), the total dose rates long with uncertainties are comparable to, or lower than, the corresponding values from the design basis calculations. This provides further confirmation that the design basis calculations are reasonable and conservative.

5.4.6 MPC-32ML ~~with Regionalized~~ Loading Pattern~~s~~ Dose Rates

The dose rates provided in ~~Section 5.1~~Tables 5.1.10 and 5.1.11 are the maximum dose rates for HI-STORM FW with MPC-32ML for conservative loading patterns in Table 5.0.3. Table 5.4.9 and Table 5.4.10 provide adjacent and 1-m dose rates for ~~selected~~all burnup-enrichment-cooling time combinations from Table 5.0.3.

The distance dose rates for arrays of HI-STORM FWs with MPC-32ML are provided in Table 5.4.11 for the most bounding loading pattern from Table 5.0.3. It should be noted that the distance dose rates at Table 5.4.11 are more than those provided in Table 5.1.3 because the dose rates in Table 5.4.11 are bounding, but the dose rates in Table 5.1.3 are representative.

The dose rates provided in Table 5.1.12 are the maximum dose rates for HI-TRAC VW with MPC-32ML for conservative loading patterns in Table 5.0.3. Table 5.4.12 provides adjacent and 1-m dose rates for all burnup-enrichment-cooling time combinations from Table 5.0.3.

~~As discussed in Section 5.2, there is only one heat load pattern with a uniform loading configuration for MPC-32ML. However, different burnup, enrichment and cooling time combinations may produce same decay heat, but different source terms. Additional regionalized shielding analysis is provided in this subsection by dividing the MPC-32ML basket cells into Regions 1 to 3, where Region 1 is the innermost cells, and Region 3 is the outermost cells. The fuel burnup, enrichment and cooling time combinations in Table 5.4.9 are used to calculate the adjacent and 1-m dose rates for HI-STORM FW with MPC-32ML. The heat load of each combination is either more than the decay heat limit per cell, or for the minimum cooling time of 3 years. Conservative enrichments are also considered for all combinations. Using very low enrichments (e.g. 1 wt%) with highly burned (e.g. 65 GWd/mtU) fuel would be unrealistically conservative since no such fuel exists. Hence the lower bound enrichment is selected as a function of the burnup, based on a review of actual fuel assemblies in the industry and other Holtec approved cask systems (e.g., HI-STAR 190 SAR [5.4.10] Appendix 7.C). Based on this approach, the source terms used in the analyses are reasonably bounding for all realistically expected assemblies. Each burnup, enrichment, and cooling time combination can be in Region 1, Region 2, and/or Region 3 cells. The maximum adjacent and 1 m dose rates are provided in Tables 5.4.10 and 5.4.11, respectively.~~ Higher concrete density may be used in site specific shielding analysis to further lower the occupational dose rates.

Table 5.4.9

ADJACENT DOSE RATES FOR ~~SELECTED~~ HI-STORM FW WITH MPC-32ML WITH 16X16D FUEL BURNUP-COOLING TIME COMBINATIONS (SEE TABLE 5.0.3 FOR LOADING PATTERNS)
~~BURNUP, ENRICHMENT, COOLING TIME COMBINATIONS FOR 3-REGION REGIONALIZED LOADING PATTERNS~~

Dose Point Location	Totals + BPRA (mrem/hr)					
	15,000 MWD/MTU 3-Year Cooling	20,000 MWD/MTU 3-Year Cooling	25,000 MWD/MTU 3.5-Year Cooling	30,000 MWD/MTU 3.6-Year Cooling	35,000 MWD/MTU 4-Year Cooling	40,000 MWD/MTU 4.5-Year Cooling
1	219	279	260	280	271	262
2	138	173	152	163	151	139
3 (surface)	34	42	41	44	44	45
3 (overpack edge)	66	77	74	77	75	75
4 (center)	1	1	1	1	1	1
4 (mid)	4	5	5	6	6	6
4 (outer)	36	43	41	43	42	42

Notes:

- Refer to Figure 5.1.1 for dose locations.
- Values are rounded to nearest integer where appropriate.
- Dose location 3 (surface) is at the surface of the outlet vent. Dose location 3 (overpack edge) is in front of the outlet vent, but located radially above the overpack outer diameter.

Table 5.4.9 (continued)

ADJACENT DOSE RATES FOR HI-STORM FW WITH MPC-32ML WITH 16X16D FUEL BURNUP-COOLING TIME COMBINATIONS (SEE TABLE 5.0.3 FOR LOADING PATTERNS)

Dose Point Location	Totals + BPRA (mrem/hr)					
	45,000 MWD/MTU 5-Year Cooling	50,000 MWD/MTU 6-Year Cooling	55,000 MWD/MTU 7-Year Cooling	60,000 MWD/MTU 9-Year Cooling	65,000 MWD/MTU 11-Year Cooling	70,000 MWD/MTU 13-Year Cooling
1	250	219	197	162	136	118
2	129	109	97	80	70	63
3 (surface)	44	41	40	36	33	31
3 (overpack edge)	73	69	65	58	52	47
4 (center)	1	1	2	2	2	2
4 (mid)	6	5	5	5	4	4
4 (outer)	41	38	36	32	28	26

Notes:

- Refer to Figure 5.1.1 for dose locations.
- Values are rounded to nearest integer where appropriate.
- Dose location 3 (surface) is at the surface of the outlet vent. Dose location 3 (overpack edge) is in front of the outlet vent, but located radially above the overpack outer diameter.
- Dose location 4 (center) is at the center of the top surface of the top lid. Dose location 4 (mid) is situated directly above the vertical section of the outlet vent. Dose location 4 (outer) is extended along the top plane of the top lid, located radially above the overpack outer diameter.

Table 5.4.10

1-METER DOSE RATES FOR HI-STORM FW WITH MPC-32ML WITH ~~SELECTED~~ 16X16D FUEL BURNUP-COOLING TIME COMBINATIONS (SEE TABLE 5.0.3 FOR LOADING PATTERNS)

Dose Point Location	Totals + BPRA (mrem/hr)					
	15,000 MWD/MTU 3-Year Cooling	20,000 MWD/MTU 3-Year Cooling	25,000 MWD/MTU 3.5-Year Cooling	30,000 MWD/MTU 3.6-Year Cooling	35,000 MWD/MTU 4-Year Cooling	40,000 MWD/MTU 4.5-Year Cooling
1	53	67	60	64	60	57
2	74	93	81	87	81	74
3	17	20	19	20	20	19
4 (center)	2	2	2	2	2	2

~~BURNUP, ENRICHMENT, COOLING TIME COMBINATIONS FOR~~
~~3-REGION REGIONALIZED LOADING PATTERNS~~
~~MAXIMUM DOSE RATES ADJACENT TO HI-STORM FW OVERPACK~~
~~FOR NORMAL CONDITIONS~~
~~MPC-32MLWITH 16X16D FUEL~~
~~BURNUP AND COOLING TIME~~
~~REGIONALIZED LOADING PATTERNS~~

Dose Point Location	Fuel Gammas (mrem/hr)	(n,γ) Gammas (mrem/hr)	^{60}Co Gammas (mrem/hr)	Neutrons (mrem/hr)	Totals (mrem/hr)	Totals with BPRAs (mrem/hr)
1	206	1	87	2	295	295
2	170	1	< 1	1	172	172
3 (surface)	16	1	18	2	37	47
3 (overpack edge)	12	< 1	45	1	57	82
4 (center)	< 1	1.0	0.2	0.2	1.5	1.7
4 (mid)	4	< 1	1	< 1	6	6
4 (outer)	10	< 1	22	< 1	33	45

Notes:

- Refer to Figure 5.1.1 for dose locations.
- Values are rounded to nearest integer where appropriate.
- The "Fuel Gammas" category includes gammas from the spent fuel, ^{60}Co from the spacer grids, and ^{60}Co from the BPRAs in the active fuel region.

Notes:
Refer to Figure 5.1.1 for dose locations.

Table 5.4.10 (continued)

1-METER DOSE RATES FOR HI-STORM FW WITH MPC-32ML WITH SELECTED 16X16D FUEL BURNUP-COOLING TIME COMBINATIONS

Dose Point Location	Totals + BPRA (mrem/hr)					
	45,000 MWD/MTU 5-Year Cooling	50,000 MWD/MTU 6-Year Cooling	55,000 MWD/MTU 7-Year Cooling	60,000 MWD/MTU 9-Year Cooling	65,000 MWD/MTU 11-Year Cooling	70,000 MWD/MTU 13-Year Cooling
1	53	46	41	34	28	25
2	69	58	51	42	36	33
3	19	17	16	14	13	12
4 (center)	2	2	2	2	2	2

Notes:

- Refer to Figure 5.1.1 for dose locations.
- Values are rounded to nearest integer where appropriate.

Table 5.4.12
DOSE RATES FOR HI-TRAC VW WITH MPC-32ML WITH SELECTED 16X16D FUEL BURNUP-COOLING TIME COMBINATIONS

Dose Point Location	Totals + BPRA (mrem/hr)					
	15,000 MWD/MTU 3-Year Cooling	20,000 MWD/MTU 3-Year Cooling	25,000 MWD/MTU 3.5-Year Cooling	30,000 MWD/MTU 3.6-Year Cooling	35,000 MWD/MTU 4-Year Cooling	40,000 MWD/MTU 4.5-Year Cooling
ADJACENT TO THE HI-TRAC VW						
1	61	82	83	92	99	110
2	1306	1666	1518	1654	1597	1553
3	516	598	585	606	602	604
4	641	757	751	795	810	846
5	1850	2389	2354	2539	2591	2719
ONE METER FROM THE HI-TRAC VW						
1	280	355	333	356	348	344
2	587	746	675	732	703	679
3	164	198	187	197	193	191
4	472	574	573	616	624	634
5	957	1223	1197	1278	1289	1329

Notes:

- Refer to Figure 5.1.2 for dose locations.
- Dose rates are based on no water within the MPC, an empty annulus, and a water jacket full of water. For the majority of the duration that the HI-TRAC bottom lid is installed, the MPC cavity will be flooded with water. The water within the MPC greatly reduces the dose rate.
- Streaming may occur through the annulus. However, during handling/operations the annulus is filled with water and lead snakes are typically present to reduce the streaming effects. Further, operators are not present on top of the transfer cask.

Table 5.4.12 (continued)
DOSE RATES FOR HI-TRAC VW WITH MPC-32ML WITH SELECTED 16X16D FUEL BURNUP-COOLING TIME COMBINATIONS

Dose Point Location	Totals + BPRA (mrem/hr)					
	45,000 MWD/MTU 5-Year Cooling	50,000 MWD/MTU 6-Year Cooling	55,000 MWD/MTU 7-Year Cooling	60,000 MWD/MTU 9-Year Cooling	65,000 MWD/MTU 11-Year Cooling	70,000 MWD/MTU 13-Year Cooling
ADJACENT TO THE HI-TRAC VW						
1	117	121	127	136	135	135
2	1504	1361	1292	1185	1105	1058
3	591	559	531	481	433	395
4	858	852	854	852	821	800
5	2734	2649	2590	2470	2259	2103
ONE METER FROM THE HI-TRAC VW						
1	333	303	283	251	221	199
2	653	587	553	501	464	441
3	186	172	163	149	136	127
4	628	590	560	502	453	418
5	1316	1246	1188	1082	952	853

Notes:

- Refer to Figure 5.1.2 for dose locations.
- Dose rates are based on no water within the MPC, an empty annulus, and a water jacket full of water. For the majority of the duration that the HI-TRAC bottom lid is installed, the MPC cavity will be flooded with water. The water within the MPC greatly reduces the dose rate.
- Streaming may occur through the annulus. However, during handling/operations the annulus is filled with water and lead snakes are typically present to reduce the streaming effects. Further, operators are not present on top of the transfer cask.