Table 6.E.1

POYNOMIAL FUNCTIONS FOR THE MINIMUM BURNUP AS A FUNCTION OF INITIAL ENRICHMENT

Assembly Classes	Configuration †	Maximum Enrichment (wt% ^{235}U)	Minimum Burnup B (GWD/MTU) as a Function of the Initial Enrichment E (wt% ^{235}U)
15x15D, E, F, H	A	4.65	B = +(1.6733) * E^3 -(18.72) * E^2 +(80.5967) * E - 88.3
	B	4.38	B = +(2.175) * E^3 -(23.355) * E^2 +(94.77) * E - 99.95
	C	4.48	B = +(1.9517) * E^3 -(21.45) * E^2 +(89.1783) * E - 94.6
	D	4.45	B = +(1.93) * E^3 -(21.095) * E^2 +(87.785) * E - 93.06
17x17A, B, C	A	4.49	B = +(1.08) * E^3 -(12.25) * E^2 +(60.13) * E - 70.86
	B	4.04	B = +(1.1) * E^3 -(11.56) * E^2 +(56.6) * E -62.59
	C	4.28	B = +(1.36) * E^3 -(14.83) * E^2 +(67.27) * E - 72.93
	D	4.16	B = +(1.4917) * E^3 -(16.26) * E^2 +(72.9883) * E - 79.7

† See Section 6.E.2.2 for a description of these condifurations

Table 6.E.2

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Table 6.E.3

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Table 6.E.4

B&W 15x15 BURNABLE POISON ROD ASSEMBLY SPECIFICATIONS (DESIGN BASIS)

Property	**Value**	**Reference**
Dimensions		[6.E.4]
Pellet OD	0.8636 cm	
Clad ID	0.9144 cm	
Clad OD	1.0922 cm	
$Al_2O_3 - B_4C$ density	3.7 g/cm3	[6.E.4]
B_4C content	3 wt%	[6.E.7]
$Al_2O_3 - B_4C$ composition		Calculated
Aluminum	51.33732 wt%	
Oxygen	45.66268 wt%	
Carbon	0.65213 wt%	
B-10	0.42262 wt%	
B-11	1.92525 wt%	

Table 6.E.5

B&W 15x15 CONTROL ROD AND AXIAL POWER SHAPING ROD ASSEMBLY SPECIFICATIONS

Property	**Value**	**Reference**
Dimensions		[6.E.4]
Pellet OD	0.99568 cm	
Clad ID	1.01092 cm	
Clad OD	1.11760 cm	
AgInCd density	10.17 g/cm3	[6.E.4]
AgInCd composition		[6.E.4] (rounded)
Silver	80 wt%	
Indium	15 wt%	
Cadmium	5 wt%	

Table 6.E.6

WE 17x17 PYREX BURNABLE POISON ROD ASSEMBLY SPECIFICATIONS
(DESIGN BASIS)

Property	**Value**	**Reference**
Dimensions		[6.E.18]
Inner Clad ID	0.42799 cm	
Inner Clad OD	0.46101 cm	
Pellet ID	0.48260 cm	
Pellet OD	0.85344 cm	
Outer Clad ID	0.87376 cm	
Outer Clad OD	0.96774 cm	
$SiO_2 - B_2O_3$ density	2.299 g/cm3	[6.E.7]
B_2O_3 content	12.5 wt%	[6.E.18]
$SiO_2 - B_2O_3$ composition		Calculated
Silicon	40.9006 wt%	
Oxygen	55.2173 wt%	
B-10	0.698784 wt%	
B-11	3.18335 wt%	

Table 6.E.7

WE 17x17 WABA BURNABLE POISON ROD ASSEMBLY SPECIFICATIONS

Property	**Value**	**Reference**
Dimensions		[6.E.18]
Inner Clad ID	0.5715 cm	
Inner Clad OD	0.6782 cm	
Pellet ID	0.7061 cm	
Pellet OD	0.8077 cm	
Outer Clad ID	0.8357 cm	
Outer Clad OD	0.96774 cm	
$Al_2O_3 - B_4C$ density	2.593 g/cm3	[6.E.7]
B_4C content	14 wt%	[6.E.18]
$Al_2O_3 - B_4C$ composition		Calculated
Aluminum	45.5156 wt%	
Oxygen	40.4844 wt%	
Carbon	3.04318 wt%	
B-10	1.97223 wt%	
B-11	8.9846 wt%	

Table 6.E.8

WE 17x17 CONTROL ROD ASSEMBLY SPECIFICATIONS

Property	Value	Reference
Dimensions Pellet OD Clad ID Clad OD	 0.86614 cm 0.87376 cm 0.96774 cm	[6.E.18]
AgInCd density	10.16 g/cm3	[6.E.18]
AgInCd composition Silver Indium Cadmium	 80 wt% 15 wt% 5 wt%	[6.E.18]

Table 6.E.9

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Table 6.E.14

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Table 6.E.15

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Table 6.E.15 (continued)

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Table 6.E.16

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Table 6.E.16 (continued)

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Table 6.E.17

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Table 6.E.17 (continued)

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Table 6.E.18

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Table 6.E.18 (continued)

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Table 6.E.20

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Table 6.E.20a

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Table 6.E.21

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Table 6.E.21a

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Table 6.E.22

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Table 6.E.25

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Table 6.E.26

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Table 6.E.27

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Table 6.E.28

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Table 6.E.29

REACTIVITY BIASES AND BIAS UNCERTAINTIES FOR BURNUP CREDIT

Enrichment	2	3	4	5
Burnup	7.5	27.5	40	52.5
Critical Experiments				
Bias	-0.0004	-0.0004	-0.0004	-0.0004
Bias, truncated	0	0	0	0
Bias Uncertainty	0.0083†	0.0083	0.0083	0.0083
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Total Bias (Truncated) and Bias Uncertainty	0.0285	0.0217	0.0223	0.0245

† This value is calculated from the standard deviation of the population, see text for a comparison with Appendix 6.A

Table 6.E.30

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Table 6.E.31

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Table 6.E.36

REACTIVITY EFFECT OF ECCENTRIC FUEL POSITIONING

Assembly Class	Calculated k_{eff} with assemblies centered in each basket cell	Calculated k_{eff} with assemblies moved towards the basket center	Difference between k_{eff} Values
15x15F (4 wt%, 40 GWD/MTU)	0.9317	0.9333	0.0013
17x17A (4 wt%, 40 GWD/MTU)	0.9153	0.9217	0.0064

Table 6.E.37

REACTIVITY EFFECTS OF VARTIATIONS IN FUEL DIMENSIONS FOR ASSEMBLY CLASS 15x15F AT 4 wt% ENRICHMENT AND 40 GWD/MTU

Condition	Calculated k_{eff}	Difference k_{eff} to Reference
Reference	0.9301	n/a
Pellet OD +0.001"	0.9297	-0.0004
Pellet OD -0.001"	0.9300	-0.0001
Clad ID +0.004"	0.9321	0.0020
Clad ID -0.004"	0.9272	-0.0029
Clad OD +0.004"	0.9281	-0.0020
Clad OD -0.004"	0.9320	0.0019
GT Thickness +0.01"	0.9287	-0.0014
GT Thickness -0.01"	0.9320	0.0019

Table 6.E.38

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Table 6.E.39

DESIGN BASIS MATERIAL SPECIFICATION FOR WE 17x17 FUEL (ASSEMBLY CLASS 17x17A) WITH 4.0 wt% ^{235}U INITIAL ENRICHMMENT AND 40 GWD/MTU BURNUP

Isotope	MCNP Cross-Section	Atom Density	Isotope	MCNP Cross-Section	Atom Density
U-234	92234.50c	4.238E-06	[redacted]	[redacted]	[redacted]
U-235	92235.50c	2.814E-04	[redacted]	[redacted]	[redacted]
U-236	92236.50c	1.147E-04	[redacted]	[redacted]	[redacted]
U-238	92238.50c	2.181E-02	[redacted]	[redacted]	[redacted]
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Pu-238	94238.50c	4.549E-06	[redacted]	[redacted]	[redacted]
Pu-239	94239.50c	1.656E-04	[redacted]	[redacted]	[redacted]
Pu-240	94240.50c	5.580E-05	[redacted]	[redacted]	[redacted]
Pu-241	94241.50c	3.288E-05	[redacted]	[redacted]	[redacted]
Pu-242	94242.50c	1.312E-05	[redacted]	[redacted]	[redacted]
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Table 6.E.40

CRITICALITY RESULTS FOR BURNUPS CORRESPONDING TO THE BOUNDING POLYNOMIAL FITS, B&W 15x15 Assemblies

Enrichment (wt%)	Configuration	Burnup (GWD/MTU)	Calculated k_{eff}	Standard Deviation	EALF	Maximum k_{eff}
1.8	A	0	0.9242	0.0006	0.2114	0.9281
2.0	A	11.4	0.9176	0.0004	0.2831	0.9466
2.5	A	22.34	0.922	0.0004	0.3169	0.9463
3.0	A	30.19	0.9219	0.0004	0.3459	0.9444
3.5	A	36.21	0.9227	0.0005	0.3716	0.9456
4.0	A	41.66	0.9239	0.0004	0.3946	0.9471
4.5	A	47.79	0.9212	0.0005	0.4148	0.9456
5.0	A	55.85	0.9217	0.0005	0.4329	0.9476
2.0	B	13.57	0.918	0.0004	n/c	0.9469
3.0	B	32.89	0.9195	0.0004	n/c	0.9421
4.0	B	44.65	0.9209	0.0005	n/c	0.9446
5.0	B	61.9	0.9195	0.0005	n/c	0.9462
2.0	C	13.57	0.918	0.0004	n/c	0.9469
3.0	C	32.58	0.9203	0.0004	n/c	0.9429
4.0	C	43.82	0.9215	0.0004	n/c	0.9449
5.0	C	59	0.9208	0.0005	n/c	0.9471
2.0	D	13.57	0.918	0.0004	n/c	0.9469
3.0	D	32.55	0.9214	0.0004	n/c	0.944
4.0	D	44.08	0.924	0.0005	n/c	0.9476
5.0	D	59.74	0.9217	0.0005	n/c	0.9481
					Maximum	0.9481

Table 6.E.40 (continued)

CRITICALITY RESULTS FOR BURNUPS CORRESPONDING TO THE BOUNDING POLYNOMIAL FITS, Westinghouse 17x17 Assemblies

Enrichment (wt%)	Configuration	Burnup (GWD/MTU)	Calculated k_{eff}	Standard Deviation	EALF	Maximum k_{eff}
1.8	A	0	0.9187	0.0006	0.1948	0.9226
2.0	A	9.04	0.9175	0.0004	0.2635	0.9466
2.5	A	19.78	0.9188	0.0004	0.2949	0.9431
3.0	A	28.44	0.9218	0.0005	0.3242	0.9445
3.5	A	35.84	0.9234	0.0004	0.348	0.9461
4.0	A	42.78	0.9207	0.0005	0.3699	0.9442
4.5	A	50.08	0.9207	0.0005	0.3896	0.9453
5.0	A	58.54	0.9199	0.0005	0.4067	0.9462
2.0	B	13.17	0.9169	0.0005	n/c	0.946
3.0	B	32.87	0.9252	0.0004	n/c	0.9478
4.0	B	49.25	0.9236	0.0004	n/c	0.9475
5.0	B	68.91	0.9201	0.0004	n/c	0.9476
2.0	C	13.17	0.9169	0.0005	n/c	0.946
3.0	C	32.13	0.9228	0.0005	n/c	0.9456
4.0	C	45.91	0.9234	0.0004	n/c	0.947
5.0	C	62.67	0.9215	0.0005	n/c	0.9483
2.0	D	13.17	0.9169	0.0005	n/c	0.946
3.0	D	33.2	0.9234	0.0004	n/c	0.946
4.0	D	47.56	0.922	0.0004	n/c	0.9458
5.0	D	65.2	0.919	0.0005	n/c	0.9462
					Maximum	0.9483

Table 6.E.41

SUMMARY OF THE CRITICALITY RESULTS TO DEMONSTRATE COMPLIANCE WITH 10CFR71.55 AND 10CFR71.59

Configuration	% Internal Moderation	% External Moderation	Max. k_{eff}	1 σ	EALF (eV)
B&W 15x15, 5 wt%, 59.74 GWD/MTU, Configuration D					
Single Package, unreflected	100%	0%	0.9476	0.0005	0.4337
Single Package, fully reflected	100%	100%	0.9476	0.0005	0.4319
Containment, fully reflected	100%	100%	0.9463	0.0005	0.4357
Infinite Array of Damaged Packages	100%	100%	0.9473	0.0005	0.436
Infinite Array of Undamaged Packages	0%	0%	0.4205	0.0002	39928
Westinghouse 17x17, 3.5 wt%, 41.06 GWD/MTU, Configuration B					
Single Package, unreflected	100%	0%	0.9481	0.0005	0.3613
Single Package, fully reflected	100%	100%	0.9472	0.0005	0.3639
Containment, fully reflected	100%	100%	0.9467	0.0005	0.3629
Infinite Array of Damaged Packages	100%	100%	0.9476	0.0004	0.36
Infinite Array of Undamaged Packages	0%	0%	0.4021	0.0002	35671

Table 6.E.41a

ALF AND EALF VALUES FOR TWO ENERGY RANGES

Enrich-ment	All Energies		Energies < 1eV			Energies > 1 eV		
	ALF	EALF	ALF	EALF	%	ALF	EALF	%
1.8	17.67	0.2114	19.37	0.039	86.5%	6.87	10396.1	13.5%
2	17.38	0.2831	19.17	0.047	85.6%	6.72	12012.2	14.4%
3	17.18	0.3459	19.06	0.053	84.3%	7.13	7992.65	15.7%
4	17.05	0.3946	19.00	0.056	83.2%	7.40	6103.98	16.8%
5	16.96	0.4329	18.96	0.058	82.3%	7.61	4956.83	17.7%

Table 6.E.42

[redacted]

[redacted]		[redacted]	[redacted]	[redacted]
[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 6.E.43

[redacted]

[redacted]		[redacted]	[redacted]	[redacted]
[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 6.E.44

ISG-8 REV. 2 TO SECTION NUMBER CROSS REFERENCE

ISG-8 Recommendation	Corresponding Section
...allowance for burnup credit ... based on actinide compositions ...	6.E.7.1, 6.E.3.3
... assembly-average burnup value up to 50 GWD/MTU ...	6.E.5
...cooled out-of-reactor for a time period between 1 and 40 years.	6.E.1.2, 6.E.3.3.3
...removing the loading offset for initial ^{235}U enrichments between 4 and 5 percent; ...	6.E.7.2
...computational methodologies ... should be properly validated.	6.E.3.1/2/3
Bias and uncertainties associated with predicting the actinide compositions should be determined from benchmarks of applicable fuel assay measurements.	6.E.3.1
Bias and uncertainties associated with the calculation of k-effective should be derived from benchmark experiments that closely represent the important features of the cask design and spent fuel contents.	6.E.3.2, 6.E.3.3.3
The particular set of nuclides used to determine the k-effective value should be limited to that established in the validation process.	6.E.3.1, 6.E.3.3
... utilize bias and uncertainty values that can be justified as bounding ...	6.E.3.1/2/3
...fuel design and in-reactor operating parameters that appropriately encompass the range of design and operating conditions for the proposed contents.	6.E.2.1
...cask models, appropriate analysis assumptions, and code inputs that allow adequate representation of the physics.	6.3, 6.4.1, 6.E.4
...account for and effectively model the axial and horizontal variation of the burnup within a spent fuel assembly ...	6.E.4.1, 6.E.4.2
...consider the potential for increased reactivity due to the presence of burnable absorbers and control rods ...	6.E.2.2
Separate loading curves should be established for each set of applicable licensing conditions.	6.E.5
The applicability of the loading curve to bound various fuel types should be justified.	6.E.5
The administrative procedures should include a measurement that confirms the reactor record burnup for each assembly.	6.E.8

Table 6.E.44 (continued)

ISG-8 REV. 2 TO SECTION NUMBER CROSS REFERENCE

ISG-8 Recommendation	Corresponding Section
...design-specific analyses are provided that estimate the additional reactivity margins ...	6.E.6

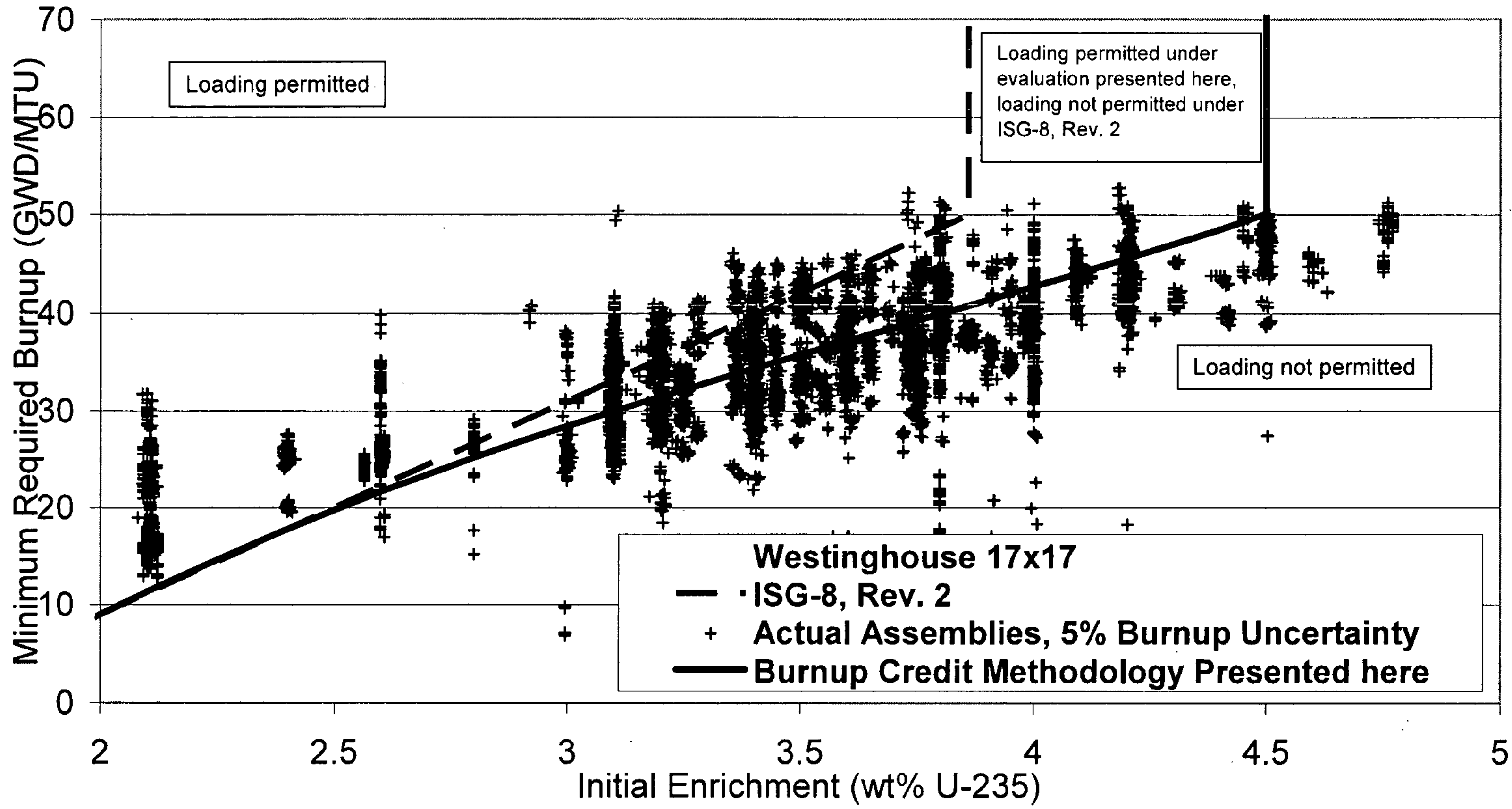

FIGURE 6.E.1: BURNUP CREDIT LOADING CURVES COMPARED TO BURNUP AND ENRICHMENT OF UNLOADED ASSEMBLIE

FIGURES 6.E.2 thru 6.E.17	NOT INCLUDED DUE TO PROPRIETARY INFORMATION
FIGURE 6.E.18	NOT USED
FIGURE 6.E.19	NOT USED
FIGURE 6.E.20	NOT USED
FIGURES 6.E.21 thru 6.E.58	NOT INCLUDED DUE TO PROPRIETARY INFORMATION

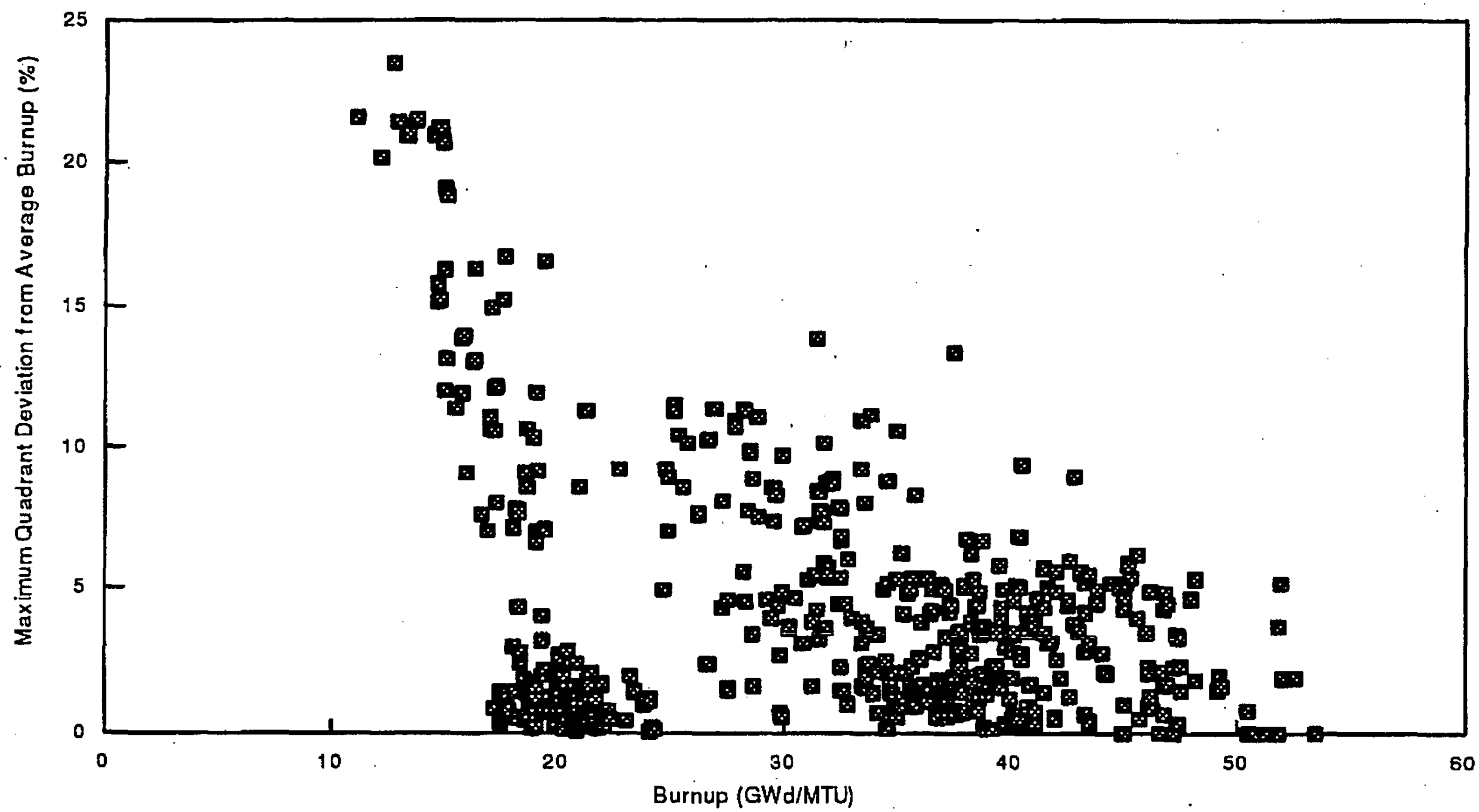

FIGURE 6.E.59 MAXIMUM QUADRANT DEVIATION FROM ASSEMBLY AVERAGE BURNUP AS A FUNCTION OF AVERAGE BURNUP (FROM [6.E.23])

FIGURES 6.E.60 thru 6.E.62 NOT INCLUDED DUE TO PROPRIETARY INFORMATION

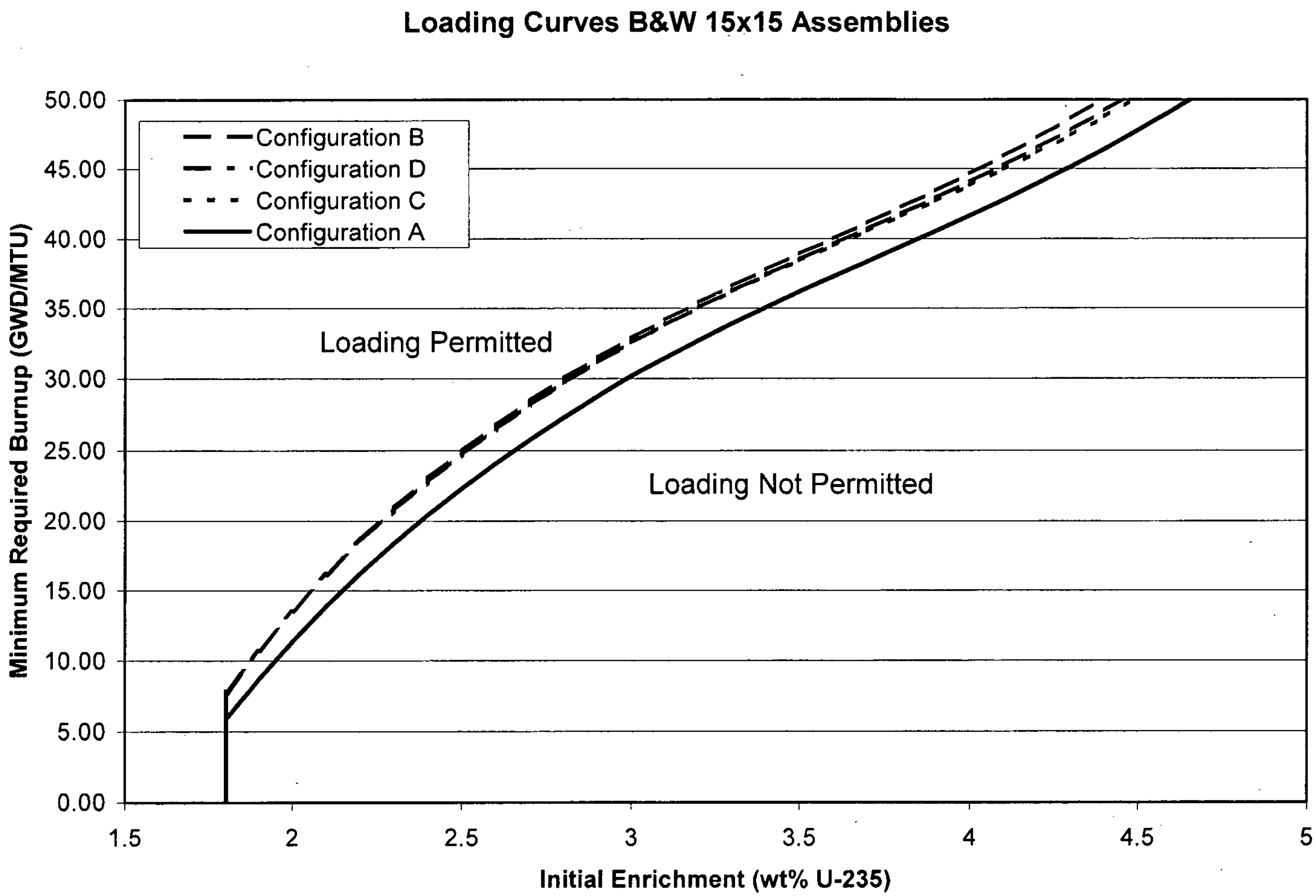

FIGURE 6.E.63: MINIMUM REQUIRED BURNUP AS A FUNCTION OF INITIAL ENRICHMENT FOR B&W 15x15 ASSEMBLIES IN THE MPC-32

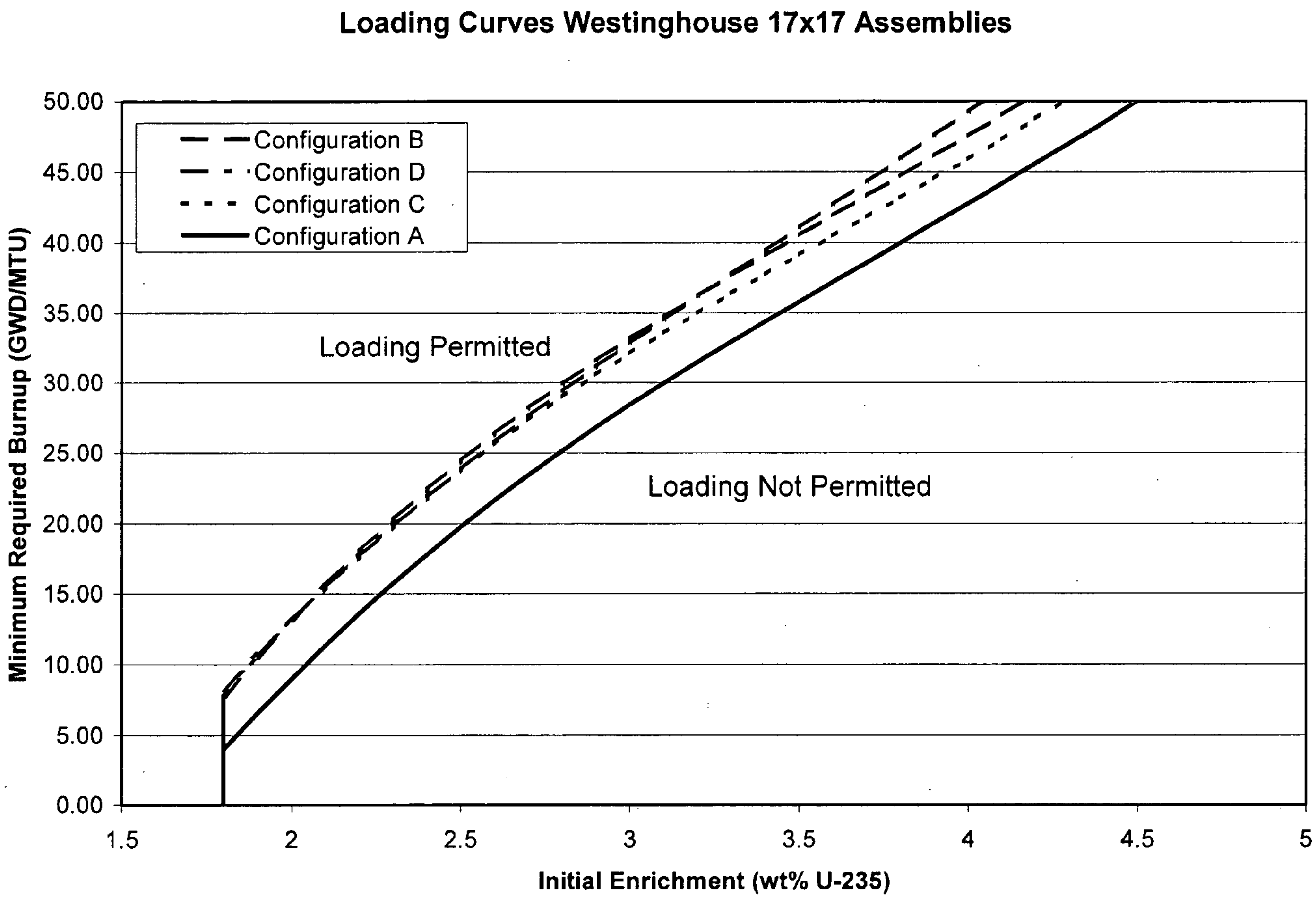

FIGURE 6.E.64: MINIMUM REQUIRED BURNUP AS A FUNCTION OF INITIAL ENRICHMENT FOR WE 17x17 ASSEMBLIES IN THE MPC-32

FIGURE 6.E.65 NOT INCLUDED DUE TO PROPRIETARY INFORMATION

SUPPLEMENT 6.I

CRITICALITY EVALUATION OF HUMBOLDT BAY FUEL IN THE MPC-HB

6.I.0 INTRODUCTION

This supplement is focused on providing criticality evaluations for fuel from the Humboldt Bay Power Plant (HBPP) in the HI-STAR HB. The evaluation presented herein supplements those evaluations contained in the main body of Chapter 6 of this SAR, and information in the main body of Chapter 6 is not repeated in this supplement. To aid the reader, the sections in this supplement are numbered in the same fashion as the corresponding sections in the main body of this chapter, i.e., Sections 6.I.1 through 6.I.6 correspond to Sections 6.1 through 6.6. Tables and figures in this supplement are labeled sequentially. The results of the evaluations in this supplement demonstrate that, for the designated fuel assembly classes and basket configurations, an infinite number of HI-STAR 100 Systems remain subcritical with a margin of subcriticality greater than 0.05Δk. This corresponds to a Criticality Safety Index (CSI) of zero (0) and demonstrates compliance with 10CFR71 criticality requirements for normal and hypothetical accident conditions of transport.

6.I.1 DISCUSSION AND RESULTS

Fuel from the HBPP is qualified in the main body of Chapter 6 of this SAR for transport in the HI-STAR 100 using the MPC-68 and MPC-68F. The assembly classes corresponding to this fuel are 6x6C and 7x7A. However, subsequent to these analyses, an additional basket design was developed for the HBPP fuel. Taking advantage of the smaller physical size of these assemblies, the capacity of the basket was increased to 80 assemblies while maintaining the same outer MPC diameter. The designated name of this MPC version is MPC-HB. Section 6.I.3 of this supplement provides the relevant details for this design. The MPC-HB is placed into the HI-STAR HB overpack, which is a shorter version of the HI-STAR 100 overpack. Also, revised assembly classes, designated 6x6D and 7x7C, are used in this supplement for the calculations with the MPC-HB. Finally, the number of cell locations for damaged fuel is increased to up to 40 per basket for the MPC-HB, compared to only 16 in the MPC-68. This is necessary since it is possible that a larger number of HBPP assemblies need to be loaded as damaged fuel.

The principal calculational results from this supplement, which address the following conditions:

- A single package, under the conditions of 10 CFR 71.55(b), (d), and (e);
- An array of undamaged packages, under the conditions of 10 CFR 71.59(a)(1); and
- An array of damaged packages, under the conditions of 10 CFR 71.59(a)(2)

are summarized in Table 6.I.1 for MPCs-HB and for the most reactive configuration and fuel condition. Results are shown for both intact or undamaged assemblies only, and the bounding condition for intact or undamaged and damaged fuel (see Section 6.I.4.1 for a discussion on undamaged assemblies). The results demonstrate that the HI-STAR 100 System is in full compliance with 10CFR71 (71.55(b), (d), and (e) and 71.59(a)(1) and (a)(2)). The calculations for package arrays are performed for infinite arrays of HI-STAR 100 Systems under flooded conditions. Therefore, the CSI is zero (0). In addition, the table shows the result for an unreflected, internally flooded cask for each MPC. This configuration is used in many calculations and studies throughout this chapter, and is shown to yield results that are statistically equivalent to the results for the corresponding reflected package.

6.I.2 SPENT FUEL LOADING

The evaluations in Section 6.2 of the main body of Chapter 6 demonstrate that the bounding fuel dimensions consist of maximum active fuel length, maximum fuel pellet diameter, minimum cladding outside diameter (OD), maximum cladding inside diameter (ID), minimum guide tube/water rod thickness, and maximum channel thickness. A detailed review of the HBPP fuel information indicated that not all assemblies were bounded by the specification of the assembly classes 6x6C and 7x7A defined in Section 6.2. Therefore, expanded assembly classes, designated 6x6D and 7x7C, are used in this supplement for the calculations with the MPC-HB. The characteristics of these assembly classes are provided in Table 6.I.2.

6.I.3 MODEL SPECIFICATION

6.I.3.1 Calculational model

Figure 6.I.1 shows a representative horizontal cross section of the MPC-HB cells used in the calculations, and Figure 6.I.2 illustrates the basket configuration used. Based on the evaluations performed for the MPC-68 described in Section 6.3 of the main body of Chapter 6, the calculations use the minimum cell pitch and cell ID, and nominal cell wall thickness. The same techniques and the same level of detail are used in the calculational models as described in the main body of this chapter. Although the neutron absorber panels are 88 inches in length, which is much longer than the active fuel length (maximum of 80 inches), they are assumed equal to the active fuel length in the calculations.

6.I.3.2 Regional Densities

The densities and material compositions unique to the calculations in the MPC-HB are for the fuel and for the neutron absorber. These are listed in Table 6.I.3. All other compositions are the same as listed in Section 6.3 of the main body of this chapter. Note that the calculations conservatively take credit for only 75% of the minimum B-10 areal density of the neutron absorber, which is less than the maximum value of 90% supported by the tests and qualifications prescribed in Chapter 8.

6.I.4 CRITICALITY CALCULATIONS

6.I.4.1 Intact and Undamaged Assemblies

Intact Assemblies

Results for calculation with intact assemblies of assembly class 6x6D and 7x7C are summarized in Table 6.I.4. The following conditions are evaluated:

- Standard: Corresponds to assemblies located in the center of each cell, without DFCs
- Assemblies in DFCs: It might be beneficial to place not only damaged, but also intact assemblies into DFCs.
- Potential Poison Plate Damage: This condition is consistent with the condition evaluated in Section 6.4.11 of the main body of this chapter, assuming a 1 inch diameter at the center of each poison plate is replaced by water.
- Eccentric positioning: All assemblies are placed closest to the basket center

The results demonstrate that the assembly class 6x6D, with eccentric positioning and assumed poison plate damage is the bounding condition for intact assemblies.

Undamaged Assemblies

Fuel inspection for HB fuel is limited to visual inspection, focusing predominantly on the rods on the periphery of the fuel assemblies. Assemblies with defects are considered damaged, and need to be placed into DFCs. The modeling of those assemblies is discussed in detail in the following subsection. However, even if no defects are detected in the inspection, some defects could exist in the inner rods of the assemblies that are not easily visible in the inspection. This means that even if no defects are detected, the assemblies may not be intact. This condition could later result in rod-breakage, which could potentially result in local relocation of fuel, creating areas with larger or smaller fuel amounts in the assembly. Note that any lateral relocation would be limited by the outer row of intact rods, and axial relocation would be limited by the grid spacers. To ensure such assemblies are qualified for loading without DFCs, additional calculations were performed where potential defects in those assemblies are modeled. The assemblies qualified this way are considered undamaged in respect to the criticality function of the cask, but not intact. In these models, the fuel rods on the periphery of the assembly remain in its original location, whereas inside the assembly various arrays of fuel rods are assumed. The array size is varied between a 3x3 array and a 7x7 array, which conservatively represents various rod damages, including axial relocation of fuel within the assembly. For each array size, two different rod pitch values are analyzed, one which spaces the rods evenly within the bounds of the peripheral rods, and one with an enlarged pitch where the outer rods of the array are closer to the peripheral rods of the assembly. The higher of the two results is then used, which is typically that for the enlarged pitch. This variation in pitch is the reason that the undamaged 6x6 assembly with a 4x4 array of rods inside the peripheral rods has a higher k_{eff} than the corresponding intact assembly, despite the fact that the number of fuel rods is the same. To maximize any reactivity effect of these conditions, they are simultaneously assumed to be present in all assemblies in the basket, and along the entire active length. In the model for damaged fuel (see Section 6.I.4.2 below) it is conservatively assumed that all cladding has disappeared. This is not a credible condition for the defects in the interior rods of the assemblies, since there is no path for the cladding to get out of the interior of the assemblies. The various arrays used to represent the result of defects in the interior of the assembly are therefore modeled as cladded rods. Results of the analyses are shown in Table 6.I.4, and indicate a slight increase in reactivity for both assembly types compared to the intact condition. The maximum k_{eff} is determined for a 4x4 and 5x5 array within the fuel assembly for the 6x6 and 7x7 assemblies, respectively. As for intact fuel, the 6x6 assembly presents the higher k_{eff} value.

The condition with assembly class 6x6D, undamaged fuel, eccentric positioning, and assumed poison plate damage is therefore used for the calculations demonstrating compliance with the regulatory requirements shown in Table 6.I.1 for intact and undamaged fuel, except for the condition of the single unreflected package, which was analyzed without the assumed poison damage.

6.I.4.2 Damaged Assemblies

To conservatively model conditions of damaged fuel and fuel debris, the same approach is used as in Section 6.4.9 of the main body of this chapter, i.e., the fuel is represented by arrays of bare fuel rods in the DFC. Both the fuel rod diameter of the 6x6D fuel and 7x7C fuel is analyzed. A total of 6 different array sizes are analyzed for each condition. Additionally, two different DFC patterns are evaluated. The first pattern allows damaged fuel/fuel debris in DFCs in the 28 peripheral cells of the basket only. This first configuration is shown in Figure 6.I.3. For the second configuration, a checkerboard array of cells with intact and damaged fuel is analyzed, resulting in a total of 40 cells qualified for damaged fuel and fuel debris. This second configuration is shown in Figure 6.I.4. The calculations are performed in several steps, where in each step some of the principal parameters are varied such that the k_{eff} value is maximized. In all cases, the intact or undamaged assemblies are assumed to be assembly class 6x6D, which is bounding as shown in the previous subsection. For the damaged fuel and fuel debris in the DFCs, it is assumed that the fuel is present along the entire length of the DFC, including the areas that are not covered by the poison in the basket. Results for the two patterns, two pellet diameters, and various array sizes are listed in Table 6.I.5 for damaged and intact fuel. The results show that the bounding condition exists for the checkerboard array with the larger pellet ID, and a 7x7 array of bare rods. For this condition, further calculations were performed with assumed poison plate damage and eccentric positioning, as for intact fuel in the previous subsection. These results are listed in Table 6.I.6. As for the intact assemblies, the eccentric position results in a higher reactivity. The assumed poison plate damage shows a slight reduction in reactivity, however, the difference is still within two standard variations, indicating that the results are statistically identical. Nevertheless, the condition with eccentric positioning and assumed poison plate damage is used as the bounding condition. Finally, calculations are performed with undamaged instead of intact assemblies, varying the array size inside those assemblies (see previous subsection). The bounding condition corresponds again to a 4x4 array to represent the inner area of the undamaged assembly, as shown in Table 6.I.7. The overall bounding condition is therefore characterizes as follows:

• DFC Configuration	40 DFC
• Damaged Fuel Representation	7x7 rod array, 0.488" OD
• Remaining Assemblies	6x6D, undamaged
• Undamaged Configuration	4x4 cladded rod array inside peripheral rods, Increased rod pitch
• DFC and assembly position	Eccentric
• Poison Plate Damage	yes

This condition is then used to perform the calculations demonstrating compliance with the regulatory requirements shown in Table 6.I.1, except for the condition of the single unreflected package, which was analyzed without the assumed poison damage.

Two HBPP assemblies contain one fuel rod with an enrichment of 5.5 wt% ^{235}U. At least one of these two assemblies is considered damaged. These assemblies have a planar average enrichment of less than 2.6 wt% ^{235}U. For damaged fuel and fuel debris it is assumed that the fuel can relocate freely within the DFC. However, even if it would be conservatively assumed that the entire amount of fuel from one of these rods would accumulate in one area in the DFC, this area would be rather small. For example, the bounding configuration for damaged fuel consists of a 7x7 array of bare fuel rods. Under this configuration, a single rod with an active length of 80 inches would only occupy an axial length of 80 inches / 7x7 = 1.63 inches. Such a small section, which would only be present in a few DFCs in the basket, would have a negligible effect on reactivity. Further, it needs to be recognized that the damaged fuel and fuel debris model is a non-credible configuration (bare fuel rods in optimum moderation) chosen to conservatively bound any realistic fuel configuration by a significant margin, and that the average enrichment of the assemblies with the high enriched rods is below the enrichment used in the analysis. Therefore, the presence of the highly enriched rods is considered to be bounded by the damaged fuel model, and no specific calculations are necessary for the assemblies with these rods.

6.I.4.3 Test for Optimum Moderation at Lower Water Densities

Section 6.4 demonstrates that no optimum moderation exists in the MPC basket, i.e. that the maximum reactivity corresponds to the fully flooded conditions. To confirm this for the MPC-HB, additional calculations were performed with reduced water densities, for a bounding case with intact assemblies and intact and damaged assemblies for a single fully reflected package. The intact assembly in all cases is from array class 6x6D. The results are presented in Table 6.I.8, and show that reducing the water density results in a monotonic reduction of the reactivity. Optimum moderation at lower water densities does therefore not exist, and the fully flooded condition is bounding.

6.I.5 CRITICALITY BENCHMARKS

Fuel design, fuel conditions, basket design and moderation conditions are bounded by the corresponding conditions in the main body of Chapter 6. The benchmark calculations in the main body are therefore directly applicable to the calculations performed in this supplement.

6.I.6 REGULATORY COMPLIANCE

In summary, the evaluation presented in this supplement demonstrates that the HI-STAR HB System with fuel of the assembly classes 6x6D and 7x7C in the MPC-HB is in full compliance with the criticality requirements of 10CFR71.

Table 6.I.1

SUMMARY OF THE CRITICALITY RESULTS FOR THE MOST REACTIVE ASSEMBLY FROM THE ASSEMBLY CLASSES 6x6D AND 7x7C IN THE MPC-HB TO DEMONSTRATE COMPLIANCE WITH 10CFR71.55 AND 10CFR71.59

MPC-HB, 2.6 wt% ^{235}U, all Intact or Undamaged Assemblies				
Configuration	% Internal Moderation	% External Moderation	Applicable Requirement	Maximum k_{eff}
Single Package, unreflected	100%	0%	n/a	0.8464
Single Package, fully reflected	100%	100%	10CFR71.55 (b), (d), and (e)	0.8480
Containment, fully reflected	100%	100%		0.8472
Infinite Array of Damaged Packages	100%	100%	10CFR71.59 (a)(2)	0.8477
Infinite Array of Undamaged Packages	0%	0%	10CFR71.59 (a)(1)	0.3790
MPC-HB, , 2.6 wt% ^{235}U, Intact or Undamaged and Damaged Assemblies				
Configuration	% Internal Moderation	% External Moderation	Applicable Requirement	Maximum k_{eff}
Single Package, unreflected	100%	0%	n/a	0.9018
Single Package, fully reflected	100%	100%	10CFR71.55 (b), (d), and (e)	0.9017
Containment, fully reflected	100%	100%		**0.9026**
Infinite Array of Damaged Packages	100%	100%	10CFR71.59 (a)(2)	0.9022
Infinite Array of Undamaged Packages	0%	0%	10CFR71.59 (a)(1)	0.3858

Table 6.I.2
BWR FUEL CHARACTERISTICS AND ASSEMBLY CLASS DEFINITIONS FOR HBPP FUEL
(all dimensions are in inches)

Fuel Assembly Designation	Clad Material	Pitch	Number of Fuel Rods	Cladding OD	Cladding Thickness	Pellet Diameter	Active Fuel Length	Number of Water Rods	Water Rod OD	Water Rod ID	Channel Thickness	Channel ID
6x6D Assembly Class												
6x6D01	Zr	0.740	36	0.5585	0.02675	0.4880	80	0	n/a	n/a	0.060	4.542
7x7C Assembly Class												
7x7C01	Zr	0.631	49	0.4860	0.0300	0.4110	80	0	n/a	n/a	0.060	4.542

Table 6.I.3

COMPOSITION OF THE MAJOR COMPONENTS OF THE HI-STAR HB SYSTEM

METAMIC (0.0075 g $^{10}B/cm^2$), DENSITY = 2.667 g/cm^3	
Nuclide	**Atom Density (atoms/(barn*cm))**
^{10}B	3.5529E-03
^{11}B	1.4721E-02
C	4.5656E-03
Al	5.0402E-02
UO_2, 2.6 wt% INITIAL ENRICHMENT, DENSITY = 10.522 g/cm^3	
Nuclide	**Wgt. Fraction**
^{235}U	0.02292
^{238}U	0.85858
O	0.11850

Table 6.I.4

MAXIMUM k_{eff} VALUES FOR ASSEMBLY CLASSES 6x6D AND 7x7C IN THE MPC-HB FOR INTACT AND UNDAMAGED FUEL WITH AN AVERAGE ENRICHMENT OF 2.6 wt% ^{235}U.

Assembly Class	**Configuration**	**Maximum k_{eff}**
6x6D	Intact, Standard	0.8318
7x7C	Intact, Standard	0.8237
6x6D	Intact Assemblies in DFCs	0.8069
6x6D	Intact, Potential Poison Plate Damage	0.8335
6x6D	Intact, Eccentric Fuel Positioning	0.8401
6x6D	Undamaged, Eccentric Fuel Positioning	**0.8464**
7x7C	Undamaged	0.8333
7x7C	Undamaged, Eccentric Fuel Positioning	0.8400

Table 6.I.5

MAXIMUM k_{eff} VALUES FOR THE MPC-HB WITH INTACT FUEL AND DAMAGED FUEL/FUEL DEBRIS WITH AN AVERAGE ENRICHMENT OF 2.6 wt% ^{235}U

	Maximum k_{eff}			
DFC Pattern	Basket Periphery (28 DFCs)		Checkerboard (40 DFCs)	
Pellet Diameter	0.411"	0.488"	0.411"	0.488"
DFC Rod Array				
5x5	n/c†	0.8307	n/c	0.8092
6x6	0.8324	0.8389	0.8234	0.8682
7x7	0.8383	0.8444	0.8684	**0.8906**
8x8	0.8433	0.8422	0.8875	0.8846
9x9	0.8449	0.8372	0.8875	0.8602
10x10	0.8400	0.8331	0.8742	0.8343
11x11	0.8352	n/c	0.8512	n/c

† n/c = not calculated

Table 6.I.6

MAXIMUM k_{eff} VALUES FOR THE MPC-HB WITH INTACT FUEL AND DAMAGED FUEL/FUEL DEBRIS WITH AN AVERAGE ENRICHMENT OF 2.6 wt% ^{235}U

Configuration	**Maximum k_{eff}**
Standard	0.8906
Potential Poison Plate Damage	0.8896
Eccentric Fuel Positioning	**0.8981**

Table 6.I.7

MAXIMUM k_{eff} VALUES FOR THE MPC-HB WITH UNDAMAGED FUEL AND DAMAGED FUEL/FUEL DEBRIS WITH AN AVERAGE ENRICHMENT OF 2.6 wt% ^{235}U

Rod Array inside undamaged assemblies	**Maximum k_{eff}**	
	Fuel and DFCs Centered in Basket Cells	Eccentric positioning of Fuel and DFCs
3x3	0.8784	0.8849
4x4	0.8938	**0.9018**
5x5	0.8786	0.8874
6x6	0.8601	0.8671

Table 6.I.8

MAXIMUM k_{eff} VALUES
WITH REDUCED WATER DENSITY IN THE MPC.

Water Density (% of Full Density)	**Maximum k_{eff}, all intact assemblies**	**Maximum k_{eff}, intact and damaged assemblies**
100 (Reference)	0.8410	0.9003
98	0.8385	0.8997
95	0.8380	0.8951
90	0.8304	0.8857
80	0.8127	0.8717
70	0.7963	0.8513
50	0.7444	0.8113
30	0.6549	0.7870
10	0.5045	0.5832
5	0.4470	0.4782

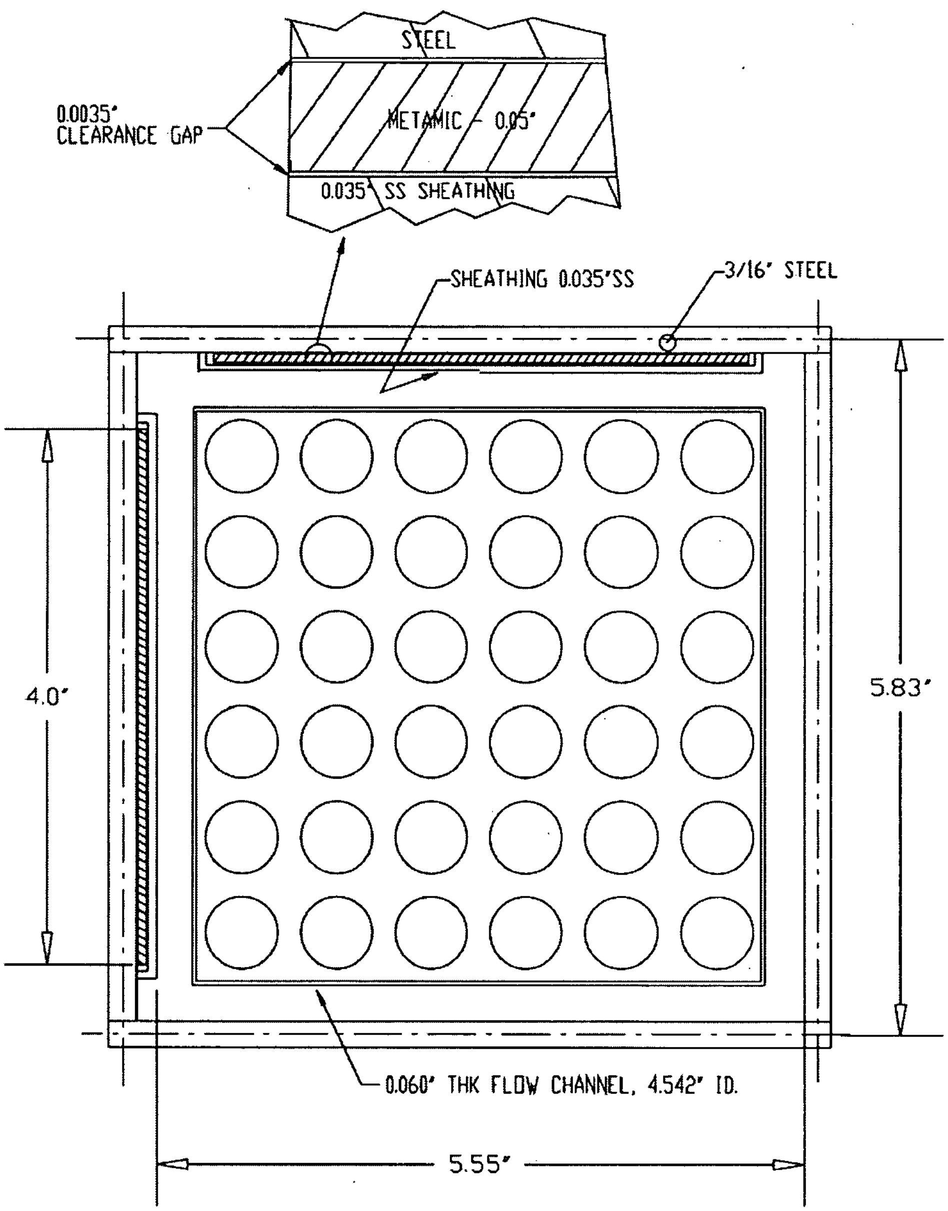

FIGURE 6.1.1; TYPICAL CELL IN THE CALCULATION MODEL (PLANAR CROSS-SECTION) WITH REPRESENTATIVE FUEL IN THE MPC-HB BASKET
(SEE CHAPTER 1 FOR TRUE BASKET DIMENSIONS)

NOTE: THESE DIMENSIONS WERE CONSERVATIVELY USED FOR CRITICALITY ANALYSES.

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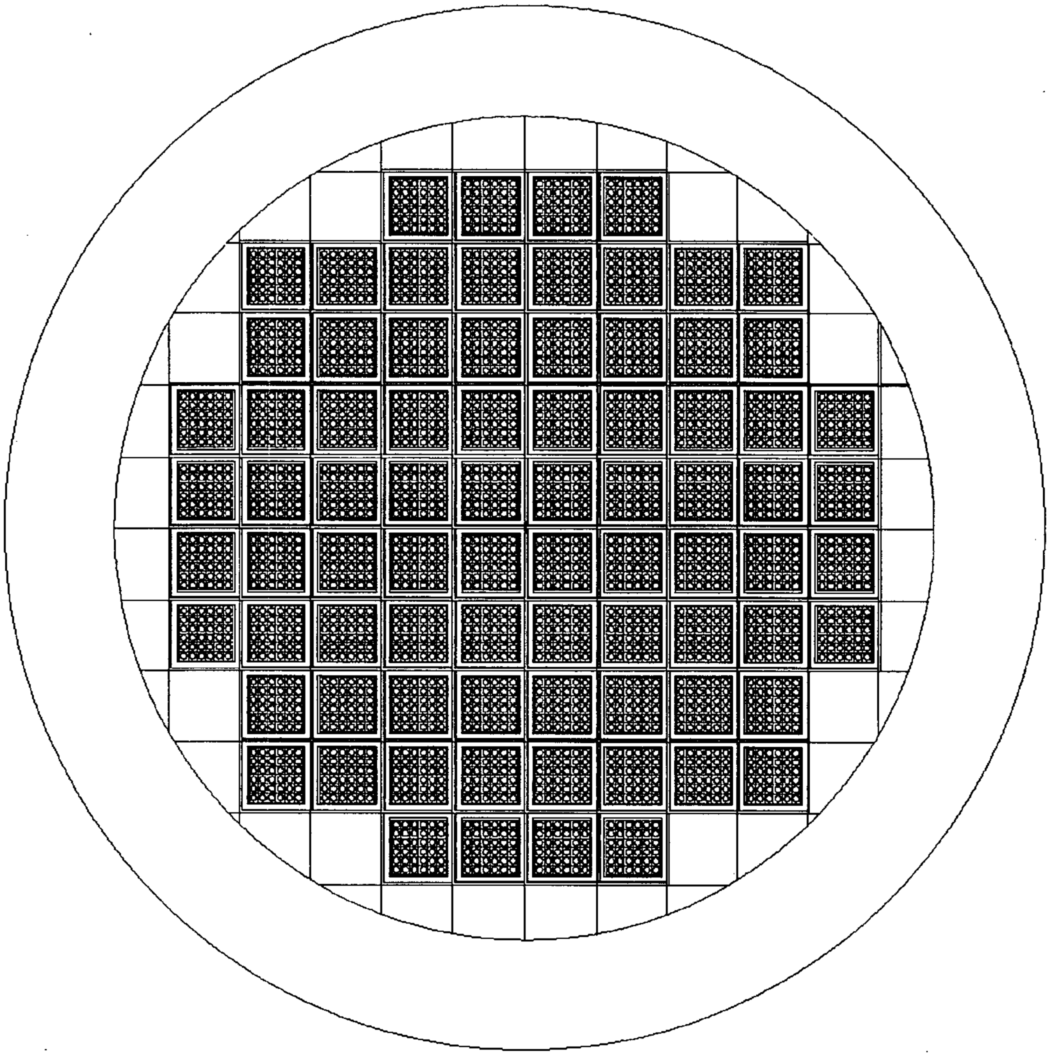

Figure 6.I.2 Radial Cross Section of Criticality Model (Intact Assemblies) generated by MCNP

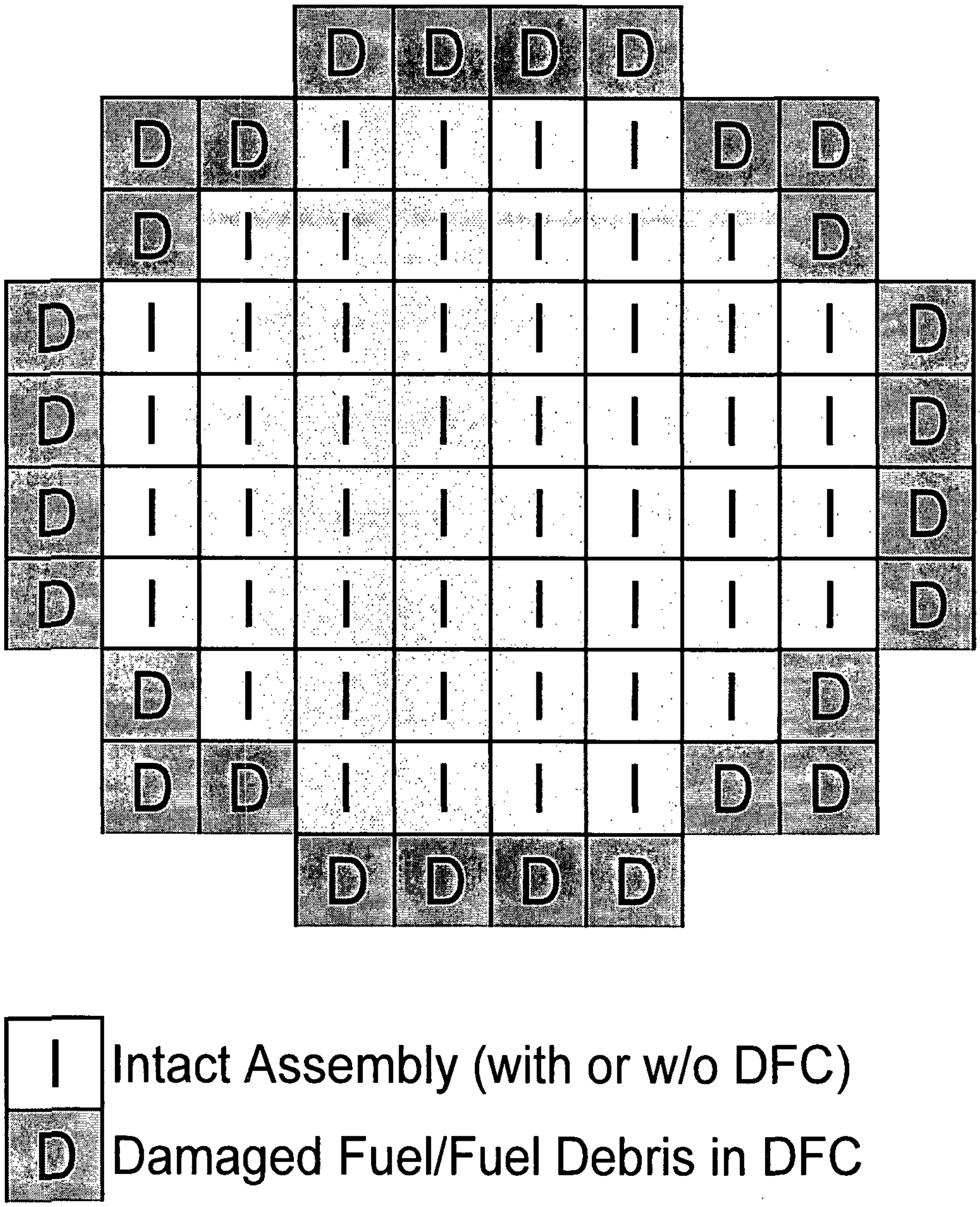

Figure 6.I.3: Damaged Fuel/Fuel Debris in Peripheral Cells of Basket only. Note that undamaged assemblies are permitted in all locations for intact assemblies.

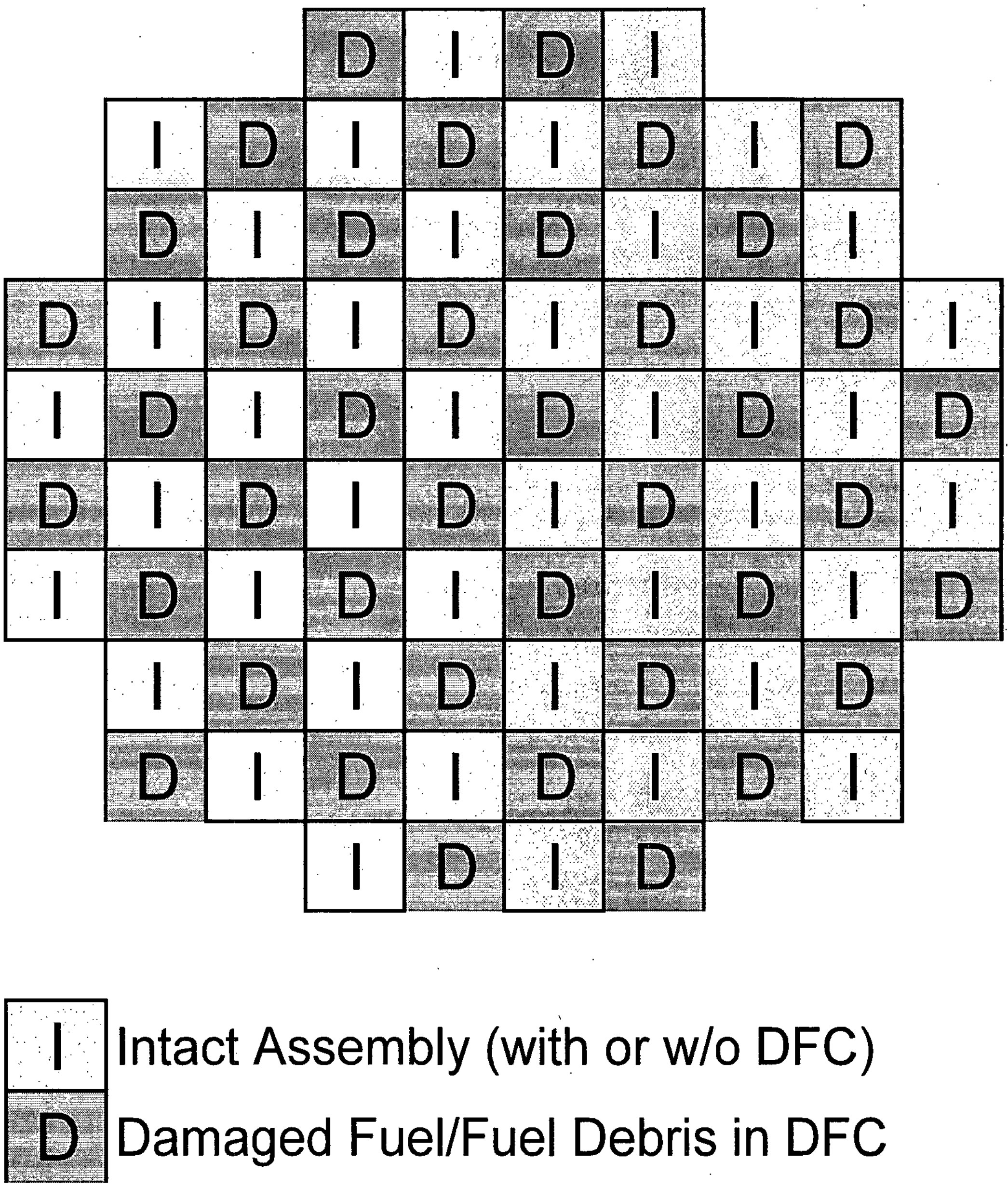

Figure 6.I.4: Checkerboard of Damaged Fuel/Fuel Debris and Intact Fuel. Note that undamaged assemblies are permitted in all locations for intact assemblies.

CHAPTER 7: OPERATING PROCEDURES

7.0 INTRODUCTION

This chapter provides the high level description of the essential elements necessary to prepare the system for shipment and to ensure that its performance under normal and accident conditions will be as described in the system evaluation. The information described in the chapter contains the minimum requirements that will ensure that the HI-STAR 100 System is operated in a safe and reliable manner consistent with the evaluation in the SAR. Holtec will use the information presented in this chapter along with their knowledge of the technical basis of the system design described in chapters 2 through 6 to develop more detailed generic procedures for the HI-STAR 100 System. Equipment specific operating details such as valve manipulation and onsite transporter operation will be provided to users based on the specific equipment selected and the configuration of the site. Licensees will utilize the information provided in this chapter, (understanding that it provides the essential operation elements that must be included in the detailed operating procedures), the conditions of the Certificate of Compliance (CoC), equipment-specific operating instructions, and plant working procedures and apply them to develop the site-specific written loading, unloading, and handling procedures to ensure that the system is operated in accordance with the system CoC and all applicable government regulatory requirements.

The operations described in this chapter assume that the fuel will be loaded into, or unloaded from, an MPC while in the HI-STAR overpack submerged in a spent fuel pool. Because the HI-STAR is a dual-use cask certified for use as a dry storage cask under 10 CFR 72, the descriptions below include the steps required to transport the cask after a period of storage. The chapter also provides a description of the essential elements necessary to transfer a Holtec MPC from a dry storage system into the HI-STAR system for transportation.

It is the cask user's responsibility to develop the site-specific operating procedures in accordance with the system CoC, the information presented in this chapter, and applicable regulatory requirements. Users will be required to develop or modify existing programs and procedures to account for the transport operation of the HI-STAR 100 System. Written procedures are required and will be developed or modified to account for such things as nondestructive examination (NDE) of the MPC welds, handling and storage of items and components identified as important to safety, heavy load handling, specialized instrument calibration, special nuclear material accountability, fuel handling procedures, training, equipment and process qualifications. Users shall implement controls to ensure that the lifted weights do not exceed the HI-STAR 100 lifting trunnion design limit. Users shall implement controls to monitor the time limit from the removal of the HI-STAR 100 from the spent fuel pool to the commencement of MPC draining to prevent boiling. Users shall also implement controls to ensure that the HI-STAR 100 overpack cannot be subjected to a fire in excess of design limits during loading operations.

Control of system operation shall be performed in accordance with the licensee's Quality Assurance (QA) program to ensure critical steps are not overlooked and that the MPC and overpack, as applicable, have been confirmed to meet all requirements of the Part 71 CoC before being released for shipment.

Table 7.1.1 provides the HI-STAR 100 System bolt torque and sequencing requirements. Fuel assembly selection and verification shall be performed by the licensee in accordance with written, approved procedures that ensure that only SNF assemblies authorized in the CoC are loaded into the HI-STAR 100 System. Fuel handling, including the handling of fuel assemblies in the Damaged Fuel Container (DFC) shall be performed in accordance with written site-specific procedures. Damaged fuel and fuel debris, as defined in the CoC, shall be loaded in DFCs.

ALARA notes and warnings are included to alert users to radiological issues. Actions identified with these notes and warnings are not mandatory and shall be implemented based on a determination by radiation protection.

Supplementary guidance for each of the sections in Chapter 7 that are specific to HI-STAR HB operations are found in Supplement 7.I.

7.1 PROCEDURE FOR LOADING AND PREPARATION FOR TRANSPORT OF THE HI-STAR 100 SYSTEM

7.1.1 Overview of HI-STAR Loading Operations

The MPC loading operations described herein are for HI-STAR 100 systems prepared for "load-and-go" directly into transportation under 10CFR71. HI-STAR 100 systems that are loaded and stored on an ISFSI site must be prepared in accordance with the applicable Part 72 HI-STAR FSAR or HI-STORM FSAR license and respective Certificate of Compliance (CoC). Any HI-STAR overpack and/or MPC deployed at an ISFSI must be confirmed to meet all conditions of the 10CFR71 CoC prior to shipment. The dryness criteria under the Part 72 CoC shall be considered acceptable for use in transport under Part 71 [7.1.2], [7.1.6].

The HI-STAR 100 System (HI-STAR) is used to load and transport spent nuclear fuel (SNF). The essential elements required to prepare the HI-STAR for fuel loading, to load the fuel, to ready the system for transport, and to ship the HI-STAR are described below.

7.1.2 Preparation of HI-STAR for Loading

1. If the HI-STAR overpack has previously been used to transport SNF, the HI-STAR overpack is received and the personnel barrier, if attached, is removed. The security seals, if used, are inspected to verify there was no tampering and that they match the corresponding shipping documents.

2. The HI-STAR is visually receipt inspected to verify that there are no outward visual indications of impaired physical condition except for superficial marks and dents. Any road dirt is washed off and any foreign material is removed.

3. Radiological surveys are performed in accordance with 49CFR173.443 [7.1.3] and 10CFR20.1906 [7.1.4]. Any issues are identified to site management and the overpack is decontaminated as directed by site radiation protection and make appropriate notifications as detailed in the surveillance requirements.

4. The impact limiters, if attached, are removed and a second visual inspection to verify that there are no outward visual indications of impaired physical condition is performed.

5. The HI-STAR overpack is upended and the neutron shield relief devices are inspected to confirm that they are installed, intact, and not covered by tape or any other covering.

7.1.3 Loading of Contents into HI-STAR

7.1.3.1 Loading of SNF into HI-STAR from a Spent Fuel Pool

1. The HI-STAR is positioned in the MPC loading area.

2. An empty MPC is upended and prepared for loading. The MPC is subjected to receipt

inspection (inspected for cleanliness and outward visual indications of impaired physical condition except for superficial marks and dents). Road dirt/debris and any foreign material are removed from the MPC prior to placement in the spent fuel pool. Verification is made to ensure that the appropriate fuel spacers, as necessary, are used to position the active fuel zone within the neutron absorber plates of the MPC, and limit axial movement of the fuel assemblies in the MPC cavity. The empty MPC is raised and inserted into the HI-STAR overpack while being careful not to damage the HI-STAR sealing surface. The MPC is inspected to ensure that the neutron absorber panel sheathing is present and there are no signs of potential damage to the neutron absorber.

3. The annulus is filled with clean (uncontaminated) water and the annulus seal is installed in the annulus between the MPC and the HI-STAR overpack.

ALARA Note:
A bottom protective cover may be attached to the cask bottom or placed in the designated preparation area or spent fuel pool. This will help prevent embedding contaminated particles in the cask bottom surface and ease the decontamination effort. Waterproof tape placed over empty bolt holes, and bolt plugs may also reduce the time required for decontamination. Wetting the components that enter the spent fuel pool may reduce the amount of decontamination work to be performed later.

4. The MPC is filled with either spent fuel pool water or clean water and the HI-STAR is raised and lowered into the spent fuel pool for fuel loading.

5. Prior to loading the fuel into the MPC, the user identifies the fuel to be loaded. A pre-loading verification is made to assure that damaged fuel and fuel debris will be placed in damaged fuel containers and that the DFCs will occupy authorized locations in the MPC. The fuel is independently verified to see that it meets the conditions of the CoC. The pre-selected assemblies are loaded into the MPC using DFCs as required, and a visual verification of the assembly identification is performed.

6. While still underwater, a thickly shielded lid (the MPC lid) is positioned over the pool surface and the drain line is installed. The MPC lid drain line is guided into its receiver and the MPC lid is installed. The upper surface of the MPC lid will seat approximately flush with the top edge of the MPC shell when properly installed. The lid may be removed and the drain line replaced should it be damaged during installation of the MPC lid. The user performs a site-specific Time-to-Boil analysis. This determines a time limit that ensures water in the MPC will not boil prior to the start of the draining operations. If it appears that the Time-to-Boil limit will be exceeded prior to draining the MPC, the user shall take appropriate action to prevent water from boiling.

ALARA Note:
Activated debris may have settled on flat surfaces of the cask during fuel loading. Cask surfaces suspected of carrying activated debris should be kept under water until a preliminary dose rate scan clears the cask for removal.

7. The lift attachment engages the HI-STAR overpack lifting trunnions to lift the HI-STAR overpack and loaded MPC close to the spent fuel pool surface.

8. The HI-STAR is removed from the spent fuel pool. If a lid retention system is being used, it is installed to secure the MPC lid for the transfer to the cask preparation area. The lift attachment and HI-STAR overpack are sprayed with clean water to help remove contamination as they are removed from the spent fuel pool.

9. The HI-STAR overpack is placed in the designated preparation area and the lift attachment and lid retention system, as applicable, are removed.

10. The top surfaces of the MPC lid, upper accessible regions of the MPC external shell and the upper flange of the HI-STAR overpack are decontaminated.

ALARA Note:
The water in the HI-STAR 100 overpack-to-MPC annulus provides personnel shielding. The level should be checked periodically and refilled accordingly. Pocket trunnions, if present and not used are plugged to reduce radiation levels around the lower region of the overpack.

11. The temporary shield ring, if used, is installed. The annulus seal is removed, and an annulus shield is installed. The temporary shield ring provides additional personnel shielding around the top of the HI-STAR overpack during MPC closure operations. The annulus shield also provides additional personnel shielding at the top of the annulus and prevents small items from being dropped into the annulus.

12. Dose rates are measured at the MPC lid and around the HI-STAR overpack to establish appropriate radiological control.

ALARA Warning:
Personnel should remain clear of the drain lines any time water is being pumped or purged from the cask. Assembly crud, suspended in the water, may create a radiation hazard to workers. Dose rates will rise as water is drained from the cask. Continuous dose rate monitoring is recommended.

ALARA Warning:
The use of manual welding should be minimized and only used when deemed advantageous from an ALARA perspective. If manual welding is elected, it should only be performed under conditions consistent with ALARA principals (e.g., utilizing temporary shielding).

13. The MPC water level and water level in the annulus are lowered slightly. Appropriate monitoring for combustible gas shall be performed prior to, and during MPC lid welding operations. The space below the MPC lid shall be vented/exhausted or purged with inert gas prior to, and during MPC lid welding operations to provide additional assurance that flammable gas concentrations will not develop in this space. Purging is the recommended method to mitigate flammable gas accumulation. The MPC lid is seal welded using an automated welding system, by manual welding, or a combination of both.

14. Visual examinations are performed on the tack welds. Liquid penetrant (PT) examinations are performed on the root and final passes. A volumetric examination is performed on the MPC welds using the ultrasonic method to ensure that the completed weld is satisfactory. As an alternative to volumetric examination of the MPC lid-to-shell weld, a multi-layer PT may be performed including intermediate examinations after approximately every three-eighth inch of weld depth. Any unsatisfactory indications are repaired in accordance with the code requirements [7.1.1].

15. At the appropriate time in the sequence of activities, based on the type of test performed (hydrostatic or pneumatic), an ASME pressure test of the MPC enclosure vessel is performed in accordance with the requirements of Section III, Subsection NB, Article NB-6000 and applicable sub-articles [7.1.1]. Any non-satisfactory conditions require the user to determine the cause of the leak and make repairs as necessary to achieve a successful result.

ALARA Note:
Dose rates will rise as water is drained from the MPC. Continuous dose rate monitoring is recommended.

16. The MPC water is displaced from the MPC and the water is drained from the annulus area.

17. The Forced Helium Dehydration (FHD) is connected to the MPC and is used to remove moisture from the MPC. To ensure that the MPC cavity is suitably dry either the temperature or the dew point of the helium exiting the FHD demoisturizer shall be less than or equal to 22.9 °F for no less than 30 minutes.

18. The MPC helium backfill is adjusted to the pressure equivalent of greater than 0 psig and less than 44.8 psig at a reference temperature of 70 degrees Fahrenheit.

19. Cover plates are installed and seal welded over the MPC vent and drain ports and PT examinations are performed on the root (for multi-pass welds) and final passes. Any unsatisfactory indications are repaired in accordance with the code requirements.

20. The MPC closure ring is placed on the MPC.

21. The closure ring is aligned, tacked in place, and seal welded. Tack welds are visually examined and PT examinations are performed on the root (for multi-pass welds) and final welds.

22. The annulus shield and the temporary shield ring (if used) are removed.

7.1.3.2 Not Used

7.1.3.3 Loading a Loaded and Sealed MPC into HI-STAR Overpack

1. After the HI-STAR overpack has been prepared in accordance with Section 7.1.2 above, it is placed in the MPC transfer location and is fitted with a mating device to interface with the transfer cask.

2. The transfer cask with loaded MPC is brought to the MPC transfer location and placed atop the HI-STAR overpack and mating device.

3. The mating device is used to open the bottom of the transfer cask and the MPC is lowered into the HI-STAR overpack.

4. The transfer cask and mating device are removed from the HI-STAR.

7.1.4 Closure of HI-STAR

1. The MPC lid and accessible areas at the top of the MPC shell are smeared for removable contamination. Decontamination of the MPC lid and accessible areas at the top of the MPC may be performed at any time prior to closure of the HI-STAR overpack.

2. The sealing surfaces for the HI-STAR overpack are inspected for signs of damage. Any damage that would prevent a seal is remedied, any old seals are discarded, new seals are inserted for the closure plate, and the closure plate is installed with the bolts torqued in accordance with requirements in Table 7.1.1 and the order prescribed in Figure 7.1.1.

3. The HI-STAR overpack annulus is dried by evacuating to a pressure of less than or equal to 3 torr. The overpack annulus shall be considered dry when it can hold a stable pressure of less than or equal to 3 torr for at least 30 minutes.

4. The HI-STAR overpack is then backfilled with helium gas to a pressure of greater than or equal to 10 psig and less than or equal to 14 psig.

5. Any old seals are removed from the HI-STAR overpack vent and drain plugs and the

plugs are installed with new seals and torqued in accordance with Table 7.1.1.

6. All HI-STAR overpack containment boundary seals, e.g. closure plate, vent and drain ports, are leak tested to assure they will provide long-term retention of the annulus helium. All HI-STAR overpack containment boundary seals shall be leak tested in accordance with ANSI N14.5 [7.1.5] and shall demonstrate compliance with the leakage rate acceptance criterion in SAR Section 4.1. Unacceptable leakage rates will require repair and re-testing of the seals. The leak test shall be performed within the 12-month period prior to each shipment and after de-tensioning one or more overpack lid bolts, drain port, or the vent port plug;
7. The HI-STAR 100 overpack vent and drain port cover plates are installed.
8. The HI-STAR 100 overpack is surveyed for removable contamination per 49CFR173.443 [7.1.3]. If necessary, the overpack is further decontaminated to meet the surveillance requirements.

7.1.5 Preparation of HI-STAR for Transport

1. Verify the HI-STAR has been leak tested within the past 12 months and no overpack lid bolts and vent and drain port plugs have been de-tensioned. If not, the HI-STAR is leak tested in accordance with Step 6 of Section 7.1.4 above.
2. The relief devices on the neutron shield vessel are verified that they have been replaced within the past 5 years. If not, the relief devices are replaced.

ALARA Warning:
Dose rates around the unshielded bottom end of the cask may be higher that other locations around the cask. After the cask is downended on the transport frame, the bottom impact limiter should be installed promptly. Personnel should remain clear and exercise other appropriate ALARA controls when working around the bottom end of the cask.

3. Buttress plate is installed and the HI-STAR overpack is moved to the transport location. The HI-STAR is down-ended and placed on the transport vehicle. Pocket trunnions, if present, are plugged.
4. HI-STAR is visually inspected for signs of impaired condition.
5. Contamination surveys are performed on the HI-STAR per 49CFR173.443 [7.1.3]. If necessary, the overpack is further decontaminated to meet the surveillance requirements.
6. The impact limiters are installed on the HI-STAR and the bolts are torqued in accordance with Table 7.1.1.

7. The tie-down system is installed and a security seal, one per impact limiter is installed and the seal numbers are recorded in the shipping documents.

8. Final radiation surveys of the package surfaces per 10CFR71.47 [7.1.4] and 49CFR173.443 [7.1.3] are performed and recorded in the shipping documents.

9. The personnel barrier is installed.

10. The assembled package is given a final inspection to verify that all conditions for transport have been met (inspection steps may be performed in any order):

    a. Verify that required radiation survey results are properly documented on the shipping documentation.

    b. Perform a HI-STAR overpack surface temperature check. The accessible surfaces of the HI-STAR Package (impact limiters and personnel barrier) shall not exceed the Exclusive Use temperature limits of 49CFR173.442 [7.1.3].

    c. Verify that all required leakage testing has been performed, the acceptance criteria have been met, and the results have been documented on the shipping documentation.

    d. Verify that the receiver has been notified of the impending shipment and that the receiver has the appropriate procedures and equipment available to safely receive and handle the HI-STAR (10CFR20.1906(e)) [7.1.4].

    e. Verify that the carrier has the written instructions and a list of appropriate contacts for notification of accidents or delays.

    f. Verify that the carrier has written instructions that the shipment is to be Exclusive Use in accordance with 49CFR173.441 [7.1.3].

    g. Verify that route approvals and notification to appropriate agencies have been completed.

    h. Verify that the appropriate labels have been applied in accordance with 49CFR172.403 [7.1.3].

    i. Verify that the appropriate placards have been applied in accordance with 49CFR172.500 [7.1.3].

    j. Verify that all required information is recorded on the shipping documentation.

11. Following the above checks, the HI-STAR 100 System is released for transport.

Table 7.1.1
HI-STAR 100 SYSTEM TORQUE REQUIREMENTS

Fastener	Torque (ft-lbs)	Pattern
Overpack Closure Plate Bolts†, ††	First Pass – Hand Tight Second Pass – Wrench Tight Third Pass – 860 +25/-25 Fourth Pass – 1725 +50/-50 Final Pass - 2000 +250/-0	See Figure 7.1.1
Overpack Vent and Drain Port Plugs	45+5/-2	None
Closure Plate Test Port Plug	45+5/-2	None
Top Impact Limiter Attachment Bolt	256+10/-0	None
Bottom Impact Limiter Attachment Bolt	1500+45/-0	None

† Detorquing shall be performed by turning the bolts counter-clockwise in 1/3 turn +/- 30 degrees increments per pass according to Figure 7.1.1 for three passes. The bolts may then be removed.

†† Bolts shall be cleaned and inspected for damage or excessive wear (replaced if necessary) and coated with a light layer of Fel-Pro Chemical Products, N-5000, Nuclear Grade Lubricant (or equivalent).

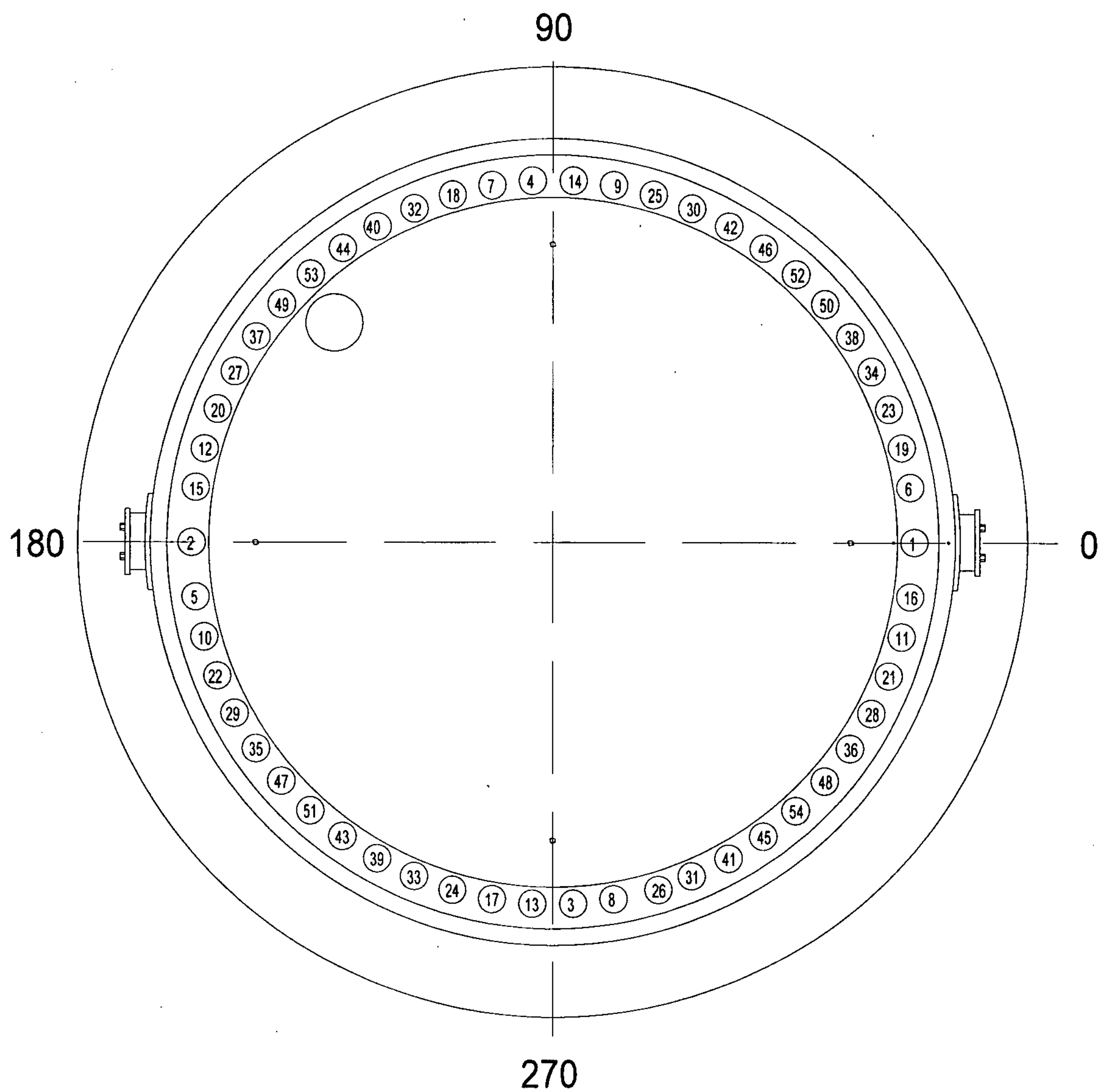

Figure 7.1.1; HI-STAR Closure Plate Bolt Torquing Pattern

7.2 PROCEDURE FOR UNLOADING THE HI-STAR 100 SYSTEM

The essential elements required to prepare the system for fuel unloading, to cool the stored fuel assemblies in the MPC, to flood the MPC cavity, to remove the lid welds, to unload the spent fuel assemblies, and to recover the HI-STAR 100 overpack and empty MPC are described below.

7.2.1 Receipt of Package from Carrier

1. The HI-STAR 100 overpack is received from the carrier and inspected to verify that there are no outward visual indications of impaired physical conditions except for superficial marks and dents. Any road dirt is washed off and any foreign material is removed.

2. The personnel barrier is removed and the security seals are inspected to verify there was no evidence of tampering and that they match the corresponding shipping documents. Any discrepancies are identified to the site management and appropriate authorities.

ALARA Warning:
Dose rates around the unshielded bottom end of the HI-STAR 100 cask may be higher that other locations around the cask. After the impact limiter is removed, the cask should be upended promptly. Personnel should remain clear of the bottom of the unshielded cask and exercise other appropriate ALARA controls.

3. The impact limiters are removed.

4. The HI-STAR is visually inspected to verify there are no outward visual indications of impaired physical conditions except for superficial marks and dents, the neutron shield relief devices are inspected to confirm that they are installed, intact, and not covered, and radiation survey and removable contamination survey are performed per 49CFR173.443 [7.1.3]. Any issues are identified to site management and the overpack is decontaminated as directed by site radiation protection. Note that portions of the inspections, surveys, and decontamination activities described here-in may be performed prior to removal of the impact limiters.

5. The HI-STAR 100 overpack is upended and returned to the fuel building or other unloading area.

6. The buttress plate is removed and the HI-STAR 100 overpack is placed in the designated preparation area. Removal of the buttress plate may be performed prior to placing the HI-STAR in the designated preparation area.

7.2.2 Removal of Contents

1. The HI-STAR 100 overpack vent port cover plate is removed and a gas sample is drawn from the HI-STAR 100 overpack annulus to determine the condition of the MPC confinement boundary.

2. The annulus is depressurized in accordance with Radiation Protection directions and the HI-STAR 100 overpack closure plate is removed.

3. The annulus is filled with clean water and an annulus shield is installed to protect the annulus from debris produced from the lid removal process.

4. The MPC closure ring above the vent and drain ports and the vent and drain port cover plates are core-drilled and removed to access the vent and drain ports.

ALARA Warning:
Gas sampling is performed to assess the condition of the fuel cladding. If a leak is discovered in the fuel cladding, the user's Radiation Control organization may require special actions to vent the cask cavity.

5. A temporary attachment is connected to the vent port to open the vent port and collect a gas sample from inside the MPC. A gas sample analysis is performed to assess the condition of the fuel assembly cladding.

6. The MPC is cooled as necessary to reduce the MPC internal temperature. This allows water flooding without thermally shocking the fuel assemblies or over-pressurizing the MPC from the formation of steam. The MPC is then filled with water.

7. Appropriate monitoring for combustible gas shall be performed prior to, and during MPC lid welding operations. The space below the MPC lid shall be vented/exhausted or purged with inert gas prior to, and during MPC lid cutting operations to provide additional assurance that flammable gas concentrations will not develop in this space. Purging is the recommended method to mitigate flammable gas accumulation.

8. The MPC lid to MPC shell weld is removed using an automated weld removal system or other suitable equipment. The weld removal equipment is removed with the MPC lid left in place.

9. The top surfaces of the HI-STAR 100 overpack and MPC are cleared of metal shavings.

10. The annulus shield is removed and if necessary, the annulus is re-filled with clean water and an annulus seal is installed.

11. The MPC lid is rigged to the lift equipment and the lift attachment is engaged to the HI-STAR 100 overpack lifting trunnions.

ALARA Note:
Wetting the components that enter the spent fuel pool may reduce the amount of decontamination work to be performed later.

12. The HI-STAR 100 overpack is placed in the spent fuel pool or other appropriate unloading area and the MPC lid is removed.

13. All fuel assemblies are returned to the spent fuel storage racks and the MPC fuel cells are vacuumed to remove any assembly debris and crud.

14. The fuel cells are inspected for any remaining items and these are removed as appropriate.

ALARA Warning:
Activated debris may have settled on flat surfaces of the cask during fuel unloading. Surfaces suspected of carrying activated debris should be kept under water until a preliminary dose rate scan clears the cask for removal. To reduce contamination of the cask, the surfaces of the cask and lift yoke should be kept wet until decontamination can begin.

15. The HI-STAR 100 overpack and MPC are returned to the designated preparation area where any water in the MPC is pumped back into the spent fuel pool, liquid radwaste system or other approved location as necessary.

16. The annulus water is drained and the MPC and overpack are decontaminated.

7.3 PREPARATION OF AN EMPTY PACKAGE FOR TRANSPORT

The essential elements for preparing an empty package (previously used) for transport are similar to those required for transporting the loaded package with several exceptions. A survey for removable contamination is performed to verify that the removable contamination on the internal and external surfaces of the HI-STAR 100 overpack are ALARA and that the limits of 49CFR173.428 [7.1.3] and 10CFR71.87(i) [7.1.4] are met. At the user's discretion, impact limiters are installed and the personnel barrier is installed and locked. The installation of the impact limiters and personnel barrier are described in this Section. These steps may be omitted.

1. The Seal Surface Protector is removed from the HI-STAR 100 overpack if necessary.

2. HI-STAR 100 Overpack is surveyed for contamination and verified to be empty and contain less than 15 gm U-235 in accordance with 49CFR173.421(a)(5) [7.1.3].

3. The closure plate is installed on the HI-STAR 100 overpack and the bolts are torqued in accordance with requirements in Table 7.1.1 and the order prescribed in Figure 7.1.1.

4. The vent and drain port cover plates are installed if necessary.

5. The HI-STAR 100 overpack is downended and positioned on the transport equipment.

6. A final inspection of the HI-STAR 100 overpack is performed and includes the following:

   - A final survey for removable contamination on the accessible external surfaces of the HI-STAR 100 overpack in accordance with 49CFR173.443(a) [7.1.3]. If necessary, the overpack is further decontaminated to meet the surveillance requirements.

   - A radiation survey of the HI-STAR 100 overpack to confirm that the radiation levels on any external surface of the overpack do not exceed the levels required by 49CFR173.421(a)(2) [7.1.3]. Any issues are identified to site management and the overpack is decontaminated as directed by site radiation protection.

   - A visual inspection of the HI-STAR 100 overpack to verify that there are no outward visual indications of impaired physical condition except for superficial marks and dents and that the package is securely closed in accordance with 49CFR173.428(b) [7.1.3].

   - Verification is made that the HI-STAR 100 overpack neutron shield relief devices are installed, intact, and are not covered by tape or other covering.

7. If desired, the impact limiters are installed and the impact limiter bolts are torqued in accordance with requirements in Table 7.1.1.

8. A security seal is installed either on the closure plate or on both impact limiters, if installed. The security seal number(s) is (are) recorded on the shipping documentation.

9. Final radiation surveys of the package surfaces are performed per 10CFR71.47 [7.1.4], and 49CFR173.428(a) [7.1.3].

10. If desired, the personnel barrier and personnel barrier locks are installed and the personnel barrier keys are transferred to the carrier.

11. A final check to ensure that the package is ready for release is performed and includes the following checks:

    - Verification that the receiver has been notified of the impending shipment.

    - Verification that any labels previously applied in conformance with Subpart E of 49CFR172 [7.1.3] have been removed, obliterated, or covered and the "Empty" label prescribed in 49CFR172.450 [7.1.3] is affixed to the packaging in accordance with 49CFR173.428(d) [7.1.3].

    - Verification that the package for shipment is prepared in accordance with 49CFR173.422 [7.1.3].

    - Verification that all required information is recorded on the shipping documentation.

12. The HI-STAR 100 System is then released for transport.

7.4 PROCEDURE FOR PREPARING THE HI-STAR 100 OVERPACK FOR TRANSPORT FOLLOWING A PERIOD OF STORAGE

The operations for preparing the loaded HI-STAR 100 Overpack for transport following a period of storage (in excess of one year from the date of completion of HI-STAR 100 overpack mechanical seal leakage testing) are identical to the cask loading and preparation for transport described in Section 7.1.5.

7.5 REFERENCE

[7.1.1] American Society of Mechanical Engineers "Boiler and Pressure Vessel Code". 1995 Edition with 1996 and 1997 Addenda.

[7.1.2] Holtec International Report HI-2012610, HI-STAR 100 System Final Safety Analysis Report.

[7.1.3] U.S. Code of Federal Regulations, "Shippers – General Requirements for Shipments and Packages," Part 49, "Transportation."

[7.1.4] U.S. Code of Federal Regulations, "Standards for Protection Against Radiation", Part 10, "Energy."

[7.1.5] American National Standards Institute, Institute for Nuclear Materials Management, "American National Standard for Radioactive Materials – Leakage Tests on Packages for Shipment," ANSI N14.5-1997.

[7.1.6] Holtec International Report HI-2002444, Final Safety Analysis Report for the HI-STORM 100 Cask System

SUPPLEMENT 7.I

OPERATING PROCEDURES OF THE HI-STAR HB SYSTEM

7.I.0 INTRODUCTION

This chapter outlines the procedures for loading, preparation for shipment, unloading, and preparation for empty cask shipment of the HI-STAR HB System where it differs from the HI-STAR 100 System in accordance with 10CFR71 [7.0.1].

7.I.1 PROCEDURE FOR LOADING AND PREPARATION FOR TRANSPORT OF THE HI-STAR HB SYSTEM

7.I.1.1 Loading of Contents into HI-STAR HB

7.I.1.1.1 Loading of SNF into HI-STAR HB from a Spent Fuel Pool

Steps 1 through 17 as well as 19 through 22 are equivalent to HI-STAR 100 in Section 7.1.3.1. The following is an exception for HI-STAR HB:

18. The helium backfill is adjusted to the pressure equivalent of ≥0 psig and ≤48.8 psig at a reference temperature of 70 degrees Fahrenheit.

CHAPTER 8: ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.0 INTRODUCTION

This chapter identifies the acceptance tests and maintenance program to be conducted on the HI-STAR 100 Package to verify that the structures, systems, and components (SSCs) classified as important to safety have been fabricated, assembled, inspected, tested, accepted, and maintained in accordance with the requirements set forth in this Safety Analysis Report (SAR), the applicable regulatory requirements, and the Certificate of Compliance (CoC). The acceptance criteria and maintenance program described in this chapter fully comply with the requirements of 10CFR Part 71 [8.0.1].

8.1 ACCEPTANCE TESTS

This section provides the workmanship inspections and acceptance tests to be performed on the HI-STAR 100 Package prior to or during use. These inspections and tests provide assurance that the HI-STAR 100 Package has been fabricated, assembled, inspected, tested, and accepted for use and loading under the conditions specified in this SAR and the CoC issued by the NRC in accordance with the requirements of 10CFR Part 71.

8.1.1 Visual Inspections and Measurements

The following visual inspections and measurements shall be performed on the HI-STAR 100 Package, including the MPCs, in order to assure compliance with this SAR and the Certificate of Compliance. Inspections and measurements shall be performed in accordance with written and approved procedures and results shall be documented and become part of the quality documentation package. Any area found to be under the specified minimum thickness shall be repaired in accordance with the applicable ASME code requirements.

1. Visual inspections and measurements shall be made and controls shall be exercised to ensure that the packaging conforms to the dimensions and tolerances specified on the applicable drawings referenced in the CoC, specifically the following:
   a. The radial neutron shield minimum thickness
   b. The impact limiter neutron shield minimum thickness.
   c. The minimum flux trap sizes, if applicable.
   d. The minimum fuel cell pitch, if applicable.
   e. Correct thickness of top flange, closure plate, and bottom plate for gamma shielding.
   f. Correct total measured thickness of inner shell plus intermediate shells over the total surface area.

2. The packaging shall be inspected for cleanliness and proper preparation for shipping in accordance with written and approved procedures.

3. The sealing surfaces (including the lid and all penetrations) shall be inspected to ensure that there are no gouges, cracks, or scratches that could result in unacceptable leakage.

4. The locations, types, and sizes of welds shall be confirmed by measurement to be as specified on the drawings.

5. The packaging will be visually inspected to ensure it is conspicuously and durably marked with the proper markings/labels in accordance with 10CFR71.85(c) and if applicable also in accordance with 10CFR 72.236(k).

6. Visual inspections shall be made to verify that neutron absorber panels are present on the basket cell walls as required by the basket design.

8.1.2 Weld Examinations

All weld examinations shall be performed in accordance with the applicable ASME Code sections as specified on the drawings [8.1.1]. Examination of MPC components shall be performed per ASME Code Section III, Subsections NB, NF, and NG, per NB-5300, NF-5300, and NG-5300 and the code alternatives listed in Table 1.3.2, as applicable. Examination of the overpack shall be performed per ASME Code, Subsection NB, NB-5300 for containment boundary components, and Subsection NF, NF-5300 and the code alternatives listed in Table 1.3.2 for non-containment boundary components.

The MPC lid-to-shell weld shall be verified by either volumetric examination using ultrasonic methods or by surface examination using multi-layer liquid penetrant methods. Regardless of which method is used, the root and final layers shall be examined by liquid penetrant. If liquid penetrant alone is used, additional intermediate examinations shall be conducted after each approximately 3/8 inch of the weld is completed.

All weld examinations shall be performed in accordance with written and approved procedures, by qualified personnel, in accordance with SNT-TC-1A [8.1.2]. All results, including relevant indications, shall be made a permanent part of the quality records by video, photographic, or other means providing an equivalent retrievable record of weld integrity.

8.1.3 Structural and Pressure Tests

The HI-STAR 100 system containment boundary shall be examined and tested using pressure testing, ultrasonic testing, MT and/or PT, as applicable, to verify that it is free of cracks, pinholes, uncontrolled voids or other defects that could significantly reduce the effectiveness of the packaging.

8.1.3.1 Lifting Trunnions

Two trunnions (located near the top of the HI-STAR overpack) are provided for vertical lifting and handling of the HI-STAR 100 Package without the impact limiters installed. The trunnions are designed and shall be inspected and tested in accordance with ANSI N14.6 [8.1.3] as detailed in this Subsection. The trunnions are fabricated using a high-strength and high-ductility material (see overpack drawing in Section 1.4). The trunnions contain no welded components.

In order to ensure that the lifting trunnions do not have any hidden material flaws, the trunnions shall be tested at 300% of the maximum design (service) lifting load. The load shall be applied for a minimum of 10 minutes to the pair of lifting trunnions. The accessible parts of the trunnions (areas outside the HI-STAR overpack), and the local HI-STAR 100 cask areas shall then be visually examined to verify no deformation, distortion, or cracking has occurred. Any evidence of deformation, distortion or cracking of the trunnion or adjacent HI-STAR 100 cask areas shall require replacement of the trunnion and/or repair of the HI-STAR 100 cask. Following any replacements and/or repair, the load testing shall be re-performed and the components re-examined in accordance with the original procedure and acceptance criteria. Testing shall be performed in accordance with written and approved procedures. Certified material test reports verifying trunnion material mechanical properties meet ASME Code Section II requirements provide further verification of the trunnion load capabilities. Test results shall be documented and shall become part of the final quality documentation package.

8.1.3.2 Pressure Testing

8.1.3.2.1 HI-STAR 100 Containment Boundary

The containment boundary of the HI-STAR Package shall be hydrostatically or pneumatically pressure tested to 150 psig +10/-0 psig, in accordance with the requirements of the ASME Code Section III, Subsection NB, Article NB-6000 and the code alternatives listed in Table 1.3.2. The test pressure of 150 psig is 150% of the Maximum Normal Operating Pressure (MNOP).

The overpack pressure test may be performed at any time during fabrication after the containment boundary is complete. The HI-STAR overpack shall be assembled for this test with the closure plate mechanical seal (only one required) or temporary test seal installed.

The test pressure shall be maintained for ten minutes. During this time period, the pressure gauge reading shall not fall below 150 psig. At the end of ten minutes, and while the pressure is being maintained at a minimum of 150 psig, the overpack shall be observed for leakage. In particular, the closure plate-to-top forging joint (the only credible leakage point) shall be examined. If a leak is discovered, the overpack shall be emptied and an evaluation shall be performed to determine the cause of the leakage. Repairs and retest shall be performed until the pressure test acceptance criterion is met.

After completion of the pressure testing, the overpack closure plate shall be removed and the internal surfaces shall be visually examined for cracking or deformation. Any evidence of cracking or deformation shall be cause for rejection or repair and retest, as applicable. The overpack shall be required to be pressure tested until the examinations are found to be acceptable.

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

8.1.3.2.2 MPC Pressure Boundary

Pressure testing (hydrostatic or pneumatic) of the MPC pressure boundary shall be performed in accordance with the requirements of the ASME Code Section III, Subsection NB, Article NB-6000, applicable sub-articles, and the code alternatives listed in Table 1.3.2 when field welding of the MPC lid-to-shell weld is completed. If hydrostatic testing is used, the MPC shall be pressure tested to 125% of design pressure. The minimum hydrostatic test pressure shall be 125 psig. If pneumatic testing is used, the MPC shall be pressure tested to 120% of the design pressure. The minimum pneumatic test pressure shall be 120 psig. Following completion of the required hold period at the test pressure, and after determining the leakage acceptance criterion is met, the surface of the MPC lid-to-shell weld shall be re-examined by liquid penetrant examination performed in accordance with ASME Code Section V, Article 6, with acceptance criteria per ASME Code Section III, Subsection NB, Article NB-5350.

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

8.1.3.3 Pneumatic Testing of the Neutron Shield Enclosure Vessel

A pneumatic pressure test of the neutron shield enclosure vessel shall be performed following final closure welding of the enclosure shell returns and enclosure panels. The pneumatic test pressure shall be 37.5 +2.5,-0 psig, which is 125 percent of the relief device set pressure. The test shall be performed in accordance with approved written procedures.

During the test, the relief devices on the neutron shield enclosure vessel shall be removed. One of the relief device threaded connections is used for connection of the air pressure line and the other connection will be used for connection of the pressure gauge.

Following the introduction of pressurized gas into the neutron shield enclosure vessel, a 15-minute pressure hold time is required. If the neutron shield enclosure vessel fails to hold pressure, an approved soap bubble solution shall be applied to determine the location of the leak. The leak shall be repaired using weld repair procedures prepared in accordance with the ASME Code Section III, Subsection NF, Article NF-4450. The pneumatic pressure test shall be re-performed until no pressure loss is observed.

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

8.1.4 Leakage Tests

Leakage testing shall be performed in accordance with the requirements of ANSI N14.5-1997 [8.1.4]. Testing shall be performed in accordance with written and approved procedures. A leakage test of the HI-STAR overpack shall be performed at any time after the containment boundary fabrication is complete. The leakage test instrumentation shall have a minimum test sensitivity of $2.15x10^{-6}$ atm cm^3/s (helium). Containment boundary welds shall have indicated leakage rates not exceeding $4.3x10^{-6}$ atm cm^3/s (helium).

8.1.5 Component and Material Tests

The majority of materials used in the HI-STAR overpack are ferritic steels. ASME Code Section III and Regulatory Guides 7.11 [8.1.5] and 7.12 [8.1.6] require that certain materials be tested in order to assure that these materials are not subject to brittle fracture failures.

Each plate or forging for the HI-STAR 100 Package containment boundary (overpack inner shell, bottom plate, top flange, and closure plate) shall be required to be drop weight tested in accordance with the requirements of Regulatory Guides 7.11 and 7.12, as applicable. Additionally, per the ASME Code Section III, Subsection NB, Article NB-2300, Charpy V-notch testing shall be performed on these materials. Weld material used in welding the containment boundary shall be Charpy V-notch tested in accordance with ASME Section III, Subsection NB, Articles NB-2300 and NB-2430.

Non-containment portions of the overpack, as required, shall be Charpy V-notch tested in accordance with ASME Section III, Subsection NF, Articles NF-2300, and NF-2430. The non-containment materials to be tested include the intermediate shells, overpack port cover plates, and applicable weld materials.

Tables 2.1.22 and 2.1.23 provide the test temperatures or T_{NDT}, and test requirements to be used when performing the testing specified above.

8.1.5.1 Valves, Relief Devices, and Fluid Transport Devices

No fluid transport devices are associated with the HI-STAR 100 Package. The only valve-like components in the HI-STAR 100 Package are the specially designed caps installed in the MPC lid for the drain and vent ports. These caps are recessed inside the MPC lid and covered by the fully welded vent and drain port cover plates. No credit is taken for the caps' ability to confine helium or radioactivity. After completion of drying and backfill operations, the drain and vent port cover plates are welded in place on the MPC lid and are leak tested to verify the MPC pressure boundary.

There are two relief devices (rupture discs) installed in the upper ledge surface of the neutron shield enclosure vessel of the HI-STAR overpack. These relief devices are provided for venting purposes under hypothetical fire accident conditions in which vapor formation from neutron shielding material degradation may occur. The relief devices are designed to relieve at 30 psig (± 5 psig).

8.1.5.2 Seals and Gaskets

Two concentric mechanical seals are provided on the HI-STAR overpack closure plate to provide containment boundary sealing. Mechanical seals are also used on the overpack vent and drain port plugs of the HI-STAR overpack containment boundary. Each primary seal is individually leak tested, in accordance with Subsection 8.1.4, prior to the HI-STAR 100 Package's first use and during each loading operation. An independent and redundant seal is provided for each penetration (e.g., closure plate, port cover plates, and closure plate test plug). No containment credit is taken for these redundant seals and they are not leakage tested. Details on these seals are provided in Chapter 4.

8.1.5.3 Transport Impact Limiter

The removable HI-STAR transport impact limiters consist of aluminum honeycomb crush material arranged around a carbon steel structure and enclosed by a stainless steel shell. The drawings in Chapter 1 specify the crush strength of the aluminum honeycomb materials (nominal +/- 7%) for each zone of the impact limiter. For manufacturing purposes, verification of the impact limiter material is accomplished by performance of a crush test of sample blocks of aluminum honeycomb material for each large block manufactured. The verification tests are performed in accordance with approved procedures. The certified test results shall be submitted to Holtec International with each shipment of material.

All welds on the HI-STAR impact limiter shall be visually examined in accordance with the ASME Code, Section V, Article 9, with acceptance criteria per ASME Section III, Subsection NF, Article NF-5360.

8.1.5.4 Neutron Shielding Material

Neutron shield properties of Holtite-A are provided in Chapter 1. Each manufactured lot of neutron shield material shall be tested to verify that the material composition (aluminum and hydrogen), boron concentration, and neutron shield density (or specific gravity) meet the requirements specified in Chapter 1. A manufactured lot is defined as the total amount of material used to make any number of mixed batches comprised of constituent ingredients from the same lot/batch identification numbers supplied by the constituent manufacturer. Testing shall be performed in accordance with written and approved procedures and/or standards. Material composition, boron concentration, and density (or specific gravity) data for each manufactured lot of neutron shield material shall become part of the quality record documentation package.

The installation of the neutron shielding material shall be performed in accordance with written, approved, and qualified procedures. The procedures shall ensure that mix ratios and mixing methods are controlled in order to achieve proper material composition, boron concentration and distribution, and that pours are controlled in order to prevent gaps or voids from occurring in the material. Holtec International shall maintain samples of each manufactured lot of neutron shield material.

Users shall implement procedures which verify the integrity of the Holtite-A neutron shield once for each overpack. Neutron shield integrity shall be verified via measurements either at first use or with a check source using, at a maximum, a 6x6 inch test grid over the entire surface of the neutron shield, including the impact limiters. Measurements shall be compared to calculated values representative of either the check source being used or the loaded contents.

If a check source was used in the shielding integrity test, following the first fuel loading of each HI-STAR 100 Package, a shielding effectiveness test shall be performed to verify the effectiveness of the neutron shield using written and approved procedures. Calibrated radiation detection equipment shall be used to take measurements at the surface of the HI-STAR overpack. Measurements shall be taken at three cross sectional planes through the radial shield and at four points along each plane's circumference. The average measurement results from each sectional plane shall be compared to calculated values to assess the continued effectiveness of the neutron shield. The calculated values shall be representative of the loaded contents (i.e., fuel type, enrichment, burnup, cooling time, etc...). Measurements shall be documented and become part of the quality documentation package.

8.1.5.5 Neutron Absorber Material

Each plate of neutron absorber shall be visually inspected for damage such as scratches, cracks, burrs, peeled cladding, foreign material embedded in the surfaces, voids, delamination, and surface finish.

8.1.5.5.1 Boral

After manufacturing, a statistical sample of each lot of neutron absorber shall be tested using wet chemistry and/or neutron attenuation testing to verify minimum ^{10}B content (areal density) in samples taken from the ends of the panel. The minimum ^{10}B loading of the neutron absorber panels for each MPC model must comply with the limits specified on the drawings. Any panel in which ^{10}B loading is less than the minimum allowed shall be rejected. Testing shall be performed using written and approved procedures. Results shall be documented and become part of the cask quality records documentation package.

8.1.5.5.2 METAMIC®

8.1.5.5.2.1 Manufacturing Process

METAMIC is manufactured by Nanotec Metals which is a division of Holtec International.

The following is a description of the manufacturing process for the METAMIC neutron absorber panels.

Aluminum alloy 6061 powder and Type 1 ASTM C-750 B_4C powder with a specified minimum B-10 content are analyzed for particle size, screened, and carefully blended to form a lot in an inert atmosphere, without binders or other additives that could potentially adversely influence performance. Each lot will make approximately 200 mixed batches, all with the same isotopic percentage of B-10.

Each mixed batch is further blended and three powder samples are taken from the mixed batch. One sample is tested via wet chemistry to verify the correct B_4C weight percent. The other samples are kept for archiving purposes. This blend of powders is isostatically compacted into a billet under high pressure. Then the billet is vacuum sintered to near theoretical density. The vacuum levels and temperatures are monitored during the process. Each mixed batch will typically make three billets, all with the same B_4C weight percent.

The compacted material (billet) is then extruded into a piece of bloom stock under tight temperature monitoring and controlled extrusion speed. An inert gas blanket prevents oxide formation. The surfaces of the bloom stock are cleaned, either chemically or mechanically, in accordance with written procedures to remove any contaminants which may cause corrosion. Procedures are in place to ensure that the bloom stock remains covered or on surfaces free of metals such as iron or steel. The cleaning procedure and precautions reduce the amount of contaminants in the final product. The bloom stock is typically cut into two pieces and each is rolled to final thickness and appropriate length using a strict reduction schedule.

Typically two panels are made from each piece of bloom stock. The panel is made by shearing the top, bottom and sides of the rolled piece to the specified length and width. Before shearing to the final length a test coupon that is approximately 4"x6" is sheared from the end of the panel and kept as a permanent record or used for further testing.

8.1.5.5.2.2 Acceptance Criteria

The parameter most important for the criticality control function of the neutron absorber is the so-called B-10 areal density, i.e. the amount of B-10 per unit area of the absorber panel (usually specified as gm B-10/cm^2). While this parameter can be measured in the final product (via neutron attenuation testing), it is not a direct input into the manufacturing process. However, the value is the mathematical product of three input and process parameters, namely the B_4C weight percent of the material, the percent B-10 in the Boron in the B_4C, and the thickness of the panel, together with an appropriate proportionality constant (Equation (1) from the Metamic qualification program documentation [1.2.21]).

Areal Density (g B-10 /cm^2) = 0.7826 * FB4C * t * ρ * FB-10 (Equation 8-1)

Where: FB4C is the weight percent of B4C in the Metamic
t is the thickness of the panel (cm)
ρ is the density of the Metamic (g/cm^3)
FB-10 is the isotopic percentage of B-10 in the Boron

To provide a robust and conservative acceptance criteria approach, each of these three parameters is controlled independently in the manufacturing process and each parameter must independently meet a specified minimum required value. The density used in the calculations is 99% of the theoretical density. Further, the evaluations in Chapter 6 are also based on the minimum value of each parameter (with a further reduction per NUREG/CR-5661 [1.2.20], as discussed below). This approach essentially guarantees that the panels exceed the required areal density. Since the approach uses a worst-case combination of the minimum value for each parameter, no statistical evaluation or criteria is required. The specific requirements are therefore:

- All lots of B_4C will contain boron with an isotopic B-10 content of at least 18.4%.

- The B_4C content in METAMIC® shall be greater than or equal to 31.5 and less than or equal to 33.0 weight percent.

- The Metamic panel thickness must be no less than the minimum thickness specified in the drawings in Section 1.4

NUREG/CR-5661 identifies the main reason for a penalty in the neutron absorber B-10 density as the potential of neutron streaming due to non-uniformities in the neutron absorber, and recommends comprehensive acceptance tests to verify the presence and uniformity of the neutron absorber for credits more than 75%. Since a 90% credit is taken for METAMIC®, the following criteria must be satisfied:

- The boron carbide powder used in the manufacturing of METAMIC® must have 50% of the particles with particle size less than 25 microns and 97% of the particles with particle size less than 50 microns to preclude neutron streaming.

- The ^{10}B areal density must comply with the limits specified on the drawings.

- The B_4C powder must be uniformly dispersed locally i.e. must not show any particle agglomeration. This precludes neutron streaming.

- The B_4C powder must be uniformly dispersed macroscopically i.e. must have a consistent concentration throughout the entire neutron absorber panel.

- The maximum B_4C content in METAMIC® shall be less than or equal to 33.0 weight percent.

8.1.5.5.2.3 Acceptance Testing

To effectively and reliably ensure that all manufactured panels are acceptable, a two-phase approach is used: a) a qualification testing program is performed such that the manufacturing process and procedures consistently result in panels with acceptable parameters and properties. This program also confirms the validity of the wet chemistry tests using neutron attenuation testing; and b) during production runs, the three main parameters are verified for each panel, and neutron attenuation testing is performed on coupons from a percentage of the panels to provide additional assurance. Further details are discussed below.

Qualification Testing Program

- The following qualification testing shall be performed on the first production run[1] of METAMIC® panels for the MPCs in order to validate the acceptability and consistency of the manufacturing process and verify the acceptability of the METAMIC® panels for neutron absorbing capabilities:

  1) The boron carbide powder weight percent shall be verified by testing a sample from forty different mixed batches. (A mixed batch is defined as a single mixture of aluminum powder and boron carbide powder used to make one or more billets. Each billet will produce several panels.) The samples shall be drawn from the mixing containers after mixing operations have been completed. Testing shall be performed using the wet chemistry method.

  2) The ^{10}B areal density shall be verified by testing a sample from one panel from each of forty different mixed batches. The samples shall be drawn from areas contiguous to the manufactured panels of METAMIC® and shall be tested using the wet chemistry method. Alternatively, or in addition to the wet chemistry tests, neutron attenuation tests on the samples may be performed to quantify the actual ^{10}B areal density.

  3) To verify the local uniformity of the boron particle dispersal, neutron attenuation measurements of random test coupons shall be performed. These test coupons may come from the production run or from pre-production trial runs.

  4) To verify the macroscopic uniformity of the boron particle distribution, test samples shall be taken from the sides of one panel from five different mixed batches before the panels are cut to their final sizes. The sample locations shall be chosen to be representative of the final product. Wet chemistry or neutron attenuation shall be performed on each of the samples.

Testing of Production Runs

To ensure that the acceptance criteria are met the following tests shall be performed during production:

- All lots of boron carbide powder are analyzed to meet particle size distribution requirements.

- All lots of B_4C will be certified as containing Boron with a minimum 18.4% of isotopic B-10 per the purchase specification.

1 The requirement for qualification testing of the first production run of METAMIC® panels has been fulfilled and records are maintained by Holtec International. The results of the qualification testing demonstrated that the manufacturing process produces METAMIC® panels which meet or exceed the requirements for criticality control.

- Wet chemistry testing of a sample from each mixed batch shall be performed to verify the correct boron carbide weight percent is being mixed. The mixing of the batch is controlled via approved procedures.

- The thickness of each final panel will be measured in at least six places, with two at one end, two at the other end and two in the middle.

The measurements of B_4C content, particle size, thickness, and uniformity of B_4C distribution (via wet chemistry test) shall be made using written and approved procedures. If any one of the acceptance criteria is not met, the panel shall not be used in the fuel basket. Results shall be documented and become part of the cask quality records documentation package.

As an additional verification, ten percent of the test coupons from random METAMIC® panels shall be tested via neutron attenuation testing using a 1 inch diameter thermal neutron beam to verify the ^{10}B areal density. These coupons shall be taken from areas contiguous to the manufactured panels. This test shall be performed to verify the continued acceptability of the manufacturing process.

8.1.5.6 Gamma Shielding

The gamma shielding (steel) in the construction of the HI-STAR 100 package is dimensionally inspected to assure compliance with the applicable drawings referenced in the CoC and as required in Subsection 8.1.1.

8.1.6 Thermal Tests

The first fabricated HI-STAR 100 overpack was tested to confirm its heat transfer capability. The test was performed and documented in Holtec Document DOC-5014-03 [8.1.7]. The tests have shown that the HI-STAR 100 system is within acceptable limits and future thermal testing is no longer required.

8.2 MAINTENANCE PROGRAM

An ongoing maintenance program is defined and incorporated in the HI-STAR 100 System Operations Manual that will be prepared and issued to each user prior to delivery and first use of the HI-STAR 100 Package. This document shall delineate the detailed inspections, testing, and parts replacement necessary to ensure continued radiological safety, proper handling, and containment performance of the HI-STAR 100 Package in accordance with 10CFR71 regulations, conditions in the Certificate of Compliance (CoC), and the design requirements and criteria contained in this Safety Analysis Report (SAR).

The HI-STAR 100 Package is totally passive by design. There are no active components or systems required to assure the continued performance of its safety functions. As a result, only minimal maintenance will be required over its lifetime, and this maintenance would primarily result from weathering effects, and pre- and post-usage requirements for transportation. Typical of such maintenance would be the reapplication of corrosion inhibiting materials on accessible external surfaces, and seal replacement and leak testing following replacement. Such maintenance requires methods and procedures are no more demanding than those currently in use at power plants.

The maintenance program schedule for the HI-STAR 100 Package is provided in Table 8.2.1.

8.2.1 Structural and Pressure Tests

Prior to each fuel loading, a visual examination in accordance with a written and approved procedure shall be required of the following HI-STAR 100 Package components: lifting trunnions (area outside of the overpack); overpack internals and externals; and impact limiters. The examination shall inspect for indications of overstress such as cracking, deformation or wear marks, gross damage to components, or areas of chipped or missing surface coatings. Repairs or replacement in accordance with written and approved procedures shall be required if unacceptable conditions are identified.

No periodic structural or pressure tests on the overpack or MPCs following the initial acceptance tests are required to verify continuing performance.

8.2.2 Leakage Tests

Mechanical seals are used on the HI-STAR 100 overpack containment boundary to ensure the retention of the radioactive material contents in the HI-STAR 100 Package. These seals are not temperature sensitive within the design temperature range, are resistant to corrosion and radiation environments, and are helium leak tested after fuel loading. The containment system has been designed to withstand normal and accident conditions of transport without loss of containment integrity. The overpack containment penetration seals shall be leakage tested in accordance with Chapter 7 and the acceptance criteria of Subsection 8.1.4.

The mechanical seals on the overpack containment boundary shall be replaced as defined in Table 8.2.1. After each replacement, the helium leak test of the overpack containment seals described in Chapter 7 shall be performed. Prior to replacement of each seal, the mating surfaces shall be cleaned and visually inspected for scratches, pitting or roughness, and affected surface areas shall be polished smooth or repaired as necessary in accordance with written and approved procedures. The bolting for the closure plate and the vent and drain port cover plates, and port plugs shall also be inspected for indications of wear, galling, or indentations on the threaded surfaces prior to reinstallation and closure torquing. Any bolt or port plug showing any of these indications shall be replaced.

8.2.3 Component and Material Tests

The relief devices on the overpack neutron shield enclosure shell shall be visually inspected prior to each use of the HI-STAR 100 Package for damage or indications of excessive corrosion. If the inspection determines an unacceptable condition, the relief devices shall be replaced. The relief devices shall be replaced with approved spares every five years while the cask is in transport service.

8.2.4 Shielding

Periodic verification of the neutron shield integrity shall be performed within 5 years prior to each shipment. The periodic verification shall be performed by radiation measurements with either loaded contents or a check source. Measurements shall be taken at three cross sectional planes through the radial shield and at four points along each plane's circumference. The average measurement results from each sectional plane shall be compared to calculated values to assess the continued effectiveness of the neutron shield. The calculated values shall be representative of the loaded contents (i.e., fuel type, enrichment, burnup, cooling time, etc...) or the particular check source used for the measurements.

8.2.5 Thermal Tests

For each package, a periodic thermal performance test shall be performed within 5 years prior to each shipment, to demonstrate that the thermal capabilities of the cask remain within its design basis.

8.2.6 Miscellaneous Tests

The impact limiters shall be visually inspected in accordance with a written procedure prior to each use to inspect for surface denting, surface penetrations, and weld cracking. Any areas found to not meet the defined acceptance criteria shall be repaired and/or replaced in accordance with written and approved procedures.

Table 8.2.1

MAINTENANCE AND INSPECTION PROGRAM SCHEDULE

Task	Frequency
Overpack cavity and external surface (accessible) visual inspection	Prior to each fuel loading
Overpack bolting and port plug visual inspection	Prior to installation and prior to each transport
Lifting trunnion and pocket trunnion recess visual inspection	Prior to each fuel loading and prior to each transport
Containment System Periodic Leakage Test of closure plate, and vent and drain port plugs	Following each fuel loading, and prior to off-site transport if period from last test exceeds 1 year
Containment System Fabrication Verification Leakage Test of containment boundary closures	After third use
Transport impact limiter visual inspection	Prior to each transport
Closure plate mechanical seal replacement	Following removal of closure plate bolting
Closure plate bolt replacement	Every 240 bolting cycles (assumes 20 years at 12 cycles per year)
Port plug seal replacement	Following removal of applicable port plug
Port cover plate seal replacement	Following removal of applicable cover plate
Relief Device visual inspection	Prior to each transport
Relief Device replacement	Every five years
Thermal Test	Within 5 years prior to each shipment
Shielding Test	Within 5 years prior to each shipment

8.3 REFERENCES

[8.0.1] U.S. Code of Federal Regulations, Title 10, "Energy", Part 71, "Packaging and Transportation of Radioactive Materials."

[8.1.1] American Society of Mechanical Engineers, " Boiler and Pressure Vessel Code," Sections II, III, V, IX, and XI, 1995 Edition with 1996 and 1997 Addenda.

[8.1.2] American Society for Nondestructive Testing, "Personnel Qualification and Certification in Nondestructive Testing," Recommended Practice No. SNT-TC-1A, December 1992.

[8.1.3] American National Standards Institute, Institute for Nuclear Materials Management, "American National Standard for Radioactive Materials - Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4500 kilograms) or More", ANSI N14.6, September 1993.

[8.1.4] American National Standards Institute, Institute for Nuclear Materials Management, "American National Standard for Radioactive Materials Leakage Tests on Packages for Shipment", ANSI N14.5, 1997.

[8.1.5] U.S. Nuclear Regulatory Commission, "Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Maximum Wall Thickness of 4 Inches (0.1m)," Regulatory Guide 7.11, June 1991.

[8.1.6] U.S. Nuclear Regulatory Commission, "Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Wall Thickness Greater than 4 Inches (0.1m) But Not Exceeding 12 Inches (0.3m)," Regulatory Guide 7.12, June 1991.

[8.1.7] Holtec International Document DOC-5014-03, "Acceptance Testing of First HI-STAR Overpack (Thermal and He Leak Tests)", September 2006.

SUPPLEMENT 8.I

ACCEPTANCE TEST & MAINTENANCE PROGRAM

The main body of this chapter remains fully applicable for the HI-STAR HB configuration of the HI-STAR 100 System.