TABLE 6.4.1

MAXIMUM REACTIVITIES WITH REDUCED EXTERNAL WATER DENSITIES

Water Density		**Maximum k_{eff}**	
Internal	**External**	**MPC-37 (17x17B, 5.0%)**	**MPC-89 (10x10A, 4.8%)**
100%	100%	0.9380	0.9435
100%	70%	0.9377	0.9432
100%	50%	0.9399	0.9439
100%	20%	0.9366	0.9428
100%	10%	0.9374	0.9437
100%	5%	0.9376	0.9435
100%	1%	0.9383	0.9435

TABLE 6.4.2

REACTIVITY EFFECTS OF PARTIAL CASK FLOODING

MPC-37 (17x17B, 5.0% ENRICHMENT)		
Flooded Condition (% Full)	Maximum k_{eff}, Vertical Orientation	Maximum k_{eff}, Horizontal Orientation
25	0.9175	0.8306
50	0.9325	0.9093
75	0.9357	0.9349
100	0.9380	0.9380
MPC-89 (10x10A, 4.8% ENRICHMENT)		
Flooded Condition (% Full)	Maximum k_{eff}, Vertical Orientation	Maximum k_{eff}, Horizontal Orientation
25	0.9204	0.8345
50	0.9382	0.9128
75	0.9416	0.9392
100	0.9435	0.9435

TABLE 6.4.3

REACTIVITY EFFECT OF FLOODING THE PELLET-TO-CLAD GAP

Pellet-to-Clad Condition	Maximum k_{eff}	
	MPC-37 (17x17B, 5.0% ENRICHMENT)	**MPC-89 (10x10A, 4.8% ENRICHMENT)**
dry	0.9335	0.9391
flooded with unborated water	0.9380	0.9435

TABLE 6.4.4

REACTIVITY EFFECT OF PREFERENTIAL FLOODING OF THE DFCs

DFC Configuration	**Maximum k_{eff}**	
	Preferential Flooding	**Fully Flooded**
MPC-37 with 12 DFCs (5% Enrichment, Undamaged assembly 15x15F, 20x20 Bare Rod Array)	0.8705	0.9276
MPC-89 with 16 DFCs (4.8 % Enrichment, Undamaged assembly 10x10A, 9x9 Bare Rod Array)	0.8296	0.9464

TABLE 6.4.5

MAXIMUM k_{eff} VALUES WITH REDUCED WATER DENSITIES

Internal Water Density† in g/cm^3	**Maximum k_{eff}**						
	MPC-89 10x10A, 4.8%	**MPC-37 (1500ppm) 17x17B, 4.0 %**		**MPC-37 (2000ppm) 17x17B, 5.0 %**		**MPC-37† (2300ppm) 15x15F and Damaged Fuel 5.0 %**	
Guide Tubes	N/A	filled	void	filled	void	filled	void
1.00	0.9435	0.9181	0.9071	0.9380	0.9292	0.9276	0.9265
0.99	0.9415	0.9181	0.9059	0.9367	0.9296	0.9271	0.9264
0.98	0.9391	0.9162	0.9054	0.9368	0.9279	0.9271	0.9257
0.97	0.9370	0.9166	0.9035	0.9364	0.9272	0.9265	0.9242
0.96	0.9345	0.9147	0.9005	0.9360	0.9265	0.9265	0.9232
0.95	0.9304	0.9148	0.9010	0.9356	0.9243	0.9253	0.9217
0.94	0.9280	0.9133	0.8995	0.9335	0.9238	0.9255	0.9225
0.93	0.9259	0.9128	0.8986	0.9355	0.9237	0.9263	0.9214
0.92	0.9232	0.9120	0.8955	0.9327	0.9203	0.9237	0.9204
0.91	0.9183	0.9105	0.8947	0.9335	0.9208	0.9229	0.9194
0.90	0.9169	0.9090	0.8934	0.9303	0.9189	0.9226	0.9169
0.85	0.9013	0.9042	0.8840	0.9272	0.9109	0.9190	0.9127
0.80	0.8850	0.8973	0.8733	0.9222	0.9022	0.9138	0.9040
0.70	0.8462	0.8813	0.8477	0.9068	0.8780	0.9000	0.8851
0.60	0.7980	0.8565	0.8132	0.8866	0.8478	0.8806	0.8571
0.40	0.6762	0.7876	0.7195	0.8244	0.7585	0.8192	0.7735
0.20	0.5268	0.6827	0.5806	0.7284	0.6298	0.7237	0.6517
0.10	0.4649	0.6206	0.5112	0.6698	0.5639	0.6669	0.5889

† External moderator is modeled at 100%.

† With undamaged and damaged fuel. All other cases with undamaged fuel only

TABLE 6.4.6

MAXIMUM k_{eff} VALUES IN THE MPC-37 WITH UNDAMAGED (15x15F) AND DAMAGED FUEL

Bare Rod Array inside the DFC	**Maximum k_{eff}, 4.0 wt%**	**Maximum k_{eff}, 5.0 wt%**
8x8	0.8883	0.9122
10x10	0.8899	0.9135
12x12	0.8910	0.9152
14x14	0.8945	0.9177
15x15	0.8966	0.9198
16x16	0.8982	0.9224
17x17	0.9003	0.9238
18x18	0.9027	0.9262
20x20	0.9032	0.9276
22x22	0.9023	0.926
24x24	0.9008	0.9239

TABLE 6.4.7

MAXIMUM k_{eff} VALUES IN THE MPC-89 WITH UNDAMAGED (10x10A) AND DAMAGED FUEL

Bare Rod Array inside the DFC	Maximum k_{eff}, 4.8 wt% (planar average)
4x4	0.9389
6x6	0.9411
8x8	0.9432
9x9	0.9464
10x10	0.9454
11x11	0.9451
12x12	0.9460
13x13	0.9453
14x14	0.9444
16x16	0.9429
18x18	0.9423

TABLE 6.4.8
MAXIMUM k_{eff} VALUES IN THE MPC-89 WITH LOW ENRICHED (3.3 wt% ^{235}U), CHANNELED, BWR FUEL

Rod Array inside the Channel	Maximum k_{eff}
4x4	0.4018
6x6	0.7320
8x8	0.8999
9x9	0.9294
10x10	0.9325
11x11	0.9131
12x12	0.8762
13x13	0.8237
14x14	0.7606
16x16	0.6664
18x18	0.6334

TABLE 6.4.9

COMPARISON OF MCNP CONVERGENCE PARAMETERS

Calculation Parameters		**Maximum k_{eff}**	
Particles per Cycle	Skipped Cycles	**MPC-37 (17x17B, 5.0% ENRICHMENT)**	**MPC-89 (10x10A, 4.8% ENRICHMENT)**
20,000	20	0.9380	0.9435
50,000	20	0.9376	0.9428
20,000	100	0.9387	0.9436
50,000	100	0.9379	0.9434

TABLE 6.4.10

COMPARISON OF MAXIMUM k_{eff} VALUES FOR EACH ASSEMBLY CLASS IN THE MPC-37 WITH CONDITIONS OF FILLED AND VOIDED GUIDE AND INSTRUMENT TUBES AT 5 % ENRICHMENT

Fuel Assembly Class	Maximum k_{eff}, Filled Tubes	Maximum k_{eff}, Voided Tubes
14x14A	0.8983	0.8887
14x14B	0.9282	0.9148
14x14C	0.9275	0.9277
15x15B	0.9311	0.9251
15x15C	0.9188	0.9134
15x15D	0.9421	0.9379
15x15E	0.9410	0.9365
15x15F	0.9455	0.9404
15x15H	0.9325	0.9317
15x15I	0.9357	0.9362
16x16A	0.9366	0.9320
16x16A[DFC]	0.9400	0.9404
16x16B	0.9334	0.9301
16x16C	0.9187	0.9015
17x17A	0.9194	0.9135
17x17B	0.9380	0.9292
17x17C	0.9424	0.9345
17x17D	0.9384	0.9293
17x17E	0.9392	0.9314

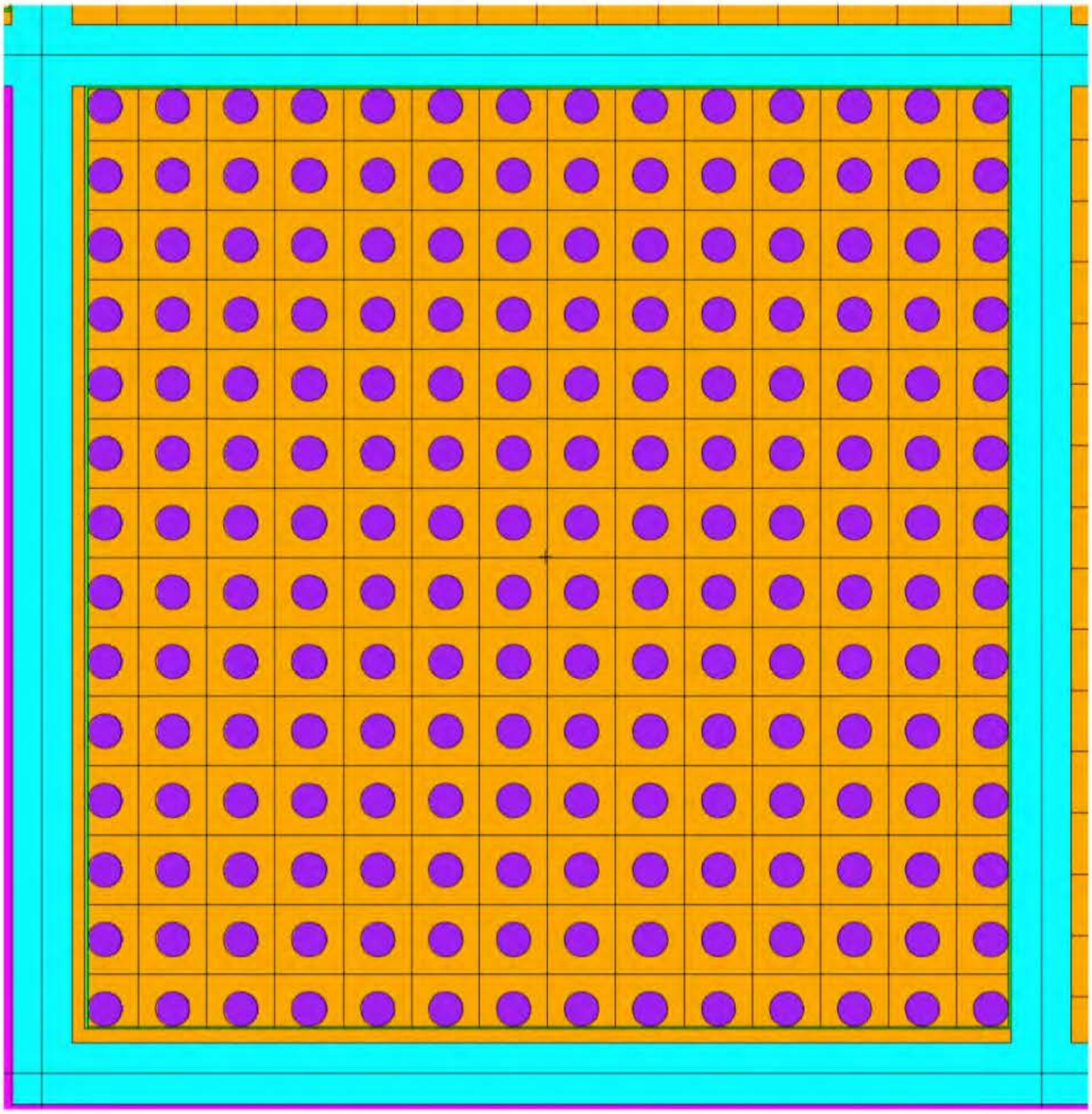

Figure 6.4.1: Calculational Model (planar cross-section) of a DFC in a MPC-37 cell with a 14x14 array of bare fuel rods

6.5 CRITICALITY BENCHMARK EXPERIMENTS

Benchmark calculations have been made on selected critical experiments, chosen, insofar as possible, to bound the range of variables in the cask designs. The most important parameters are (1) the enrichment, (2) cell spacing, and (3) the ^{10}B loading of the neutron absorber panels. Other parameters, within the normal range of cask and fuel designs, have a smaller effect, but are also included. No significant trends were evident in the benchmark calculations or the derived bias. Detailed benchmark calculations are presented in Appendix 6.A.

The benchmark calculations were performed with the same computer codes and cross-section data, described in Section 6.4, that were used to calculate the k_{eff} values for the cask. Further, all calculations were performed on the same computer hardware (personal computers).

6.6 REGULATORY COMPLIANCE

This section documents the criticality evaluation of the HI-STORM FW system for the storage of spent nuclear fuel. This evaluation demonstrates that the HI-STORM FW system is in full compliance with the criticality requirements of 10CFR72 and NUREG-1536.

Structures, systems, and components important to criticality safety, as well as the limiting fuel characteristics, are described in sufficient detail in this section to enable an evaluation of their effectiveness.

The HI-STORM FW system is designed to be subcritical under all credible conditions. The criticality design is based on favorable geometry and fixed neutron poisons. An appraisal of the fixed neutron poison has shown that they will remain effective for a storage period greater than 60 years, and there is no credible way to lose it; therefore, there is no need to provide a positive means to verify their continued efficacy as required by 10CFR72.124(b).

The criticality evaluation has demonstrated that the cask will enable the storage of spent fuel for a minimum of 60 years with an adequate margin of safety. Further, the evaluation has demonstrated that the design basis accidents have no adverse effect on the design parameters important to criticality safety, and therefore, the HI-STORM FW system is in full compliance with the double contingency requirements of 10CRF72.124. Therefore, it is concluded that the criticality design features for the HI-STORM FW system are in compliance with 10 CFR Part 72 and that the applicable design and acceptance criteria have been satisfied. The criticality evaluation provides reasonable assurance that the HI-STORM FW system will allow safe storage of spent fuel.

6.7 REFERENCES

[6.0.1] HI-STORM 100 FSAR, NRC Docket 72-1014, Holtec Report HI-2002444, Latest revision

[6.0.2] "Criticality Analyses for the HI-STORM FW System", Holtec Report HI-2094432 Rev.6 (proprietary)

[6.1.1] NUREG-1536, Standard Review Plan for Dry Cask Storage Systems, USNRC, Washington, D.C., January 1997.

[6.1.2] 10CFR72.124, "Criteria For Nuclear Criticality Safety."

[6.1.3] not used

[6.1.4] "MCNP - A General Monte Carlo N-Particle Transport Code, Version 5"; Los Alamos National Laboratory, LA-UR-03-1987 (2003).

[6.1.5] M.G. Natrella, Experimental Statistics, National Bureau of Standards, Handbook 91, August 1963.

[6.1.6] "CASMO-4 Methodology", Studsvik/SOA-95/2, Rev. 0, 1995.

"CASMO-4 A Fuel Assembly Burnup Program, Users Manual," SSP-01/400, Rev. 1, Studsvik Scandpower, Inc., 2001.

"CASMO-4 Benchmark Against Critical Experiments", Studsvik/SOA-94/13, Studsvik of America, 1995.

[6.4.1] J.M. Cano, R. Caro, and J.M Martinez-Val, "Supercriticality Through Optimum Moderation in Nuclear Fuel Storage," Nucl. Technol., 48, 251-260, (1980).

APPENDIX 6.A: BENCHMARK CALCULATIONS

(b)(4)

(b)(4)

(b)(4)

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6 EALF is the energy of the average lethargy causing fission

(b)(4)

[7] Arranged in order of increasing reflector fuel spacing.

(b)(4)

(b)(4)

(b)(4)

APPENDIX 6.B: MISCELLANEOUS INFORMATION

6.B.1 Sample Input File MPC-37

(b)(4)

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6.B.3 Analyzed Distributed Enrichment Patterns

(b)(4)

6.B.4 Assembly Cross Sections

(b)(4)

(b)(4)

CHAPTER 7*: CONFINEMENT

7.0 INTRODUCTION

Confinement of all radioactive materials in the HI-STORM FW system is provided by the MPC. The design of the HI-STORM FW MPC assures that there are no credible design basis events that would result in a radiological release to the environment. The HI-STORM FW overpack and HI-TRAC VW transfer cask are designed to provide physical protection to the MPC during normal, off-normal, and postulated accident conditions to assure that the integrity of the MPC is maintained. The dry inert atmosphere in the MPC and the passive heat removal capabilities of the HI-STORM FW also assure that the SNF assemblies remain protected from long-term degradation.

A detailed description of the confinement structures, systems, and components important to safety is provided in Chapter 2. The structural adequacy of the MPC is demonstrated by the analyses documented in Chapter 3. The physical protection of the MPC provided by the overpack and the HI-TRAC Transfer Cask is demonstrated by the structural analyses documented in Chapter 3 for off-normal and postulated accident conditions that are considered in Chapter 11. The heat removal capabilities of the HI-STORM FW system are demonstrated by the thermal analyses documented in Chapter 4. Materials evaluation in Chapter 8 demonstrates the compatibility and durability of the MPC materials for long term spent fuel storage.

This chapter describes the HI-STORM FW confinement design and describes how the design satisfies the confinement requirements of 10CFR72 [7.0.1]. It also provides an evaluation of the MPC confinement boundary as it relates to the criteria contained in Interim Staff Guidance (ISG)–18 [7.0.2] and applicable portions of ANSI N14.5-1997 [7.0.3] as justification for reaching the determination that leakage from the confinement boundary is not credible and, therefore, a quantification of the consequence of leakage from the MPC is not required. This chapter is in general compliance with NUREG-1536 [7.0.4] as noted in Chapter 1.

It should be observed that the configuration of the confinement boundary of the MPCs covered by this FSAR is identical to that used in the MPCs in Docket No. 72-1014 (HI-STORM 100 system), including weld joint details and weld types and weld sizes. Therefore, it is reasonable to conclude that the safety evaluation conducted to establish confinement integrity in Docket No. 72-1014 is also applicable herein.

*This chapter has been prepared in the format and section organization set forth in Regulatory Guide 3.61. However, the material content of this chapter also fulfills the requirements of NUREG-1536.

7.1 CONFINEMENT DESIGN CHARACTERISTICS

The confinement against the release of radioactive contents is the all welded MPC. There are no bolted closures or mechanical seals in the MPC confinement boundary.

The confinement boundary of the MPC consists of the following parts:

- MPC shell
- MPC base plate
- MPC lid
- MPC vent and drain port covers
- MPC closure ring
- associated welds

The combination of the welded MPC lid and the welded closure ring form the redundant closure of the MPC and satisfies the requirements of 10 CFR 72.236(e) [7.0.1]. The confinement boundary is shown in the licensing drawing package in Section 1.5. Chapter 2 provides design criteria for the confinement boundary. All components of the confinement boundary are important-to-safety, as specified on the licensing drawings. The MPC confinement boundary is designed, fabricated, inspected and tested in accordance with the applicable requirements of ASME Code, Section III, Subsection NB [7.1.1], with alternatives given in Chapter 2.

7.1.1 Confinement Vessel

The HI-STORM FW system confinement vessel is the MPC. The MPC is designed to provide confinement of all radionuclides under normal, off-normal and accident conditions. The three major components of the MPC vessel are the shell, baseplate, and lid. The shell welds and the shell to baseplate weld are performed at the fabrication facility. The remaining confinement boundary welds are performed in the field (Table 7.1.1).

The MPC lid consists of two sections (referred to as upper and lower) welded together. Only the upper portion of the lid is credited in the confinement boundary. The lid is made intentionally thick by the addition of the lower portion of the lid to minimize radiation exposure to workers during MPC closure operations. The MPC lid has a stepped recess around the perimeter for accommodating the closure ring. The MPC closure ring is welded to the MPC lid on the inner diameter of the ring and to the MPC shell on the outer diameter.

Following fuel loading and MPC lid welding, the MPC lid-to-shell weld is examined by progressive liquid penetrant examinations (a multi-layer liquid penetrant examination), and a pressure test is performed. The MPC lid-to shell weld is not helium leakage tested since the weld meets the guidance of NRC Interim Staff Guidance (ISG)-15 [7.1.2] and criteria of ISG-18 [7.0.2], therefore leakage from the MPC lid-to-shell weld is not considered credible. Table 7.1.2 provides the matrix of ISG-18 criteria and how the Holtec MPC design and associated inspection, testing, and QA requirements meet each one.

After the MPC lid weld is ensured to be acceptable the vent and drain port cover plates are welded in place, examined by the liquid penetrant method and a helium leakage test of each of the vent and drain port cover plate welds is performed. These welds are tested in accordance to the leakage test methods and procedures of ANSI N 14.5 [7.0.3] to the "leaktight" criterion of the standard. Finally, the MPC closure ring which also covers the vent and drain cover plates is installed, welded, and inspected by the liquid penetrant method. Chapters 9, 10, and 13 provide procedural guidance, acceptance criteria, and operating controls, respectively, for performance and acceptance of non-destructive examination of all welds made in the field.

After moisture removal and prior to sealing the MPC vent and drain ports, the MPC cavity is backfilled with helium. The helium backfill provides an inert, non-reactive atmosphere within the MPC cavity that precludes oxidation and hydride attack on the SNF cladding. Use of a helium atmosphere within the MPC contributes to the long-term integrity of the fuel cladding, reducing the potential for release of fission gas or other radioactive products to the MPC cavity. Helium also aids in heat transfer within the MPC and helps reduce the fuel cladding temperatures. The inert atmosphere in the MPC, in conjunction with the thermal design features of the MPC and storage cask, assures that the fuel assemblies are sufficiently protected against degradation, which might otherwise lead to gross cladding ruptures during long-term storage.

The confinement boundary welds completed at the fabrication facility (i.e., the MPC longitudinal and circumferential shell welds and the MPC shell to baseplate weld) are referred to as the shop welds. After visual and liquid penetrant examinations, the shop welds are volumetrically inspected by radiography. The MPC shop welds are multiple-pass (6 to 8 passes) austenitic stainless steel welds. Helium leakage testing of the shop welds is performed as described in Table 10.1.1.

7.1.2 Confinement Penetrations

Two penetrations (the MPC vent and drain ports) are provided in the MPC lid for MPC draining, moisture removal and backfilling during MPC loading operations, and also for MPC re-flooding during unloading operations. No other confinement penetrations exist in the MPC.

The MPC vent and drain ports are sealed by cover plates that are integrally welded to the MPC lid. No credit is taken for the sealing action provided by the vent and drain port cap joints. The MPC closure ring covers the vent and drain port cover plate welds and the MPC lid-to-shell weld, providing the redundant closure of these penetrations. The redundant closure of the MPC satisfies the requirements of 10CFR72.236(e) [7.0.1].

7.1.3 Seals and Welds

Section 7.1.1 describes the design of the confinement boundary welds. The welds forming the confinement boundary is summarized in Table 7.1.1.

The use of multi-pass welds with surface liquid penetrant inspection of root, intermediate, and final passes renders the potential of a leak path through the weld between the MPC lid and the shell to be non-credible. The vent and drain port cover plate welds are helium leak tested in the field, providing added assurance of weld integrity. Additionally after fuel loading, a Code pressure test is performed on the MPC lid-to-shell weld to confirm the structural integrity of the weld.

The ductile stainless steel material used for the MPC confinement boundary is not susceptible to delamination or other failure modes such as hydrogen-induced weld degradation. The closure weld redundancy assures that failure of any single MPC confinement boundary closure weld will not result in release of radioactive material to the environment. Section 10.1 provides a summary of the closure weld examinations and tests.

7.1.4 Closure

The MPC is an integrally welded pressure vessel without any unique or special closure devices. All closure welds are examined using the liquid penetrant technique to ensure their integrity. Additionally, the vent and drain port cover plate welds are each helium leakage tested to be "leaktight" in accordance with the leakage test methods and procedures of ANSI N14.5-1997 [7.0.3]. Since the MPC uses an entirely welded redundant closure system with no credible leakage, no direct monitoring of the closure is required.

Table 7.1.1

MPC CONFINEMENT BOUNDARY WELDS

MPC Weld Location	Weld Type†	ASME Code Category (Section III, Subsection NB)
Shell longitudinal seam	Full Penetration Groove (shop weld)	A
Shell circumferential seam	Full Penetration Groove (shop weld)	B
Baseplate to shell	Full Penetration Groove (shop weld)	C
MPC lid to shell	Partial Penetration Groove (field weld)	C
MPC closure ring to shell	Fillet (field weld)	††
Vent and drain port covers to MPC lid	Partial Penetration Groove (field weld)	D
MPC closure ring to MPC lid	Partial Penetration Groove (field weld)	C
MPC closure ring to closure ring radial weld	Partial Penetration Groove (field weld)	††

† The tests and inspections for the Confinement Boundary welds are listed in Section 10.1

†† This joint is governed by NB-5271 (liquid penetrant examination).

Table 7.1.2

COMPARISON OF HOLTEC MPC DESIGN WITH ISG-18 GUIDANCE

DESIGN/QUALIFICATION GUIDANCE	HOLTEC MPC DESIGN
The canister is constructed from austenitic stainless steel.	The MPC enclosure vessel is constructed entirely from austenitic stainless steel (Alloy X). Alloy X is defined as Type 304, 304LN, 316, or 316LN material.
The canister closure welds meet the guidance of ISG-15 (or approved alternative), Section X.5.2.3.	The MPC lid-to-shell closure weld meets ISG-15, Section X.5.2.3 for austenitic stainless steels. UT examination is permitted and NB-5332 acceptance criteria are required. An optional multi-layer PT examination is also permitted. The multi-layer PT is performed at each approximately 3/8" of weld depth, which corresponds to the critical flaw size.
The canister maintains its confinement integrity during normal conditions, anticipated occurrences, and credible accidents and natural phenomena as required in 10CFR72.	The MPC is shown by analysis to maintain confinement integrity for all normal, off-normal, and accident conditions, including natural phenomena. The MPC is designed to ensure that the Confinement Boundary will not leak during any credible accident event and under the non-mechanistic tip-over scenario.
Records documenting the fabrication and closure welding of canisters shall comply with the provisions 10CFR72.174 and ISG-15. Record storage shall comply with ANSI N45.2.9.	Records documenting the fabrication and closure welding of MPCs meet the requirements of ISG-15 via controls required by the FSAR and HI-STORM FW CoC. Compliance with 10CFR72.174 and ANSI N.45.2.9 is achieved via Holtec QA program and implementing procedures.
Activities related to inspection, evaluation, documentation of fabrication, and closure welding of canisters shall be performed in accordance with an NRC-approved quality assurance program.	The NRC has approved Holtec's Quality Assurance program under 10CFR71. That same QA program has been adopted for activities governed by 10CFR72 as permitted by 10 CFR 72.140(d)

7.2 REQUIREMENTS FOR NORMAL AND OFF-NORMAL CONDITIONS OF STORAGE

Once sealed and transferred into the HI-STORM FW overpack there is no mechanism under normal and off-normal conditions of storage for the confinement boundary to be breached. Chapter 3 shows that all confinement boundary components are maintained within their Code-allowable stress limits during normal and off-normal storage conditions. Chapter 4 shows that the peak confinement boundary component temperatures and pressures are within the design basis limits for all normal and off-normal conditions of storage. Since the MPC confinement vessel remains intact, the design temperatures and pressure are not exceeded, and leakage from the MPC confinement boundary as discussed in Section 7.1 is not credible, there can be no release of radioactive material during normal and off-normal conditions of storage.

The MPC is dried and helium backfilled prior to sealing and no significant moisture or other gases remain inside the MPC. Therefore, a credible mechanism for any radiolytic decomposition that could cause an increase in the MPC internal pressure is absent. The potential for an explosive level of gases due to the radiological decomposition in the MPC is eliminated by excluding foreign materials in the MPC or by evaluating foreign material to demonstrate the effect on the MPC internal pressure is negligible.

7.3 CONFINEMENT REQUIREMENTS FOR HYPOTHETICAL ACCIDENT CONDITIONS

The analysis in Chapter 3 and results discussed in Chapter 12 demonstrates that the MPC remains intact during and after all postulated accident conditions; therefore there can be no release of radioactive material causing any additional dose contribution to the site boundary during these events.

7.4 REFERENCES

[7.0.1] 10CFR72, Code of Federal Regulations, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor Related Greater than Class C Waste," USNRC, Washington, DC.

[7.0.2] Interim Staff Guidance-18, "The Design/Qualification of Final Closure Welds on Austenitic Stainless Steel Canisters as Confinement Boundary for Spent Fuel Storage and Containment Boundary for Spent Fuel Transportation," USNRC, Washington, DC, May 2003.

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

[7.0.4] NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems", USNRC, Washington, DC, January, 1997.

[7.1.1] ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, Class 1 Components, American Society of Mechanical Engineers, New York, NY, 2007 Edition.

[7.1.2] Interim Staff Guidance-15, "Materials Evaluation", USNRC, Washington, DC, January 2001.

[7.1.3] Holtec Proprietary Report HI-2022850, Revision 0, "Summary Report on MPC Leak Tightness Test", April 2002.

CHAPTER 8: MATERIAL EVALUATION

8.1 INTRODUCTION

This chapter presents an assessment of the materials selected for use in the HI-STORM FW System components identified in the licensing drawings in Section 1.5. In this chapter and Chapter 3 of this FSAR, the significant mechanical, thermal, radiological and metallurgical properties of materials identified for use in the components of the HI-STORM FW System are presented. This chapter focuses on the HI-STORM FW material properties to assess compliance with the ISG-15 [8.1.1] and ISG-11 [8.1.2] requirements. The principal purpose of ISG-15 is to evaluate the dry cask storage system to ensure adequate material performance of the independent spent fuel storage installation (ISFSI) components designated as important to safety under normal, off-normal and accident conditions. Some areas of review applicable to the suitability assessment of the materials have been addressed elsewhere in this FSAR and are referenced from this chapter as necessary. Areas that require further details are reviewed within this chapter as necessary to satisfy the requirements of ISG-15. Guidance on performing the review is adopted directly from ISG-15 and ISG-11.

ISG-15 sets down the following general acceptance criteria for material evaluation.

- The safety analysis report should describe all materials used for dry spent fuel storage components designated as important to safety, and should consider the suitability of those materials for their intended functions in sufficient detail to evaluate their effectiveness in relation to all safety functions.

- The dry spent fuel storage system should employ materials that are compatible with wet and dry spent fuel loading and unloading operations and facilities. These materials should not degrade to the extent that a safety concern is created.

The information compiled in this chapter addresses the above acceptance criteria. To perform the material suitability evaluation, it is necessary to characterize the following for each component: (i) the applicable environment, (ii) the potential degradation modes and (iii) the potential hazards to continued effectiveness of the selected material.

The operating environments of the different components of the cask system are not the same. Likewise, the potential degradation modes and hazards are different for each component. Tables 8.1.1, 8.1.2, and 8.1.3 provide a summary of the environmental states, potential degradation modes and hazards applicable to the MPC, the HI-STORM FW overpack and the HI-TRAC VW cask, respectively. The above referenced tables serve to guide the material suitability evaluation for the HI-STORM FW System.

To provide a proper context for the subsequent evaluations, the potential degradation mechanisms applicable to the ventilated systems are summarized in Table 8.1.4. The degradation mechanisms listed in Table 8.1.4 are considered in the suitability evaluation presented later in this chapter.

The material evaluation presented in this chapter is intended to be complete, even though a conclusion of the adequacy of the materials can be made on the strength of the following facts:

i. The materials used in HI-STORM FW are, with the sole exception of Metamic-HT, identical to those used in the widely deployed HI-STORM 100 System (Docket No. 72-1014).

ii. The thermal environment in the HI-STORM FW system emulates the HI-STORM 100 system in all respects.

iii. The fuel loading and short-term operations are essentially identical to those that have been practiced in the HI-STORM 100 system throughout the industry.

Table 8.1.1

CONSIDERATIONS GERMANE TO THE MPC MATERIAL PERFORMANCE

Consideration	Short-Term Operations	Long-Term Storage
Environment	Aqueous (with Boric acid in PWR plants), characterized by moderately hot (<212ºF) water during fuel loading, rapid evaporation during welding and drying operations	MPC's internal environment is hot (≤752ºF), inertized and dry. Temperature of the MPC cycles very gradually due to changes in the environmental temperature.
Potential degradation modes	Hydrogen generation from oxidation of aluminum and aluminum alloy internals. Risk to the integrity of fuel cladding from thermal transients caused by vacuum drying.	Corrosion of the external surfaces of the MPC (stress, corrosion, cracking, pitting, etc.)
Potential hazards to effective performance	Inadequate drying of waterlogged fuel rods.	Blockage of ventilation ducts under an extreme environmental phenomenon leading to a rapid heat-up of the MPC internals.

Table 8.1.2

CONSIDERATIONS GERMANE TO THE HI-STORM FW OVERPACK MATERIAL PERFORMANCE*

Consideration	Performance Data
Environment	Cool ambient air progressively heated as it rises in the overpack/MPC annulus heating the inside surface of the cask. The heated air has reduced relative humidity. Direct heating of the overpack inner shell by radiation can be prevented using the optional "heat shields" described in Chapter 1, on a site specific basis. External surface of the overpack including the top lid is heated and in contact with ambient air, rain, and snow, as applicable.
Potential degradation modes	Peeling or perforation of surface preservatives and corrosion of any exposed steel surfaces.
Potential hazards to effective performance	Blockage of ducts by debris leading to overheating of the concrete in the overpack, scorching of the cask by proximate fire, lightning.

* Short-term operations are not applicable to the HI-STORM FW overpack.

Table 8.1.3

CONSIDERATIONS GERMANE TO THE OF HI-TRAC VW MATERIAL PERFORMANCE*

Consideration	Performance Data
Environment	Heated fuel pool water on the outside and demineralized water in contact with the inside surface, heated water in the "water jacket". Temperature ramps on the inside surface during the drying and "backfill" operation.
Potential degradation modes	Peeling or perforation of surface coatings, loss of effectiveness of bottom lid gasket.
Potential hazards to effective performance	Lead slump due to sudden inertial loading; contamination of the inside surface of the cask by pool water, partial loss of heat rejection resulting in boiling of water in the water jacket, impact from tornado missile during transfer to the ISFSI.

* Long-term storage conditions are not applicable to the transfer cask.

Table 8.1.4

FAILURE AND DEGRADATION MECHANISMS APPLICABLE TO VENTILATED SYSTEMS[§]

	Mechanism	**Area of Performance Affected**	**Vulnerable Parts**
1.	General Corrosion	Structural capacity	All carbon steel parts
2.	Hydrogen Generation	Personnel safety during short-term operations	Coatings, parts made of aluminum or aluminum alloys
3.	Stress Corrosion Cracking	Structural	Austenitic Stainless Steel
4.	Creep	Criticality control	Fuel Basket
5.	Galling	Equipment handling and deployment	Threaded Fasteners
6.	Hysteresis	During fuel loading in the pool	HI-TRAC VW Bottom Lid Gaskets
7.	Fatigue	Structural Integrity	Fuel Cladding & Bolting
8.	Brittle Fracture	Structural Capacity	Thick Steel Parts
9.	Boron Depletion	Criticality Control	Neutron Absorber

[§] This table lists all potential (generic) mechanisms, whether they are credible for the HI-STORM FW System or not. The viability of each failure mechanism is discussed later in this chapter.

8.2 MATERIAL SELECTION

The following acceptance criteria are applicable for material selection per ISG-15.

a. The material properties of a dry spent fuel storage component should meet its service requirements in the proposed cask system for the duration of the licensing period.

b. The materials that comprise the dry spent fuel storage should maintain their physical and mechanical properties during all conditions of operations. The spent fuel should be readily retrievable without posing operational safety problems.

c. Over the range of temperatures expected prior to and during the storage period, any ductile-to-brittle transition of the dry spent fuel storage materials, used for structural and nonstructural components, should be evaluated for its effects on safety.

d. Dry spent fuel storage gamma shielding materials (e.g. lead) should not experience slumping or loss of shielding effectiveness to an extent that compromises safety. The shield should perform its intended function throughout the licensed service period.

e. Dry spent fuel storage materials used for neutron absorption should be designed to perform their safety function.

f. Dry spent fuel storage protective coatings should remain intact and adherent during all loading and unloading operations within wet or dry spent fuel facilities, and during long-term storage.

The above criteria have been utilized in selecting the material types for the HI-STORM FW system. The selected materials provide the required heat transfer, confinement, shielding and the criticality control of the stored spent fuel and are capable of withstanding loadings including seismic, temperature cycles due to internal heat and ambient temperature variation, extreme temperature conditions, loads due to natural phenomena like tornado missiles, flooding and other credible hypothetical accident scenarios. The HI-STORM FW components must withstand the environmental conditions experienced during normal operation, off-normal conditions and accident conditions for the entire service life.

The selection of materials is guided by the applicable loadings and potential failure modes. An emphasis has been placed on utilizing proven materials that have established properties and characteristics and are of proven reliability. Where a relatively new material (e.g., Metamic-HT) is used, comprehensive tests have been conducted to ensure reliability.

The major structural materials used in HI-STORM FW System are discussed in this section. The mechanical and thermal properties of these materials are presented in Section 8.4. The materials for welds are discussed in Section 8.5. The structural materials for bolts and fasteners are discussed in Section 8.6. Coatings and paints are discussed in Section 8.7. Gamma and neutron

shielding materials are treated in Section 8.8. The neutron absorbing materials are discussed in Section 8.9.

Chapter 1 provides a general description of the HI-STORM FW System including information on materials of construction. All materials of construction are identified in the drawing package provided in Section 1.5 and the ITS categories of the sub-components are identified in Table 2.0.1 through 2.0.8.

8.2.1 Structural Materials

8.2.1.1 Cask Components and Their Constituent Materials

The major structural materials that are used in the HI-STORM FW System are Alloy X, Metamic-HT, carbon steel, and aluminum. They are further discussed below in light of the ISG-15 requirements.

MPC

All structural components in an MPC Enclosure Vessel are made of Alloy X (stainless steel). Appendix 1.A provides discussions on Alloy X materials. The fuel basket is made of Metamic-HT neutron absorber described in Chapter 1, Section 1.2.1.4. The confinement boundary is made of stainless steel material for its superior strength, ductility, and resistance to corrosion and brittle fracture for long term storage. The basket shims used to support the basket are made of a creep resistant aluminum alloy. The two-piece MPC lid is either made entirely of Alloy X or the bottom portion of the lid is made of carbon steel with stainless steel veneer. The principal materials used in the fabrication of the MPC are listed in Section 1.2.

HI-STORM

The main structural function of the overpack is provided by carbon steel and the main shielding function is provided by plain concrete. Chapter 1 presents discussions on these materials. The materials used in the fabrication of the overpack are listed in Section 1.2.

HI-TRAC

As discussed in Chapter 1, the HI-TRAC VW transfer cask is principally made of carbon steel and lead. The HI-TRAC VW is equipped with a water jacket. The materials used in the fabrication of the transfer cask are listed in Section 1.2.

8.2.1.2 Synopsis of Structural Materials

i. Alloy X

The MPC enclosure vessel design allows use of any one of the four Alloy X materials: Types 304, 304LN, 316 and 316LN. Qualification of structures made of Alloy X is accomplished by

using the least favorable mechanical and thermal properties of the entire group for all MPC mechanical, structural, neutronic, radiological, and thermal conditions. Each of these material properties are provided in the ASME Code Section II [8.3.1].

As discussed in Appendix 1.A, the Alloy X approach is conservative because, no matter which material is ultimately utilized, the Alloy X guarantees that the performance of the MPC will meet or exceed the analytical predictions. The material properties are provided at various temperatures.

All structural analyses utilize conservatively established material properties such as design stress intensity, tensile strength, yield strength, and coefficient of thermal expansion for the range of temperature conditions that would be experienced by the cask components.

Chapter 3 provides the structural evaluation for the MPC Enclosure Vessel which is made of Alloy X. It is demonstrated that Alloy X provides adequate structural integrity for the MPC enclosure vessel under normal, off normal, and accident conditions. As shown in Chapter 4, the maximum metal temperature for Alloy X for the Confinement Boundary remains the design temperatures in Table 2.2.3 under all service modes. As shown in ASME Code Case N-47-33 (Class 1 Components in Elevated Temperature Service, 1995 Code Cases, Nuclear Components), the strength properties of austenitic stainless steels do not change due to exposure to $1000^{o}F$ temperature for up to 10,000 hours.

Since stainless steel materials do not undergo a ductile-to-brittle transition in the minimum permissible service temperature range of the HI-STORM FW System, brittle fracture is not a concern for the MPC components. Subsection 8.4.3 presents further discussions on brittle fracture.

In Section 8.12, the potential for chemical and galvanic reaction of Alloy X in short-term and long-term operating conditions is evaluated. Alloy X is also used in the Confinement Boundary of all HI-STORM 100 MPCs.

ii. Metamic-HT

Criticality control in the HI-STORM FW System is provided by the coplanar grid work of the Fuel Basket honeycomb, made entirely of the Metamic-HT extruded metal matrix composite plates. The boron in Metamic-HT provides criticality control in the HI-STORM FW System. The Metamic-HT neutron absorber is a successor to the Metamic (classic) product widely used in dry storage fuel baskets and spent fuel storage racks (the "HT" designation in Metamic-HT stands for high temperature and is derived from this characteristic). Metamic-HT has been licensed in the HI-STAR 180 transport cask (Docket No. 71-9325).

Metamic-HT is also engineered to possess the necessary mechanical characteristics for structural application. The mechanical properties of Metamic-HT are derived from the strengthening of its aluminum matrix with ultra fine-grained (nano-particle size) alumina (Al_2O_3) particles that anchor the grain boundaries for high temperature strength and creep resistance.

Critical properties of Metamic-HT have been established as minimum guaranteed values by conducting tests using ASTM sanctioned procedures (Metamic-HT Sourcebook [8.9.7]). The critical structural properties include yield strength, tensile strength, Young's modulus, and area reduction, (See Chapter 1, Section 1.2.1.4).

The neutron absorbing properties of Metamic-HT are addressed in Section 8.9 and also in Chapter 1, Section 1.2.1.4.

Chapter 3 presents structural evaluation of spent fuel basket made of Metamic-HT wherein it is concluded that the Metamic-HT plates possess adequate structural strength to meet the loadings postulated for the fuel basket. Section 8.12 presents potential for chemical and galvanic reaction in Metamic-HT under short-term and long-term operating conditions.

All Metamic-HT material procured for use in the Holtec casks is qualified as *important-to-safety* (ITS). Accordingly, material and manufacturing control processes are established to eliminate the incidence of errors, and inspection steps are implemented to serve as an independent set of barriers to ensure that all *critical characteristics* defined for the material by the cask designer are met in the manufactured product. Additional discussions on the manufacturing of Metamic-HT are provided in Chapter 1, Section 1.2.1.4 and also in Chapter 10.

iii. Carbon Steel, Low-Alloy, and Nickel Alloy Steel

Materials for HI-STORM FW overpack and HI-TRAC VW transfer cask including the parts used to lift the overpack and the transfer cask, which may also be referred to as "significant-to-handling" or "STH" parts, are selected to preclude any concern of brittle fracture. Details of discussions are provided in Subsection 8.4.3.

Steel forging materials for low temperature applications have been selected for the STH components that have thicknesses greater than 2" so that acceptable fracture toughness at low temperatures can be assured. All other major steel structural materials in the HI-STORM FW overpack and HI-TRAC VW cask are made of fine grain low carbon steel (see drawings in Section 1.5).

The mechanical properties of these materials are provided in Section 3.3. Section 3.1 provides allowable stresses under different loading conditions and impact testing requirements for these materials.

Chapter 3 provides structural evaluations of the HI-STORM FW System components. It is demonstrated that the structural steel components of the HI-STORM FW overpack meet the allowable stress limits for normal, off-normal and accident loading conditions.

8.2.2 Nonstructural Materials

i. Aluminum Alloy

The space between the fuel basket and the inside surface of the Confinement Boundary is occupied by specially shaped precision extruded or machined basket shims made of a high strength and creep resistant aluminum alloy. The basket shims establish a conformal contact interface with the fuel basket and the MPC shell, and thus prevent significant movement of the basket. The basket shims are extruded and/or machined to a precise shape with a high degree of accuracy.

The clearance between the basket shims and the interfacing machined surface of the MPC cavity is set to be sufficiently small such that the thermal expansion of the parts inside the MPC under Design Basis heat load conditions will minimize any macro-gaps at the interface and thus minimize any resistance to the outward flow of heat, while ensuring that there is no restraint of free thermal expansion.

To further enhance thermal performance, the aluminum alloy basket shims are hard anodized. This provides for added corrosion protection and to achieve the emissivity value specified in Section 4.2. Mechanical properties of the shim material are provided in Section 3.3.

The basket shim material utilized in the HI-STORM FW system has also been used in other casks (viz. HI-STAR 180).

ii. Concrete

The plain concrete between the overpack inner and outer steel shells and in the overpack lid is specified to provide the necessary shielding properties and compressive strength. Appendix 1.D of the HI-STORM 100 FSAR which provides technical and placement requirements on plain concrete is also invoked for HI-STORM FW concrete.

The HI-STORM FW overpack concrete is enclosed in steel inner and outer shells connected to each other by radial ribs, and top and bottom plates and does not require rebar. As the HI-STORM FW overpack concrete is not reinforced, the structural analysis of the overpack only credits the compressive strength of the concrete.

The technical requirements on testing and qualification of the HI-STORM FW plain concrete are identical to those used in the HI-STORM 100 program. Accordingly, the testing and placement guidelines in Appendix 1.D of the HI-STORM 100 FSAR (Docket No. 72-1014), is incorporated in this SAR by reference.

ACI 318 is the reference code for the plain concrete in the HI-STORM FW overpack. ACI 318.1-85(05) is the applicable code utilized to determine the allowable compressive strength of the plain concrete credited in structural analysis.

The gamma shielding characteristics of concrete is considered in Section 8.8.

iii. Lead

HI-TRAC VW contains lead between its inner and the middle shell for gamma shielding. The load carrying capacity of lead is neglected in all structural analysis. However, in the analysis of a tornado missile strike the elasto-plastic properties of lead are considered in characterizing the penetration action of the missile.

Applicable mechanical properties of lead are provided in Section 3.3. Shielding properties of lead are provided in Section 8.8.

8.2.3 Critical Characteristics and Equivalent Materials

As defined in the Glossary, the *critical characteristics* of a material are those attributes that have been identified, in the associated material specification, as necessary to render the material's intended function. However, material designations adopted by the International Standards Organization (ISO) also affect the type of steels and steel alloys available from suppliers around the world. Therefore, it is necessary to provide for the ability in this FSAR to substitute materials with equivalent materials in the manufacture of the equipment governed by this FSAR.

As defined in the Glossary, *equivalent materials* are those materials with critical characteristics that meet or exceed those specified for the designated material. Substitution by an equivalent material can be made after the equivalence in accordance with the provisions of this FSAR has been established.

The concept of equivalent materials explained above has been previously used in this FSAR to qualify four different austenitic stainless steel alloys (ASME SA240 Types 304, 304LN, 316, and 316LN) to serve as candidate MPC materials.

The equivalence of materials is directly tied to the notion of *critical characteristics*. A critical characteristic of a material is a material property whose value must be specified and controlled to ensure an SSC will render its intended function. The numerical value of the critical characteristic invariably enters in the safety evaluation of an SSC and therefore its range must be guaranteed. To ensure that the safety calculation is not adversely affected properties such as Yield Strength, Ultimate Strength and Elongation must be specified as *minimum* guaranteed values. However, there are certain properties where both minimum and maximum acceptable values are required (in this category lies specific gravity and thermal expansion coefficient).

Table 8.2.1 lists the array of properties typically required in safety evaluation of an SSC in dry storage and transport applications. The required value of each applicable property, guided by the safety evaluation needs defines the critical characteristics of the material. The subset of applicable properties for a material depends on the role played by the material. The role of a material in the SSC is divided into three categories:

Type	Technical Area of Applicability
S	Those needed to ensure structural compliance
T	Those needed to ensure thermal compliance (temperature limits)
R	Those needed to ensure radiation compliance (criticality and shielding)

The properties listed in Table 8.2.1 are the ones that may apply in a dry storage or transport application.

The following procedure shall be used to establish acceptable equivalent materials for a particular application.

Criterion i: Functional Adequacy:
Evaluate the guaranteed critical characteristics of the equivalent material against the values required to be used in safety evaluations. The required values of each critical characteristic must be met by the minimum (or maximum) guaranteed values (MGVs of the selected material).

Criterion ii: Chemical and Environmental Compliance:
Perform the necessary evaluations and analyses to ensure the candidate material will not excessively corrode or otherwise degrade in the operating environment.

A material from another designation regime that meets Criteria (i) and (ii) above is deemed to be an acceptable material, and hence, equivalent to the candidate material.

Equivalent materials as an alternative to the U.S. national standards materials (e.g., ASME, ASTM, or ANSI) shall not be used for the Confinement Boundary materials. Equivalent materials as alternative to Holtec's specialty engineered Metamic-HT material shall not be used for the MPC fuel basket. For other ITS materials, recourse to equivalent materials shall be made only in the extenuating circumstances where the designated material in this FSAR is not readily available.

As can be ascertained from its definition in the glossary, the *critical characteristics* of the material used in a subcomponent depend on its function. The overpack lid, for example, serves as a shielding device and as a physical barrier to protect the MPC against loadings under all service conditions, including extreme environmental phenomena. Therefore, the critical characteristics of steel used in the lid are its strength (yield and ultimate), ductility, and fracture resistance.

The appropriate critical characteristics for structural components of the HI-STORM FW System, therefore, are:

i. Material yield strength, σ_y
ii. Material ultimate strength, σ_u
iii. Elongation, ε
iv. Charpy impact strength at the lowest service temperature for the part, C_i

Thus, the carbon steel specified in the drawing package can be substituted with different steel so long as each of the four above properties in the replacement material is equal to or greater than their minimum values used in the qualifying analyses used in this FSAR. The above *critical characteristics* apply to all materials used in the primary and secondary structural parts of the steel weldment in the overpack.

In the event that one or more of the *critical characteristics* of the replacement material is slightly lower than the original material, then the use of the §72.48 process shall be necessary to ensure that all regulatory predicates for the material substitution are fully satisfied.

Table 8.2.1
Critical Characteristics of Materials Required for Safety Evaluation of Storage and Transport Systems

	Property	Type	Purpose	Bounding Acceptable Value
1.	Minimum Yield Strength	S	To ensure adequate elastic strength for normal service conditions	Min.
2.	Minimum Tensile Strength	S	To ensure material integrity under accident conditions	Min.
3.	Young's Modulus	S	For input in structural analysis model	Min.
4.	Minimum elongation of $\delta_{min.}$, %	S	To ensure adequate material ductility	Min.
5.	Impact Resistance at ambient conditions	S	To ensure protection against crack propagation	Min.
6.	Maximum allowable creep rate	S	To prevent excessive deformation under steady state loading at elevated temperatures	Max.
7.	Thermal conductivity (minimum averaged value in the range of ambient to maximum service temperature, t_{max})	T	To ensure that the basket will conduct heat at the rate assumed in its thermal model	Min.
8.	Minimum Emissivity	T	To ensure that the thermal calculations are performed conservatively	Min.
9.	Specific Gravity	S (and R)	To compute weight of the component (and shielding effectiveness)	Max. (and Min.)
10.	Thermal Expansion Coefficient	T (and S)	To compute the change in basket dimension due to temperature (and thermal stresses)	Min. (and Max.)
11.	Boron-10 Content	R	To control reactivity	Min.

8.3 APPLICABLE CODES AND STANDARDS

The principle codes and standards applied to the HI-STORM FW System components are the ASME Boiler and Pressure Vessel Code [8.3.1], the ACI code [8.3.2], the ASTM Standards and the ANSI standards. Chapter 1 provides details of the specific applications of these codes and standards along with the other codes and standards that are applicable.

Section 1.0 of this FSAR provides a tabulation of this FSAR's compliance with NUREG-1536. This section also provides a list of clarifications and alternatives to NUREG-1536. This list of clarifications and alternatives discusses Holtec International's approach for compliance with the underlying intent of the guidance and also provides the justification for the alternative method for compliance adopted in this FSAR. Section 1.2 identifies the ASME code paragraphs applicable for the design of the HI-STORM FW overpack primary load bearing parts, summarizes the code requirements for the fabrication of the HI-STORM FW components, and refers to the national standards (e.g., ASTM, AWS, ANSI, etc.) used for the material procurement and welding.

Chapter 2 discusses factored load combinations for ISFSI pad design per NUREG-1536 [8.3.3], which is consistent with ACI-349-85. Codes ACI 360R-92, "Design of Slabs on Grade"; ACI 302.1R, "Guide for Concrete Floor and Slab Construction"; and ACI 224R-90, "Control of Cracking in Concrete Structures" are also used in the design and construction of the concrete pad. Section 2.2 elaborates on the specific applications of ASME Boiler and Pressure Vessel code and provides a list of ASME code alternatives for the HI-STORM FW System.

Section 3.1 provides allowable stresses and stress intensities for various materials extracted from applicable ASME code sections for various service conditions. This section also provides discussions on fracture toughness test requirements per ASME code sections. Mechanical properties of materials are extracted from applicable ASME sections and are tabulated for various materials used in HI-STORM FW System. Concrete properties are from ACI 318-89 code. Section 3.7 presents discussions on compliance on NUREG-1536 and stipulations of 10CFR72 requirements to provide reasonable assurance with respect to the adequacy of the HI-STORM FW System.

In order to meet the requirements of the codes and standards the materials must conform to the minimum acceptable physical strengths and chemical compositions and the fabrication procedures must satisfy the prescribed requirements of the applicable codes.

Additional codes and standards applicable to welding are discussed in Section 8.5 and those for the bolts and fasteners are discussed in Section 8.6.

Review of the above shows that the identified codes and standards are appropriate for the material control of major components. Additional material control is identified in material specifications. Material selections are appropriate for environmental conditions to be encountered during loading, unloading, transfer and storage operations. The materials and fabrication of major components are suitable based on the applicable codes of record.

8.4 MATERIAL PROPERTIES

This section provides discussions on material properties that mainly include mechanical and thermal properties. The material properties used in the design and analysis of the HI-STORM FW System are obtained from established industry codes such as ASME Boiler and Pressure Vessel Code [8.4.1], ASTM publications, handbooks, textbooks, other NRC-reviewed SARs, and government publications, as appropriate.

8.4.1 Mechanical Properties

Section 3.3 presents mechanical properties of materials used in the HI-STORM FW System. The structural materials include Alloy X, Metamic-HT, carbon steel, low-alloy and nickel-alloy steel, bolting materials and weld materials. The properties include yield stress, mean coefficient of thermal expansion, ultimate stress and the Young's modulus of these materials and their variations with temperature. Certain mechanical properties are also provided for nonstructural materials such as concrete and lead used for shielding. Additional properties of the neutron absorbing material Metamic-HT are discussed in Section 8.9.

The discussion on mechanical properties of materials in Chapter 3 provides reasonable assurance that the class and grade of the structural materials are acceptable under the applicable construction code of record. Selected parameters such as the temperature dependent values of stress allowables, modulus of elasticity, Poisson's ratio, density, thermal conductivity and thermal expansion have been appropriately defined in conjunction with other disciplines. The material properties of all code materials are guaranteed by procuring materials from Holtec approved vendors through material dedication*, process if necessary.

8.4.2 Thermal Properties

Section 4.2 presents thermal properties of materials used in the MPC such as Alloy X, Metamic-HT, aluminum shims and helium gas; materials present in HI-STORM FW such as carbon steel and concrete; and materials present in HI-TRAC VW transfer cask that include carbon steel, lead and demineralized water. The properties include density, thermal conductivity, heat capacity, viscosity, and surface emissivity/absorptivity. Variations of these properties with temperature are also provided in tabular forms.

The thermal properties of fuel (UO_2) and fuel cladding are also reported in Section 4.2.

Thermal properties are often obtained from standard handbooks and established text books (see Table 4.2.1). When variations of thermal properties are observed the most conservative values are established as input for the design of the components of the HI-STORM FW System.

* A term of art in nuclear quality assurance.

8.4.3 Low Temperature Ductility of Ferritic Steels*

The risk of brittle fracture in the HI-STORM FW components is eliminated by utilizing materials that maintain high fracture toughness under extremely cold conditions.

The MPC canister is constructed from a menu of stainless steels termed Alloy X. These stainless steel materials do not undergo a ductile-to-brittle transition in the minimum service temperature range of the HI-STORM FW System. Therefore, brittle fracture is not a concern for the MPC components.

Such an assertion cannot be made *a' priori* for the HI-STORM FW storage overpack and HI-TRAC VW transfer cask that contain ferritic steel parts. In general, the impact testing requirement for the HI-STORM FW overpack and the HI-TRAC VW transfer cask is a function of two parameters: the Lowest Service Temperature (LST)† and the normal stress level. The significance of these two parameters, as they relate to impact testing of the overpack and the transfer cask, is discussed below.

In normal storage mode, the LST of the HI-STORM FW storage overpack structural members may reach -40°F in the limiting condition wherein the spent nuclear fuel (SNF) in the contained MPCs emits no (or negligible) heat and the ambient temperature is at -40°F (design minimum per Chapter 2: Principal Design Criteria). However, during the HI-STORM FW overpack transport operations, the applicable lowest service temperature is per 0°F (per the Technical Specifications). Therefore, two distinct LSTs are applicable to load bearing metal parts within the HI-STORM FW System; namely,

LST = 0°F for the HI-STORM FW overpack during transport operations and for the HI-TRAC VW transfer cask during all normal operating conditions.

LST = -40°F for the HI-STORM FW overpack during storage operations.

SA350-LF2 and SA350-LF3 have been selected as the material for the STH parts due to their capability to maintain acceptable fracture toughness at low temperatures (see Table 5 in SA350 of ASME Section IIA). For the HI-TRAC VW Version P, the lifting trunnions are fabricated from SB-637 Grade N07718. SB-637 Grade N07718 is a high strength nickel alloy material, which has high resistance to fracture at low temperatures. Therefore, brittle fracture is not a concern for the lifting trunnions.

Table 3.1.9 provides a summary of impact testing requirements for the materials used in the HI-STORM FW System to ensure prevention of brittle fracture.

* This subsection has been copied from the HI-STORM 100 FSAR (Section 3.1) without any substantive change.
† LST (Lowest Service Temperature) is defined as the daily average for the host ISFSI site when the outdoors portions of the "short-term operations" are carried out.

8.4.4 Creep Properties of Materials

Creep, a visco-elastic and visco-plastic effect in metals, manifests itself as a monotonically increasing deformation if the metal part is subjected to stress under elevated temperature. Since certain parts of the HI-STORM FW System, notably the fuel basket, operate at relatively high temperatures, creep resistance of the fuel basket is an important property. Creep is not a concern in the MPC enclosure vessel, the HI-STORM FW overpack, or the HI-TRAC VW steel weldment because of the operating metal temperatures, stress levels and material properties. Steels used in ASME Code pressure vessels have a high threshold temperature at which creep becomes a factor in the equipment design. The ASME Code Section II material properties provide the acceptable upper temperature limit for metals and alloys acceptable for pressure vessel service. In the selection of steels for the HI-STORM FW System, a critical criterion is to ensure that the sustained metal temperature of the part made of the particular steel type shall be less than the Code allowable temperature for pressure vessel service (ASME Section III Subsection ND). This criterion guarantees that excessive creep deformation will not occur in the steels used in the HI-STORM FW System.

As discussed below, the incidence of creep in the fuel basket is a not a trivial matter because lateral creep deformation can alter the reactivity control characteristics of the basket.

8.4.4.1 Metamic-HT

Metamic-HT is the sole constituent material in the HI-STORM FW fuel basket. The suitability of Metamic-HT for the conditions listed in Table 8.1.1 are considered in the "Metamic-HT Qualification Sourcebook" [8.9.7].

The Metamic Sourcebook contains data on the testing to determine the creep characteristics of the Metamic-HT under both unirradiated and irradiated conditions. A creep equation to estimate a bounding estimate of total creep as a function of stress and temperature is also provided. The creep equation developed from this test provides a conservative prediction of accumulated creep strain by direct comparison to measured creep in unirradiated and irradiated coupons.

The creep equation for Metamic-HT that bounds *all* measured data (tests run for 20,000 hours) is of the classical exponential form in stress and temperature (see Table 1.2.8) stated symbolically $e = f(\sigma, T)$.

Creep in the fuel basket will not affect reactivity because the basket is oriented vertically during all operations (except as described in Subsection 4.5.1 which requires a site-specific stress evaluation per Subsection 3.1.2.2). The lateral loading of the fuel basket walls is insignificant and hence there is no mechanistic means for the basket panels to undergo lateral deformation from creep.

The creep effect would tend to shorten the fuel basket under the self-weight of the basket. An illustrative calculation of the cumulative reduction of the basket length is presented below to demonstrate the insignificant role of creep in the fuel basket.

The in-plane compressive stress, σ, at height x in the basket panel is given by

$$\sigma = \rho(H\text{-}x) \qquad (8.1)$$

Where
ρ = density of Metamic-HT
H = height of the fuel basket

Using the above stress equation, the total creep shrinkage, δ, is given by

$$\delta = \int_o^{\tau^*} \{\int_o^H (\sigma, T)\, dx\} d\tau \qquad (8.2)$$

Where
T = panel's metal temperature, initial value conservatively assumed to be 350°C (from Section 4.6) and dropping linearly to 150°C at 60 years.
τ* = 60 years
H = height of the basket (approximately 200 inches)

Using the creep equation [1.2.6] and performing the above double integration numerically with Mathcad yields δ = 0.044 inch. In other words, the computed shrinkage of the basket is less than 0.022% of its original length.

It is concluded that for vertical configuration of storage the creep effects of the MPC basket are insignificant due to absence of any meaningful loads on the panels. Therefore, creep in the Metamic-HT fuel basket is not a matter of safety concern.

8.4.4.2 Aluminum Alloy

The basket shims are not subject to any significant loading during storage. Similar to the fuel basket, the stress levels from self-weight in long-term storage eliminates creep as a viable concern for the basket shims.

8.5 WELDING MATERIAL AND WELDING SPECIFICATION

Welds in the HI-STORM FW System are divided into two broad categories:

i. Structural welds
ii. Non-structural welds

Structural welds are those that are essential to withstand mechanical and inertial loads exerted on the component under normal storage and handling.

Non-structural welds are those that are subject to minor stress levels and are not critical to the safety function of the part. Non-structural welds are typically located in the redundant parts of the structure. The guidance in the ASME Code Section NF-1215 for secondary members may be used to determine whether the stress level in a weld qualifies it to be categorized as non-structural.

Both structural and non-structural welds must satisfy the material considerations listed in Tables 8.1.1, 8.1.2, and 8.1.3, for the MPC, the HI-STORM FW overpack and the HI-TRAC VW transfer cask, respectively. In addition, the welds must not be susceptible to any of the applicable failure modes in Table 8.1.4.

To ensure that all welds in the HI-STORM FW System shall render their intended function, the following requirements are observed:

i. The weld joint configuration is selected to accord with the function of the joint (Holtec Position Paper DS-329 [8.5.1] provided to the USNRC in Docket No. 72-1014).

ii. The welding procedure specifications comply with ASME Section IX for every Code material used in the system.

iii. The quality assurance requirements applied to the welding process correspond to the highest ITS classification of the parts being joined.

iv. The non-destructive examination of every code weld is carried out using quality procedures that comply with ASME Section V.

v. Metamic-HT welding and welder qualifications, requirements, and examinations will be in accordance with Paragraphs 10.1.6.2, 10.1.1.4, and the drawing package in Section 1.5.

The welding operations are performed in accordance with the requirements of codes and standards depending on the design and functional requirements of the components.

The selection of the weld wire, welding process, range of essential and non-essential variables,* and the configuration of the weld geometry has been carried out to ensure that each weld will have:

i. Greater mechanical strength than the parent metal.
ii. Acceptable ductility, toughness, and fracture resistance.
iii. Corrosion resistance properties comparable to the parent metal.
iv. No risk of crack propagation under the applicable stress levels.

The welding procedures implemented in the manufacturing of HI-STORM FW System components are intended to fulfill the above performance expectations.

Additional information on the welding for HI-STORM FW System components is provided in Section 1.2. Lists of codes and standards applicable for the manufacturing of HI-STORM FW System are also provided therein.

A list of ASME code alternatives for the MPC fabrication including welding is presented in Section 2.2. The structural strength requirements of welds including fracture toughness test requirements of weld materials are provided in Section 3.1. The confinement boundary welds and their testing requirements are discussed in Section 7.1. The inspection and testing requirements of the HI-STORM FW System component welds are provided in Section 10.1.

The weld filler material shall comply with requirements set forth in the applicable Welding Procedure Specifications qualified to ASME Section IX at the manufacturer's facility. Only those welding procedures that have been qualified to the Code are permitted in the manufacturing of HI-STORM FW components.

Review of the above shows that except for the MPC lid welds, all welds of the Enclosure Vessel are full penetration weld with volumetric NDE. All weld filler metals are specified by ASME Section II, Part C and associated AWS classification in applicable weld procedures.

The weld procedure qualification record specifies the requirements for fracture control (e.g. post weld heat treatment). The HI-STORM FW overpack and HI-TRAC VW transfer cask do not require any post weld heat treatment due to the material combinations and provisions in the applicable codes and standards. With respect to the MPC Lid-to-Shell weld, the progressive P.T. requirements on the shell/lid weld are identical to those in Docket No. 72-1014 (which are derived from the analysis summarized in Holtec Position Paper DS-213 [8.5.2], provided to the USNRC on Docket No. 72-1014.

* Please refer to Section IX of the ASME Code for the definition and delineation of essential and non-essential variables.

Non-structural welds shall meet the following requirements:

1. The welding procedure shall comply with Section IX of the ASME Code or AWS D1.1.
2. The welder shall be qualified, at minimum, to the commercial code such as ASME Section VIII, Div.1, or AWS D1.1.
3. The weld shall be visually examined by the weld operator or a Q.C. inspector qualified to Level 1 (or above) per ASNT designation.

8.6 BOLTS AND FASTENERS

Chapter 3 provides information on the structural evaluation of the bolts and fasteners. Section 3.1 discusses fracture toughness requirements for bolting materials. Section 3.3 provides the bolting materials used in the HI-STORM FW System. Section 3.3 (Table 3.3.4) provides mechanical properties of bolting materials.

Chapter 9 provides pre-tensioning requirements for HI-STORM FW System bolts to ensure that the bolts shall not be overstressed under any condition of loading applicable to the system.

Bolts and fasteners made of low alloy steel are not expected to experience any significant corrosion in the operating environment. The ISFSI operation and maintenance program shall call for coating of bolts and fasteners if the ambient environment is aggressive.

A review of the above shows that the materials for the bolts and the fasteners have been selected to possess the required tensile strengths, resistance to corrosion and brittle fracture. To prevent a change in the bolt pre-stress during operating conditions, the coefficient of thermal expansion of each bolt material has been closely matched to that of the parts being fastened together.

Preventing galling of interfacing surfaces is another critical consideration in selecting bolt materials. Use of austenitic stainless bolts on interfacing austenitic stainless steel surfaces is not permitted. All threaded surfaces are treated with a preservative to prevent corrosion. The O&M program for the storage system calls for all bolts to be monitored for corrosion damage and replaced, as necessary.

8.7 COATINGS AND CORROSION MITIGATION

Protective coatings are used primarily as a corrosion barrier and/or as a means to facilitate decontamination. Coating materials for the HI-STORM FW system components are guided by the successful experience in similar service applications of the HI-STORM 100 and HI-STAR 100 components and parts. The main considerations in the selection of coatings are the ruggedness and physical integrity in the specific service environment, ease of decontamination as applicable to immersion service, thermal and radiation stability, and ease of application to facilitate touch-up activities for preventive maintenance. Surface preparation and repair are performed in accordance with manufacturer recommendations.

The coatings applied on specific HI-STORM FW System components are selected to be compatible with their respective conditions of service. For example, equipment used in the fuel pool environment must be conducive to convenient decontamination. Protective coatings are applied to surfaces vulnerable to corrosion such as exposed carbon steel surfaces on the HI-STORM FW overpack and HI-TRAC VW transfer cask. The MPC surfaces are not coated but may be subjected to certain optional surface treatments discussed in Section 8.7.4.

8.7.1 Environmental Conditions Applicable to Coating Selection and Evaluation Criteria:

8.7.1.1 Environmental Conditions

The environmental conditions that warrant consideration in the selection of coatings are:

i. Temperature, humidity, and insolation
ii. Radiation field
iii. Immersion service

Temperature, humidity, and insolation conditions may vary at different ISFSI sites. The coating selected for the HI-STORM FW overpack, which is subject to long-term exposure, must be stable under the entire range of psychometric conditions that prevail in the territorial United States. The coating selected for HI-TRAC VW must withstand the thermal exposure during fuel drying operations and during immersion in the spent fuel pool.

Stable performance under radiation is important for coatings applied on the inside surfaces of the HI-STORM FW overpack and the HI-TRAC VW transfer cask, which are proximate to the lateral surfaces of the MPC.

Immersion in the pool implies three major challenges to the coating on the HI-TRAC VW:

a. Risk of penetration of tiny contaminant particulates in the pores of the coating.
b. Chemical attack (by boric acid in PWR pools and demineralized water in BWR pools).
c. Temperature change as the transfer cask is immersed in or withdrawn from water.

Coatings that have been determined to be unsuitable for the immersion service shall not be used in the HI-TRAC VW transfer cask.

8.7.1.2 Coating Evaluation Criteria

The evaluation criteria for selecting coatings are summarized below. These criteria shall be used if a pre-approved coating listed in Subsection 8.7.2, for any reason, is no longer available for use.

	Coating Acceptance Criteria
1.	Non-reactive to the surrounding environment
2.	Structural performance (bendability, ductility, resistance to cracking, and resistance to abrasion)
3.	Adherence to base material
4.	Chemical immersion resistance, if applicable
5.	Emissivity and absorptivity consistent with thermal analysis
6.	Temperature resistance for analyzed temperature conditions with humidity and insolation, as applicable
7.	Radiation resistance for analyzed conditions

The paint suppliers may certify the properties by performance of applicable ASTM tests. In the absence of ASTM test data for a required characteristic in the above table, the coating supplier will provide evidentiary information to justify acceptance. Alternatively, Holtec International will perform its own independent tests to establish compliance with the required criteria.

8.7.2 Acceptable Coatings

Proven (previously used on HI-STORM 100 System components and other cask designs) coatings and paints that adequately satisfy the requirements are presented below and pre-approved for use on HI-STORM FW System components.

Carboguard 890 (Cycloaliphatic Amine Epoxy) of Carboline Company which demonstrates acceptable performance for short-term exposure in mild borated pool water may be used for coating the HI-TRAC VW transfer cask exterior surfaces as well as HI-STORM FW overpack surfaces. This coating is certified for immersion services and provides excellent chemical resistance and abrasion resistance. It provides a smooth surface with no porosity and thereby, excellent decontamination characteristics. No adverse interaction has been experienced in many years of use.

Thermaline 450 (Amine-Cured Novolac Epoxy) of Carboline Company may be used for coating HI-TRAC VW transfer cask internal surfaces which are exposed only to demineralized water during in-pool operations (the annulus is filled prior to placement in the spent fuel pool and the inflatable seal prevents fuel pool water in-leakage) and higher service temperatures. This coating provides excellent resistance to corrosion, abrasion, and permeation. No adverse interaction has been experienced in many years of use.

Carbozinc 11 (also known as CZ-11) may be used for coating HI-STORM FW overpack internal cavity and external surfaces (including lid surfaces). This solvent based coating material has excellent corrosion resistant properties in harsh environments and provides inorganic zinc (galvanic) protection to steel surfaces. As an alternative to the Carbozinc 11, Sherwin Williams Zinc Clad II HS, Sherwin Williams Zinc Clad II Plus may also be used.

Product information for the above coatings is provided in Appendix 8.A.

Coatings that are specified in this section shall not be substituted with another coating unless the substitute meets or exceeds the performance of the coating listed above under all the applicable coating evaluation criteria set forth in the previous subsection.

8.7.3 Coating Application

Holtec utilizes Q.A.-validated written procedures (HSP-318 [8.7.1] and HSP-319 [8.7.2]) to achieve the desired performance for the coating. These procedures provide requirements for the preparation and painting of the HI-STORM FW overpack, HI-TRAC VW transfer cask and associated components. These procedures are based on paint manufacturers' applicable specifications, instructions and recommendations.

The procedures provide details for the preparation prior to blasting, surface preparation, mixing and application, painting in the field, and touch up steps or repairs. The procedures also provide details of the dry film thickness testing and the acceptance criteria. Painting documentation is maintained for the record of the completion of various painting steps and the environmental conditions including the ambient temperature, humidity and the component surface temperature.

8.7.4 Optional MPC Surface Treatment (Peening)

To further enhance the confinement boundary resistance to stress corrosion cracking (SCC), selected areas of the MPC can be treated using a peening process as an optional operation during manufacture of MPCs. The peening process induces a beneficial compressive stress in the surface layer of the material, hence reducing or eliminating the possibility of crack formation on the surface from potential degradation corrosion mechanisms such as CISCC (Chloride Induced Stress Corrosion Cracking).

Holtec utilizes Q.A.-validated written procedures to achieve the desired performance for the surface treatment and to ensure that the integrity of the MPC Confinement Boundary is maintained. The qualification of the procedures is discussed in Section 10.1.

8.8 GAMMA AND NEUTRON SHIELDING MATERIALS

Gamma and neutron shield materials in the HI-STORM FW System are discussed in Section 1.2. The primary shielding materials used in the HI-STORM FW system, like the HI-STORM 100 system, are plain concrete, steel, lead, and water.

The plain concrete enclosed by cylindrical steel shells, a thick steel baseplate, and a top annular plate provides the main shielding function in the HI-STORM FW overpack. The overpack lid has appropriate concrete shielding to provide neutron and gamma attenuation to minimize skyshine.

The transfer cask in the HI-STORM FW system (HI-TRAC VW) is provided with steel and lead shielding to ensure that the radiation and exposure objectives of 10CFR72.104 and 10CFR72.106 are met. The space between the inner shell and the middle shell is occupied by lead, conforming to ASTM B29, which provides the bulk of the cask's (gamma) radiation shielding capability. The water jacket between the middle shell and the outermost shell (filled with demineralized water or ethylene glycol fortified water, depending on the site environmental constraints) provides most of the neutron shielding capability to the cask. The water in the water jacket serves as the neutron shield on demand: When the cask is in the pool and the MPC is full of water, the water jacket is kept empty (or partially empty as necessary) to minimize the cask's weight, the neutron shielding function being provided by the water in the MPC cavity. However, when the MPC is emptied of water at the Decontamination and Assembly Station (DAS), then the neutron shielding capacity of the cask is replenished by filling the water jacket. The HI-TRAC VW bottom lid is extra thick steel to provide an additional measure of gamma shielding to supplement the gamma shielding at the bottom of the MPC.

8.8.1 Concrete

Appendix 1.D of HI-STORM 100 FSAR provides details of the concrete properties and the testing requirements. The *critical characteristics* of concrete are its density and compressive strength.

The density of plain concrete within the HI-STORM FW overpack is subject to a minor decrease due to long-term exposure to elevated temperatures. The reduction in density occurs primarily due to liberation of unbonded water by evaporation.

The density of concrete has been classified into three states in the published literature [8.8.1].

a) fresh density: the density of freshly mixed concrete
b) air-dry density: drying in air under ambient conditions, where moisture is lost until a quasi-equilibrium is reached
c) oven-dry density: concrete dried in an oven at 105°C (221°F)

Because the bulk temperature of concrete in HI-STORM FW is spatially variable, the oven-dry density is conservatively used as the reference density for shielding analysis.

Density loss during the initial drying process is considered in the fabrication of the HI-STORM FW overpack by providing wet concrete densities above the minimum required dry (hardened paste) density. Density loss during drying is on the order of 1% and conservatively imposes a larger delta between wet density and the minimum dry density. The data in the literature, viz., Neville [8.8.1] indicates that the density difference between the air-dry condition and oven-dry condition is about one fourth of the density difference experienced during the drying process. Therefore, the loss in density would be expected to be on the order of 0.25%. This density loss is very low and is considered too small to have a significant impact on the shielding performance of the overpack. Thus, the minimum "fresh density" during concrete placement is set equal to the reference density (Table 1.2.5) plus 1.25%.

Section 5.3 considers the minimum density requirements of concrete for effective shielding. The density requirement is confirmed per Appendix 1.D of the HI-STORM 100 FSAR.

8.8.2 Steel

Section 5.3 provides a discussion on steel as a shielding material and its composition used in the evaluation of its shielding characteristics.

8.8.3 Lead

Section 1.2 provides a discussion on lead used in HI-TRAC VW for gamma shielding. In the HI-TRAC VW transfer cask radial direction, gamma and neutron shielding consists of steel-lead-steel and water, respectively. In the HI-TRAC VW bottom lid, layers of steel-lead-steel provide an additional measure of gamma shielding to supplement the gamma shielding at the bottom of the MPC.

Mechanical properties of lead are provided in Section 3.3. Section 5.3 provides the minimum density and composition (mass fraction of trace elements) of lead.

8.8.4 Water

Water is used as a neutron shield in the HI-TRAC VW transfer cask. Section 5.3 provides the minimum density requirements of water for transfer cask water jacket and inside MPC. The shielding effectiveness is calculated based on the minimum water density at the highest operating temperature. Calculations show that additives for freeze protection (at low temperature operation) such as ethylene glycol do not have any adverse effect on effectiveness of the neutron shielding function of water in the water jacket.

As discussed in Section 5.1, there is only one accident that has any significant impact on the shielding configuration. This accident is the postulated loss of the neutron shield (water) in the HI-TRAC VW. The change in the neutron shield was conservatively analyzed by assuming that the entire volume of the liquid neutron shield was replaced by air.

8.9 NEUTRON ABSORBING MATERIALS

Inside the MPC enclosure vessel is a structure referred to as the fuel basket. The fuel basket is an egg-crate assemblage of Metamic-HT plates which creates prismatic cells with square cross sectional openings for fuel storage. Metamic-HT is the neutron absorber and structural material of the MPC fuel basket. Metamic-HT is a composite material of nano-particles of aluminum oxide (alumina) and finely ground boron carbide particles dispersed in a metal matrix of pure aluminum [8.9.7].

8.9.1 Qualification and Properties of Metamic-HT

The qualification and properties of Metamic-HT are presented in Chapter 1, Section 1.2.1.4 where its key characteristics necessary for insuring nuclear reactivity control, thermal, and structural performance are discussed. A test program configured to address the Metamic-HT properties was conducted by Holtec International and the minimum guaranteed values (MGVs) of the *critical characteristics* of Metamic-HT were determined [8.9.7] and summarized in Chapter 1, Section 1.2.1.4. All testing was conducted in accordance with the applicable ASTM test standards. The role in the fuel basket safety function of each of the critical characteristics is provided in Chapter 1, Section 1.2.1.4.

A rigorous quality control regimen and Holtec QA procedures ensure that all extruded Metamic-HT plates meet the requirements for the quality genre of the casks.

To ensure that the manufactured Metamic material will render its intended function with reasonable assurance, a sampling plan based on Mil Standard 105E [8.9.8] has been specified and made a part of the Metamic-HT Manufacturing Manual [8.9.6]. The Sampling plan shall provide a reasonable level of confidence that the Minimum Guaranteed Values of all critical mechanical properties will be met in the production lots. Additional information regarding manufacturing of Metamic-HT is provided in Chapter 1, Section 1.2.1.4.

Chapter 2 provides discussions on criticality parameters for design basis SNF, and the controls and methods utilized for prevention of criticality.

Criticality evaluation is presented in Chapter 6. The material heterogeneity parameters are adequately characterized and controlled and the criticality calculations employ appropriate corrections when modeling the heterogeneous material as an idealized homogeneous mixture. It is demonstrated that the MPC provides criticality control for all design basis normal, off-normal, and postulated accident conditions, as discussed in Section 6.1. The effective neutron multiplication factor is limited to $k_{eff} < 0.95$ for fresh unirradiated fuel with optimum water moderation and close reflection, including all biases, uncertainties, and MPC manufacturing tolerances. Additional neutronic properties of Metamic-HT are provided in Chapter 1, Section 1.2.1.4.

8.9.2 Consideration of Boron Depletion

The effectiveness of the borated neutron absorbing material used in the MPC fuel basket design requires that sufficient concentrations of boron be present to assure criticality safety during worst case design basis conditions over the design life of the MPC. Analysis discussed in Section 6.3 demonstrates that the boron depletion in the neutron absorber material is negligible over the expected service life of the HI-STORM FW System. This is due to the fact that the borated material is subjected to a relatively low neutron flux. Analyses show that the depletion of boron is a small fraction of the quantity present. Therefore, sufficient levels of boron will remain in the fuel basket neutron absorbing material to maintain criticality safety functions over the design life of the MPC. Furthermore, the boron content of Metamic-HT used in the criticality safety analysis is conservatively based on the minimum specified boron areal density (rather than the nominal), which is further reduced by 10% (see Chapter 6) for conservatism in the analysis.

8.10 CONCRETE AND REINFORCING STEEL

The HI-STORM FW System does not utilize concrete with rebar. The plain concrete used in the HI-STORM FW overpack serves as the neutron shielding. The absence of rebar in the HI-STORM FW overpack concrete ensures that radiation streaming paths due to the development of cracks and discontinuities at the rebar/concrete interfaces will not develop. Concrete in the overpack is not considered as a structural member, except to withstand compressive, bearing, and penetrant loads. Therefore the mechanical behavior of concrete must be quantified to determine the stresses in the structural members (steel shells surrounding it) under accident conditions.

Section 3.3 provides the concrete mechanical properties. Allowable, bearing strength in concrete for normal loading conditions is calculated in accordance with ACI 318-05 [8.3.2]. The procedure specified in ASTM C-39 is utilized to verify that the assumed compressive strength will be realized in the actual in-situ pours. Appendix 1.D in the HI-STORM 100 FSAR provides additional information on the requirements on plain concrete for use in HI-STORM FW storage overpack.

To enhance the shielding performance of the HI-STORM FW storage overpack, high density concrete can be used during fabrication. The permissible range of concrete densities is specified in Table 1.2.5.

Review of the above shows that the HI-STORM FW System concrete components are acceptable. All concrete is either encased in steel or covered underneath the overpack lid, therefore; it is not subject to weathering or other atmospheric degradation, even in marine environments. To ensure that the concrete performs its primary function (shielding integrity/effectiveness) tests are performed as required by Chapter 10.

8.11 SEALS

The HI-STORM FW System does not rely upon mechanical seals for maintaining the integrity of the Confinement Boundary. The MPC Vent/Drain caps washers are made of a soft and malleable metal such as aluminum 1100.

The HI-TRAC VW transfer cask bottom lid utilizes a gasket to prevent ingress of pool water when the cask is staged in the fuel pool and leakage during MPC processing operations. Gaskets used may be silicone, neoprene, and a similar elastomeric material that is inert in the pool's aqueous environment.

In selecting the gasket material, it is necessary to ensure that none of the following materials will leach out in the pool water in measurable quantities.

- Viton
- Saran
- Silastic L8-53
- Teflon
- Nylon
- Carbon steel
- Neoprene or similar materials made of halogen containing elastomers
- Rubber bonded asbestos
- Polyethelene film colored with pigments over 50 ppm fluorine, measurable amount of mercury or halogens, or more than 0.05% lead
- Materials containing lead, mercury, sulfur, phosphorus, zinc, copper and copper alloys, cadmium, tin, antimony, bismuth, mischmetal, magnesium oxide, and halogens exceeding 75 ppm (including cleaning compound).

The gaskets used in the HI-TRAC VW shall be the same or equivalent to those that have proven to be satisfactory in prior service (such as in other Holtec transfer casks).

The mechanical design details of the gasketed joint in the transfer cask follow the guidelines in Chapter 3 of [8.11.1], which recommend joints subjected to cyclic loadings to be made of the "controlled compression" genré. The "controlled compression" joint minimizes cyclic damage to the gasket.

The O&M program for the storage system calls for HI-TRAC VW transfer cask elastomeric seals to be inspected for damage and replaced on an appropriate schedule as recommended by the manufacturer.

8.12 CHEMICAL AND GALVANIC REACTIONS

The materials used in the HI-STORM FW System are examined to establish that these materials do not participate in any chemical or galvanic reactions when exposed to the various environments during all normal operating conditions and off-normal and accident events.

The following acceptance criteria for chemical and galvanic reactions are extracted from ISG-15 [8.1.1] for use in HI-STORM FW components.

a. The DCSS should prevent the spread of radioactive material and maintain safety control functions using, as appropriate, noncombustible and heat resistant materials.

b. A review of the DCSS, its components, and operating environments (wet or dry) should confirm that no operation (e.g., short term loading/unloading or long-term storage) will produce adverse chemical and/or galvanic reactions, which could impact the safe use of the storage cask.

c. Components of the DCSS should not react with one another, or with the cover gas or spent fuel, in a manner that may adversely affect safety. Additionally, corrosion of components inside the containment vessel should be effectively prevented.

d. The operating procedures should ensure that no ignition of hydrogen gas should occur during cask loading or unloading.

e. Potential problems from general corrosion, pitting, stress corrosion cracking, or other types of corrosion, should be evaluated for the environmental conditions and dynamic loading effects that are specific to the component.

The materials and their ITS pedigree are listed in the drawing package provided in Section 1.5. The compatibility of the selected materials with the operating environment and to each other for potential galvanic reactions is discussed in this section.

8.12.1 Operating Environments

During fuel loading, handling or storage the components of the HI-STORM FW System experience the following environments (see Tables 8.1.1, 8.1.2, and 8.1.3).

- Spent Fuel Pool Water – During the fuel loading steps, the MPC confinement space is flooded with water (borated water in PWRs and demineralized water in BWRs). As water is withdrawn from the MPC space, the temperature of its contents rises, facilitating an Arrhenius-like acceleration of any chemical reaction that may occur in the presence of water and water vapor or boric acid (in PWRs). These same conditions would exist in the event an MPC needs to be unloaded and the MPC is reflooded prior to lid removal.

- Helium – During loading operations, all water is removed from the interior of the MPC and an inert gas is injected. Internal MPC components get exposed to dry helium under pressure during storage.

- External atmosphere – During long term storage the casks are exposed to outside atmosphere, air with temperature variations, solar radiation, rain, snow, ice, etc.

As discussed below, the components of the HI-STORM FW System has been engineered to ensure that the environmental conditions expected to exist at nuclear power plant installations do not prevent the cask components from rendering their respective intended functions.

8.12.2 Compatibility of MPC Materials

8.12.2.1 MPC Confinement Boundary Materials

Austenitic Stainless Steels

The MPC confinement boundary is composed entirely of corrosion-resistant austenitic stainless steel. The corrosion-resistant characteristics of such materials for dry SNF storage canister applications, as well as the protection offered by these materials against other material degradation effects, are well established in the nuclear industry. The available austenitic stainless steels are AISI Types 304, 304LN, 316 and 316LN containing a minimum of 16% chromium and 8% nickel, and at least traces of molybdenum. The passive films (formed due to atmospheric exposure) of stainless steels range between 10 to 50 angstroms ($1x10^{-6}$ to $5x10^{-6}$ mm) thick [8.12.4]. Of all types of stainless steels (i.e., austenitic, ferritic, martensitic, precipitation hardenable and two-phase), “the austenitic stainless alloys are considered the most resistant to industrial atmospheres and acid media” [8.12.4].

The MPC contains no gasketed, threaded, or packed joints for maintaining confinement. The all-welded construction of the MPC confinement boundary and the inert backfill gas within ensures that the interior surfaces and the MPC internals (Metamic-HT baskets, shims, etc.) are not subject to corrosion. Exterior MPC surfaces would be exposed to the ambient environment while inside of a HI-STORM FW storage overpack or a HI-TRAC VW transfer cask.

Austenitic Stainless Steels in Demineralized and Borated Water Environments

The average MPC may be in contact with borated and/or demineralized water at temperatures below boiling and at pressures of up to three atmospheres (not including hydrotest) for approximately 2 to 3 days. For PWRs, the soluble boron levels are typically maintained at or below 2,500 ppm (0.25% boric acid solution). Experimental corrosion data for AISI Type 304 and 316 stainless steels (Swedish Designations SIS-14-2333 and SIS-14-2343, respectively) are available from the Swedish Avesta Jernverk laboratory [8.12.4]. Corrosive media evaluated in these tests include 4% (40,000 ppm) and 20% (200,000 ppm) boric acid solutions and water, all at boiling. Under the evaluated conditions, the tested steels are identified as “fully resistant”, with corrosion rates of less than 0.1 mm per year. Even more extensive experimental corrosion

data is available from ASM International [8.12.1]. For test conditions without rapid agitation, similar to conditions that would exist during MPC fuel loading in a spent fuel pool, all austenitic stainless steels available for MPC fabrication (i.e., AISI Types 304, 304LN, 316 and 316LN) are extremely resistant to corrosion in boric acid and water. More specifically, one set of data (UNS No. S30400) for 2.5% boric acid solution and water at 90.6°C (195°F), under no aeration and rapid agitation yielded a maximum corrosion rate of 0.003 mm per year [8.12.1].

No structural effects from any potential corrosion from demineralized and borated water environments are expected. Loading of a dry storage cask with reasonable delays can take up to two weeks. Adjusting the worst-case data for a 0.25% boric acid concentration the maximum thinning of any structural member in an MPC is only 4.80 x 10^{-6} mm (1.89 microinches). This is a negligibly small fraction (0.0006%) of the thickness of the thinnest structural member 7.9 mm (0.3125 in.) and a negligibly small fraction (0.004%) of the tolerance on the material thickness (0.045 in.) permitted by the governing ASME Code [8.12.2].

Austenitic Stainless Steels and Crud

Corrosion products cause "crud" deposits on fuel assemblies. Industry experience shows that crud, which is stable in oxygenated solutions, has not been found to contain materials that can react with stainless steel and cause significant degradation. Crud may leave a slight film of rust on the interior surfaces of the MPC during fuel loading and closure activities.

Austenitic Stainless Steels and Boron Crystals

Dry boron or boric acid crystals that remain in the MPC after drying and helium backfill are expected to have negligible corrosive effects on stainless steel due to the absence of the necessary reagents (oxygen and moisture).

Austenitic Stainless Steels and Marine Environments

The MPC is designed to be loaded with spent fuel assemblies from most light water reactor (LWR) nuclear power plants. LWR nuclear power plants, in general, are located near large bodies of water to ensure an adequate supply of cooling water. As a result many nuclear power plants and, subsequently, many potential ISFSI sites are located in coastal areas where dissolved salts may be present in atmospheric moisture. Casks deployed at coastal ISFSI sites that would be exposed to the harsh marine environment for prolonged periods must not suffer corrosion that will impair their functionality.

Extensive data show corrosion rates (pitting) to 0.0018 (mm/yr) for 304, 304LN, 316 and 316LN in marine environments at ambient temperatures after 26 years [8.12.1]. Using this bounding corrosion rate data, a Holtec Position Paper [8.12.3] estimates the total corrosion of the external surface of the MPC in 100 years of service is about half a millimeter which is significantly smaller than the available design margins in the material thickness. It is to be noted that this upper-bound is estimated for an extreme hypothetical marine environment. As discussed earlier for inland applications the corrosion rates are insignificant.

Therefore, corrosion of the MPC in long-term storage is not a credible safety concern.

Austenitic Stainless Steels and Hydrogen Damage

Traces of hydrogen may be present under the MPC Lid during welding operations. The hydrogen content is limited due to a low hydrogen generation rate and the (required) purging of the underside of the lid with helium. Hydrogen damage is classified into four distinct types (1) hydrogen blistering, (2) hydrogen embrittlement, (3) decarburization, (4) hydrogen attack. Decarburization and hydrogen attack are high temperature processes and therefore may be of concern during cooling of the weld puddle. Austenitic stainless steels are one of the few metals that perform satisfactorily at all temperatures and pressures in the presence of hydrogen [8.12.6]. Considering the limited hydrogen concentration, limited time (2-3 days) for fuel loading and limited pressures and temperatures (with the exception of high temperatures at the lid to shell weld), hydrogen damage is not an applicable corrosion mechanism during fuel loading. With respect to the lid to shell weld, the weld design, use of a continuous inert gas purge, the weld method and NDE inspections provide assurance that the weld has no credible damage and is of high integrity.

8.12.2.2 Materials of MPC Internals

The internals of the MPC consists of Metamic-HT fuel baskets and aluminum alloy shims for basket support. Besides these internals, SNF, possible failed fuel and/or damaged fuel with containers, and non-fuel hardware, a sealed MPC may also contain boric acid crystals (in PWRs) and cruds. The cleanliness requirements and inspections during fabrication and fuel loading operations ensure that the MPC has minimal surface debris and impurities.

Tests on Metamic-HT

Extensive tests [8.9.7] have been conducted to establish material properties of Metamic-HT including its corrosion-resistance characteristics. The Metamic-HT specimens were used for corrosion testing in demineralized water and in 2000 ppm boric acid solution. The tests concluded that the Metamic-HT panels will sustain no discernible degradation due to corrosion when subjected to the severe thermal and aqueous environment that exists around a fuel basket during fuel loading or unloading conditions.

Aluminum Alloy

Aluminum alloy used in the fuel basket shims are hard anodized. The anodizing is an electrolytic passivation process used to increase the thickness of the natural oxide layer on the surface of metal parts. Anodizing increases corrosion resistance and wear resistance of the material surface. There is no mechanistic process for the basket shims with hard anodized surface to react with borated water or demineralized water during fuel loading operation. Under the long-term storage condition, the basket shims are exposed to dry and inert helium with no potential for reaction.

Effect of Forced Helium Dehydration (FHD) Process

The operation of the FHD consists of flowing hot dry helium through the MPC at pressures and temperature limited by the MPC design pressure and temperature of the MPC. Due to the purity of the helium stream and the relatively short duration (normally 10 to 60 hours), no significant corrosion mechanisms are identified.

Maintenance of Helium Atmosphere

The inert helium atmosphere in the MPC provides a non-oxidizing environment for the SNF cladding to assure its integrity during long-term storage. The preservation of the helium atmosphere in the MPC is assured by the robust design of the MPC Confinement Boundary (see Section 7.1). Maintaining an inert environment in the MPC mitigates conditions that might otherwise lead to SNF cladding failures. The required mass quantity of helium backfilled into the canister at the time of closure and the associated fabrication and closure requirements for the canister are specifically set down to assure that an inert helium atmosphere is maintained in the canister throughout the MPC's service life.

Allowable Fuel Cladding Temperatures

The helium atmosphere in the MPC promotes heat removal and thus reduces SNF cladding temperatures during dry storage. In addition, the SNF decay heat will substantially attenuate over the dry storage period. Maintaining the fuel cladding temperatures below allowable levels during long-term dry storage mitigates the damage mechanism that might otherwise lead to SNF cladding failures. The allowable long-term SNF cladding temperatures used for thermal acceptance of the MPC design are conservatively determined, as discussed in Section 4.3.

8.12.2.3 Galvanic Corrosion

The MPC is principally constructed of stainless steel shell and Metamic-HT. Borated aluminum and stainless steel have been used in close proximity in wet storage for over 30 years. Many spent fuel pools at nuclear plants contain fuel racks, which are fabricated from Metamic (classic) and stainless steel materials. Not one case of chemical or galvanic degradation has been found in such fuel racks. This experience provides a sound basis to conclude that corrosion will not occur in these materials. For further protection, both Metamic-HT and aluminum basket shims are installed in the anodized state in the MPC.

Furthermore, galvanic corrosion is not an applicable mechanism since the interior of the MPC during normal operation is essentially devoid of any moisture and the MPC shell surfaces are expected to be practically free from condensation. Finally, the interior of the carbon steel HI-STORM FW overpack is painted to inhibit corrosion.

During long-term storage in the HI-STORM FW overpack, the MPC operates at elevated temperatures under normal conditions while inside the HI-STORM. The external ambient environment normally consists of atmospheric conditions, which include humidity and perhaps airborne contaminants such as sulfur dioxide, chlorine gas, sulfur gas and ozone. The interior is

backfilled with highly pure helium. The spent fuel irradiates the MPC but at much lower levels than those experienced in an operating reactor. It is recognized that in general the higher the temperature the higher the rate of chemical reaction. It is also recognized that moisture will not exist on the MPC exterior surfaces for many years since moisture will not condense on hot surfaces and the protection afforded by the HI-STORM FW overpack. It is estimated that it would take decades for the hottest MPC to approach ambient temperatures and once at ambient temperature, any MPC surfaces will be highly corrosion resistance even when wet.

8.12.2.4 Cyclic Fatigue

As discussed in Section 3.1, passive non-cyclic nature of dry storage conditions does not subject the MPC to conditions that might lead to structural fatigue failure. Ambient temperature and insolation cycling during normal dry storage conditions and the resulting fluctuations in MPC thermal gradients and internal pressure is the only mechanism for fatigue. These low-stress, high-cycle conditions cannot lead to a fatigue failure of the MPC that is made from stainless alloy stock (endurance limit well in excess of 20,000 psi). All other off-normal or postulated accident conditions are infrequent or one-time occurrences, which cannot produce fatigue failures.

8.12.3 Compatibility of HI-STORM FW Overpack Materials

The principal operational considerations that bear on the adequacy of the storage overpack for the service life are addressed as follows:

Exposure to Environmental Effects

All exposed surfaces of the HI-STORM FW overpack are made from ferritic steels that are readily painted. Concrete, which serves strictly as a shielding material, is encased in steel. Therefore, the potential of environmental vagaries such as spalling of concrete, are ruled out for HI-STORM FW overpack. Under normal storage conditions, the bulk temperature of the HI-STORM FW overpack will change very gradually with time because of its large thermal inertia. Therefore, material degradation from rapid thermal ramping conditions is not credible for the HI-STORM FW overpack. Similarly, corrosion of structural steel embedded in the concrete structures due to salinity in the environment at coastal sites is not a concern for HI-STORM FW because HI-STORM FW does not rely on rebars (indeed, it contains no rebars). As discussed in Appendix 1.D of the HI-STORM 100 FSAR, the aggregates, cement and water used in the storage cask concrete are adequately controlled to provide high durability and resistance to temperature effects. The configuration of the storage overpack assures resistance to freeze-thaw degradation. In addition, the storage overpack is specifically designed for a full range of enveloping design basis natural phenomena that could occur over the service life of the storage overpack as catalogued in Section 2.2 and evaluated in Chapter 11.

Material Degradation

The relatively low neutron flux to which the storage overpack is subjected cannot produce measurable degradation of the cask's material properties and impair its intended safety function. Exposed carbon steel components are coated to prevent corrosion. The ambient environment of the ISFSI storage pad mitigates damage due to exposure to corrosive and aggressive chemicals that may be produced at other industrial plants in the surrounding area.

Maintenance and Inspection Provisions

The requirements for periodic inspection and maintenance of the storage overpack throughout its service life are defined in Section 10.2. These requirements include provisions for routine inspection of the storage overpack exterior and periodic visual verification that the ventilation flow paths of the storage overpack are free and clear of debris. ISFSIs located in areas subject to atmospheric conditions that may degrade the storage cask or canister should be evaluated by the licensee on a site-specific basis to determine the frequency for such inspections to assure long-term performance. In addition, the HI-STORM FW system is designed for easy retrieval of the MPC from the storage overpack should it become necessary to perform more detailed inspections and repairs on the storage overpack.

The above findings are consistent with those of the NRC's Waste Confidence Decision Review [8.12.5], which concluded that dry storage systems designed, fabricated, inspected, and operate in accordance with such requirements are adequate for a 100-year service life while satisfying the requirements of 10CFR72.

8.12.4 Compatibility of HI-TRAC VW Transfer Cask Materials

The principal design considerations that bear on the adequacy of the HI-TRAC VW Transfer Cask for the service life are addressed as follows:

Exposure to Environmental Effects

All transfer cask materials that come in contact with the spent fuel pool are coated to facilitate decontamination. The HI-TRAC VW is designed for repeated normal condition handling operations with a high factor of safety to assure structural integrity. The resulting cyclic loading produces stresses that are well below the endurance limit of the cask's materials, and therefore, will not lead to a fatigue failure in the transfer cask. All other off-normal or postulated accident conditions are infrequent or one-time occurrences that do not contribute significantly to fatigue. In addition, the transfer cask utilizes materials that are not susceptible to brittle fracture during the lowest temperature permitted for loading, as discussed in Section 8.4 in the foregoing.

Material Degradation

All transfer cask materials that are susceptible to corrosion are coated. The controlled environment in which the HI-TRAC VW is used mitigates damage due to direct exposure to corrosive chemicals that may be present in other industrial applications. The infrequent use and relatively low neutron flux to which the HI-TRAC VW materials are subjected do not result in radiation embrittlement or degradation of the shielding materials in the HI-TRAC VW that could impair the intended safety function. The HI-TRAC VW transfer cask materials have been selected for durability and wear resistance for their deployment.

Maintenance and Inspection Provisions

The requirements for periodic inspection and maintenance of the HI-TRAC VW transfer cask throughout its service life are defined in Section 10.2. These requirements include provisions for routine inspection of the HI-TRAC VW transfer cask for damage prior to each use. Precautions are taken during bottom lid handling operations to protect the sealing surfaces of the bottom lid. The leak tightness of the liquid neutron shield is verified periodically. The water jacket pressure relief devices and connections for water injection/removal have been engineered for convenient removal and replacement.

8.12.5 Potential Combustible Gas Generation

To ensure safe fuel loading operation the operating procedure described in Chapter 9 provides for the monitoring of hydrogen gas in the area around the MPC lid prior to and during welding or cutting activities. Although the aluminum surfaces (Metamic-HT basket and aluminum basket shims) are anodized, there is still a potential for generation of hydrogen in minute amounts when immersed in spent fuel pool water for an extended period. Accordingly, as a defense-in-depth measure, the lid welding procedure requires purging the space below the MPC lid prior to and during welding or cutting operation to eliminate any potential for formation of any combustible mixture of hydrogen and oxygen. Following the completion of the MPC lid welding and hydrostatic testing the MPC is drained and dried. As discussed earlier, after the completion of the drying operation there is no credible mechanism for any combustible gases to be generated within the MPC.

8.12.6 Oxidation of Fuel During Loading/Unloading Operations

During the loading and unloading operations in a spent fuel pool, the fuel cladding is surrounded by water. During fuel drying operation the water is displaced with a non-oxidizing gas environment. Therefore, there is no credible mechanism for oxidation of fuel.

8.12.7 Conclusion

The above discussion leads to the conclusion that the materials selected for the HI-STORM FW System components are compatible with the environment for all operating conditions. There is no potential for significant corrosion, chemical reaction or galvanic reaction to shorten the intended service life of the equipment. In other words, the acceptance criteria set forth in ISG-15 are completely satisfied.

8.13 FUEL CLADDING INTEGRITY

8.13.1 Regulatory Guidance

The acceptance criteria from ISG-11that apply to the fuel cladding are:

a. For all fuel burnups (low and high), the maximum calculated fuel cladding temperature should not exceed 400°C (752°F) for normal conditions of storage and short-term loading operations (e.g., drying, backfilling with inert gas, and transfer of the cask to the storage pad).

   However, for low burnup fuel, a higher short-term temperature limit may be used, if it can be shown by calculation that the best estimate cladding hoop stress is equal to or less than 90 MPa (13.053 psi) for the temperature limit proposed.

b. During loading operations, for high burnup fuel, repeated thermal cycling (repeated heatup/cooldown cycles) may occur but should be limited to less than 10 cycles, with cladding temperature variations that are less than 65°C (149°F) each.

c. For off-normal and accident conditions, the maximum cladding temperature should not exceed 570°C (1058°F).

The ISG-15 guidance on cladding integrity in its entirety provides the following supplemental requirements:

a. The cladding temperature should be maintained below maximum allowable limits, and an inert environment should be maintained inside the cask cavity to maintain reasonable assurance that the spent fuel cladding will be protected against degradation that may lead to gross rupture, loss of retrievability, or severe degradation.

b. Cladding should not rupture during re-flood operations.

8.13.2 Measures to Meet Regulatory Guidance

The HI-STORM FW System features and processes minimize the potential for any spent fuel cladding degradation during transfer and storage conditions by limiting the fuel cladding temperature and the environment around the fuel rod to within ISG-11 limits (Table 4.3.1).

The highly pure helium under positive pressure in the canister limits the amount of oxidants and controls the cladding temperature. The MPC drying and helium backfilling operations result in the creation of an inert environment around the fuel. As prescribed by NUREG-1536 [8.3.3], if the classical vacuum drying method is used, the partial pressure of water vapor is brought down to below 3 torr to minimize [8.13.1] residual oxidizing gas concentration.

An alternative method (preferred) for drying the MPC internals utilizes Holtec's patented Forced Helium Dehydration technology [8.13.1, 8.13.2] described in the HI-STORM 100 FSAR (Appendix 2.B). The Forced Helium Dehydrator has been successfully used at numerous nuclear plants since its regulatory approval in 2001. The efficacy of the Forced Gas Dehydrator (FGD) has been tested in a full-scale demonstration [8.13.4] for demoisturizing simulated water-logged RBMK fuel [8.13.3].

The FHD uses helium as the working substance. The use of the FHD prevents the elevation of the fuel cladding temperature during drying, which is a chief demerit of the vacuum drying method. The use of the FHD method of drying is compulsory for high burnup fuel to protect its (relatively) ductility challenged cladding from severe thermal transients.

Chapter 2 provides the allowable fuel cladding temperature limits along with other design conditions. Chapter 4 presents performance evaluation of the HI-STORM FW System under normal conditions of storage, MPC temperatures during moisture removal operations and HI-STORM FW System long term storage maximum temperature conditions. Chapter 4 provides MPC temperatures under various accident conditions. It is demonstrated that the maximum calculated fuel cladding temperature is within 400°C (752°F) with substantial margins for normal conditions of storage and short-term loading operations. For off-normal and accident conditions, the maximum cladding temperature does not exceed 570°C (1058°F).

The short-term operations described in Chapter 9 are specifically configured to prevent severe thermal stresses in the fuel cladding due to rapid thermal transients.

The thermal stresses from MPC reflood analysis during fuel unloading operations shall be lower than typical MPCs because the HI-STORM FW fuel assemblies operate at considerably lower temperatures at Design Basis heat loads (see Chapter 4) than is permitted by ISG-11.

8.14 EXAMINATION AND TESTING

Examination and testing are integral parts of manufacturing of the HI-STORM FW System components. A comprehensive discussion on the examinations and testing that are conducted during the manufacturing process is provided in Section 10.1. The applicable codes and standards used are also referred and the acceptance criteria are listed.

8.14.1 Helium Leak Testing of Canister &Welds

Helium leakage testing of the MPC base metals (shell, baseplate, and MPC lid) and MPC shell to baseplate and shell to shell welds shall be performed in accordance with the leakage test methods and procedures of ANSI N14.5 [8.14.1]. Acceptance criterion is specified in Chapter 10. Testing shall be performed in accordance with written and approved procedures.

Leak testing results for the MPC shall be documented and shall become part of the quality record documentation package.

The helium leakage test of the vent and drain port cover plate welds shall be performed using a helium mass spectrometer leak detector (MSLD). If a leakage rate exceeding the acceptance criterion is detected, then the area of leakage shall be determined and the area repaired per ASME Code Section III, Subsection NB, Article NB-4450 requirements. Re-testing shall be performed until the leakage rate acceptance criteria are met.

Leakage testing of the field welded MPC lid-to-shell weld and closure ring welds are not required.

Leakage testing of the vent and drain port cover plate welds shall be performed after welding of the cover plates and subsequent NDE. The description and procedures for these field leakage tests are provided in Chapter 9 of this SAR and the acceptance criteria are defined in the Technical Specifications for the HI-STORM FW System.

8.14.2 Periodic Inspections

Post-fabrication inspections are discussed in Section 10.2 as part of the HI-STORM FW System maintenance program. Inspections are conducted prior to fuel loading or prior to each fuel handling campaign. Other periodic inspections are conducted during storage.

The HI-STORM FW overpack is a passive device with no moving parts. Overpack vent screens are inspected monthly for damage, holes, etc. The overpack external surface including identification markings is visually examined annually. The temperature monitoring system, if used, is inspected per licensee's QA program and manufacturer's recommendations. HI-TRAC VW transfer cask visual inspection is performed annually for compliance with the licensing drawings.

8.15 CONCLUSION

The preceding sections describe the materials used in important to safety SSCs and the suitability of those materials for their intended functions in the HI-STORM FW System.

The requirements of 10CFR72.122(a) are met: The material properties of SSCs important to safety conform to quality standards commensurate with their safety functions.

The requirements of 10CFR72.104(a), 106(b), 124, and 128(a)(2) are met: Materials used for criticality control and shielding are adequately designed and specified to perform their intended function.

The requirements of 10CFR72.122(h)(1) and 236(h) are met: The design of the DCSS and the selection of materials adequately protect the spent fuel cladding against degradation that might otherwise lead to gross rupture of the cladding.

The requirements of 10CFR72.236(h) and 236(m) are met: The material properties of SSCs important to safety will be maintained during normal, off-normal, and accident conditions of operation as well as short-term operations so the spent fuel or MPC, as appropriate, can be readily retrieved without posing operational safety problems.

The requirements of 10CFR72.236(g) are met: The material properties of SSCs important to safety will be maintained during all conditions of operation so the spent fuel can be safely stored for the specified service life and maintenance can be conducted as required.

The requirements of 10CFR72.236(h) are met: The HI-STORM FW System employs materials that are compatible with wet and dry spent fuel loading and unloading operations and facilities. These materials should not degrade over time or react with one another during long-term storage.

8.16 REFERENCES

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[8.12.3] Holtec Position Paper DS-330, "Estimating an Upper Bound on the Cumulative Corrosion in Stainless Steel MPCs in Highly Corrosive Environments." (Holtec Proprietary)

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[8.13.2] Holtec Patent No. 7,096,600B2, "Forced Gas Flow Canister Dehydration », August 29, 2006.

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[8.13.4] Holtec Report No. HI-2084060, "FGD Performance Test Program for ISF-2 Project for Chernobyl Nuclear Plant," 2008.

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APPENDIX 8.A

Datasheets for Coatings and Paints[§]

[§] The materials in this Appendix can also be found in the suppliers' website.

product data carboline®

Carboguard® 890 & 890 LT

Selection & Specification Data

Generic Type Cycloaliphatic Amine Epoxy

Description Highly chemical resistant epoxy mastic coating with exceptionally versatile uses in all industrial markets. Self-priming and suitable for application over most existing coatings, and tightly adherent to rust. Carboguard 890 serves as stand-alone system for a variety of chemical environments. Carboguard 890 is also designed for various immersion conditions.

Features
- Excellent chemical resistance
- Surface tolerant characteristics
- Conventional and low-temperature versions
- Self-priming and primer/finish capabilities
- Very good abrasion resistance
- VOC compliant to current AIM regulations
- Suitable for use in USDA inspected facilities

Color Refer to Carboline Color Guide. Certain colors may require multiple coats for hiding. Note: The low temperature formulation will cause most colors to yellow or discolor more than normal in a short period of time. (Epoxies lose gloss, discolor and chalk in sunlight exposure.)

Finish Gloss

Primers Self-priming. May be applied over inorganic zinc primers and other tightly adhering coatings. A mist coat may be required to minimize bubbling over inorganic zinc primers.

Topcoats Acrylics, Epoxies, Polyurethanes

Dry Film Thickness 4.0-6.0 mils (100-150 microns) per coat
6.0-8.0 mils (150-200 microns) over light rust and for uniform gloss over inorganic zincs.
Don't exceed 10 mils (250 microns) in a single coat. Excessive film thickness over inorganic zincs may increase damage during shipping or erection.

Solids Content By Volume (890): 75% ± 2%
(890LT): 80% ± 2%

Theoretical Coverage Rate
890: 1203 mil ft² (30.0 m²/l at 25 microns)
241 ft² at 5 mils (6.0 m²/l at 125 microns)
890LT: 1283 mil ft² (31.0 m²/l at 25 microns)
257 ft² at 5 mils (6.3 m²/l at 125 microns)
Allow for loss in mixing and application

VOC Values

	890	890 LT
As supplied	1.7lbs/gal (214 g/l)	1.5lbs/gal (180g/l)
Thinned w/#2*:	7oz/gal=2.0lbs/gal (250g/l) 13oz/gal=2.2lbs/gal (271g/l)	15oz/gal=2.0lbs/gal (250g/l)
Thinned w/#33*:	7oz/gal=2.0lbs/gal (250g/l) 16oz/gal=2.3lbs/gal (285g/l)	14oz/gal=2.0 lbs/gal (250g/l) 16oz/gal=2.1lbs/gal (258g/l)

*Use Thinner #76 up to 8 oz/gal for 890 and 16 oz/gal for 890 LT where non-photochemically reactive solvents are required.

Dry Temp. Resistance Continuous: 250°F (121°C)
Non-Continuous: 300°F (149°C)
Discoloration and loss of gloss is observed above 200°F (93°C).

Limitations Do not apply over latex coatings. For immersion projects use only factory made material in special colors. Consult Technical Service for specifics. Carboguard 890 LT should not be used for immersion and should only be used as a primer or intermediate coat. Discoloration may be objectionable if used as a topcoat.

Substrates & Surface Preparation

General Surfaces must be clean and dry. Employ adequate methods to remove dirt, dust, oil and all other contaminants that could interfere with adhesion of the coating.

Steel Immersion: SSPC-SP10
Non-immersion: SSPC-SP6
1.5-3.0 mils (38-75 microns)
SSPC-SP2 or SP3 are suitable cleaning methods for mild environments.

Galvanized Steel Prime with specific Carboline primers as recommended by your Carboline Sales Representative. Refer to the specific primer's Product Data Sheet for substrate preparation requirements.

Concrete or CMU Concrete must be cured 28 days at 75°F (24°C) and 50% relative humidity or equivalent. Prepare surfaces in accordance with ASTM D4258 Surface Cleaning of Concrete and ASTM D4259 Abrading Concrete. Voids in concrete may require surfacing. Mortar joints should be cured a min of 15 days. Prime with itself, Carboguard® 1340, or suitable filler/sealer.

Drywall & Plaster Joint compound and plaster should be fully cured prior to coating application. Prime with Carbocrylic® 120 or Carboguard 1340.

Previously Painted Surfaces Lightly sand or abrade to roughen surface and degloss the surface. Existing paint must attain a minimum 3B rating in accordance with ASTM D3359 "X-Scribe" adhesion test.

Performance Data

Test Method	System	Results	Report #
ASTM D3359 Adhesion	Blasted Steel 1 ct. 890	5A	0270
ASTM D4060 Abrasion	Blasted Steel 1 ct. Epoxy Pr. 1 ct. 890	85 mg. loss after 1000 cycles, CS17 wheel, 1000 gm. load	02411
ASTM B117 Salt Fog	Blasted Steel 2 cts. 890	No effect on plane, rust in scribe. 1/16" undercutting at scribe after 2000 hours	02594
ASTM B117 Salt Fog	Blasted Steel 1 ct. IOZ 1 ct. 890	No effect on plane, no rust in scribe and no undercutting after 4000 hours	L40-42,45,95
ASTM D1735 Water Fog	Blasted Steel 1 ct. Epoxy Pr. 1 ct. 890	No blistering, rusting or delamination after 2800 hours	08564
ASTM D3363 Pencil Hardness	Blasted Steel 2 cts. 890	Greater than 8H	02775
ASTM D2486 Scrub Resistance	Blasted Steel 1 ct. 890	93% gloss retained after 10,000 cycles w/ liquid scrub medium	03142
ASTM E84 Flame and Smoke	2 ct. 890	5 Flame 5 Smoke Class A	03110

Test reports and additional data available upon written request.

April 2007 replaces February 2007

0986/0983

Carboguard® 890 & 890 LT

Application Equipment

Listed below are general equipment guidelines for the application of this product. Job site conditions may require modifications to these guidelines to achieve the desired results. **General Guidelines:**

Spray Application (General) This is a high solids coating and may require adjustments in spray techniques. Wet film thickness is easily and quickly achieved. The following spray equipment has been found suitable and is available from manufacturers such as Binks, DeVilbiss and Graco.

Conventional Spray Pressure pot equipped with dual regulators, 3/8" I.D. minimum material hose, .070" I.D. fluid tip and appropriate air cap.

Airless Spray

Pump Ratio:	30:1 (min.)*
GPM Output:	3.0 (min.)
Material Hose:	3/8" I.D. (min.)
Tip Size:	.017"-.021"
Output PSI:	2100-2300
Filter Size:	60 mesh

*Teflon packings are recommended and available from the pump manufacturer.

Brush & Roller (General) Multiple coats may be required to obtain desired appearance, recommended dry film thickness and adequate hiding. Avoid excessive re-brushing or re-rolling. For best results, tie-in within 10 minutes at 75°F (24°C).

Brush Use a medium bristle brush.

Roller Use a short-nap synthetic roller cover with phenolic core.

Mixing & Thinning

Mixing Power mix separately, then combine and power mix. DO NOT MIX PARTIAL KITS.

Ratio 890 and 890 LT 1:1 Ratio (A to B)

Thinning* Spray: Up to 13 oz/gal (10%) w/ #2
Brush: Up to 16 oz/gal (12%) w/ #33
Roller: Up to 16 oz/gal (12%) w/ #33
Thinner #33 can be used for spray in hot/windy conditions. Use of thinners other than those supplied or recommended by Carboline may adversely affect product performance and void product warranty, whether expressed or implied.
*See VOC values for thinning limits.

Pot Life 890 3 Hours at 75°F (24°C)
890 LT 2 Hours at 75°F (24°C)
Pot life ends when coating loses body and begins to sag. Pot life times will be less at higher temperatures.

Cleanup & Safety

Cleanup Use Thinner #2 or Acetone. In case of spillage, absorb and dispose of in accordance with local applicable regulations.

Safety Read and follow all caution statements on this product data sheet and on the MSDS for this product. Employ normal workmanlike safety precautions. Hypersensitive persons should wear protective clothing, gloves and use protective cream on face, hands and all exposed areas.

Ventilation When used as a tank lining or in enclosed areas, thorough air circulation must be used during and after application until the coating is cured. The ventilation system should be capable of preventing the solvent vapor concentration from reaching the lower explosion limit for the solvents used. User should test and monitor exposure levels to insure all personnel are below guidelines. If not sure or if not able to monitor levels, use MSHA/NIOSH approved supplied air respirator.

Caution This product contains flammable solvents. Keep away from sparks and open flames. All electrical equipment and installations should be made and grounded in accordance with the National Electric Coce. In areas where explosion hazards exist, workmen should be required to use non-ferrous tools and wear conductive and non-sparking shoes.

Application Conditions

890

Condition	Material	Surface	Ambient	Humidity
Normal	60°-85°F (16°-29°C)	60°-85°F (16°-29°C)	60°-90°F (16°-32°C)	0-80%
Minimum	50°F (10°C)	50°F (10°C)	50°F (10°C)	0%
Maximum	90°F (32°C)	125°F (52°C)	110°F (43°C)	80%

890 LT

Condition	Material	Surface	Ambient	Humidity
Normal	60-85°F (16-29°C)	60-85°F (16-29°C)	60-90°F (16-32°C)	10-80%
Minimum	40°F (4°C)	35°F (2°C)	35°F (2°C)	0%
Maximum	90°F (32°C)	125°F (52°C)	110°F (43°C)	80%

This product simply requires the substrate temperature to be above the dew point. Condensation due to substrate temperatures below the dew point can cause flash rusting on prepared steel and interfere with proper adhesion to the substrate. Special application techniques may be required above or below normal application conditions.

Curing Schedule

890 (Based on 4–8 mils, 100-200 microns dry film thickness.)

Surface Temp. & 50% Relative Humidity	Dry to Recoat	Dry to Topcoat w/ Other Finishes	Final Cure	
			General	Immersion
50°F (10°C)	12 Hours	24 Hours	3 Days	N/R
60°F (16°C)	8 Hours	16 Hours	2 Days	10 Days
75°F (24°C)	4 Hours	8 Hours	1 Day	5 Days
90°F (32°C)	2 Hours	4 Hours	16 Hours	3 Days

890 LT (Based on 5 mils, 125 microns dry film thickness.)

Surface Temp. & 50% Relative Humidity	Dry to Touch	Dry to Handle	Dry to Recoat & Topcoat w/ Others	Final Cure General Service
35°F (2°C)	5 Hours	18 Hours	20 Hours	7 Days
40°F (4°C)	4.5 Hours	15.5 Hours	16 Hours	5 Days
50°F (10°C)	3.5Hours	6.5 Hours	12 Hours	3 Days
60°F (16°C)	2 Hours	5 Hours	8 Hours	2 Days
75°F (24°C)	1.5Hours	2 Hours	4 Hours	24 Hours
90°F (32°C)	1 Hour	1.5 Hours	2 Hours	16 Hours

Higher film thickness, insufficient ventilation or cooler temperatures will require longer cure times and could result in solvent entrapment and premature failure. Excessive humidity or condensation on the surface during curing can interfere with the cure, can cause discoloration and may result in a surface haze. Any haze or blush must be removed by water washing before recoating. During high humidity conditions, it is recommended that the application be done while temperatures are increasing. **Maximum recoat/topcoat times are 30 days for epoxies and 90 days for polyurethanes at 75°F (24°C).** If the maximum recoat times have been exceeded, the surface must be abraded by sweep blasting or sanding prior to the application of additional coats. 890 LT applied below 50°F (10°C) may temporarily soften as temperatures rise to 60°F (16°C). This is a normal condition and will not affect performance.

Packaging, Handling & Storage

Shipping Weight (Approximate)	2 Gallon Kit 29 lbs (13 kg)	10 Gallon Kit 145 lbs (66 kg)
Flash Point (Setaflash)	89°F (32°C) for Part A; 890 & 890 LT 73°F (23°C) for Part B; 890 & 890 LT	
Storage Temperature & Humidity	40° -110°F (4°-43°C) Store indoors. 0-100% Relative Humidity	
Shelf Life: 890 & 890LT	Part A: Min. 36 months at 75°F (24°C) 890 Part B: Min. 15 months at 75°F (24°C) 890 LT Part B: Min. 15 months at 75°F (24°C)	

***Shelf Life: (actual stated shelf life) when kept at recommended storage conditions and in original unopened containers.**

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April 2007 replaces February 2007

product data **carboline**®

Carbozinc® 11

Includes Carbozinc 11 FG

Selection & Specification Data

Generic Type Solvent Based Inorganic Zinc

Description Time-tested corrosion resistant primer that protects steel galvanically in the harshest environments. For over four decades, Carbozinc 11 (CZ 11) has been the industry standard for high-performance inorganic zinc protection on steel structures worldwide.

Features
- CZ 11 and CZ 11 FG meet Class B slip co-efficient and creep testing criteria for use on faying surfaces
- Rapid cure. Dry to handle in 45 minutes at 60°F (16°C) and 50% relative humidity.
- Low temperature cure down to 0°F (-18°C).
- High zinc loading.
- Meets FDA requirements in gray color.
- Available in ASTM D520, Type II zinc version.
- Very good resistance to salting.
- May be applied with standard airless or conventional spray equipment.
- VOC compliant in certain areas

CZ 11 FG
- Lower zinc loading for economics.
- VOC compliant for shop/fabricator use only.

Color Green (0300); Gray (0700)

Finish Flat

Primers Self Priming

Topcoats Not required for certain exposures. Can be topcoated with Epoxies, Polyurethanes, Acrylics, High-Heat Silicones and others as recommended by your Carboline sales representative. Under certain conditions, a mist coat is required to minimize topcoat bubbling.

Dry Film Thickness 2.0-3.0 mils (50-75 microns). Dry film thickness in excess of 6.0 mils (150 microns) per coat is not recommended.

		CZ 11	CZ 11 FG
Solids Content	By Weight:	79% ± 2%	74% ± 2%
Zinc Content in dry film	By Weight:	85% ± 2%	79% ± 2%

Theoretical Coverage Rate
CZ 11: 1000 mil ft² (22.8 m²/l at 25 microns)
333 ft² at 3.0 mils (8.2 m²/l at 75 microns)
CZ 11 FG: 850 mil ft² (19.4 m²/l at 25 microns)
283 ft² at 3.0 mils (7.0 m²/l at 75 microns)
Allow for loss in mixing and application

VOC Values Carbozinc 11
EPA Method 24: 4.0 lbs./gal (479 g/l)
Thinned:
7 oz/gal w/ #21: 4.1 lbs./gal (492 g/l)
5 oz/gal w/ #26: 4.1 lbs./gal (492 g/l)
5 oz/gal w/ #33: 4.1 lbs./gal (492 g/l)
These are nominal values.

VOC Values Carbozinc 11 FG
EPA Method 24: 4.3 lbs./gal (515 g/l)
Thinned: For use in fabrication shops only to remain in VOC compliance in accordance with EPA Standards.
7 oz/gal w/ #21: 4.5 lbs./gal (539 g/l)
5 oz/gal w/ #26: 4.5 lbs./gal (539 g/l)
5 oz/gal w/ #33: 4.5 lbs./gal (539 g/l)
These are nominal values.

Dry Temp. Resistance
Untopcoated:
Continuous: 750°F (399°C)
Non-Continuous: 800°F (427°C)
With recommended silicone topcoats:
Continuous: 1000°F (538°C)
Non-Continuous: 1200°F (649°C)

Substrates & Surface Preparation

General Surfaces must be clean and dry. Employ adequate methods to remove dirt, dust, oil and all other contaminants that could interfere with adhesion of the coating.

Steel Non-Immersion: SSPC-SP6 and obtain a 1.0-3.0 mil (25-75 micron) angular blast profile.

Performance Data

CZ 11

Test Method	System	Results	Report #
ASTM A-325 Slip Co-efficient	Blasted steel 1 ct. CZ 11	0.668; meets requirements for Class B rating	02722
ASTM B117 Salt Spray	1 ct. CZ 11 at 2 mils dry film thickness over blasted steel	No rusting or blistering, cracking or delamination after 43000 hrs. Moderate salting of the surface only.	SR 408
ASTM D3363 Pencil Hardness	1 ct. CZ 11	Pencil Hardness "2H"	03278
AASHTO M300 Bullet Hole Immersion Paragraph 4.6.9	1 ct. CZ 11 over Abrasive blasted steel	No blistering or rusting of coating or rusting of bare steel area after 650 hrs. Immersion in 5% sodium chloride solution; 1.5" round bare area in coating.	02514

Test reports and additional data available upon written request.

Application Equipment

Listed below are general equipment guidelines for the application of this product. Job site conditions may require modification to these guidelines to achieve the desired results.

General Guidelines:

Spray Application (General) The following spray equipment has been found suitable and is available from manufacturers such as Binks, DeVilbiss and Graco. Keep material under mild agitation during application. If spraying stops for more than 10 minutes, recirculate the material remaining in the spray line. Do not leave mixed primer in the hoses during work stoppages.

Conventional Spray Agitated pressure pot equipped with dual regulators, 3/8" I.D. minimum material hose, with a maximum length of 50', .070" I.D. fluid tip and appropriate air cap.

Airless Spray
Pump Ratio: 30:1 (min.)
GPM Output: 3.0 (min.)
Material Hose: 3/8" I.D. (min.)
Tip Size: .019-.023"
Output PSI: 1500-2000
Filter Size: 60 mesh
Teflon packings are recommended and available from the pump manufacturer.

Brush For touch-up of areas less than one square foot only. Use medium bristle brush and avoid rebrushing.

Roller Not recommended

October 2006 replaces September 2006 0250

Carbozinc® 11

Mixing & Thinning

Mixing Power mix base, then combine and power mix as follows. Pour zinc filler very slowly into premixed base with continuous agitation. Mix until free of lumps. Pour mixture through a 30 mesh screen. DO NOT MIX PARTIAL KITS.
Tip: Sifting zinc through a window screen will aid in the mixing process by breaking up or catching dry zinc lumps.

Ratio

	CZ 11 1 Gal Kit	CZ 11 5 Gallon Kit	CZ 11 FG 4.6 Gallon Kit
Part A:	.75 gal.	3.75 gallons	3.75 gallons
Zinc Filler:	14.6 lbs.	73 lbs.	50 lbs.

Thinning May be thinned up to 5 oz/gal (4%) with #26 for ambient and warm surfaces. For extremely warm or windy conditions, may be thinned up to 5 oz/gal (4%) with #33. In cool weather (below 40°F (4°C)), thin up to 7 oz/gal (6%) with #21. Use of thinners other than those supplied or recommended by Carboline may adversely affect product performance and void product warranty, whether expressed or implied.

Pot Life 8 Hours at 75°F (24°C) and less at higher temperatures. Pot life ends when coating becomes too viscous to use.

Cleanup & Safety

Cleanup Use Thinner #21 or Isopropyl Alcohol. In case of spillage, absorb and dispose of in accordance with local applicable regulations.

Safety Read and follow all caution statements on this product data sheet and on the MSDS for this product. Employ normal workmanlike safety precautions. Hypersensitive persons should wear protective clothing, gloves and use protective cream on face, hands and all exposed areas.

Ventilation When used as a tank lining or in enclosed areas, thorough air circulation must be used during and after application until the coating is cured. The ventilation system should be capable of preventing the solvent vapor concentration from reaching the lower explosion limit for the solvents used. In addition to ensuring proper ventilation, appropriate respirators must be used by all application personnel.

Caution This product contains flammable solvents. Keep away from sparks and open flames. All electrical equipment and installations should be made and grounded in accordance with the National Electric Code. In areas where explosion hazards exist, workmen should be required to use non-ferrous tools and wear conductive and non-sparking shoes.

Application Conditions

Condition	Material	Surface	Ambient	Humidity
Normal	40°-95°F (4°-35°C)	40°-110°F (4°-43°C)	40°-95°F (4°-35°C)	40-90%
Minimum	0°F (-18°C)	0°F (-18°C)	0°F (-18°C)	30%
Maximum	130°F (54°C)	200°F (93°C)	130°F (54°C)	95%

This product simply requires the substrate temperature to be above the dew point. Condensation due to substrate temperatures below the dew point can cause flash rusting on prepared steel and interfere with proper achesion to the substrate. Special application techniques may be required above or below normal application conditions.

Curing Schedule

Surface Temp. & 50% Relative Humidity	Dry to Handle	Dry to Topcoat/Recoat
0°F (-18°C)	4 Hours	7 Days
40°F (4°C)	1 Hour	48 Hours
60°F (16°C)	¾ Hour	24 Hours
80°F (27°C)	¾ Hour	18 Hours
100°F (38°C)	¼ Hour	16 Hours

These times are based on a 3.0-4.0 mil (75-100 micron) dry film thickness. Higher film thickness, insufficient ventilation or cooler temperatures will require longer cure times and could result in solvent entrapment and premature failure. Humidity levels below 50% will require longer cure times. **Notes**: Any salting that appears on the zinc surface as a result of prolonged weathering exposure must be removed prior to the application of additional coatings. Also, loose zinc must be removed from the cured film by rubbing with fiberglass screen wire if: 1) The Carbozinc 11 is to be used without a topcoat in immersion service and "zinc pick up" could be detrimental, or 2) When "dry spray/overspray" is evident on the cured film and a topcoat will be applied. For **accelerated curing or where the relative humidity is below 40%**, allow an initial 2-hour ambient cure. Follow 2 hour cure with water misting or steam to keep the coated surface wet for a minimum of 8 hours and until the coated surface achieves a "2H" pencil hardness per ASTM D3363.

Packaging, Handling & Storage

CZ 11 Shipping Weight (Approximate) 1 Gallon Kit: 23 lbs (10 kg); 5 Gallon Kit: 113 lbs (51 kg)

CZ 11 FG Shipping Weight (Approximate) 4.6 Gallon Kit: 104 lbs. (47 kg)

Flash Point (Setaflash) Part A: 55°F (13°C)
Zinc Filler: NA

Storage (General) Store Indoors.

Storage Temperature & Humidity 40° -100°F (4-38°C).
0-90% Relative Humidity

Shelf Life: 11 & 11FG Part A: 12 months at 75°F (24°C)
Part B: 24 months at 75°F (24°C)

***Shelf Life: (actual stated shelf life) when kept at recommended storage conditions and in original unopened containers.**

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Thermaline® 450
Novolac

Selection & Specification Data

Generic Type Amine-Cured Novolac Epoxy

Description Highly cross-linked, glass flake-filled polymer that offers exceptional barrier protection and resistance to wet/dry cycling at elevated temperatures. Suitable for insulated and non-insulated pipes, stacks and equipment operating up to 450°F (232°C). Th s coating provides excellent resistance to corrosion, abrasion and permeation, and its novolac-modification resists severe chemical attack.

Features
- Temperature resistance up to 450°F (232°C)
- High-build single-coat capabilities
- Excellent resistance to thermal shock
- Superior abrasion and chemical resistance through internal reinforcement
- Ambient-temperature cure
- VOC compliant to current AIM regulations

Color Red (0500); Gray (5742)

Finish Eggshell

Primers Self-priming. May be applied over epoxies and phenolics.

Topcoats Epoxies, Polyurethanes

Dry Film Thickness 8.0-10.0 mils (200-250 microns)
Do not exceed 15 mils (375 microns) per coat.

Solids Content By Volume: 70% ± 2%

Theoretical Coverage Rate 1117 mil ft² (27.9 m²/l at 25 microns)
Allow for loss in mixing and application

VOC Values
As supplied: 2.08 lbs/gal (250 g/l)
Thinned:
13 oz/gal w/ #213: 2.58 lbs/gal (308 g/l)
13 oz/gal w/#2 2.54 lbs/gal (305 g/l)
These are nominal values.

Dry Temp. Resistance
Continuous: 425°F (218°C)
Non-Continuous: 450°F (232°C)
Discoloration and loss of gloss may be observed above 200°F (93°C).

Limitations Epoxies lose gloss, discolor and eventually chalk in sunlight exposure.

Substrates & Surface Preparation

General Surfaces must be clean and dry. Employ adequate methods to remove dirt, dust, oil and all other contaminants that could interfere with adhesion of the coating.

Steel
Non-Insulated: SSPC-SP6
Insulated: SSPC-SP10
Surface Profile: 2.0-3.0 mils (50-75 microns)

Performance Data

Test Method	System	Results	Report #
ASTM D3359 Adhesion	Blasted Steel 2 cts. 450	4A	08460
ASTM D4060 Abrasion	Blasted Steel 2 cts. 450	171 mg loss after 1000 cycles; CS17 wheel, 1000 gram load	02910
ASTM D2794 Impact	Blasted Steel 1 ct. 450	.375 in. from damaged area. 100-in./lbs	02675
Heat Cycling Test	Blasted Steel 1 ct. 450	No cracking, blistering or delamination of film after 425°F for 1 hr/ambient/ -10°F for 24 hrs/ambient/ 425°F for 24 hrs/ambient/ -10°F for 24 hrs/ambient/ 425°F for 200 hr/ambient	SR342
Modified NACE Std. TM-01-74B Immersion	Blasted Steel 2 cts. 450	No effect to coating film except discoloration after 6 month exposure, Deionized water	02551
Chemical Resistance	Blasted Steel 1 ct. 450	Resistant to fumes of commons acids, alkalis, solvents and hydrocarbon compounds. Resistant to splash and spillage of alkalis, solvents and hydrocarbons. Acid contact may cause discoloration of coating.	SR 359 02735 03133 02794

Test reports and additional data available upon written request.

January 2009 replaces June 2006 1039

Thermaline® 450 Novolac

Application Equipment

Listed below are general equipment guidelines for the application of this product. Job site conditions may require modifications to these guidelines to achieve the desired results.
General Guidelines:

Spray Application (General) — The following spray equipment has been found suitable and is available from manufacturers such as Binks, DeVilbiss and Graco.

Conventional Spray — Pressure pot equipped with dual regulators, ½" I.D. minimum material hose, .110" I.D. fluid tip and appropriate air cap.

Airless Spray —
Pump Ratio: 45:1 (min.)*
GPM Output: 3.0 (min.)
Material Hose: ½" I.D. (min.)
Tip Size: .035-.041"
Output PSI: 2200-2500
*Teflon packings are recommended and available from the pump manufacturer.

Brush — For striping of welds and touch-up of small areas only. Use a medium natural bristle brush and avoid rebrushing.

Roller — Not recommended.

Mixing & Thinning

Mixing — Power mix separately, then combine and power mix. DO NOT MIX PARTIAL KITS.

Ratio — 4:1 Ratio (A to B)

Thinning — May be thinned up to 13 oz/gal (10%) with Thinner #213. For application on horizontal surfaces, may be thinned up to 13 oz/gal (10)% with Thinner #2. Agitate Thinner #213 before use. Thinner #213 will have a thick viscous appearance which is normal. Use of thinners other than those supplied by Carboline may adversely affect product performance and void product warranty, whether expressed or implied.

Pot Life — 3 Hours at 75°F (24°C). Pot life ends when coating loses body and begins to sag. Pot life times will be less at higher temperatures.

Cleanup & Safety

Cleanup — Use Thinner #2 or Acetone. In case of spillage, absorb and dispose of in accordance with local applicable regulations.

Safety — Read and follow all caution statements on this product data sheet and on the MSDS for this product. Employ normal workmanlike safety precautions. Hypersensitive persons should wear protective clothing, gloves and use protective cream on face, hands and all exposed areas.

Ventilation — When used in enclosed areas, thorough air circulation must be used during and after application until the coating is cured. The ventilation system should be capable of preventing the solvent vapor concentration from reaching the lower explosion limit for the solvents used. User should test and monitor exposure levels to insure all personnel are below guidelines. If not sure or if not able to monitor levels, use MSHA/NIOSH approved supplied air respirator.

Caution — This product contains flammable solvents. Keep away from sparks and open flames. All electrical equipment and installations should be made and grounded in accordance with the National Electric Code. In areas where explosion hazards exist, workmen should be required to use non-ferrous tools and wear conductive and non-sparking shoes.

Application Conditions

Condition	Material	Surface	Ambient	Humidity
Normal	65°-85°F (18°-29°C)	65°-85°F (18°-29°C)	65°-85°F (18°-29°C)	30-60%
Minimum	55°F (13°C)	50°F (10°C)	50°F (10°C)	0%
Maximum	90°F (32°C)	110°F (43°C)	100°F (38°C)	85%

This product simply requires the substrate temperature to be above the dew point. Condensation due to substrate temperatures below the dew point can cause flash rusting on prepared steel and interfere with proper adhesion to the substrate. Special application techniques may be required above or below normal application conditions.

Curing Schedule

Surface Temp. & 50% Relative Humidity	Dry to Handle	Dry to Topcoat w/ Other Finishes	Final Cure
50°F (10°C)	18 Hours	48 Hours	21 Days
60°F (16°C)	12 Hours	32 Hours	14 Days
75°F (24°C)	6 Hours	16 Hours	7 Days
90°F (32°C)	3 Hours	8 Hours	4 Days

These times are based on a 10.0 mil (250 micron) dry film thickness. Higher film thickness, insufficient ventilation or cooler temperatures will require longer cure times and could result in solvent entrapment and premature failure. Excessive humidity or condensation on the surface during curing can interfere with the cure, can cause discoloration and may result in a surface haze. Any haze or blush must be removed by water washing before recoating. During high humidity conditions, it is recommended that the application be done while temperatures are increasing. If the final cure time is exceeded, the surface must be abraded by sweep blasting prior to the application of additional coats.

Packaging, Handling & Storage

Shipping Weight (Approximate) — 1 Gallon Kit: 12 lbs (6 kg); 5 Gallon Kit: 58 lbs (26 kg)

Flash Point (Setaflash) — Part A: 53°F (12°C); Part B: >200°F (93°C)

Storage (General) — Store Indoors.

Storage Temperature & Humidity — 40° - 110°F (4°-43°C); 0-90% Relative Humidity

Shelf Life — Part A & B: Min. 36 months at 75°F (24°C)

***Shelf Life: (actual stated shelf life) when kept at recommended storage conditions and in original unopened containers.**

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Industrial & Marine Coatings

SHERWIN WILLIAMS.

6.13

ZINC CLAD® II PLUS

INORGANIC ZINC-RICH COATING

PART A	B69VZ12	BASE
PART B	B69VZ13	ACCELERATOR
PART B	B69VZ15	ACCELERATOR
PART F	B69D11	ZINC DUST

PRODUCT INFORMATION

Revised 12/05

PRODUCT DESCRIPTION

ZINC CLAD II PLUS is a solvent-based, three component, inorganic ethyl silicate, zinc rich coating. This is fast drying, high solids, low VOC coating with 82%, by weight, of zinc dust in the dry film.

- Coating self-heals to resume protection if damaged
- Provides cathodic/sacrificial protection by the same mechanism as galvanizing
- Forms an inorganic barrier to moisture and solvents
- Meets Class B requirements for Slip Coefficient and Creep Resistance, 0.67
- Meets AASHTO M-300 specification

RECOMMENDED USES

For use over prepared blasted steel and galvanized steel in areas such as:

- Bridges
- Refineries
- Shop or field application
- Drilling rigs
- As a one-coat maintenance coating or as a permanent primer for severe corrosive environments (pH range 5-9)
- Ideal for application at low temperatures or service at high temperatures and/or humidity conditions
- Fresh and demineralized water immersion service (non-potable)
- Compliance with Class B Slip Coefficient rating when used alone or as part of a system with Steel Spec Epoxy Primer as a topcoat

PRODUCT CHARACTERISTICS

Finish: Flat

Color: Gray-Green

Volume Solid: 76% ± 2%, mixed

Weight Solid: 90% ± 2%, mixed

VOC (EPA Method 24): Unreduced: <320 g/L; 2.67 lb/gal (mixed)
Reduced 4%: <340 g/L; 2.8 lb/gal

Zinc Content in Dry Film: 82% by weight

Mix Ratio: 3 components, premeasured
3.66 gallons mixed

Recommended Spreading Rate per coat:
Wet mils: 3.0 - 6.0
Dry mils: 2.0 - 4.0
Coverage: 400 - 610 sq ft/gal approximate

Note: Brush application is for small areas only.
Application of coating above maximum or below minimum recommended spreading rate may adversely affect coating performance.

Drying Schedule @ 4.0 mils wet @ 50% RH:

	@40°F	@ 77°F	@100°F
To touch:	25 minutes	20 minutes	5 minutes
To handle:	1 hour	20 minutes	15 minutes
To topcoat:	7 days	24 hours	8 hours
To cure:	7 days	36 hours	24 hours
To stack	6 hours	2 hours	1 hour

Drying time is temperature, humidity, and film thickness dependent.

Pot Life: 8 hours @ 77°F
High humidity will shorten pot life

Sweat-in-time: None required, but material should be mixed for at least 5 minutes before use

Shelf Life: Part A - 12 months, unopened
Part B - 24 months, unopened
Part F - 24 months, unopened
Store indoors at 40°F to 100°F

Flash Point (mixed): 55°F

Reducer/Clean up:
Above 70°F: R2KT4, 150 Flash Naphtha
Below 70°F: R2K4, Xylene

PERFORMANCE CHARACTERISTICS

System Tested: (unless otherwise indicated)
Substrate: Steel
Surface Preparation: SSPC-SP10
1 ct. Zinc Clad II Plus @ 3.0 mils dft

Adhesion:
Method: ASTM D4541
Result: 689 psi

Direct Impact Resistance:
Method: ASTM D2794-92
Result: 60 in lbs.

Dry Heat Resistance:
Method: ASTM D2485
Result: 750°F*

Flexibility:
Method: ASTM D522, 180° bend, 1" mandrel
Result: Passes

Pencil Hardness:
Method: ASTM D3363
Result: 3H

Salt Fog Resistance:
Method: ASTM B117, 7000 hours
Result: Rating 9 per ASTM D714 for blistering
Rating 9 per ASTM D610 for rusting

Slip Coefficient (zinc only):
Method: AISC Specification for Structural Joints Using ASTM A325 or ASTM A490 Bolts
Result: Class B, 0.67

Slip Coefficient (system listed below):
1 ct. Zinc Clad II Plus @ 2.0 - 4.0 mils dft
1 ct. Steel Spec Epoxy Primer @ 4.0 - 6.0 mils dft
Method: AISC Specifiction for Structural Joints using ASTM A325 or ASTM A490 Bolts
Result: Passes Class B, .56

Provides performance comparable to products formulated to specifications Mil-P-38336 and Mil-P-46105.

*Acceptable for use up to 1000°F when topcoated with Kem Hi-Temp Heat-Flex II 800 Aluminum.

Zinc Rich 6.13

continued on back

Industrial & Marine Coatings

SHERWIN WILLIAMS.

6.13

ZINC CLAD® II PLUS

INORGANIC ZINC-RICH COATING

PART A	B69VZ12	BASE
PART B	B69VZ13	ACCELERATOR
PART B	B69VZ15	ACCELERATOR
PART F	B69D11	ZINC DUST

PRODUCT INFORMATION

RECOMMENDED SYSTEMS

Steel, Immersion:
1 ct. Zinc Clad II Plus @ 2.0 - 4.0 mils dft

Steel, Epoxy Topcoat, Atmospheric:
1 ct. Zinc Clad II Plus @ 2.0 - 4.0 mils dft
1 ct. Macropoxy 646 @ 5.0 - 10.0 mils dft

Steel, Polyurethane Topcoat, Atmospheric:
1 ct. Zinc Clad II Plus @ 2.0 - 4.0 mils dft
1 ct. Macropoxy 646 @ 5.0 - 10.0 mils dft
1 ct. Acrolon 218 HS @ 3.0 - 6.0 mils dft

Steel, Polyurethane Topcoat, Atmospheric:
1 ct. Zinc Clad II Plus @ 2.0 - 4.0 mils dft
1 ct. Macropoxy 646 @ 5.0 - 10.0 mils dft
1 ct. Hi-Solids Polyurethane @ 3.0 - 4.0 mils dft

NOTE: 1 ct. of DTM Wash Primer can be used as an intermediate coat under recommended topcoats to prevent pinholing.

Steel (Class B Compliant System):
1 ct. Zinc Clad II Plus @ 2.0 - 4.0 mils dft
1 ct. Steel Spec Epoxy Primer, red @ 4.0 - 6.0 mils dft

The systems listed above are representative of the product's use. Other systems may be appropriate.

SURFACE PREPARATION

Surface must be clean, dry, and in sound condition. Remove all oil, dust, grease, dirt, loose rust, and other foreign material to ensure adequate adhesion.

Refer to product Application Bulletin for detailed surface preparation information.

Minimum recommended surface preparation:
Iron & Steel:
Atmospheric: SSPC-SP6/NACE 3, 2 mil profile
Immersion: SSPC-SP10/NACE 2, 2 mil profile

TINTING

Do not tint.

APPLICATION CONDITIONS

Temperature:	20°F minimum, 100°F maximum (air, surface, and material) At least 5°F above dew point
Relative humidity:	40% - 90% maximum Water misting may be required at humidities below 50%

Refer to product Application Bulletin for detailed application information.

ORDERING INFORMATION

Packaging:	3.66 gallons total, mixed
Part A:	2.21 gallon kit
Part B:	0.20 gallon
Part F:	73 lbs zinc dust
Weight per gallon:	26.83 ± 0.2 lb, mixed

SAFETY PRECAUTIONS

Refer to the MSDS sheet before use.

Published technical data and instructions are subject to change without notice. Contact your Sherwin-Williams representative for additional technical data and instructions.

DISCLAIMER

The information and recommendations set forth in this Product Data Sheet are based upon tests conducted by or on behalf of The Sherwin-Williams Company. Such information and recommendations set forth herein are subject to change and pertain to the product offered at the time of publication. Consult your Sherwin-Williams representative to obtain the most recent Product Data Information and Application Bulletin.

WARRANTY

The Sherwin-Williams Company warrants our products to be free of manufacturing defects in accord with applicable Sherwin-Williams quality control procedures. Liability for products proven defective, if any, is limited to replacement of the defective product or the refund of the purchase price paid for the defective product as determined by Sherwin-Williams. NO OTHER WARRANTY OR GUARANTEE OF ANY KIND IS MADE BY SHERWIN-WILLIAMS, EXPRESSED OR IMPLIED, STATUTORY, BY OPERATION OF LAW OR OTHERWISE, INCLUDING MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

Industrial & Marine Coatings

6.13A
ZINC CLAD® II PLUS
INORGANIC ZINC-RICH COATING

PART A	B69VZ12	BASE
PART B	B69VZ13	ACCELERATOR
PART B	B69VZ15	ACCELERATOR
PART F	B69D11	ZINC DUST

APPLICATION BULLETIN

Revised 12/05

SURFACE PREPARATION

Zinc rich coatings require direct contact between the zinc pigment in the coating and the metal substrate for optimum performance. Surface must be dry, free from oil, dirt, dust, mill scale or other contaminants to ensure adequate adhesion.

Iron & Steel (atmospheric service):
Remove all oil and grease from surface by Solvent Cleaning per SSPC-SP1. Minimum surface preparation is Commercial Blast Cleaning per SSPC-SP6/NACE 3. For better performance, use Near White Metal Blast Cleaning per SSPC-SP10/NACE 2. Blast clean all surfaces using a sharp, angular abrasive for optimum surface profile (2 mils). Prime any bare steel the same day as it is cleaned or before flash rusting occurs.

Iron & Steel (immersion service):
Remove all oil and grease from surface by Solvent Cleaning per SSPC-SP1. Minimum surface preparation is Near White Metal Blast Cleaning per SSPC-SP10/NACE 2. Blast clean all surfaces using a sharp, angular abrasive for optimum surface profile (2 mils). Remove all weld spatter and round all sharp edges by grinding. Prime any bare steel the same day as it is cleaned or before flash rusting occurs.

Note: If blast cleaning with steel media is used, an appropriate amount of steel grit blast media may be incorporated into the work mix to render a dense, angular 1.5 - 2.0 mil surface profile. This method may result in improved adhesion and performance.

APPLICATION CONDITIONS

Temperature:	20°F minimum, 100°F maximum (air, surface, and material) At least 5°F above dew point
Relative humidity:	40% - 90% maximum Water misting may be required at humidities below 50%

APPLICATION EQUIPMENT

The following is a guide. Changes in pressures and tip sizes may be needed for proper spray characteristics. Always purge spray equipment before use with listed reducer. Any reduction must be compliant with existing VOC regulations and compatible with the existing environmental and application conditions.

Reducer/Clean up
Above 70°F .... R2KT4, 150 Flash Naphtha
Below 70°F .... R2K4, Xylene

Airless Spray
(use Teflon packings and continuous agitation)
Unit .... Graco 30:1
Pressure .... 2700 psi
Hose .... 3/8" ID
Tip .... .019" - .021"
Filter .... 30 mesh
Reduction .... As needed up to 4% by volume
For continuous operation in larger areas, use Speeflo Airless Commander Zinc Pump. Set ball checks to maximum travel for viscous material.

Conventional Spray
(continuous agitation required)
Gun .... Binks 95
Fluid Nozzle 66
Fluid Hose .... 1/2" ID, 50 ft maximum
Air Nozzle 63PB
Air Hose .... 1/2" ID, 50 ft maximum
Atomization Pressure ... 25 psi
Fluid Pressure .... 10-20 psi
Reduction .... As needed up to 4% by volume

Keep pressure pot at level of applicator to avoid blocking of fluid line due to weight of material. Blow back coating in fluid line at intermittent shutdowns, but continue agitation at pressure pot.

Brush .... For touch up in small areas only

If specific application equipment is not listed above, equivalent equipment may be substituted.

continued on back

Industrial & Marine Coatings

SHERWIN WILLIAMS.

6.13A
ZINC CLAD® II PLUS
INORGANIC ZINC-RICH COATING

PART A	B69VZ12	BASE
PART B	B69VZ13	ACCELERATOR
PART B	B69VZ15	ACCELERATOR
PART F	B69D11	ZINC DUST

APPLICATION BULLETIN

APPLICATION PROCEDURES

Surface preparation must be completed as indicated.
Zinc Clad II Plus comes in premeasured containers, which when mixed provides ready-to-apply material.

Mixing Instructions:
Thoroughly agitate Binder, Part A. Using continuous air driven agitation, slowly mix all of Zinc Dust, Part F, into all of Binder Part A until mixture is completely uniform. Continue agitation and add Part B. After mixing, pour mixture through 30-mesh screen. Mixed material must be used within 8 hours. Do not mix previously mixed material with new. No "sweat-in" period is required.

If reducer solvent is used, add only after components have been thoroughly mixed.

Continuous agitation of mixture during application is required, otherwise zinc dust will quickly settle out.

Apply paint at the recommended film thickness and spreading rate as indicated below:

Recommended Spreading Rate per coat:

Wet mils:	3.0 - 6.0
Dry mils:	2.0 - 4.0
Coverage:	400 - 610 sq ft/gal approximate

Note: Brush application is for small areas only.
Application of coating above maximum or below minimum recommended spreading rate may adversely affect coating performance.

Drying Schedule @ 4.0 mils wet @ 50% RH:

	@40°F	@ 77°F	@100°F
To touch:	25 minutes	20 minutes	5 minutes
To handle:	1 hour	20 minutes	15 minutes
To topcoat:	7 days	24 hours	8 hours
To cure:	7 days	36 hours	24 hours
To stack	6 hours	2 hours	1 hour

Drying time is temperature, humidity, and film thickness dependent.

Pot Life: 8 hours @ 77°F
High humidity will shorten pot life

Sweat-in-time: None required, but material should be mixed for at least 5 minutes before use

PERFORMANCE TIPS

Topcoating: Note minimum cure times at normal conditions before topcoating. Longer drying periods are required if primer cannot be water mist sprayed when humidity is low. Water misting may be required at humidities below 50% to enhance cure rate.

Occasionally topcoats will pinhole or delaminate from zinc-rich coatings. This is usually due to poor ambient conditions or faulty application of topcoats. This can be minimized by:

- Provide adequate ventilation and suitable application and substrate temperature.
- If pinholing develops during topcoating, apply a mist coat of the topcoat, reduced up to 50%. Allow 10 minutes flash off and follow with a full coat.

An intermediate coat is recommended to provide uniform appearance of the topcoat.

Stripe coat all crevices, welds, and sharp angles to prevent early failure in these areas.

When using spray application, use a 50% overlap with each pass of the gun to avoid holidays, bare areas, and pinholes. If necessary, cross spray at a right angle.

Spreading rates are calculated on volume solids and do not include an application loss factor due to surface profile, roughness or porosity of the surface, skill and technique of the applicator, method of application, various surface irregularities, material lost during mixing, spillage, overthinning, climatic conditions, and excessive film build.

Excessive reduction of material can affect film build, appearance, and performance.

Do not mix previously catalyzed material with new.

Do not apply the material beyond recommended pot life.

In order to avoid blockage of spray equipment, clean equipment before use or before periods of extended downtime with Reducer R2KT4, 150 Flash Naphtha.

Keep pressure pot at level of applicator to avoid blocking of fluid line due to weight of material. Blow back coating in fluid line at intermittent shutdowns, but continue agitation at pressure pot.

Application above recommended film thickness may result in mud cracking and poor topcoat appearance.

During the early stages of drying, the coating is sensitive to rain, dew, high humidity, and moisture condensation. If possible, plan painting schedules to avoid these influences during the first 16-24 hours of curing.

Topcoats may be applied once 50 MEK double rubs are achieved. No zinc or only slight traces should be visible. Coin hardness test can also be used.

Refer to Product Information sheet for additional performance characteristics and properties.

CLEAN UP INSTRUCTIONS

Clean spills and spatters immediately with Reducer R2KT4, 150 Flash Naphtha or R2K4, Xylene. Clean hands and tools immediately after use with Reducer R2KT4, 150 Flash Naphtha or R2K4, Xylene. Follow manufacturer's safety recommendations when using any solvent.

SAFETY PRECAUTIONS

Refer to the MSDS before use.

Published technical data and instructions are subject to change without notice. Contact your Sherwin-Williams representative for additional technical data and instructions.

DISCLAIMER

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WARRANTY

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CHAPTER 9: OPERATING PROCEDURES

9.0 INTRODUCTION

This chapter contains the operating procedures required for the dry storage of spent nuclear fuel at an on-site HI-STORM FW ISFSI. The decay heat, initial enrichment, burnup and cooling time of the SNF must accord with the restrictions in the Technical Specification. The unloading procedure is also described in this chapter. This sequence of activities is collectively referred to as short-term operations in this safety analysis report (SAR).

The procedures provided in this chapter are prescriptive to the extent that they provide the basis and general guidance for plant personnel in preparing detailed, written, site-specific, loading, handling, storage, and unloading procedures. Users may add, modify the sequence of, perform in parallel, or delete steps as necessary provided that the intent of this guidance are met and the requirements of the Certificate of Compliance (CoC) are complied with *literally*. The information provided in this chapter complies with the provisions of NUREG-1536 [9.0.1].

The information presented in this chapter along with the technical basis of the system design described in this SAR will be used to develop detailed operating procedures. Equipment specific operating details such as valve manipulation, canister drying method, special rigging, etc., will be provided to individual users of the system based on the specific ancillary equipment selected and the configuration of the site. In preparing the site-specific procedures, the user must consult the conditions of the CoC, equipment-specific operating instructions, and the plant's working procedures as well as the information in this chapter to ensure that the short-term operations shall be carried out with utmost safety and ALARA.

The following generic criteria shall be used to determine whether the site-specific operating procedures developed pursuant to the guidance in this chapter are acceptable for use:

- All heavy load handling instructions are in keeping with the guidance in industry standards, and Holtec-provided instructions.
- The procedures are in conformance with this FSAR and the COC.
- The operational steps are ALARA.
- The procedures contain provisions for documenting successful execution of all safety significant steps for archival reference.
- Procedures contain provisions for classroom and hands-on training and for a Holtec-approved personnel qualification process to ensure that all operations personnel are adequately trained.
- The procedures are sufficiently detailed and articulated to enable craft labor to execute them in *literal compliance* with their content.

The operations described in this chapter assume that the fuel will be loaded into or unloaded from the MPC submerged in a spent fuel pool. With some modifications, the information presented herein can be used to develop site-specific procedures for loading or unloading fuel into the system within a hot cell or other remote handling facility.

Users are required to develop or modify existing programs and procedures to account for the implementation of the HI-STORM FW system. Written procedures are required to be developed or modified to account for such items as handling and storage of systems, structures 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 all critical set points do not exceed the design limit of lifting equipment and appurtenances.

Control of the operation shall be performed in accordance with the user's Quality Assurance (QA) program to ensure critical steps are not overlooked and that the cask has been confirmed to meet all requirements of the CoC before being released for on-site storage under Part 72.

Fuel assembly selection and verification shall be performed by the user in accordance with written, approved procedures that ensure that only SNF assemblies authorized in the CoC are loaded into the MPC. Fuel handling shall be performed in accordance with written site-specific procedures.

ALARA notes and warnings in this chapter are included to alert users to radiological issues. Actions identified with these notes and warnings are of an advisory nature and shall be implemented based on a site-specific determination by radiation protection personnel.

Section 9.1 provides a technical basis for loading and unloading procedures. Section 9.2 provides the guidance for loading the HI-STORM FW system. Section 9.3 provides the procedures for ISFSI operations and general guidance for performing maintenance and responding to abnormal events. Responses to abnormal events that may occur during normal loading operations are provided with the procedure steps. Section 9.4 provides the procedure for unloading the HI-STORM FW system.

9.1 TECHNICAL AND SAFETY BASIS FOR LOADING AND UNLOADING PROCEDURES

The procedures herein are developed for the loading, storing, and unloading of spent fuel in the HI-STORM FW system. The activities involved in loading of spent fuel in a canister system, if not carefully performed, may present physical risk to the operations staff. The design of the HI-STORM FW system, including these procedures, the ancillary equipment and the Technical Specifications, serve to minimize potential risks and mitigate consequences of potential events.

The primary objective of the information presented in this chapter is to identify and describe the sequence of significant operations and actions that are important to safety for cask loading, cask handling, storage operations, and cask unloading to adequately protect health and minimize danger to life or property, protect the fuel from significant damage or degradation, and provide for the safe performance of tasks and operations.

In the event of an extreme abnormal condition the appropriate procedural guidance to respond to the situation must be available and ready for implementation. As a minimum, the procedures shall address establishing emergency action levels, implementation of emergency action program, establishment of personnel exclusions zones, monitoring of radiological conditions, actions to mitigate or prevent the release of radioactive materials, and recovery planning and execution and reporting to the appropriate regulatory agencies, as required.

Table 9.1.1

OPERATIONAL CONSIDERATIONS

POTENTIAL EVENTS	METHODS USED TO ADDRESS AN ADVERSE EVENT
Cask Drop During Handling Operations	Cask lifting and handling equipment is designed to ANSI N14.6, as required.
Cask Tip-Over Prior to welding of the MPC lid	The design of the Lift Yoke prevents inadvertent disconnection during periods where it is attached.
Contamination of the MPC external shell	The annulus seal, bottom lid, and Annulus Overpressure System minimize the potential for the MPC external shell to become contaminated from contact with the spent fuel pool water.
Contamination spread from cask process system exhausts	Processing systems are equipped with exhausts that can be directed to the plant's processing systems.
Damage to fuel assembly cladding from oxidation	Fuel assemblies are not directly exposed to air or oxygen during loading and unloading operations. Fuel will be blanketed with an inert gas when not immersed in water. Water is introduced at a slow rate to avoid thermal shocking of the system.
Damage to Vacuum Drying System vacuum gauges from positive pressure	Vacuum gauges will be isolated from pressurized gas and water systems when not used for vacuum. Isolation valves allow gauges to be easily replaced in service.
Ignition of combustible mixtures of gas (e.g., hydrogen) during MPC lid welding or cutting	The area around MPC lid shall be appropriately monitored for combustible gases prior to and during welding or cutting activities. The space below the MPC lid shall be purged prior to and during these activities.
Excess dose from failed fuel assemblies during unloading operations	MPC gas sampling allows operators to determine the integrity of the fuel cladding prior to opening the MPC. This allows preparation and planning for failed fuel. The RVOAs allow the vent and drain ports to be operated like valves and prevent the need to hot tap into the penetrations during unloading operation.
Excess dose to operators	The procedures provide ALARA Notes and Warnings when radiological conditions may change.

Table 9.1.1

OPERATIONAL CONSIDERATIONS

POTENTIAL EVENTS	METHODS USED TO ADDRESS AN ADVERSE EVENT
Excess generation of radioactive waste	The HI-STORM FW system uses process systems that minimize the amount of radioactive waste generated. Such features include smooth surfaces for ease of decontamination efforts, prevention of avoidable contamination, and procedural guidance to reduce decontamination requirements. Where possible, items are installed by hand and require no tools.
Fuel assembly misloading event	Procedural guidance is given to perform assembly selection verification and a post-loading visual verification of assembly identification prior to installation of the MPC lid.
Incomplete moisture removal from MPC	The vacuum drying process reduces the MPC pressure in a controlled manner to prevent the formation of ice. Vacuum is held below 3 torr for 30 minutes with the vacuum pump isolated to assure dryness. If the forced helium dehydration process is used, the temperature of the gas exiting the demoisturizer is held below 21 ^{o}F for a minimum of 30 minutes. The TS require the surveillance requirement for moisture removal to be met before entering transport operations.
Incorrect MPC lid installation	Procedural guidance is given to visually verify correct MPC lid installation prior to HI-TRAC removal from the spent fuel pool.
Load Drop	Rigging diagrams and procedural guidance are provided to users for all applicable lifts. Component weights are provided to users on a site-specific basis. Heavy loads are handled in accordance with the guidance of NUREG-0612.
Over-pressurization of MPC during loading and unloading	Pressure relief devices in the water and gas processing systems limit the MPC pressure to acceptable levels.
Overstressing MPC lift lugs from side loading	Procedural guidance is provided for all heavy load handling activities on a site-specific basis.
Overweight cask lift	Procedural guidance is given to alert operators to potential overweight lifts. Site-specific weight evaluations are provided.
Personnel contamination by cutting/grinding activities	Procedural guidance is given to warn operators prior to cutting or grinding activities.

Table 9.1.1

OPERATIONAL CONSIDERATIONS

POTENTIAL EVENTS	METHODS USED TO ADDRESS AN ADVERSE EVENT
Transfer cask carrying hot particles out of the spent fuel pool	Procedural guidance is given to scan the transfer cask prior to removal from the spent fuel pool.
Unplanned or uncontrolled release of radioactive materials	The MPC vent and drain ports are equipped with metal-to-metal seals to minimize the leakage during moisture removal and helium backfill operations. Unlike elastomer seals, the metal seals resist degradation due to temperature and radiation and allow future access to the MPC ports without hot tapping. The RVOAs allow the port to be opened and closed like a valve so gas sampling may be performed.

9.2 PROCEDURE FOR LOADING THE HI-STORM FW SYSTEM IN THE SPENT FUEL POOL

9.2.1 Overview of Loading Operations

The HI-STORM FW system is used to load, transfer, and store spent fuel. Specific steps, required to prepare the HI-STORM FW system for fuel loading, to load the fuel, to prepare the system for storage, and to place it in storage at an ISFSI are described in this chapter. The MPC transfer may be performed in the cask receiving area, at the ISFSI, or any other location deemed appropriate by the user. HI-TRAC VW and/or HI-STORM FW may be moved between the ISFSI and the fuel loading facility using any load handling equipment designed for such applications. Users of the HI-STORM FW system are required to develop detailed written procedures to control on-site transport operations. Instructions for general lifting, handling, and placement of the HI-STORM FW overpack, MPC, and HI-TRAC VW vary by site and are provided on a site-specific basis in Holtec-approved procedures and instructions.

The broad operational steps are explained below and illustrative figures are provided at the end of this section (note the figures are strictly illustrative and do not show minor details such as the trunnions used in Version P of the HI-TRAC VW in lieu of the Lift Block). At the start of loading operations, an empty MPC is upended. The empty MPC is raised and inserted into the HI-TRAC VW. The annulus is filled with plant demineralized water[1] and an inflatable seal is installed in the upper end of the annulus between the MPC and HI-TRAC VW to prevent spent fuel pool water from contaminating the exterior surface of the MPC when it is submerged in the pool. The MPC is filled with either spent fuel pool water or plant demineralized water (borated as required)[2]. The HI-TRAC VW top flange is outfitted with the lift blocks and the HI-TRAC VW and MPC are then raised and lowered into the spent fuel pool[3] for fuel loading using the lift yoke. For HI-TRAC VW Version P, lifting trunnions embedded in the top flange engage with the lift yoke to raise and lower the HI-TRAC and MPC. Pre-selected assemblies[4] are loaded into the MPC and a visual verification of the assembly identification is performed.

While still underwater, a thick shielded lid (the MPC lid) is installed. The lift yoke remotely engages to the HI-TRAC VW lift blocks or to the HI-TRAC VW Version P lifting trunnions to lift the HI-TRAC VW and loaded MPC close to the spent fuel pool surface. When radiation dose rate measurements confirm that it is safe to remove the HI-TRAC VW from the spent fuel pool, the cask is removed from the spent fuel pool. The lift yoke and HI-TRAC VW are decontaminated, in accordance with instructions from the site's radiological protection personnel, as they are removed from the spent fuel pool.

1 Users may substitute domestic water or radiologically clean borated water in each step where demineralized water is specified.

2 Users may also fill the MPC with water during HI-TRAC placement in the spent fuel pool.

3 Spent Fuel Pool as used in this chapter generically refers to the users designated cask loading location.

4 Damaged fuel assemblies are loaded and stored in Damaged Fuel Containers in the MPC basket.

HI-TRAC VW is placed in the designated preparation area and the lift yoke is removed. The next phase of decontamination is then performed. The top surfaces of the MPC lid and the upper flange of HI-TRAC VW are decontaminated. The neutron shield water jacket is filled with water (if drained). The inflatable annulus seal is removed and an annulus shield is installed. Dose rates are measured at the MPC lid to ensure that the dose rates are within expected values.

The MPC water level and annulus water level are lowered slightly, the MPC is vented, and the MPC lid is welded on using the automated welding system. Visual examinations are performed on the tack welds. Liquid penetrant (PT) examinations are performed on the root and final passes. A progressive PT examination as described in the Code Alternatives listed in the CoC is performed on the MPC Lid-to-Shell weld to ensure that the weld is satisfactory. As an alternative to volumetric examination of the MPC lid-to-shell weld, a multi-layer PT is performed including one intermediate examination after approximately every three-eighth inch of weld depth. The MPC welds are then pressure tested followed by an additional liquid penetrant examination performed on the MPC Lid-to-Shell weld to verify structural integrity. To calculate the helium backfill requirements for the MPC (if the backfill is based upon helium mass or volume measurements), the free volume inside the MPC must first be determined. This free volume may be determined by measurement or determined analytically. The remaining bulk water in the MPC is drained.

Depending on the burn-up or decay heat load of the fuel to be loaded in the MPC, moisture is removed from the MPC using either a vacuum drying system (VDS) or forced helium dehydration (FHD) system. For MPCs without high burn-up fuel or with high burnup fuel and with sufficiently low decay heat, the vacuum drying system may be connected to the MPC and used to remove all liquid water from the MPC. The annular gap between the MPC and HI-TRAC is filled with water during vacuum drying to promote heat transfer from the MPC and maintain lower fuel cladding temperatures. The internal pressure is reduced and held in accordance with Technical Specifications to ensure that all liquid water is removed.

An FHD system is required for high-burn-up fuel at higher decay heat (it can be used as an alternative to vacuum drying) to remove residual moisture from the MPC. Gas is circulated through the MPC to evaporate and remove moisture. The residual moisture is condensed until no additional moisture remains in the MPC. The temperature of the gas exiting the system demoisturizer is maintained in accordance with Technical Specification requirements to ensure that all liquid water is removed.

Following MPC moisture removal, by VDS or FHD, the MPC is backfilled with a predetermined amount of helium gas. The helium backfill ensures adequate heat transfer during storage, and provides an inert atmosphere for long-term fuel integrity. Cover plates are installed and seal welded over the MPC vent and drain ports with liquid penetrant examinations performed on the root and final passes (for multi-pass welds). The cover plate welds are then leak tested.

The MPC closure ring is then placed on the MPC and aligned, tacked in place, and seal welded providing redundant closure of the MPC confinement boundary closure welds. Tack welds are visually examined, and the root and final welds are inspected using the liquid penetrant examination technique to ensure weld integrity.

The annulus shield (if utilized) is removed and the remaining water in the annulus is drained. The MPC lid and accessible areas of the top of the MPC shell are smeared for removable contamination. HI-TRAC VW surface dose rates are measured in accordance with the technical specifications. The MPC lift attachments are installed on the MPC lid. The MPC lift attachments are the primary lifting point on the MPC. MPC slings are installed between the MPC lift attachments and the lift yoke.

MPC transfer may be performed inside or outside the fuel building. The empty HI-STORM FW overpack is inspected and positioned with the lid removed. Next, the mating device is positioned on top of the HI-STORM FW and HI-TRAC VW is placed on top of it. The mating device assists in the removal of the HI-TRAC VW bottom lid and helps guide the HI-TRAC VW during its placement on the HI-STORM FW. The MPC slings are attached to the MPC lift attachments. The MPC is transferred using a suitable load handling device.

Next, the HI-TRAC VW bottom lid is removed and the mating device drawer is opened. The MPC is transferred into HI-STORM FW. Following verification that the MPC is fully lowered, the MPC slings are disconnected from the lifting device and lowered onto the MPC lid. Next, the HI-TRAC VW is removed from the top of HI-STORM FW[5]. The MPC slings and MPC lift attachments are removed. Plugs are installed in the empty MPC lifting holes to fill the voids left by the lift attachment bolts. Next, the mating device is removed. The HI-STORM FW lid, along with the temperature elements (if used), and vent screens may be installed at any time after the mating device is removed. The HI-STORM FW is secured to the transporter (as applicable) and moved to the ISFSI pad. The HI-STORM FW overpack and HI-TRAC VW transfer cask may be moved using a number of methods as long as the lifting equipment requirements of this FSAR are met. Finally, the temperature elements connections are installed (if used), final dose rate measurements are taken, and any thermal testing (if required) is performed to ensure that the system is functioning within its design parameters.

5 The empty HI-TRAC VW may be removed from the mating device with its bottom lid installed or removed.

9.2.2 Preparation of HI-TRAC VW and MPC

Note:
Handling of loaded equipment shall only be performed if the ambient temperature is above 0°F

1. Place HI-TRAC VW in the cask receiving area.

2. Perform a HI-TRAC VW receipt inspection and cleanliness inspection (See Table 9.2.5 for example).

3. Clear the HI-TRAC VW top for installation of the MPC.

4. Remove any road dirt. Remove any foreign objects from cavity locations.

5. If necessary, perform a radiological survey of the inside of HI-TRAC VW to verify there is no residual contamination from previous uses of the cask.

6. If necessary, configure HI-TRAC VW with the bottom lid*.

7. Perform an MPC receipt inspection and cleanliness inspection (See Table 9.2.4 for example).

8. Install the MPC inside HI-TRAC VW in accordance with site-approved rigging procedures.

9. If necessary, perform an MPC, lid, closure ring, drain line, vent, and drain port cover plate fit test and verify that the weld prep is in accordance with the approved fabrication drawings.

Note:
Annulus filling and draining operations vary by site. Instructions for filling and draining the annulus along with the use of the annulus overpressure system are provided on a site-specific basis.

10. Fill the annulus with non-contaminated water to just below the inflatable seal seating surface.

11. Install the inflatable annulus seal around the MPC.

12. To the extent practicable, apply waterproof tape over any empty bolt holes or locations where water may create a decontamination issue.

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

Note:
Canister filling and draining operations vary by site. Instructions are provided on a site-specific basis.

13. Fill the MPC with water to approximately 12 inches below the top of the MPC shell. Refer to LCO 3.3.1 for boron concentration requirements.

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

14. Place HI-TRAC VW in the designated cask loading area.

15. Verify spent fuel pool for boron concentration requirements in accordance with LCO 3.3.1. Testing must be completed within four hours prior to loading and every 48 hours after in accordance with the LCO. Two independent measurements shall be taken to ensure that the requirement of 10 CFR 72.124(a) is met.

9.2.3 MPC Fuel Loading

Note:
When loading an MPC requiring soluble boron, the boron concentration of the water shall be checked in accordance with LCO 3.3.1 before and during operations with fuel and water in the MPC.

1. Perform a fuel assembly selection verification using plant fuel records to ensure that only fuel assemblies that meet all the conditions for loading, as specified in the Approved Contents Section of Appendix B to the CoC, have been selected for loading into the MPC. Perform a verification of the types, amounts, and location of non-fuel hardware using plant fuel records to ensure that only non-fuel hardware that meet the conditions for loading, as specified in the Approved Contents Section of Appendix B to the CoC, have been selected for loading into the MPC.

2. Load the pre-selected fuel assemblies into the MPC in accordance with the approved fuel loading pattern[6].

3. Perform a post-loading visual verification of the assembly identification to confirm that the serial numbers match the approved fuel loading pattern.

4. If required, install fuel shims where necessary in the fuel cells.

6 Damaged fuel must be loaded into Damage Fuel Containers in the MPC basket.

9.2.4 MPC Closure

1. Install MPC lid and remove the HI-TRAC VW from the spent fuel pool as follows:

   a. Rig the MPC lid for installation in the MPC in accordance with site-approved rigging procedures.

   b. Install the drain line to the underside of the MPC lid.

   c. Align the MPC lid and lift yoke so the drain line will be positioned in the MPC for installation.

   d. Seat the MPC lid in the MPC and visually verify that the lid is properly installed.

   e. Record the time to begin the time-to-boil monitoring, if necessary.

Note:
See FSAR Section 4.5.3 for more information regarding the determination and monitoring of time-to-boil.

   f. Engage the lift yoke to HI-TRAC VW.

ALARA Note:
Activated debris may have settled on the top face of HI-TRAC VW and MPC during fuel loading. The cask top surface should be kept under water until a preliminary dose rate scan clears the cask for removal. Soluble boron concentration, when applicable, shall be monitored to prevent non-compliance with the Technical Specification LCO 3.3.1.

   g. Raise the HI-TRAC VW until the MPC lid is just below the surface of the spent fuel pool. Survey the area above the cask lid to check for hot particles. Remove any activated or highly radioactive particles from the HI-TRAC VW or MPC.

   h. Continue to raise the HI-TRAC VW under the direction of the plant's radiological control personnel. Continue general decontamination activities.

   i. Remove HI-TRAC VW from the spent fuel pool while performing outer decontamination activities in accordance with directions from the radiological control personnel.

   j. Place HI-TRAC VW in the designated cask preparation area.

Note:
If the transfer cask is expected to be operated in an environment below 32 °F, the water jacket shall be filled with an ethylene glycol solution (25% ethylene glycol). Otherwise, the jacket shall be filled with clean potable or demineralized water. Depending on weight limitations, the neutron shield jacket may remain filled (with pure water or 25% ethylene glycol solution, as required). Cask weights shall be evaluated to ensure that the equipment load limitations are not violated.

k. If previously drained, fill the neutron shield jacket with plant demineralized water or an ethylene glycol solution (25% ethylene glycol) as necessary.

l. Disconnect any special rigging from the MPC lid and disengage the lift yoke in accordance with site-approved rigging procedures.

Warning:
MPC lid dose rates are measured to ensure that dose rates are within expected values. Dose rates exceeding the expected values could be an indication that fuel assemblies not meeting the CoC have been loaded.

m. Measure the dose rates at the MPC lid and verify that the combined gamma and neutron dose is below expected values.

n. Perform decontamination and a dose rate/contamination survey of HI-TRAC.

o. Prepare the MPC annulus for MPC lid welding by removing the annulus seal and draining the annulus approximately 6 inches.

2. Prepare for MPC lid welding as follows:

a. Clean the vent and drain ports to remove any dirt or standing water. Install the RVOAs to the MPC lid vent and drain ports, leaving caps open.

b. Lower the MPC internal water level in preparation for MPC lid-to-shell welding.

ALARA Note:
The MPC exterior shell survey is performed. Indications of contamination could require the MPC to be unloaded. In the event that the MPC shell is contaminated, users must decontaminate the annulus. If the contamination cannot be reduced to acceptable levels, the MPC must be returned to the spent fuel pool and unloaded. The MPC may then be removed and the external shell decontaminated.

c. Survey the MPC lid top surfaces and the accessible areas (approximately the top three inches) of the MPC external shell. Decontaminate the MPC lid and accessible surfaces of the MPC shell in accordance with LCO 3.2.1.

3. Weld the MPC lid as follows:

   a. As necessary, install the MPC lid shims around the MPC lid to make the weld gap uniform and to close the gap to the requirements of the licensing drawings.

   b. Install the Automated Welding System (AWS).

Note:
It may be necessary to remove the RVOAs to allow access for the automated welding system. In this event, the vent and drain port caps should be opened to allow for thermal expansion of the MPC water.
Caution:
A radiolysis of water may occur in high flux conditions inside the MPC creating combustible gases. Appropriate monitoring for combustible gas concentrations shall be performed prior to, and during MPC lid welding operations. The space below the MPC lid shall be purged with inert gas prior to, and during MPC lid welding operations, including welding, grinding, and other hot work, to provide additional assurance that flammable gas concentrations will not develop in this space.

   c. Perform combustible gas monitoring and purge the space under the MPC lid with an inert gas to ensure that there is no combustible mixture present in the welding area.

Note:
MPC closure welding procedures dictate the performance requirements and acceptance requirements of the weld examinations.

   d. Perform the MPC lid-to-shell weld and NDE in accordance with the licensing drawings using approved procedures. Repair any weld defects in accordance with the applicable code and re-perform the NDE until the weld meets the required acceptance criteria.

4. Perform MPC lid-to-shell weld pressure testing in accordance with site-approved procedures.

5. Repeat the liquid penetrant examination on the final pass of the MPC lid-to-shell weld.

   a. Repair any weld defects in accordance with the applicable code requirements and re-perform the NDE in accordance with approved procedures.

6. Drain the MPC and terminate time-to-boil monitoring and boron sampling program, where required.

Note:
Detailed procedures for MPC drying are provided on a site-specific basis. The following summarize those procedures.

7. Dry and backfill the MPC (Vacuum Drying Method).

> **Note:**
> During drying activities, the annulus between the MPC and the HI-TRAC VW must be maintained full of water. Water lost due to evaporation or boiling must be replaced to maintain the water level.

a. Fill the annulus between the MPC and HI-TRAC VW with clean water. The water level must be within 6" of the top of the MPC.

b. Attach the vacuum drying system (VDS) to the vent and drain port RVOAs. Other equipment configurations that achieve the same results may also be used.

> **Caution:**
> Rapidly reducing the pressure in the VDS piping and MPC while the system contains significant amounts of water can lead to freezing of the water and to improper conclusions that the system is dry. To prevent freezing of water, the MPC internal pressure should be lowered in a controlled fashion. The vacuum drying system pressure will remain at about 30 torr until most of the liquid water has been removed from the MPC.

c. Start the VDS system and slowly reduce the MPC pressure to below 3 torr.

> **Note:**
> Helium backfill shall be in accordance with the Technical Specification using 99.995% (minimum) purity. If at any time during final closure operations the helium backfill gas is lost or oxidizing gases are introduced into the MPC, then the dryness test shall be repeated and the MPC refilled with helium in accordance with the Technical Specifications.

d. Perform the MPC drying pressure test in accordance with the Technical Specifications.

e. When the MPC is dry, in accordance with the acceptance criteria in the LCO 3.1.1, close the vent and drain port valves.

f. Backfill the MPC in accordance with LCO 3.1.1 using site-specific procedures.

g. Disconnect the VDS from the MPC.

h. Close the drain port RVOA cap and remove the drain port RVOA.

i. If used, stop the water flow through the annulus between the MPC and HI-TRAC. Drain.

j. Close the vent port RVOA and disconnect the vent port RVOA.

8. Dry and Backfill the MPC (FHD Method):

Note:
Helium backfill shall be in accordance with the Technical Specification using 99.995% (minimum) purity. When using the FHD system to perform the MPC helium backfill, the FHD system shall be evacuated or purged and the system operated with high purity helium.
Note:
MPC internal pressure during FHD operation must comply with Technical Specification.
Caution:
MPC internal pressure during FHD operation may be less than the Technical Specification minimum backfill requirement. In the event of an FHD System failure where the MPC internal pressure is below the Technical Specification limit, the MPC internal pressure must be raised to at least 20 psig to place the MPC in an acceptable condition.

a. Attach the moisture removal system to the vent and drain port RVOAs. Other equipment configurations that achieve the same results may also be used.

b. Drain the water from the annulus.

c. Circulate the drying gas through the MPC while monitoring the circulating gas for moisture. Collect and remove the moisture from the system as necessary.

d. Continue the monitoring and moisture removal until LCO 3.1.1 is met for MPC dryness.

Note:
The demoisturizer module must maintain the temperature of the helium exiting the FHD below the Technical Specification limits continuously from the end of the drying operations until the MPC has been backfilled and isolated. If the temperature of the gas exiting the FHD exceeds the temperature limit, the dryness test must be repeated and the backfill re-performed.

e. Continue operation of the FHD system with the demoisturizer on.

f. While monitoring the temperatures into and out of the MPC, adjust the helium pressure in the MPC to provide a fill pressure as required by LCO 3.1.1.

g. Open the FHD bypass line and Close the vent and drain port RVOAs.

h. Shutdown the FHD system and disconnect it from the RVOAs.

i. Remove the vent and drain port RVOAs.

9. Weld the vent and drain port cover plates and perform NDE in accordance with the licensing drawings using approved procedures. Repair any weld defects in accordance with the applicable code and re-perform the NDE until the weld meets the required acceptance criteria.

10. Perform a leakage test of the MPC vent port cover plate and drain port cover plate in accordance with the following and site-approved procedures:

    a. If necessary, remove the cover plate set screws.

    b. Flush the cavity with helium to remove the air and immediately install the set screws recessed approximately ¼ inch below the top of the cover plate.

    c. Plug weld the recess above each set screw to complete the penetration closure welding in accordance with the licensing drawings using approved procedures. Repair any weld defects in accordance with the applicable code and re-perform the NDE until the weld meets the required acceptance criteria.

    d. Flush the area around the vent and drain cover plates with compressed air or nitrogen to remove any residual helium gas.

    e. Perform a helium leakage rate test of vent and drain cover plate welds in accordance with the Mass Spectrometer Leak Detector (MSLD) manufacturer's instructions and leakage test methods and procedures of ANSI N14.5 [9.1.2]. The MPC Helium Leak Rate acceptance criterion is provided in LCO 3.1.1.

11. Weld the MPC closure ring as follows:

    a. Install and align the closure ring.

    b. Weld the closure ring to the MPC shell and the MPC lid, and perform NDE in accordance with the licensing drawings using approved procedures. Repair any weld defects in accordance with the applicable code and re-perform the NDE until the weld meets the required acceptance criteria.

    c. If necessary, remove the AWS.

9.2.5 Preparation for Storage

ALARA Warning:
Dose rates will rise around the top of the annulus as water is drained from the annulus. Apply appropriate ALARA practices.
Caution:
Limitations for the handling an MPC containing high burn-up fuel in a HI-TRAC VW are evaluated and established on a canister basis to ensure that acceptable cladding temperatures are not exceeded. Refer to SAR Chapter 4.

1. Drain the remaining water from the annulus.

2. Perform the HI-TRAC VW surface dose rate measurements in accordance with the Technical Specifications. Measured dose rates must be compared with calculated dose rates that are consistent with the calculated doses that demonstrate compliance with the

dose limits of 10CFR 72.104(a). Remove any surface contamination from the HI-TRAC surfaces as required by LCO 3.2.1.

> **Note:**
>
> HI-STORM FW receipt inspection and preparation may be performed independent of procedural sequence, but prior to transfer of the loaded MPC. See Table 9.2.3 for example of HI-STORM FW Receipt Inspection Checklist.

3. Perform a HI-STORM FW receipt inspection and cleanliness inspection in accordance with a site-approved inspection site-approved inspection checklist, if required.

> **Note:**
>
> MPC transfer may be performed at any location deemed appropriate by the licensee. The following steps describe the general transfer operations. The HI-STORM FW may be positioned on an air pad, roller skid or any other suitable equipment in the cask receiving area or at the ISFSI. The HI-STORM FW or HI-TRAC VW may be transferred to the ISFSI using any equipment specifically designed for such a function. The licensee is responsible for assessing and controlling floor loading conditions during the MPC transfer operations. Installation of the lid, vent screen, and other components may vary according to the cask movement methods and location of MPC transfer.

9.2.6 Placement of HI-STORM FW into Storage

1. Position an empty HI-STORM FW module at the designated MPC transfer location.

2. Remove any road dirt with water. Remove any foreign objects from cavity locations.

3. Transfer the HI-TRAC VW to the MPC transfer location.

> **Note:**
>
> For most efficient heat rejection, the HI-TRAC transfer cask is envisaged to be routinely handled in the vertical orientation. However, architectural constraints at a plant, such as a low roll-up door opening or a low hung overhead duct work, may require the cask to be tilted or even downended for a short duration during this transfer step (as described in Subsection 4.5.1). In such a case, the continued thermal compliance of the cask's contents to ISG-11 Rev 3 will be verified by simulating the short term handling operation on the NRC-reviewed Fluent model and any possible adverse effect on the occupational dose shall be mitigated by use of suitably configured custom shielding."

4. Install the mating device on top of the HI-STORM FW.

5. Position HI-TRAC VW above HI-STORM FW.

6. Align HI-TRAC VW over HI-STORM FW and mate the components.

7. Attach the MPC to the lifting device in accordance with the site-approved rigging procedures.

8. Raise the MPC slightly to remove the weight of the MPC from the mating device.

9. Remove the bottom lid from HI-TRAC VW using the mating device.

ALARA Warning:
Personnel should remain clear (to the maximum extent practicable) of the HI-STORM FW annulus when HI-TRAC VW is removed due to radiation streaming. The mating device may be used to supplement shielding during removal of the MPC lift rigging.

10. Lower the MPC into HI-STORM FW.

11. Disconnect the MPC lifting slings from the lifting device.

Note:
It may be necessary, due to site-specific circumstances, to move HI-STORM FW from under the empty HI-TRAC VW to install the HI-STORM FW lid, while inside the Part 50 facility. In these cases, users shall evaluate the specifics of their movements within the requirements of their Part 50 license.

12. Remove HI-TRAC VW from on top of HI-STORM FW with or without the HI-TRAC bottom lid.

13. Remove the MPC lift rigging and install plugs in the empty MPC bolt holes*.

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

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

a. Remove the mating device.

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

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

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

c. Install the HI-STORM FW lid and the lid studs and nuts or lid closure bolts*.

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

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

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

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

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

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

h. Transfer the HI-STORM FW to its designated storage location at the appropriate pitch.

i. Attach the HI-STORM FW temperature elements (if used) and screens.

15. If required per CoC Condition #8 the user must perform the following annular air flow thermal test or cite a test report that was performed and prepared by another user.

a. The annular air flow thermal test shall be conducted at least 7 days after the HI-STORM is loaded in order for the overpack to establish thermal equilibrium.

b. The user or other qualified engineer shall calculate and record the actual heat load of the fuel stored in the HI-STORM.

c. To minimize the effects on the annular air flow, the test shall be performed when the weather is relatively dry and calm.

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

d. The ambient air temperature at the cask shall be recorded.

e. The test data shall be collected for the annular flow between the MPC and HI-STORM inner shell as follows:

   1. The outlet vent screen shall be removed from one outlet vent, if necessary for instrument access. Alternatively, if access ports have been provided in the HI-STORM lid, the access port plugs may be removed and access ports used for instrument access.

   2. A hot wire anemometer or similar flow measuring instrument shall be inserted into the annular space between the MPC and HI-STORM inner shell.

   3. The flow measuring instrument shall be at positioned at least 6" below the top of the MPC and shall not significantly block the air flow.

   4. The instrument shall not be placed too close to the MPC or HI-STORM shells to avoid edge effects on the flow.

   5. The outlet gamma shield and vent screen shall be re-installed if removed.

   6. Measurements of the air flow shall be taken and recorded for a minimum of three places radially across the annular gap.

   7. The outlet vent screen and gamma shield shall be removed from the outlet vent, if necessary, and the flow measuring instrument removed.

   8. The outlet gamma shield and vent screen shall be re-installed if removed.

   9. Re-install access port plugs if removed.

f. Air flow in each of the three remaining outlet vents or access ports shall be measured and recorded in accordance with step 15.e above.

g. All test data shall be transmitted to the general license holder for evaluation and validation of the thermal model.

h. Users shall forward test and analysis results to the NRC in accordance with 10 CFR 72.4.

Table 9.2.1

HI-STORM FW SYSTEM ANCILLARY EQUIPMENT OPERATIONAL DESCRIPTION

Equipment	Important To Safety Classification*	Description
Air Pads/Rollers	Not Important To Safety	Used for HI-STORM FW or HI-TRAC VW cask positioning. May be used in conjunction with the cask transporter or other HI-STORM FW or HI-TRAC VW lifting device.
Annulus Overpressure System	Not Important To Safety	The Annulus Overpressure System is used for protection against spent fuel pool water contamination of the external MPC shell and baseplate surfaces by providing a slight annulus overpressure during in-pool operations.
Automated Welding System	Not Important To Safety	Used for remote field welding of the MPC.
Cask Transporter	Not Important to Safety unless used for MPC transfers	Used for handling of the HI-STORM FW overpack and/or the HI-TRAC VW Transfer Cask around the site. The cask transporter may take the form of heavy haul transfer trailer, special transporter or other equipment specifically designed for such a function. May also be used for MPC transfers if appropriately configured.
Lid and empty component lifting rigging	Not Important To Safety, Rigging shall be provided in accordance with NUREG 0612	Used for rigging components such as the HI-TRAC VW top lid, bottom lid, MPC lid, AWS, and HI-STORM FW Lid and the empty MPC.
Helium Backfill System	Not Important To Safety	Used for controlled insertion of helium into the MPC for pressure testing, blowdown and placement into storage.
HI-STORM FW Special Lifting Device	Determined site-specifically based on type, location, and height of lift being performed. Special lifting devices shall be provided in accordance with ANSI N14.6.	A special lifting device used for connecting the crane (or other primary lifting device) to the HI-STORM FW for cask handling.
HI-TRAC VW Lift Yoke/Lifting Links	Determined site-specifically based on type and location, and height of lift being performed. Lift yoke and lifting devices for loaded HI-TRAC VW handling shall be provided in accordance with ANSI N14.6.	Used for connecting the crane (or other primary lifting device) to the HI-TRAC VW for cask handling. Does not include the crane hook (or other primary lifting device). May include one or more extensions to prevent immersion of the crane hook into the spent fuel pool water.
HI-TRAC VW transfer frame	Not Important To Safety	A steel frame used to support HI-TRAC VW during delivery, on-site movement and upending/downending operations.

* Per Holtec's QA program, components may be purchased to a higher safety category than what is designated in this table.

Table 9.2.1

HI-STORM FW SYSTEM ANCILLARY EQUIPMENT OPERATIONAL DESCRIPTION

Equipment	Important To Safety Classification*	Description
Inflatable Annulus Seal	Not Important To Safety	Used to prevent spent fuel pool water from contaminating the external MPC shell and baseplate surfaces during in-pool operations.
MPC Lift Attachments	Important To Safety – Category A. MPC Lift Attachments shall be provided in accordance with ANSI N14.6.	MPC lift attachments consist of the strongback and attachment hardware. The MPC lift attachments are used to support the MPC during MPC transfer from HI-TRAC VW into HI-STORM FW and vice versa. The ITS classification of the lifting device attached to the attachments may be lower than the attachment itself, as determined site-specifically. Lift Attachments may take different forms based on site specific needs and may include remote disconnect features.
Pressure Test System	Not Important to Safety	Used to pressure test the MPC lid-to-shell weld.
HI-TRAC Lift Block	Important-To-Safety Category A. Lift Blocks shall be provided in accordance with ANSI N14.6.	Used to attach the HI-TRAC to the lifting yoke.
Mating Device	Important-To-Safety – Category B	Used to mate HI-TRAC VW to HI-STORM FW during transfer operations. Used to shield operators during MPC transfer operations. Includes sliding drawer for use in removing HI-TRAC VW bottom lid.
MPC Lifting Slings	Important To Safety – Category A (When used inside a Part 50 structure); Important To Safety – Category B (When used outside a Part 50 structure) – Rigging shall be provided in accordance with NUREG 0612.	Used to secure the MPC to the overhead lifting device during HI-TRAC VW bottom lid removal and MPC transfer operations. Attaches between the MPC lift attachments and the lift yoke or overhead lifting device.
MPC Upending Device	Not Important to Safety	Used to evenly support the MPC during handling and upending operations and help control the upending process.
MSLD (Helium Leakage Detector)	Not Important to Safety	Used for helium leakage testing of the MPC closure welds.
Vacuum Drying System	Not Important To Safety	Used for removal of residual moisture from the MPC following water draining.
Forced Helium Dehydration System	Not Important To Safety	Used for removal of residual moisture from the MPC following water draining.
Vent and Drain RVOAs	Not Important To Safety	Used to access the vent and drain ports. The vent and drain RVOAs allow the vent and drain ports to be operated like valves.
Weld Removal System	Not Important To Safety	Semi-automated weld removal system used for removal of the MPC field weld to support unloading operations.

Table 9.2.2

HI-STORM FW SYSTEM INSTRUMENTATION SUMMARY FOR LOADING AND UNLOADING OPERATIONS†

Instrument	Function
Contamination Survey Instruments	Monitors fixed and non-fixed contamination levels.
Dose Rate Monitors/Survey Equipment	Monitors dose rate and contamination levels and ensures proper function of shielding. Ensures assembly debris is not inadvertently removed from the spent fuel pool during overpack removal.
Flow Rate Monitor	Monitors fluid flow rate during various loading and unloading operations.
Helium Mass Spectrometer Leakage Detector (MSLD)	Ensures leakage rates of welds are within acceptable limits.
Volumetric Examination Testing Rig	Used to assess the integrity of the MPC lid-to-shell weld.
Pressure Gauges	Ensures correct pressure during loading and unloading operations.
Temperature Gauges	Monitors the state of gas and water temperatures during closure and unloading operations.
Vacuum Gages (Optional)	Used for vacuum drying operations and to prepare an MPC evacuated sample bottle for MPC gas sampling for unloading operations.
Moisture Monitoring Instruments	Used to monitor the MPC moisture levels as part of the moisture removal system.

† All instruments require calibration. See figures at the end of this section for additional instruments, controllers and piping diagrams.

Table 9.2.3 HI-STORM FW SYSTEM OVERPACK INSPECTION CHECKLIST
Note: This checklist provides the basis for establishing a site-specific inspection checklist for the HI-STORM FW overpack. Specific findings shall be brought to the attention of the appropriate site organizations for assessment, evaluation and potential corrective action prior to use.

HI-STORM FW Overpack Lid:

1. Lid studs and nuts or lid closure bolts shall be inspected for general condition*.
2. The painted surfaces shall be inspected for corrosion and chipped, cracked or blistered paint.
3. All lid surfaces shall be relatively free of dents, scratches, gouges or other damage.
4. The lid shall be inspected for the presence or availability of studs and nuts and hole plugs, as required.
5. Lid lifting device attachment points/bolt holes shall be inspected for dirt and debris, deformation, and thread condition as applicable.
6. Lid bolt holes shall be inspected for general condition.
7. Vent screens shall be inspected for proper fit and for tears and holes that would allow debris entry into the vent openings.
8. Vent openings shall be inspected for foreign material that may cause vent blockage.

HI-STORM FW Main Body:

1. Lid bolt holes shall be inspected for dirt, debris, and thread condition.
2. Vents shall be free from obstructions.
3. Vent screens shall be inspected for proper fit and for tears and holes that would allow debris entry into the vent openings.
4. The interior cavity shall be free of debris, litter, tools, and equipment.
5. Painted surfaces shall be inspected for corrosion, and chipped, cracked or blistered paint.
6. The nameplate shall be inspected for presence, legibility, and general condition and conformance to Quality Assurance records package.

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

Table 9.2.4 MPC INSPECTION CHECKLIST
Note: This checklist provides the basis for establishing a site-specific inspection checklist for MPC. Specific findings shall be brought to the attention of the appropriate site organizations for assessment, evaluation and potential corrective action prior to use.

MPC Lid and Closure Ring:

1. The MPC lid and closure ring surfaces shall be relatively free of dents, gouges or other shipping damage.
2. The drain line shall be inspected for straightness, thread condition, and blockage.
3. Vent and Drain attachments shall be inspected for availability, thread condition operability, and general condition.
4. Fuel spacers (if used) shall be inspected for availability and general condition.
5. Drain and vent port cover plates shall be inspected for availability and general condition.
6. Serial numbers shall be inspected for readability.
7. The MPC lid lift holes shall be inspected for thread condition*.
8. The MPC lid, cover plates, and closure ring shall be checked for proper fit-up.

MPC Main Body:

1. All visible MPC body surfaces shall be inspected for dents, gouges, or other shipping damage.
2. Fuel cell openings shall be inspected for debris, dents, and general condition.
3. Basket panels shall be inspected for gross deformation that may inhibit fuel assembly insertion.
4. Lift lugs shall be inspected for general condition.
5. Lift lug threads shall be in inspected for thread condition
6. Verify proper MPC basket type for contents.
7. Serial numbers shall be inspected for readability.

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

Table 9.2.5 HI-TRAC VW TRANSFER CASK INSPECTION CHECKLIST
Note: This checklist provides the basis for establishing a site-specific inspection checklist for the HI-TRAC VW Transfer Cask. Specific findings shall be brought to the attention of the appropriate site organizations for assessment, evaluation, and potential corrective action prior to use.

HI-TRAC VW Main Body:

1. The painted surfaces shall be inspected for corrosion, chipped, cracked, or blistered paint.
2. Annulus inflatable seal groove shall be inspected for cleanliness, scratches, dents, gouges, sharp corners, burrs, or any other condition that may damage the inflatable seal.
3. The nameplate shall be inspected for presence and general condition.
4. The neutron shield jacket shall be inspected for leaks.
5. Neutron shield jacket pressure relief device shall be inspected for presence and general condition.
6. The neutron shield jacket fill and neutron shield jacket drain plugs shall be inspected for presence, leaks, and general condition.
7. Bottom lid flange surface shall be clean and free of large scratches and gouges that may inhibit sealing of the lid to body.
8. The threaded anchor locations, if provided, shall be inspected for thread damage, excessive wear, and general condition.

HI-TRAC VW Bottom lid:

1. Seal shall be inspected for cracks, breaks, cuts, excessive wear, flattening, and general condition.
2. Drain line shall be inspected for blockage and thread condition.
3. The lifting holes shall be inspected for thread damage.
4. The bolts shall be inspected for indications of overstressing (i.e., cracks and deformation, thread damage, and excessive wear*).
5. The painted surfaces shall be inspected for corrosion, chipped, cracked, or blistered paint.
6. Threads shall be inspected for indications of damage.

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

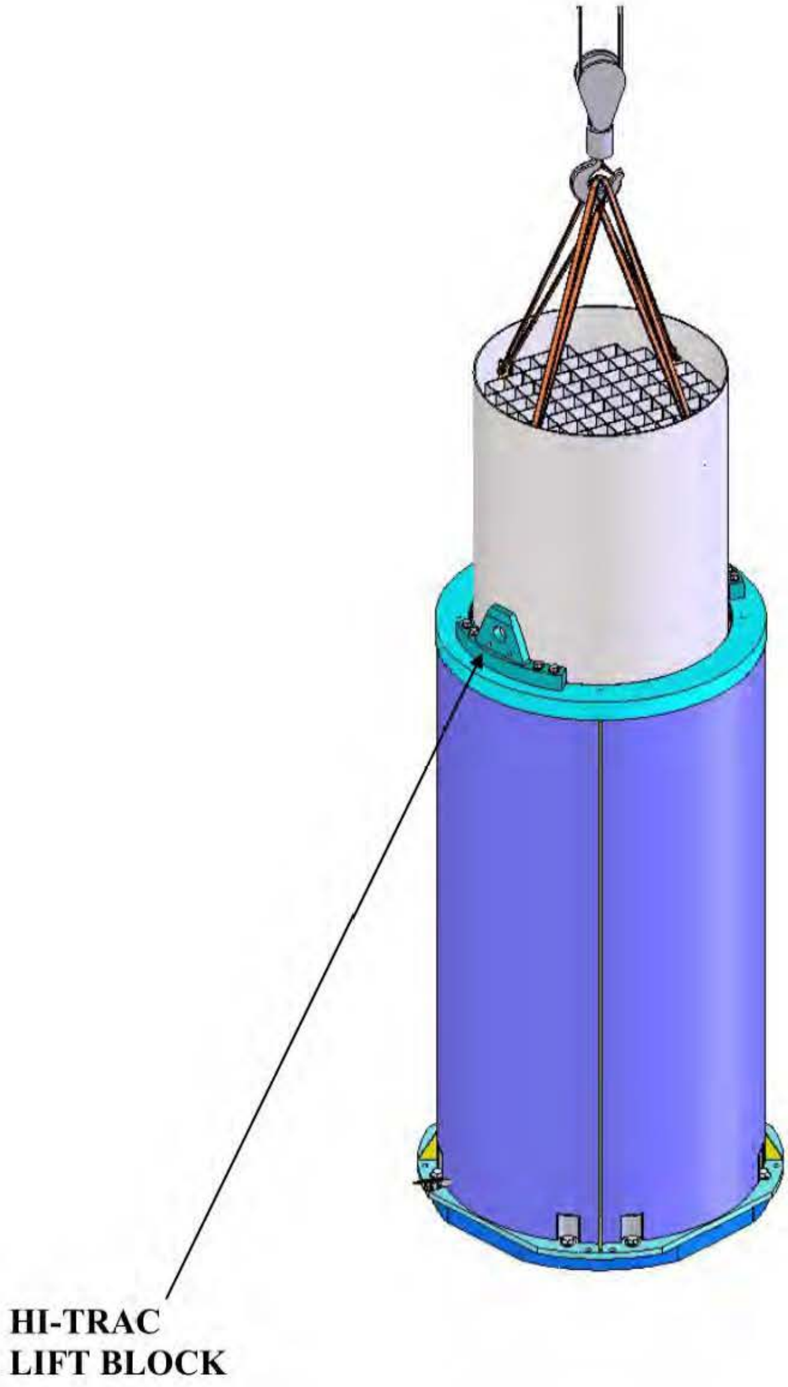

FIGURE 9.2.1: MPC INSTALLATION IN HI-TRAC

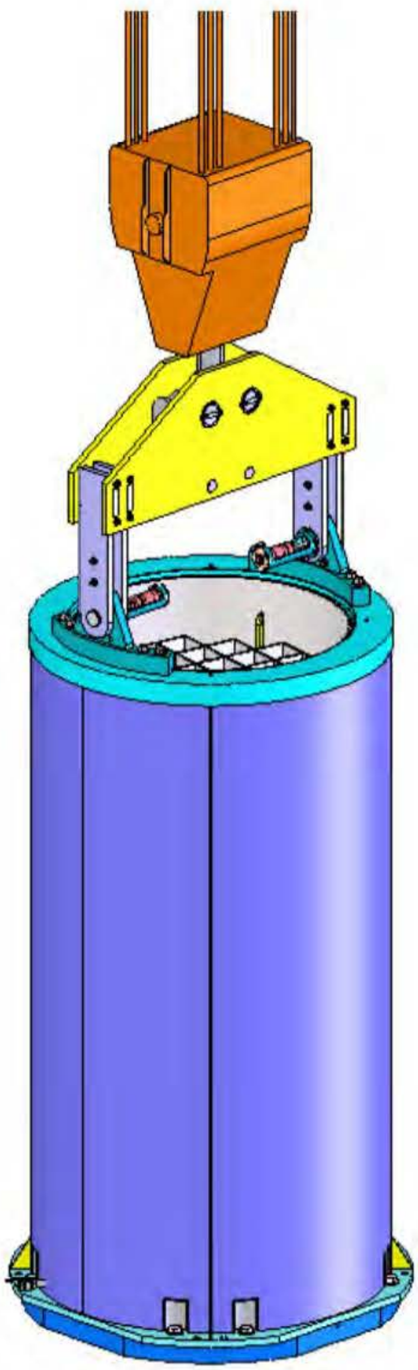

FIGURE 9.2.2: HI-TRAC LIFTING SHOWN USING A REPRESENTATIVE LIFT YOKE

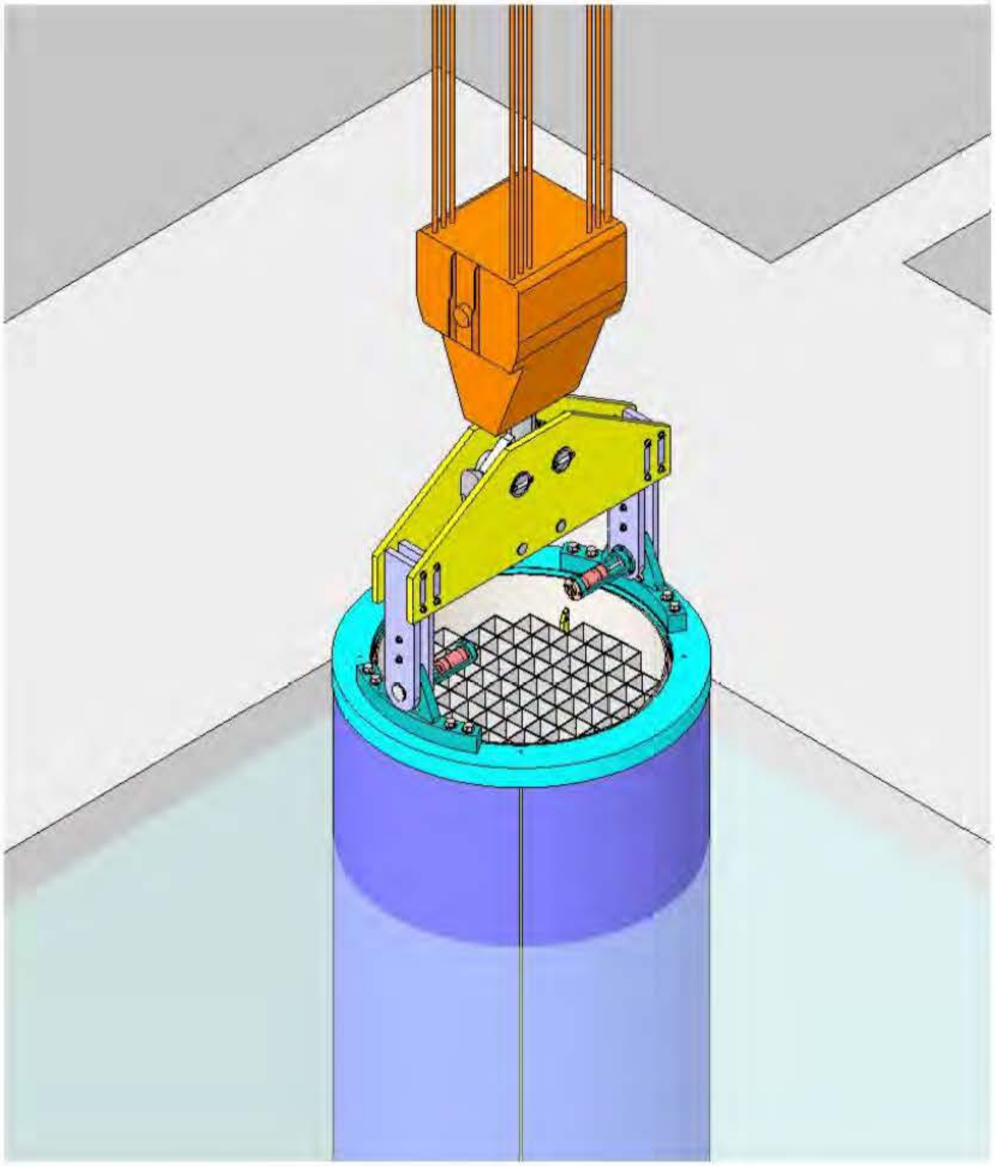

FIGURE 9.2.3: HI-TRAC PLACEMENT IN THE SPENT FUEL POOL

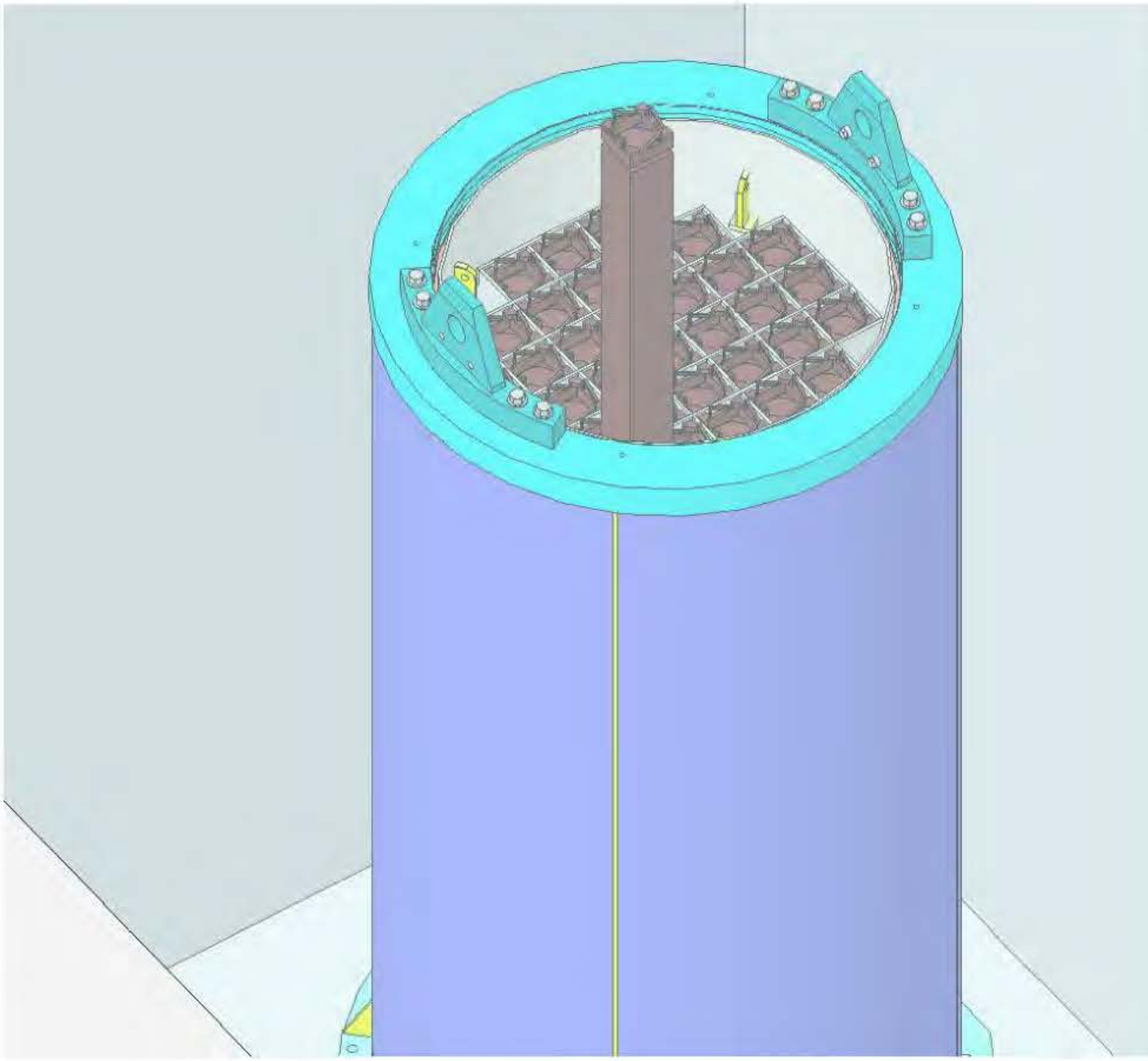

FIGURE 9.2.4: FUEL ASSEMBLY PLACEMENT IN THE MPC (CRANE NOT SHOWN)

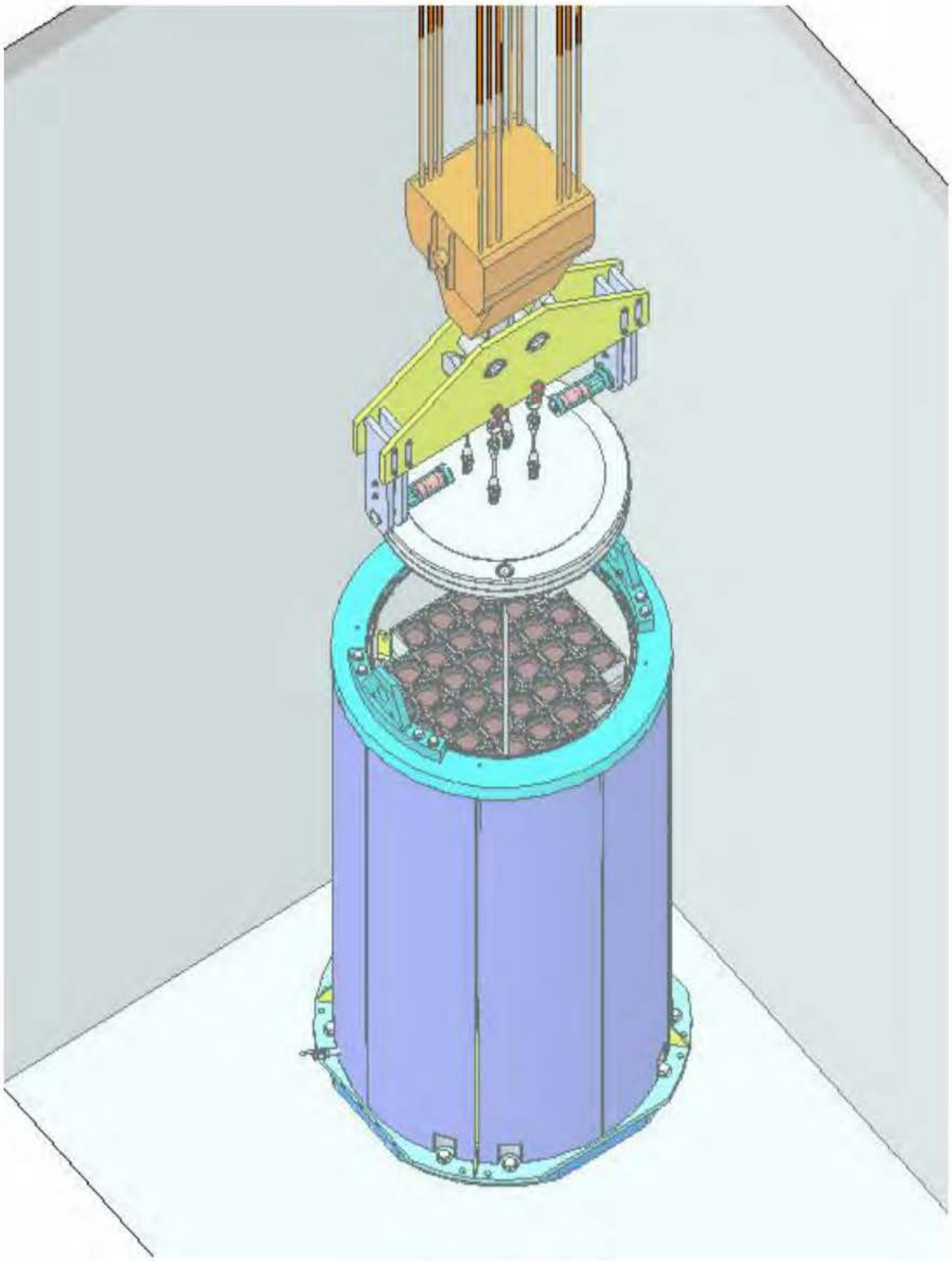

FIGURE 9.2.5: MPC LID INSTALLATION USING THE LIFT YOKE

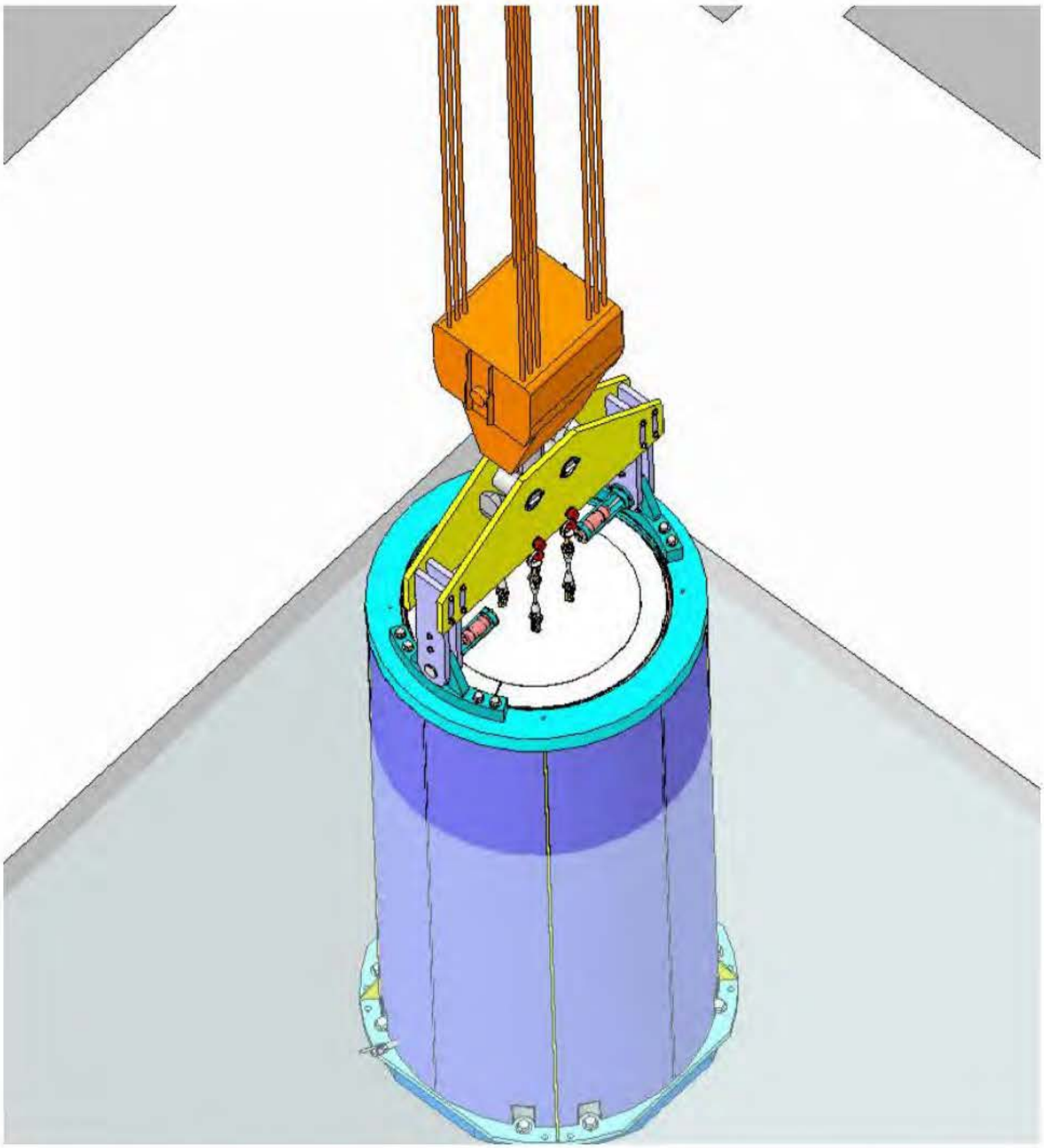

FIGURE 9.2.6: HI-TRAC REMOVAL FROM THE SPENT FUEL POOL

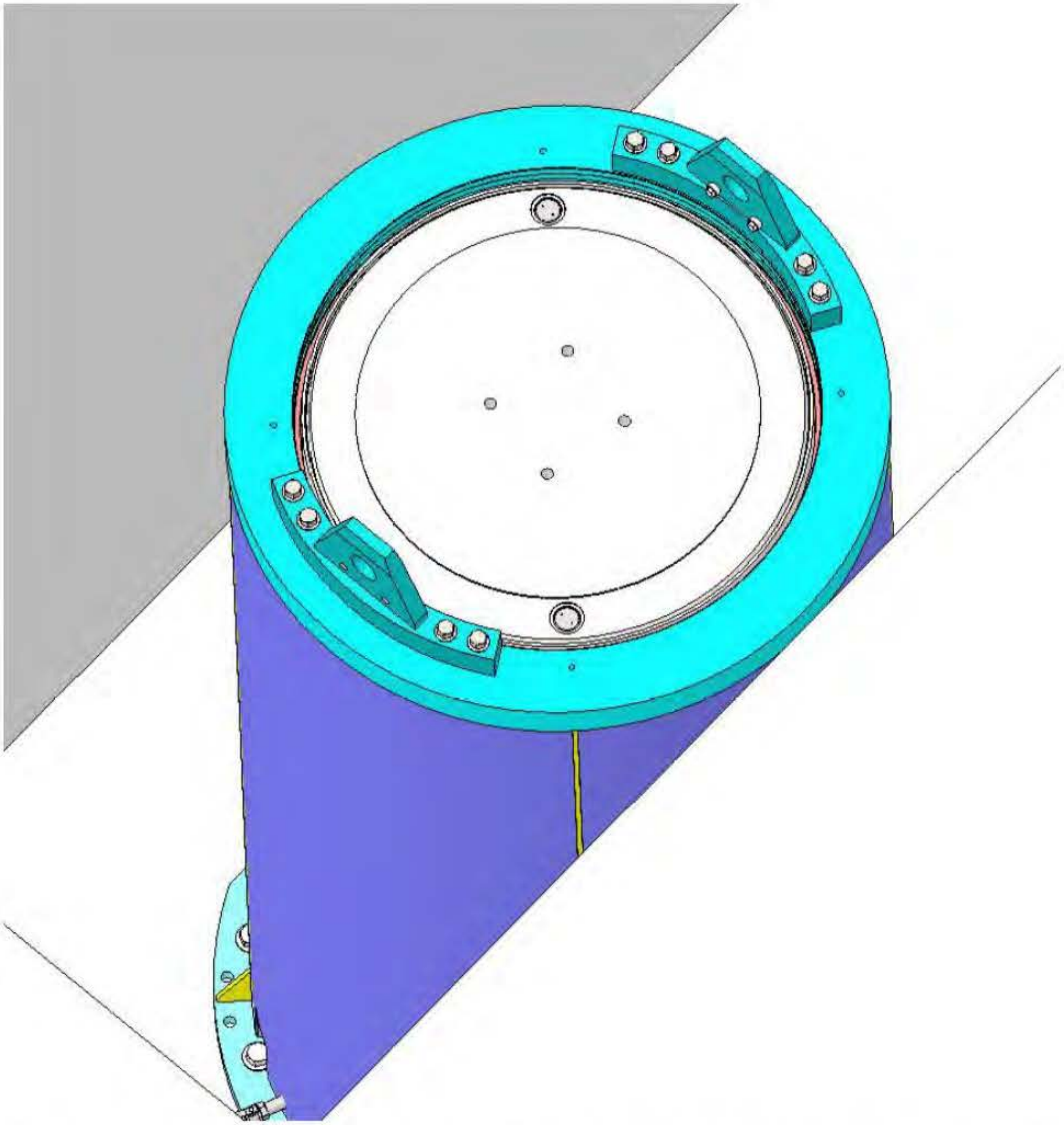

FIGURE 9.2.7: HI-TRAC PLACEMENT IN THE CASK PREPARATION AREA

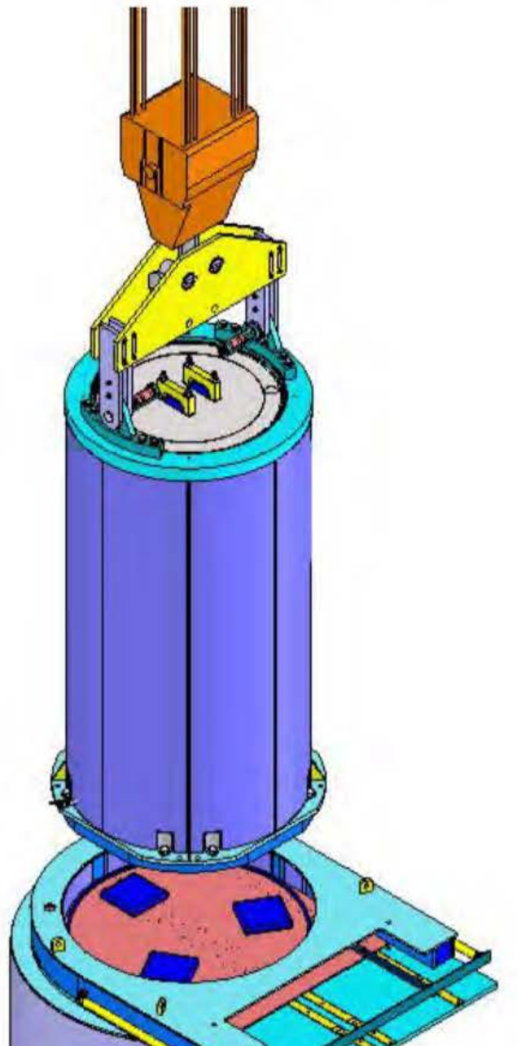

FIGURE 9.2.8: HI-TRAC PLACEMENT ON THE HI-STORM 100 OVERPACK USING THE MATING DEVICE

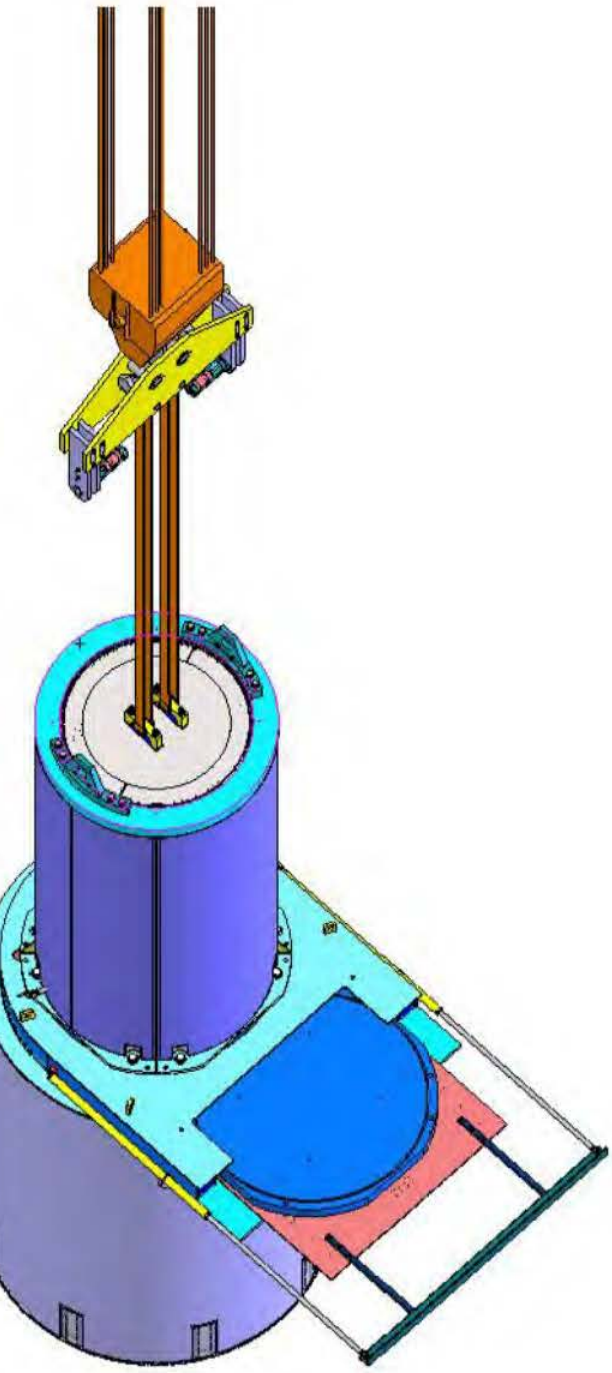

FIGURE 9.2.9: HI-TRAC READY FOR MPC TRANSFER INTO HI-STORM FW OVERPACK

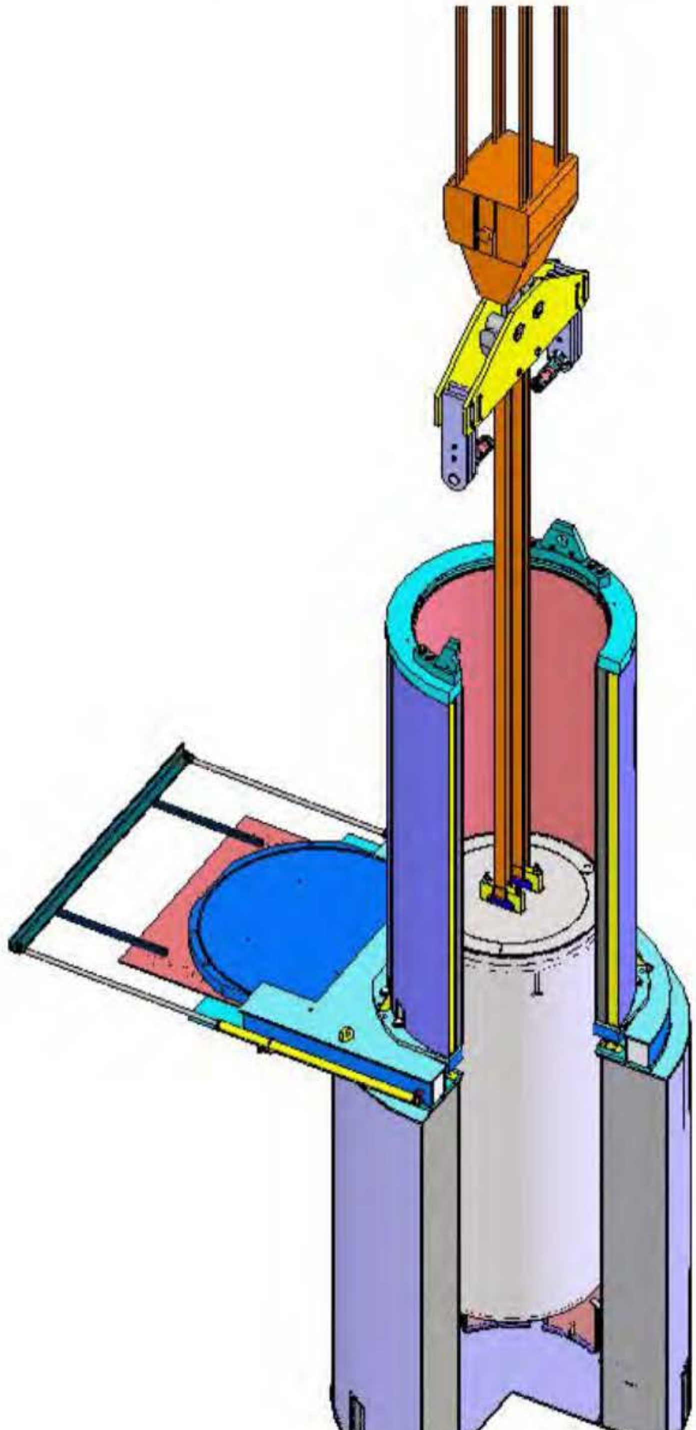

FIGURE 9.2.10: MPC TRANSFER INTO HI-STORM FW OVERPACK (CUT-AWAY VIEW)

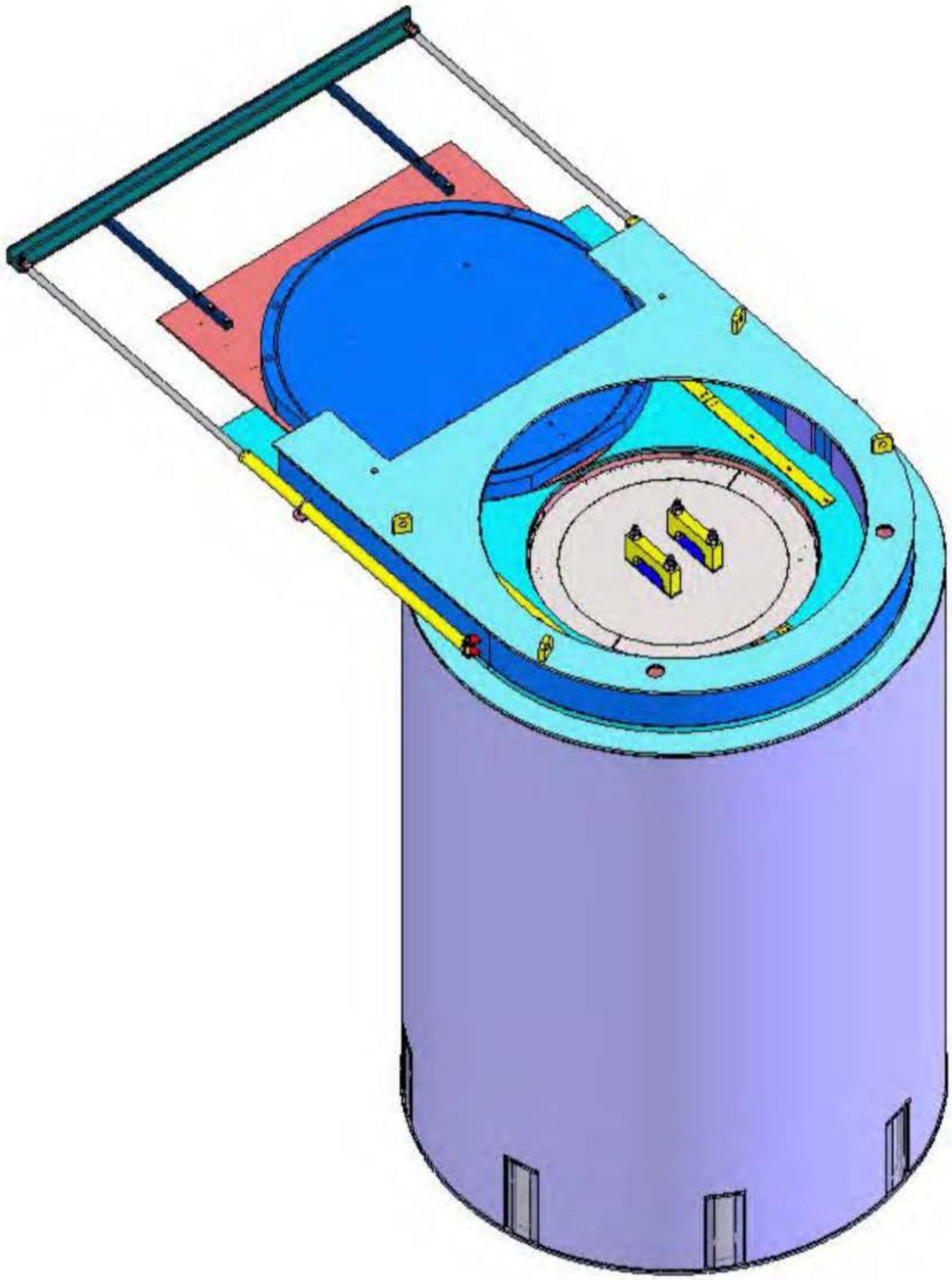

FIGURE 9.2.11: MPC SHOWN FULLY LOWERED INTO HI-STORM (HI-TRAC NOT SHOWN)

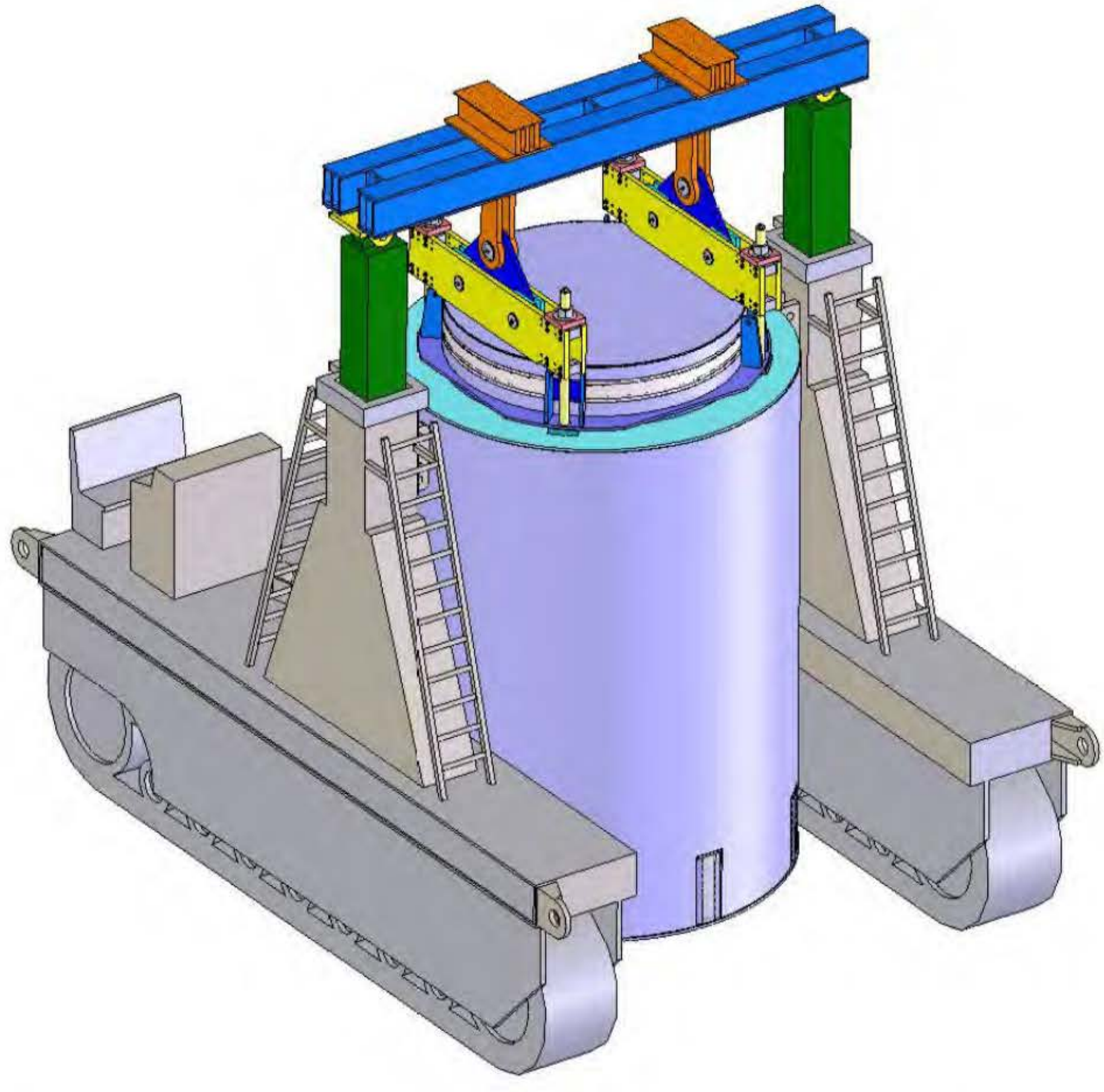

FIGURE 9.2.12: HI-STORM FW OVERPACK MOVEMENT SHOWN WITH A REPRESENTATIVE CASK TRANSPORTER

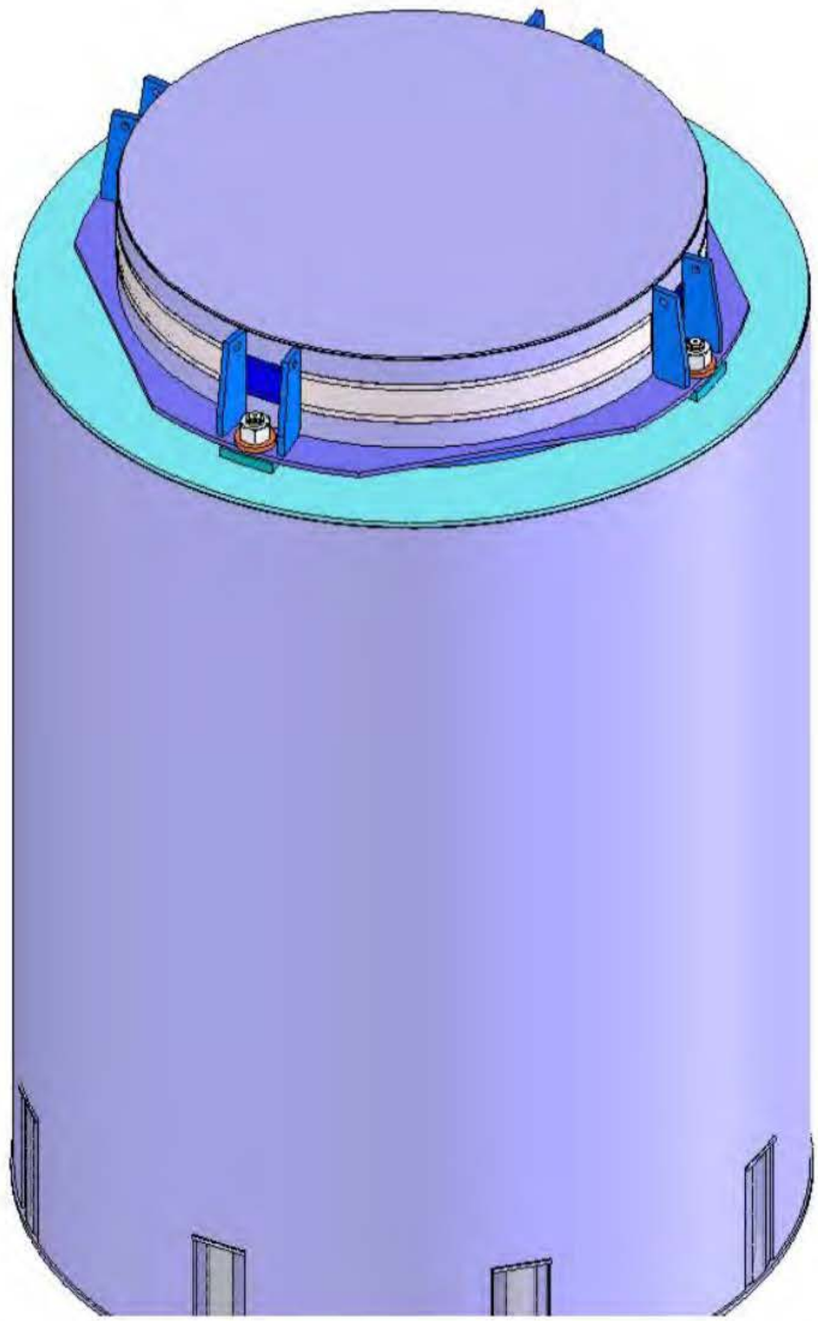

FIGURE 9.2.13: HI-STORM SHOWN IN STORAGE WITH THE LID INSTALLED

9.3 ISFSI OPERATIONS

The HI-STORM FW system heat removal system is a totally passive system. Maintenance on the HI-STORM FW system is typically limited to cleaning and touch-up painting of the overpacks, repair and replacement of damaged vent screens, and removal of vent blockages (e.g., leaves, debris). The heat removal system operability surveillance should be performed after any event that may have an impact on the safe functioning of the HI-STORM FW system. These include, but are not limited to, wind storms, heavy snow storms, fires inside the ISFSI, seismic activity, flooding of the ISFSI, and/or observed animal or insect infestations. The responses to these conditions involve first assessing the dose impact to perform the corrective action (inspect the HI-STORM FW overpack, clear the debris, check the cask pitch, and/or replace damaged vent screens), perform the corrective action, verify that the system is operable (check ventilation flow paths and radiation). In the unlikely event of significant damage to the HI-STORM FW, the situation may warrant removal of the MPC, and repair or replacement of the damaged HI-STORM FW overpack. If necessary, the procedures in Section 9.2 may be used to reposition a HI-STORM FW overpack for minor repairs and maintenance. In extreme cases, Section 9.4 may be used as guidance for unloading the MPC from the HI-STORM FW.

Note:
The heat removal system operability surveillance involves performing a visual examination on the HI-STORM FW exit and inlet vent screens to ensure that the vents remain clear or verifying the temperature rise from ambient to outlet is within prescribed limits if using a temperature monitoring system. The metallic vent screens if damaged may allow leaves, debris, or animals to enter the duct and block the flow of air to the MPC.

ALARA Warning:
Operators should practice ALARA principles when inspecting the vent screens. Binoculars or boroscopes may be used to allow the operator to perform the surveillance from a low dose area.

1. Perform the heat removal operability surveillance in accordance with the CoC.

2. ISFSI Security Operations shall be performed in accordance with the approved site security program plan.