FINAL SAFETY ANALYSIS REPORT

for the

HOLTEC INTERNATIONAL STORAGE, TRANSPORT
AND REPOSITORY CASK SYSTEM
(HI-STAR 100 CASK SYSTEM)

NRC DOCKET NO. 72-1008

HOLTEC REPORT HI-2012610, VOLUME I of II

Prepared by

HOLTEC
INTERNATIONAL

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CHAPTER 1: GENERAL DESCRIPTION

1.0 GENERAL INFORMATION

This Final Safety Analysis Report (FSAR) for Holtec International's HI-STAR 100 System is a compilation of information and analyses to support a United States Nuclear Regulatory Commission (NRC) licensing review as a spent nuclear fuel dry storage cask under the requirements specified in 10CFR72 [1.0.1]. This application seeks NRC approval and issuance of a Certificate of Compliance (C of C) for storage under provisions of 10CFR72, Subpart L for the HI-STAR 100 to safely store spent nuclear fuel (SNF) at an Independent Spent Fuel Storage Installation (ISFSI) facility. This report has been prepared in the format and content suggested in NRC Regulatory Guide 3.61 [1.0.2] and NUREG-1536 Standard Review Plan for Dry Cask Storage Systems [1.0.3] to facilitate the NRC review process.

The purpose of this chapter is to provide a general description of the design features and storage capabilities of the HI-STAR 100 System, drawings of the structures, systems, and components important to safety, and the qualifications of the applicant. This report is also suitable for incorporation into a site-specific Safety Analysis Report which may be submitted by an applicant for a license to store SNF at an ISFSI or a facility similar in objective and scope. Table 1.0.1 contains a listing of the terminology and notation used in this FSAR.

To aid NRC review, additional tables and references have been added to facilitate the location of information requested by NUREG-1536. Table 1.0.2 provides a matrix of the topics in NUREG-1536 and Regulatory Guide 3.61, the corresponding 10CFR72 requirements, and a reference to the applicable FSAR section that addresses each topic.

The HI-STAR 100 FSAR is in full compliance with the intent of all Regulatory Requirements listed in Section III of each chapter of NUREG-1536. However, an exhaustive review of the provisions in NUREG-1536, particularly Section IV (Acceptance Criteria) and Section V (Review Procedures) has identified certain deviations from a verbatim compliance to all requirements. A list of all such items, along with a discussion of their intent and Holtec International's approach for compliance with the underlying intent is presented in Table 1.0.3 herein. Table 1.0.3 also contains the justification for the alternative method for compliance adopted in this FSAR. The justification may be in the form of a supporting analysis, established industry practice, or other NRC guidance documents. Each chapter in this FSAR provides a clear statement with respect to the extent of compliance to the NUREG-1536 provisions.

Chapter 1 is in full compliance with NUREG-1536; no exceptions are taken.

The generic design basis and the corresponding safety analysis of the HI-STAR 100 System contained in this FSAR are intended to bound the SNF characteristics, design, conditions, and interfaces that exist in the vast majority of domestic power reactor sites and potential away-from-reactor storage sites in the contiguous United States. This FSAR also provides the basis for component fabrication and acceptance, and the requirements for safe operation and maintenance of the components, consistent with the design basis and safety analysis documented herein. In accordance with 10CFR72, Subpart K, site-specific implementation of the generically certified HI-STAR 100 System requires that the licensee perform a site-specific safety evaluation, as defined in 10CFR72.212. The HI-STAR 100 System FSAR identifies a limited number of conditions that are necessarily site-specific and are to be addressed in the licensee's 10CFR72.212 evaluation. These include:

- Siting of the ISFSI and design of the storage pad and security system. Site-specific demonstration of compliance with regulatory dose limits. Implementation of a site-specific ALARA program.

- An evaluation of site-specific hazards and design conditions that may exist at the ISFSI site or the transfer route between the plant's cask receiving bay and the ISFSI. These include, but are not limited to, explosion and fire hazards, flooding conditions, land slides, and lightning protection.

- Determination that the physical and nucleonic characteristics and the condition of the SNF assemblies to be dry stored meet the fuel acceptance requirements of the Certificate of Compliance.

- An evaluation of interface and design conditions that exist within the plant's fuel building in which canister fuel loading, canister closure, and cask handling operations are to be conducted in accordance with the applicable 10CFR50 requirements and technical specifications for the plant.

- Detailed site-specific operating, maintenance, and inspection procedures prepared in accordance with the generic procedures and requirements provided in Chapters 8 and 9, and the technical specifications provided in the Certificate of Compliance.

- Performance of pre-operational testing.

- Implementation of a safeguards and accountability program in accordance with 10CFR73. Preparation of a physical security plan in accordance with 10CFR73.55.

- Review of the reactor emergency plan, quality assurance (QA) program, training program, and radiation protection program.

The generic safety analyses contained in the HI-STAR 100 FSAR may be used as input and for guidance by the licensee in performing a 10CFR72.212 evaluation.

A Safety Analysis Report (SAR) has been submitted to the NRC (Docket No. 71-9261) requesting issuance of a Certificate of Compliance under provisions of 10CFR71, Subpart D [1.0.4] for the HI-STAR 100 as a Type B(U)F-85 packaging for transport by exclusive use shipment (10CFR71.47).

Within this report, all figures, tables and references cited are identified by the double decimal system m.n.i, where m is the chapter number, n is the section number, and i is the sequential number. Thus, for example, Figure 1.2.3 is the third figure in Section 1.2 of Chapter 1.

Revision 0 of this FSAR, issued in March 2001, includes information supporting changes to CoC 72-1008 made in Amendment 1 (effective December 26, 2000), as well as information from the original version of the CoC that did not change as a result of that amendment. This is because the safety analysis report updating requirements of 10 CFR 72.248 did not become effective until after the original version of CoC 72-1008 became effective in October 1999. Therefore, a Final Safety Analysis Report (FSAR) was never issued to replaced Revision 10 of the HI-STAR 100 Topical Safety Analysis Report (TSAR). This Holtec report (HI-2012610) supersedes Holtec Report HI-941184 in its entirety. Differences between TSAR Revision 10 and FSAR Revision 0 include:

1. Changes related to CoC Amendment 1.
2. The term "TSAR" is changed to FSAR throughout the document.
3. Corrections to typographical errors and other minor editorial changes.

Table 1.0.1

TERMINOLOGY AND NOTATION

ALARA is an acronym for As Low As Reasonably Achievable.

Boral is a generic term to denote an aluminum-boron carbide cermet manufactured in accordance with U.S. Patent No. 4027377. The individual material supplier may use another trade name to refer to the same product.

Boral^{TM} means Boral manufactured by AAR Advanced Structures.

BWR is an acronym for boiling water reactor.

C.G. is an acronym for center of gravity.

Confinement Boundary means the outline formed by the sealed, cylindrical enclosure of the multi-purpose canister (MPC) shell welded to a solid baseplate, a lid welded around the top circumference of the shell wall, the port cover plates welded to the lid, and the closure ring welded to the lid and MPC shell.

Confinement System means the HI-STAR 100 multi-purpose canister (MPC) which encloses and confines the spent nuclear fuel during storage.

Controlled Area means that area immediately surrounding an ISFSI for which the owner/user exercises authority over its use and within which operations are performed.

DBE means Design Basis Earthquake.

DCSS is an acronym for Dry Cask Storage System.

Damaged Fuel Assembly is defined as a fuel assembly with known or suspected cladding defects, as determined by a review of records, greater than pinhole leaks or hairline cracks, missing fuel rods that are not replaced with dummy fuel rods, or those that cannot be handled by normal means. Fuel assemblies that cannot be handled by normal means due to fuel cladding damage are considered fuel debris.

Damaged Fuel Container means a specially designed enclosure for damaged fuel or fuel debris which permits gaseous and liquid media to escape while minimizing dispersal of gross particulates. DFCs authorized for use in the HI-STAR 100 System are the Holtec design or the Transnuclear Dresden Unit 1 design.

Table 1.0.1 (continued)

TERMINOLOGY AND NOTATION

Enclosure Vessel means the pressure vessel defined by the cylindrical shell, baseplate, port cover plates, lid, and closure ring which provides confinement for the helium gas contained within the MPC. The Enclosure Vessel (EV) and the fuel basket together constitute the multi-purpose canister.

Fuel Basket means a honeycomb structural weldment with square openings that can accept a fuel assembly of the type for which it is designed.

Fuel Debris is defined as ruptured fuel rods, severed fuel rods, loose fuel pellets, or fuel assemblies with known or suspected defects which cannot be handled by normal means due to fuel cladding damage.

FSAR is an acronym for Final Safety Analysis Report (10CFR72).

Helium Retention Boundary means the enclosure formed by the overpack inner shell welded to a bottom plate and top main flange plus the bolted closure plate and port plugs with metallic seals. The helium retention boundary is an additional independent confinement boundary, however, no credit is taken for this additional barrier. The helium retention boundary maintains an inert helium atmosphere around the MPC.

HI-STAR 100 MPC means the sealed spent nuclear fuel container which consists of a honeycombed fuel basket contained in a cylindrical canister shell which is welded to a baseplate, lid with welded port cover plates, and closure ring. MPC is an acronym for multi-purpose canister. There are different MPCs with different fuel basket geometries for storing PWR or BWR fuel, but all MPCs have identical exterior dimensions. The MPC is the confinement boundary for storage conditions.

HI-STAR 100 overpack or overpack means the cask that receives and contains the sealed multi-purpose canisters containing spent nuclear fuel. It provides the retention boundary for the helium atmosphere, gamma and neutron shielding, and a set each of lifting and pocket trunnions. It is not defined as the confinement boundary for the radioactive material during storage.

HI-STAR 100 System consists of the HI-STAR 100 MPC sealed within the HI-STAR 100 overpack.

Holtite™ is the trade name for all present and future neutron shielding materials formulated under Holtec International's R&D program dedicated to developing shielding materials for application in dry storage and transport systems. The Holtite development program is an ongoing experimentation effort to identify neutron shielding materials with enhanced shielding and temperature tolerance characteristics. Holtite-A™ is the first, and only shielding material qualified under the Holtec R&D program. As such, the terms Holtite and Holtite-A may be used inter changeably throughout this FSAR.

Table 1.0.1 (continued)

TERMINOLOGY AND NOTATION

Holtite-A^{TM} is a trademarked Holtec International neutron shield material.

Important to Safety (ITS) means a function or condition required to store spent nuclear fuel safely; to prevent damage to spent nuclear fuel during handling and storage, and to provide reasonable assurance that spent nuclear fuel can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public.

Independent Spent Fuel Storage Installation (ISFSI) means a facility designed, constructed, and licensed for the interim storage of spent nuclear fuel and other radioactive materials associated with spent fuel storage in accordance with 10CFR72.

Intact Fuel Assembly is defined as a fuel assembly without known or suspected cladding defects greater than pinhole leaks and hairline cracks, and which can be handled by normal means. Partial fuel assemblies, that is fuel assemblies from which fuel rods are missing, shall not be classified as intact fuel assemblies unless dummy fuel rods used to displace an amount of water greater than or equal to that displaced by the original fuel rod(s).

Maximum Reactivity means the highest possible k-effective including bias, uncertainties, and calculational statistics evaluated for the worst-case combination of fuel basket manufacturing tolerances.

MGDS is an acronym for Mined Geological Depository System.

Multi-Purpose Canister (MPC) means the sealed canister which consists of a honeycombed fuel basket for spent nuclear fuel storage, contained in a cylindrical canister shell which is welded to a baseplate, lid with welded port cover plates, and closure ring. There are different MPCs with different fuel basket geometries for storing PWR or BWR fuel, but all MPCs have identical exterior dimensions. The MPC is the confinement boundary for storage conditions. MPC is an acronym for multi-purpose canister. The MPCs used as part of the HI-STORM 100 System (Docket No. 72-1014) are identical to the HI-STAR 100 MPCs evaluated in the HI-STAR 100 storage (Docket No. 72-1008) and transport (Docket No. 71-9261) applications.

MPC Fuel Basket means the honeycombed composite cell structure utilized to maintain subcriticality of the spent nuclear fuel. The number and size of the storage cells depends on the type of spent nuclear fuel to be stored. Each MPC fuel basket has sheathing welded to the storage cell walls for retaining the Boral neutron absorber. Boral is a commercially-available thermal neutron poison material composed of boron carbide and aluminum.

Neutron Shielding means Holtite or Holtite-A, a material used in the HI-STAR overpack to thermalize and capture neutrons emanating from the radioactive spent nuclear fuel.

Table 1.0.1 (continued)

TERMINOLOGY AND NOTATION

PWR is an acronym for pressurized water reactor.

Reactivity is used synonymously with effective multiplication factor or k-effective.

SAR is an acronym for Safety Analysis Report (10CFR71).

Single Failure Proof means that the handling system is designed so that a single failure will not result in the loss of the capability of the system to safely retain the load.

SNF is an acronym for spent nuclear fuel.

SSC is an acronym for Structures, Systems and Components.

STP is Standard Temperature (298°K) and Pressure (1 atm) conditions.

ZPA is an acronym for zero period acceleration.

Table 1.0.2

HI-STAR 100 SYSTEM FSAR REGULATORY COMPLIANCE CROSS-REFERENCE MATRIX

Regulatory Guide 3.61 Section and Content	Associated NUREG-1536 Review Criteria	Applicable 10CFR72 or 10CFR20 Requirement	HI-STAR FSAR
1. General Description			
1.1 Introduction	1.III.1 General Description & Operational Features	10CFR72.24(b)	1.1
1.2 General Description	1.III.1 General Description & Operational Features	10CFR72.24(b)	1.2
1.2.1 Cask Characteristics	1.III.1 General Description & Operational Features	10CFR72.24(b)	1.2.1
1.2.2 Operational Features	1.III.1 General Description & Operational Features	10CFR72.24(b)	1.2.2
1.2.3 Cask Contents	1.III.3 DCSS Contents	10CFR72.2(a)(1) 10CFR72.236(a)	1.2.3
1.3 Identification of Agents & Contractors	1.III.4 Qualification of the Applicant	10CFR72.24(j) 10CFR72.28(a)	1.3
1.4 Generic Cask Arrays	1.III.1 General Description & Operational Features	10CFR72.24(c)(3)	1.4
1.5 Supplemental Data	1.III.2 Drawings	10CFR72.24(c)(3)	1.5
NA	1.III.6 Consideration of Transport Requirements	10CFR72.230(b) 10CFR72.236(m)	1.1
NA	1.III.5 Quality Assurance	10CFR72.24(n)	1.3
2. Principal Design Criteria			
2.1 Spent Fuel To Be Stored	2.III.2.a Spent Fuel Specifications	10CFR72.2(a)(1) 10CFR72.236(a)	2.1

Table 1.0.2 (continued)

HI-STAR 100 SYSTEM FSAR REGULATORY COMPLIANCE CROSS-REFERENCE MATRIX

2.2 Design Criteria for Environmental Conditions and Natural Phenomena	2.III.2.b External Conditions, 2.III.3.b Structural, 2.III.3.c Thermal	10CFR71.122(b)	2.2
		10CFR72.122(c)	2.2.3.3, 2.2.3.10
		10CFR72.122(b)(1)	2.2
		10CFR72.122(b)(2)	2.2.3.11
		10CFR72.122(h)(1)	2.0
2.2.1 Tornado and Wind Loading	2.III.2.b External Conditions	10CFR72.122(b)	2.2.3.5
2.2.2 Water Level (Flood)	2.III.2.b External Conditions 2.III.3.b Structural	10CFR72.122(b)(2)	2.2.3.6
2.2.3 Seismic	2.III.3.b Structural	10CFR72.102(f) 10CFR72.122(b)(2)	2.2.3.7
2.2.4 Snow and Ice	2.III.2.b External Conditions 2.III.3.b Structural	10CFR72.122(b)	2.2.1.6
2.2.5 Combined Load	2.III.3.b Structural	10CFR72.24(d) 10CFR72.122(b)(2)(ii)	2.2.7
NA	2.III.1 Structures, Systems, and Components Important to Safety	10CFR72.122(a) 10CFR72.24(c)(3)	2.2.4
NA	2.III.2 Design Criteria for Safety Protection Systems	10CFR72.236(g) 10CFR72.24(c)(1) 10CFR72.24(c)(2) 10CFR72.24(c)(4) 10CFR72.120(a) 10CFR72.236(b)	2.0, 2.2
NA	2.III.3.c Thermal	10CFR72.128(a)(4)	2.3.2.2, 4.0
NA	2.III.3.f Operating Procedures	10CFR72.24(f) 10CFR72.128(a)(5)	10.0, 8.0
		10CFR72.236(h)	8.0
		10CFR72.24 (l)(2)	1.2.1, 1.2.2

Table 1.0.2 (continued)

HI-STAR 100 SYSTEM FSAR REGULATORY COMPLIANCE CROSS-REFERENCE MATRIX

		10CFR72.236(l)	2.3.2.1
		10CFR72.24(e) 10CFR72.104(b)	10.0, 8.0
	2.III.3.g Acceptance Tests & Maintenance	10CFR72.122 (l) 10CFR72.236 (g) 10CFR72.122 (f) 10CFR72.128 (a)(1)	9.0
2.3 Safety Protection Systems	--	--	2.3
2.3.1 General	--	--	2.3
2.3.2 Protection by Multiple Confinement Barriers and Systems	2.III.3.b Structural	10CFR72.236(1)	2.3.2.1
	2.III.3.c Thermal	10CFR72.236(f)	2.3.2.2
	2.III.3.d Shielding/ Confinement/ Radiation Protection	10CFR72.126(a) 10CFR72.128(a)(2)	2.3.5.2
		10CFR72.128(a)(3)	2.3.2.1
		10CFR72.236(d)	2.3.2.1, 2.3.5.2
		10CFR72.236(e)	2.3.2.1
2.3.3 Protection by Equipment & Instrument Selection	2.III.3.d Shielding/ Confinement/ Radiation Protection	10CFR72.122(h)(4) 10CFR72.122(i) 10CFR72.128(a)(1)	2.3.5
2.3.4 Nuclear Criticality Safety	2.III.3.e Criticality	10CFR72.124(a) 10CFR72.236(c) 10CFR72.124(b)	2.3.4, 6.0
2.3.5 Radiological Protection	2.III.3.d Shielding/ Confinement/ Radiation Protection	10CFR72.24(d) 10CFR72.104(a) 10CFR72.236(d)	10.4.1
		10CFR72.24(d) 10CFR72.106(b) 10CFR72.236(d)	10.4.2
		10CFR72.24(m)	2.3.2.1
2.3.6 Fire and Explosion Protection	2.III.3.b Structural	10CFR72.122(c)	2.3.6, 2.2.3.10

Table 1.0.2 (continued)

HI-STAR 100 SYSTEM FSAR REGULATORY COMPLIANCE CROSS-REFERENCE MATRIX

2.4 Decommissioning Considerations	2.III.3.h Decommissioning	10CFR72.24(f) 10CFR72.130 10CFR72.236 (h)	2.4
	14.III.1 Design	10CFR72.130	2.4
	14.III.2 Cask Decontamination	10CFR72.236(i)	2.4
	14.III.3 Financial Assurance & Record Keeping	10CFR72.30	(1)
	14.III.4 License Termination	10CFR72.54	(1)
3. Structural Evaluation			
3.1 Structural Design	3.III.1 SSC Important to Safety	10CFR72.24(c)(3) 10CFR72.24(c)(4)	3.1
	3.III.6 Concrete Structures	10CFR72.182 (b) 10CFR72.182 (c)	3.1
3.2 Weights and Centers of Gravity	3.V.1.b.2 Structural Design Features	--	3.2
3.3 Mechanical Properties of Materials	3.V.1.c Structural Materials	10CFR72.24(c)(3)	3.3
	3.V.2.c Structural Materials		
NA	3.III.2 Radiation Shielding, Confinement, and Subcriticality	10CFR72.24(d) 10CFR72.124(a) 10CFR72.236(c) 10CFR72.236(d) 10CFR72.236(l)	3.4.4.3 3.4.7.3 3.4.10
NA	3.III.3 Ready Retrieval	10CFR72.122(f) 10CFR72.122(h) 10CFR72.122(l)	3.4.4.3
NA	3.III.4 Design-Basis Earthquake	10CFR72.24(c) 10CFR72.236(g)	3.4.7
NA	3.III.5 20 Year Minimum Design Length	10CFR72.24(c) 10CFR72.182(b) 10CFR72.182(c)	3.4.11 3.4.12

Table 1.0.2 (continued)

HI-STAR 100 SYSTEM FSAR REGULATORY COMPLIANCE CROSS-REFERENCE MATRIX

3.4 General Standards for Casks	--	--	3.4
3.4.1 Chemical and Galvanic Reactions	3.V.1.b.2 Structural Design Features	--	3.4.1
3.4.2 Positive Closure	--	--	3.4.2
3.4.3 Lifting Devices	3.V.1.ii(4)(a) Trunnions	--	3.4.3, Appendices 3.E, 3AC, 3.D
3.4.4 Heat	3.V.1.d Structural Analysis	10CFR72.24(d) 10CFR72.122(b) 10CFR72.236(g)	3.4.4, Appendices 3.U, 3.W, 3.AD
3.4.5 Cold	3.V.1.d Structural Analysis	10CFR72.24(d) 10CFR72.102(f) 10CFR72.122(b) 10CFR72.122(c) 10CFR72.236(g)	3.4.5
3.5 Fuel Rods	--	10CFR72.122(h)(1)	3.5
4. Thermal Evaluation			
4.1 Discussion	4.III Regulatory Requirements	10CFR72.24(c)(3) 10CFR72.128(a)(4) 10CFR72.236(f)	4.1, 4.5
		10CFR72.236(h)	
4.2 Summary of Thermal Properties of Materials	4.V.4.b Material Properties	--	4.2
4.3 Specifications for Components	4.IV Acceptance Criteria	10CFR72.122(h)(1)	4.3
4.4 Thermal Evaluation for Normal Conditions of Storage	4.IV Acceptance Criteria	10CFR72.24(d) 10CFR72.236(g)	4.4
NA	4.IV Acceptance Criteria	10CFR72.24(d) 10CFR72.122(c)	11.1, 11.2

Table 1.0.2 (continued)

HI-STAR 100 SYSTEM FSAR REGULATORY COMPLIANCE CROSS-REFERENCE MATRIX

4.5 Supplemental Data	4.V.6 Supplemental Info.	--	--
5. Shielding Evaluation			
5.1 Discussion and Results	--	10CFR72.104(a) 10CFR72.106(b)	5.1
5.2 Source Specification	5.V.2 Radiation Source Definition	--	5.2
5.2.1 Gamma Source	5.V.2.a Gamma Source	--	5.2.1, 5.2.3
5.2.2 Neutron Source	5.V.2.b Neutron Source	--	5.2.2, 5.2.3
5.3 Model Specification	5.V.3 Shielding Model Specification	--	5.3
5.3.1 Description of the Radial and Axial Shielding Configuration	5.V.3.a Configuration of the Shielding and Source	10CFR72.24(c)(3)	5.3.1
5.3.2 Shield Regional Densities	5.V.3.b Material Properties	10CFR72.24(c)(3)	5.3.2
5.4 Shielding Evaluation	5.V.4 Shielding Analysis	10CFR72.24(d) 10CFR72.104(a) 10CFR72.106(b) 10CFR72.128(a)(2) 10CFR72.236(d)	5.4
5.5 Supplemental Data	5.V.5 Supplemental Info.	--	Appendices 5.A, 5.B, and 5.C
6. Criticality Evaluation			
6.1 Discussion and Results	--	--	6.1
6.2 Spent Fuel Loading	6.V.2 Fuel Specification	--	6.1, 6.2
6.3 Model Specifications	6.V.3 Model Specification	--	6.3
6.3.1 Description of Calculational Model	6.V.3.a Configuration	-- 10CFR72.124(b) 10CFR72.24(c)(3)	6.3.1

Table 1.0.2 (continued)

HI-STAR 100 SYSTEM FSAR REGULATORY COMPLIANCE CROSS-REFERENCE MATRIX

6.3.2 Cask Regional Densities	6.V.3.b Material Properties	10CFR72.24(c)(3) 10CFR72.124(b) 10CFR72.236(g)	6.3.2
6.4 Criticality Calculations	6.V.4 Criticality Analysis	10CFR72.124	6.4
6.4.1 Calculational or Experimental Method	6.V.4.a Computer Programs and 6.V.4.b Multiplication Factor	10CFR72.124	6.4.1
6.4.2 Fuel Loading or Other Contents Loading Optimization	6.V.3.a Configuration	--	6.4.2
6.4.3 Criticality Results	6.IV Acceptance Criteria	10CFR72.24(d) 10CFR72.124 10CFR72.236(c)	6.1, 6.2, 6.3.1, 6.3.2
6.5 Critical Benchmark Experiments	6.V.4.c Benchmark Comparisons	--	6.5, Appendix 6.A, 6.4.3
6.6 Supplemental Data	6.V.5 Supplemental Info.		Appendices 6.B, 6.C, and 6.D
7. Confinement			
7.1 Confinement Boundary	7.III.1 Description of Structures, Systems, and Components Important to Safety	10CFR72.24(c)(3) 10CFR72.24(l)	7.0, 7.1
7.1.1 Confinement Vessel	7.III.2 Protection of Spent Fuel Cladding	10CFR72.122(h)(l)	7.1, 7.1.1, 7.2.2
7.1.2 Confinement Penetrations	--	--	7.1.2
7.1.3 Seals and Welds	--	--	7.1.3
7.1.4 Closure	7.III.3 Redundant Sealing	10CFR72.236(e)	7.1.1, 7.1.4

Table 1.0.2 (continued)

HI-STAR 100 SYSTEM FSAR REGULATORY COMPLIANCE CROSS-REFERENCE MATRIX

7.2 Requirements for Normal Conditions of Storage	7.III.7	Evaluation of Confinement System	10CFR72.24(d) 10CFR72.236(l)	7.2
7.2.1 Release of Radioactive Material	7.III.6	Release of Nuclides to the Environment	10CFR72.24(1)(l)	7.2.1
	7.III.4	Monitoring of Confinement System	10CFR72.122(h)(4) 10CFR72.128(a)(l)	7.1.4
	7.III.5	Instrumentation	10CFR72.24(l) 10CFR72.122(i)	7.1.4
	7.III.8	Annual Dose	10CFR72.104(a)	7.3.5
7.2.2 Pressurization of Confinement Vessel	--		--	7.2.2
7.3 Confinement Requirements for Hypothetical Accident Conditions	7.III.7	Evaluation of Confinement System	10CFR72.24(d) 10CFR72.122(b) 10CFR72.236(l)	7.3
7.3.1 Fission Gas Products	--		--	7.3.1
7.3.2 Release of Contents	--		--	7.3.3
NA	--		10CFR72.106(b)	7.3
7.4 Supplemental Data	7.V	Supplemental Info.	--	--
8. Operating Procedures				
8.1 Procedures for Loading the Cask	8.III.1	Develop Operating Procedures	10CFR72.40(a)(5)	8.1 to 8.5
	8.III.2	Operational Restrictions for ALARA	10CFR72.24(e) 10CFR72.104(b)	8.1.5
	8.III.3	Radioactive Effluent Control	10CFR72.24(l)(2)	8.1.5, 8.5.2

Table 1.0.2 (continued)

HI-STAR 100 SYSTEM FSAR REGULATORY COMPLIANCE CROSS-REFERENCE MATRIX

	8.III.4 Written Procedures	10CFR72.212(b)(9)	8.0
	8.III.5 Establish Written Procedures and Tests	10CFR72.234(f)	8.0
	8.III.6 Wet or Dry Loading and Unloading Compatibility	10CFR72.236(h)	8.0
	8.III.7 Cask Design to Facilitate Decon	10CFR72.236(i)	8.1, 8.3
8.2 Procedures for Unloading the Cask	8.III.1 Develop Operating Procedures	10CFR72.40(a)(5)	8.3
	8.III.2 Operational Restrictions for ALARA	10CFR72.24(e) 10CFR72.104(b)	--
	8.III.3 Radioactive Effluent Control	10CFR72.24(l)(2)	8.3.3
	8.III.4 Written Procedures	10CFR72.212(b)(9)	8.0
	8.III.5 Establish Written Procedures and Tests	10CFR72.234(f)	8.0
	8.III.6 Wet or Dry Loading and Unloading Compatibility	10CFR72.236(h)	8.0
	8.III.8 Ready Retrieval	10CFR72.122(l)	8.3
8.3 Preparation of the Cask	--	--	8.3.2
8.4 Supplemental Data	--	--	Tables 8.1.1 to 8.1.10
NA	8.III.9 Design To Minimize Radwaste	10CFR72.24(f) 10CFR72.128(a)(5)	8.1, 8.3
	8.III.10 SSCs Permit Inspection, Maintenance, and Testing	10CFR72.122(f)	Table 8.1.6

Table 1.0.2 (continued)

HI-STAR 100 SYSTEM FSAR REGULATORY COMPLIANCE CROSS-REFERENCE MATRIX

9. Acceptance Criteria and Maintenance Program			
9.1 Acceptance Criteria	9.III.1.a Preoperational Testing & Initial Operations	10CFR72.24(p)	8.1, 9.1
	9.III.1.c SSCs Tested and Maintained to Appropriate Quality Standards	10CFR72.24(c) 10CFR72.122(a)	9.1
	9.III.1.d Test Program	10CFR72.162	9.1
	9.III.1.e Appropriate Tests	10CFR72.236(l)	9.1
	9.III.1.f Inspection for Cracks, Pinholes, Voids and Defects	10CFR72.236(j)	9.1
	9.III.1.g Provisions that Permit Commission Tests	10CFR72.232(b)	9.1(2)
9.2 Maintenance Program	9.III.1.b Maintenance	10CFR72.236(g)	9.2
	9.III.1.c SSCs Tested and Maintained to Appropriate Quality Standards	10CFR72.122(f) 10CFR72.128(a)(l)	9.2
	9.III.1.h Records of Maintenance	10CFR72.212(b)(8)	9.2
NA	9.III.2 Resolution of Issues Concerning Adequacy of Reliability	10CFR72.24(i)	(3)
	9.III.1.d Submit Pre-Op Test Results to NRC	10CFR72.82(e)	(4)
	9.III.1.i Casks Conspicuously and Durably Marked	10CFR72.236(k)	9.1.7, 9.1.1.(12)
	9.III.3 Cask Identification		

Table 1.0.2 (continued)

HI-STAR 100 SYSTEM FSAR REGULATORY COMPLIANCE CROSS-REFERENCE MATRIX

10. Radiation Protection			
10.1 Ensuring that Occupational Exposures Are As Low As Reasonably Achievable (ALARA)	10.III.4 ALARA	10CFR20.1101 10CFR72.24(e) 10CCR72.104(b) 10CFR72.126(a)	10.1
10.2 Radiation Protection Design Features	10.V.1.b Design Features	10CFR72.126(a)(6)	10.2
10.3 Estimated Onsite Collective Dose Assessment	10.III.2 Occupational Exposures	10CFR20.1201 10CFR20.1207 10CFR20.1208 10CFR20.1301	10.3
NA	10.III.3 Public Exposure	10CFR72.104 10CFR72.106	10.4
	10.III.1 Effluents and Direct Radiation	10CFR72.104	
11. Accident Analyses			
11.1 Off-Normal Operations	11.III.2 Meet Dose Limits for Anticipated Events	10CFR72.24(d) 10CFR72.104(a) 10CFR72.236(d)	11.1
	11.III.4 Maintain Subcritical Condition	10CFR72.124(a) 10CFR72.236(c)	11.1
	11.III.7 Instrumentation and Control for Off-Normal Condition	10CFR72.122(i)	11.1
11.2 Accidents	11.III.1 SSCs Important to Safety Designed for Accidents	10CFR72.24(d)(2) 10CFR72.122(b)(2) 10CFR72.122(b)(3) 10CFR72.122(d) 10CFR72.122(g)	11.2
	11.III.5 Maintain Confinement for Accident	10CFR72.236(l)	11.2
	11.III.4 Maintain Subcritical Condition	10CFR72.124(a) 10CFR72.236(c)	11.2, 6.0

Table 1.0.2 (continued)

HI-STAR 100 SYSTEM FSAR REGULATORY COMPLIANCE CROSS-REFERENCE MATRIX

	11.III.3 Meet Dose Limits for Accidents	10CFR72.24(d)(2) 10CFR72.24(m) 10CFR72.106(b)	11.2, 5.1.2, 7.3
	11.III.6 Retrieval	10CFR72.122(l)	8.3
	11.III.7 Instrumentation and Control for Accident Conditions	10CFR72.122(i)	(5)
NA	11.III.8 Confinement Monitoring	10CFR72.122(h)(4)	7.1.4
12. Operating Controls and Limits			
12.1 Proposed Operating Controls and Limits	--	10CFR72.44(c)	12.0
	12.III.1.e Administrative Controls	10CFR72.44(c)(5)	12.0
12.2 Development of Operating Controls and Limits	12.III.1 General Requirement for Technical Specifications	10CFR72.24(g) 10CFR72.26 10CFR72.44(c) 10CFR72 Subpart F 10CFR72 Subpart F	12.0
12.2.1 Functional and Operating Limits, Monitoring Instruments, and Limiting Control Settings	12.III.1.a Functional/ Operating Units, Monitoring Instruments and Limiting Controls	10CFR72.44(c)(l)	Appendix 12.A
12.2.2 Limiting Conditions for Operation	12.III.1.b Limiting Controls	10CFR72.44(c)(2)	Appendix 12.A
	12.III.2.a Type of Spent Fuel	10CFR72.236(a)	Appendix 12.A
	12.III.2.b Enrichment		
	12.III.2.c Burnup		
	12.III.2.d Minimum Acceptable Cooling Time		

Table 1.0.2 (continued)

HI-STAR 100 SYSTEM FSAR REGULATORY COMPLIANCE CROSS-REFERENCE MATRIX

	12.III.2.f Maximum Spent Fuel Loading Limit		
	12.III.2.g Weights and Dimensions		
	12.III.2.h Condition of Spent Fuel		
	12.III.2.e Maximum Heat Dissipation	10CFR72.236(a)	Appendix 12.A
	12.III.2.i Inerting Atmosphere Requirements	10CFR72.236(a)	Appendix 12.A
12.2.3 Surveillance Specifications	12.III.1.c Surveillance Requirements	10CFR72.44(c)(3)	Chapter 12
12.2.4 Design Features	12.III.1.d Design Features	10CFR72.44(c)(4)	Chapter 12
12.2.5 Suggested Format for Operating Controls and Limits	--	--	Appendix 12.A
NA	12.III.2 SCC Design Bases and Criteria	10CFR72.236(b)	2.0
NA	12.III.2 Criticality Control	10CFR72.236(c)	2.3.4, 6.0
NA	12.III.2 Shielding and Confinement	10CFR20 10CFR72.236(d)	2.3.5, 7.0, 5.0, 10.0
NA	12.III.2 Redundant Sealing	10CFR72.236(e)	7.1, 2.3.2
NA	12.III.2 Passive Heat Removal	10CFR72.236(f)	2.3.2.2, 4.0
NA	12.III.2 20 Year Storage and Maintenance	10CFR72.236(g)	1.2.1.5, 9.0, 3.4.10, 3.4.11
NA	12.III.2 Decontamination	10CFR72.236(i)	8.0, 10.1
NA	12.III.2 Wet or Dry Loading	10CFR72.236(h)	8.0

Table 1.0.2 (continued)

HI-STAR 100 SYSTEM FSAR REGULATORY COMPLIANCE CROSS-REFERENCE MATRIX

NA	12.III.2 Confinement Effectiveness	10CFR72.236(j)	9.0
NA	12.III.2 Evaluation for Confinement	10CFR72.236(l)	7.1, 7.2, 9.0
13. Quality Assurance			
13.1 Quality Assurance	13.III Regulatory Requirements	10CFR72.24 (m)	13.0
	13.IV Acceptance Criteria	10CFR72, Subpart G	

Notes:

(1) The stated requirement is the responsibility of the licensee (i.e., utility) as part of the ISFSI pad and is therefore not addressed in this application.

(2) It is assumed that approval of the FSAR by the NRC is the basis for the Commission's acceptance of the tests defined in Chapter 9.

(3) Not applicable to HI-STAR 100 System. The functional adequacy of all-important to safety components is demonstrated by analyses.

(4) The stated requirement is the responsibility of licensee (i.e., utility) as part of the ISFSI and is therefore not addressed in this application.

(5) The stated requirement is not applicable to the HI-STAR 100 System. No monitoring is required for accident conditions.

"--" There is no corresponding NUREG-1536 criteria, no applicable 10CFR72 or 10CFR20 regulatory requirement, or the item is not addressed in the FSAR.

"NA" There is no Regulatory Guide 3.61 section that corresponds to the NUREG-1536, 10CFR72, or 10CFR20 requirement being addressed.

Table 1.0.3

HI-STAR 100 SYSTEM FSAR CLARIFICATIONS AND EXCEPTIONS TO NUREG-1536

NUREG-1536 Requirement	**Alternate Method to Meet NUREG-1536 Intent**	**Justification**
2.V.2.(b)(1) "The NRC accepts as the maximum and minimum "normal" temperatures the highest and lowest ambient temperatures recorded in each year, averaged over the years of record."	<u>Exception:</u> Section 2.2.1.4 for environmental temperatures utilizes an upper bounding value of 80°F on the annual average ambient temperatures for the United States.	The 80°F temperature set forth in Table 2.2.2 is greater than the annual average ambient temperature at any location in the continental United States. Inasmuch as the primary effect of the environmental temperature is on the computed fuel cladding temperature to establish long-term fuel cladding integrity, the annual average ambient temperature for each ISFSI site should be below 80°F. The large thermal inertia of the HI-STAR 100 System ensures that the daily fluctuations in temperatures do not affect the temperatures of the system. Additionally, the 80°F ambient temperature is combined with insolation in accordance with 10CFR71.71 averaged over 24 hours.

HI-STAR 100 SYSTEM FSAR CLARIFICATIONS AND EXCEPTIONS TO NUREG –1536

NUREG-1536 Requirement	Alternate Method to Meet NUREG-1536 Intent	Justification
2.V.2.(b)(3)(f) "10CFR Part 72 identifies several other natural phenomena events (including seiche, tsunami, and hurricane) that should be addressed for spent fuel storage."	<u>Clarification:</u> A site-specific safety analysis of the effects of seiche, tsunami, and hurricane on the HI-STAR 100 System must be performed prior to use if these events are applicable to the site.	In accordance with NUREG-1536, 2.V.(b)(3)(f), if seiche, tsunami, and hurricane are not addressed in the SAR and they prove to be applicable to the site, a safety analysis is required prior to approval for use of the DCSS under either a site specific, or general license.
3.V.(d), page 3-11, "Drops with the axis generally vertical should be analyzed for both the conditions of a flush impact and an initial impact at a corner of the cask..."	<u>Clarification</u>: As stated in NUREG-1536, 3.V.(d), page 3-11, "Generally, applicants establish the design basis in terms of the maximum height to which the cask is lifted outside the spent fuel building, or the maximum deceleration that the cask could experience in a drop." The maximum deceleration for a corner drop is specified as 60g's for the HI-STAR overpack. No carry height limit is specified for the corner drop.	In Chapter 3, the MPC is evaluated under a 60g radial and axial loading while in the HI-STAR overpack and is shown to meet ASME Code allowable stress limits. Therefore, the HI-STAR 100 System is qualified for a 60g loading as a result of a corner drop. Depending on the type of rigging used, the administrative vertical carry height limit, and the stiffness of the impacted surface, site-specific analyses are required to demonstrate that the deceleration limit of 60g's is not exceeded.

Table 1.0.3 (continued)

HI-STAR 100 SYSTEM FSAR CLARIFICATIONS AND EXCEPTIONS TO NUREG –1536

NUREG-1536 Requirement	Alternate Method to Meet NUREG-1536 Intent	Justification
4.IV.5, Page 4-2 "for each fuel type proposed for storage, the DCSS should ensure a very low probability (e.g., 0.5 percent per fuel rod) of cladding breach during long-term storage." 4.IV.1, Page 4-3, Para. 1 "the staff should verify that cladding temperatures for each fuel type proposed for storage will be below the expected damage thresholds for normal conditions of storage." 4.IV.1, Page 4-3, Para. 2 "fuel cladding limits for each fuel type should be defined in the SAR with thermal restrictions in the DCSS technical specifications." 4.V.1, Page 4-3, Para. 4 "the applicant should verify that these cladding temperature limits are appropriate for all fuel types proposed for storage, and that the fuel cladding temperatures will remain below the limit for facility operations (e.g., fuel transfer) and the worst-case credible accident."	<u>Clarification:</u> As described in Section 4.3, all fuel array types authorized for storage have been evaluated for the peak fuel cladding temperature.	As described in Section 4.3, all fuel array types authorized for storage have been evaluated for the peak fuel cladding temperature. All major variations in fuel parameters are considered in the determination of the peak fuel cladding temperatures. Minor variations in fuel parameters within an array type are bounded by the conservative determination of the allowable peak fuel cladding temperature.

HI-STAR 100 SYSTEM FSAR CLARIFICATIONS AND EXCEPTIONS TO NUREG –1536

NUREG-1536 Requirement	Alternate Method to Meet NUREG-1536 Intent	Justification
4.V.4.a, Page 4-6, Para. 3 "applicants seeking NRC approval of specific internal convection models should propose, in the SAR, a comprehensive test program to demonstrate the adequacy of the cask design and validation of the convection models."	Exception: The natural convection model described in Subsection 4.4.1.1.5 is based on classical correlations for natural convection in differentially heated cavities which have been validated by many experimental studies. Therefore, no additional test program is proposed.	Many experimental studies of this mechanism have been performed by others and reported in open literature sources. As discussed in Subsection 4.4.1.1.5, natural convection has been limited to the relatively large MPC basket to shell peripheral gap. Subsection 4.4.1.1.5 provides sufficient references to experiments which document the validity of the classical correlation used in the analysis.
4.V.4.a, Page 4-6, Para. 6 "the basket wall temperature of the hottest assembly can then be used to determine the peak rod temperature of the hottest assembly using the Wooten-Epstein correlation."	Clarification: As discussed in Subsection 4.4.2, conservative maximum fuel temperatures are obtained directly from the cask thermal analysis. The peak fuel cladding temperatures are then used to determine the corresponding peak basket wall temperatures using a finite-element based update of Wooten-Epstein (described in Subsection 4.4.1.1.2)	The finite-element based thermal conductivity is greater than a Wooten-Epstein based value. This larger thermal conductivity minimizes the fuel-to-basket temperature difference. Since the basket temperature is less than the fuel temperature, minimizing the temperature difference conservatively maximizes the basket wall temperature.

Table 1.0.3 (continued)

HI-STAR 100 SYSTEM FSAR CLARIFICATIONS AND EXCEPTIONS TO NUREG –1536

NUREG-1536 Requirement	Alternate Method to Meet NUREG-1536 Intent	Justification
4.V.4.b, Page 4-7, Para. 2 "if the thermal model is axisymmetric or three-dimensional, the longitudinal thermal conductivity should generally be limited to the conductivity of the cladding (weighted fractional area) within the fuel assembly."	Clarification: As described in Subsection 4.4.1.1.4, the axial thermal conductivity of the fuel basket is set equal to the cross-sectional thermal conductivity.	Due to the large number of gaps in the cross-sectional heat transfer paths, use of the fuel basket cross-sectional thermal conductivity for the axial thermal conductivity severely underpredicts the axial thermal conductivity of the fuel basket region. This imposed axial thermal conductivity restriction is even more limiting than that imposed by this requirement of NUREG-1536.
4.V.4.b, Page 4-7, Para. 2 "high burnup effects should also be considered in determining the fuel region effective thermal conductivity."	Exception: All calculations of fuel assembly effective thermal conductivities, described in Subsection 4.4.1.1.2, use nominal fuel design dimensions, neglecting wall thinning associated with high burnup.	Within Subsection 4.4.1.1.2, the calculated effective thermal conductivities based on nominal design fuel dimensions are compared with available literature values and are demonstrated to be conservative by a substantial margin.
4.V.4.c, Page 4-7, Para. 5 "a heat balance on the surface of the cask should be given and the results presented."	Clarification: No additional heat balance is performed or provided.	The FLUENT computational fluid dynamics program used to perform evaluations of the HI-STAR 100 System, which uses a discretized numerical solution algorithm, enforces an energy balance on all discretized volumes throughout the computational domain. This solution method, therefore, ensures a heat balance at the surface of the cask.

HI-STAR 100 SYSTEM FSAR CLARIFICATIONS AND EXCEPTIONS TO NUREG –1536

NUREG-1536 Requirement	Alternate Method to Meet NUREG-1536 Intent	Justification
4.V.5.a, Page 4-8, Para. 2 "the SAR should include input and output file listings for the thermal evaluations."	<u>Exception:</u> No input or output file listings are provided in Chapter 4.	A complete set of computer program input and output files would be in excess of three hundred pages. All computer files are considered proprietary because they provide details of the design and analysis methods. In order to eliminate proprietary information in the FSAR, computer files are provided in the proprietary calculation packages.
4.V.5.c, Page 4-10, Para. 3 "free volume calculations should account for thermal expansion of the cask internal components and the fuel when subjected to accident temperatures.	<u>Exception:</u> All free volume calculations use nominal confinement boundary dimensions, but the volume occupied by the MPC internals (i.e., fuel assemblies, fuel basket, etc.) are calculated using maximum weights and minimum densities.	Calculating the volume occupied by the MPC internals (i.e., fuel assemblies, fuel basket, etc.) using maximum weights and minimum densities conservatively overpredicts the volume occupied by the internal components and correspondingly underpredicts the remaining free volume.

Table 1.0.3 (continued)

HI-STAR 100 SYSTEM FSAR CLARIFICATIONS AND EXCEPTIONS TO NUREG –1536

NUREG-1536 Requirement	Alternate Method to Meet NUREG-1536 Intent	Justification
7.V.4.c "Because the leak is assumed to be instantaneous, the plume meandering factor of Regulatory Guide 1.145 is not typically applied." and "Note that for an instantaneous release (and instantaneous exposure), the time that an individual remains at the controlled area boundary is not a factor in the dose calculation."	Exception: As described in Section 7.3, in lieu of an instantaneous release, the assumed leakage rate is set equal to the MPC leakage rate acceptance criteria ($5x10^{-6}$ cm^3/s) plus the sensitivity ($2.5x10^{-6}$ cm^3/s), which yields an assumed leakage rate of $7.5x10^{-6}$ cm^3/s. Because the release is assumed to be a leakage rate, the individual is assumed to be at the controlled area boundary for 720 hours. Additionally, the atmospheric dispersion factors of Regulatory Guide 1.145 are applied.	The MPC uses redundant closures to assure that there is no release of radioactive materials under all credible conditions. Analyses presented in Chapters 3 and 11 demonstrate that the confinement boundary does not degrade under all normal, off-normal, and accident conditions. Multiple inspection methods are used to verify the integrity of the confinement boundary (e.g., helium leakage, hydrostatic, and volumetric (or multi-layer liquid penetrant) weld inspection). The HI-STAR overpack provides an additional barrier to the release of radionuclides. The NRC letter to Holtec International dated 9/15/97, Subject: Supplemental Request for Additional Information - HI-STAR 100 Dual Purpose Cask System (TAC No. L22019), RAI 7.3 states "use the verified confinement boundary leakage rate in lieu of the assumption that the confinement boundary fails."

Table 1.0.1 (continued)

HI-STAR 100 SYSTEM FSAR CLARIFICATIONS AND EXCEPTIONS TO NUREG –1536

NUREG-1536 Requirement	Alternate Method to Meet NUREG-1536 Intent	Justification
9.V.1.a, Page 9-4, Para. 4 "Acceptance criteria should be defined in accordance with NB/NC-5330, "Ultrasonic Acceptance Standards"."	Clarification: Section 9.1.1.1 and the Design Drawings specify that the ASME Code, Section III, Subsection NB, Article NB-5332 will be used for the acceptance criteria for the volumetric examination of the MPC lid-to-shell weld.	In accordance with the first line on page 9-4, the NRC endorses the use of "...appropriate acceptance criteria as defined by either the ASME code, or an alternative approach..." The ASME Code, Section III, Subsection NB, Paragraph NB-5332 is appropriate acceptance criteria for pre-service examination.

Table 1.0.3 (continued)

HI-STAR 100 SYSTEM FSAR CLARIFICATIONS AND EXCEPTIONS TO NUREG –1536

NUREG-1536 Requirement	**Alternate Method to Meet NUREG-1536 Intent**	**Justification**
9.V.1.d, Para. 1 "Tests of the effectiveness of both the gamma and neutron shielding may be required if, for example, the cask contains a poured lead shield or a special neutron absorbing material."	Exception: Subsection 9.1.5 describes the control of special processes, such as shield material installation and post-loading shield effectiveness testing, to be performed in lieu of scanning or probing with neutron sources.	The dimensional compliance of all neutron shielding cavities is verified by inspection to Design Drawing requirements prior to shield installation. The neutron shield is installed in accordance with written, approved, and qualified special process procedures. The composition of the neutron shielding material is confirmed by inspection and tests prior to first use. Following the first loading of each HI-STAR overpack, a shield effectiveness test is performed in accordance with written approved procedures, as specified in the Technical Specifications.

1.1 INTRODUCTION

HI-STAR 100 (acronym for Holtec International Storage, Transport and Repository) is a spent nuclear fuel (SNF) packaging designed to be in general compliance with the U.S. Department of Energy's (DOE) design procurement specifications for multi-purpose canisters and large transportation casks [1.1.1], [1.1.2]. The annex "100" is a model number designation which denotes a system weighing in the range of 100 tons. The HI-STAR 100 System consists of a sealed metallic canister, herein abbreviated as the "MPC", contained within an overpack. Figure 1.1.1 depicts the HI-STAR 100.

The HI-STAR 100 System is designed to accommodate a wide variety of spent fuel assemblies in a single overpack by utilizing different MPCs. The external dimensions of all MPCs are identical to allow the use of a single overpack design. Each of the MPCs has different internals (baskets) to accommodate distinct fuel characteristics. Each MPC is identified by the maximum quantity of fuel assemblies it is capable of receiving. The MPC-24 can contain a maximum of 24 PWR assemblies and the MPC-68 can contain a maximum of 68 BWR assemblies. Figure 1.1.2 depicts the HI-STAR 100 with two of its major constituents, the MPC and the overpack, in a cutaway view.

The HI-STAR 100 is designed for both storage and transport. The HI-STAR 100 System's multi-purpose design reduces SNF handling operations and thereby enhances radiological protection. Once the SNF is loaded and the MPC and cask are sealed, the HI-STAR 100 System can be positioned on-site for temporary or long-term storage or transported directly off-site. The HI-STAR 100 System's ability to both store and transport SNF eliminates repackaging.

The HI-STAR 100 System is a completely passive stand-alone storage system which provides SNF confinement, radiation shielding, structural integrity, criticality control, and heat removal independent of any other facility, structures or components. This Final Safety Analysis Report (FSAR) provides bounding values for design criteria to facilitate NRC review and evaluation for both General License use under 10CFR72, Subpart K, and as reference for a site-specific storage facility application.

This FSAR demonstrates the inherent safety of one loaded overpack as well as interactions among an array of overpacks at an ISFSI. The HI-STAR 100 System can be used alone or as part of a multi-unit array at an ISFSI. The site for the ISFSI can be located either at a reactor or away from a reactor.

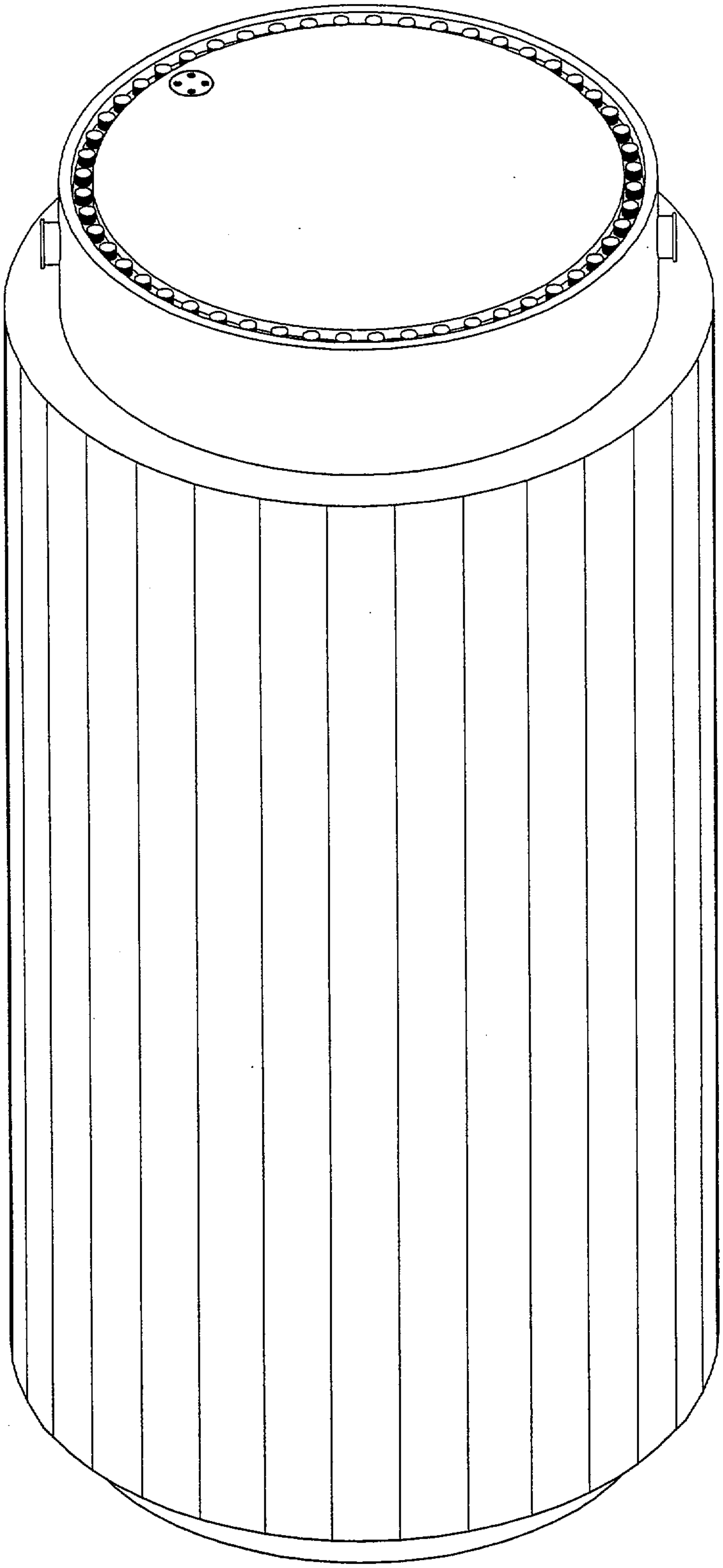


FIGURE 1.1.1; PICTORIAL VIEW OF HI-STAR 100

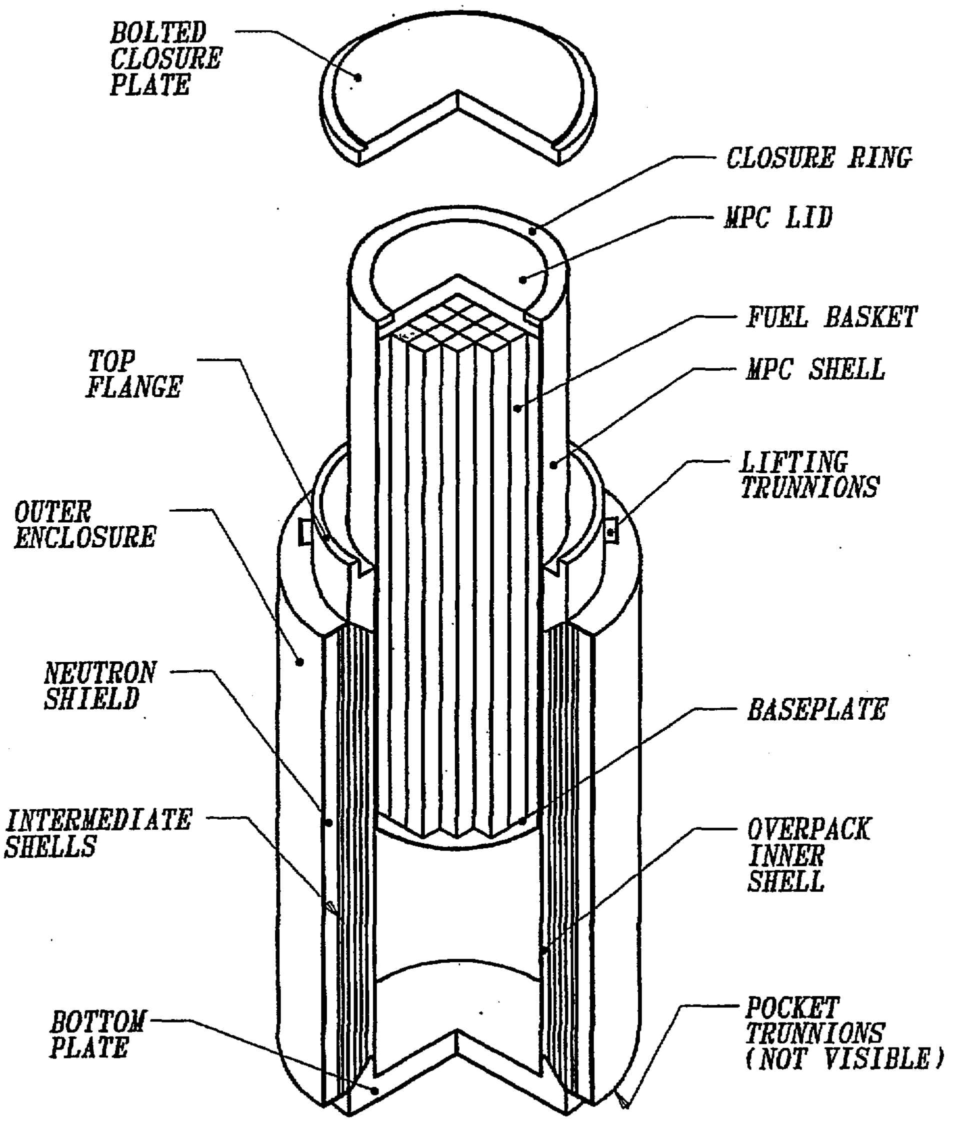


Figure 1.1.2; HI-STAR 100 OVERPACK WITH MPC PARTIALLY INSERTED

1.2 GENERAL DESCRIPTION AND OPERATING FEATURES OF HI-STAR 100

1.2.1 System Characteristics

The complete HI-STAR 100 System for storage of spent nuclear fuel is comprised of two discrete components:

- the multi-purpose canister (MPC), and
- the storage/transport overpack

Necessary auxiliaries required to deploy the HI-STAR 100 System for storage are:

- lifting and handling systems
- welding equipment
- vacuum drying system and helium backfill system with leak detector
- a heavy haul transfer device (to move the cask from the fuel building to the cask pad)

The HI-STAR 100 System consists of interchangeable MPCs which constitute the confinement boundary for BWR or PWR spent nuclear fuel, and an overpack which provides the helium retention boundary. Tables 1.2.1 and 1.2.2 contain the key parameters for the HI-STAR 100 MPCs. Figure 1.2.1 provides a cross sectional elevation view of the HI-STAR 100 System in storage.

All MPCs have identical exterior dimensions which render them interchangeable. The outer diameter of the MPC is nominally 68-3/8 inches and the length is approximately 190-1/2 inches. Due to the differing storage contents of each of the MPCs, the maximum loaded weight differs between each MPC. However, the maximum weight of a loaded MPC is approximately 44-1/2 tons.

A single overpack design is provided which is capable of storing each type of MPC. The inner diameter of the overpack is approximately 68-3/4 inches and the height of the cavity is nominally 191-1/8 inches. The overpack inner cavity is sized to accommodate the MPCs. The outer diameter of the overpack is approximately 96 inches and the height is approximately 203-1/8 inches. The weight of the overpack without an MPC is approximately 77 tons.

Before proceeding to present detailed physical data on the HI-STAR 100 System, it is contextual to summarize the design attributes which set it apart from the prior generation of casks. There are several features in the HI-STAR 100 System design which increase its effectiveness with respect to the safe storage and transport of spent nuclear fuel (SNF). Some of the principal features of the HI-STAR 100 System which enhance its effectiveness as an SNF storage device and a safe SNF confinement structure are:

- the honeycomb design of the MPC fuel basket
- the effective distribution of neutron and gamma shielding materials within the system

- the high heat expulsion capability
- the structural robustness of the multi-shell overpack construction

The honeycomb design of the MPC fuel baskets renders the basket into a multi-flange plate weldment where all structural elements (box walls) are arrayed in two orthogonal sets of plates. Consequently, the walls of the cells are either completely co-planar (no offset) or orthogonal with each other. There is complete edge-to-edge continuity between the contiguous cells.

Among the many benefits of the honeycomb construction is the uniform distribution of the metal mass of the basket over the body of the basket (in contrast to the "box and spacer disk" construction where the support plates are localized mass points). Physical reasoning suggests that a uniformly distributed mass provides a more effective shielding barrier than can be obtained from a nonuniform (box and spacer disk) basket. In other words, the honeycomb basket is a more effective radiation attenuation device.

The complete cell-to-cell connectivity inherent in the honeycomb basket structure provides an uninterrupted heat transmission path, making the HI-STAR 100 MPC an effective heat rejection device.

Finally, the multilayer shell construction in the overpack provides a natural barrier against crack propagation in the radial direction through the overpack structure. If, during a mechanical accident (drop) event, a crack was initiated in one layer, the crack could not propagate to the adjacent layer. Additionally, it is less likely that a crack would initiate as the thinner layers are more ductile than a thicker plate.

A description of each of the HI-STAR components is provided in the following subsections, along with information with respect to its fabrication and safety features. This discussion is supplemented with the full set of Design Drawings and Bills-of-Material in Section 1.5.

1.2.1.1 Multi-Purpose Canisters

The HI-STAR 100 MPCs are welded cylindrical structures with flat ends as shown in cross sectional views of Figures 1.2.2 and 1.2.4. Each MPC is an assembly consisting of a honeycombed fuel basket, a baseplate, canister shell, a lid, and a closure ring, as depicted in the MPC cross section elevation view, Figure 1.2.5. The outer diameter and cylindrical height of each MPC is fixed. However, the number of spent nuclear fuel storage locations in each of the MPCs depends on the fuel assembly characteristics. Design Drawings of the MPCs are provided in Section 1.5.

The MPC provides the confinement boundary for the stored fuel. Figure 1.2.6 provides an elevation view of the MPC confinement boundary. The confinement boundary is a seal-welded enclosure constructed entirely of stainless steel.

The construction features of the PWR MPC-24 and the BWR MPC-68 are similar. However, the PWR MPC-24 canister in Figure 1.2.4, which is designed for highly enriched PWR fuel without credit for soluble boron, differs in construction from the MPC-68 in one important aspect: The fuel storage cells are physically separated from one another by a "flux trap" between each storage cell for criticality control. All MPC baskets are formed from an array of plates welded to each other, such that a honeycomb structure is created which resembles a multiflanged, closed-section beam in its structural characteristics.

The MPC fuel basket is positioned and supported within the MPC shell by a basket support structure welded to the inside of the MPC shell. Between the periphery of the basket, the MPC shell, and the basket supports, heat conduction elements are installed. These heat conduction elements are fabricated from thin aluminum alloy 1100 in shapes and a design which allow a snug fit in the confined spaces and ease of installation. The heat conduction elements are installed along the full length of the MPC basket, except at the drain pipe location, to create a nonstructural thermal connection which facilitates heat transfer from the basket to shell. In their operating condition, the heat conduction elements will conform to and contact the MPC shell and basket walls.

Lifting lugs attached to the inside surface of the MPC canister shell serve to permit lifting and placement of the empty MPC into the overpack. The lifting lugs also serve to axially locate the lid prior to welding. These internal lifting lugs are not used to handle a loaded MPC. Since the MPC lid is installed prior to any handling of the loaded MPC, there is no access to the lifting lugs once the MPC is loaded.

The top end of the HI-STAR 100 MPC incorporates a redundant closure system. Figure 1.2.6 provides a sketch of the MPC closure details. The MPC lid is a circular plate edge-welded to the MPC outer shell. This plate is equipped with vent and drain ports which are utilized to remove moisture and air from the MPC, and backfill the MPC with a specified pressure of inert gas (helium). The vent and drain ports are covered and welded before the closure ring is installed. The closure ring is a circular ring edge-welded to the MPC shell and lid. The MPC lid provides sufficient rigidity to allow the entire MPC loaded with SNF to be lifted by threaded holes in the MPC lid.

To maintain a constant exterior axial length between the MPC-24 and MPC-68, the thickness of the MPC-24 lid is a 2 inch thinner than the MPC-68 lid to accommodate the longest PWR fuel assembly which is approximately a 2 inch longer than the longest BWR fuel assembly. For fuel assemblies that are shorter than the design basis length, upper and lower fuel spacers (as appropriate) maintain the axial position of the fuel assembly within the MPC basket. The upper fuel spacers are threaded into the underside of the MPC lid as shown in Figure 1.2.5. The lower fuel spacers are placed in the bottom of each fuel basket cell. The upper and lower fuel spacers are designed to withstand normal, off-normal, and accident conditions of storage. An axial clearance of approximately 2 inches is provided to account for the irradiation and thermal growth of the fuel assemblies. The suggested values for the upper and lower fuel spacer lengths are listed in Tables 2.1.9 and 2.1.10 for each fuel assembly type.

The MPC is constructed entirely from stainless steel alloy materials (except for the neutron absorber and aluminum heat conduction elements). No carbon steel parts are permitted in the MPC. Concerns regarding interaction of coated carbon steel materials and various MPC operating environments [1.2.1] are not applicable to the MPC. All structural components in a MPC shall be made of Alloy X, a designation which warrants further explanation.

Alloy X is a material which is expected to be acceptable as a Mined Geological Depository System (MGDS) waste package and which meets the thermophysical properties set forth in this document.

At this time, there is considerable uncertainty with respect to the material of construction for an MPC which would be acceptable as a waste package for the MGDS. Candidate materials being considered for acceptability by the DOE include:

- Type 316
- Type 316LN
- Type 304
- Type 304LN

The DOE material selection process is primarily driven by corrosion resistance in the potential environment of the MGDS. As the decision regarding a suitable material to meet disposal requirements is not imminent, this application requests approval for use of any one of the four Alloy X materials.

For the MPC design and analysis, Alloy X (as defined in this application) may be one of the following materials (only a single alloy from the list of acceptable Alloy X materials may be used in the fabrication of a single MPC).

- Type 316
- Type 316LN
- Type 304
- Type 304LN

The Alloy X approach is accomplished by qualifying the MPC for all mechanical, structural, neutronic, radiological, and thermal conditions using material thermophysical properties which are the least favorable for the entire group for the analysis in question. For example, when calculating the rate of heat rejection to the outside environment, the value of thermal conductivity used is the lowest for the candidate material group. Similarly, the stress analysis calculations use the lowest value of the ASME Code allowable stress intensity for the entire group. Stated differently, we have defined a material, which is referred to as Alloy X, whose thermophysical properties, from the MPC design perspective, are the least favorable of the candidate materials.

The evaluation of the Alloy X constituents to determine the least favorable properties is provided in Appendix 1.A.

Other alloy materials which are identified to be more suitable by the DOE for the MGDS in the future and which are also bounded by the Alloy X properties set forth in Appendix 1.A can be used in the HI-STAR 100 MPC after an amendment to this FSAR is approved.

The Alloy X approach is conservative because no matter which material is ultimately utilized in the MPC construction, the Alloy X approach guarantees that the performance of the MPC will exceed the analytical predictions contained in this document.

1.2.1.2 HI-STAR 100 Overpack

The HI-STAR 100 overpack is a heavy-walled steel cylindrical vessel. Figure 1.2.7 provides a cross sectional elevation view of the HI-STAR 100 overpack. The overpack helium retention boundary is formed by an inner shell welded at the bottom to a cylindrical forging and, at the top, to a heavy main flange with bolted closure plate. Two concentric grooves are machined into the closure plate for the metallic seals. The closure plate is recessed into the top flange and the bolted joint is configured to provide maximum protection to the closure bolts and seals in the event of a drop accident. The closure plate has a vent port which is sealed by a threaded port plug with a seal. The bottom plate has a drain port which is sealed by a threaded port plug with a seal. The inner surfaces of the HI-STAR overpack form an internal cylindrical cavity for housing the MPC.

As shown in Figure 1.2.8, the outer surface of the overpack inner shell is buttressed with intermediate shells of gamma shielding which are installed in a manner to ensure a permanent state of contact between adjacent layers. Besides serving as an effective gamma shield, these layers provide additional strength to the overpack to resist potential punctures or penetrations from external missiles. Radial channels are vertically welded to the outside surface of the outermost intermediate shell at equal intervals around the circumference. These radial channels act as fins for improved heat conduction to the overpack outer enclosure shell surface and as cavities for retaining and protecting the neutron shielding. The enclosure shell is formed by welding enclosure shell panels between each of the channels to form additional cavities. Neutron shielding material is placed into each of the radial cavity segments formed by the radial channels, the outermost intermediate shell, and the enclosure shell panels. The exterior flats of the radial channels and the enclosure shell panels form the overpack outer enclosure shell. Atop the outer enclosure shell, rupture disks are positioned in a recessed area. The rupture disks relieve internal pressure which may develop as a result of the fire accident and subsequent off-gassing of the neutron shield material. Within each radial channel, a layer of silicone sponge is positioned to act as a thermal expansion foam to compress as the neutron shield expands. Appendix 1.C provides material information on the thermal expansion foam. Figure 1.2.9 contains a mid-plane cross section of the overpack depicting the inner shell, intermediate shells, radial channels, outer enclosure shell, and neutron shield.

The exposed steel surfaces of the overpack are coated with paint to prevent corrosion. The paint is specified on the design drawings and the material data on the paint is provided in Appendix 1.C. The inner cavity of the overpack is coated with a paint appropriate to its higher temperatures and the exterior of the overpack is coated with a paint appropriate for fuel pool operations and environmental exposure.

Lifting trunnions are attached to the overpack top flange forging for lifting and for rotating the cask body between vertical and horizontal positions. The lifting trunnions are located 180° apart in the sides of the top flange. Pocket trunnions are welded to the lower side of the overpack to provide a pivoting axis for rotation. The pocket trunnions are located slightly off-center to ensure the proper rotation direction of the overpack. As shown in Figure 1.2.7, the lifting trunnions do not protrude beyond the cylindrical envelope of the overpack enclosure shell. This feature reduces the potential for a direct impact on a trunnion in the event of an overpack side impact.

1.2.1.3 Shielding

The HI-STAR 100 System is provided with sufficient shielding to ensure that the external radiation requirements in 10CFR72.126, 10CFR72.104, and 10CFR72.106 are met. This shielding is an important factor in minimizing personnel doses from gamma and neutron sources in the spent nuclear fuel for ALARA considerations during loading, handling, and storage operations.

The initial attenuation of gamma and neutron radiation emitted by the radioactive spent fuel is provided by the fuel basket structure built from inter-welded intersecting plates and Boral neutron poison panels attached to the fuel storage cell walls. The MPC canister shell, baseplate, and lid provide additional thicknesses of steel to further reduce gamma radiation and, to a smaller extent, neutron radiation at the outer MPC surfaces.

The primary HI-STAR 100 shielding is located in the overpack and consists of neutron shielding and additional layers of steel for gamma shielding. Neutron shielding is provided around the outer circumferential surface of the overpack. Gamma shielding is provided by the overpack inner, intermediate, and enclosure shells with additional axial shielding provided by the bottom plate and the closure plate.

1.2.1.3.1 Boral Neutron Absorber

Boral is a thermal neutron poison material composed of boron carbide and aluminum (aluminum powder and plate). Boron carbide is a compound having a high boron content in a physically stable and chemically inert form. The boron carbide contained in Boral is a fine granulated powder that conforms to ASTM C-750-80 nuclear grade Type III. The Boral cladding is made of alloy aluminum, a lightweight metal with high tensile strength which is protected from corrosion by a highly resistant oxide film. The two materials, boron carbide and aluminum, are chemically compatible and ideally suited for long-term use in the radiation, thermal, and chemical environment of a nuclear reactor, spent fuel pool, or dry cask.

The documented historical applications of Boral, in environments comparable to those in spent fuel pools and fuel storage casks, dates to the early 1950s (the U.S. Atomic Energy Commission's AE-6 Water-Boiler Reactor [1.2.2]). Technical data on the material was first printed in 1949, when the report "Boral: A New Thermal Neutron Shield" was published [1.2.3]. In 1956, the first edition of the *Reactor Shielding Design Manual* [1.2.4] contains a section on Boral and its properties.

In the research and test reactors built during the 1950s and 1960s, Boral was frequently the material of choice for control blades, thermal-column shutters, and other items requiring very good thermal-neutron absorption properties. It is in these reactors that Boral has seen its longest service in environments comparable to today's applications.

Boral found other uses in the 1960s, one of which was a neutron poison material in baskets used in the shipment of irradiated, enriched fuel rods from Canada's Chalk River laboratories to Savannah River. Use of Boral in shipping containers continues, with Boral serving as the poison in current British Nuclear Fuels Limited casks and the recently licensed Storable Transport Cask by Nuclear Assurance Corporation [1.2.5].

As indicated in Tables 1.2.3-1.2.5, Boral has been licensed by the USNRC for use in numerous BWR and PWR spent fuel storage racks and has been extensively used in international nuclear installations.

Boral has been exclusively used in fuel storage applications in recent years. Its use in spent fuel pools as a neutron absorbing material can be attributed to its proven performance and several unique characteristics, such as:

- Boron carbide, in the form of fine particles, is homogeneously dispersed throughout the central layer of the Boral panels.
- The neutron absorbing central layer of Boral is clad with permanently bonded surfaces of aluminum.
- The content and placement of boron carbide provides a very high removal cross section for thermal neutrons.
- The boron carbide and aluminum materials in Boral do not degrade as a result of long-term exposure to radiation.
- Boral is stable, strong, durable, and corrosion resistant.

Boral absorbs thermal neutrons without physical change or degradation of any sort from the anticipated exposure to gamma radiation and heat. The material does not suffer loss of neutron attenuation capability when exposed to high levels of radiation dose.

Holtec International's QA Program ensures that Boral is manufactured under the control and surveillance of a Quality Assurance/Quality Control Program that conforms to the requirements of 10CFR72, Subpart G. Holtec International has procured over 200,000 panels of Boral from AAR Advanced Structures in over 20 projects. Boral has always been purchased with a minimum ^{10}B loading requirement. Coupons extracted from production runs were tested using the wet chemistry procedure. The actual ^{10}B loading, out of thousands of coupons tested, has never been found to fall below the design specification. The size of this coupon data base is sufficient to provide confidence that all future procurements will continue to yield Boral in full compliance with the stipulated minimum loading. Furthermore, the surveillance, coupon testing, and material tracking processes which have so effectively controlled the quality of Boral are expected to continue to yield Boral of similar quality in the future. Nevertheless, to add another layer of insurance, only 75% ^{10}B credit of the fixed neutron absorber is assumed in the criticality analysis in compliance with Chapter 6.0, IV, 4.c of NUREG-1536, Standard Review Plan for Dry Cask Storage Systems.

1.2.1.3.2 Holtite™ Neutron Shielding

The specification of the overpack neutron shield material is predicated on functional performance criteria. These criteria are:

- Attenuation of neutron radiation and associated neutron capture to appropriate levels;
- Durability of the shielding material under normal conditions, in terms of thermal, chemical, mechanical, and radiation environments;
- Stability of the homogeneous nature of the shielding material matrix;
- Stability of the shielding material in mechanical or thermal accident conditions to the desired performance levels; and
- Predictability of the manufacturing process under adequate procedural control to yield an in-place neutron shield of desired function and uniformity.

Other aspects of a shielding material, such as ease of handling and prior nuclear industry use, are also considered, within the limitations of the main criteria. Final specification of a shield material is a result of optimizing the material properties with respect to the main criteria, along with the design of the shield system, to achieve the desired shielding results.

Holtite-A is the only approved neutron shield material which fulfills the aforementioned criteria. Holtite-A is a poured-in-place solid borated synthetic neutron-absorbing polymer. Holtite-A is specified with a nominal B_4C loading of 1 weight percent for the HI-STAR 100 System. Appendix 1.B provides the Holtite-A material properties germane to its function as a neutron shield. Holtec has performed confirmatory qualification tests on Holtite-A under the company's QA program.

In the following, a brief summary of the performance characteristics and properties of Holtite-A is provided.

Density

The specific gravity of Holtite-A is 1.68 g/cm^3 as specified in Appendix 1.B. To conservatively bound any potential weight loss at the design temperature and any inability to reach the theoretical density, the density is reduced by 4% to 1.61 g/cm^3. The density used for the shielding analysis is conservatively assumed to be 1.61 g/cm^3 to underestimate the shielding capabilities of the neutron shield.

Hydrogen

The weight concentration of hydrogen is 6.0%. However, all shielding analyses conservatively assume 5.9% hydrogen by weight in the calculations.

Boron Carbide

Boron carbide dispersed within Holtite-A in finely dispersed powder form is present in 1% weight concentration. Holtite-A may be specified with a B_4C content of up to 6.5 weight percent. For the HI-STAR 100 System, Holtite-A is specified with a nominal B_4C weight percent of 1%.

Design Temperature

The design temperature of Holtite-A is set at 300°F. The maximum spatial temperature of Holtite-A under all normal operating conditions must be demonstrated to be below this design temperature.

Thermal Conductivity

It is evident from Figure 1.2.9 that Holtite-A is directly in the path of heat transmission from the inside of the overpack to its outside surface. For conservatism, however, the design basis thermal conductivity of Holtite-A under heat rejection conditions is set equal to zero. The reverse condition occurs under a postulated fire event when the thermal conductivity of Holtite-A aids in the influx of heat to the stored fuel in the fuel basket. The thermal conductivity of Holtite-A is conservatively set at 1 Btu/hr-ft-°F for all fire event evaluations.

The Holtite-A neutron shielding material is stable below the design temperature for long-term use and provides excellent shielding properties for neutrons.

1.2.1.3.3 Gamma Shielding Material

For gamma shielding, HI-STAR 100 utilizes carbon steel in plate stock form. Instead of utilizing a thick forging, the gamma shield design in the HI-STAR 100 overpack borrows from the concept of layered vessels from the field of ultra-high pressure vessel technology. The shielding is made from successive layers of plate stock. The fabrication of the shell begins by rolling the inner shell plate and making the longitudinal weld seam. Each layer of the intermediate shells are constructed from two halves. The two halves of the shell shall be precision sheared, bevelled, and rolled to the required radii. The two halves of the second layer are wrapped around the first shell. Each shell half is positioned in its location and while applying pressure using a specially engineered fixture, the halves are tack welded. The bevelled edges to be joined will be positioned to make contact or have a slight root gap. The second layer is made by joining the two halves using two longitudinal welds. Successive layers are assembled in a like manner. Thus, the welding of every successive shell provides a certain inter-layer contact (Figure 1.2.8). The longitudinal and circumferential welds of the intermediate shells are offset from the previous layer, as shown on the Design Drawings in Section 1.5. A thick structural component radiation barrier is thus constructed with four key features, namely:

- The number of layers can be increased as necessary to realize the required design objectives.
- The layered construction is ideal to stop propagation of flaws.
- The thinner plate stock is much more ductile than heavy forgings.
- Post-weld heat treatment is not required by the ASME Code, simplifying fabrication.

1.2.1.4 Lifting Devices

The HI-STAR 100 overpack is equipped with two lifting trunnions located in the top flange. The trunnions are manufactured from a high strength alloy and are installed in tapped openings. The lifting trunnions are designed in accordance with NUREG-0612 and ANSI N14.6. The trunnions are secured in position by a locking pad shaped to make conformal contact with the curved overpack. Once the locking pad is bolted in position, the locking pad inner diameter is sized to restrain the trunnion from backing out.

The lifting, upending, and downending of the HI-STAR 100 System requires the use of external handling devices. A lift yoke is utilized when the cask is to be lifted or set in a vertical orientation. Rotation cradles provide rotation trunnions which interface with pocket trunnions to provide a pivot axis. The lift yoke is connected to the lifting trunnions and the crane hook is used for upending or downending the HI-STAR 100 System by rotating on the rear pocket trunnions.

The top of the MPC lid is equipped with four threaded holes that allow lifting of the loaded MPC. These holes allow the loaded MPC to be raised/lowered from the HI-STAR overpack. MPC handling operations are performed using a HI-TRAC transfer cask of the HI-STORM 100 System (Docket No. 72-1014). The HI-TRAC transfer cask allows the sealed MPC loaded with spent fuel to be transferred from the HI-STORM Overpack (storage-only) to the HI-STAR Overpack, or vice versa. The threaded holes in the MPC lid are designed in accordance with NUREG-0612 and ANSI N14.6.

1.2.1.5 Design Life

The design life of the HI-STAR 100 System is 40 years. This is accomplished by using materials of construction with a long proven history in the nuclear industry and specifying materials known to withstand their operating environments with little to no degradation. A maintenance program, as specified in Chapter 9, is also implemented to ensure the HI-STAR 100 System will exceed its design life of 40 years. The design considerations that assure the HI-STAR 100 System performs as designed throughout the service life include the following:

HI-STAR Overpack

- Exposure to Environmental Effects
- Material Degradation
- Maintenance and Inspection Provisions

MPC

- Corrosion
- Structural Fatigue Effects
- Maintenance of Helium Atmosphere
- Allowable Fuel Cladding Temperatures
- Neutron Absorber Boron Depletion

The adequacy of the HI-STAR 100 System for its design life is discussed in Sections 3.4.10 and 3.4.11.

1.2.2 Operational Characteristics

1.2.2.1 Design Features

The HI-STAR 100 System is engineered to store different types of MPCs for varying PWR and BWR fuel characteristics.

The HI-STAR 100 System can safely store spent nuclear fuel with minimum cooling times. The maximum thermal decay heat load and SNF enrichments for each of the MPCs are identified in Chapter 2. The decay heat emitted by the spent nuclear fuel is dissipated in an entirely passive mode without any mechanical or forced cooling.

Both the free volume of the HI-STAR 100 MPCs and the annulus between the external surface of the MPC and the inside surface of the overpack are inerted with 99.995% pure helium gas during the spent nuclear fuel loading operations. Table 1.2.2 specifies the helium pressure to be placed in the MPC internal cavity.

The primary heat transfer mechanisms are metal conduction and surface radiation for the HI-STAR 100 System. The MPC internal helium atmosphere, in addition to providing a noncorrosive dry atmosphere for the fuel cladding, provides for heat transfer through helium conduction. The most adverse temperature profiles and thermal gradients for the HI-STAR 100 System with each of the MPCs are discussed in detail in Chapter 4.

The criticality control features of the HI-STAR 100 are designed to maintain the neutron multiplication factor k-effective (including uncertainties and calculational bias) at less than 0.95 under all normal, off-normal, and accident conditions of storage as analyzed in Chapter 6.

1.2.2.2 Sequence of Operations

Table 1.2.6 provides the basic sequence of operations necessary to defuel a spent fuel pool using the HI-STAR 100 System. The detailed sequence of steps for storage-related loading and handling operations is provided in Chapter 8 and is supported by the Design Drawings in Section 1.5. A summary of general actions needed for the loading and unloading operations is provided below. Figures 1.2.11 and 1.2.12 provide a pictorial view of the loading and unloading operations, respectively.

Loading Operations

At the start of loading operations, the overpack is configured with the closure plate removed. The lift yoke is used to position the overpack in the designated preparation area or setdown area for overpack inspection and MPC insertion. The annulus is filled with plant demineralized water and an inflatable annulus seal is installed. The inflatable seal prevents contact between spent fuel pool water and the MPC shell reducing the possibility of contaminating the outer surfaces of the MPC. The MPC is then filled with spent fuel pool water or plant demineralized water. The overpack and MPC are lowered into the spent fuel pool for fuel loading using the lift yoke. Pre-selected assemblies are loaded into the MPC and a visual verification of the assembly identification is performed.

While still underwater, a thick shielding lid (the MPC lid) is installed. The lift yoke is remotely engaged to the overpack lifting trunnions and is used to lift the overpack close to the spent fuel pool surface. As an ALARA measure, dose rates are measured on the top of the overpack and MPC prior to removal from the pool to check for activated debris on the top surface. The MPC lift bolts (securing the MPC lid to the lift yoke) are removed. As the overpack is removed from the spent fuel pool, the lift yoke and overpack are sprayed with demineralized water to help remove contamination.

The overpack is removed from the pool and placed in the designated preparation area. The top surfaces of the MPC lid and the top flange of the overpack are decontaminated. The inflatable annulus seal is removed, and an annulus shield is installed. The annulus shield provides additional personnel shielding at the top of the annulus and also prevents small items from being dropped into the annulus. Dose rates are measured to ensure that the dose rates are within expected values. The Automated Welding System baseplate shield is installed to reduce dose rates around the top of the cask. The MPC water level is lowered slightly and the MPC lid is seal-welded using the Automated Welding System (AWS). Liquid penetrant examinations are performed on the root and final passes.

A volumetric (or multi-layer liquid penetrant) examination is also performed on the MPC lid-to-shell weld. The water level is raised to the top of the MPC and the weld is hydrostatically tested. Then a small volume of the water is displaced with helium gas. The helium gas is used for leakage testing. A helium leakage rate test is performed on the MPC lid confinement weld (lid-to-shell) to verify weld integrity and to ensure that required leakage rates are within acceptance criteria. The MPC water is displaced from the MPC by blowing pressurized helium or nitrogen gas into the vent port of the MPC, thus displacing the water through the drain line.

The Vacuum Drying System (VDS) is connected to the MPC and is used to remove all residual water from the MPC in a stepped evacuation process. The stepped evacuation process is used to preclude the formation of ice in the MPC and VDS lines. The internal pressure is reduced and held for a duration to ensure that all liquid water has evaporated.

Following this dryness test, the VDS is disconnected, the Helium Backfill System (HBS) is attached, and the MPC is backfilled with a predetermined amount of helium gas. The helium backfill ensures adequate heat transfer during storage, provides an inert atmosphere for long-term fuel integrity, and provides the means of future leakage rate testing of the MPC confinement boundary welds. 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. The cover plates are helium leakage tested to confirm that they meet the established leakage rate criteria.

The MPC closure ring is then placed on the MPC, aligned, tacked in place, and seal welded, providing redundant closure of the MPC confinement cavity 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 is removed and the remaining water in the annulus is drained. The AWS Baseplate shield is removed. The MPC lid and accessible areas of the top of the MPC shell are smeared for removable contamination and overpack dose rates are measured. The overpack closure plate is installed and the bolts are torqued. The overpack annulus is dried using the VDS, and backfilled with helium gas for heat transfer and seal testing. Concentric metallic seals in the overpack closure plate prevent the leakage of the helium gas from the annulus and provide an additional confinement boundary to the release of radioactive materials. The seals on the overpack vent and drain port plugs are leak tested along with the overpack closure plate inner seal. Cover plates with metallic seals are installed over the overpack vent and drain ports to provide redundant closure of the overpack penetrations. A port plug with a metallic seal is installed in the overpack closure plate test port to provide fully redundant closure of all potential leakage paths in the overpack penetrations.

The overpack is secured to the transporter and moved to the ISFSI pad. The overpack may be moved using a number of methods as long as the handling height limitations listed in the Technical Specifications are not exceeded.

The HI-STAR 100 System can also be remotely loaded at a specially-designed dry loading facility (i.e., hot cell) with appropriate modifications to the loading procedures.

Unloading Operations

The HI-STAR 100 System unloading procedures describe the general actions necessary to prepare the MPC for unloading, cool the stored fuel assemblies in the MPC, flood the MPC cavity, remove the lid welds, unload the spent fuel assemblies, and recover the overpack and empty MPC. Special precautions are outlined to ensure personnel safety during the unloading operations, and to prevent the risk of MPC overpressurization and thermal shock to the stored spent fuel assemblies.

The overpack and MPC are returned to the designated preparation area from the ISFSI. At the site's discretion, a gas sample is drawn from the annulus and analyzed. The gas sample provides an indication of MPC confinement performance. The annulus is depressurized, the overpack closure plate is removed, and the annulus is filled with plant demineralized water. The annulus shield is installed to protect the annulus from debris produced from the lid removal process. Similarly, overpack top surfaces are covered with a protective fire-retarding blanket.

The Weld Removal System (WRS) is positioned on the MPC lid. The MPC closure ring is core drilled over the locations of the vent and drain port cover plates. Local ventilation is established around the MPC vent port and a hot tap is attached to the vent port cover plate. The hot tap allows access to the vent port cavity to determine if the coupling is leaking at a significant rate. If the coupling is leaking, the MPC is allowed to depressurize through the hot tap. Otherwise, the vent port cover plate weld is removed, the vent port cover plate is removed, and the MPC is vented using local ventilation. The drain port cover plate weld is removed. The MPC is cooled using a closed-loop heat exchanger to reduce the MPC internal temperature to allow water flooding. Following the fuel cool-down, the MPC is flooded with water. The WRS is positioned for MPC lid-to-MPC shell weld removal. The WRS is then removed with the MPC lid left in place.

The inflatable annulus seal is installed and pressurized. The MPC lid is rigged to the lift yoke and the lift yoke is engaged to overpack lifting trunnions. The overpack is placed in the spent fuel pool and the MPC lid is removed. All fuel assemblies are returned to the spent fuel storage racks and the MPC fuel cells are vacuumed to remove any assembly debris. The overpack and MPC are returned to the designated preparation area where the MPC water is pumped back into the spent fuel pool. The annulus water is drained and the MPC and overpack are decontaminated in preparation for re-utilization.

The HI-STAR 100 System can also be remotely unloaded at a specially designed dry unloading facility (i.e., hot cell) with appropriate modifications to the unloading procedures.

1.2.2.3 Identification of Subjects for Safety and Reliability Analysis

1.2.2.3.1 Criticality Prevention

Criticality is controlled by geometry and neutron absorption materials in the fuel basket. The MPC-24 and MPC-68 do not rely on soluble boron credit or the assurance that water cannot enter the MPC to meet the stipulated criticality limits.

The MPC-68 basket is equipped with Boral with a minimum ^{10}B areal density of 0.0372 g/cm^2. The MPC-24 basket is equipped with Boral with a minimum ^{10}B areal density of 0.0267 g/cm^2. Due to the lower reactivity of the fuel to be stored in the MPC-68F as specified by the Technical Specifications, the MPC-68F is equipped with Boral with a minimum ^{10}B areal density of 0.01 g/cm^2.

1.2.2.3.2 Chemical Safety

There are no chemical safety hazards associated with operations of the HI-STAR 100 dry storage system. A detailed evaluation is provided in Section 3.4.

1.2.2.3.3 Operation Shutdown Modes

The HI-STAR 100 System is totally passive and consequently, operation shutdown modes are unnecessary. Guidance is provided in Chapter 8, which outlines the HI-STAR 100 unloading procedures, and Chapter 11, which outlines the corrective course of action in the wake of all postulated accidents.

1.2.2.3.4 Instrumentation

As stated earlier, the HI-STAR 100 confinement boundary is the MPC, which is seal welded, volumetrically (or multi-layer liquid penetrant) examined, hydrostatically tested, and leak tested. Including the overpack, there are three completely independent barriers to the release of radioactivity to the outside environment. These barriers, proven through decades of use in numerous industries, are arrayed in a sequential manner, making the escape of radioactivity to the outside environment unlikely. The HI-STAR 100 is a completely passive system with appropriate margins of safety; therefore, it is not necessary to deploy any instrumentation to monitor the cask in the storage mode, and none is provided.

1.2.2.3.5 Maintenance Technique

Because of their passive nature, the HI-STAR 100 Systems require minimal maintenance over their lifetime. Chapter 9 describes the acceptance criteria and maintenance program set forth for the HI-STAR 100 System.

1.2.3 Cask Contents

The HI-STAR 100 System is designed to house different types of MPCs. The MPCs are designed to store both BWR and PWR spent nuclear fuel assemblies. Tables 1.2.1 and 1.2.2 provide key design parameters for the MPCs. A description of acceptable fuel assemblies for storage in the MPCs is provided in Chapter 2.

Fuel assemblies classified as damaged fuel or fuel debris (assembly array/class 6x6A, 6x6B, 6x6C, 7x7A, and 8x8A as specified in Table 1.2.11) have been evaluated. Damaged fuel assemblies and fuel debris shall be placed in damaged fuel containers (see Figure 1.2.10) prior to loading into the MPC to facilitate handling and contain loose components. Damaged fuel assemblies in damaged fuel containers may be stored in the standard MPC-68. The MPC-68 design to store fuel debris is identical to the MPC-68 design to store intact or damaged fuel. The sole additional restriction imposed on an MPC-68 to load damaged fuel containers with fuel assemblies classified as fuel debris is a stricter leakage rate criteria prior to shipment. Therefore, an MPC-68 which is to store damaged fuel containers with fuel assemblies classified as fuel debris must be designated during fabrication to ensure the proper leakage rate criteria is applied. To distinguish an MPC-68, which is fabricated to store damaged fuel containers with fuel assemblies classified as fuel debris, the MPC shall be designated as an "MPC-68F".

Up to 4 damaged fuel containers containing specified fuel debris may be stored within an MPC-68F. The quantity of damaged fuel containers with fuel debris is limited to meet the off-site transportation requirements of 10CFR71, specifically, 10CFR71.63(b).

Table 1.2.1

KEY SYSTEM DATA FOR HI-STAR 100

ITEM	QUANTITY	NOTES
Types of MPCs included in this revision of the submittal	2	1 for PWR 1 for BWR
MPC storage capacity:	MPC-24	Up to 24 intact zircaloy or stainless steel clad PWR fuel assemblies
	MPC-68	Up to 68 intact zircaloy or intact stainless steel clad BWR fuel assemblies or damaged zircaloy clad fuel assemblies in damaged fuel containers in the MPC-68 or Up to 4 damaged fuel containers with zircaloy clad BWR fuel debris and the complement intact or damaged zircaloy clad BWR fuel assemblies within an MPC-68F.

Table 1.2.2

KEY PARAMETERS FOR HI-STAR 100 MULTI-PURPOSE CANISTERS

	PWR	BWR
Pre-disposal service life (years)	40	40
Design temperature, max./min. (°F)	725 °F /-40°C	725 °F /-40 °C
Design internal pressure (psig)		
Normal conditions	100	100
Off-normal conditions	100	100
Accident Conditions	125	125
Total heat load, max. (kW)	19.0 (MPC-24)	18.5 (MPC-68)
Maximum permissible peak fuel cladding temperature:		
Normal (°F)	See Table 2.2.3	See Table 2.2.3
Short Term & Accident (°F)	1058	1058
MPC internal environment Helium fill (psig)	≤ 22.2	≤ 28.5
MPC external environment/overpack internal pressure		
Helium fill initial pressure (psig, at STP)	10	10
Maximum permissible reactivity including all uncertainties and biases	<0.95	<0.95
Boral ^{10}B Areal Density (g/cm^2)	0.0267 (MPC-24)	0.0372 (MPC-68) 0.01 (MPC-68F)
End closure(s)	Welded	Welded
Fuel handling	Opening compatible with standard grapples	Opening compatible with standard grapples
Heat dissipation	Passive	Passive

Table 1.2.3

BORAL EXPERIENCE LIST
DOMESTIC PRESSURIZED WATER REACTORS

Plant	Utility
Donald C. Cook	American Electric Power
Indian Point 3	New York Power Authority
Maine Yankee	Maine Yankee Atomic Power
Salem 1,2	Public Service Electric and Gas
Sequoyah 1,2	Tennessee Valley Authority
Yankee Rowe	Yankee Atomic Power
Zion 1,2	Commonwealth Edison Company
Byron 1,2	Commonwealth Edison Company
Braidwood 1,2	Commonwealth Edison Company
Three Mile Island I	GPU Nuclear
Sequoyah (rerack)	Tennessee Valley Authority
D.C. Cook (rerack)	American Electric Power
Maine Yankee	Maine Yankee Atomic Power Company
Connecticut Yankee	Northeast Utilities Service Company
Salem Units 1 & 2 (rerack)	Public Service Electric & Gas Company
Plant	Utility
Browns Ferry 1,2,3	Tennessee Valley Authority
Brunswick 1,2	Carolina Power & Light
Clinton	Illinois Power

Dresden 2,3	Commonwealth Edison Company
Duane Arnold Energy Center	Iowa Electric Light and Power
J.A. FitzPatrick	New York Power Authority
E.I. Hatch 1,2	Georgia Power Company
Hope Creek	Public Service Electric and Gas
Humboldt Bay	Pacific Gas and Electric Company
LaCrosse	Dairyland Power
Limerick 1,2	Philadelphia Electric Company
Monticello	Northern States Power
Peachbottom 2,3	Philadelphia Electric Company
Perry 1,2	Cleveland Electric Illuminating
Pilgrim	Boston Edison Company
Susquehanna 1,2	Pennsylvania Power & Light
Vermont Yankee	Vermont Yankee Atomic Power
Hope Creek	Public Service Electric and Gas Company
Shearon Harris Pool B	Carolina Power & Light Company
Duane Arnold	Iowa Electric Light and Power
Pilgrim	Boston Edison Company
LaSalle Unit 1	Commonwealth Edison Company
Millstone Point Unit One	Northeast Utilities Service Company

INTERNATIONAL INSTALLATIONS USING BORAL	
COUNTRY	PLANT(S)
France	12 PWR Plants
South Africa	Koeberg 1,2
Switzerland	Beznau 1,2 Gosgen
Taiwan	Chin-Shan 1,2 Kuosheng 1,2
Mexico	Laguna Verde Units 1,2
Korea	Ulchin Unit One
Brazil	Angra 1
United Kingdom	Sizewell B
Korea	Ulchin Unit Two

Table 1.2.6

HI-STAR 100 OPERATIONS DESCRIPTION

Site-specific handling and operations procedures will be prepared, reviewed, and approved by each owner/user.	
1	Overpack and MPC lowered into the fuel pool without closure plate and MPC lid
2	Fuel assemblies transferred into the MPC fuel basket
3	MPC lid lowered onto the MPC
4	Overpack/MPC assembly moved to the decon pit and MPC lid welded in place, volumetrically (or multi-layer liquid penetrant) examined, hydrostatically tested, and leak tested
5	MPC dewatered, vacuum dried, backfilled with helium and the vent/drain port cover plates and closure ring welded
6	Overpack drained and external surfaces decontaminated
7	Overpack seals and closure plate installed and bolts torqued
8	Overpack cavity dried, backfilled with helium, and helium leak tested
9	HI-STAR 100 loaded onto transporter and moved to the ISFSI pad for on-site storage
10	HI-STAR 100 emplaced onto the ISFSI pad at its designated location

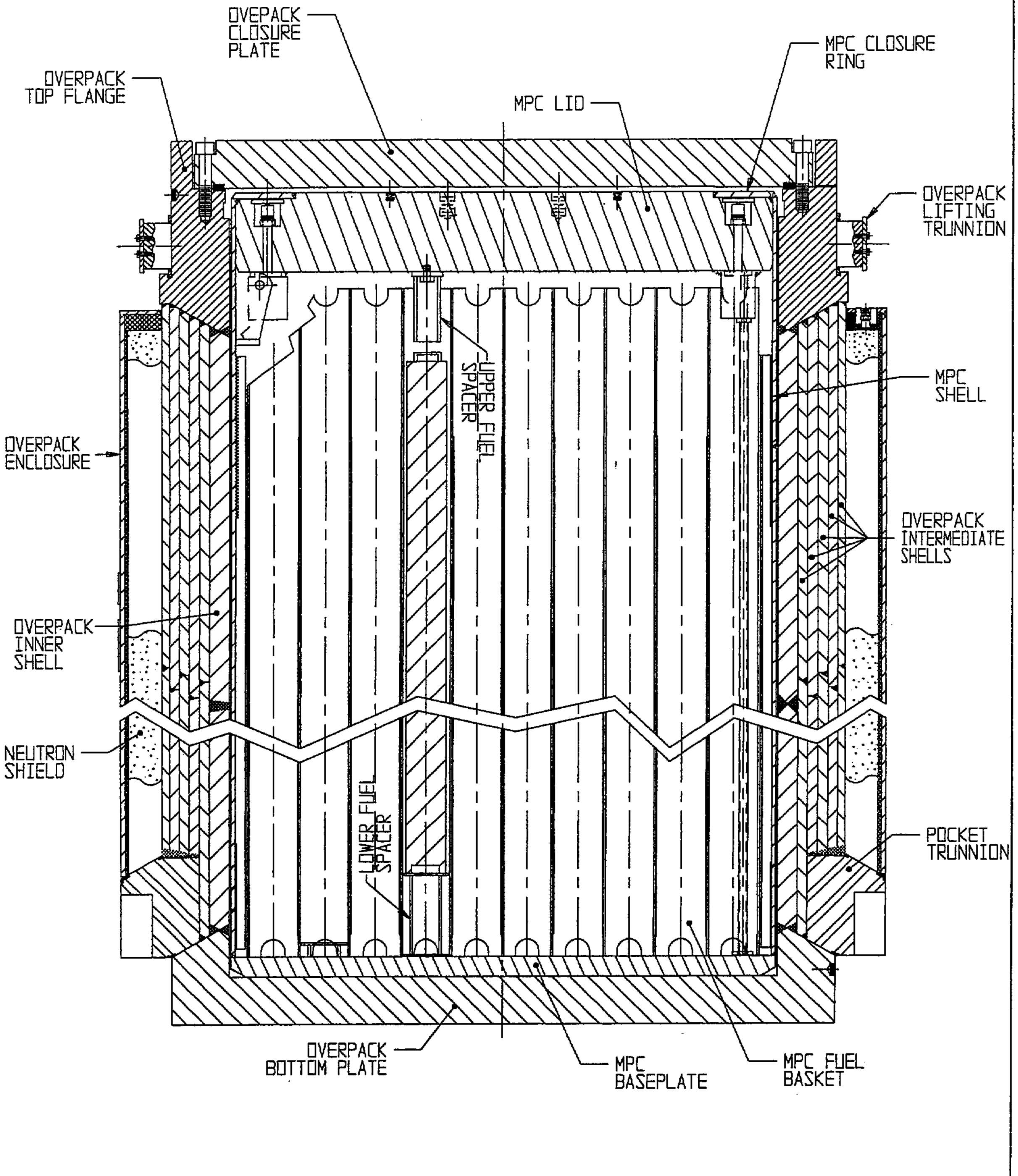


FIGURE 1.2.1; CROSS SECTION ELEVATION VIEW OF HI-STAR 100 SYSTEM

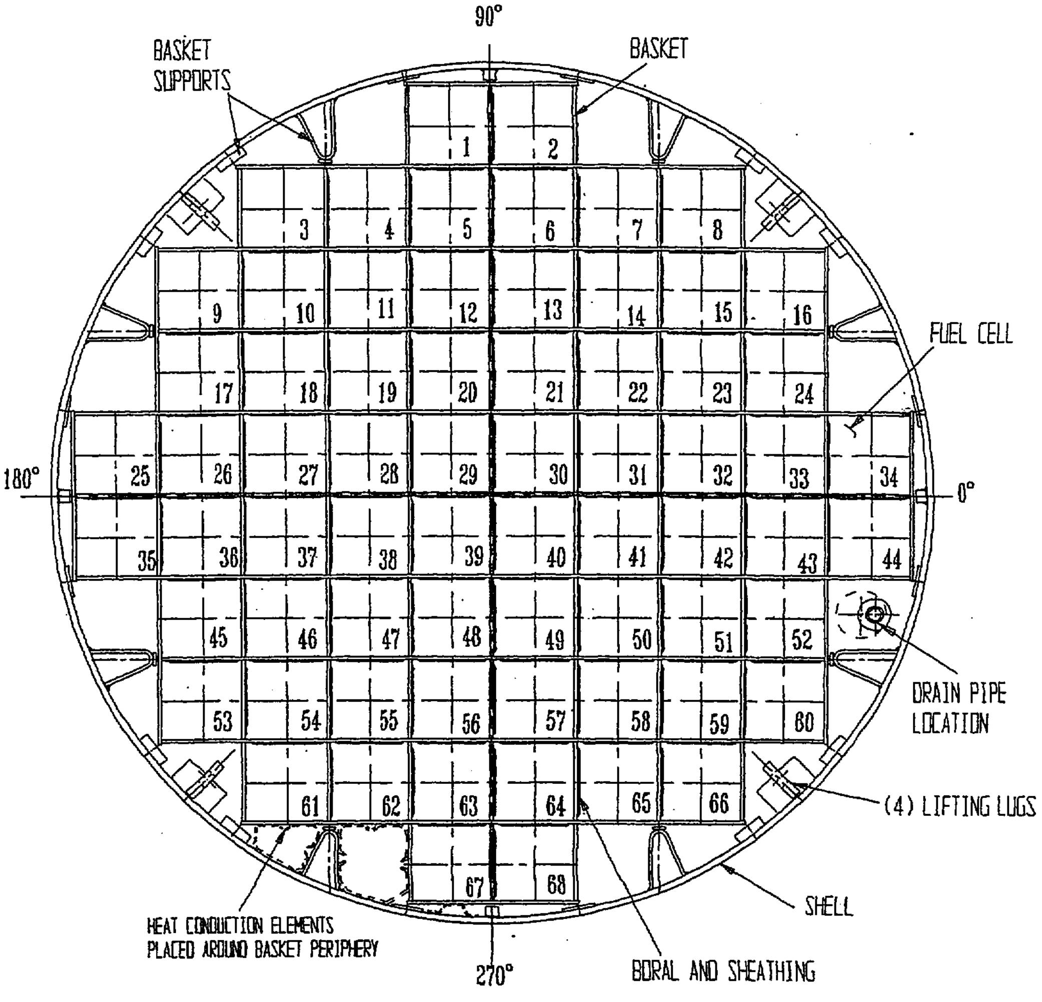


FIGURE 1.2.2; MPC-68 CROSS SECTION VIEW

DELETED

FIGURE 1.2.3; MPC-32 CROSS SECTION

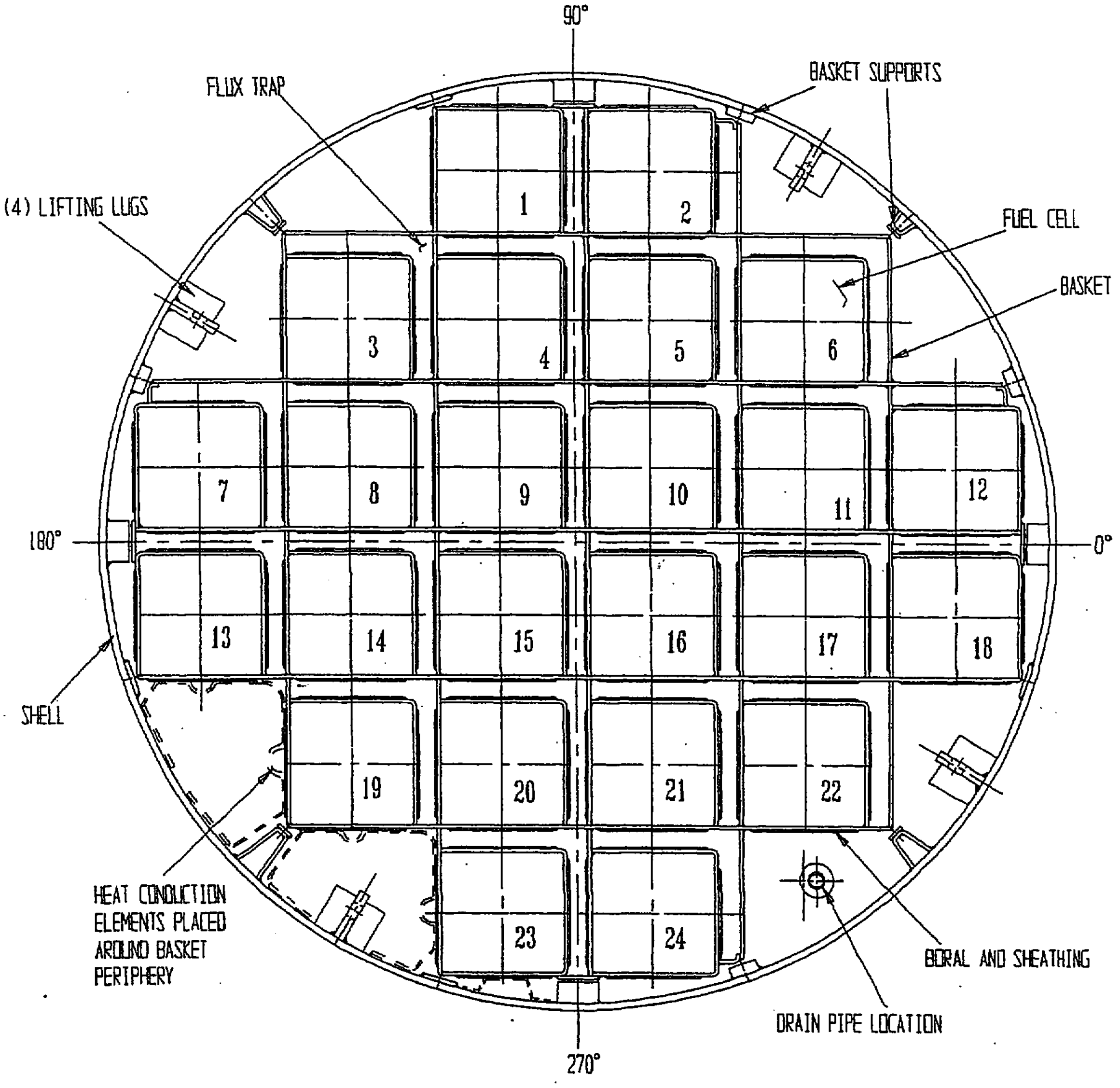


FIGURE 1.2.4; MPC-24 CROSS SECTION VIEW

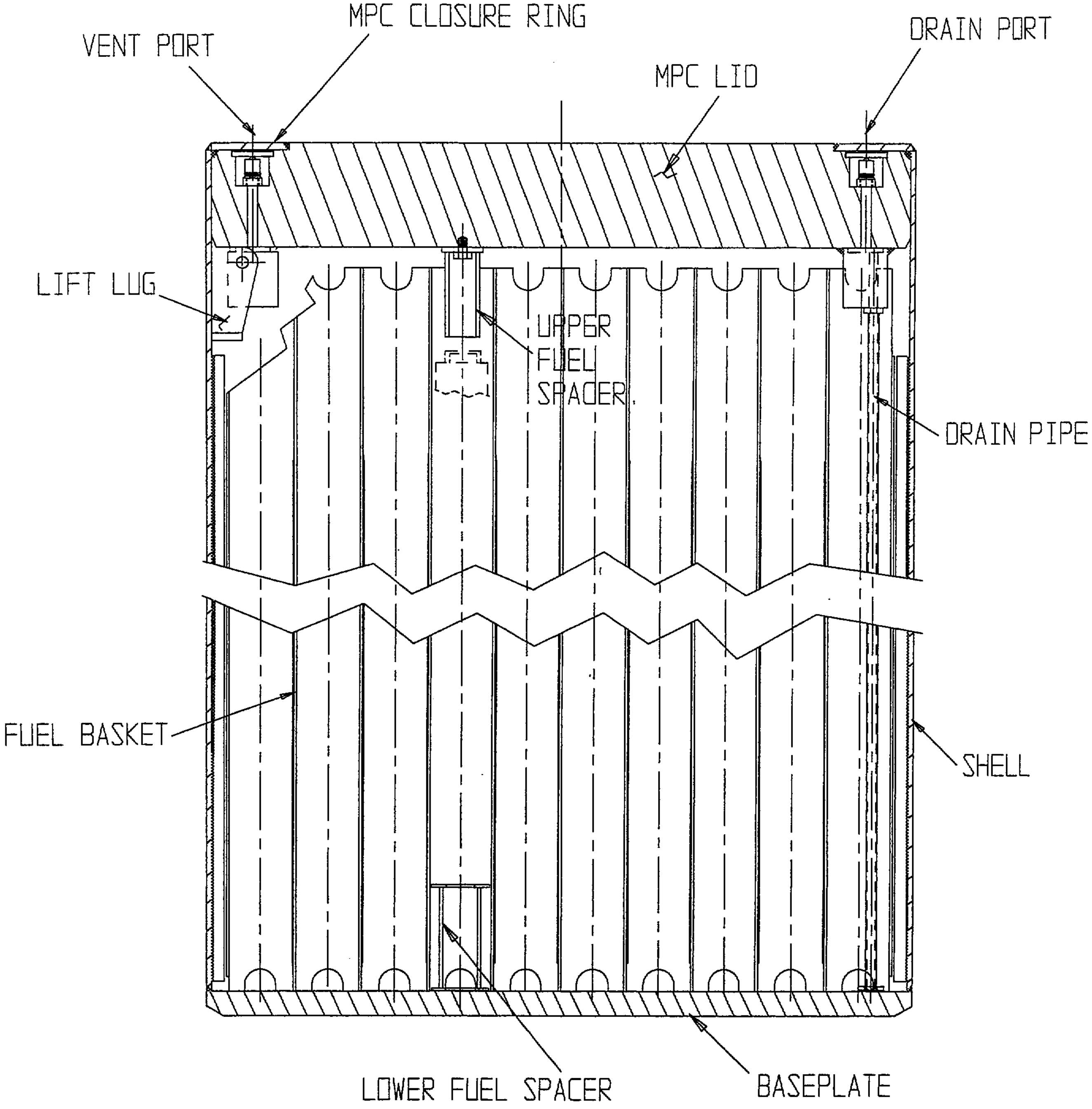


FIGURE 1.2.5; CROSS SECTION ELEVATION VIEW OF MPC

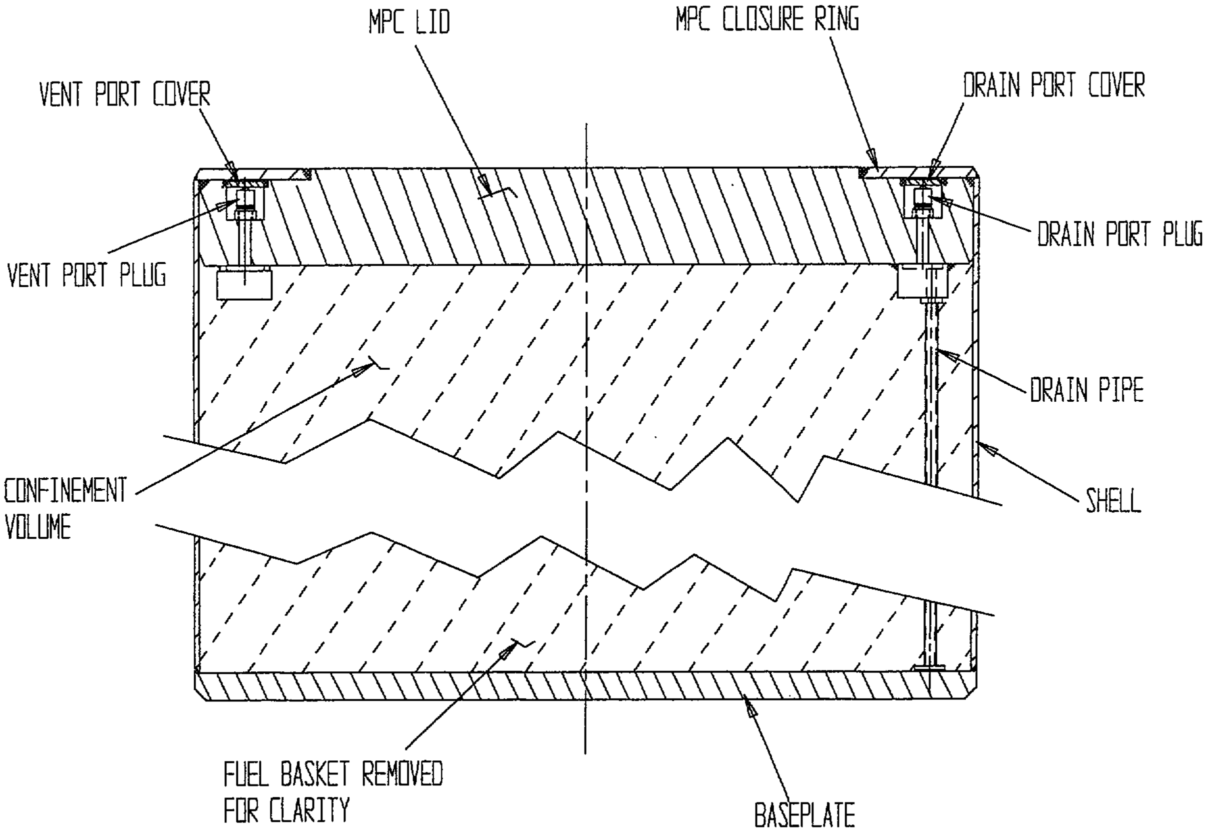


FIGURE 1.2.6; MPC CONFINEMENT BOUNDARY

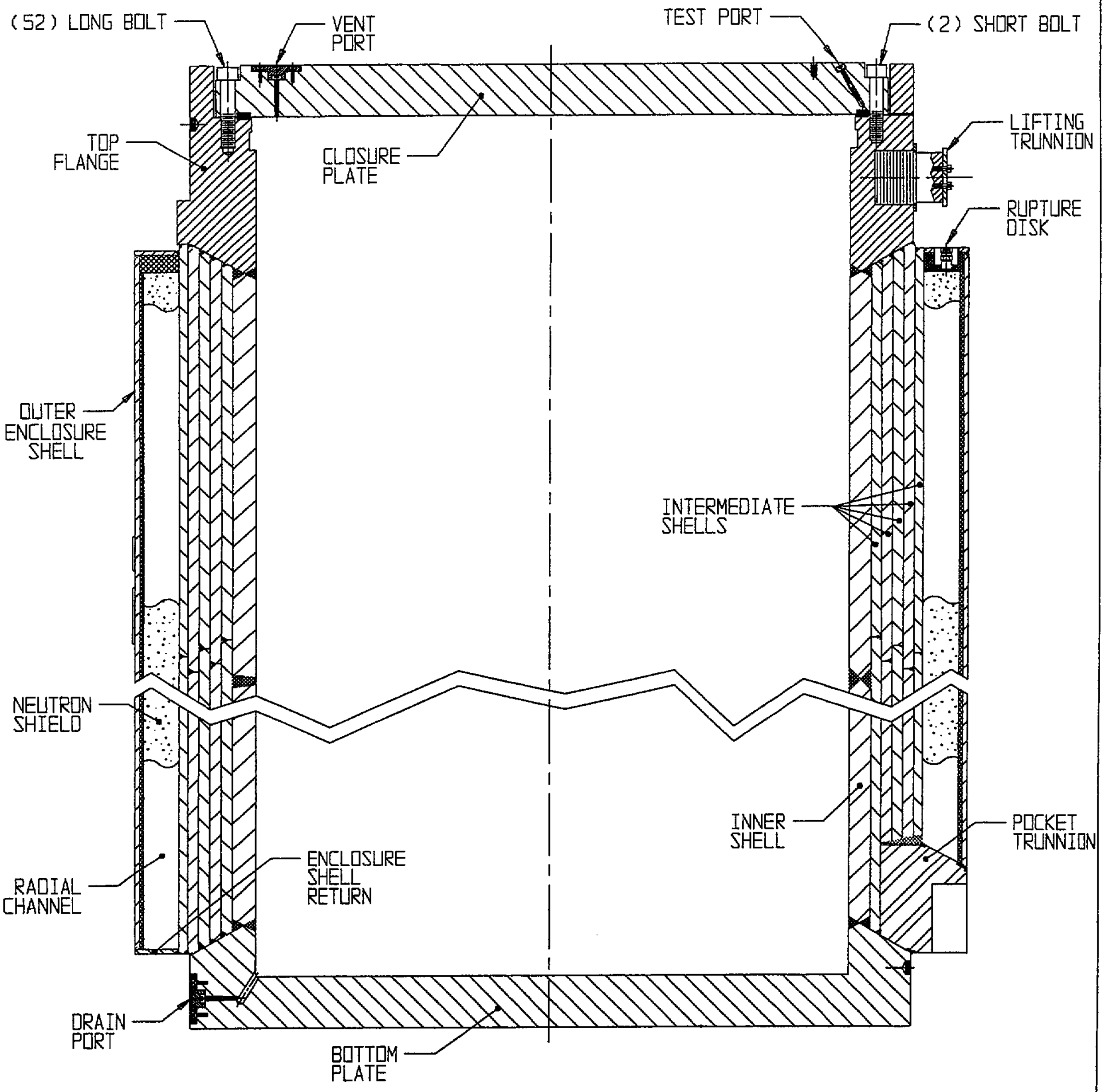
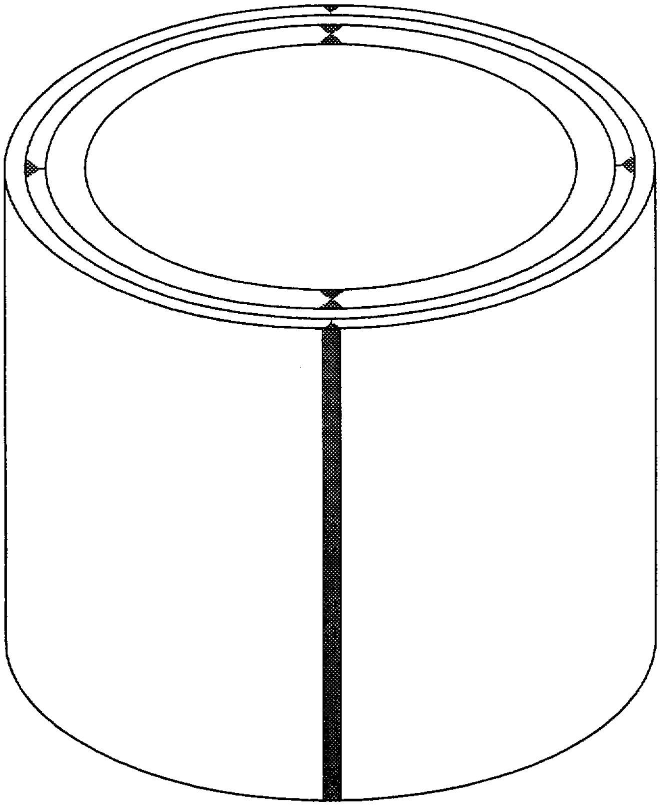
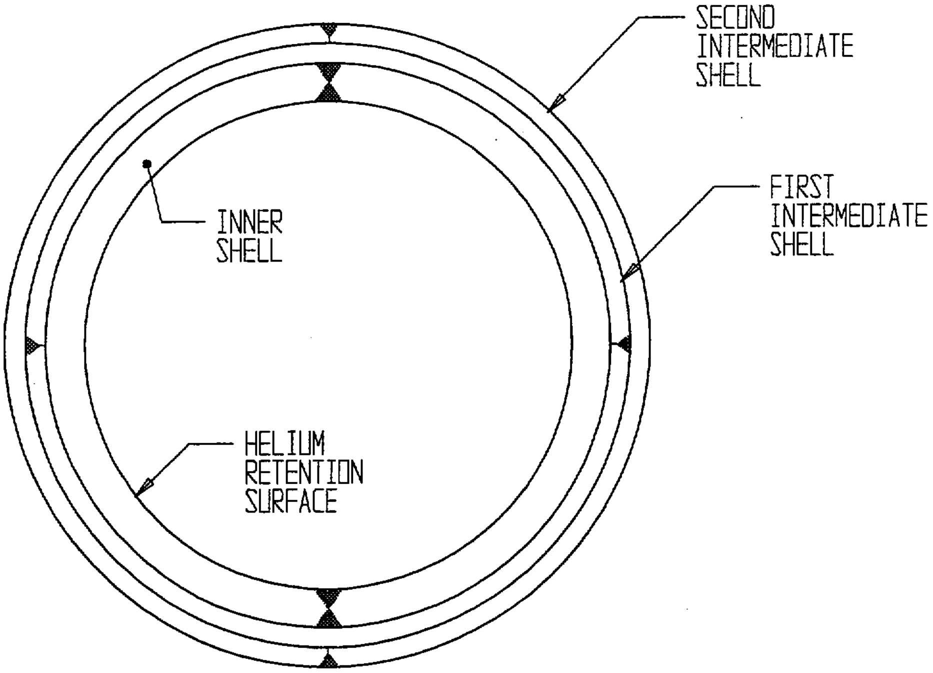


FIGURE 1.2.7; CROSS SECTION ELEVATION VIEW OF OVERPACK



ISOMETRIC VIEW OF CENTRAL REGION OF THE OVERPACK



CROSS SECTION AT MID-HEIGHT

FIGURE 1.2.8; HI-STAR 100 OVERPACK SHELL LAYERING

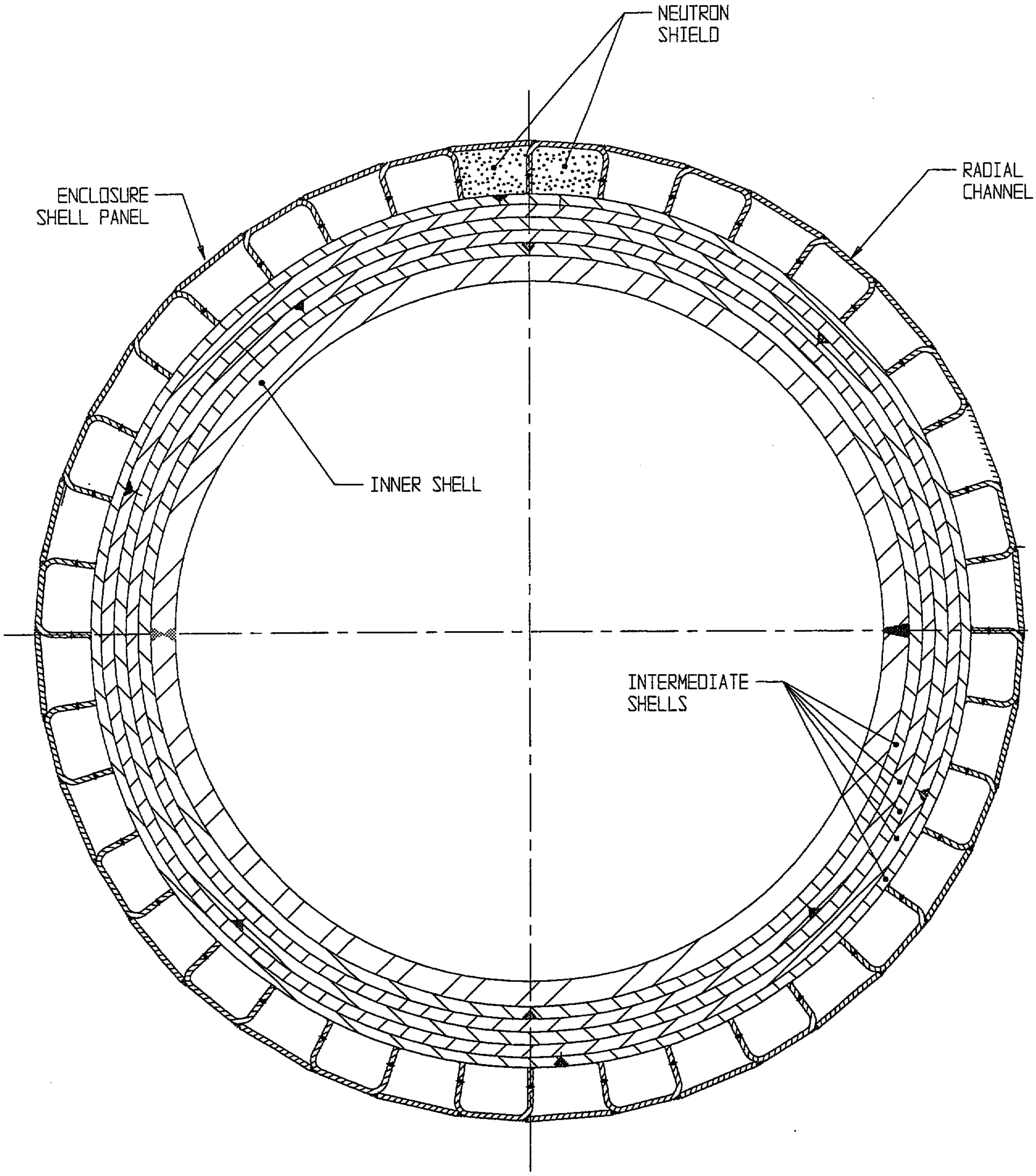
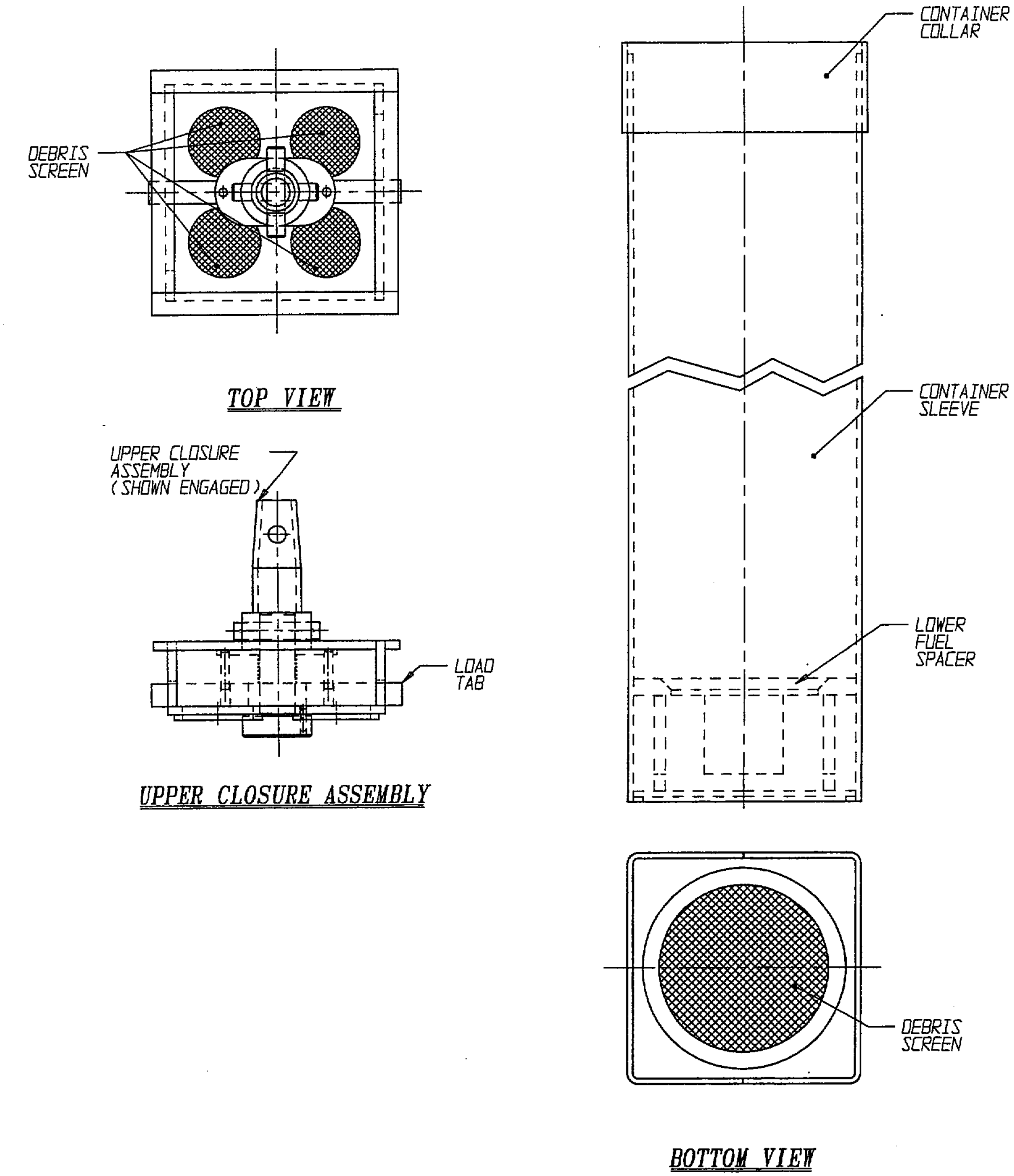


FIGURE 1.2.9; OVERPACK MID-PLANE CROSS SECTION



TOP VIEW

UPPER CLOSURE ASSEMBLY

BOTTOM VIEW

FIGURE 1.2.10; DAMAGED FUEL CONTAINER FOR DRESDEN UNIT-1/ HUMBOLDT BAY SNF

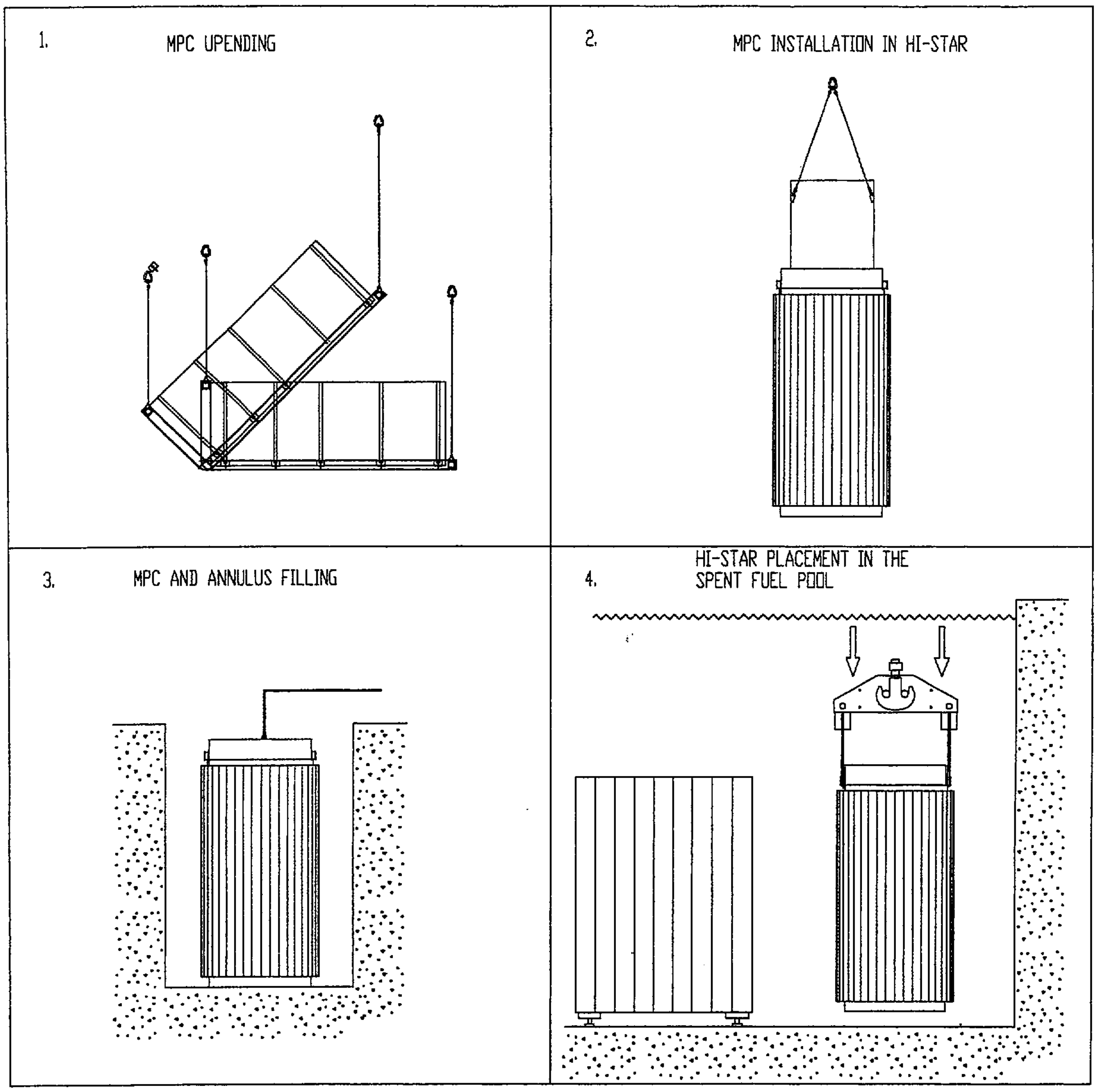


Figure 1.2.11a; Major HI-STAR 100 Loading Operations (Sheet 1 of 3)

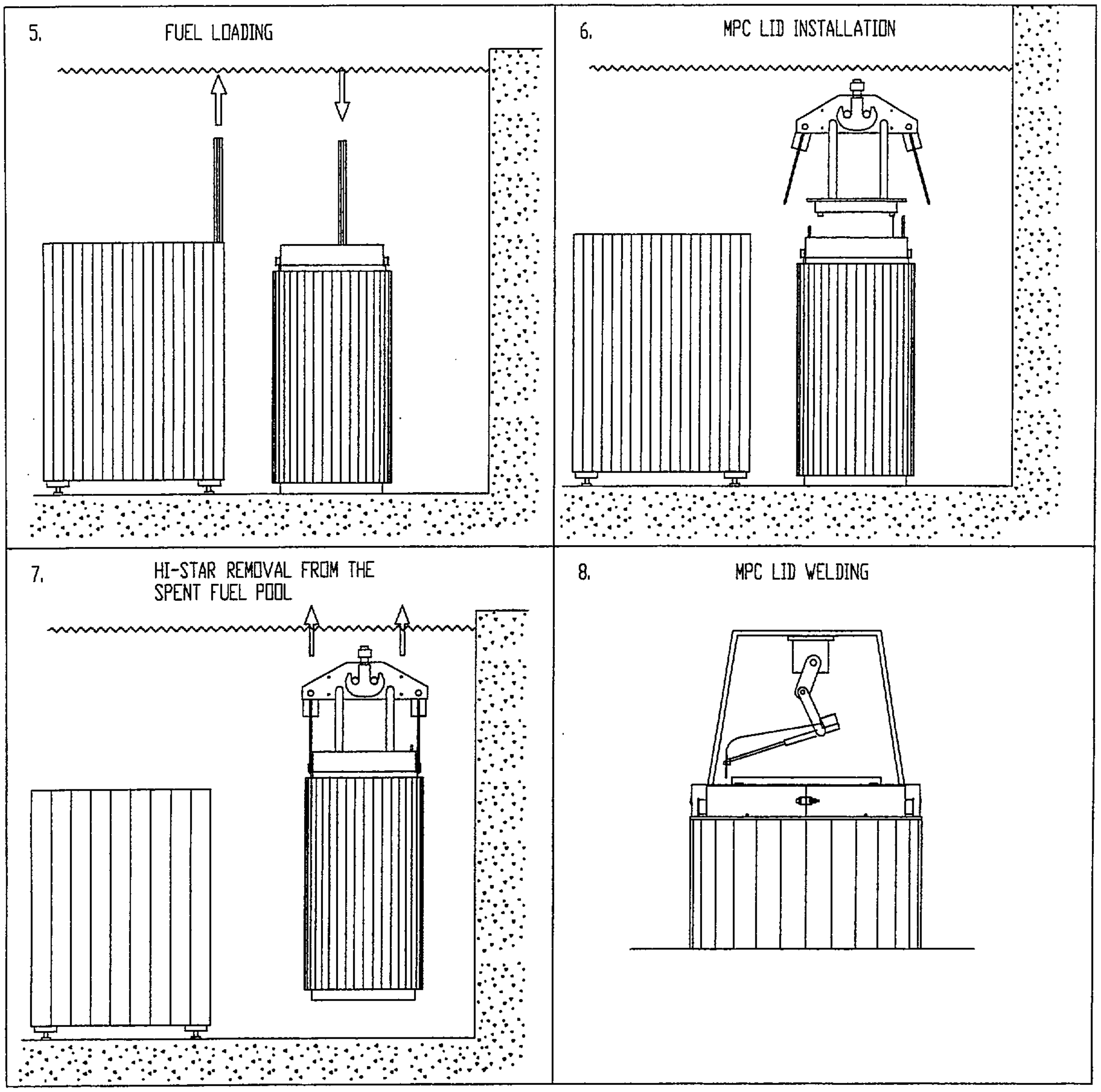


Figure 1.2.11b; Major HI-STAR 100 Loading Operations (Sheet 2 of 3)

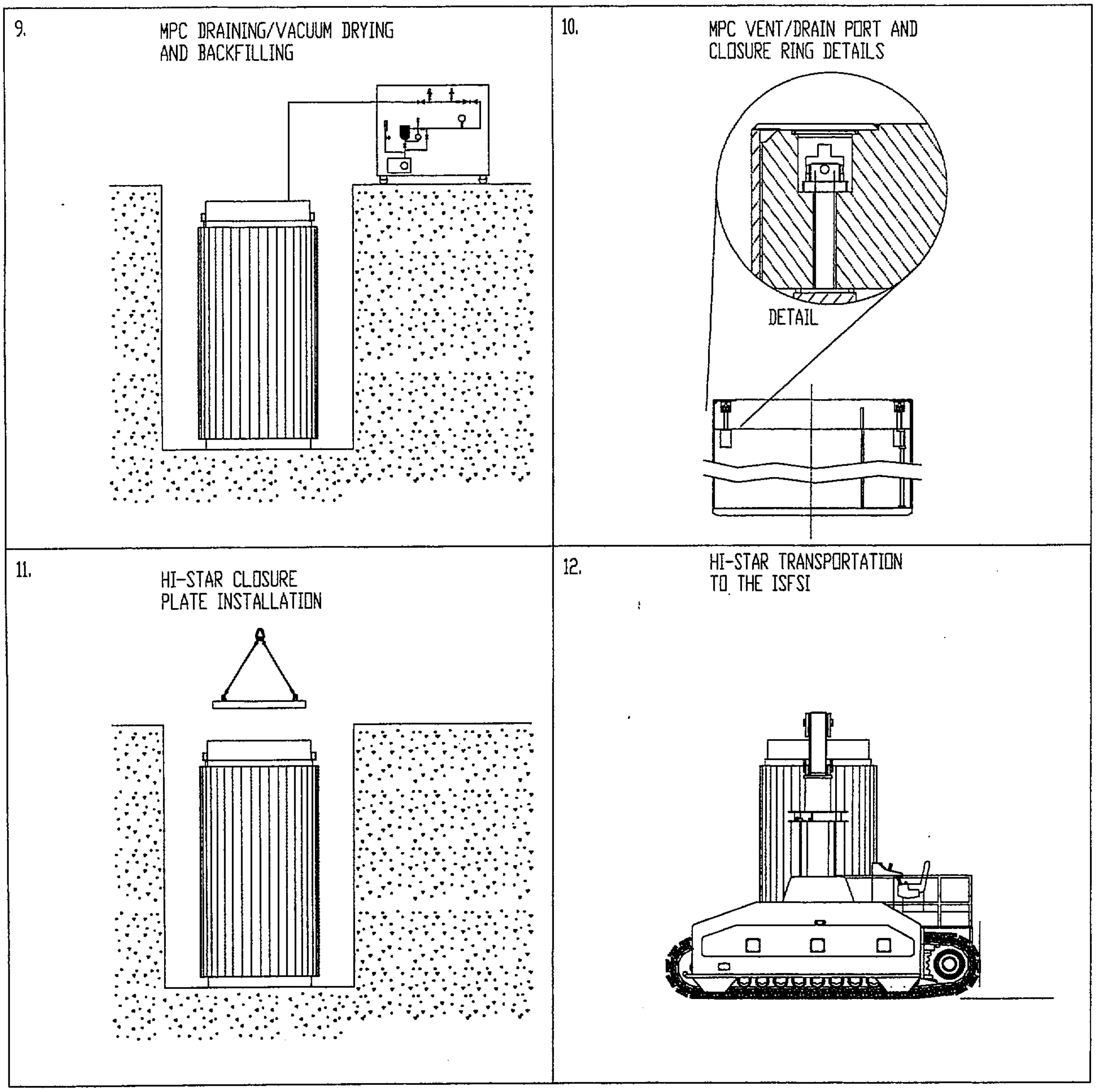


Figure 1.2.11c; Major HI-STAR 100 Loading Operations (Sheet 3 of 3)

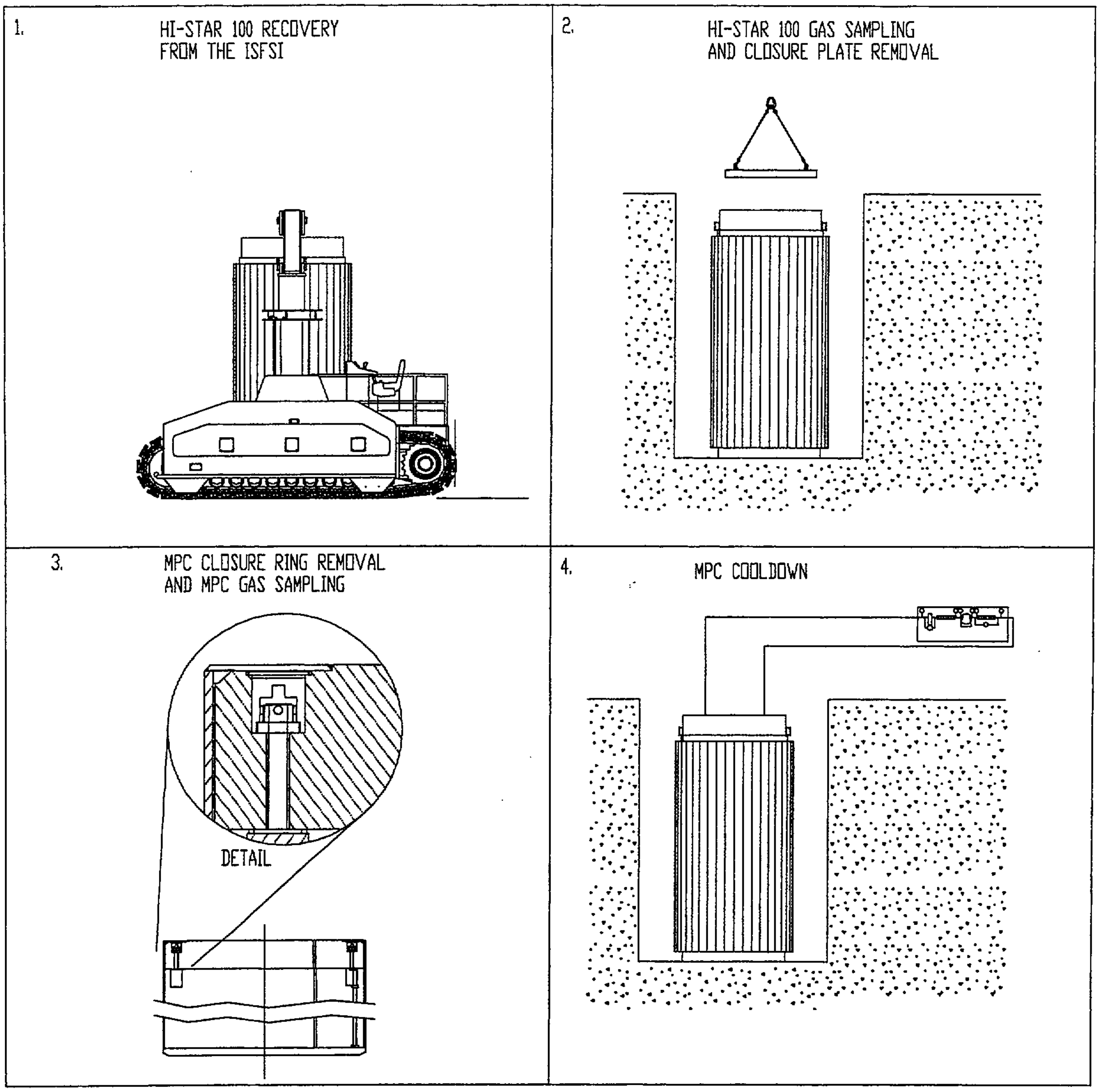


Figure 1.2.12a; Major HI-STAR 100 Unloading Operations (Sheet 1 of 3)

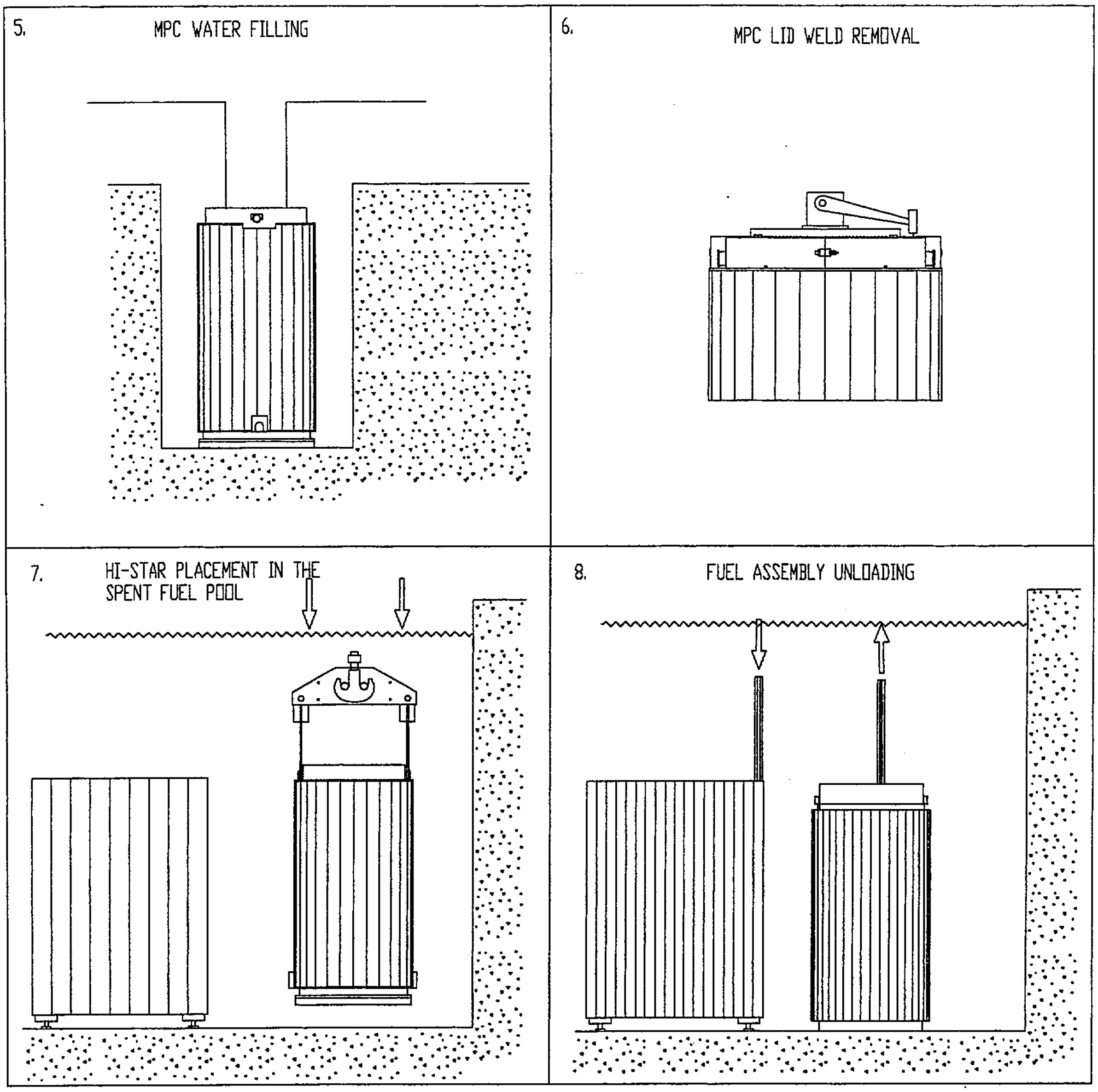


Figure 1.2.12b; Major HI-STAR 100 Unloading Operations (Sheet 2 of 3)

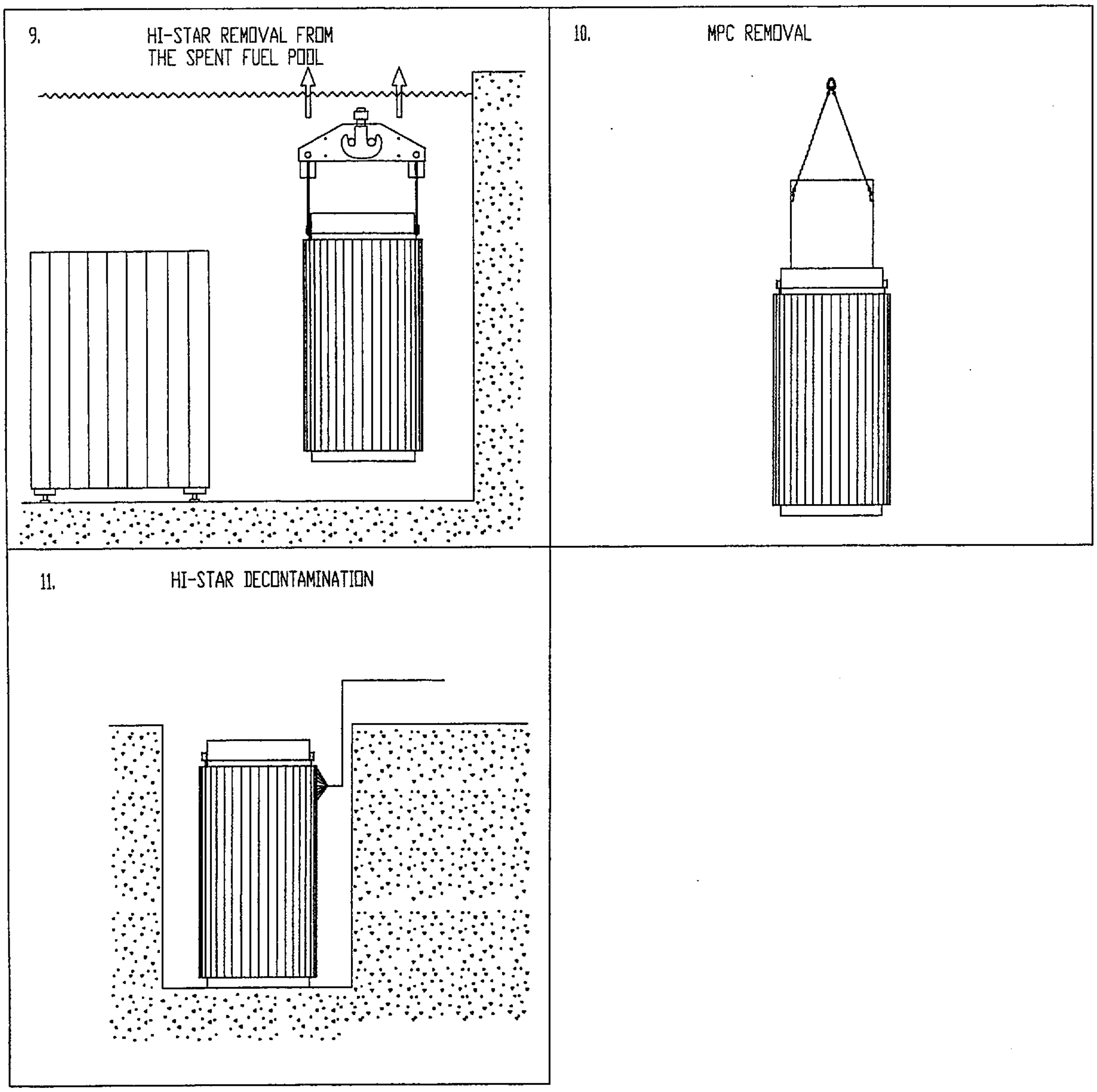


Figure 1.2.12c; Major HI-STAR 100 Unloading Operations (Sheet 3 of 3)

1.3 IDENTIFICATION OF AGENTS AND CONTRACTORS

Holtec International is a specialty engineering company with a principal focus on spent fuel storage technologies. Holtec has carried out turnkey wet storage capacity expansions (engineering, licensing, fabrication, removal of existing racks, performance of underwater modifications, volume reduction of the old racks and hardware, installation of new racks, and commissioning of the pool for increased storage capacity) in numerous plants around the world. Over 45 plants in the U.S., Britain, Brazil, Korea, and Taiwan have utilized Holtec's wet storage technology to extend their in-pool storage capacity.

Holtec's corporate engineering consists of experts with advanced degrees (Ph.D.'s) in every discipline germane to the fuel storage technologies, namely structural mechanics, heat transfer, computational fluid dynamics, and nuclear physics. All engineering analyses for Holtec's fuel storage projects (including HI-STAR 100) are carried out in-house.

Holtec International's quality assurance program was originally developed to meet NRC requirements delineated in 10CFR50, Appendix B, and was expanded to include provisions of 10CFR71, Subpart H, and 10CFR72, Subpart G, for structures, systems, and components designated as important to safety. A description of the quality assurance program and its method of satisfying all 18 criteria in 10CFR72, Subpart G, that apply to the design, fabrication, construction, testing, operation, modification, and decommissioning of structures, systems, and components important to safety is provided in Chapter 13.

It is currently planned that the HI-STAR 100 Systems will be fabricated by U.S. Tool & Die, Inc. (UST&D) of Pittsburgh, Pennsylvania. UST&D is an N-Stamp holder and a highly respected fabricator of nuclear components. UST&D is on Holtec's Approved Vendors List (AVL) and has a quality assurance program meeting 10CFR50 Appendix B criteria. Extensive prototypical fabrication of the MPCs has been carried out at the UST&D shop to resolve fixturing and tolerance issues. If another fabricator is to be used for fabrication of the HI-STAR 100 Systems, the proposed fabricator will be evaluated and audited in accordance with Holtec International's Quality Assurance Program described in Chapter 13.

Construction, assembly, and operations on-site may be performed by Holtec or a licensee as the prime contractor. A licensee shall be suitably qualified and experienced to perform selected activities. Typical licensees are technically qualified and experienced in commercial nuclear power plant construction and operation activities under a quality assurance program meeting 10CFR50 Appendix B criteria.

1.4 GENERIC CASK ARRAYS

The only system required for storage of the HI-STAR 100 System is the loaded overpack itself. The HI-STAR 100 System is stored in a vertical orientation. A typical ISFSI storage pattern is illustrated in Figure 1.4.1, which shows an array in a rectangular layout pattern. The required center-to-center spacing between the modules (layout pitch) is guided by heat transfer considerations. Table 1.4.1 provides the nominal pitch, determined by heat transfer calculations in Chapter 4. The pitch may be increased to suit facility considerations.

Table 1.4.1

CASK LAYOUT MINIMUM PITCH DATA BASED ON THERMAL EVALUATION

MPC Type	**Nominal Cask Pitch (ft.)**
MPC-24	12
MPC-68	12

REPORT HI-2012610

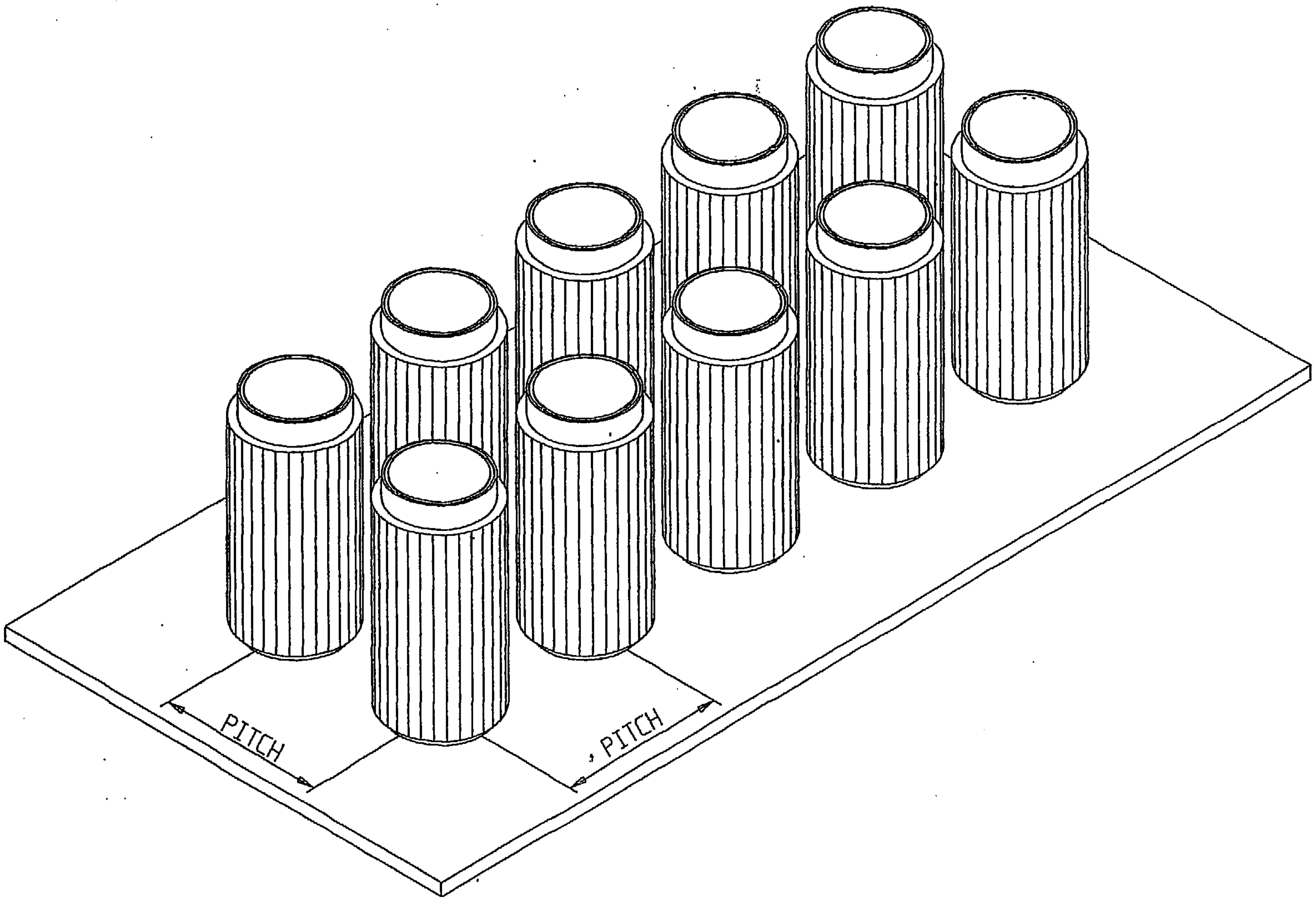


Figure 1.4.1; HI-STAR 100 TYPICAL ISFSI STORAGE PATTERN

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1.5 GENERAL ARRANGEMENT DRAWINGS and BILLS-OF-MATERIAL

The following detailed HI-STAR 100 System design drawings are provided in this section:

Drawing Number/Sheet	Description	Rev.
5014-1395 Sht 1/4	HI-STAR 100 MPC-24 Construction	12
5014-1395 Sht 2/4	HI-STAR 100 MPC-24 Construction	10
5014-1395 Sht 3/4	HI-STAR 100 MPC-24 Construction	10
5014-1395 Sht 4/4	HI-STAR 100 MPC-24 Construction	9
5014-1396 Sht 1/6	HI-STAR 100 MPC-24 Construction	13
5014-1396 Sht 2/6	HI-STAR 100 MPC-24 Construction	11
5014-1396 Sht 3/6	HI-STAR 100 MPC-24 Construction	10
5014-1396 Sht 4/6	HI-STAR 100 MPC-24 Construction	9
5014-1396 Sht 5/6	HI-STAR 100 MPC-24 Construction	8
5014-1396 Sht 6/6	HI-STAR 100 MPC-24 Construction	8
5014-1397 Sht 1/7	Cross Sectional View of HI-STAR 100 Overpack	17
5014-1397 Sht 2/7	Detail of Top Flange & Bottom Plate of HI-STAR 100 Overpack	12
5014-1397 Sht 3/7	Detail of Bolt Hole & Bolt of HI-STAR 100 Overpack	11
5014-1397 Sht 4/7	Detail of Closure Plate Test Port and Name Plate Detail of HI-STAR 100 Overpack	12
5014-1397 Sht 5/7	Detail of Lifting Trunnion & Locking Pad of HI-STAR 100 Overpack	10
5014-1397 Sht 6/7	Detail of Shear Ring and Closure Plate Bolt Installation of HI-STAR 100 Overpack	10
5014-1397 Sht 7/7	Detail of Shear Ring of HI-STAR 100 Overpack	9
5014-1398 Sht 1/3	HI-STAR 100 Overpack Orientation	13

Drawing Number/Sheet	Description	Rev.
5014-1398 Sht 2/3	Detail of Drain & Rupture Disk of HI-STAR 100 Overpack	10
5014-1398 Sht 3/3	Detail of Vent & Port Plug of HI-STAR 100 Overpack	9
5014-1399 Sht 1/3	Section "G" - "G" of HI-STAR 100 Overpack	12
5014-1399 Sht 2/3	Section "X"-"X" & View "Y" of HI-STAR 100 Overpack	9
5014-1399 Sht 3/3	Detail of Trunnion Pocket Forging of HI-STAR 100 Overpack	12
5014-1401 Sht 1/4	HI-STAR 100 MPC-68 Construction	13
5014-1401 Sht 2/4	HI-STAR 100 MPC-68 Construction	9
5014-1401 Sht 3/4	HI-STAR 100 MPC-68 Construction	10
5014-1401 Sht 4/4	HI-STAR 100 MPC-68 Construction	9
5014-1402 Sht 1/6	HI-STAR 100 MPC-68 Construction	14
5014-1402 Sht 2/6	HI-STAR 100 MPC-68 Construction	13
5014-1402 Sht 3/6	HI-STAR 100 MPC-68 Construction	12
5014-1402 Sht 4/6	HI-STAR 100 MPC-68 Construction	10
5014-1402 Sht 5/6	HI-STAR 100 MPC-68 Construction	9
5014-1402 Sht 6/6	HI-STAR 100 MPC-68 Construction	9
5014-1763 Sht 1/1	HI-STAR 100 Assembly	4
BM-1476, Sht 1/2	Bills-of-Material for HI-STAR 100 Overpack	14
BM-1476, Sht 2/2	Bills-of-Material for HI-STAR 100 Overpack	16
BM-1478, Sht 1/2	Bills-of-Materials for 24-Assembly HI-STAR 100 PWR MPC	10

BM-1479, Sht 1/2	Bills-of-Material for 68-Assembly HI-STAR 100 BWR MPC	11
BM-1479, Sht 2/2	Bills-of-Material for 68-Assembly HI-STAR 100 BWR MPC	14

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

BY: BY:

REVISION

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EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
HI-STAR 100 MPC-24 CONSTRUCTION

CLIENT N/A

A

COMPANION DRAWINGS
1396

REV.
12

PROJECT No. 5014

P.O. No. N/A

DRAWING No.
1395 SHT 1 OF 4
(E.I.D. 2853)

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

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EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
HI-STAR 100 MPC-24 CONSTRUCTION

CLIENT N/A

COMPANION DRAWINGS
1396

REV.
10

PROJECT No. 5014
P.O. No. N/A

DRAWING No.
1395 SHT 2 OF 4

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION		
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING	
DESCRIPTION HI-STAR 100 MPC-24 CONSTRUCTION		A
CLIENT N/A		
COMPANION DRAWINGS 1396	REV. 10	
PROJECT No. 5014 P.O. No. N/A	DRAWING No. 1395 SHT 3 OF 4	

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

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CLIENT N/A	
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PROJECT No. 5014 P.O. No. N/A	DRAWING No. 1395 SHT 4 OF 4

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FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

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EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
HI-STAR 100 MPC-24 CONSTRUCTION

CLIENT N/A

COMPANION DRAWINGS
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REV.
13

PROJECT No. 5014

P.O. No. N/A

DRAWING No.
1396 SHT 1 OF 6

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FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION

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INTERNATIONAL

EQUIPMENT DESIGN
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CONSULTING

DESCRIPTION
HI-STAR 100 MPC-24 CONSTRUCTION

CLIENT N/A

COMPANION DRAWINGS
1395

REV.
11

PROJECT No. 5014
P.O. No. N/A

DRAWING No.
1396 SHT 2 OF 6
(E.I.D. 2881)

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

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EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
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COMPANION DRAWINGS
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REV.
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PROJECT No. 5014
P.O. No. N/A

DRAWING No.
1396 SHT 3 OF 6

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION

HOLTEC
INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
HI-STAR 100 MPC-24 CONSTRUCTION

CLIENT N/A

COMPANION DRAWINGS
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REV.
9

PROJECT No. 5014

P.O. No. N/A

DRAWING No.
1396 SHT 4 OF 6

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION

HOLTEC INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION HI-STAR 100 MPC-24 CONSTRUCTION	
CLIENT N/A	
COMPANION DRAWINGS 1395	REV. 8
PROJECT No. 5014	DRAWING No. 1396 SHT 5 OF 6
P.O. No. N/A	

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FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION

HOLTEC
INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
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CLIENT N/A

COMPANION DRAWINGS
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REV.
8

PROJECT No. 5014
P.O. No. N/A

DRAWING No.
1396 SHT 6 OF 6

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION

HOLTEC
INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
HI-STAR 100 MPC-68 CONSTRUCTION

CLIENT N/A

COMPANION DRAWINGS
1402

REV.
13

PROJECT No. 5014
P.O. No. N/A

DRAWING No.
1401 SHT 1 OF 4
(E.I.D. 2859)

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION

HOLTEC
INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION	HI-STAR 100 MPC-68 CONSTRUCTION
CLIENT	N/A
COMPANION DRAWINGS	1402
REV.	9
PROJECT No.	5014
P.O. No.	N/A
DRAWING No.	1401 SHT 2 OF 4

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION

HOLTEC
INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
HI-STAR 100 MPC-68 CONSTRUCTION

CLIENT N/A

COMPANION DRAWINGS
1402

REV.
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PROJECT No. 5014
P.O. No. N/A

DRAWING No.
1401 SHT 3 OF 4

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION

HOLTEC
INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
HI-STAR 100 MPC-68 CONSTRUCTION

CLIENT N/A

COMPANION DRAWINGS
1402

REV.
9

PROJECT No. 5014
P.O. No. N/A

DRAWING No.
1401 SHT 4 OF 4

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

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INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
HI-STAR 100 MPC-68 CONSTRUCTION

CLIENT N/A

COMPANION DRAWINGS
1401

REV.
14

PROJECT No. 5014

P.O. No. N/A

DRAWING No.
1402 SHT 1 OF 6

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION

HOLTEC
INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
HI-STAR 100 MPC-68 CONSTRUCTION

CLIENT N/A

COMPANION DRAWINGS
1401

REV.
13

PROJECT No. 5014
P.O. No. N/A

DRAWING No.
1402 SHT 2 OF 6
(E.I.D. 2882)

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

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INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
HI-STAR 100 MPC-68 CONSTRUCTION

CLIENT N/A

COMPANION DRAWINGS
1401

REV.
12

PROJECT No. 5014
P.O. No. N/A

DRAWING No.
1402 SHT 3 OF 6

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION

HOLTEC
INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
HI-STAR 100 MPC-68 CONSTRUCTION

CLIENT N/A

COMPANION DRAWINGS
1401

REV.
10

PROJECT No. 5014
P.O. No. N/A

DRAWING No.
1402 SHT 4 OF 6

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION

HOLTEC
INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
HI-STAR 100 MPC-68 CONSTRUCTION

CLIENT N/A

COMPANION DRAWINGS
1401

REV.
9

PROJECT No. 5014
P.O. No. N/A

DRAWING No.
1402 SHT 5 OF 6

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION	
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING
DESCRIPTION HI-STAR 100 MPC-68 CONSTRUCTION	
CLIENT N/A	
COMPANION DRAWINGS 1401	REV. 9
PROJECT No. 5014	DRAWING No. 1402 SHT 6 OF 6 (E.I.D. 2880)
P.O. No. N/A	

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION

HOLTEC
INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
CROSS SECTIONAL VIEW
OF HI-STAR 100 OVERPACK

CLIENT N/A

COMPANION DRAWINGS
1398, 1399

REV.
17

PROJECT No. 5014
P.O. No. N/A

DRAWING No.
1397 SHT. 1 OF 7
(E.I.D. 2854)

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION

HOLTEC
INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
DETAIL OF TOP FLANGE & BOTTOM PLATE
OF HI-STAR 100 OVERPACK

CLIENT N/A

COMPANION DRAWINGS
1398, 1399

REV.
12

PROJECT No. 5014

P.O. No. N/A

DRAWING No.
1397 SHT. 2 OF 7
(E.I.D. 2855)

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION

HOLTEC INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
DETAIL OF BOLT HOLE & BOLT
OF HI-STAR 100 OVERPACK

CLIENT N/A

COMPANION DRAWINGS	REV.
1398, 1399	11

PROJECT No. 5014	DRAWING No.
P.O. No. N/A	1397 SHT. 3 OF 7

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION

HOLTEC
INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
DETAIL OF CLOSURE PLATE TEST PORT
AND NAME PLATE DETAIL
OF HI-STAR 100 OVERPACK

CLIENT N/A

COMPANION DRAWINGS 1398, 1399

REV. 12

PROJECT No. 5014

P.O. No. N/A

DRAWING No. 1397 SHT. 4 OF 7

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION

HOLTEC
INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
DETAIL OF LIFTING TRUNNION & LOCKING PAD
OF HI-STAR 100 OVERPACK

CLIENT N/A

COMPANION DRAWINGS
1398, 1399

REV.
10

PROJECT No. 5014

P.O. No. N/A

DRAWING No.
1397 SHT. 5 OF 7
(E.I.D. 2856)

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION

HOLTEC
INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION DETAIL OF SHEAR RING AND CLOSURE PLATE BOLT INSTALLATION OF HI-STAR 100 OVERPACK

CLIENT N/A

COMPANION DRAWINGS	REV.
1398, 1399	10

PROJECT No. 5014
P.O. No. N/A

DRAWING No.
1397 SHT. 6 OF 7
(E.I.D.2857)

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

NOV 1.99	9	INCORPORATED ECO/ SMDR/MISC CHANGES	S.GEE 11-1-99	11/22/99	[illegible]	[illegible]
MAY 19.98	8	INCORPORATED DCR# 5014 - 97	S.GEE 5-19-98	M.S 5-19-98	B.G. 5-19-98	V G 5-19-98
DATE	**REV.**	**DESCRIPTION**	**PREP. BY:**	**CHECKED BY:**	**ENG.**	**Q. A.**

REVISION

HOLTEC INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
DETAIL OF SHEAR RING
OF HI-STAR 100 OVERPACK

CLIENT N/A

COMPANION DRAWINGS 1398, 1399

REV. 9

PROJECT No. 5014

P.O. No. N/A

DRAWING No. 1397 SHT. 7 OF 7

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION	
HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING
DESCRIPTION HI-STAR 100 OVERPACK ORIENTATION	
CLIENT N/A	
COMPANION DRAWINGS 1397, 1399	REV. 13
PROJECT No. 5014	DRAWING No.
P.O. No. N/A	1398 SHT. 1 OF 3

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

HOLTEC
INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
DETAIL OF DRAIN & RUPTURE DISK
OF HI-STAR 100 OVERPACK

CLIENT N/A

COMPANION DRAWINGS 1397, 1399
REV. 10

PROJECT No. 5014
P.O. No. N/A
DRAWING No. 1398 SHT. 2 OF 3

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION

HOLTEC INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
DETAIL OF VENT & PORT PLUG
OF HI-STAR 100 OVERPACK

CLIENT N/A

COMPANION DRAWINGS	REV.
1397, 1399	9

PROJECT No. 5014	DRAWING No.
P.O. No. N/A	1398 SHT. 3 OF 3

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

BY: BY:

REVISION

HOLTEC
INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
SECTION "G" - "G"
OF HI-STAR 100 OVERPACK

CLIENT N/A

COMPANION DRAWINGS
1397, 1398

REV.
12

PROJECT No. 5014

P.O. No. N/A

DRAWING No.
1399 SHT. 1 OF 3

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

BY: BY:

REVISION

HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING
DESCRIPTION SECTION "X"-"X" & VIEW "Y" OF HI-STAR 100 OVERPACK	
CLIENT N/A	
COMPANION DRAWINGS 1397, 1398	REV. 9
PROJECT No. 5014 P.O. No. N/A	DRAWING No. 1399 SHT. 2 OF 3

A

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

REVISION

HOLTEC
INTERNATIONAL

EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION
DETAIL OF TRUNNION POCKET FORGING
OF HI-STAR 100 OVERPACK

CLIENT N/A

COMPANION DRAWINGS
1397, 1398

REV.
12

PROJECT No. 5014

P.O. No. N/A

DRAWING No.
1399 SHT. 3 OF 3
(E.I.D. 2858)

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

HOLTEC INTERNATIONAL	EQUIPMENT DESIGN ANALYSIS CONSULTING
DESCRIPTION HI-STAR 100 ASSEMBLY	
CLIENT N/A	
COMPANION DRAWINGS ---	REV. 4
PROJECT No. 5014	DRAWING No.
P.O. No. N/A	1763

A

BILL OF MATERIALS FOR HI-STAR 100 OVERPACK (BM-1476)
(E.I.D. 2851)

REF. DWGS. 1397,1398 & 1399.

SHEET 1 OF 2

REV. NO.	PREP. BY & DATE	CHECKED BY DATE	PROJ. MANAGER & DATE	QA. MANAGER & DATE
14	S.GEE 2-1-2000 INCORPORATED ECO-1020-3	2/14/00	2/14/00	2/14/00

ITEM NO.	QTY.	MATERIAL	DESCRIPTION	NOMENCLATURE
1	1	SA-350 LF3	12" X 83 1/4" O.D. BASE PLATE	BOTTOM PLATE
2	1	SA-203-E	2 1/2" THK. X 223 7/8" X 174 1/8" PLATE	INNER SHELL
3	20	SA-515 GRADE 70	1/2" THK. X 172 1/8" X 8" APPROX. PLATE	ENCLOSURE SHELL PANELS
4	20	SA-515 GRADE 70	1/2" THK. X 172 1/8" X 17 1/2" LG. APPROX.	RADIAL CHANNELS
5	2	SA-705 630 17-4 PH OR SA-564 630 17-4 PH	11" THK. X 12 3/8" WIDE X 14" LG.	POCKET TRUNNION
6	4	SA-193 GRADE B7	5/8" - 11 UNC X 1 1/4" LG. SOCKET SET SCREW	CLOSURE PLATE PLUG
7	2	SB-637-N07718	7 1/4" O.D. X 9 1/4" LG. BAR	LIFTING TRUNNION
8	1	SA-350 LF3	68 3/4" I.D. X 86 1/4" O.D. X 24" LG. FORGING	TOP FLANGE
9	2	SA-203-E OR SA-350-LF3	1 1/2" THK. X 5 5/8" WIDE X 25" LG. BAR	REMOVEABLE SHEAR RING
10	1	SA-350 LF3	6" THK. X 77 3/8" O.D.	CLOSURE PLATE
11	2	SB-637-N07718	1 5/8" - 8 UN X 7 1/8" LG. 12 POINT CAP SCREW W/ 3 1/2" LG. THREAD (W/2.43" DIA. X 1 5/8" TOTAL HIGH HD. PER DET. DWG.1397 SHT.3)	CLOSURE PLATE SHORT BOLT
12	1	SA-516 GRADE 70	1 1/4" THK. X 174 1/8" X 235 5/8" APPROX. PLATE	INTERMEDIATE SHELL #1
13	1	SA-516 GRADE 70	1 1/4" THK. X 174 1/8" X 243 1/2" APPROX. PLATE	INTERMEDIATE SHELL #2
14	1	SA-516 GRADE 70	1 1/4" THK. X 174 1/8" X 251 3/8" APPROX. PLATE	INTERMEDIATE SHELL #3
15	1	SA-516 GRADE 70	1 1/4" THK. X 174 1/8" X 259 3/16" APPROX. PLATE	INTERMEDIATE SHELL #4
16	1	SA-516 GRADE 70	1" THK. X 173 7/8" X 266 1/4" APPROX. PLATE	INTERMEDIATE SHELL #5
17	2	SA-515 GRADE 70	1/2" THK. X 85 3/4" I.D. X 96" O.D. PLATE	ENCLOSURE SHELL RETURN
18	2	SA-193 GRADE B8	7/8" Ø X 4 7/16" LG. BAR (SEE DETAIL ON DWG. 1398 SHT. 3)	PORT PLUG
19	3	ALLOY X750	0.75 O.D. X 0.615 I.D. SPRING ENERGIZED SEAL, PART ASE50033 (AMERICAL SEAL) OR EQUIVALENT	PORT PLUG SEAL
20	4	SA-193 GRADE B7	1/4 - 20 UNC X 1/2 LG. SOCKET CAP SCREW	TRUNNION LOCKING PAD BOLT
21	2	SA-516 GRADE 70	1/2" THK. X 6 1/4" O.D PLATE	LIFTING TRUNNION END CAP
22	4	SA-193 GRADE B7	1/2" - 13 UNC X 1" LG. HEX. BOLTS	TRUNNION END CAP BOLT
23	2	SA-516 GRADE 70	3/8" THK. X 7 3/4" X 9 3/4" PLATE	LIFTING TRUNNION LOCKING PAD
24	AS REQ.	HOLTITE - A	HOLTITE-A WITH 1 WT. % B_4C	NEUTRON SHIELD
25	8	SA-193 GRADE B7	3/8" - 16 UNC X 1/2" LG. SOCKET SET SCREW	REMOVEABLE SHEAR RING PLUG
26	1	COMMERCIAL	3/8" X 71" O.D. SELF ENERGIZED SEAL, INTERNAL PRESSURE OR EQUIVALENT	CLOSURE PLATE INNER SEAL

△16

BILL OF MATERIALS FOR HI-STAR 100 OVERPACK (BM-1476)
(E.I.D. 2852)

REF. DWGS. 1397,1398 & 1399.

SHEET 2 OF 2

REV. NO.	PREP. BY & DATE	CHECKED BY DATE	PROJ. MANAGER & DATE	QA. MANAGER & DATE
16	S.GEE 2-1-2000 INCORPORATED ECO-1020-2, -3	2/4/00	2/4/00	2/4/00

	ITEM NO.	QTY.	MATERIAL	DESCRIPTION	NOMENCLATURE
△15	27	1	COMMERCIAL	3/8" X 72.5" O.D. SELF ENERGIZED SEAL, INTERNAL PRESSURE OR EQUIVALENT	CLOSURE PLATE OUTER SEAL
	28	2	SA-350-LF3 OR SA-203-E	1 1/2" THK. X 5 1/2" Ø PLATE	PORT COVER
△15	29	8	SA-193 GRADE B7	3/8 - 16 UNC X 5/8 LG. SOCKET CAP SCREW	PORT COVER BOLT
	30	2	ALLOY X750	2 1/2" O.D. SPRING ENERGIZED C-RING, INTERNAL PRESSURE (AMERICAL SEAL) OR EQUIVALENT	PORT COVER SEAL
△15	31	--	---	DELETED	---
	32	52	SB-637-N07718	1 5/8" - 8 UN X 7 3/8" LG. 12 POINT CAP SCREW W/ 3 3/4" LG. THREAD. (W/2.43" DIA. X 1 5/8" TOTAL HIGH HD. PER DET.DWG.1397. SHT.3)	CLOSURE PLATE LONG BOLT
△15	33	2	COMMERCIAL	RUPTURE DISK (RELIEVE AT 30 PSIG (±5 PSIG)) (1 1/2 IN^2 FLOW AREA)	RUPTURE DISK
△15	34	8	SA-193 GRADE B7	3/8" - 16 UNC X 1 3/8" LG. SOCKET CAP SCREW	REMOVEABLE SHEAR RING BOLT
	35	1	SA-193 GRADE B8	7/8" Ø X 3 13/16" LG. BAR (SEE DETAIL ON DWG. 1398)	DRAIN PORT PLUG
△16	36	AS REQD	SA 515 GR.70	1/2" THK PLATE	POCKET TRUNNION SURROUND
	37	AS REQ.	SILICONE FOAM	TYPE HT-870 (BISCO PRODUCTS) OR EQUIVALENT	THERMAL EXPANSION FOAM
△15	38	--	---	DELETED	---
△15	39	2	SA-516 GRADE 70 OR A569	11 GAGE (1/8" THK.)	RUPTURE DISK PLATE
	40	1	SA 240 304	14 GAGE (0.0751" THK.) X 4" WIDE X 10" LG. SHEET	STORAGE MARKING NAME PLATE
	41	1	SA 240 304	14 GAGE (0.0751" THK.) X 6 1/2" WIDE X 10" LG. SHEET	TRANSPORTATION MARKING NAME PLATE
△15	42	AS REQD	SA515-70	AS REQUIRED	BRIDGE
	43	2	SA 240 304	11 GAGE (1/8" THK.) X 6 1/8" WIDE X 7 11/16" LG. PLATE	POCKET TRUNNION PLUG PLATE
	44	2	SA 240 304	11 GAGE (1/8" THK.) X 1 1/2" WIDE X 9 1/2" LG. PLATE	POCKET TRUNNION PLUG PLATE
	45	2	SA 240 304	11 GAGE (1/8" THK.) X 3 1/2" WIDE X 18 7/8" LG. PLATE	POCKET TRUNNION PLUG PLATE
	46	2	SA 240 304	11 GAGE (1/8" THK.) X 3 3/4" WIDE X 6 1/8" LG. PLATE	POCKET TRUNNION PLUG PLATE
	47	2	SA 240 304	11 GAGE (1/8" THK.) X 6 1/8" WIDE X 7 11/16" LG. PLATE	POCKET TRUNNION PLUG PLATE
△15	48	4	SA-193 GRADE B7	3/8 - 16 UNC X 1/2" LG. SOCKET CAP SCREW	POCKET TRUNNION PLUG SCREW
△15	49	54	S/S	11 GAGE (1/8" THK.) X 1 3/4" ID. X 2 5/8" OD.	CLOSURE BOLT WASHER
	50	40	SA-193-B7	1 3/4"-5UNC X 1 1/8" LG. SOCKET SET SCREW	TOP FLG. LIP HOLE PLUGS
	51	20	SA-193-B7	1"-8UNC X 1 1/4" LG. SOCKET SET SCREW	TOP FLG. SIDE HOLE PLUGS
△15	52	16	SA-193-B7	1 3/4"-8UNC X 2 1/4" LG. SOCKET SET SCREW	BOTTOM PLATE HOLE PLUGS
△16 △15	53	8	SA-193-B7	2 1/2"-4UN X 2 1/2 LG SOCKET SET SCREW	THREADED PLUG
	54	4	SA-193-B7	1/2-13UNC X 5/8" LG SOCKET SET SCREW	THREADED PLUG

NOTES:
1) ALL DIMENSIONS ARE APPROXIMATE.
2) HOLTITE IS A NEUTRON SHIELD MATERIAL WITH 1 WT. % B_4C, 6 WT. % H, AND A DENSITY OF 1.68g/cm^3.
3) ITEMS 12 THRU 16, MATERIAL SA-516-GR 70 IS TO BE NORMALIZED.
△15 4) THICKNESS OF ITEM 16 MAY VARY DEPENDING ON THICKNESSES OF ITEMS 12-15.
5) ITEMS 2,12-17 MAY BE MADE FROM MORE THAN ONE PIECE.

\DRAWINGS\5014\5014\OVERPACK\BM1476-2.R16

BILL OF MATERIALS FOR 24-ASSEMBLY HI-STAR 100 PWR MPC.(BM-1478)

SHEET 1 OF 2

REF. DWG. 1395 & 1396.

REV.NO.	PREP. BY & DATE	CHECKED BY & DATE	PROJ. MANAGER & DATE	QA. MANAGER & DATE
10	S.GEE 11-3-99 REVISED AS INDICATED	11/22/99	B.G. 11/23/99	MC 11/22/99

	ITEM NO.	QTY.	MATERIAL	DESCRIPTION	NOMENCLATURE
	1A	2	ALLOY "X" SEE NOTE 1.	PLATE 5/16" THK.X 63.20" REF W. X 176 1/2" LG	BASKET CELL PLATE
	1B	1	↓	PLATE 5/16" THK X 60.57" REF W. X 176 1/2"LG.	BASKET CELL PLATE
	1C	2	↓	PLATE 5/16" THK X 43.42" REF W. X 176 1/2"LG.	BASKET CELL PLATE
	1D	1	↓	PLATE 5/16" THK X 20.402 " REF W. X 176 1/2"LG.	BASKET CELL PLATE
	1E	1	↓	PLATE 5/16" THK X 7.7175" REF W. X 176 1/2"LG.	BASKET CELL PLATE
	1F	22	↓	PLATE 5/16" THK X10.4625 " REF W. X 176 1/2"LG.	BASKET CELL PLATE
	1G	1	↓	PLATE 5/16" THK X 9.7445 " REF W. X 176 1/2"LG.	BASKET CELL PLATE
	1H	2	↓	PLATE 5/16" THK X 9.03 " REF W. X 176 1/2"LG.	BASKET CELL PLATE
	2	24	▽	PIPE 3"-SCH 80 LGTH AS REQD.	UPPER FUEL SPACER PIPE
	3A (3B)	84(12)	BORAL	.075"THK. X 7.5"W.(6 1/4") X 156" LG.PER DET.DWG.1395. SEE NOTE 2.	NEUTRON ABSORBER
	4A (4B)	84(12)	ALLOY "X" SEE NOTE 1.	.06" THK. SHEATHING PER DET. DWG. 1395.	SHEATHING
	5A	4	↓	PLATE 5/16"THK X 3" W. X 176 1/2"LG.	BASKET CELL PLATE
	5B	4	↓	PLATE 5/16"THK X 3 3/4" APPROX. W. X 176 1/2"LG.	BASKET CELL PLATE
	5C	4	↓	PLATE 1.5" APP. THK. X 3" W. X 168"LG.	BASKET SUPPORT
△10	5D	4	↓	2 1/2" W X 168" LG	BASKET SUPPORT
	5E	4	↓	2 "WIDE X 168"LG. THICKNESS AS REQD.	BASKET SUPPORT
△10	5F	-	↓	DELETED	---
△10	5G	4	↓	1 1/4" W X 1" THK X 168" LG.	BASKET SUPPORT SHIM
	5H	---	↓	DELETED	-----
	6	1	↓	1/2" THK X 68 3/8" O.D. X 187 5/8" LG. CYLINDER.	SHELL
	7	1	↓	BASEPLATE 2 1/2" THK X 68 3/8" O.D.	BASEPLATE
	8A	22	↓	9/32"THK. ANGLE X 176 1/2" LG. FROM PLATE PER DET. DWG.1395.	BASKET CELL ANGLE
	8B	2	↓	9/32"THK. CHANNEL X 176 1/2" LG. FROM PLATE PER DET.DWG. 1395.	BASKET CELL CHANNEL
	9A	1	↓	5/16" THK.X 10" W. APP. X 168" LG. PER DET.	BASKET SUPPORT
	9B	2	↓	5/16"THK. X 7 1/2" APP. W. X 168" LG. PER DET.	BASKET SUPPORT
	9C	1	↓	5/16"THK. X 5" APP. W. X 168" LG. PER DET.	BASKET SUPPORT
△10	9D	AS REQD	↓	AS REQUIRED	BASKET SUPPORT
	9E	----	↓	DELETED	---
	9F	---	↓	DELETED	---
	9G	---	↓	DELETED	---
	9H	---	↓	DELETED	---
	10	4	▽	PLATE 3/4" THK. X 3 1/2" WIDE X 8 3/4" LG.	LIFT LUG

BILL OF MATERIALS FOR 24-ASSEMBLY HI-STAR 100 PWR MPC.(BM-1478)

SHEET 2 OF 2

REF. DWG. 1395 & 1396.

REV.NO.	PREP. BY & DATE	CHECKED BY & DATE	PROJ. MANAGER & DATE	QA. MANAGER & DATE
12	S.GEE 11-3-99 REVISED AS INDICATED	11/22/99	B.G. 11/22/99	MS 11/22/99

	ITEM NO.	QTY.	MATERIAL	DESCRIPTION	NOMENCLATURE
	11	4	ALLOY "X" SEE NOTE 1.	PLATE 3/4" THK. X 4" WIDE X 3" LG.	LIFT LUG BASEPLATE
	12	1	ALLOY "X" SEE NOTE 1.	BAR 3.75" OD. X 5 7/8" LG.	DRAIN SHIELD BLOCK
△12	13A	2	304 S/S	BAR 2 11/16" OD X 6.75" LG. DIMENSIONS AS SHOWN ON DWG 1396 SH 4	VENT AND DRAIN TUBE
△12	13B	2	304 S/S	BAR 2 1/4 OD X 2 1/4 LG. DIMENSIONS AS SHOWN ON DWG 1396 SH 4	VENT AND DRAIN TUBE CAP
△12	14	1	ALLOY "X" SEE NOTE 1.	9 1/2" THK. X 67 1/4" O.D.	MPC LID
	15	1	↓	RING 3/8" THK.X 53 1/4" ID. X 67 5/8" O.D.	MPC CLOSURE RING
△12	16	---	----	DELETED	---
	17	----	----	DELETED	----
△12	18	AS REQD	ALLOY "X" SEE NOTE 1.	AS REQUIRED	BASKET SUPPORT
	19	2	ALLOY "X" SEE NOTE 1.	PLATE 3/8" THK. X 3 7/8"OD.	PORT COVER PLATE
△12	20	24	A-193-B8 OR SIMILAR	3/4"-10UNC X 1 1/4"LG. HEX BOLT WITH FULL THRD.	UPPER FUEL SPACER BOLT
△12	21	AS REQD	ALLOY "X" SEE NOTE 1.	3/4" X 2" X THICKNESS AS REQUIRED	LIFT LUG SHIM
	22	---	---	DELETED	---
	23	4	A-193-B8 OR SIMILAR	1 3/4"-5UNC X 2 3/4"LG SOCKET SET SCREW	LID LIFT HOLE PLUG
	24	24	ALLOY "X" SEE NOTE 1.	PLATE 3/8" THK X 4" OD.	UPPER FUEL SPACER END PLATE
	25	1 SET	ALLOY "X" SEE NOTE 1.	LENGTH, WIDTH AND THICKNESS OF SHIMS AS REQUIRED.	LID SHIM
△12	26	1	S/S	COUPLING	COUPLING
△12	27	AS REQD	ALLOY "X" SEE NOTE 1.	3/4" X 5" DIAM.	UPPER FUEL SPACER END PLATE
	28	1	ALLOY "X" SEE NOTE 1.	BAR 3.75" OD. X 5.5"LG.	VENT QUICK DISCONN. CPLG.
	29	4	ALLOY "X" SEE NOTE 1.	BAR 3/4" OD. X 1/2" LG.	VENT SHIELD BLOCK SPACER
	30	1	ALLOY "X" SEE NOTE 1.	2"-SCH 10 PIPE X 173 1/2"APPROX. LG.	DRAIN LINE
	31	--	-------	DELETED	-----
	32	24	↓	6" SQ. TUBING X 1/4" WALL LENGTH AS REQ'D.	LOWER FUEL SPACER CLUMN
	33A	24		PLATE 3/8" THK X 8.5" SQ.	LOWER FUEL SPCAER END PLATE
	33B	24		PLATE 3/8" THK X 8.5" SQ.	LOWER FUEL SPCAER END PLATE
△12	34	---	--------	DELETED	-------
△12	35	AS REQ'D.	ALUM. ALLOY 1100 & S/S	1/8" THICK X 176 1/2" LG. ALUM. SHEET (153" LG (APP.) AT DRAIN PIPE LOCATION) WITH S/S SPRINGS	HEAT CONDUCTION ELEMENTS
	36	2	ALUMINUM	0.065" THK 1.494 OD, 0.250" HOLE	SEAL WASHER
	37	2	S/S	1/4" DIA X 3/8" LG	SEAL WASHER BOLT
	38	2	ALLOY "X" SEE NOTE 1.	1/8" X 10 1/2" X 9 1/2" SHEET	DRAINLINE
	39	8	ALLOY "X" SEE NOTE 1.	1/8" X 4" X 4 1/2" APPRPX SHEET	DRAINLINE

NOTES: (FOR SHEET 1 & 2)

1. ALLOY X IS ANY OF THE FOLLOWING ACCEPTABLE STAINLESS STEEL ALLOYS: ASME TYPE 316, 316LN, 304, 304LN. THE ALLOY TO BE USED SHALL BE SPECIFIED BY THE LICENSEE.
2. MINIMUM BORAL B-10 LOADING IS 0.0267 g/cm^2. BORAL TO BE PASSIVATED PRIOR TO INSTALLATION.
3. ALL DIMENSIONS ARE APPROXIMATE DIMENSIONS.
4. △12 ITEMS 5C,5D,5E,5G 9A,9B,9C,9D,16,18, AND 35 MAY BE MADE FROM MORE THAN ONE PIECE. THE ENDS OF PIECES DO NOT NEED TO BE WELDED TOGETHER BUT THEY MUST NE FLUSH WITH EACH OTHER WHEN INSTALLED.

\DRAWINGS\5014\5014\MPC\BM1478-2.R12

BILL OF MATERIALS FOR 68-ASSEMBLY HI-STAR 100 BWR MPC.(BM-1479)

SHEET 1 OF 2

REF. DWGS. 1401 & 1402.

REV. NO.	PREP. BY & DATE	CHECKED BY DATE	PROJ. MANAGER & DATE	QA. MANAGER & DATE
11	S.GEE 11-3-99 REVISED AS INDICATED	11/22/99	B.G. 11/22/99	MS 11/22/99

	ITEM NO.	QTY.	MATERIAL	DESCRIPTION	NOMENCLATURE
	1A	3	ALLOY "X" SEE NOTE 1.	PLATE 1/4" THK. X 65.65"W. X 176" LG PER DET. DWG.1401.	BASKET CELL PLATE
	1B	4	↓	PLATE 1/4" THK. X 52.67"W. X 176" LG PER DET. DWG.1401.	BASKET CELL PLATE
	1C	2	↓	PLATE 1/4" THK. X 39.69W. X 176" LG PER DET. DWG.1401.	BASKET CELL PLATE
	1D	2	↓	PLATE 1/4" THK. X 13.73"W. X 176" LG PER DET. DWG.1401.	BASKET CELL PLATE
	1E	78	↓	PLATE 1/4" THK. X 6.24"W. X 176" LG PER DET. DWG.1401.	BASKET CELL PLATE
	2	68	▽	3"- SCH 80 PIPE LGTH AS REQD.	UPPER FUEL SPCER CLUMN
	3A	116	BORAL	.101"THK. X 4 3/4"W. X 156" LG.PER DET.DWG.1401. SEE NOTE 2.	NEUTRON ABSORBER
	4A	116	ALLOY "X" SEE NOTE 1.	.075" THK. SHEATHING PER DET. DWG.1401.	SHEATHING
11	5	8	↓	BAR 1" WIDE X 168" LG X THICKNESS AS REQUIRED	BASKET SUPPORT SHIM
	6	1	↓	1/2" THK X 68 3/8" O.D. X 187 5/8" LG. CYLINDER.	SHELL
	7	1	↓	BASEPLATE 2 1/2" THK X 68 3/8" O.D.	BASEPLATE
	8	8	↓	PLATE 5/16"THK. X 10" APPROX.W.X 168 1/2" LG. PER DET. DWG.1401.	BASKET SUPPORT
	9A	4	↓	BAR 1" W. X .8" APPROX.THK. X 168 1/2" LG.	BASKET SUPPORT
11	9B	---	↓	DELETED	---
	9C	8	↓	2 1/2" WIDE X 168 1/2" LG. THICKNESS AS REQD. ROLL TO SHELL I.D.	BASKET SUPPORT
11	9D	AS REQD	↓	AS REQUIRED	BASKET SUPPORT
	10	4	↓	PLATE 3/4" THK. X 3 1/2" WIDE X 8 3/4" LG.	LIFT LUG
	11	4	↓	PLATE 3/4" THK. X 2 1/2" WIDE X 4" LG.	LIFT LUG BASEPLATE
	12	1	▽	BAR 3.75"OD. X 5 7/8" LG.	DRAIN SHIELD BLOCK
11	13A	2	304 S/S	BAR 2 11/16" OD X 6 3/4" REF LG, DIMENSION ON DWG 1402 SHT 4	VENT AND DRAIN TUBE
11	13B	2	304 S/S	BAR 2 1/4" OD X 2 1/4" REF LG, DIMENSION ON DWG 1402 SHT 4	VENT AND DRAIN TUBE CAP
11	14	1	ALLOY "X" SEE NOTE 1.	10" THK. X 67 1/4" O.D. [MPC-68] 10" THK. X 66 1/4" O.D. [MPC-68F]	MPC LID
	15	1	ALLOY "X" SEE NOTE 1.	RING 3/8" THK. X 53 1/4" ID. X 67 5/8" O.D. [MPC-68] RING 3/8" THK. X 53 1/4" ID. X 67 1/8" O.D. [MPC-68F]	MPC CLOSURE RING
11	16	---	---	DELETED	---

BILL OF MATERIALS FOR 68-ASSEMBLY HI-STAR 100 BWR MPC. (BM-1479)

SHEET 2 OF 2

REF. DWGS. 1401 & 1402.

REV. NO.	PREP. BY & DATE	CHECKED BY DATE	PROJ. MANAGER & DATE	QA. MANAGER & DATE
14	S. GEE 11-3-99 REVISED AS INDICATED	11/22/99	B.G. 11/22/95	MS 11/22/99

	ITEM NO.	QTY.	MATERIAL	DESCRIPTION	NOMENCLATURE
	17	1	ALLOY "X" SEE NOTE 1.	1" THK X 68 3/8" OD X 11 5/8" LG. CYLINDER [MPC-68F]	SHELL
△14	18	AS REQD	ALLOY "X" SEE NOTE 1.	AS REQUIRED	BASKET SUPPORT
	19	2	ALLOY "X" SEE NOTE 1.	PLATE 3/8" THK X 3 7/8" OD.	PORT COVER PLATE
	20	68	A-193-B8 OR SIMILAR	3/4"-10UNC X 1.25"LG. FULL THRD. HEX. BOLT	UPPER FUEL SPACER BOLT
△14	21	AS REQD	ALLOY "X" SEE NOTE 1.	3/4" W X 2' LG X THICKNESS AS REQUIRED	LIFT LUG SHIM
	22	---	---	DELETED	---
	23	4	A-193-B8 OR SIMILAR	1 3/4"-5UNC X 2 3/4" LG. SOCKET SET SCREW.	LIFT HOLE PLUG
△14	24	68	ALLOY "X" SEE NOTE 1.	PLATE 3/8" THK X 4" OD.	UPPER FUEL SPACER END PLATE
	25	1 SET	ALLOY "X" SEE NOTE 1	LENGTH, WIDTH , THICKNESS AND QUANTITY AS REQD.	LID SHIM
△14	26	1	S/S	COUPLING	COUPLING
	27			DELETED	
	28	1	ALLOY "X" SEE NOTE 1.	BAR 3.75" OD. X 5.5" LG.	VENT SHIELD BLOCK
	29	4	ALLOY "X" SEE NOTE 1.	BAR .75"OD X .5"LG.	VENT SHIELD BLOCK SPACER
	30	1	ALLOY "X" SEE NOTE 1.	2"-SCH 10 PIPE X 173" APPROX.LG.	DRAIN LINE
	31	--	--	DELETED	---
	32	--	--	DELETO	---
	33	68	ALLOY "X" SEE NOTE 1.	4" SQ. TUBE X 1/4" WALL LENGTH AS REQD. (FOR SHORT FUEL ONLY)	LOWER FUEL SPACER CLUMN
	34A	68	ALLOY "X" SEE NOTE 1.	3/8" THK. X 5 3/4" SQ. PLATE (FOR SHORT FUEL ONLY)	LOWER FUEL SPACER END PLATE
	34B	68	ALLOY "X" SEE NOTE 1.	3/8" THK. X 5 3/4" SQ. PLATE (FOR SHORT FUEL ONLY)	LOWER FUEL SPACER END PLATE
	35	----	----------	DELETED	
△14	36	----	----------	DELETED	
△14	37	AS REQD	ALUM. ALLOY 1100 & S/S	1/8" THK. X 176" LG. ALUM. SHEET (153" LG APP. AT DRAIN PIPE LOCATION.) W/S/S SPRINGS.	HEAT CONDUCTION ELEMENTS
	38	2	ALUMINUM	.065" THK X 1.494 OD, .250 HOLE	SEAL WASHER
	39	2	S/S	1/4" DIA X 3/8 LG	SEAL WASHER BOLT
	40	2	ALLOY "X" SEE NOTE 1	1/8" THK. 6" X 6" APPROX. SHEET	DRAIN LINE
	41	8	ALLOY "X" SEE NOTE 1.	1/8" THK. X 6" X 6" APPROX. SHEET	DRAIN LINE

NOTES: (FOR SHEET 1 & 2)

1. ALLOY X IS ANY OF THE FOLLOWING ACCEPTABLE STAINLESS STEEL ALLOYS: ASME TYPE 316, 316LN, 304, 304LN. THE ALLOY TO BE USED SHALL BE SPECIFIED BY THE LICENSEE.
2. MINIMUM BORAL B-10 LOADING IS 0.0372 g/cm^2. BORAL TO BE PASSIVATED PRIOR TO INSTALLATION. FOR MPC-68F, MINIMUM BORAL B-10 LOADING IS 0.01 g/cm^2.
3. ALL DIMENSIONS ARE APPROXIMATE DIMENSIONS.
4. △14 ITEMS 5,8,9A,9C,9D,16,18, AND 37 MAY BE MADE FROM MORE THAN ONE PIECE. THE ENDS OF PIECES DO NOT NEED TO BE WELDED TOGETHER BUT THEY MUST BE FLUSH WITH EACH OTHER WHEN INSTALLED.

1.6 REGULATORY COMPLIANCE

Chapter 1 provides a general description of the HI-STAR 100 System which allows a reviewer to obtain a basic understanding of the system, its components, and the protection afforded for the health and safety of the public. The chapter has been written to provide the following pertinent information to allow verification of compliance with 10CFR72, NUREG-1536, and Regulatory Guide 3.61:

- A general description and discussion of the HI-STAR 100 System is presented in Sections 1.1 and 1.2 of the FSAR with special attention to design and operating characteristics, unusual or novel design features, and principal safety features.

- Drawings for structures, systems, and components (SSCs) important to safety are presented in Section 1.5 of the FSAR.

- Specifications for the spent fuel to be stored in the HI-STAR 100 System are provided in FSAR Subsection 1.2.3. Additional details concerning these specifications are provided in Section 2.1 of the FSAR.

- The technical qualifications of the Holtec International to engage in the proposed activities are identified in Section 1.3 of the FSAR.

- The quality assurance program and implementing procedures are described in Chapter 13 of the FSAR.

- The HI-STAR 100 System SAR has been submitted, Docket No. 71-9261, to request certification of the HI-STAR 100 System under 10CFR71 for use in transportation.

1.7 REFERENCES

[1.0.1] 10CFR Part 72, *Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste.*

[1.0.2] Regulatory Guide 3.61 (Task CE306-4) "Standard Format for a Topical Safety Analysis Report for a Spent Fuel Storage Cask", USNRC, February 1989.

[1.0.3] NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems", U.S. Nuclear Regulatory Commission, January 1997.

[1.0.4] 10CFR Part 71, "Packaging and Transportation of Radioactive Materials", Title 10 of the Code of Federal Regulations, 1998 Edition, Office of the Federal Register, Washington, D.C.

[1.1.1] U.S. Department of Energy, "Multi-Purpose Canister (MPC) Subsystem Design Procurement Specification", Document No. DBG000000-01717-6300-00001, Rev. 5, January 11, 1996.

[1.1.2] U.S. Department of Energy, "MPC Transportation Cask Subsystem Design Procurement Specification", Document No. DBF 000000-01717-6300-00001, Rev. 5, January 11, 1996.

[1.2.1] U.S. NRC Information Notice 96-34, "Hydrogen Gas Ignition During Closure Welding of a VSC-24 Multi-Assembly Scale Basket".

[1.2.2] *Directory of Nuclear Reactors, Vol. II, Research, Test & Experimental Reactors*, International Atomic Energy Agency, Vienna, 1959.

[1.2.3] V.L. McKinney and T. Rockwell III, Boral: A New Thermal-Neutron Shield, USAEC Report AECD-3625, August 29, 1949.

[1.2.4] *Reactor Shielding Design Manual*, USAEC Report TID-7004, March 1956.

[1.2.5] "Safety Analysis Report for the NAC Storable Transport Cask", Revision 8, August 1994, Nuclear Assurance Corporation (USNRC Docket No. 71-9235).

[1.2.6] HI-STAR 100 Safety Analysis Report, Holtec Report No. HI-951251, Current Revision.

APPENDIX 1.A: ALLOY X DESCRIPTION

1.A ALLOY X DESCRIPTION

1.A.1 Alloy X Introduction

Alloy X is used within this licensing application to designate a group of stainless steel alloys. Alloy X can be any one of the following alloys:

- Type 316
- Type 316LN
- Type 304
- Type 304LN

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. The Alloy X approach is conservative because no matter which material is ultimately utilized, the Alloy X approach guarantees that the performance of the MPC will meet or exceed the analytical predictions.

This appendix defines the least favorable material properties of Alloy X.

1.A.2 Alloy X Common Material Properties

Several material properties do not vary significantly from one Alloy X constituent to the next. These common material properties are as follows:

- density
- specific heat
- Young's Modulus (Modulus of Elasticity)
- Poisson's Ratio

The values utilized for this licensing application are provided in their appropriate chapters.

1.A.3 Alloy X Least Favorable Material Properties

The following material properties vary between the Alloy X constituents:

- Design Stress Intensity (S_m)
- Tensile (Ultimate) Strength (S_u)
- Yield Strength (S_y)

- Coefficient of Thermal Expansion (α)
- Coefficient of Thermal Conductivity (k)

Each of these material properties are provided in the ASME Code Section II [1.A.1]. Tables 1.A.1 through 1.A.5 provide the ASME Code values for each constituent of Alloy X along with the least favorable value utilized in this licensing application. The ASME Code only provides values to -20°F. The design temperature of the MPC is -40 °F to 725 °F as stated in Table 1.2.2. Most of the above-mentioned properties become increasingly favorable as the temperature drops. Conservatively, the values at the lowest design temperature for the HI-STAR 100 System have been assumed to be equal to the lowest value stated in the ASME Code. The lone exception is the thermal conductivity. The thermal conductivity decreases with the decreasing temperature. The thermal conductivity value for -40 °F is linearly extrapolated from the 70 °F value using the difference from 70 °F to 100 °F.

The Alloy X material properties are the minimum values of the group for the design stress intensity, tensile strength, yield strength, and coefficient of thermal conductivity. Using minimum values of design stress intensity is conservative because lower design stress intensities lead to lower allowables that are based on design stress intensity. Similarly, using minimum values of tensile strength and yield strength is conservative because lower values of tensile strength and yield strength lead to lower allowables that are based on tensile strength and yield strength. When compared to calculated values, these lower allowables result in factors of safety that are conservative for any of the constituent materials of Alloy X. Further discussion of the justification for using the minimum values of coefficient of thermal conductivity is given in Chapter 4. The maximum and minimum values are used for the coefficient of thermal expansion of Alloy X. The maximum and minimum coefficients of thermal expansion are used as appropriate in this submittal. Figures 1.A.1-1.A.5 provide a graphical representation of the varying material properties with temperature for the Alloy X materials.

1.A.4 References

[1.A.1] ASME Boiler & Pressure Vessel Code Section II, 1995 ed. with Addenda.

Table 1.A.1

ALLOY X AND CONSTITUENT DESIGN STRESS INTENSITY (S_m) vs. TEMPERATURE

Temp. (°F)	Type 304	Type 304LN	Type 316	Type 316LN	Alloy X (minimum of constituent values)
-40	20.0	20.0	20.0	20.0	20.0
100	20.0	20.0	20.0	20.0	20.0
200	20.0	20.0	20.0	20.0	20.0
300	20.0	20.0	20.0	20.0	20.0
400	18.7	18.7	19.3	18.9	18.7
500	17.5	17.5	18.0	17.5	17.5
600	16.4	16.4	17.0	16.5	16.4
650	16.2	16.2	16.7	16.0	16.0
700	16.0	16.0	16.3	15.6	15.6
750	15.6	15.6	16.1	15.2	15.2
800	15.2	15.2	15.9	14.9	14.9

Notes:

1. Source: Table 2A on pages 314, 318, 326, and 330 of [1.A.1].
2. Units of design stress intensity values are ksi.

Table 1.A.2

ALLOY X AND CONSTITUENT TENSILE STRENGTH (S_u) vs. TEMPERATURE

Temp. (°F)	Type 304	Type 304LN	Type 316	Type 316LN	Alloy X (minimum of constituent values)
-40	75.0	75.0	75.0	75.0	75.0
100	75.0	75.0	75.0	75.0	75.0
200	71.0	71.0	75.0	75.0	71.0
300	66.0	66.0	73.4	70.9	66.0
400	64.4	64.4	71.8	67.1	64.4
500	63.5	63.5	71.8	64.6	63.5
600	63.5	63.5	71.8	63.1	63.1
650	63.5	63.5	71.8	62.8	62.8
700	63.5	63.5	71.8	62.5	62.5
750	63.1	63.1	71.4	62.2	62.2
800	62.7	62.7	70.9	61.7	61.7

Notes:

1. Source: Table U on pages 437, 439, 441, and 443 of [1.A.1].
2. Units of tensile strength are ksi.

Table 1.A.3

ALLOY X AND CONSTITUENT YIELD STRESSES (S_y) vs. TEMPERATURE

Temp. (°F)	Type 304	Type 304LN	Type 316	Type 316LN	Alloy X (minimum of constituent values)
-40	30.0	30.0	30.0	30.0	30.0
100	30.0	30.0	30.0	30.0	30.0
200	25.0	25.0	25.8	25.5	25.0
300	22.5	22.5	23.3	22.9	22.5
400	20.7	20.7	21.4	21.0	20.7
500	19.4	19.4	19.9	19.4	19.4
600	18.2	18.2	18.8	18.3	18.2
650	17.9	17.9	18.5	17.8	17.8
700	17.7	17.7	18.1	17.3	17.3
750	17.3	17.3	17.8	16.9	16.9
800	16.8	16.8	17.6	16.6	16.6

Notes:

1. Source: Table Y-1 on pages 518, 519, 522, 523, 530, 531, 534, and 535 of [1.A.1].
2. Units of yield stress are ksi.

Table 1.A.4

ALLOY X AND CONSTITUENT COEFFICIENT OF THERMAL EXPANSION vs. TEMPERATURE

Temp. (°F)	Type 304 and Type 304LN	Type 316 and Type 316LN	Alloy X Maximum	Alloy X Minimum
-40	8.55	8.54	8.55	8.54
100	8.55	8.54	8.55	8.54
150	8.67	8.64	8.67	8.64
200	8.79	8.76	8.79	8.76
250	8.90	8.88	8.90	8.88
300	9.00	8.97	9.00	8.97
350	9.10	9.11	9.11	9.10
400	9.19	9.21	9.21	9.19
450	9.28	9.32	9.32	9.28
500	9.37	9.42	9.42	9.37
550	9.45	9.50	9.50	9.45
600	9.53	9.60	9.60	9.53
650	9.61	9.69	9.69	9.61
700	9.69	9.76	9.76	9.69
750	9.76	9.81	9.81	9.76
800	9.82	9.90	9.90	9.82

Notes:

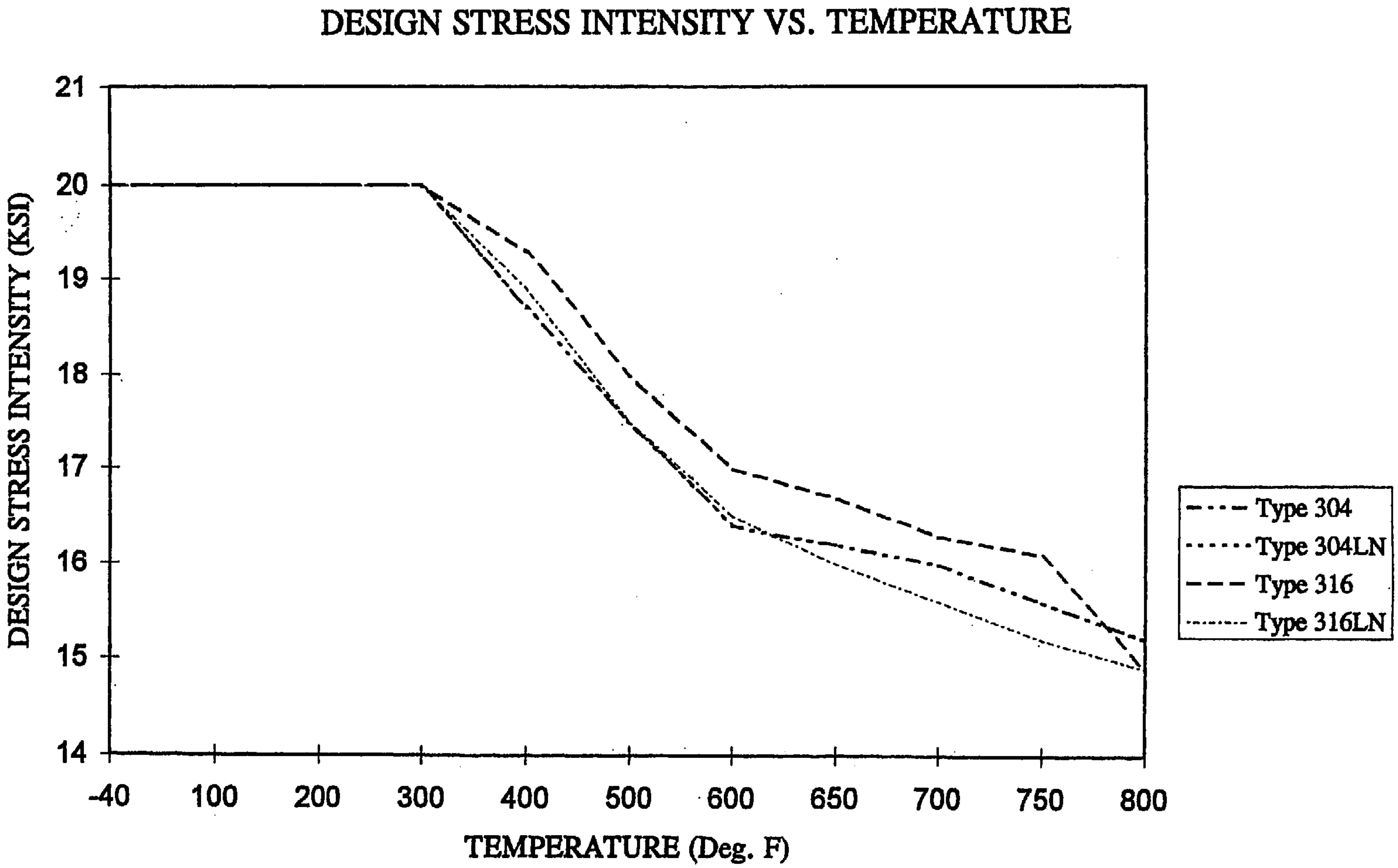
1. Source: Table TE-1 on pages 590 and 591 of [1.A.1].
2. Units of coefficient of thermal expansion are in./in.- °F x 10^{-6}.

Table 1.A.5
ALLOY X AND CONSTITUENT THERMAL CONDUCTIVITY vs. TEMPERATURE

Temp. (°F)	Type 304 and Type 304LN	Type 316 and Type 316LN	Alloy X (minimum of constituent values)
-40	8.23	6.96	6.96
70	8.6	7.7	7.7
100	8.7	7.9	7.9
150	9.0	8.2	8.2
200	9.3	8.4	8.4
250	9.6	8.7	8.7
300	9.8	9.0	9.0
350	10.1	9.2	9.2
400	10.4	9.5	9.5
450	10.6	9.8	9.8
500	10.9	10.0	10.0
550	11.1	10.3	10.3
600	11.3	10.5	10.5
650	11.6	10.7	10.7
700	11.8	11.0	11.0
750	12.0	11.2	11.2
800	12.2	11.5	11.5

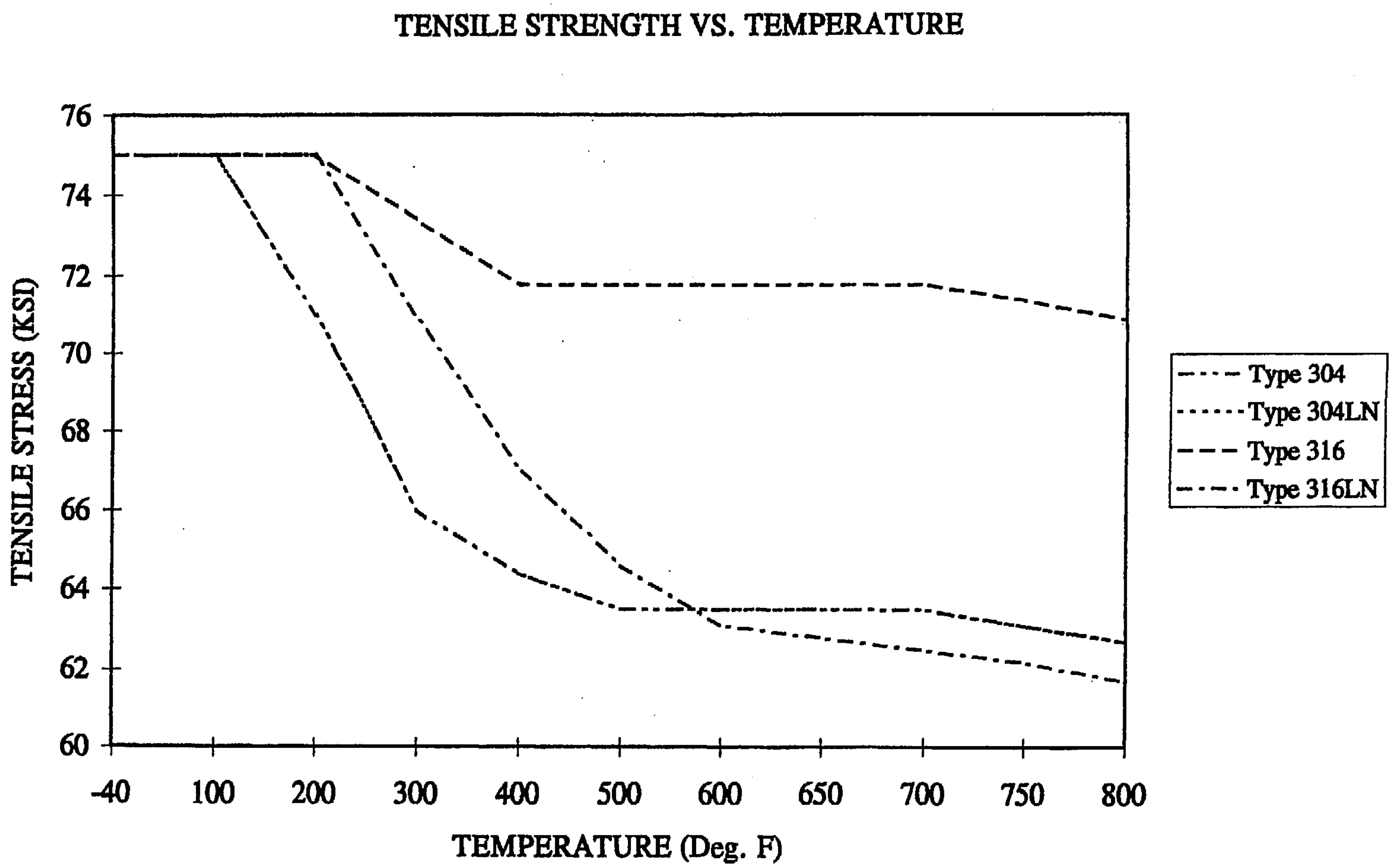
Notes:

1. Source: Table TCD on page 606 of [1.A.1].
2. Units of thermal conductivity are Btu/hr-ft-°F.



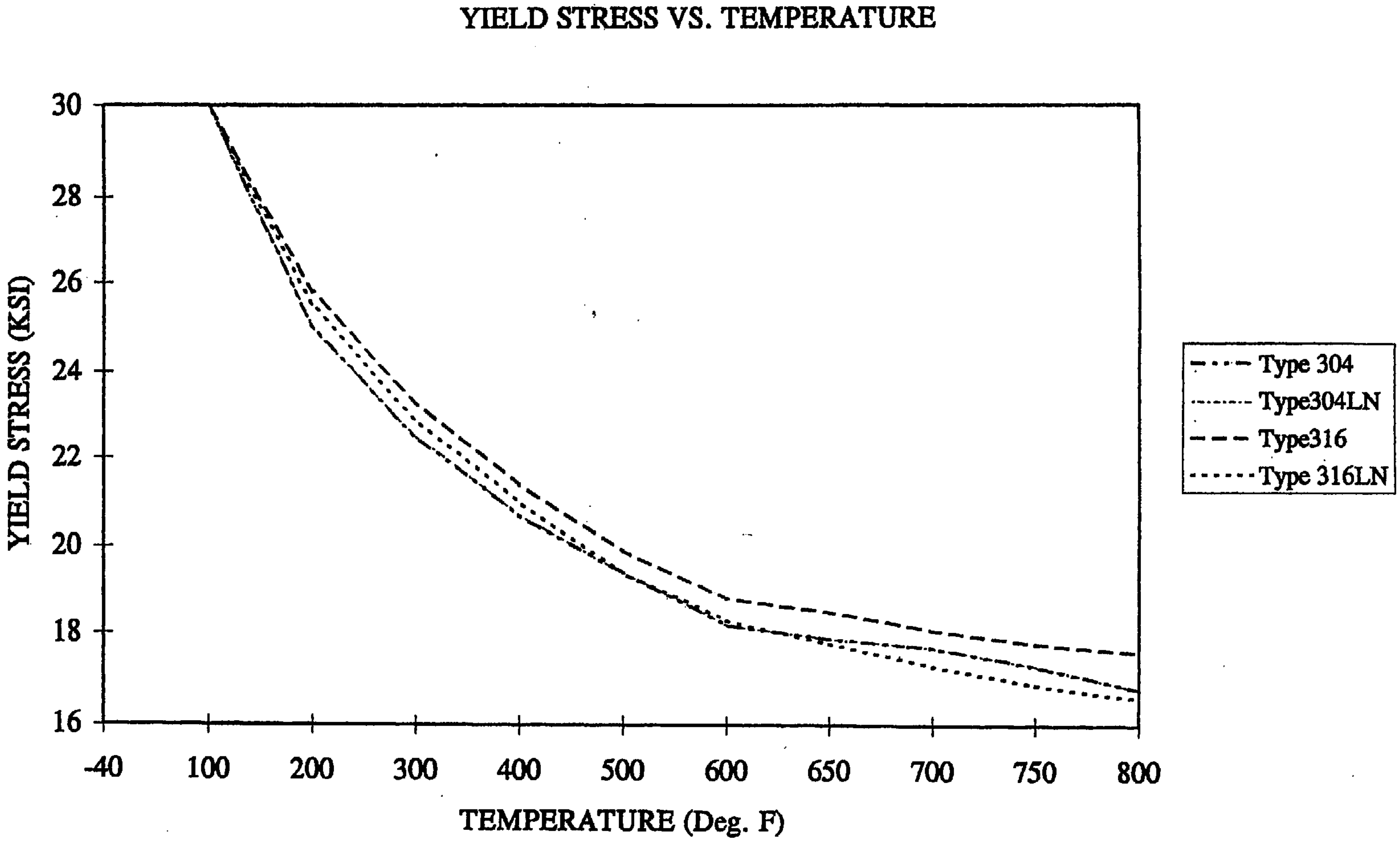
SOURCE: TABLE 1.A.1

FIGURE 1.A.1; DESIGN STRESS INTENSITY VS. TEMPERATURE



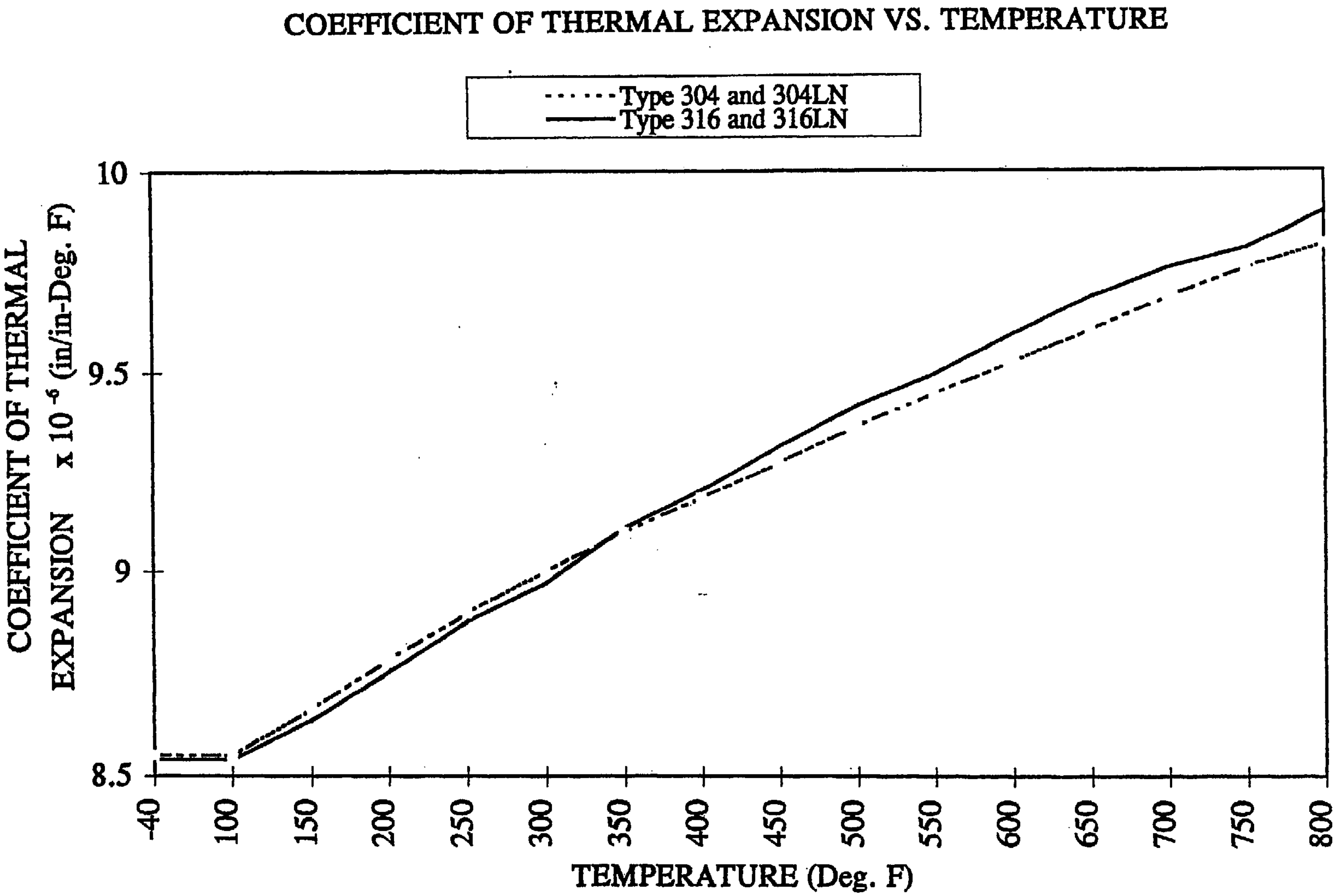
SOURCE: TABLE 1.A.2

FIGURE 1.A.2; TENSILE STRENGTH VS. TEMPERATURE

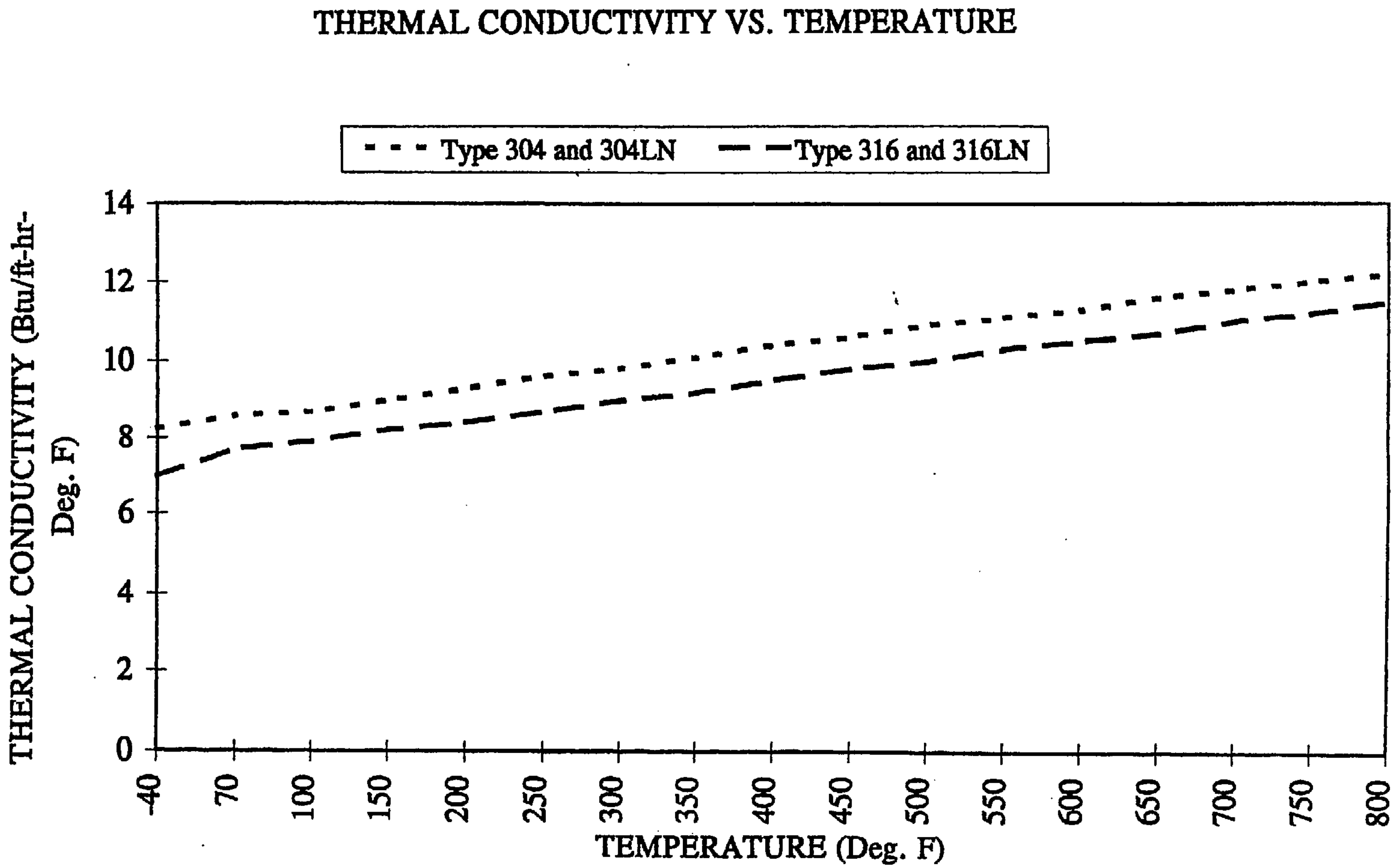


SOURCE: TABLE 1.A.3

FIGURE 1.A.3; YIELD STRESS VS. TEMPERATURE



SOURCE: TABLE 1.A.4 FIGURE 1.A.4; COEFFICIENT OF THERMAL EXPANSION VS. TEMPERATURE



SOURCE: TABLE 1.A.5

FIGURE 1.A.5; THERMAL CONDUCTIVITY VS. TEMPERATURE

APPENDIX 1.B: HOLTITE-A ™ MATERIAL DATA
(Total of 4 Pages Including This Page)

The information provided in this appendix describes the neutron absorber material, Holtite-A for the purpose of confirming its suitability for use as a neutron shield material in spent fuel storage casks. Holtite-A is one of the family of Holtite neutron shield materials denoted by the generic name Holtite™. It is currently the only neutron shield material approved for installation in the HI-STAR 100 cask. It is chemically identical to NS-4-FR which was originally developed by Bisco Inc. and used for many years as a shield material with B_4C or Pb added.

Holtite-A contains aluminum hydroxide ($Al(OH)_3$) in an epoxy resin binder. Aluminum hydroxide is also known by the industrial trade name of aluminum tri-hydrate or ATH. ATH is often used commercially as a fire-retardant. Holtite-A contains approximately 62% ATH supported in a typical 2-part epoxy resin as a binder. Holtite-A contains 1% (nominal) by weight B_4C, a chemically inert material added to enhance the neutron absorption property. Pertinent properties of Holtite-A are listed in Table 1.B.1.

The essential properties of Holtite-A are:

1. the hydrogen density (needed to thermalize neutrons),
2. thermal stability of the hydrogen density, and
3. the uniformity in distribution of B_4C needed to absorb the thermalized neutrons.

ATH and the resin binder contain nearly the same hydrogen density so that the hydrogen density of the mixture is not sensitive to the proportion of ATH and resin in the Holtite-A mixture. B_4C is added as a finely divided powder and does not settle out during the resin curing process. Once the resin is cured (polymerized), the ATH and B_4C are physically retained in the hardened resin. Qualification testing for B_4C throughout a column of Holtite-A has confirmed that the B_4C is uniformly distributed with no evidence of settling or non-uniformity. Furthermore, an excess of B_4C is specified in the Holtite-A mixing and pouring procedure as a precaution to assure that the B_4C concentration is always adequate throughout the mixture.

The specific gravity specified in Table 1.B.1 does not include an allowance for weight loss. The specific gravity assumed in the shielding analysis includes a 4% reduction to conservatively account for potential weight loss at the design temperature of 300°F or an inability to reach theoretical density. Tests on the stability of Holtite-A were performed by Holtec International. The results of the tests are summarized in Holtec Reports HI-2002396, "Holtite-A Development History and Thermal Performance Data" and HI-2002420, "Results of Pre- and Post-Irradiation Test Measurements." The information provided in these reports demonstrates that Holtite-A™ possesses the necessary thermal and radiation stability characteristics to function as a reliable shielding material in the HI-STAR 100 overpack.

The Holtite-A is encapsulated in the HI-STAR 100 overpack and, therefore, should experience a very small weight reduction during the design life of the HI-STAR 100 System.

The data and test results confirm that Holtite-A remains stable under design thermal and radiation conditions, the material properties meet or exceed that assumed in the shielding analysis, and the B_4C remains uniformly distributed with no evidence of settling or non-uniformity.

Based on the information described above, Holtite-A meets all of the requirements for an acceptable neutron shield material.

Table 1.B.1

REFERENCE PROPERTIES OF HOLTITE-A NEUTRON SHIELD MATERIAL

PHYSICAL PROPERTIES	
% ATH	62 nominal
Specific Gravity	1.68 g/cc nominal
Max. Continuous Operating Temperature	300°F
Hydrogen Density	0.096 g/cc minimum
Radiation Resistance	Excellent
CHEMICAL PROPERTIES (Nominal)	
wt% Aluminum	21.5
wt% Hydrogen	6.0
wt% Carbon	27.7
wt% Oxygen	42.8
wt% Nitrogen	2.0
wt% B_4C	1.0

PAGES 1.B-4 THROUGH 1.B-20 INTENTIONALLY DELETED

APPENDIX 1.C: MISCELLANEOUS MATERIAL DATA
(Total of 8 Pages Including This Page)

The information provided in this appendix specifies the thermal expansion foam (silicone sponge), paint, and anti-seize lubricant properties and demonstrates their suitability for use in spent nuclear fuel storage casks. The following is a listing of the information provided.

- HT-800 Series, Silicone Sponge, Bisco Products Technical Data Sheet
- Thermaline 450, Carboline, Product Data Sheet and Application Instructions
- Carboline 890, Carboline, Product Data Sheet and Application Instructions
- FEL-PRO Technical Bulletin, N-5000 Nickel Based-Nuclear Grade Anti-Seize Lubricant

HT-870 silicone sponge is specified as a thermal expansion foam to be placed in the overpack outer enclosure with the neutron shield. Due to differing thermal expansion of the neutron shield and outer enclosure carbon steel, the silicone sponge is provided to compress and allow the neutron shield material to expand. The compression-deflection physical properties are provided for the silicone sponge.

Silicone has a long and proven history in the nuclear industry. Silicone is highly resistant to degradation as a result of radiation at the levels required for the HI-STAR 100 System. Silicone is inherently inert and stable and will not react with the metal surfaces or neutron shield material. Additionally, typical operating temperatures for silicone sponges range from -50°F to 400°F.

Thermaline 450 is specified to coat the inner cavity of the overpack and Carboline 890 is specified to coat the external surfaces of the overpack. As can be seen from the product data sheets, the paints are suitable for the design temperatures (see Table 2.2.3) and chemical environment.

Nuclear grade anti-seize lubricant, N-5000, from FEL-PRO is specified as the lubricant for the overpack closure bolts. The lubricant is formulated to have the lowest practical levels of halogens, sulfur, and heavy metals.

Bisco Products
A Dow Corning Subsidiary

Technical Data

HT-800 SERIES

Specification Grade
Silicone Sponge

PHYSICAL PROPERTIES

PROPERTY	SPECIFICATION			TEST METHOD
	HT-870 (Soft)	HT-800 (Medium)	HT-820 (Firm)	
Density	12 - 24 pcf	16 - 28 pcf	20 - 32 pcf	ASTM D-3574
Compression Force @ 25% Deflection	2 - 7 psi	6 - 14 psi	12 - 20 psi	ASTM D-1056
Compression Set (Maximum)	10%	10%	10%	ASTM D-1056 (Compressed 50%for 22 hrs. @ 100°C)
Water Absorption (Maximum)	10%	5%	5%	ASTM D-1056

Available Industry Specifications:

AMS-3195 (HT-800)
AMS-3196 (HT-820)
UL-94 (Limited to specific classes, densities, thicknesses and colors)

carboline®

THERMALINE 450

VOC PLUS

SELECTION DATA

GENERIC TYPE: A glass flake filled, phenolic modified, amine cured epoxy novalac.

GENERAL PROPERTIES: A dense cross-linked polymer which exhibits outstanding barrier protection against a variety of chemical exposures. Excellent resistance to wet/dry cycling conditions at elevated temperatures. Designed to coat the exterior of insulated piping. It is also suitable for coating non-insulated piping and equipment exposed to chemical attack. The glass flakes help provide excellent abrasion resistance, permeation resistance and internal reinforcement.

- Temperature resistance to 450°F
- Excellent abrasion resistance
- Excellent overall chemical resistance
- Excellent thermal shock resistance

RECOMMENDED USES: Typically used as a one coat system to coat pipes and tanks that will be insulated. May also be used to coat non-insulated pipe, structural steel, equipment or concrete that may be subjected to severe chemical attack, abrasion or other abuse typical of a chemical plant environment.

TYPICAL CHEMICAL RESISTANCE:

Exposure	Splash & Spillage	Fumes
Acids	Excellent	Excellent
Alkalies	Excellent	Excellent
Solvents	Excellent	Excellent
Salt	Excellent	Excellent
Water	Excellent	Excellent

TEMPERATURE RESISTANCE (Under insulation):

Continuous:	425°F (218°C)
Excursions to:	450°F (232°C)

At 200°F (93°C) coating discoloration may be observed without loss of film integrity.

SUBSTRATES: Apply over properly prepared steel.

COMPATIBLE COATINGS: Normally applied directly to substrate. May be applied over epoxies and phenolics as recommended. May be topcoated with epoxies, polyurethanes or other finish coats as recommended.

July 96 Replaces September 95

SPECIFICATION DATA

0928

THEORETICAL SOLIDS CONTENT OF MIXED MATERIAL:

	By Volume
THERMALINE 450	70 ± 2%

VOLATILE ORGANIC CONTENT (VOC):
The following are nominal values:
As supplied: 2.13 lbs./gal. (255 gm./liter).

Thinner	Fluid Ounces/Gal.	Pounds/ Gallon	Grams/ Liter
213	13	2.56	307

RECOMMENDED DRY FILM THICKNESS:
8-10 mils (200-250 microns) to be achieved in 1 or 2 coats.

THEORETICAL COVERAGE PER MIXED GALLON:*
1,117 mil sq. ft. (27.9 sq.m/l at 25 microns)
139 sq. ft at 8 mils (3.5 sq. m/l at 200 microns)
111 sq. ft at 10 mils (2.8 sq.m/l at 250 microns)

*Mixing and application losses will vary and must be taken into consideration when estimating job requirements.

STORAGE CONDITIONS: Store indoors.
Temperature: 40-110°F (4-43°C) Humidity: 0-90%

SHELF LIFE: 24 months when stored indoors at 75°F (24°C)

COLOR: Red (0500) and Gray (5742)

GLOSS: Low (Epoxies lose gloss, discolor and eventually chalk in sunlight exposure.)

ORDERING INFORMATION

Prices may be obtained from your Carboline Sales Representative or Carboline Customer Service Department.

APPROXIMATE SHIPPING WEIGHT:

	1's	5's
THERMALINE 450	12 lbs. (5.5 kg)	58 lbs. (26.3 kg)
Thinner 213	8.4 lbs. (3.8 kg)	41 lbs. (18.6 kg)

FLASH POINT: (Setaflash)

THERMALINE 450 Part A:	53°F	(12°C)
THERMALINE 450 Part B:	>200°F	(>93°C)
Thinner 213	22°F	(-6°C)

APPLICATION INSTRUCTIONS

THERMALINE 450

These instructions are not intended to show product recommendations for specific service. They are issued as an aid in determining correct surface preparation, mixing instructions and application procedure. It is assumed that the proper product recommendations have been made. These instructions should be followed closely to obtain the maximum service from the materials.

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SURFACE PREPARATION: Remove all oil or grease from surface to be coated with Thinner 2 or Surface Cleaner 3 (refer to Surface Cleaner 3 instructions) in accordance with SSPC-SP 1.

STEEL:

Not Insulated: Abrasive blast to a Commercial Finish in accordance with SSPC-SP 6 and obtain a 2-3 mil (50-75 micron) blast profile.

Under Insulation: Abrasive blast to a Near White Finish in accordance with SSPC-SP 10 and obtain a 2-3 (50-75 micron) blast profile.

MIXING: Power mix each component separately, then combine and power mix in the following proportions.

Allow 30 minutes induction time at 75°F (24°C) prior to use.

	1 Gal. Kit	5 Gal. Kit
THERMALINE 450 Part A:	0.8 gals.	4.0 gals.
THERMALINE 450 Part B:	0.2 gals.	1.0 gals.

THINNING: May be thinned up to 13 oz/gal with Thinner 213.

Use of thinners other than those supplied or approved by Carboline may adversely affect product performance and void product warranty, whether express or implied.

POT LIFE: Three hours at 75°F (24°C) and less at higher temperatures. Pot life ends when coating loses body and begins to sag.

APPLICATION CONDITIONS:

	Material	Surfaces	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%

Do not apply when the surface temperature is less than 5°F or 3°C above the dew point.

Special thinning and application techniques may be required above or below normal conditions.

SPRAY: The following spray equipment has been found suitable and is available from manufacturers such as Binks, DeVilbiss and Graco.

Conventional: Pressure pot equipped with dual regulators, 1/2" I.D. minimum material hose, .110" I.D. fluid tip and appropriate air cap.

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Airless:

Pump Ratio:	30:1 (min)*
GPM Output:	3.0 (min)
Material Hose:	1/2" I.D. (min)
Tip Size:	.035"-.041"
Output psi:	2200-2500

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

BRUSH: For striping of welds, touch-up of small areas only. Use a natural bristle brush, applying full strokes. Avoid rebrushing.

ROLLER: Not recommended.

DRYING TIMES: These times are based on a dry film thickness of 10 mils (250 microns). Higher film thickness, insufficient ventilation or cooler temperatures will require longer cure times and could result in solvent entrapment and premature failure.

Surface Temperature	Dry To Handle	Dry to Topcoat	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

If the final cure time has been exceeded, the surface must be abraded by sweep blasting prior to the application of any additional coats.

EXCESSIVE HUMIDITY OR CONDENSATION ON THE SURFACE DURING CURING MAY RESULT IN A SURFACE HAZE OR BLUSH; ANY HAZE OR BLUSH MUST BE REMOVED BY WATER WASHING BEFORE RECOATING.

VENTILATION & SAFETY: WARNING: VAPORS MAY CAUSE EXPLOSION. 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. In addition to insuring proper ventilation, fresh air respirators or fresh air hoods must be used by all application personnel. Where flammable solvents exist, explosion-proof lighting must be used. Hypersensitive persons should wear clean, protective clothing, gloves and/or protective cream on face, hands and all exposed areas.

CLEANUP: Use Thinner 2.

CAUTION: READ AND FOLLOW ALL CAUTION STATEMENTS ON THIS PRODUCT DATA SHEET AND ON THE MATERIAL SAFETY DATA SHEET FOR THIS PRODUCT.

CAUTION: Contains flammable solvents. Keep away from sparks and open flames. Workmen in confined areas must wear fresh airline respirators. Hypersensitive persons should wear gloves or use protective cream. All electrical equipment and installations should be made in accordance with the National Electrical Code. In areas where explosion hazards exist, workmen should be required to use nonferrous tools and to wear conductive and nonsparking shoes.

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CARBOLINE® 890

0986

SELECTION DATA

GENERIC TYPE: Cross-linked epoxy.

GENERAL PROPERTIES: CARBOLINE 890 is a self priming, high solids, high gloss, high build epoxy mastic. It can be applied by spray, brush, or roller over hand or power tool cleaned steel and is compatible with most existing coatings and tightly adhered rust. The cured film provides a tough, cleanable surface and is available in a wide variety of colors.

- Single coat corrosion protection.
- Excellent chemical resistance.
- Good flexibility and lower stress upon curing than most epoxy coatings.
- Excellent tolerance of damp (not wet) substrates.
- Very good abrasion resistance.
- Suitable replacement for Carbomastic 801.

RECOMMENDED USES: Recommended where a high performance, chemically resistant epoxy coating is desired. Offers outstanding protection for interior floors, walls, piping, equipment and structural steel or as an exterior coating for railcars, structural steel and equipment in various corrosive environments. Industrial environments include Chemical Processing, Offshore Oil and Gas, Food Processing, Pharmaceutical, Water and Waste Water Treatment, Pulp and Paper and Power Generation among others. May be used as a two coat system direct to metal or concrete for Water and Municipal Waste Water immersion. Acceptable for use in incidental food contact areas and as a lining for hopper cars carrying food grade plastic pellets when processed according to FDA criteria (ref: FDA 21 CFR 175.300). Consult Carboline Technical Service Department for other specific uses.

NOT RECOMMENDED FOR: Strong acid or solvent exposures, immersion service other than water, exterior weathering where color retention is desired, such as a finish for tank exteriors or over chlorinated rubber and latex coatings.

TYPICAL CHEMICAL RESISTANCE:

Exposure	Immersion	Splash & Spillage	Fumes
Acids	NR	Very Good	Very Good
Alkalies	NR	Excellent	Excellent
Solvents	NR	Very Good	Excellent
Salt Solutions	Excellent	Excellent	Excellent
Water	Excellent	Excellent	Excellent

TEMPERATURE RESISTANCE: (Non-Immersion)

Continuous:	250°F (121°C)
Non-continuous:	300°F (149°C)

At temperatures above 225°F, coating discoloration and loss of gloss can be observed, without loss of film integrity.

SUBSTRATES: Apply over suitably prepared metal, concrete, or other surfaces as recommended.

COMPATIBLE COATINGS: May be applied directly over inorganic zincs, weathered galvanizing, epoxies, phenolics or other coatings as recommended. A test patch is recommended before use over existing coatings. A mist coat of CARBOLINE 890 is required when applied over inorganic zincs to minimize bubbling. May be topcoated with polyurethanes or acrylics to upgrade weathering resistance. Not recommended over chlorinated rubber or latex coatings. Consult Carboline Technical Service Department for specific recommendations.

SPECIFICATION DATA

THEORETICAL SOLIDS CONTENT OF MIXED MATERIAL:*

	By Volume
CARBOLINE 890	75% ± 2%

VOLATILE ORGANIC CONTENT:*

As Supplied: 1.78 lbs./gal. (214 grams/liter)

Thinned:

Thinner	Fluid Ounces/Gal.	Pounds/ Gallon	Grams/ Liter
2	8	2.08	250
2	13	2.26	271
33	16	2.38	285

*Varies with color

RECOMMENDED DRY FILM THICKNESS PER COAT:
4-6 mils (100-150 microns).
6-8 mils (150-200 microns) DFT for a more uniform gloss over inorganic zincs, or for use over light rust.

In more severe environments a second coat of 4-6 mils (100-150 microns) is recommended.

Dry film thickness in excess of 10 mils (250 microns) per coat is not recommended. Excessive film thickness over inorganic zinc may increase damage during shipping or erection.

THEORETICAL COVERAGE PER MIXED GALLON:
1203 mil sq. ft. (30 sq. m/l at 25 microns)
241 sq. ft. at 5 mils (6.0 sq. m/l at 125 microns)

Mixing and application losses will vary and must be taken into consideration when estimating job requirements.

STORAGE CONDITIONS: Store Indoors
Temperature: 40-110°F (4-43°C) Humidity: 0-100%

SHELF LIFE: 36 months when stored at 75°F (24°C).

COLORS: Available in Carboline Color Chart colors. Some colors may require two coats for adequate hiding.

GLOSS: High gloss (Epoxies lose gloss, discolor and eventually chalk in sunlight exposure).

ORDERING INFORMATION

Prices may be obtained from your Carboline Sales Representative or Carboline Customer Service Department.

APPROXIMATE SHIPPING WEIGHT:

	2 Gal. Kit	10 Gal. Kit
CARBOLINE 890	29 lbs. (13 kg)	145 lbs. (66 kg)

	1's	5's
THINNER #2	8 lbs. (4 kg)	39 lbs. (18 kg)
THINNER #33	9 lbs. (4 kg)	45 lbs. (20 kg)

FLASH POINT: (Setaflash)

CARBOLINE 890 Part A	89°F (32°C)
CARBOLINE 890 Part B	71°F (22°C)
THINNER #2	24°F (-5°C)
THINNER #33	89°F (32°C)

June 96 Replaces December 95

APPLICATIONS INSTRUCTIONS
CARBOLINE® 890

These instructions are not intended to show product recommendations for specific service. They are issued as an aid in determining correct surface preparation, mixing instructions and application procedure. It is assumed that the proper product recommendations have been made. These instructions should be followed closely to obtain the maximum service from the materials.

SURFACE PREPARATION: Remove all oil or grease from surface to be coated with Thinner #2 or Surface Cleaner #3 (refer to Surface Cleaner #3 instructions) in accordance with SSPC-SP 1.

Steel: For mild environments Hand Tool or Power Tool Clean in accordance with SSPC-SP 2, SSPC-SP 3 or SSPC-SP 11 to produce a rust-scale free surface.

For more severe environments, abrasive blast to a Commercial Finish in accordance with SSPC-SP 6 and obtain a 1½ - 3 mil (40-75 micron) blast profile.

For immersion service, abrasive blast to a Near White Metal Finish in accordance with SSPC-SP10 and obtain a 1½ - 3 mil (40-75 micron) blast profile.

Concrete: Must be cured at least 28 days at 70°F (21°C) and 50% R.H. or equivalent time. Remove fins and other protrusions by stoning, sanding or grinding. Abrasive blast to open all surface voids and remove all form oils, incompatible curing agents, hardeners, laitance and other foreign matter and produce a surface texture similar to that of a medium grit sandpaper. Voids in the concrete may require surfacing. Blow or vacuum off sand and dust.

MIXING: Power mix separately, then combine and power mix in the following proportions:

	2 Gal. Kit	10 Gal. Kit
CARBOLINE 890 Part A	1 gallon	5 gallons
CARBOLINE 890 Part B	1 gallon	5 gallons

THINNING: For spray applications, may be thinned up to 13 oz./gal. with Thinner #2. For hot and windy conditions, or for brush and roller application, may be thinned up to 16 oz./gal. with Thinner #33.

Use of thinners other than those supplied or approved by Carboline may adversely affect product performance and void product warranty, whether express or implied.

POT LIFE: Three hours at 75°F (24°C) and less at higher temperatures. Pot life ends when material loses film build.

APPLICATION CONDITIONS:

	Material	Surfaces	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)	90%

Do not apply or cure the material when the surface temperature is less than 5°F or 3°C above the dew point.

Special thinning and application techniques may be required above or below normal conditions.

SPRAY: This is a high solids coating and may require slight adjustments in spray techniques. Wet film thicknesses are easily and quickly achieved. The following spray equipment has been found suitable and is available from manufacturers such as Binks, DeVilbiss and Graco.

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

June 96 Replaces December 95

Airless:

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 are available from the pump manufacturer.

BRUSH OR ROLLER: Use medium bristle brush, or good quality short nap roller. Avoid excessive rebrushing and rerolling. Two coats may be required to obtain desired appearance, hiding and recommended DFT. For best results, tie-in within 10 minutes at 75°F (24°C).

DRYING TIMES: These times are based on a 5 mils (125 microns) dry film thickness. Higher film thicknesses, insufficient ventilation or cooler temperatures will require longer cure times and could result in solvent entrapment and premature failure.

Dry to Touch 2 1/2 hours at 75°F (24°C)
Dry to Handle 6 1/2 hours at 75°F (24°C)

Surface Temperature	Recoating With Itself	Dry to Topcoat	Final Cure
50°F (10°C)	12 hours	24 hours	3 days
60°F (16°C)	8 hours	16 hours	2 days
75°F (24°C)	4 hours	8 hours	1 day
90°F (32°C)	2 hours	4 hours	16 hours

Excessive humidity or condensation on the surface during curing can interfere with the cure, can cause discoloration and may result in a surface haze or blush. 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. For best results over "damp" surfaces, apply by brush or roller.

Maximum Recoat or Topcoat Times at 75°F (24°C):

With Epoxies - 30 days
With Polyurethanes - 90 days

If the maximum recoat time has been exceeded, surface must be abraded by sweep blasting prior to the application of any additional coats.

Minimum cure time before immersion service is 5 days at 75°F (24°C) surface temperature. Cure at temperatures below 60°F (16°C) is not recommended for immersion service.

VENTILATION & SAFETY: WARNING: VAPORS MAY CAUSE EXPLOSION. 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, fresh air respirators or fresh air hoods must be used by all application personnel. Where flammable solvents exist, explosion-proof lighting must be used. Hypersensitive persons should wear clean, protective clothing, gloves and/or protective cream on face, hands and all exposed areas.

CLEANUP: Use Thinner # 2.

CAUTION: READ AND FOLLOW ALL CAUTION STATEMENTS ON THIS PRODUCT DATA SHEET AND ON THE MATERIAL SAFETY DATA SHEET FOR THIS PRODUCT.

CAUTION: CONTAINS FLAMMABLE SOLVENTS. KEEP AWAY FROM SPARKS AND OPEN FLAMES. IN CONFINED AREAS, WORKMEN MUST WEAR FRESH AIRLINE RESPIRATORS. HYPERSENSITIVE PERSONS SHOULD WEAR GLOVES OR USE PROTECTIVE CREAM. ALL ELECTRIC EQUIPMENT AND INSTALLATIONS SHOULD BE MADE AND GROUNDED IN ACCORDANCE WITH THE NATIONAL ELECTRICAL CODE. IN AREAS WHERE EXPLOSION HAZARDS EXIST, WORKMEN SHOULD BE REQUIRED TO USE NONFERROUS TOOLS AND TO WEAR CONDUCTIVE AND NONSPARKING SHOES.

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FEL-PRO®
Technical Bulletin

N-5000 NICKEL BASED - NUCLEAR GRADE ANTI-SEIZE LUBRICANT

N-5000 is a nickel based nuclear grade anti-seize lubricant produced under 100% controlled conditions for highest purity and traceability. It is formulated to have the lowest practical levels of halogens, sulfur, and heavy metals, including copper. N-5000 has a general composition of nickel and graphite flake in petroleum carrier. All ingredients are selected for extreme purity. It meets or exceeds the following specifications, appendix A of NEDE-31295P, "BWR Operator's Manual for Materials and Processes", Westinghouse Material Specification 53701WQ, and 10CFR Ch1, Part 21, and Part 50, appendix B.

Special Features:
- High purity- made from highest purity ingredients.
- Traceability- each can marked.
- Free from copper- less than 50 ppm copper.
- Testing- each batch tested before packaging. Certifications- 3 copies with each case.

Recommended applications:
- Bolts, studs, valves, pipe fittings, slip fits and press fits in electric power generating plants, chemical plants, pharmaceutical plants, paper mills, and other locations where stainless steel fasteners are used.

Operational Benefits:
- Before assembly - certifications and traceability.
- During assembly - prevents high friction, galling,
- and seizing. Promotes uniform and predictable clamping.
- During operation - high purity prevents stress corrosion.
- Disassembly - prevents seizing, galling, destruction of threads.

Typical Physical Properties:

Composition	Nickel and Graphite in Petroleum Oil
Appearance	Silver-Gray paste
Specific gravity	1.2
Flash point (ASTM D 92-85)	424°F/218°C
Torque coefficient, k (Steel nuts and Bolts)	0.15
(Type 304 Stainless)	0.18
Maximum use temperature	1800°F/982°C

Quality Control Physical Properties:

Weight per gallon (ASTM D 1475-85)	Range 9.5 - 10.4
Penetration (ASTM D 217-88 unworked)	300 - 380

Purity:

Impurities - Elemental and Combined	Test Method Type	References ASTM OR (SM16)	Controlled Maximum	Average Values
Halogens ,Chlorine, Bromine, Iodine	Parr Bomb, Turbidimetric	D808-87, C69979	50 ppm	18 ppm
Fluorine	Parr Bomb, Specific ION Electrode	D3761-84	200 ppm	7 ppm
Sulfur	Parr Bomb, Turbidimetric	D129-64, D1266-87	100 ppm	9 ppm
Lead	Wet Digestion, AAS	(302D), D3559-84	25 ppm	1ppm
Cadmium	Wet Digestion, AAS	(302D), D3557-84	2 ppm	0.2 ppm
Tin	Wet Digestion, AAS	(302D), E37-76	25 ppm	9 ppm
Zinc	Wet Digestion, AAS	(302D), D1691-84	25 ppm	1 ppm
Copper	Wet Digestion, AAS	(302D), D1688-84	50 ppm	12 ppm
Mercury	Wet Digestion, Cold Vapor AAS	(302D), D3223-80	2 ppm	0.04 ppm

Directions for use:

- Before or during assembly, wipe brush onto threads and other joint surfaces needing protection.
- Do not overuse, as excess will be pushed off.
- Use full strength, do not thin.

Packaging:

Part Number	Net Contents	Type Container	Units/Case	Shipping Wt./Case
51243	8 oz. (227 g)	Can-brush top	12	9 lb. (4. Kg.)
51245	8 lb. (3.6 kg)	Can	2	18 lb. (8. Kg.)
51246	2 lb. (908 g)	Can	12	29 lb. (13. Kg.)
51269	1 lb. (454 g)	Can-brush top	12	16 lb. (7. Kg.)
51346	1 oz. (28 g)	Tube	48	6 lb. (2.7 Kg.)

N-5000 has an unlimited shelf life when stored at room temperature in the original unopened container.

FOR INDUSTRIAL USE ONLY.
WASH THOROUGHLY AFTER HANDLING.
KEEP OUT OF REACH OF CHILDREN.
SEE MATERIAL SAFETY DATA For immediate answers to your technical questions, in the United States or Canada call the **Technical Support Line at 1-800-992-9799.** International customers call (303) 289-5651, or fax (303) 289-5283

For a Material Safety Data Sheet or Technical Bulletin on this or any Fel-Pro product call our toll-free **FAX FOR THE INFO** line 24 hours a day, 7 days a week, in the United States or Canada call **800-583-3069.** International customers call (303) 289-5651, or fax (303) 289-5283.

Except as expressly stipulated, Fel-Pro's liability, expressed or implied, is limited to the stated selling price of any defective goods.

N-5000 8/97

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CHAPTER 2: PRINCIPAL DESIGN CRITERIA

This chapter contains a compilation of design criteria applicable to the HI-STAR 100 System. The loadings and conditions prescribed herein for the MPC, particularly those pertaining to mechanical accidents, are far more severe in most cases than those required for 10CFR72 compliance. The underlying reason for the more stringent design criteria selected in this submittal is the dual-purpose nature B storage and transport B of the HI-STAR 100 System and its concurrent application for 10CFR71 certification [2.0.1]. This chapter sets forth the loading conditions and relevant acceptance criteria; it does not provide results of any analyses. The analyses and results carried out to demonstrate compliance with the design criteria are presented in the subsequent chapters of this report.

This chapter is in full compliance with NUREG-1536, except for the exceptions and clarifications provided in Table 1.0.3. Table 1.0.3 provides the NUREG-1536 requirement, the justification for the exception or clarification, and the Holtec approach to meet the intent of the NUREG-1536 requirement.

2.0 PRINCIPAL DESIGN CRITERIA

The design criteria for the MPC and HI-STAR overpack are summarized in Tables 2.0.1 and 2.0.2, respectively, and described in the sections that follow.

2.0.1 MPC Design Criteria

General

The MPC is designed for 40 years of service, while satisfying the requirements of 10CFR72 [2.0.2]. The adequacy of the MPC design for the design life is discussed in Section 3.4.11.

Structural

The MPC is classified as important to safety. The MPC structural components include the internal fuel basket and the enclosure vessel. The fuel basket is designed and fabricated as a core support structure, in accordance with the applicable requirements of Section III, Subsection NG of the ASME Code [2.0.3], to the maximum extent practicable, as discussed in Section 2.2.4. The enclosure vessel is designed and fabricated as a Class 1 component pressure vessel in accordance with Section III, Subsection NB of the ASME Code, to the maximum extent practicable, as discussed in Section 2.2.4. The principal exceptions are the MPC lid, vent and drain cover plates, and closure ring welds to the MPC lid and shell, as discussed in Section 2.2.4. In addition, the threaded holes in the MPC lid are designed in accordance with the requirements of ANSI N14.6 [2.0.4] for critical lifts to facilitate vertical MPC transfer.

The MPC closure welds are partial penetration welds that are structurally qualified by analysis, as presented in Chapter 3. The MPC lid and closure ring welds are inspected by performing a liquid penetrant examination of the root pass and final weld surface, in accordance with the Design Drawings contained in Section 1.5. The integrity of the MPC lid weld is further verified by performing a volumetric (or multi-layer liquid penetrant) examination, a hydrostatic pressure test and a helium leak test, in accordance with the Design Drawings and Technical Specification requirements.

The structural analysis of the MPC, in conjunction with the redundant closures and nondestructive examination, hydrostatic pressure testing, and helium leak testing performed during MPC fabrication and MPC closure, provides assurance of canister closure integrity in lieu of the specific weld joint requirements of the ASME Code, Section III, Subsection NB.

Compliance with the ASME Code as it is applied to the design and fabrication of the MPC, and the associated justification, are discussed in Section 2.2.4. Compliance with the ASME Code is fully consistent with that used by other canister-based dry storage systems previously approved by the NRC.

The MPC is designed for all design basis normal, off-normal, and postulated accident conditions, as defined in Section 2.2. These design loadings include the postulated drop accidents while in the cavity of the HI-STAR overpack. The load combinations for which the MPC is designed are defined in Section 2.2.7. In addition, the maximum allowable weight and dimensions of a fuel assembly to be stored in the MPC are limited in accordance with Section 2.1.4.

Thermal

The allowable fuel cladding temperatures imposed to prevent cladding degradation during long-term dry storage conditions for the MPC are based on the PNL Report [2.0.5], and LLNL Report [2.0.6]. The allowable cladding temperatures which correspond to varying cooling times for the SNF to be stored in the MPCs are provided in Table 2.2.3.

The short-term allowable cladding temperature that is applicable to off-normal and accident conditions of storage, as well as the fuel loading, canister closure, and transfer operations, is 570°C (1058°F) based on PNL-4835 [2.0.7]. Further, the MPC is backfilled with 99.995% pure helium at a pressure specified in Chapter 12 during canister sealing operations to promote heat transfer and prevent cladding degradation.

The design temperatures for the structural steel components of the MPC are based on the temperature limits provided in ASME Section II, Part D, tables referenced in ASME Section III, Subsection NB and NG, for those load conditions under which material properties are relied on for a structural load combination. The specific design temperatures for the components of the MPC are provided in Table 2.2.3.

The MPCs are designed for a bounding thermal source term, as described in Section 2.1.5. The maximum allowable fuel assembly heat load for each MPC is limited in accordance with the Technical Specifications.

Shielding

The allowable doses for an ISFSI using the HI-STAR 100 System are delineated in 10CFR72.104 and 72.106. Compliance with this criteria is necessarily site-specific and is to be demonstrated by the licensee, as discussed in Chapters 5 and 10.

The MPC provides axial gamma shielding at the top and bottom ends to maintain occupational exposures ALARA during canister closure and handling operations. The maximum allowable top axial dose rates for the MPC are controlled in accordance with plant-specific procedures and ALARA requirements (discussed in Chapter 10).

The MPCs are designed for the design basis fuel at the maximum burnup and minimum cooling times, as described in Sections 2.1.6 and 5.2. The radiological source term for the MPCs are limited based on the burnup and cooling times specified in the Technical Specifications. Calculated dose rates for each MPC are provided in Section 5.1. These dose rates are used to perform an occupational exposure evaluation in accordance with 10CFR20, as discussed in Chapter 10.

Criticality

The MPCs provide 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 intact and damaged fuel assemblies with optimum unborated water moderation and close reflection, including all biases, uncertainties, and MPC manufacturing tolerances.

Criticality control is maintained by the geometric spacing of the fuel assemblies and fixed borated neutron absorbing materials incorporated into the fuel basket assembly. The minimum specified boron concentration verified during Boral manufacture is further reduced by 25% for criticality analysis. No credit is taken for burnup. The maximum allowable initial enrichment for fuel assemblies to be stored in each MPC are limited in accordance with the Technical Specifications.

Confinement

The MPC provides for confinement of all radioactive materials for all design basis normal, off-normal, and postulated accident conditions, as discussed in Section 7.1. A non-mechanistic postulated breach of the canister release of available fission products in accordance with specified release fractions is considered, as discussed in Section 7.3. The confinement function of the MPC is verified through hydrostatic testing, helium leak testing and weld examinations performed in accordance with the acceptance test program in Chapter 9 and the Technical Specifications.

Operations

There are no radioactive effluents that result from storage or transfer operations. Effluents generated during MPC loading and closure operations are handled by the plant's radwaste system and procedures under the licensee's 10CFR50 license.

Generic operating procedures for the HI-STAR 100 System are provided in Chapter 8. Detailed operating procedures will be developed by the licensee based on site-specific requirements that comply with the 10CFR50 Technical Specifications for the plant and the 10CFR72 Technical Specifications for the HI-STAR 100 System.

Acceptance Tests and Maintenance

The fabrication acceptance basis and maintenance program to be applied to the MPCs are described in Chapter 9. The operational controls and limits to be applied to the MPCs are contained in the Technical Specifications. Application of these requirements will assure that the MPC is fabricated, operated, and maintained in a manner that satisfies the design criteria defined in this chapter.

Decommissioning

The MPCs are designed to be transportable in the HI-STAR 100 overpack and are not required to be unloaded prior to shipment off-site. Decommissioning of the HI-STAR 100 System is addressed in Section 2.4.

2.0.2 HI-STAR Overpack

General

The HI-STAR overpack is designed for 40 years of service, while satisfying the requirements of 10CFR72. The adequacy of the overpack design for the design life is discussed in Section 3.4.10.

Structural

The HI-STAR overpack is classified as important to safety. The HI-STAR overpack top flange, closure plate, inner shell, and bottom plate are designed and fabricated in accordance with the requirements of ASME Code, Section III, Subsection NB, to the maximum extent practical (see Subsection 2.2.4). The remainder of the HI-STAR overpack steel structure is designed and fabricated in accordance with the requirements of ASME Code, Section III, Subsection NF, to the maximum extent practical (see Subsection 2.2.4). Compliance with the ASME Code is fully consistent with that used by other dry storage systems previously approved by the NRC.

The overpack is designed for all normal, off-normal, and design basis accident condition loadings, as defined in Section 2.2. These design loadings include a postulated drop accident from the maximum allowable handling height, consistent with Technical Specification requirements. The load combinations for which the overpack is designed are defined in Section 2.2.7. The physical characteristics of the MPCs for which the overpack is designed are defined in Chapter 1.

Thermal

The allowable temperatures for the structural steel components are based on the maximum temperature for which material properties and allowable stresses are provided in Section II of the ASME Code. The specific allowable temperatures for the structural steel components of the overpack are provided in Table 2.2.3. The allowable temperature for the Holtite-A neutron shield material specified in Table 2.2.3 is based on the data provided in Appendix 1.B.

The overpack is designed for extreme cold conditions, as discussed in Section 2.2.2.2. The structural steel materials used for the overpack that are susceptible to brittle fracture are discussed in Section 3.1.2.3.

The overpack is designed for the maximum allowable heat load for steady-state normal conditions, in accordance with Section 2.1.5. The thermal characteristics of the MPC for which the overpack is designed are defined in Chapter 4.

Shielding

The off-site dose for normal operating conditions and anticipated occurrences at the site boundary to a real individual is limited by 10CFR72.104(a) to a maximum of 25 mrem/year whole body, 75 mrem/year thyroid, and 25 mrem/year for other critical organs, including contributions from all nuclear fuel cycle operations. Since these limits are dependent on plant operations as well as site-specific conditions (e.g., the ISFSI design and proximity to the site boundary, and the number and arrangement of loaded storage casks), the determination and comparison of ISFSI doses to this limit are necessarily site-specific. Dose rates for a typical ISFSI using the HI-STAR 100 System are provided in Chapters 5 and 10. The determination of site-specific ISFSI dose rates at the site boundary and demonstration of compliance with regulatory limits shall be performed by the licensee in accordance with 10CFR72.212.

The overpack is designed to limit the calculated surface dose rate at the cask midplane for all MPCs to 125 mrem/hr or less, as defined in Section 2.3.5. The overpack is also designed to maintain occupational exposures ALARA during MPC transfer operations, in accordance with 10CFR20. The calculated overpack dose rates are presented in Section 5.1. These dose rates are used to perform a generic occupational exposure estimate for MPC loading operations and a dose assessment for a typical ISFSI, as described in Chapter 10. In addition, overpack dose rates are limited in accordance with the Technical Specifications.

Confinement

The overpack is not defined as the confinement boundary for radioactive materials. Confinement during storage is provided by the MPC which is addressed in Chapter 7. The overpack provides physical protection and biological shielding for the MPC confinement boundary during MPC dry storage operations.

Operations

There are no radioactive effluents that result from MPC transfer or storage operations with the overpack. Effluents generated during MPC loading and closure operations are handled by the plant's radwaste system and procedures under the licensee's 10CFR50 license.

Generic operating procedures for the HI-STAR 100 System are provided in Chapter 8. The licensee is required to develop detailed operating procedures based on site-specific conditions and requirements that also comply with the applicable 10CFR50 Technical Specification requirements for the site and the HI-STAR 100 System Technical Specifications.

Acceptance Tests and Maintenance

The fabrication acceptance basis and maintenance program to be applied to the overpack are described in Chapter 9. The operational controls and limits to be applied to the overpack are contained in the Technical Specifications. Application of these requirements will assure that the overpack is fabricated, operated, and maintained in a manner that satisfies the design criteria defined in this chapter.

Decommissioning

Decommissioning considerations for the HI-STAR 100 System, including the overpack, are addressed in Section 2.4.

Table 2.0.1

MPC DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
Design Life:			
Design	40 yrs.	-	Table 1.2.2
Regulatory	20 yrs.	10CFR72.42(a) and 10CFR72.236(g)	-
Structural:			
Design Codes:			
Enclosure Vessel	ASME Code, Section III, Subsection NB	10CFR72.24(c)(4)	Section 2.0.1
Fuel Basket	ASME Code, Section III, Subsection NG	10CFR72.24(c)(4)	Section 2.0.1
MPC Lifting Points	ANSI N14.6/NUREG-0612	10CFR72.24(c)(4)	Section 1.2.1.4
Design Dead Weights:			
Max. Loaded Canister (dry)	79,987 lb. (MPC-24) 87,241 lb. (MPC-68)	ANSI/ANS 57.9	Table 3.2.1
Empty Canister (dry)	39,667 lb. (MPC-24) 39,641 lb. (MPC-68)	ANSI/ANS 57.9	Table 3.2.1
Design Cavity Pressures:			
Normal:	100 psig	ANSI/ANS 57.9	Section 2.2.1.3

Table 2.0-1 (continued)

MPC DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
Off-Normal:	100 psig	ANSI/ANS 57.9	Section 2.2.2.1
Accident (Internal)	125 psig	ANSI/ANS 57.9	Section 2.2.3.8
Accident (External)	60 psig	ANSI/ANS 57.9	Sections 2.2.3.6 and 2.2.3.10
Response and Degradation Limits	SNF assemblies confined in dry, inert environment	10CFR72.122(h)(l)	Section 2.0.1
Thermal:			
Maximum Design Temperatures:			
Structural Materials:			
Stainless Steel (Normal)	725°F	ASME Code Section II, Part D	Table 2.2.3
Stainless Steel (Accident)	950 °F	ASME Code Section II, Part D	Table 2.2.3
Neutron Poison:			
Boral (normal)	800 °F	See Section 4.3.1	Table 2.2.3
Boral (accident)	950 °F	See Section 4.3.1	Table 2.2.3
PWR Fuel Cladding:			
5-year cooled	720 °F	PNL-6189	Section 4.3
6-year cooled	698 °F	PNL-6189	Section 4.3

Table 2.0-1 (continued)

MPC DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
7-year cooled	657 °F	PNL-6189	Section 4.3
10-year cooled	647 °F	PNL-6189	Section 4.3
15-year cooled	633 °F	PNL-6189	Section 4.3
BWR Fuel Cladding:			
5-year cooled	749 °F	PNL-6189	Section 4.3
6-year cooled	720 °F	PNL-6189	Section 4.3
7-year cooled	676 °F	PNL-6189	Section 4.3
10-year cooled	665 °F	PNL-6189	Section 4.3
15-year cooled	653 °F	PNL-6189	Section 4.3
Canister Backfill Gas	Helium	-	Chapter 12
Canister Backfill Pressure	Varies by MPC	-	Chapter 12
Short-Term Allowable Fuel Cladding Temperature	1058 °F	PNL-4835	Sections 2.0.1 & 4.3
Insolation	Protected by Overpack	10CFR71.71	-

Table 2.0-1 (continued)

MPC DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
Confinement:		10CFR72.128(a)(3) and 10CFR72.236(d) and (e)	
Closure Welds:			
Shell Seams and Shell-to-Baseplate	Full Penetration	-	Section 1.5 and Table 9.1.3
MPC Lid	Multi-pass Partial Penetration	10CFR72.236(e)	Section 1.5 and Table 9.1.3
MPC Closure Ring	Multi-pass Partial Penetration		
Port Covers	Full Penetration		
NDE:			
Shell Seams and Shell-to-Baseplate	100% RT or UT	NUREG-1536	Chapter 8 and Table 9.1.3
MPC Lid	Root Pass/Final Surface 100% PT and Volumetric or Multi-Layer PT	NUREG-1536	Chapter 8 and Table 9.1.3
Closure Ring	Root Pass/Final Surface 100% PT	NUREG-1536	Chapter 8 and Table 9.1.3
Port Covers	Root Pass/Final Surface 100% PT	NUREG-1536	Chapter 8 and Table 9.1.3
Leak Testing:			

Table 2.0-1 (continued)

MPC DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
Welds Tested	Shell seams, shell-to-baseplate, MPC lid-to-shell, and port covers-to-MPC lid	-	Section 7.1, Chapters 8, 9 and Technical Specifications
Medium	Helium	-	Section 7.2 and Technical Specifications
Max. Leak Rate	$5x10^{-6}$ atm cm^3/sec (helium)	-	Technical Specifications
Monitoring System	None	10CFR72.128(a)(1)	Section 2.3.2.1
Hydrostatic Testing:			
Test Pressure	125 psig (+3, -0 psig)	-	Chapters 8 and 9
Welds Tested	MPC Lid-to-Shell, MPC shell seams, MPC shell-to-baseplate	-	Section 8.1 and Table 9.1.1
Medium	Water	-	Section 8.1 and Chapter 9
Retrievability:			
Normal and Off-normal:	No Encroachment on Fuel Assemblies or Exceeding Fuel Assembly Deceleration Limits	10CFR72.122(f),(h)(1), & (l)	Sections 3.4, 3.5, and 3.1.2
Post (design basis) Accident			

Table 2.0-1 (continued)

MPC DESIGN CRITERIA SUMMARY

Criticality:		10CFR72.124 & 10CFR72.236(c)	
Method of Control	Fixed Borated Neutron Absorber & Geometry	-	Section 2.3.4
Min. Boron Loading	0.0267 g/cm^2 (MPC-24) 0.0372 g/cm^2 (MPC-68) 0.01 g/cm^2 (MPC-68F)	-	Section 2.1.7
Max. k_{eff}	0.95	-	Sections 6.1 and 2.3.4
Min. Burnup	0.0 GWd/MTU (fresh fuel)	-	Section 6.1
Radiation Protection/Shielding:		10CFR72.126, & 10CFR72.128(a)(2)	
MPC: (normal/off-normal/accident)			
MPC Closure	ALARA	10CFR20	Sections 10.1, 10.2, & 10.3
MPC Transfer	ALARA	10CFR20	Sections 10.1, 10.2, & 10.3
Exterior of Shielding: (normal/off-normal/accident)			
Storage Mode Position	See Table 2.0.2	10CFR20	Section 5.1.1
ISFSI Controlled Area Boundary	See Table 2.0.2	10CFR72.104 & 10CFR72.106	Section 5.1.1 and Chapter 10

Table 2.0-1 (continued)

MPC DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
Design Bases:		10CFR72.236(a)	
Spent Fuel Specification:			
Assemblies/Canister	Up to 24 (MPC-24) Up to 68 (MPC-68)	-	Table 1.2.1
Type of Cladding	Zircaloy*	-	Table 2.1.6
Fuel Condition	Intact*	-	Section 2.1.2 & Table 2.1.6
* Also designed to accommodate failed fuel, stainless clad fuel, and MOX fuel (Tables 2.1.7 and 2.1.11 and Appendix B to CoC 72-1008)			
PWR Fuel Assemblies:			
Type/Configuration	Various	-	Table 2.1.3
Max. Burnup	42,100 MWD/MTU (MPC-24)	-	Figure 2.1.6
Max. Enrichment	Varies by fuel design	-	Table 2.1.3
Max. Decay Heat/Assembly:			
5-year cooled	791.6 W (MPC-24)	-	Figure 2.1.8
6-year cooled	773 W (MPC-24)	-	Figure 2.1.8
7-year cooled	703 W (MPC-24)	-	Figure 2.1.8

Table 2.0-1 (continued)

MPC DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
10-year cooled	687 W (MPC-24)	-	Figure 2.1.8
15-year cooled	665 W (MPC-24)	-	Figure 2.1.8
Minimum Cooling Time:	5 years (Intact Zr Clad Fuel) 9 years (Intact SS Clad Fuel)	-	Chapter 12
Max. Fuel Assembly Weights:	1,680 lb.	-	Table 2.1.6
Max. Fuel Assembly Length: (unirradiated nominal)	176.8 in.	-	Table 2.1.6
Max. Fuel Assembly Width (unirradiated nominal)	8.54 in.	-	Table 2.1.6
Fuel Rod Fill Gas:			
Pressure (max.)	500 psig	-	Section 4.3 & Table 4.3.2
BWR Fuel Assemblies:			
Type	Various	-	Table 2.1.4
Max. Burnup	37,600 MWd/MTU	-	Figures 2.1.6 and Appendix B to CoC 72-1008
Max. Enrichment	Varies by fuel design	-	Section 6.1 and Appendix B to CoC 72-1008

Table 2.0-1 (continued)

MPC DESIGN CRITERIA SUMMARY

Max. Decay Heat/Assy.:			
5-year cooled	272 W (MPC-68)	-	Figure 2.1.8
6-year cooled	261 W (MPC-68)	-	Figure 2.1.8
7-year cooled	238 W (MPC-68)		Figure 2.1.8
10-year cooled	232 W (MPC-68)	-	Figure 2.1.8
15-year cooled	226 W (MPC-68)	-	Figure 2.1.8
Minimum Cooling Time:	5 years (Intact Zr Clad Fuel) 18 years (Damaged Zr Clad Fuel) 18 years (Zr Clad Fuel Debris) 10 years (Intact SS Clad Fuel)	-	Appendix B to CoC 72-1008
Max. Fuel Assembly Weight:			
w/channels	700 lb.	-	Table 2.1.6
Max. Fuel Assembly Length (unirradiated nominal)	176.2 in.	-	Table 2.1.6
Max. Fuel Assembly Width (unirradiated nominal)	5.85 in.	-	Table 2.1.6
Fuel Rod Fill Gas:			
Pressure (max.)	147 psig	-	Table 4.3.5

Table 2.0-1 (continued)

MPC DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
Normal Design Event Conditions:		10CFR72.122(b)(1)	
Ambient Temperatures	See Table 2.0.2	ANSI/ANS 57.9	Section 2.2.1.4
Handling:			Section 2.2.1.2
Handling Loads	115% of Dead Weight	CMAA #70	Section 2.2.1.2
Lifting Attachment Acceptance Criteria	1/10 Ultimate 1/6 Yield	NUREG-0612	Section 2.2.1.2
Attachment/Component Interface Acceptance Criteria	1/3 Yield	Regulatory Guide 3.61	Section 2.2.1.2
Away from Attachment Acceptance Criteria	ASME Code Level A	ASME Code	Section 2.2.1.2
Wet/Dry Loading	Wet or Dry	-	Section 1.2.2.2
Transfer Orientation	Vertical or Horizontal	-	Section 1.2.2.2
Storage Orientation	Vertical	-	Section 1.2.2.2
Fuel Rod Rupture Releases:			
Fuel Rod Failures	1%	NUREG-1536	Section 2.2.1.3
Fill Gases	100%	NUREG-1536	Section 2.2.1.3
Fission Gases	30%	NUREG-1536	Section 2.2.1.3

Table 2.0-1 (continued)

MPC DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
Snow and Ice	Protected by Overpack	ASCE 7-88	Section 2.2.1.6
Off-Normal Design Event Conditions:		10CFR72.122(b)(1)	
Ambient Temperature	See Table 2.0.2	ANSI/ANS 57.9	Section 2.2.2.2
Leakage of One Seal	No Loss of Confinement	ANSI/ANS 57.9	Section 2.2.2.4
Fuel Rod Rupture Releases:			
Fuel Rod Failures	10%	NUREG-1536	Section 2.2.2.1
Fill Gases	100%	NUREG-1536	Section 2.2.2.1
Fission Gases	30%	NUREG-1536	Section 2.2.2.1
Design-Basis (Postulated) Accident Design Events and Conditions:		10CFR72.24(d)(2) & 10CFR72.94	
Tip Over	See Table 2.0.2	-	Section 2.2.3.2
End Drop	See Table 2.0.2	-	Section 2.2.3.1
Side Drop	See Table 2.0.2	-	Section 2.2.3.1
Fire	See Table 2.0.2	10CFR72.122(c)	Section 2.2.3.3
Fuel Rod Rupture Releases:			
Fuel Rod Failures	100%	NUREG-1536	Section 2.2.3.8
Fill Gases	100%	NUREG-1536	Section 2.2.3.8

Table 2.0-1 (continued)

MPC DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
Fission Gases	30%	NUREG-1536	Section 2.2.3.8
Particulates & Volatiles	See Table 7.3.1	-	Sections 2.2.3.9 and 7.3
Confinement Boundary Leakage	$5\text{x}10^{-6}$ atm cm^3/sec (helium)	-	Sections 2.2.3.9 and 7.3
Explosive Overpressure	Protected by Overpack	10CFR72.122(c)	Section 2.2.3.10
Design Basis Natural Phenomenon Design Events and Conditions:		10CFR72.92 & 10CFR72.122(b)(2)	
Flood Water Depth	125 ft.	ANSI/ANS 57.9	Section 2.2.3.6
Seismic	See Table 2.0.2	10CFR72.102(f)	Section 2.2.3.7
Wind	Protected by Overpack	ASCE-7-88	Section 2.2.3.5
Tornado & Missiles	Protected by Overpack	RG 1.76 & NUREG-0800	Section 2.2.3.5
Burial Under Debris	Adiabatic Heat-Up	-	Section 2.2.3.12
Lightning	See Table 2.0.2	NFPA 78	Section 2.2.3.11
Partial Blockage of MPC Basket Vent Holes	Crud Depth (Table 2.2.8)	ESEERCO Project EP91-29	Section 2.2.3.4
Extreme Environmental Temperature	See Table 2.0.2	-	Section 2.2.3.13

Table 2.0.2

OVERPACK DESIGN CRITERIA SUMMARY

Type	Criteria	Basis	FSAR Reference
Design Life:			
Design	40 yrs.	-	Section 2.0.2
Regulatory	20 yrs.	10CFR72.42(a) & 10CFR72.236(g)	
Structural:			
Design Codes:			
Inner Shell, Closure Plate, Top Flange, Bottom Plate, and Closure Plate Bolts			
Design	ASME Code Section III, Subsection NB	10CFR72.24(c)(4)	Section 2.0.2
Fabrication	ASME Code Section III, Subsection NB	10CFR72.24(c)(4)	Section 2.0.2
Remainder of Structural Steel			
Design	ASME Code Section III, Subsection NF	10CFR72.24(c)(4)	Section 2.0.2
Fabrication	ASME Code Section III, Subsection NF	10CFR72.24(c)(4)	Section 2.0.2

Table 2.0.2 (continued)

OVERPACK DESIGN CRITERIA SUMMARY

Design Weights:			
Max. Loaded MPC (Dry)	90,000 lb. (Bounding)	ANSI/ANS 57.9	Table 3.2.1
Max. Empty Overpack:			
Assembled with Closure Plate	153,710 lb.	ANSI/ANS 57.9	Table 3.2.1
Max. MPC/Overpack:	242,767 lb.	ANSI/ANS 57.9	Table 3.2.1
Design Cavity Pressures	40 psig (Normal) 40 psig (Off-Normal) 60 psig (Accident)	-	Table 2.2.1
Response and Degradation Limits	See Table 2.0.1	10CFR72.122(h)(1)	Section 2.0.1
Thermal:			
Maximum Design Temperatures:			
Inner Shell (SA203-E)			
Normal Condition Maximum	400 °F	ASME Code Section II, Part D	Table 2.2.3
Off-Normal/Accident Condition Maximum	500 °F	ASME Code Section II, Part D	Table 2.2.3
Top Flange & Closure Plate (SA350-LF3)			
Normal Condition Maximum	400 °F	ASME Code	Table 2.2.3

Table 2.0.2 (continued)

OVERPACK DESIGN CRITERIA SUMMARY

		Section II, Part D	
Off-Normal/Accident Condition Maximum	700 °F	ASME Code Section II, Part D	Table 2.2.3
Bottom Plate (SA350-LF3)			
Normal Condition Maximum	350 °F	ASME Code Section II, Part D	Table 2.2.3
Off-Normal/Accident Condition Maximum	700 °F	ASME Code Section II, Part D	Table 2.2.3
Remainder of Steel Structure	350 °F	ASME Code Section II, Part D	Table 2.2.3
Neutron Shield	300 °F	Manufacturer's Test Data	Table 2.2.3
Insolation:	Averaged Over 24 Hours	10CFR71.71	Section 4.4.1.1.8
Confinement:	None	10CFR72.128(a)(3) & 10CFR72.236(d) & (e)	N/A
Retrievability:			
Normal and Off-normal	No damage which precludes Retrieval of MPC or Exceeding Fuel Assembly Deceleration Limits	10CFR72.122(f),(h)(1), & (l)	Sections 3.5 and 3.4
Accident			Sections 3.5 and 3.4

Table 2.0.2 (continued)

OVERPACK DESIGN CRITERIA SUMMARY

Criticality:	Protection of MPC and Fuel Assemblies	10CFR72.124 & 10CFR72.236(c)	Section 6.1
Radiation Protection/Shielding:		10CFR72.126 & 10CFR72.128(a)(2)	
Overpack (Normal/Off-normal/Accident)			
Surface	ALARA	10CFR20	Chapters 5 and 10
Position	ALARA	10CFR20	Chapters 5 and 10
Beyond Controlled Area During Normal Operation and Anticipated Occurrences	25 mrem/yr. to whole body 75 mrem/yr. to thyroid 25 mrem/yr. to any organ	10CFR72.104	Sections 5.1.1, 7.2, and 10.4
On Controlled Area Boundary from Design Basis Accident	5 rem to whole body or to any organ	10CFR72.106	Sections 5.1.2, 7.3, and 10.4
Design Bases:			
Spent Fuel Specification	See Table 2.0.1	10CFR72.236(a)	Section 2.1
Normal Design Event Conditions:		10CFR72.122(b)(1)	
Ambient Outside Temperatures:			
Lifetime Average	80 °F	ANSI/ANS 57.9	Section 2.2.1.4

Table 2.0.2 (continued)

OVERPACK DESIGN CRITERIA SUMMARY

Handling:			
Handling Loads	115% of Dead Weight	CMAA #70	Section 2.2.1.2
Lifting Attachment Acceptance Criteria	1/10 Ultimate 1/6 Yield	NUREG-0612	Section 2.2.1.2
Snow and Ice Load	100 lb./ft^2	ASCE 7-88	Section 2.2.1.6
Wet/Dry Loading	Wet/Dry	-	Section 1.2.2.2
Storage Orientation	Vertical	-	Section 1.2.2.2
Off-Normal Design Event Conditions:		10CFR72.122(b)(1)	
Ambient Temperature			
Minimum	-40 °F	ANSI/ANS 57.9	Section 2.2.2.2
Maximum	100 °F	ANSI/ANS 57.9	Section 2.2.2.2
Design-Basis (Postulated) Accident Design Events and Conditions:		10CFR72.94	
Drop Cases:			
End	21 in.	-	Section 2.2.3.1
Side	72 in.	-	Section 2.2.3.1
Tip-Over	Assumed (Non-mechanistic)	-	Section 2.2.3.2

Table 2.0.2 (continued)

OVERPACK DESIGN CRITERIA SUMMARY

Fire:			
Duration	305 seconds	10CFR72.122(c)	Section 2.2.3.3
Temperature	1,475 °F	10CFR72.122(c)	Section 2.2.3.3
Fuel Rod Rupture	See Table 2.0.1	-	Section 2.2.3.8
Design-Basis Natural Phenomenon Design Events and Conditions:		10CFR72.92 & 10CFR72.122(b)(2)	
Flood			
Height	656 ft.	RG 1.59	Section 2.2.3.6
Velocity	13 ft/sec.	RG 1.59	Section 2.2.3.6
Seismic			
Max. ZPA Horizontal Ground (Max. ZPA Vertical Ground)	0.314g (w/1.0 vertical) 0.332g (w/0.75 vertical) 0.339g (w/0.667 vertical) 0.354g (w/0.5 vertical)	10CFR72.102(f)	Section 2.2.3.7
Tornado			
Wind			
Max. Wind Speed	360 mph	RG 1.76	Section 2.2.3.5
Pressure Drop	3.0 psi	RG 1.76	Section 2.2.3.5
Missiles			Section 2.2.3.5

Table 2.0.2 (continued)

OVERPACK DESIGN CRITERIA SUMMARY

Automobile			
Weight	1,800 kg	NUREG-0800	Table 2.2.5
Velocity	126 mph	NUREG-0800	Table 2.2.5
Rigid Solid Steel Cylinder (Artillery Shell)			
Weight	125 kg	NUREG-0800	Table 2.2.5
Velocity	126 mph	NUREG-0800	Table 2.2.5
Diameter	8 in.	NUREG-0800	Table 2.2.5
Steel Sphere			
Weight	0.22 kg	NUREG-0800	Table 2.2.5
Velocity	126 mph	NUREG-0800	Table 2.2.5
Diameter	1 in.	NUREG-0800	Table 2.2.5
Burial Under Debris	Adiabatic Heat-Up	-	Section 2.2.3.12
Lightning	Resistance Heat-Up	NFPA 70 & 78	Section 2.2.3.11
Extreme Environmental Temperature	125 °F	-	Section 2.2.3.13
Load Combinations:	See Table 2.2.14	ANSI/ANS 57.9 and NUREG-1536	Section 2.2.7

2.1 SPENT FUEL TO BE STORED

2.1.1 Determination of The Design Basis Fuel

The HI-STAR 100 System is designed to store most types of fuel assemblies generated in the commercial U.S. nuclear industry. Boiling-water reactor (BWR) fuel assemblies have been supplied by The General Electric Company (GE), Siemens (SPC), Exxon Nuclear, ANF, UNC, ABB Combustion Engineering, and Gulf Atomic. Pressurized-water reactor (PWR) fuel assemblies are generally supplied by Westinghouse, Babcock & Wilcox, ANF, and ABB Combustion Engineering. ANF, Exxon, and Siemens are historically the same manufacturing company under different ownership. Within this report, SPC is used to designate fuel manufactured by ANF, Exxon, or Siemens. Publications such as Refs. [2.1.1] and [2.1.2] provide a comprehensive description of fuel discharged from U.S. reactors. A central object in the design of the HI-STAR 100 System is to ensure that a majority of SNF discharged from the U.S. reactors can be loaded into one of the HI-STAR 100 MPCs.

The cell openings and lengths in the fuel basket have been sized to accommodate the BWR and PWR assemblies listed in Refs. [2.1.1] and [2.1.2] except as noted below. Similarly, the cavity length of the multi-purpose canisters has been set at a dimension which permits storing most types of PWR fuel assemblies and BWR fuel assemblies with or without fuel channels. The exceptions are as follows:

- The South Texas Units 1 & 2 SNF, and CE 16x16 System 80 SNF are too long to be accommodated in the available MPC cavity length.

In addition to satisfying the cross sectional and length compatibility, the active fuel region of the SNF must be enveloped in the axial direction by the neutron absorber located in the MPC fuel basket. Alignment of the neutron absorber with the active fuel region is ensured by the use of upper and lower fuel spacers suitably designed to support the bottom and restrain the top of the fuel assembly. The spacers axially position the SNF assembly such that its active fuel region is properly aligned with the neutron absorber in the fuel basket. Figure 2.1.5 provides a pictorial representation of the fuel spacers positioning the fuel assembly active fuel region. Both the upper and lower fuel spacers are designed to perform their function under normal, off-normal, and accident conditions of storage.

In summary, the geometric compatibility of the SNF with the MPC designs does not require the definition of a design basis fuel assembly. This, however, is not the case for structural, confinement, shielding, thermal-hydraulic, and criticality criteria. In fact, a particular fuel type in a category (PWR or BWR) may not control the cask design in all of the above-mentioned criteria. To ensure that no SNF listed in Refs. [2.1.1] and [2.1.2] which is geometrically admissible in the HI-STAR 100 MPC is precluded, it is necessary to determine the governing fuel specification for each analysis criteria. To make the necessary determinations, potential candidate fuel assemblies for each qualification criteria were considered. Table 2.1.1 lists the PWR fuel assemblies which were evaluated. These fuel assemblies were evaluated to define the governing design criteria for PWR fuel. The BWR fuel assembly designs evaluated are listed in Table 2.1.2. Tables 2.1.3 and 2.1.4 provide the fuel characteristics determined to be acceptable for storage in the HI-STAR 100 System. Table 2.1.5 lists the BWR and PWR fuel assembly designs which are found to govern for the three qualification criteria, namely reactivity, shielding, and decay heat generation. Substantiating results of analyses for the governing assembly types are presented in the respective chapters dealing with the specific qualification topic. Additional information on the design basis fuel definition is presented in the following subsections.

2.1.2 Intact SNF Specifications

Intact fuel assemblies are defined as fuel assemblies without known or suspected cladding defects greater than pinhole leaks and hairline cracks, and which can be handled by normal means. The design payload for the HI-STAR 100 System is intact zircaloy clad fuel assemblies with the characteristics listed in Table 2.1.6 or intact stainless steel clad fuel assemblies with the characteristics listed in Table 2.1.11. The placement of a single stainless steel clad fuel assembly in an MPC necessitates that all fuel assemblies (stainless steel clad or zircaloy clad) stored in that MPC meet the maximum heat generation requirements for stainless steel clad fuel specified in Table 2.1.11. Intact BWR MOX fuel assemblies shall meet the requirements of Table 2.1.7.

Intact fuel assemblies with missing pins cannot be loaded into the HI-STAR 100 System unless dummy fuel pins, which occupy a volume greater than or equal to the original fuel pins, replace the missing pins prior to loading. Any intact fuel assembly which falls within the geometric, thermal, and nuclear limits established for the design basis intact fuel assembly, as defined in Appendix B to Certificate of Compliance 72-1008 can be safely stored in the HI-STAR 100 System.

The fuel characteristics specified in Tables 2.1.3 and 2.1.4 have been evaluated in this FSAR and are acceptable for storage in the HI-STAR 100 System.

2.1.3 Damaged SNF and Fuel Debris Specifications

Damaged fuel assemblies are defined as fuel assemblies with known or suspected cladding defects greater than pinhole leaks and hairline cracks or missing fuel rods that are not replaced with dummy fuel rods, and which may have mechanical damage which would not allow it to be handled by normal means; however, there shall be no loose components. No loose fuel debris is allowed with the damaged fuel assembly.

Fuel debris is defined as fuel assemblies with known or suspected defects greater than pinhole leaks or hairline cracks such as ruptured fuel rods, severed fuel rods, or loose fuel pellets, and which cannot be handled by normal means.

To aid in loading and unloading, damaged fuel assemblies and fuel debris will be loaded into stainless steel damaged fuel containers (DFCs) provided with 250 micron fine mesh screens, prior to placement in the HI-STAR 100 System. This application requests approval of Dresden Unit 1 (UO_2 rods and MOX fuel rods) and Humboldt Bay fuel arrays (Assembly Classes 6x6A, 6x6B, 6x6C, 7x7A, and 8x8A) as damaged fuel assembly contents for storage in the MPC-68 and fuel debris as contents for storage in the MPC-68F. The design characteristics bounding Dresden Unit 1 and Humboldt Bay SNF are given in Table 2.1.7. The placement of a single damaged fuel assembly in an MPC-68 or a single fuel debris damaged fuel container in an MPC-68F necessitates that all fuel assemblies (intact, damaged, or debris) stored in that MPC meet the maximum heat generation requirements specified in Table 2.1.7. The fuel characteristics specified in Table 2.1.4 for Dresden 1 and Humboldt Bay fuel arrays have been evaluated in this FSAR and are acceptable for storage as damaged fuel or fuel debris in the HI-STAR 100 System. The DFC design is illustrated in Figure 2.1.1 and the Design Drawings are provided in Section 1.5. Because of the long cooling time, small size, and low weight of spent fuel assemblies qualified as damaged fuel or fuel debris, the DFC and its contents are bounded by the structural, thermal, and shielding analyses performed for the intact BWR design basis fuel. Separate criticality analysis of the bounding fuel assembly for the damaged fuel and fuel debris has been performed in Chapter 6.

2.1.4 Structural Parameters for Design Basis SNF

The main physical parameters of a SNF assembly applicable to the structural evaluation are the fuel assembly length, envelope (cross sectional dimensions), and weight. These parameters, which define the mechanical and structural design, are listed in Tables 2.1.6, 2.1.7, and 2.1.11. The centers of gravity reported in Section 3.2 are based on the maximum fuel assembly weight. Upper and lower fuel spacers (as appropriate) maintain the axial position of the fuel assembly within the MPC basket and, therefore, the location of the center of gravity. The upper and lower fuel spacers are designed to withstand normal, off-normal, and accident conditions of storage. An axial clearance of approximately 2 inches is provided to account for the irradiation and thermal growth of the fuel assemblies. The suggested upper and lower fuel spacer lengths are listed in Tables 2.1.9 and 2.1.10. In order to qualify for storage in the HI-STAR 100 MPC, the SNF must satisfy the physical parameters listed in Tables 2.1.6, 2.1.7, or 2.1.11.

2.1.5 Thermal Parameters for Design Basis SNF

The principal thermal design parameter for the stored fuel is the peak fuel cladding temperature, which is a function of the maximum heat generation rate per assembly, the allowable fuel cladding temperature based on cooling time, and the decay heat removal capabilities of the HI-STAR 100 System. The maximum heat generation rate per assembly for the design basis fuel assembly is based on the fuel assembly type with the highest decay heat for a given enrichment, burnup, and cooling time. This decay heat design basis fuel assembly is listed in Table 2.1.5. Section 5.2 describes the method used to determine the design basis fuel assembly type and calculate the decay heat load.

As can be seen in Table 2.2.3, the acceptable normal condition fuel cladding temperature limit decreases with increased cooling time. Therefore, the allowable decay heat load per fuel assembly must correspondingly decrease with increased fuel assembly cooling time. For example, the maximum decay heat load for 5-year cooled zircaloy clad BWR fuel in the MPC-68 is 272W, but for 10-year cooled zircaloy clad BWR fuel, the decay heat load is limited to 232W. To ensure the allowable fuel cladding temperature limits are not exceeded, Figure 2.1.8 specifies the allowable decay heat per assembly versus cooling time for zircaloy clad fuel in each MPC type. Tables 2.1.7 and 2.1.11 provide the maximum heat generation for damaged zircaloy clad fuel assemblies and stainless steel clad fuel assemblies, respectively. Due to the conservative thermal assessment and the long cooling time of the damaged and stainless steel clad fuel, a reduction in decay heat load is not required as the cooling time increases beyond the minimum specified.

The specified decay heat load can be attained by varying burnups and cooling times. Figure 2.1.6 provides illustrative burnup and cooling time characteristics for intact zircaloy clad fuel to meet the thermal requirements for the MPC-24 and MPC-68. Any intact zircaloy clad fuel assembly with a burnup and cooling time which lies on or below the curve of Figure 2.1.6 may be thermally acceptable for loading into the HI-STAR 100 System (MPC-24 or MPC-68). Each point on the curve produces a decay heat equal to or below the value specified in Figure 2.1.8 for the design basis fuel assembly type.

The fuel rod cladding temperature is also affected by other factors. A governing geometry which maximizes the impedance to the transmission of heat out of the fuel rods has been defined. The governing thermal parameters ensure that the range of SNF discussed previously are bounded by the thermal analysis is discussed in detail and specified in Chapter 4. By utilizing these bounding thermal parameters, the calculated peak fuel rod cladding temperatures are conservative for actual spent fuel assemblies which will have greater thermal conductivities.

Finally, the axial variation in the heat generation rate in the design basis fuel assembly is defined based on the axial burnup distribution. For this purpose, the data provided in Refs. [2.1.3] and [2.1.4] are utilized and summarized in Table 2.1.8 and Figures 2.1.3 and 2.1.4 for reference. These distributions are representative of fuel assemblies with the design basis burnup levels considered. These distributions are used for analyses only, and do not provide a criteria for fuel assembly acceptability for storage in the HI-STAR 100 System.

2.1.6 Radiological Parameters for Design Basis SNF

The principal radiological design criteria for the HI-STAR 100 System are the 10CFR72.104 site boundary dose rate limits and maintaining operational dose rates as low as reasonably achievable (ALARA). The radiation dose is directly affected by the gamma and neutron source terms of the SNF assembly.

The gamma and neutron sources are separate and are affected differently by enrichment, burnup, and cooling time. It is recognized that, at a given burnup, the radiological source terms increase monotonically as the initial enrichment is reduced. The shielding design basis fuel assembly, therefore, is evaluated at the maximum burnup, minimum cooling time, and a conservative enrichment corresponding to the burnup. The shielding design basis fuel assembly thus bounds all other fuel assemblies.

The design basis dose rates can be met by a variety of burnup levels and cooling times. Tables 2.1.7 and 2.1.11 provide the burnup and cooling time values which meet the radiological source term requirements for BWR damaged fuel/fuel debris and intact stainless steel clad fuel, respectively. Figure 2.1.6 provides illustrative burnup and cooling time values which meet the radiological source term requirements for intact zircaloy clad fuel in each MPC type.

Table 2.1.8 and Figures 2.1.3 and 2.1.4 provide the axial distribution for the radiological source terms for PWR and BWR fuel assemblies based on the axial burnup distribution. The axial burnup distributions are representative of fuel assemblies with the design basis burnup levels considered. These distributions are used for analyses only, and do not provide a criteria for fuel assembly acceptability for storage in the HI-STAR 100 System.

Thoria rods placed in Dresden Unit 1 Thoria Rod Canisters meeting the requirements of Table 2.1.12 and Dresden Unit 1 fuel assemblies with one Antimony-Beryllium neutron source have been qualified for storage. Up to one Dresden Unit 1 Thoria Rod Canister plus any combination of damaged fuel assemblies in damaged fuel containers and intact fuel, up to a total of 68 may be stored.

Burnable Poison Rod Assemblies (BPRAs) and Thimble Plug Devices (TPDs) in PWR fuel have been qualified for storage in the MPC-24.

2.1.7 Criticality Parameters for Design Basis SNF

As discussed earlier, the MPC-68 features a basket without flux traps. In the MPC-68 basket, there is one panel of neutron absorber between two adjacent fuel assemblies. The MPC-24 employs a construction wherein two neighboring fuel assemblies are separated by two panels of neutron absorber with a water gap between them (flux trap construction).

The MPC-24 Boral ^{10}B areal density is specified at a minimum loading of 0.0267 g/cm^2. The MPC-68 Boral ^{10}B areal density is specified at a minimum loading of 0.0372 g/cm^2. The MPC-68F Boral ^{10}B areal density is specified at a minimum loading of 0.01 g/cm^2.

For all MPCs, the ^{10}B areal density used for analysis is conservatively established at 75% of the minimum ^{10}B areal density to demonstrate that the reactivity under the most adverse accumulation of tolerances and biases is less than 0.95. This satisfies NUREG-1536 [2.1.5], which requires a 25% reduction in ^{10}B areal density credit. A large body of sampling data accumulated by Holtec from thousands of manufactured Boral panels indicates the average ^{10}B areal densities to be approximately 15% greater than the specified minimum.

2.1.8 Summary of SNF Design Criteria

An intact zircaloy clad fuel assembly is acceptable for storage in a HI-STAR 100 System if it fulfills the following criteria:

a. It satisfies the physical characteristics listed in Tables 2.1.3 or 2.1.4, and 2.1.6.

b. Its initial enrichment is less than that indicated by Table 2.1.6 for the MPC it is intended to be stored in.

c. The period from discharge is greater than or equal to the minimum cooling time listed in Table 2.1.6, and the decay heat is equal to or less than the value stated in Figure 2.1.8 for a given cooling time.

d. The average burnup of the fuel assembly is equal to or less than the burnup specified in Figure 2.1.6 for a given cooling time.

A damaged fuel assembly shall meet the characteristics specified in Table 2.1.7 for storage in the MPC-68. Fuel debris shall meet the characteristics specified in Table 2.1.7 for storage in the MPC-68F.

Stainless steel clad fuel assemblies shall meet the characteristics specified in Table 2.1.11 for storage in the MPC-24 or MPC-68.

MOX BWR fuel assemblies shall meet the requirements of Tables 2.1.6 and 2.1.7 for intact and damaged fuel/fuel debris, respectively.

Only control components specifically authorized by the Technical Specifications for PWR fuel are to be included with the fuel assembly. Burnable Poison Rod Assemblies (BPRAs) and Thimble Plug Devices (TPDs) are authorized for storage in the MPC-24. Fuel assemblies with BPRAs shall satisfy the more restrictive burnup and cooling time requirements in Figure 2.1.6. BPRAs and TPDs shall meet the burnup and cooling time requirements specified in the Technical Specification.

Thoria rods placed in Dresden Unit 1 Thoria Rod Canisters meeting the requirements of Table 2.1.12 are authorized for storage. Up to one Dresden Unit 1 Thoria Rod Canister plus any combination of damaged fuel assemblies in damaged fuel containers and intact fuel, up to a total of 68 may be stored.

Dresden Unit 1 fuel assemblies with one Antimony-Beryllium neutron source are authorized for loading in the MPC-68 or MPC-68F.

Table 2.1.1

PWR FUEL ASSEMBLIES EVALUATED TO DETERMINE DESIGN BASIS SNF

Assembly Class	**Array Type**
B&W 15x15	All
B&W 17x17	All
CE 14x14	All
CE 16x16	All
WE 14x14	All
WE 15x15	All
WE 17x17	All
St. Lucie	All
Ft. Calhoun	All
Haddam Neck (Stainless Steel Clad)	All
San Onofre 1 (Stainless Steel Clad)	All

Table 2.1.2

BWR FUEL ASSEMBLIES EVALUATED TO DETERMINE DESIGN BASIS SNF

Assembly Class	Array Type			
GE BWR/2-3	All 7x7	All 8x8	All 9x9	All 10x10
GE BWR/4-6	All 7x7	All 8x8	All 9x9	All 10x10
Humboldt Bay	All 6x6	All 7x7 (Zircaloy Clad)		
Dresden-1	All 6x6	All 8x8		
LaCrosse (Stainless Steel Clad)	All			

Table 2.1.3
PWR FUEL ASSEMBLY CHARACTERISTICS (Note 1)

Fuel Assembly Array and Class	**14x14 A**	**14x14 B**	**14x14 C**	**14x14 D**	**15x15 A**
Clad Material (Note 2)	Zr	Zr	Zr	SS	Zr
Design Initial U (kg/assy.) (Note 3)	≤ 407	≤ 407	≤ 425	≤ 400	≤ 464
Initial Enrichment (wt % ^{235}U)	≤ 4.6	≤ 4.6	≤ 4.6	≤ 4.0	≤ 4.1
No. of Fuel Rods (Note 5)	179	179	176	180	204
Clad O.D. (in.)	≥ 0.400	≥ 0.417	≥ 0.440	≥ 0.422	≥ 0.418
Clad I.D. (in.)	≤ 0.3514	≤ 0.3734	≤ 0.3880	≤ 0.3890	≤ 0.3660
Pellet Dia. (in.)	≤ 0.3444	≤ 0.3659	≤ 0.3805	≤ 0.3835	≤ 0.3580
Fuel Rod Pitch (in.)	≤ 0.556	≤ 0.556	≤ 0.580	≤ 0.556	≤ 0.550
Active Fuel Length (in.)	≤ 150	≤ 150	≤ 150	≤ 144	≤ 150
No. of Guide Tubes	17	17	5 (Note 4)	16	21
Guide Tube Thickness (in.)	≥ 0.017	≥ 0.017	≥ 0.038	≥ 0.0145	≥ 0.0165

Table 2.1.3 (continued)
PWR FUEL ASSEMBLY CHARACTERISTICS (Note 1)

Fuel Assembly Array and Class	**15x15 B**	**15x15 C**	**15x15 D**	**15x15 E**	**15x15 F**
Clad Material (Note 2)	Zr	Zr	Zr	Zr	Zr
Design Initial U (kg/assy.) (Note 3)	≤ 464	≤ 464	≤ 475	≤ 475	≤ 475
Initial Enrichment (wt % ^{235}U)	≤ 4.1	≤ 4.1	≤ 4.1	≤ 4.1	≤ 4.1
No. of Fuel Rods (Note 5)	204	204	208	208	208
Clad O.D. (in.)	≥ 0.420	≥ 0.417	≥ 0.430	≥ 0.428	≥ 0.428
Clad I.D. (in.)	≤ 0.3736	≤ 0.3640	≤ 0.3800	≤ 0.3790	≤ 0.3820
Pellet Dia. (in.)	≤ 0.3671	≤ 0.3570	≤ 0.3735	≤ 0.3707	≤ 0.3742
Fuel Rod Pitch (in.)	≤ 0.563	≤ 0.563	≤ 0.568	≤ 0.568	≤ 0.568
Active Fuel Length (in.)	≤ 150	≤ 150	≤ 150	≤ 150	≤ 150
No. of Guide Tubes	21	21	17	17	17
Guide Tube Thickness (in.)	≥ 0.015	≥ 0.0165	≥ 0.0150	≥ 0.0140	≥ 0.0140

Table 2.1.3 (continued)
PWR FUEL ASSEMBLY CHARACTERISTICS (Note 1)

Fuel Assembly Array and Class	**15x15 G**	**15x15 H**	**16x16 A**	**17x17A**	**17x17 B**	**17x17 C**
Clad Material (Note 2)	SS	Zr	Zr	Zr	Zr	Zr
Design Initial U (kg/assy.) (Note 3)	$\leq$ 420	$\leq$ 475	$\leq$ 443	$\leq$ 467	$\leq$ 467	$\leq$ 474
Initial Enrichment (wt % ^{235}U)	$\leq$ 4.0	$\leq$ 3.8	$\leq$ 4.6	$\leq$ 4.0	$\leq$ 4.0	$\leq$ 4.0
No. of Fuel Rods (Note 5)	204	208	236	264	264	264
Clad O.D. (in.)	$\geq$ 0.422	$\geq$ 0.414	$\geq$ 0.382	$\geq$ 0.360	$\geq$ 0.372	$\geq$ 0.377
Clad I.D. (in.)	$\leq$ 0.3890	$\leq$ 0.3700	$\leq$ 0.3320	$\leq$ 0.3150	$\leq$ 0.3310	$\leq$ 0.3330
Pellet Dia. (in.)	$\leq$ 0.3825	$\leq$ 0.3622	$\leq$ 0.3255	$\leq$ 0.3088	$\leq$ 0.3232	$\leq$ 0.3252
Fuel Rod Pitch (in.)	$\leq$ 0.563	$\leq$ 0.568	$\leq$ 0.506	$\leq$ 0.496	$\leq$ 0.496	$\leq$ 0.502
Active Fuel Length (in.)	$\leq$ 144	$\leq$ 150	$\leq$ 150	$\leq$ 150	$\leq$ 150	$\leq$ 150
No. of Guide Tubes	21	17	5 (Note 4)	25	25	25
Guide Tube Thickness (in.)	$\geq$ 0.0145	$\geq$ 0.0140	$\geq$ 0.0400	$\geq$ 0.016	$\geq$ 0.014	$\geq$ 0.020

Table 2.1.3 (continued)
PWR FUEL ASSEMBLY CHARACTERISTICS

NOTES:

1. Fuel assembly array/classes are defined in Chapter 6. All dimensions are design nominal values. Maximum and minimum dimensions are specified to bound variations in design nominal values among fuel assemblies within a given array/class.

2. Zr designates cladding material made of zirconium or zirconium alloys.

3. Design initial uranium weight is the uranium weight specified for each fuel assembly by the fuel manufacturer or reactor user. For each PWR fuel assembly, the total uranium weight limit specified in this table may be increased up to 2.0 percent for comparison with users' fuel records to account for manufacturer tolerances.

4. Each guide tube replaces four fuel rods.

5. Missing fuel rods must be replaced with dummy fuel rods that displace an equal or greater amount of water as the original fuel rods.

Table 2.1.4
BWR FUEL ASSEMBLY CHARACTERISTICS (Note 1)

Fuel Assembly Array and Class	**6x6 A**	**6x6 B**	**6x6 C**	**7x7 A**	**7x7 B**	**8x8 A**
Clad Material (Note 2)	Zr	Zr	Zr	Zr	Zr	Zr
Design Initial U (kg/assy.) (Note 3)	≤ 110	≤ 110	≤ 110	≤ 100	≤ 195	≤ 120
Maximum Planar-Average Initial Enrichment (wt. % ^{235}U)	≤ 2.7	≤ 2.7 for the UO_2 rods. See Note 4 for MOX rods	≤ 2.7	≤ 2.7	≤ 4.2	≤ 2.7
Initial Maximum Rod Enrichment (wt. % ^{235}U)	≤ 4.0	≤ 4.0	≤ 4.0	≤ 5.5	≤ 5.0	≤ 4.0
No. of Fuel Rods (Note 14)	35 or 36	35 or 36 (up to 9 MOX rods)	36	49	49	63 or 64
Clad O.D. (in.)	≥ 0.5550	≥ 0.5625	≥ 0.5630	≥ 0.4860	≥ 0.5630	≥ 0.4120
Clad I.D. (in.)	≤ 0.5105	≤ 0.4945	≤ 0.4990	≤ .4204	≤ 0.4990	≤ 0.3620
Pellet Dia. (in.)	≤ 0.4980	≤ 0.4820	≤ 0.4880	≤ 0.4110	≤ 0.4910	≤ 0.3580
Fuel Rod Pitch (in.)	≤ 0.710	≤ 0.710	≤ 0.740	≤ 0.631	≤ 0.738	≤ 0.523
Active Fuel Length (in.)	≤ 120	≤ 120	≤ 77.5	≤ 80	≤ 150	≤ 120
No. of Water Rods (Note 11)	1 or 0	1 or 0	0	0	0	1 or 0
Water Rod Thickness (in.)	≥0	≥0	N/A	N/A	N/A	≥0
Channel Thickness (in.)	≤ 0.060	≤ 0.060	≤ 0.060	≤ 0.060	≤ 0.120	≤ 0.100

Table 2.1.4 (continued)
BWR FUEL ASSEMBLY CHARACTERISTICS (Note 1)

Fuel Assembly Array and Class	**8x8 B**	**8x8 C**	**8x8 D**	**8x8 E**	**8x8 F**	**9x9 A**	**9x9 B**
Clad Material (Note 2)	Zr	Zr	Zr	Zr	Zr	Zr	Zr
Design Initial U (kg/assy.) (Note 3)	≤ 185	≤ 185	≤ 185	≤ 185	≤ 185	≤ 177	≤ 177
Maximum Planar-Average Initial Enrichment (wt. % ^{235}U)	≤ 4.2	≤ 4.2	≤ 4.2	≤ 4.2	≤ 3.6	≤ 4.2	≤ 4.2
Initial Maximum Rod Enrichment (wt. % ^{235}U)	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0
No. of Fuel Rods (Note 14)	63 or 64	62	60 or 61	59	64	74/66 (Note 5)	72
Clad O.D. (in.)	≥ 0.4840	≥ 0.4830	≥ 0.4830	≥ 0.4930	≥ 0.4576	≥ 0.4400	≥ 0.4330
Clad I.D. (in.)	≤ 0.4295	≤ 0.4250	≤ 0.4230	≤ 0.4250	≤ 0.3996	≤ 0.3840	≤ 0.3810
Pellet Dia. (in.)	≤ 0.4195	≤ 0.4160	≤ 0.4140	≤ 0.4160	≤ 0.3913	≤ 0.3760	≤ 0.3740
Fuel Rod Pitch (in.)	≤ 0.642	≤ 0.641	≤ 0.640	≤ 0.640	≤ 0.609	≤ 0.566	≤ 0.572
Design Active Fuel Length (in.)	≤ 150	≤ 150	≤ 150	≤ 150	≤ 150	≤ 150	≤ 150
No. of Water Rods (Note 11)	1 or 0	2	1 - 4 (Note 7)	5	N/A (Note 12)	2	1 (Note 6)
Water Rod Thickness (in.)	≥ 0.034	≥ 0.00	≥ 0.00	≥ 0.034	≥ 0.0315	≥ 0.00	≥ 0.00
Channel Thickness (in.)	≤ 0.120	≤ 0.120	≤ 0.120	≤ 0.100	≤ 0.055	≤ 0.120	≤ 0.120

Table 2.1.4 (continued)
BWR FUEL ASSEMBLY CHARACTERISTICS (Note 1)

Fuel Assembly Array and Class	**9x9 C**	**9x9 D**	**9x9 E (Note 13)**	**9x9 F (Note 13)**	**10x10A**
Clad Material (Note 2)	Zr	Zr	Zr	Zr	Zr
Design Initial U (kg/assy.) (Note 3)	≤ 177	≤ 177	≤ 177	≤ 177	≤ 186
Maximum Planar-Average Initial Enrichment (wt. % ^{235}U)	≤ 4.2	≤ 4.2	≤ 4.1	≤ 4.1	≤ 4.2
Initial Maximum Rod Enrichment (wt. % ^{235}U)	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0
No. of Fuel Rods (Note 14)	80	79	76	76	92/78 (Note 8)
Clad O.D. (in.)	≥ 0.4230	≥ 0.4240	≥ 0.4170	≥ 0.4430	≥ 0.4040
Clad I.D. (in.)	≤ 0.3640	≤ 0.3640	≤ 0.3640	≤ 0.3860	≤ 0.3520
Pellet Dia. (in.)	≤ 0.3565	≤ 0.3565	≤ 0.3530	≤ 0.3745	≤ 0.3455
Fuel Rod Pitch (in.)	≤ 0.572	≤ 0.572	≤ 0.572	≤ 0.572	≤ 0.510
Design Active Fuel Length (in.)	≤ 150	≤ 150	≤ 150	≤ 150	≤ 150
No. of Water Rods (Note 11)	1	2	5	5	2
Water Rod Thickness (in.)	0.020	≥ 0.0300	≥ 0.0120	≥ 0.0120	≥ 0.030
Channel Thickness (in.)	≤ 0.100	≤ 0.100	≤ 0.120	≤ 0.120	≤ 0.120

Table 2.1.4 (continued)
BWR FUEL ASSEMBLY CHARACTERISTICS (Note 1)

Fuel Assembly Array and Class	**10x10 B**	**10x10 C**	**10x10 D**	**10x10 E**
Clad Material (Note 2)	Zr	Zr	SS	SS
Design Initial U (kg/assy.) (Note 3)	≤ 186	≤ 186	≤ 125	≤ 125
Maximum Planar-Average Initial Enrichment (wt. % ^{235}U)	≤ 4.2	≤ 4.2	≤ 4.0	≤ 4.0
Initial Maximum Rod Enrichment (wt. % ^{235}U)	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0
No. of Fuel Rods (Note 14)	91/83 (Note 9)	96	100	96
Clad O.D. (in.)	≥ 0.3957	≥ 0.3780	≥ 0.3960	≥ 0.3940
Clad I.D. (in.)	≤ 0.3480	≤ 0.3294	≤ 0.3560	≤ 0.3500
Pellet Dia. (in.)	≤ 0.3420	≤ 0.3224	≤ 0.3500	≤ 0.3430
Fuel Rod Pitch (in.)	0.510	0.488	0.565	0.557
Design Active Fuel Length (in.)	≤ 150	≤ 150	≤ 83	≤ 83
No. of Water Rods (Note 11)	1 (Note 6)	5 (Note 10)	0	4
Water Rod Thickness (in.)	≥ 0.00	≥ 0.031	N/A	≥ 0.022
Channel Thickness (in.)	≤ 0.120	≤ 0.055	≤ 0.080	≤ 0.080

Table 2.1.4 (continued)
BWR FUEL ASSEMBLY CHARACTERISTICS

NOTES:

1. Fuel assembly array/classes are defined in Chapter 6. All dimensions are design nominal values. Maximum and minimum dimensions are specified to bound variations in design nominal values among fuel assemblies within a given array/class.

2. Zr designates cladding material made from zirconium or zirconium alloys.

3. Design initial uranium weight is the uranium weight specified for each fuel assembly by the fuel manufacturer or reactor user. For each PWR fuel assembly, the total uranium weight limit specified in this table may be increased up to 1.5 percent for comparison with users' fuel records to account for manufacturer tolerances.

4. $\leq$ 0.635 wt. % ^{235}U and $\leq$ 1.578 wt. % total fissile plutonium (^{239}Pu and ^{241}Pu), (wt. % of total fuel weight, i.e., UO_2 plus PuO_2).

5. This assembly class contains 74 total fuel rods; 66 full length rods and 8 partial length rods.

6. Square, replacing nine fuel rods.

7. Variable.

8. This assembly class contains 92 total fuel rods; 78 full length rods and 14 partial length rods.

9. This assembly class contains 91 total fuel rods; 83 full length rods and 8 partial length rods.

10. One diamond-shaped water rod replacing the four center fuel rods and four rectangular water cross segments dividing the assembly into four quadrants.

11. These rods may be sealed at both ends and contain Zr material in lieu of water.

12. This assembly is known as "QUAD+" and has four rectangular water cross segments dividing the assembly into four quadrants.

13. For the SPC 9x9-5 fuel assembly, each fuel rod must meet either the 9x9E or the 9x9F set of limits for clad O.D., clad I.D., and pellet diameter.

14. Missing fuel rods must be replaced with dummy fuel rods that displace an equal or greater amount of water as the original fuel rods. Storage of 6x6A, 6x6B, 6x6C, 7x7A, and 8x8A fuel assemblies with missing fuel rods are permitted provided the fuel assemblies with missing fuel rods are stored as damaged fuel assemblies or fuel debris.

Table 2.1.5

DESIGN BASIS FUEL ASSEMBLY FOR EACH DESIGN CRITERION

Criterion	**MPC-68**	**MPC-24**
Reactivity (Criticality)	GE12/14 10x10 with Partial Length Rods (Class 10x10A)	B&W 15x15 (Class 15x15F)
Source Term (Shielding)	GE 7x7 (Class 7x7B)	B&W 15x15 (Class 15x15F)
Decay Heat (Thermal-Hydraulic)	GE 7x7 (Class 7x7B)	B&W 15x15 (Class 15x15F)

Table 2.1.6
CHARACTERISTICS FOR DESIGN BASIS INTACT ZIRCALOY CLAD FUEL ASSEMBLIES

	MPC-68	MPC-24
PHYSICAL PARAMETERS:		
Max. assembly width† (in.)	5.85	8.54
Max. assembly length†† (in.)	176.2	176.8
Max. assembly weight††† (lb.)	700	1680
Max. active fuel length† (in.)	150	150
Fuel rod clad material	zircaloy	zircaloy
RADIOLOGICAL AND THERMAL CHARACTERISTICS:		
	MPC-68	**MPC-24**
Max. initial enrichment (wt% ^{235}U)	4.2 2.7 (Assembly Classes 6x6A, 6x6B†††, 6x6C, 7x7A, 8x8A)	See Table 2.1.3
Max. heat generation (W)	Figure 2.1.8 115 (Assembly Classes 6x6A, 6x6B, 6x6C, 7x7A, 8x8A) 183.5 (Assembly Class 8x8F)	Figure 2.1.8
Max. average burnup (MWD/MTU)	See Figure 2.1.6 30,000 (Assembly Classes 6x6A, 6x6B, 6x6C, 7x7A, 8x8A) 27,500 (Assembly Class 8x8F)	See Figure 2.1.6
Min. cooling time (years)	See Figure 2.1.6 18 (Assembly Classes 6x6A, 6x6B, 6x6C, 7x7A, 8x8A) 10 (Assembly Class 8x8F)	See Figure 2.1.6

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† Unirradiated nominal design dimensions are shown.

†† Fuel assembly weight including hardware based on DOE MPC DPS [2.1.6].

††† See Table 2.1.4 for MOX enrichment specifications.

Table 2.1.7

DESIGN CHARACTERISTICS FOR DAMAGED ZIRCALOY CLAD FUEL ASSEMBLIES AND BWR ZIRCALOY CLAD FUEL DEBRIS

	MPC-68 (Damaged Fuel)	MPC-68F (Fuel Debris)
PHYSICAL PARAMETERS:		
Max. assembly width† (in.)	4.7	4.7
Max. assembly length† (in.)	135	135
Max. assembly weight†† (lb.)	400	400
Max. active fuel length† (in.)	110	110
Fuel rod clad material	zircaloy	zircaloy
RADIOLOGICAL AND THERMAL CHARACTERISTICS:		
Max. heat generation (W)	115	115
Min. cooling time (yr)	18	18
Max. initial enrichment (w/o ^{235}U) for UO_2 rods	2.7	2.7
Max. initial enrichment for MOX rods	0.612 wt.% ^{235}U 1.578 wt. % Total Fissile Plutonium	0.612 wt.% ^{235}U 1.578 wt. % Total Fissile Plutonium
Max. average burnup (MWD/MTU)	30,000	30,000

Note:

1. A maximum of four (4) damaged fuel containers with BWR zircaloy clad fuel debris may be stored in the MPC-68F with the remaining locations filled with undamaged or damaged fuel assemblies meeting the maximum heat generation specifications of this table.

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† Dimensions envelop unirradiated nominal dimensions of Array/Class 6x6A, 6x6B, 6x6C, 7x7A, and 8x8A (Dresden Unit 1 and Humboldt Bay SNF).

†† Fuel assembly weight including hardware based on DOE MPC DPS [2.1.6]. Weight does not include damaged fuel container.

Table 2.1.8

NORMALIZED DISTRIBUTION BASED ON BURNUP PROFILE

PWR DISTRIBUTION†

Interval	**Axial Distance From Bottom of Active Fuel (% of Active Fuel Length)**	**Normalized Distribution**
1	0% to 4-1/6%	0.5485
2	4-1/6% to 8-1/3%	0.8477
3	8-1/3% to 16-2/3%	1.0770
4	16-2/3% to 33-1/3%	1.1050
5	33-1/3% to 50%	1.0980
6	50% to 66-2/3%	1.0790
7	66-2/3% to 83-1/3%	1.0501
8	83-1/3% to 91-2/3%	0.9604
9	91-2/3% to 95-5/6%	0.7338
10	95-5/6% to 100%	0.4670

BWR DISTRIBUTION††

Interval	**Axial Distance From Bottom of Active Fuel (% of Active Fuel Length)**	**Normalized Distribution**
1	0% to 4-1/6%	0.2200
2	4-1/6% to 8-1/3%	0.7600
3	8-1/3% to 16-2/3%	1.0350
4	16-2/3% to 33-1/3%	1.1675
5	33-1/3% to 50%	1.1950
6	50% to 66-2/3%	1.1625
7	66-2/3% to 83-1/3%	1.0725
8	83-1/3% to 91-2/3%	0.8650
9	91-2/3% to 95-5/6%	0.6200
10	95-5/6% to 100%	0.2200

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† Reference 2.1.3

†† Reference 2.1.4

Table 2.1.9

SUGGESTED PWR UPPER AND LOWER FUEL SPACER LENGTHS

Fuel Assembly Type	**Assembly Length w/o C.C.† (in.)**	**Location of Active Fuel from Bottom (in.)**	**Max. Active Fuel Length (in.)**	**Upper Fuel Spacer Length (in.)**	**Lower Fuel Spacer Length (in.)**
CE 14x14	157	4.1	137	9.5	10.0
CE 16x16	176.8	4.7	150	0	0
BW 15x15	165.7	8.4	141.8	6.7	4.1
W 17x17 OFA	159.8	3.7	144	8.2	8.5
W 17x17 Std	159.8	3.7	144	8.2	8.5
W 17x17 V5H	160.1	3.7	144	7.9	8.5
W 15x15	159.8	3.7	144	8.2	8.5
W 14x14 Std	159.8	3.7	145.2	9.2	7.5
W 14x14 OFA	159.8	3.7	144	8.2	8.5
Ft. Calhoun	146	6.6	128	10.25	20.25
St. Lucie 2	158.2	5.2	136.7	10.25	8.05
B&W 15x15 SS	137.1	3.873	120.5	19.25	19.25
W 15x15 SS	137.1	3.7	122	19.25	19.25
W 14x14 SS	137.1	3.7	120	19.25	19.25

Note: Each user shall specify the fuel spacer lengths based on their fuel length and allowing an approximate 2-inch gap.

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† C.C. is an abbreviation for Control Components. Fuel assemblies with control components may require shorter fuel spacers. Each user shall specify the fuel spacer lengths based on their fuel length and any control components and allowing an approximate 2-inch gap.

Table 2.1.10

SUGGESTED BWR UPPER AND LOWER FUEL SPACER LENGTHS

Fuel for Reactor Type	Assembly Length (in.)	Location of Active Fuel from Bottom (in.)	Max. Active Fuel Length (in.)	Upper Fuel Spacer Length (in.)	Lower Fuel Spacer Length (in.)
GE/2-3	171.2	7.3	150	4.8	0
GE/4-6	176.2	7.3	150	0	0
Dresden 1	134.4	11.2	110	18.0	23.6
Humboldt Bay	95.0	8.0	79.0	40.5	40.5
Dresden 1 Damaged Fuel or Fuel Debris	144.5[†]	11.2	110.0	17.0	14.5
Humboldt Bay Damaged Fuel or Fuel Debris	105.5[†]	8.0	79.0	35.25	35.25
LaCrosse	102.5	10.5	83.0	37.0	37.5

Note: Each user shall specify the fuel spacer lengths based on their fuel length and allowing an approximate 2-inch gap.

[†] Fuel assembly length includes the damaged fuel container.

Table 2.1.11

DESIGN CHARACTERISTICS FOR STAINLESS STEEL CLAD FUEL ASSEMBLIES

	BWR MPC-68	PWR MPC-24
PHYSICAL PARAMETERS:		
Max. assembly width† (in.)	5.62	8.42
Max. assembly length† (in.)	102.5	138.8
Max. assembly weight†† (lb.)	400	1421
Max. active fuel length† (in.)	83	122
RADIOLOGICAL AND THERMAL CHARACTERISTICS:		
Max. heat generation (W)	95	575 (MPC-24)
Min. cooling time (yr)	10	9 at 30,000 MWD/MTU (MPC-24) 15 at 40,000 MWD/MTU (MPC-24)
Max. initial enrichment (wt.% ^{235}U)	4.0	4.0
Max. average burnup (MWD/MTU)	22,500	40,000

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† Dimensions are unirradiated nominal dimensions.

†† Fuel assembly weight including hardware based on DOE MPC DPS [2.1.6].

Table 2.1.12

DESIGN CHARACTERISTICS FOR THORIA RODS IN D1 THORIA ROD CANISTERS

PARAMETER	**MPC-68 or MPC-68F**
Cladding Type	Zircaloy (Zr)
Composition	98.2 wt.% ThO_2, 1.8 wt.% UO_2 with an enrichment of 93.5 wt. % ^{235}U
Number of Rods Per Thoria Canister	≤ 18
Decay Heat Per Thoria Canister	≤ 115 watts
Post-Irradiation Fuel Cooling Time and Average Burnup Per Thoria Canister	Cooling time ≥ 18 years and average burnup $\geq 16{,}000$ MWD/MTIHM
Initial Heavy Metal Weight	≤ 27 kg/canister
Fuel Cladding O.D.	≥ 0.412 inches
Fuel Cladding I.D.	≤ 0.362 inches
Fuel Pellet O.D.	≤ 0.358 inches
Active Fuel Length	≤ 111 inches
Canister Weight	≤ 550 lbs., including Thoria Rods

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

FIGURE 2.1.1; HOLTEC DAMAGED FUEL CONTAINER FOR DRESDEN UNIT-1/ HUMBOLDT BAY SNF

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

FIGURE 2.1.2; TN DAMAGED FUEL CANISTER FOR DRESDEN UNIT-1

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

FIGURE 2.1.2A; TN THORIA ROD CANISTER FOR DRESDEN UNIT-1

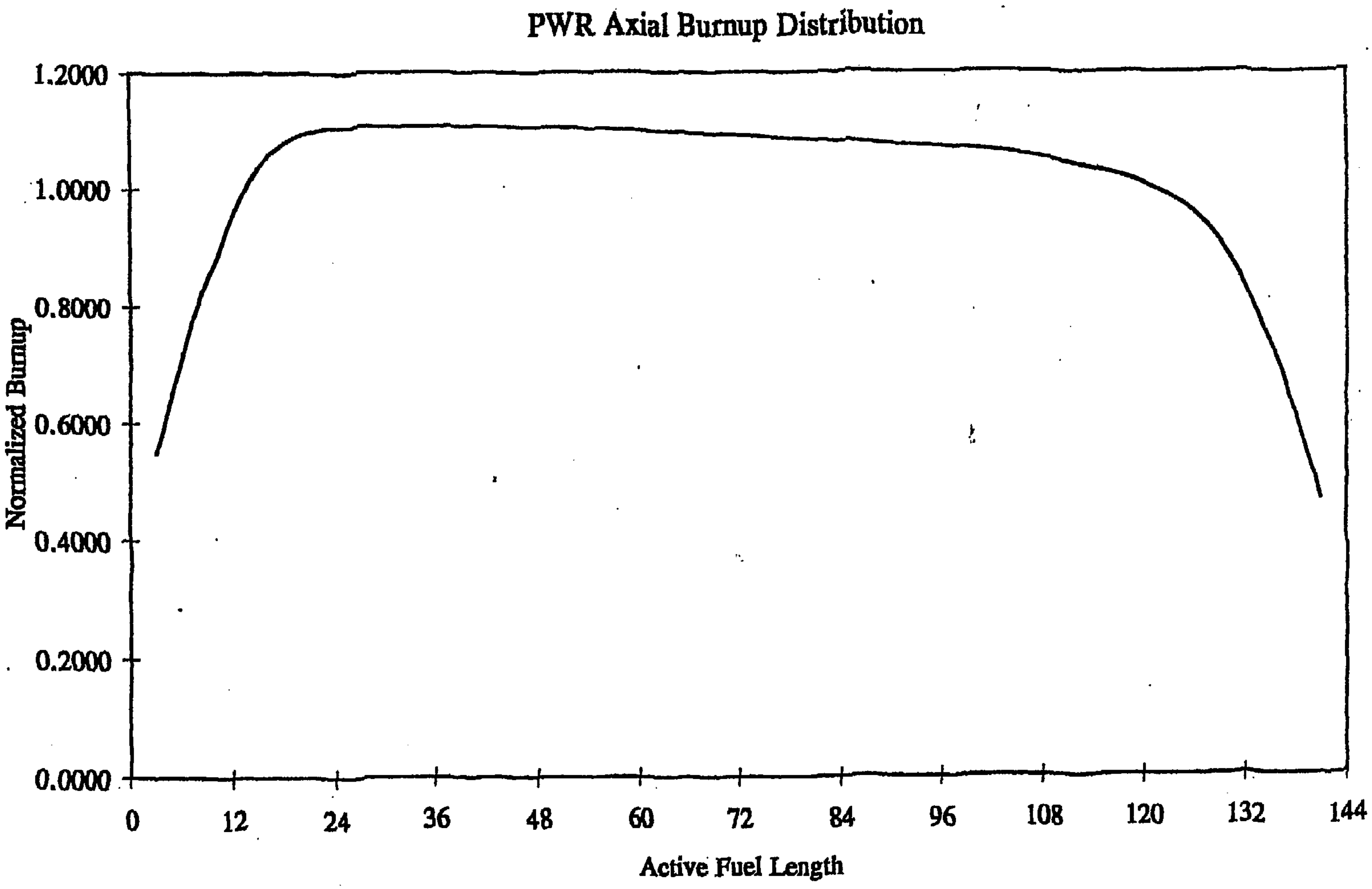

Figure 2.1.3; PWR Axial Burnup Profile with Normalized Distribution

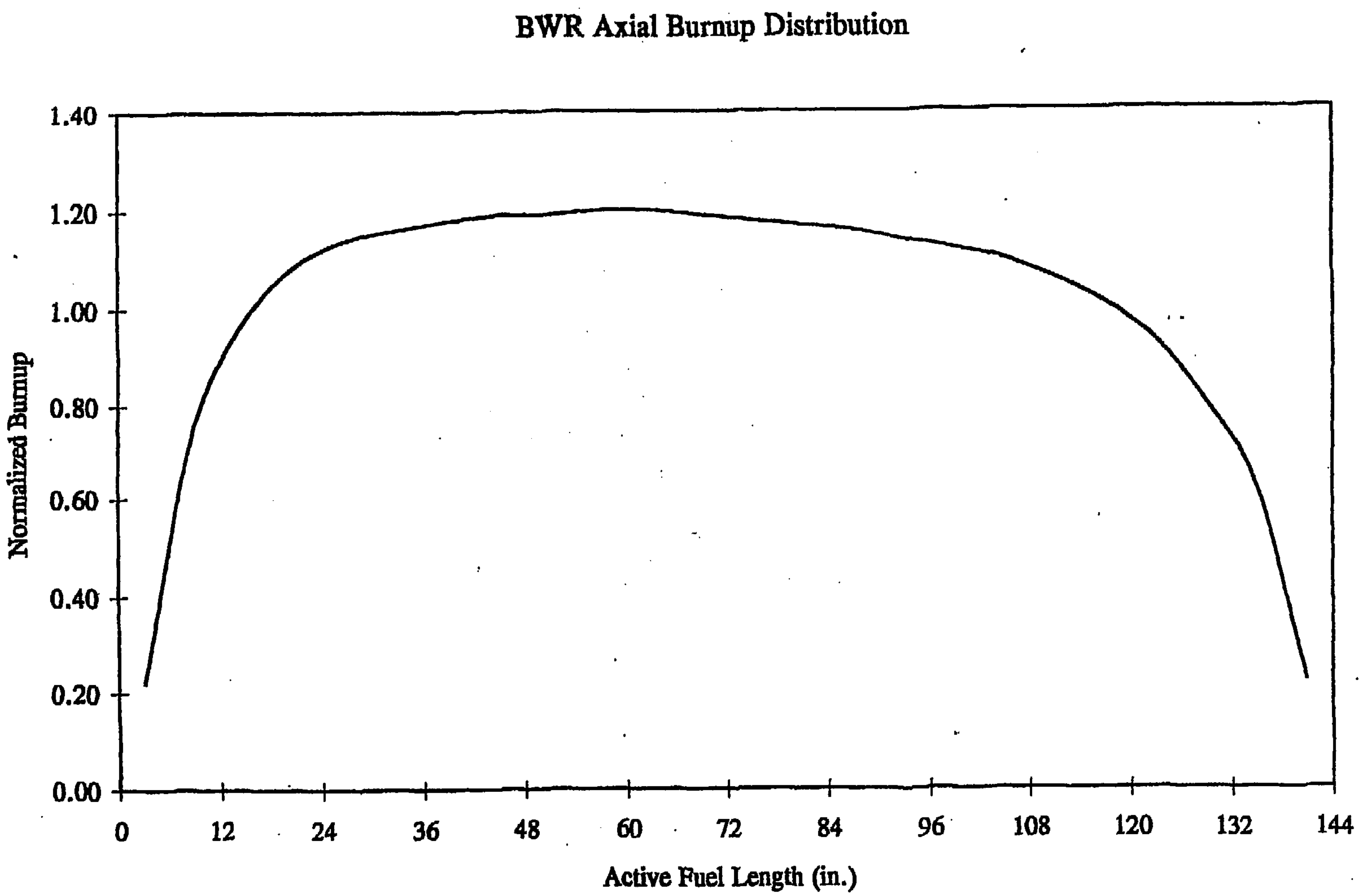

Figure 2.1.4; BWR Axial Burnup Profile with Normalized Distribution

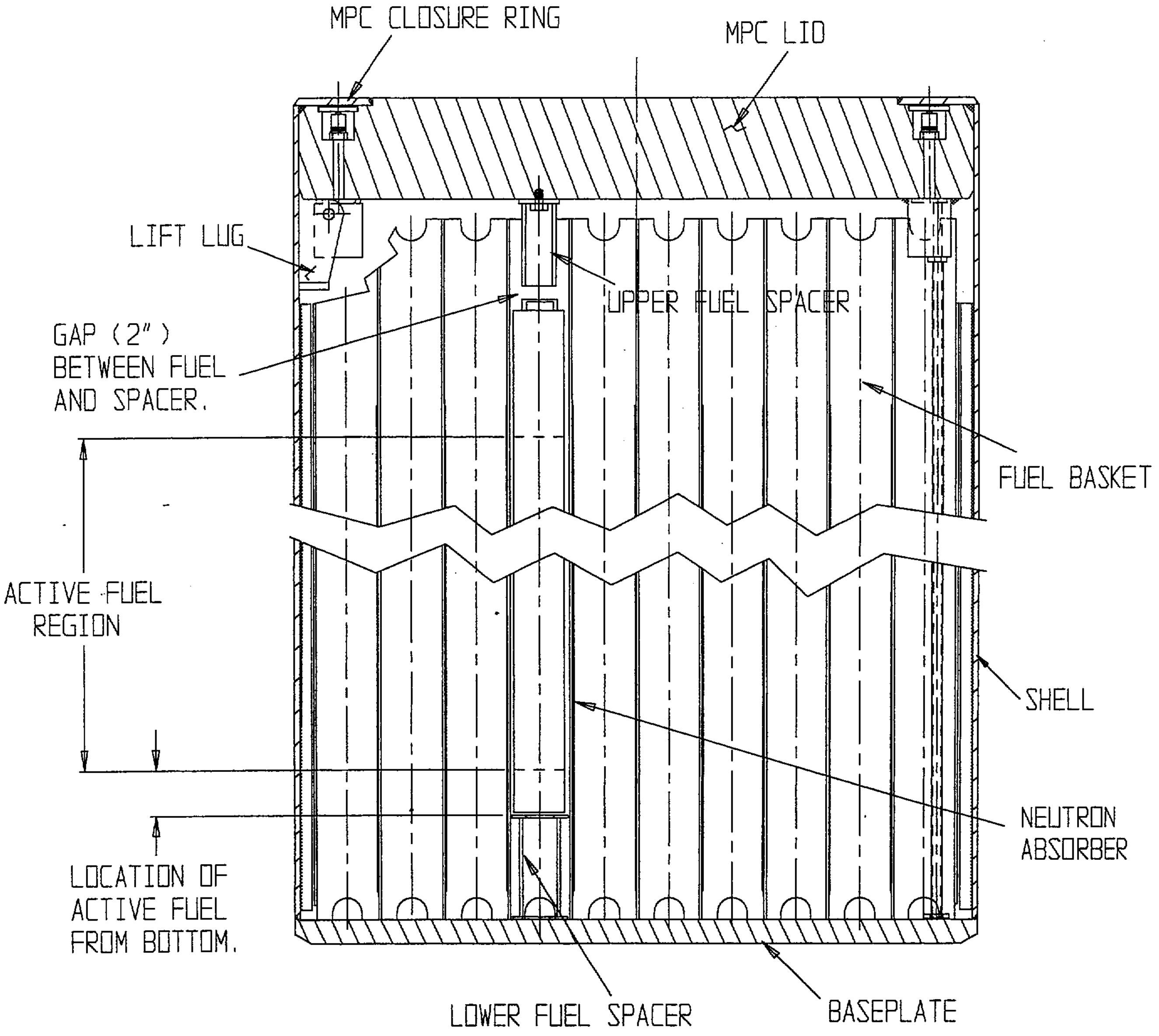

FIGURE 2.1.5; HI-STAR 100 MPC WITH UPPER AND LOWER FUEL SPACERS

ILLUSTRATIVE BURNUP AND COOLING TIME FOR DECAY HEAT AND RADIATION SOURCE TERMS

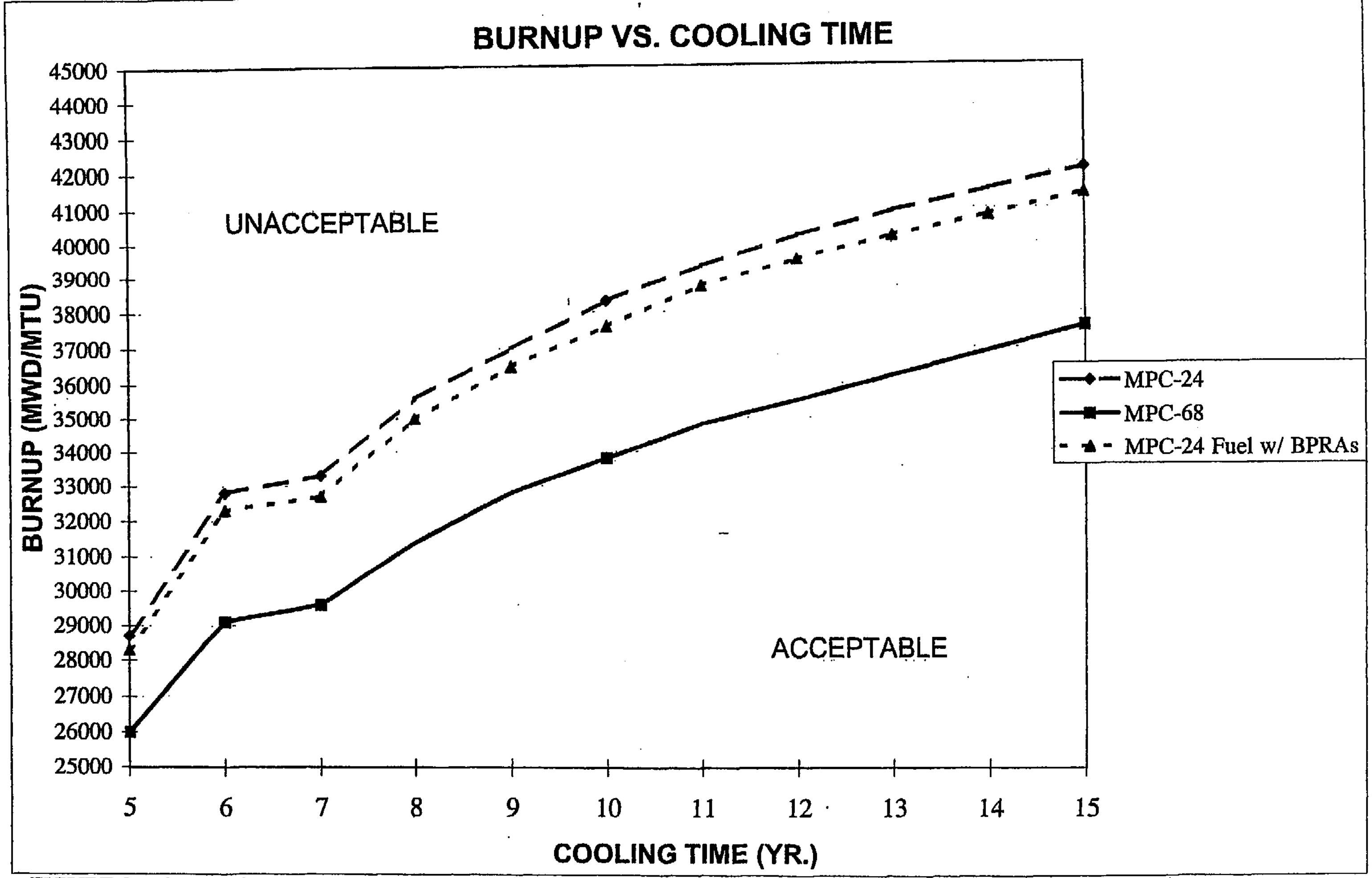

FIGURE 2.1.6; ILLUSTRATIVE BURNUP AND COOLING TIME FOR DECAY HEAT AND RADIATION SOURCE TERMS

FIGURE 2.1.7; DELETED

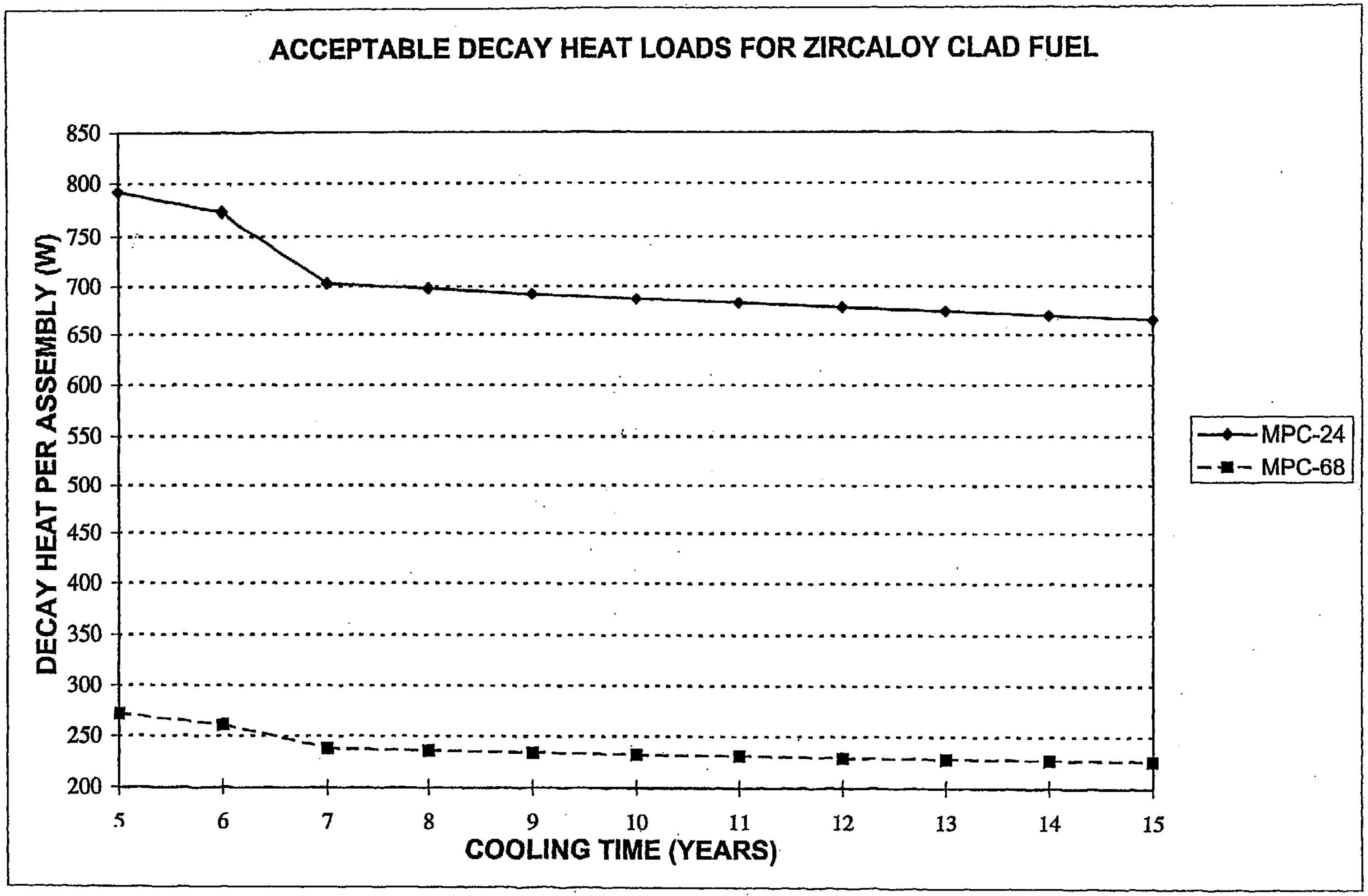

Figure 2.1.8; Acceptable Decay Heat Load Per Assembly

2.2 HI-STAR 100 DESIGN CRITERIA

The HI-STAR 100 System is engineered for unprotected outside storage for the duration of its design life. Accordingly, the cask system is designed to withstand normal, off-normal, and environmental phenomena or accident conditions of storage. Normal conditions include the conditions that are expected to occur regularly or frequently in the course of normal operation. Off-normal conditions include those infrequent events that could reasonably be expected to occur during the lifetime of the cask system. Environmental phenomena or accident conditions includes events that are postulated because their consideration establishes a conservative design basis.

Normal condition loads act in combination with all other loads. Off-normal condition loads and environmental phenomena or accident condition loads are applied alone. However, loads which occur as a result of the same phenomena are applied simultaneously. For example, the tornado wind loads are applied in combination with the tornado missile loads.

Design criteria are satisfied if the specified allowable limits are not exceeded.

2.2.1 Normal Condition Design Criteria

2.2.1.1 Dead Weight

The HI-STAR 100 System must withstand the static loads due to the weight of each of its components.

2.2.1.2 Handling

The HI-STAR 100 System must withstand loads experienced during routine handling. Normal handling includes lifting, upending/downending, and transfer to the ISFSI of the loaded HI-STAR 100 System. The loads shall be increased by 15% to include any dynamic effects from the lifting operations as directed by CMAA #70 [2.2.1].

2.2.1.3 Pressure

Pressures on the HI-STAR 100 System components depend on the bulk temperature of the helium gas and any environmental or internal factor capable of causing a pressure change. The HI-STAR 100 System must be capable of withstanding normal condition pressures.

The MPC internal pressure is dependent on the initial volume of cover gas (helium), the volume of fill gas in the fuel rods, the fraction of fission gas released from the fuel matrix, the number of fuel rods assumed to have ruptured, and temperature. The normal condition MPC internal design pressure bounds the cumulative effects of the maximum fill gas volume, normal environmental ambient temperatures, the maximum MPC heat load, and an assumed 1% of the intact fuel rods ruptured with 100% of the rod fill gas and 30% of the significant radioactive gases (e.g., H^3, Kr, and

Xe) released in accordance with NUREG-1536. The off-normal condition MPC internal design pressure bounds the cumulative effects of the maximum fill gas volume, off-normal environmental ambient temperatures, the maximum MPC heat load, and an assumed 10% of the intact fuel rods ruptured with 100% of the rod fill gas and 30% of the significant radioactive gases (e.g., H^3, Kr, and Xe) released in accordance with NUREG-1536. For conservatism, the MPC normal internal design pressure bounds both normal and off-normal conditions. Therefore, the normal and off-normal condition MPC internal pressures are set equal for analysis purposes. Table 2.2.1 provides the design pressures for the HI-STAR 100 System.

For the storage of damaged Dresden Unit 1 or Humboldt Bay BWR fuel assemblies or fuel debris (Assembly Classes 6x6A, 6x6B, 6x6C, 7x7A, and 8x8A) in a damaged fuel container, it is conservatively assumed that 100% of the fuel rods are ruptured with 100% of the rod fill gas and 30% of the significant radioactive gases (e.g., H^3, Kr, and Xe) released for both normal and off-normal conditions. This condition is bounded by the pressure calculation for design basis intact fuel with 100% of the fuel rods ruptured in all 68 of the BWR fuel assemblies. It is shown in Chapter 4 that the normal condition design pressure is not exceeded with 100% of the fuel rods ruptured in all 68 of the design basis BWR fuel assemblies. Therefore, rupture of 100% of the fuel rods in the damaged fuel assemblies or fuel debris will not cause the MPC internal pressure to exceed the normal design pressure.

The MPC internal design pressure under accident conditions is discussed in Subsection 2.2.3, as a result of the fuel rod rupture and fire accident.

The MPC external pressure is equivalent to the overpack internal pressure, since this pressure exists in the annulus between the MPC and the overpack. During loading of the HI-STAR 100 System, the annulus is evacuated, dried, and pressurized with helium. The helium gas in the annulus is compressed due to the difference in the thermal expansion of the MPC and the overpack when the HI-STAR 100 System has a positive heat load (See Subsection 3.4.4.2.1). Therefore, the normal and off-normal pressure is specified in Table 2.2.1 above the initial fill pressure (10 psig). The ratio of the initial fill pressure to the normal design pressure is 1:4. Therefore, using the ideal gas law, the volume must decrease to 1/4 its initial size to reach the normal design pressure at a constant temperature. Subsection 3.4.4.2.1 provides the reduction in the annulus due to thermal expansion and it is demonstrated that the annulus does not decrease to 1/4 its initial size. The only other cause for a pressure increase is the fire accident conditions. The elevated accident condition pressure bounds the pressure developed as a result of the fire accident condition.

The overpack external pressure is a function of environmental conditions which may produce a pressure loading. The normal and off-normal condition external design pressure is set at ambient standard pressure (1 atmosphere).

The overpack neutron shield enclosure contains the neutron shield material Holtite-A. The enclosure is equipped with two rupture disks with a relief pressure at 30 psig. The design temperature of the neutron shield material is set sufficiently low to ensure that under normal and off-normal condition any potential off-gassing will be negligible. However, the overpack neutron shield enclosure is designed to withstand 30 psig under normal conditions. Under accident conditions, where the neutron shield material bulk temperature may exceed its design temperature, the redundant rupture disks will relieve ensuring that the pressure will not exceed the overpack neutron shield enclosure design pressure.

2.2.1.4 Environmental Temperatures

To evaluate the long-term effects of ambient temperatures on the HI-STAR 100 System, an upper bound value on the annual average ambient temperatures for the continental United States is used. The normal temperature specified in Table 2.2.2 is bounding for all reactor sites in the contiguous United States. The "normal" temperature set forth in Table 2.2.2 is intended to ensure that it is greater than the annual average of ambient temperatures at any location in the continental United States. In the northern region of the U.S., the design basis "normal" temperature used in this FSAR will be exceeded only for brief periods, whereas in the southern U.S., it may be straddled daily in summer months. Inasmuch as the sole effect of the "normal" temperature is on the computed fuel cladding temperature to establish long-term fuel integrity, it should not lie below the time averaged yearly mean for the ISFSI site. Previously licensed cask systems have employed lower "normal" temperatures (viz. 75 °F in Docket 72-1007) by utilizing national meteorological data.

Confirmation of the site-specific annual average ambient temperature is to be performed by the licensee, in accordance with 10CFR72.212. The annual average temperature is combined with insolation specified in 10CFR71.71 averaged over 24 hours in accordance with NUREG-1536 to establish the normal condition temperatures in the HI-STAR 100 System.

2.2.1.5 Design Temperatures

The ASME Boiler and Pressure Vessel Code (ASME Code) requires that the value of the vessel design temperature be established with appropriate consideration for the effect of heat generation internal or external to the vessel. The decay heat load from the spent nuclear fuel is the internal heat generation source for the HI-STAR 100 System. The ASME Code (Section III, Paragraph NCA-2142) requires the Design Temperature to be set at or above the maximum through thickness mean metal temperature of the pressure part under normal service (Level A) condition. Consistent with the terminology of NUREG-1536, this temperature is referred to as the "Design Temperature for Normal Conditions". Conservative calculations of the steady-state temperature field in the HI-STAR 100 System, under assumed environmental normal temperatures with the maximum decay heat load, result in HI-STAR component temperatures below the normal condition design temperatures for the HI-STAR 100 System defined in Table 2.2.3.

Maintaining fuel rod cladding integrity is also a design consideration. The maximum fuel rod cladding temperature limits for normal conditions are, based on Pacific Northwest Laboratory Reports [2.0.5 and 2.0.7], summarized in Table 2.2.3. The PNL CSFM (Commercial Spent Fuel Management) methodology is shown to bound the DCCG (Diffusion Controlled Cavity Growth) methodology outlined in the LLNL report [2.0.6] in Section 4.3. Maximum stainless steel fuel rod cladding temperature limits recommended in EPRI report [2.2.2] are greater than allowable zircaloy fuel cladding temperature limits. However, in this FSAR the zircaloy fuel cladding temperature limits are conservatively applied to the stainless steel clad fuel. A detailed description of the maximum fuel rod cladding temperature limits determination is provided in Section 4.3.

2.2.1.6 Snow and Ice

The HI-STAR 100 System must be capable of withstanding pressure loads due to snow and ice. ASCE 7-88 (formerly ANSI A58.1) [2.2.3] provides empirical formulas and tables to compute the effective design pressure on the overpack due to the accumulation of snow for the contiguous U.S. and Alaska. Typical calculated values for heated structures such as the HI-STAR 100 System range from 50 to 70 pounds per square foot. For conservatism, the snow pressure loading is set at a level in Table 2.2.8, which bounds the ASCE 7-88 recommendation.

2.2.2 Off-Normal Conditions Design Criteria

As the HI-STAR 100 System is passive, loss of power and instrumentation failures are not defined as off-normal conditions. Off-normal condition design criteria are defined in the following subsections.

A discussion of the effects of each off-normal condition is provided in Section 11.1. Section 11.1 also provides the corrective action for each off-normal condition. The location of the detailed analysis for each event is referenced in Section 11.1.

2.2.2.1 Pressure

The HI-STAR 100 System must withstand loads due to off-normal pressure. The MPC and overpack off-normal pressure is bounded by the MPC and overpack normal condition design pressure specified in Table 2.2.1. For the MPC off-normal internal pressure, ten percent of the fuel rods are assumed to be ruptured with 100% of the fill gas and 30% of the significant radioactive gases (e.g., H^3, Kr, and Xe) released in accordance with NUREG-1536.

2.2.2.2 Environmental Temperatures

Limits on the peaks in the time-varying ambient temperature at an ISFSI site are recognized in the FSAR in the specification of the off-normal temperatures. The lower bound off-normal temperature is defined as the minimum of the 72-hour average of the ambient temperature at an ISFSI site. Likewise, the upper bound off-normal temperature is defined by the maximum of 72-hour average of the ambient temperature. The lower and upper bound off-normal temperatures listed in Table 2.2.2 are intended to cover all ISFSI sites in the continental U.S. The 72-hour average temperature used in the definition of the off-normal temperature recognizes the considerable thermal inertia of the HI-STAR 100 System which reduces the effect of undulations in instantaneous temperature on the internals of the MPC.

The HI-STAR 100 System must withstand off-normal environmental temperatures. The off-normal environmental temperatures are specified in Table 2.2.2. The lower bound temperature occurs with no solar loads and the upper bound temperature occurs with steady-state insolation. Each bounding temperature is assumed in the analysis to persist for a duration sufficient to allow the system to reach steady-state temperatures.

2.2.2.3 Design Temperatures

In addition to the normal design temperature, we also define an "off-normal/accident condition temperature" pursuant to the provisions of NUREG-1536 and Regulatory Guide 3.61. This is, in effect, the short-term temperature which may exist during a transition state or a transient event (examples of such instances are short-term temperature excursion during canister vacuum drying and backfilling operations (transition state) and fire (transient event)). The off-normal/accident design temperatures ofTable 2.2.3 are set down to bound the maximax (maximum in time and space) value of the thru-thickness average temperature of the structural or non-structural part, as applicable, during a short-term event. These enveloping values, therefore, will bound the maximum temperature reached anywhere in the part, excluding skin effects during or immediately after, a short-term event.

2.2.2.4 Leakage of One Seal

The HI-STAR 100 System must withstand leakage of one seal in the radioactive material confinement boundary.

The HI-STAR 100 confinement boundary is defined by the MPC shell, baseplate, MPC lid, port cover plates, and closure ring. Most confinement boundary welds are inspected by radiography or ultrasonic examination. Field welds are examined by the liquid penetrant method on the root and final pass. In addition to liquid penetrant examination of the root and final weld layers, the MPC lid-to-shell weld is leakage tested, hydrostatic tested, and volumetrically (or multi-layer liquid penetrant) examined. The vent and drain port cover plates are leakage tested in addition to the liquid penetrant examination. These inspection and testing techniques are performed to verify the integrity of the confinement boundary.

The helium retention boundary is defined by the overpack baseplate, inner shell, top flange, vent and drain port plugs, and bolted closure plate containing two concentric seals. All welds that form a part of the helium retention boundary are examined by radiography. The overpack welds and seals are helium leakage tested during fabrication to verify their integrity. Helium leakage tests of all overpack closure seals are performed following each loading sequence.

2.2.3 Environmental Phenomena and Accident Condition Design Criteria

Environmental phenomena and accident condition design criteria are defined in the following subsections.

The minimum acceptance criteria for the evaluation of the accident condition design criteria are that the MPC confinement boundary maintains radioactive material confinement, the MPC fuel basket structure maintains the fuel contents subcritical, and the stored SNF can be retrieved by normal means.

A discussion of the effects of each environmental phenomena and accident condition is provided in Section 11.2. The consequences of each accident or environmental phenomena are evaluated against the requirements of 10CFR72.106 and 10CFR20. Section 11.2 also provides the corrective action for each event. The location of the detailed analysis for each event is referenced in Section 11.2.

2.2.3.1 Handling Accident

The HI-STAR 100 System must withstand loads due to a handling accident. Even though the loaded HI-STAR 100 System will be handled in accordance with approved, written procedures and will use lifting equipment which complies with ANSI N14.6, certain drop events are considered herein to demonstrate the defense-in-depth features of the HI-STAR design.

The loaded overpack will be handled so that the bottom of the cask is at a height less than the calculated vertical handling limit above the floor. The horizontal handling limit is specified to limit the height the loaded overpack can be lifted while in the horizontal position. For conservatism, the postulated drop events assume that the loaded HI-STAR 100 System falls freely from the vertical or horizontal handling limit height before impacting a thick reinforced concrete pad. Table 2.2.17 provides the acceptable carry heights for the loaded HI-STAR 100 System.

The magnitude of loadings induced into the HI-STAR 100 System due to drop events is heavily influenced by the compliance characteristics of the impacted surface. The concrete pad for storing the HI-STAR 100 System shall comply with the requirements of Table 2.2.9 to ensure that impactive and impulsive loads under accident events such as cask drop and non-mechanistic tip-over are less than those calculated by the dynamic models used in the structural qualifications.

2.2.3.2 Tip-Over

The HI-STAR 100 System is demonstrated to remain kinematically stable under the design basis environmental phenomena (tornado, earthquake, etc.). However, the cask must also withstand impact due to a postulated tip-over event. The structural integrity of a loaded HI-STAR 100 System after a tip-over onto a reinforced concrete pad is demonstrated using a side drop bounding analysis. The cask tip-over is not postulated as an outcome of any environmental phenomenon or accident condition. The cask tip-over is a non-mechanistic event.

The ISFSI pad requirements are specified in Table 2.2.9.

2.2.3.3 Fire

The possibility of a fire accident near an ISFSI site is considered to be extremely remote due to the absence of significant combustible materials. The only credible concern is related to a transport vehicle fuel tank fire engulfing a cask while it is being moved to the ISFSI.

The HI-STAR 100 System must withstand temperatures due to a fire event. The fire accident for storage is conservatively specified to be the result of the spillage and ignition of 50 gallons of combustible transporter fuel. The HI-STAR overpack surfaces are considered to receive an incident radiation and convection heat flux from the fire. Table 2.2.8 provides the fire duration based on the amount of flammable materials assumed. The temperature of the fire is assumed to be 1475 °F in accordance with 10CFR71.73.

The accident condition design temperatures for the HI-STAR 100 System, and the fuel rod cladding limits are specified in Table 2.2.3. The specified accident condition fuel cladding temperature limit is the short-term temperature limit based on a PNL report [2.0.7].

2.2.3.4 Partial Blockage of MPC Basket Vent Holes

The HI-STAR 100 System is designed to withstand reduction of flow area due to partial blockage of the MPC basket vent holes. As the MPC basket vent holes are internal to the confinement barrier, the only events that could partially block the vents are fuel cladding failure and debris associated with this failure, or crud. The HI-STAR 100 System maintains the SNF in an inert environment with fuel rod cladding temperatures below accepted values. Therefore, there is no credible mechanism for gross fuel cladding degradation during storage in the HI-STAR 100 System. For the storage of damaged BWR fuel assemblies or fuel debris, the assemblies and fuel debris will be placed in damaged fuel containers prior to placement in the MPC. The damaged fuel container is equipped with fine mesh screens which ensure that the damaged fuel and fuel debris will not be escape to block the MPC basket vent holes. In addition, each MPC will be loaded once for long-term storage and, therefore, buildup of crud in the MPC due to numerous loadings is precluded. Using crud quantities reported in an Empire State Electric Energy Research Corporation Report [2.2.4], a layer of crud of conservative depth is assumed to partially block the MPC basket vent holes. The crud depths for the different MPCs are listed in Table 2.2.8.

2.2.3.5 Tornado

The HI-STAR 100 System must withstand pressures, wind loads, and missiles generated by a tornado. The prescribed design basis tornado and wind loads for the HI-STAR 100 System are consistent with NRC Regulatory Guide 1.76 [2.2.5], ANSI 57.9 [2.2.6], and ASCE 7-88 [2.2.3]. Table 2.2.4 provides the wind speeds and pressure drop which the HI-STAR 100 System must withstand while maintaining kinematic stability. The small pressure drop is bounded by the accident condition overpack internal design pressure.

The stability of the HI-STAR 100 System must be demonstrated under impact from tornado-generated missiles in conjunction with the wind loadings. Standard Review Plan (SRP) 3.5.1.4 of NUREG-0800 [2.2.7] stipulates that the postulated missiles include at least three objects: a massive high kinetic energy missile which deforms on impact (large missile), a rigid missile to test penetration resistance (penetrant missile), and a small rigid missile of a size sufficient to pass through any openings in the protective barriers (micro-missile). SRP 3.5.1.4 suggests an automobile for a large missile, an artillery shell for the penetrant missile, and a solid sphere for the small rigid missile, all impacting at 35% of the maximum horizontal wind speed of the design basis tornado. Table 2.2.5 provides the missile data used in the analysis, which is based on the above SRP guidelines.

The effects of a tornado missile are considered to bound the effects of a light general aviation airplane crashing on an ISFSI facility as specified in NUREG-1536.

2.2.3.6 Flood

The HI-STAR 100 System must withstand pressure and water forces associated with a flood. Resultant loads on the HI-STAR 100 System consist of buoyancy effects, static pressure loads, and pressure due to water velocity. The flood is assumed to deeply submerge the HI-STAR 100 System (see Table 2.2.8). The flood water depth is based on the submergence requirement of 10CFR71. This condition corresponds to a hydrostatic pressure which is bounded by the overpack external pressure stated in Table 2.2.1.

It must be shown that the overpack does not collapse, buckle, or allow water in-leakage under the hydrostatic pressure from the flood.

The flood water is assumed to be nonstagnant. The maximum allowable flood water velocity is determined by calculating the equivalent pressure loading required to slide or tip over the HI-STAR 100 System. The design basis flood water velocity is stated in Table 2.2.8. Site-specific safety reviews performed by the licensee must confirm that flood parameters do not exceed the flood depth, slide, or tip-over forces.

Most reactor sites are hydrologically characterized as required by Paragraph 100.10(C) of 10CFR100 [2.2.8] and further articulated in Reg. Guide 1.59, "Design Basis Floods for Nuclear Power Plants" [2.2.9] and Reg. Guide 1.102, "Flood Protection for Nuclear Power Plants" [2.2.10]. It is assumed that a complete characterization of the ISFSI's hydrosphere including the effects of hurricanes, floods, seiches and tsunamis is available to enable a site-specific evaluation of the HI-STAR 100 System for kinematic stability. An evaluation for tsunamis† for certain coastal sites should also be

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† A tsunami is an ocean wave from seismic or volcanic activity or from submarine landslides. A tsunami may be the result of nearby or distant events. A tsunami loading may exist in combination with wave splash and spray, storm surge and tides.

performed to demonstrate that sliding or tip-over will not occur and that the maximum flood depth will not be exceeded.

Analysis for each site for such transient hydrological loadings must be made for that site. It is expected that the plant licensee will perform this evaluation under the provisions of 10CFR Part 72.212.

2.2.3.7 Seismic Design Loadings

The HI-STAR 100 must withstand loads arising due to a seismic event and must be shown not to tip over during a seismic event. Section 3.4.7 contains calculations based on conservative static "incipient tipping" calculations which demonstrate static stability. The calculations in Section 3.4.7 result in the value specified in Table 2.2.8, which provide the maximum horizontal zero period acceleration (ZPA) versus vertical acceleration multiplier above which static incipient tipping would occur. This conservatively assumes the peak acceleration values of each of the two horizontal earthquake components occur simultaneously. The maximum horizontal ZPA provided in Table 2.2.8 is the vector sum of two horizontal earthquakes.

2.2.3.8 100% Fuel Rod Rupture

The HI-STAR 100 System must withstand loads due to 100% fuel rod rupture. For conservatism, 100 percent of the fuel rods are assumed to rupture with 100% of the rod fill gas and 30 percent of the significant radioactive gases (e.g., H^3, Kr, and Xe) released in accordance with NUREG-1536.

2.2.3.9 Confinement Boundary Leakage

No credible scenario has been identified that would cause failure of the confinement system. To demonstrate the overall safety of the HI-STAR 100 System, the largest test leakage rate for the confinement boundary plus the test sensitivity is assumed as the maximum credible confinement boundary leakage rate. No credit is taken for the overpack boundary and 100 percent of the fuel rods are assumed to have failed. Under this accident condition, doses to an individual located at the boundary of the controlled area are calculated.

2.2.3.10 Explosion

The HI-STAR 100 System must withstand loads due to an explosion. The accident condition overpack external pressure specified in Table 2.2.1 bounds all credible external explosion events. There are no credible internal explosion events since all materials are compatible with the various operating environments, as discussed in Section 3.4.1. The MPC is composed of stainless steel, Boral, and aluminum alloy 1100, all of which have a long proven history of use in fuel pool at nuclear power plants. For these materials there is no credible cause for an internal explosive event.

2.2.3.11 Lightning

The HI-STAR 100 System must withstand loads due to lightning. The effect of lightning on the HI-STAR 100 System is evaluated in Chapter 11.

2.2.3.12 Burial Under Debris

The HI-STAR 100 System must withstand burial under debris. Such debris may result from floods, wind storms, or mud slides. The thermal effects of burial under debris on the HI-STAR 100 System is evaluated in Chapter 11. Siting of the ISFSI pad shall ensure that the storage location is not located near shifting soil. Burial under debris is a highly unlikely accident, but is analyzed in this FSAR.

2.2.3.13 Extreme Environmental Temperature

The HI-STAR 100 System must withstand extreme environmental temperatures. The extreme accident level temperature is specified in Table 2.2.2. The extreme accident level temperature occurs with steady-state insolation. The environmental temperature is assumed to persist for a duration sufficient to allow the system to reach steady-state temperatures. The HI-STAR 100 System has a large thermal inertia. Therefore, this temperature is assumed to persist over three days (3-day average).

2.2.4 Applicability of Governing Documents

The ASME Boiler and Pressure Vessel Code (ASME Code), 1995 Edition with Addenda through 1997, is the governing code for the structural design of the HI-STAR 100 System. The ASME Code is applied to each component consistent with the function of the component. Table 2.2.6 lists each structure, system and component (SSC) of the HI-STAR 100 System which are labeled Important to Safety, along with its function and governing Code. Some components perform multiple functions and in those cases, the most restrictive Code is applied. In accordance with NUREG/CR-6407, "Classification of Transportation Packaging and Dry Spent Fuel Storage System Components" [2.2.11] and according to importance to safety, components of the HI-STAR 100 System are classified as A, B, C, or NITS (not important to safety) in Table 2.2.6. Section 13.1 provides the criteria used to classify each item.

Table 2.2.7 lists the applicable ASME Code section and paragraph for material procurement, design, fabrication and inspection of the components of the HI-STAR 100 System that are governed by the ASME Code. The ASME Code section listed in the design column is the section used to define allowable stresses for structural analyses.

Table 2.2.15 lists the exceptions to the ASME Code for the HI-STAR 100 System and the justification for those exceptions.

2.2.5 Service Limits

In the ASME Code, plant and system operating conditions are commonly referred to as normal, upset, emergency, and faulted. Consistent with the terminology in NRC documents, this FSAR utilizes the terms normal, off-normal, and accident conditions.

The ASME Code defines four service conditions in addition to the Design Limits for nuclear components. They are referred to as Level A, Level B, Level C, and Level D service limits, respectively. Their definitions are provided in Paragraph NCA-2142.4 of the ASME Code. The four levels are used in this FSAR as follows:

a. Level A Service Limits: Level A Service Limits are used to establish allowables for normal condition load combinations.

b. Level B Service Limits: Level B Service Limits are used to establish allowables for off-normal condition load combinations.

c. Level C Service Limits: Level C Service Limits are not used.

d. Level D Service Limits: Level D Service Limits are used to establish allowables for accident condition load combinations.

The ASME Code service limits are used in the structural analyses for definition of allowable stresses and allowable stress intensities. Allowable stresses and stress intensities for structural analyses are tabulated in Chapter 3. These service limits are matched with normal, off-normal, and accident condition loads combinations in the following subsections.

The MPC confinement boundary and the overpack helium retention boundary are required to meet Section III, Class 1 stress intensity limits. Table 2.2.10 lists the stress intensity limits for the Levels A, B, and D service limits for Class 1 structures extracted from the ASME Code (1995 Edition). The limits for the MPC fuel basket, required to meet the stress intensity limits of Subsection NG of the ASME Code, are listed in Table 2.2.11. Table 2.2.12 lists allowable stress limits for the external steel structures (intermediate shells, radial channels, and outer enclosure) which are analyzed to meet the stress limits of Subsection NF, Class 3.

2.2.6 Loads

Subsections 2.2.1, 2.2.2, and 2.2.3 describe the design criteria for normal, off-normal, and accident conditions, respectively. The individual loads listed in Table 2.2.13 are defined from the design criteria. Each load is assigned a symbol for subsequent use in the load combinations.

The loadings listed in Table 2.2.13 fall into two broad categories; namely, (i) those which affect kinematic stability, and (ii) those which produce significant stresses. The loadings in the former category are principally applicable to the overpack. Wind (W), earthquake (E), tornado (W'), and tornado-borne missile (M) are essentially loadings which can destabilize a cask. Analyses reported in Chapter 3 show that the HI-STAR 100 overpack structure will remain kinematically stable under these loadings. Additionally, for the missile impact case (M), analyses must be performed to demonstrate that the overpack structure remains unbreached by the postulated missiles.

Loadings in the second category produce global stresses which must be shown to comply with the stress intensity or stress limits, as applicable. The relevant loading combinations for the fuel basket, the MPC, and the overpack are different because of differences in their function.

2.2.7 Load Combinations

Load combinations are created by summing the effects of individual loads. The purpose of the load combinations is to define analyses which demonstrate that the HI-STAR 100 System meets the design criteria. The loads present in each condition are listed in Table 2.2.14.

The number of loading combinations is reduced by defining the internal and external pressures (P_i and P_o) such that they bound other surface-intensive loads, namely snow (S), tornado wind (W'), flood (F), and explosion (E^*). Table 2.2.14 provides the loadings applicable to the MPC (with fuel basket), and the overpack for the design normal, off-normal, and accident conditions with the bounding pressures substituting for surface-intensive loads. Further discussion of the load combinations is provided in Chapter 3.

2.2.8 Allowable Stresses

The stress intensity limits for the MPC confinement boundary and the overpack helium retention boundary for the design condition and the four service conditions are provided in Table 2.2.10. The stress intensity limits for the MPC fuel basket are presented in Table 2.2.11 (governed by Subsection NG of Section III). The external structures in the overpack meet the stress limits of Subsection NF of ASME Code, Section III for plate and shell components. Limits for the Level D condition are obtained from Appendix F of ASME Code, Section III. The MPC confinement boundary stress intensity limits are obtained from ASME Code, Section III, Subsection NB. The following definitions of terms apply to the tables on stress intensity limits; these definitions are the same as those used throughout the ASME Code:

S_m: Value of Design Stress Intensity listed in ASME Code Section II, Part D, Tables 2A, 2B and 4

S_y: Minimum yield strength at temperature

S_u: Minimum ultimate strength at temperature

The overpack closure bolts are designed in accordance with NUREG/CR-6007, "Stress Analysis of Closure Bolts for Shipping Casks" [2.2.12]. The overpack lifting trunnions and the assorted lifting bolts are designed according to NUREG-0612 [2.2.13] requirements. Table 2.2.16 provides the allowable stress criteria for the closure bolts, lifting trunnions, and lifting eye bolts.

Table 2.2.1

DESIGN PRESSURES

Pressure Location	**Condition**	**Pressure (psig)**
MPC Internal Pressure	Normal	100
	Off-Normal	100
	Accident	125
MPC External Pressure/Overpack Internal Pressure	Normal	40
	Off-Normal	40
	Accident	60
Overpack External Pressure	Normal	(0) Ambient
	Off-Normal	(0) Ambient
	Accident	300
Overpack Neutron Shield Enclosure Internal Pressure	Normal	30
	Off-Normal	30
	Accident	N/A†

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† The overpack neutron shield enclosure is equipped with two rupture disks which are set a relief pressure of 30 psig. Therefore, the pressure cannot exceed 30 psig.

Table 2.2.2

ENVIRONMENTAL TEMPERATURES

Condition	**Temperature (°F)**	**Comments**
Normal (Bounding Annual Average)	80	
Off-Normal (3-Day Average)	-40 and 100	• -40 °F with no insolation • 100 °F with insolation
Extreme Accident Level (3-Day Average)	125	• 125 °F with maximum insolation

Table 2.2.3: DESIGN TEMPERATURES

HI-STAR 100 Component	**Normal Condition Design Temp. (Long-Term Events) (°F)**	**Off-Normal and Accident Condition Design Temp. Limits (Short-Term Events) (°F)**
MPC shell	450	775
MPC basket	725	950
MPC Boral	800	950
MPC lid	550	775
MPC closure ring	400	775
MPC baseplate	400	775
MPC heat conduction elements	725	950
Overpack inner shell	400	500
Overpack bottom plate	350	700
Overpack closure plate	400	700
Overpack top flange	400	700
Overpack closure plate seals	400	1200
Overpack closure plate bolts	350	1000
Overpack port plug seals (vent and drain)	400	1600
Overpack port cover seals (vent and drain)	400	932
Neutron shielding	300	300
Overpack Neutron Shield Enclosure Shell	300	1350
Remainder of overpack	350	1000
Zircaloy fuel cladding (five-year cooled)	720 (PWR) 749 (BWR)	1058
Zircaloy fuel cladding (six-year cooled)	698 (PWR) 720 (BWR)	1058
Zircaloy fuel cladding (seven-year cooled)	657 (PWR) 676 (BWR)	1058
Zircaloy fuel cladding (ten-year cooled)	647 (PWR) 665 (BWR)	1058
Zircaloy fuel cladding (fifteen-year cooled)	633 (PWR) 653 (BWR)	1058

Table 2.2.4

TORNADO CHARACTERISTICS

Condition	Value
Rotational wind speed (mph)	290
Translational speed (mph)	70
Maximum wind speed (mph)	360
Pressure drop (psi)	3.0

Table 2.2.5

TORNADO-GENERATED MISSILES

Missile Description	Mass (kg)	Velocity (mph)
Automobile	1800	126
Artillery shell (8 in. diameter)	125	126
Solid sphere (1 in. diameter)	0.22	126

TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STAR 100 SYSTEM

MPC (1,2)

Primary Function	Component (3)	Safety Class (4)	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
Confinement	Shell	A	ASME Section III; Subsection NB	Alloy X (5)	See Appendix 1.A	NA	NA
Confinement	Baseplate	A	ASME Section III; Subsection NB	Alloy X	See Appendix 1.A	NA	NA
Confinement	Lid	A	ASME Section III; Subsection NB	Alloy X	See Appendix 1.A	NA	NA
Confinement	Closure Ring	A	ASME Section III; Subsection NB	Alloy X	See Appendix 1.A	NA	NA
Confinement	Port Cover Plates	A	ASME Section III; Subsection NB	Alloy X	See Appendix 1.A	NA	NA
Criticality Control	Basket Cell Plates	A	ASME Section III; Subsection NG	Alloy X	See Appendix 1.A	NA	NA
Criticality Control	Boral	A	Non-code	NA	NA	NA	Aluminum/SS
Shielding	Drain and Vent Shield Block	C	Non-code	Alloy X	See Appendix 1.A	NA	NA
Shielding	Plugs for Drilled Holes	NITS	Non-code	Alloy X	See Appendix 1.A	NA	NA
Heat Transfer	Heat Conduction Elements	B	Non-code	Aluminum; Alloy 1100	NA	Sandblast Specified Surfaces	Aluminum/SS
Structural Integrity	Upper Fuel Spacer Column	B	ASME Section III; Subsection NG (only for stress analysis)	Alloy X	See Appendix 1.A	NA	NA
Structural Integrity	Sheathing	A	Non-code	Alloy X	See Appendix 1.A	Aluminum/SS	NA

TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STAR 100 SYSTEM

MPC [1,2]

Primary Function	Component [3]	Safety Class [4]	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
Structural Integrity	Shims	NITS	Non-code	Alloy X	See Appendix 1.A	NA	NA
Structural Integrity	Basket Supports (Angled Plates)	A	ASME Section III; Subsection NG	Alloy X	See Appendix 1.A	NA	NA
Structural Integrity	Basket Supports (Flat Plates)	B	ASME Section III; Subsection NG	Alloy X	See Appendix 1.A	NA	NA
Structural Integrity	Lift Lug	C	Non-code	Alloy X	See Appendix 1.A	NA	NA
Structural Integrity	Lift Lug Baseplate	C	Non-code	Alloy X	See Appendix 1.A	NA	NA
Structural Integrity	Upper Fuel Spacer Bolt	NITS	Non-code	A193-B8	Per ASME Section II	NA	NA
Structural Integrity	Upper Fuel Spacer End Plate	B	Non-code	Alloy X	See Appendix 1.A	NA	NA
Structural Integrity	Lower Fuel Spacer Column	B	ASME Section III; Subsection NG (only for stress analysis)	Alloy X	See Appendix 1.A	NA	NA
Structural Integrity	Lower Fuel Spacer End Plate	B	Non-code	Alloy X	See Appendix 1.A	NA	NA
Structural Integrity	Vent Shield Block Spacer	C	Non-code	Alloy X	See Appendix 1.A	NA	NA
Operations	Vent and Drain Tube	C	Non-code	304 S/S	Per ASME Section II	Thread area surface hardened	NA
Operations	Vent & Drain Cap	C	Non-code	304 S/S	Per ASME Section II	NA	NA
Operations	Vent & Drain Cap Seal Washer	NITS	Non-code	Aluminum	NA	NA	Aluminum/SS
Operations	Vent & Drain Cap Seal Washer Bolt	NITS	Non-code	Aluminum	NA	NA	NA

TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STAR 100 SYSTEM

MPC (1,2)

Primary Function	Component (3)	Safety Class (4)	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
Operations	Reducer	NITS	Non-code	Alloy X	See Appendix 1.A	NA	NA
Operations	Drain Line	NITS	Non-code	Alloy X	See Appendix 1.A	NA	NA
Operations	Damaged Fuel Container	C	ASME Section III; Subsection NG	Primarily 304 S/S	See Appendix 1.A	NA	NA

TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STAR 100 SYSTEM

OVERPACK $^{(1,2)}$

Primary Function	Component $^{(3)}$	Safety Class $^{(4)}$	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
Helium Retention	Inner Shell	A	ASME Section III; Subsection NB	SA203-E	Table 3.3.4	Paint inside surface with Thermaline 450	NA
Helium Retention	Bottom Plate	A	ASME Section III; Subsection NB	SA350-LF3	Table 3.3.4	Paint inside surface with Thermaline 450	NA
Helium Retention	Top Flange	A	ASME Section III; Subsection NB	SA350-LF3	Table 3.3.4	Paint inside surface with Thermaline 450. Paint outside surface with Carboline 890.	NA
Helium Retention	Closure Plate	A	ASME Section III; Subsection NB	SA350-LF3	Table 3.3.4	Paint inside surface with Thermaline 450. Paint outside surface with Carboline 890.	NA
Helium Retention	Closure Plate Bolts	A	ASME Section III; Subsection NB	SB637-N07718	Table 3.3.5	NA	NA
Helium Retention	Port Plug	A	Non-code	SA193-B8	Not required	NA	NA
Helium Retention	Port Plug Seal	A	Non-code	Alloy X750	Not required	NA	NA
Helium Retention	Closure Plate Seal	A	Non-code	Alloy X750	Not required	NA	NA
Helium Retention	Port Cover Seal	B	Non-code	Alloy X750	Not required	NA	NA
Shielding	Intermediate Shells	B	ASME Section III; Subsection NF	SA516-70	Table3.3.2	Exposed areas of fifth intermediate shell to be painted with Carboline 890.	NA
Shielding	Neutron Shield	B	Non-code	Holtite-A	Not required	NA	NA

TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STAR 100 SYSTEM

OVERPACK (1,2)

Primary Function	Component (3)	Safety Class (4)	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
Shielding	Plugs for Drilled Holes	NITS	Non-code	SA193-B7	Not required	NA	NA
Shielding	Removable Shear Ring	B	ASME Section III; Subsection NF	SA203-E	Table 3.3.4	Paint external surface with Carboline 890.	NA
Shielding	Pocket Trunnion Plug Plate	C	Non-code	SA240-304	Not required	NA	NA
Heat Transfer	Radial Channels	B	ASME Section III; Subsection NF	SA515-70	Table 3.3.3	Paint outside surface with Carboline 890.	NA
Structural Integrity	Pocket Trunnion	B	ASME Section III; Subsection NF	SA705-630	Table 3.3.5	NA	NA
Structural Integrity	Lifting Trunnion	A	ANSI N14.6	SB637-N07718	Table 3.3.5	NA	NA
Structural Integrity	Rupture Disk	C	Non-code	Commercial	Not required	NA	Brass-C/S
Structural Integrity	Rupture Disk Plate	C	Non-code	A569	Not required	NA	NA
Structural Integrity	Removable Shear Ring Bolt	C	Non-code	SA193-B7	Not required	NA	NA
Structural Integrity	Thermal Expansion Foam	NITS	Non-code	Silicone Foam	Not required	NA	NA
Structural Integrity	Closure Bolt Washer	NITS	Non-code	SA240-304	Not required	NA	NA
Structural Integrity	Enclosure Shell Panels	B	ASME Section III; Subsection NF	SA515-70	Table 3.3.3	Paint outside surface with Carboline 890.	NA
Structural Integrity	Enclosure Shell Return	B	ASME Section III; Subsection NF	SA515-70	Table 3.3.3	Paint outside surface with Carboline 890.	NA
Structural Integrity	Port Cover	B	ASME Section III; Subsection NF	SA203E	Table 3.3.4	Paint outside surface with Carboline 890.	NA

TABLE 2.2.6

MATERIALS AND COMPONENTS OF THE HI-STAR 100 SYSTEM

OVERPACK (1,2)

Primary Function	Component (3)	Safety Class (4)	Codes/Standards (as applicable to component)	Material	Strength (ksi)	Special Surface Finish/Coating	Contact Matl. (if dissimilar)
Structural Integrity	Port Cover Bolt	C	Non-code	SA193-B7	Not required	NA	NA
Operations	Trunnion Locking Pad and End Cap Bolt	C	Non-code	SA193-B7	Not required	NA	NA
Operations	Lifting Trunnion End Cap	C	Non-code	SA516-70	Table 3.3.2	Paint exposed surfaces with Carboline 890.	NA
Operations	Lifting Trunnion Locking Pad	C	Non-code	SA516-70	Table 3.3.2	Paint exposed surfaces with Carboline 890.	NA
Operations	Nameplate	NITS	Non-code	SA240-304	Not required	NA	NA

Table 2.2.7

HI-STAR 100 ASME BOILER AND PRESSURE VESSEL CODE APPLICABILITY

HI-STAR 100 Component	Material Procurement	Design	Fabrication	Inspection
Overpack helium retention boundary	Section II, Section III, Subsection NB, NB-2000	Section III, Subsection NB, NB-3200	Section III, Subsection NB, NB-4000	Section III, Subsection NB, NB-5000 and Section V
Overpack intermediate shells, radial channels, outer enclosure	Section II, Section III, Subsection NF, NF-2000	Section III, Subsection NF, NF-3200	Section III, Subsection NF, NF-4000	Section III, Subsection NF, NF-5360 and Section V
MPC confinement boundary	Section II, Section III, Subsection NB, NB-2000	Section III, Subsection NB, NB-3200	Section III, Subsection NB, NB-4000	Section III, Subsection NB, NB-5000 and Section V
MPC fuel basket	Section II, Section III, Subsection NG, NG-2000	Section III, Subsection NG, NG-3300 and NG-3200	Section III, Subsection NG, NG-4000	Section III, Subsection NG, NG-5000 and Section V
Trunnions	Section II, Section III, Subsection NF, NF-2000	ANSI N14.6	Section III, Subsection NF, NF-4000	See Chapter 9
MPC basket supports	Section II, Section III, Subsection NG, NG-2000	Section III, Subsection NG, NG-3300 and NG-3200	Section III, Subsection NG, NG-4000	Section III, Subsection NG, NG-5000 and Section V
Damaged fuel Container	Section II, Section III, Subsection NG, NG-2000	Section III, Subsection NG, NG-3300 and NG-3200	Section III, Subsection NG, NG-4000	Section III, Subsection NG, NG-5000 and Section V

Table 2.2.8

ADDITIONAL DESIGN INPUT DATA FOR NORMAL, OFF-NORMAL, AND ACCIDENT CONDITIONS

Item	Condition	Value
Snow Pressure Loading (lb./ft^2)	Normal	100
Constriction of MPC Basket Vent Opening By Crud Settling (Depth of Crud, in.)	Accident	0.85 (MPC-68) 0.36 (MPC-24)
Cask Environment During the Postulated Fire Event (ºF)	Accident	1475
Fire Duration (seconds)	Accident	305
Maximum submergence depth due to flood (ft)	Accident	656
Flood water velocity (ft/s)	Accident	13
Maximum Horizontal ZPA (Zero Period Acceleration) for HI-STAR† (g's)	Accident	0.314 (w/1.0 vertical) 0.332 (w/0.75 vertical) 0.339 (w/0.667 vertical) 0.354 (w/0.5 vertical)

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† The maximum horizontal ZPA is specified as the vector sum of the g-loading in two orthogonal directions as a function of the vertical acceleration multiplier which is the maximum vertical ZPA divided by the maximum horizontal ZPA for a single orthogonal direction for the site.

Table 2.2.9

CHARACTERISTICS OF REFERENCE ISFSI PAD[†]

Concrete thickness	$\leq$ 36 inches
Concrete Compressive Strength	$\leq$ 4,200 psi at 28 days
Reinforcement Top and Bottom (both directions)	Reinforcing bar shall be 60 ksi yield strength ASTM material
Soil Effective Modulus of Elasticity[††]	$\leq$ 28,000 psi (measured prior to ISFSI pad installation)

[†] The characteristics of this pad are identical to the pad considered by Lawrence Livermore Laboratory (see Appendix 3.A).

[††] An acceptable method of defining the soil effective modulus of elasticity applicable to the drop and tipover analysis is provided in Table 13 of NUREG/CR-6608 with soil classification in accordance with ASTM-D2487 Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System USCS) and density determination in accordance with ASTM-D-1586 Standard Test Method for Penetration Test and Split/barrel Sampling of Soils.

Table 2.2.10
MPC CONFINEMENT BOUNDARY AND OVERPACK HELIUM RETENTION BOUNDARY STRESS INTENSITY LIMITS FOR DIFFERENT LOADING CONDITIONS (ELASTIC ANALYSIS PER NB-3220)[†]

STRESS CATEGORY	**DESIGN**	**LEVELS A & B**	**LEVEL D**[††]
Primary Membrane, P_m	S_m	N/A[†††]	AMIN ($2.4S_m$, $.7S_u$)
Local Membrane, P_L	$1.5S_m$	N/A	150% of P_m Limit
Membrane plus Primary Bending	$1.5S_m$	N/A	150% of P_m Limit
Primary Membrane plus Primary Bending	$1.5S_m$	N/A	150% of P_m Limit
Membrane plus Primary Bending plus Secondary	N/A	$3S_m$	N/A
Average Shear Stress[††††] (Section in Pure Shear)	$0.6S_m$	$0.6S_m$	$0.42S_u$

[†] Stress combinations including F (peak stress) apply to fatigue evaluations only.

[††] Governed by Appendix F, Paragraph F-1331 of the ASME Code, Section III.

[†††] No specific stress intensity limit applicable.

[††††] Governed by NB-3227.2 or F-1331.1(d)

Table 2.2.11

MPC BASKET STRESS INTENSITY LIMITS FOR DIFFERENT LOADING CONDITIONS (ELASTIC ANALYSIS PER NG-3220)

STRESS CATEGORY	DESIGN	LEVELS A & B	LEVEL D†
Primary Membrane, P_m	S_m	S_m	AMIN ($2.4S_m$, $.7S_u$)††
Primary Membrane plus Primary Bending	$1.5S_m$	$1.5S_m$	150% of P_m Limit
Primary Membrane plus Primary Bending plus Secondary	N/A†††	$3S_m$	N/A

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† Governed by Appendix F, Paragraph F-1331 of the ASME Code, Section III.

†† Governed by NB-3227.2 or F-1331.1(d)

††† No specific stress intensity limit applicable.

Table 2.2.12

STRESS LIMITS FOR DIFFERENT LOADING CONDITIONS FOR THE EXTERNAL STRUCTURES IN THE HI-STAR OVERPACK (ELASTIC ANALYSIS PER NF-3260)

	SERVICE CONDITION[†]		
STRESS CATEGORY	**DESIGN + LEVEL A**	**LEVEL B**	**LEVEL D**[††]
Primary Membrane, P_m	S	1.33S	AMAX ($1.2S_y$, $1.5S_m$) but < $.7S_u$
Primary Membrane, P_m, plus Primary Bending, P_b	1.5S	1.995S	150% of P_m
Shear Stress (Average)	0.6S	0.6S	$<0.42S_u$

Definitions:

S = Allowable Stress Value for Table 1A, ASME Section II, Part D
S_m = Allowable Stress Intensity Value from Table 2A, ASME Section II, Part D
S_u = Ultimate Strength

[†] Limits for Design and Levels A and B are on maximum stress.
Limits for Level D are on maximum stress intensity.

[††] Governed by Appendix F, Paragraph F-1332 of the ASME Code, Section III.

Table 2.2.13
NOTATION FOR DESIGN LOADINGS FOR NORMAL, OFF-NORMAL, AND ACCIDENT CONDITIONS

NORMAL CONDITION	
LOADING	**NOTATION**
Dead Weight	D
Handling Loads	H
Design Pressure (Internal)†	P_i
Design Pressure (External)†	P_o
Snow	S
Wind	W
Operating Temperature	T
OFF-NORMAL CONDITION	
LOADING	**NOTATION**
Off-Normal Pressure (Internal)†	P_i
Off-Normal Pressure (External)†	P_o
Off-Normal Temperature	T′

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† Internal Design Pressure P_i bounds the normal and off-normal condition internal pressures. External Design Pressure P_o bounds off-normal external pressures. Similarly, accident pressures P_i^* and P_o^*, respectively, bound actual internal and external pressures under all postulated environment phenomena and accident events.

Table 2.2.13 (continued)

NOTATION FOR DESIGN LOADINGS FOR NORMAL, OFF-NORMAL, AND ACCIDENT CONDITIONS

ACCIDENT CONDITIONS	
LOADING	**NOTATION**
Handling Accident (Drop)	H'
Earthquake	E
Fire	T^*
Tornado Missile	M
Tornado Wind	W'
Flood	F
Explosion	E^*
Accident Pressure (Internal)	P_i^*
Accident Pressure (External)	P_o^*

Table 2.2.14

APPLICABLE LOAD CASES AND COMBINATIONS FOR EACH CONDITION AND COMPONENT†, ††

CONDITION	LOADING CASE	MPC	OVERPACK
Design (ASME Code Pressure Compliance)	1	P_i, P_o	P_i, P_o
Normal (Level A)	1	D ,T , H , P_i	D , T , H , P_i
	2	D , T , H , P_o	N/A
Off-Normal (Level B)	1	D , T′, H , P_i	D , T′ , H , P_i
	2	D , T′ , H , P_o	N/A
Accident (Level D)	1	D , T , P_i , H′	D , T , P_i , H′
	2	D, T^*, P_i^*	D , T^*, P_i^*
	3	D, T^*, P_i^*	D , T^* , P_o^*†††

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† The loading notations are given in Table 2.2.13. Each symbol represents a loading type and may have different values for different components.

†† N/A stands for "Not Applicable".

††† P_o^* bounds the external pressure due to explosion.

Table 2.2.15

LIST OF ASME CODE EXCEPTIONS FOR HI-STAR 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification & Compensatory Measures
MPC	NB-1100	Statement of requirements for Code stamping of components.	MPC enclosure vessel is designed and will be fabricated in accordance with ASME Code, Section III, Subsection NB to the maximum practical extent, but Code stamping is not required.
MPC	NB-2000	Requires materials to be supplied by ASME-approved material supplier.	Materials will be supplied by Holtec approved suppliers with Certified Material Test Reports (CMTRs) in accordance with NB-2000 requirements.
MPC Lid and Closure Ring Welds	NB-4243	Full penetration welds required for Category C Joints (flat head to main shell per NB-3352.3)	MPC lid and closure ring are not full penetration welds. They are welded independently to provide a redundant seal. Additionally, a weld efficiency factor of 0.45 has been applied to the analyses of these welds.
MPC Lid to Shell Weld	NB-5230	Radiographic (RT) or ultrasonic (UT) examination required	Only UT or multi-layer liquid penetrant (PT) examination is permitted. If PT alone is used, at a minimum, it will include the root and final weld layers and each approximately 3/8 inch of weld depth.

Table 2.2.15 (continued)

LIST OF ASME CODE EXCEPTIONS FOR HI-STAR 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification & Compensatory Measures
MPC Closure Ring, Vent and Drain Cover Plate Welds	NB-5230	Radiographic (RT) or ultrasonic (UT) examination required.	Root (if more than one weld pass is required) and final liquid penetrant examination to be performed in accordance with NB-5245. The MPC vent and drain cover plate welds are leak tested. The closure ring provides independent redundant closure for vent and drain cover plates.
MPC Enclosure Vessel and Lid	NB-6111	All completed pressure retaining systems shall be pressure tested.	The MPC enclosure vessel is seal welded in the field following fuel assembly loading. The MPC enclosure vessel shall then be hydrostatically tested as defined in Chapter 9. Accessibility for leakage inspections preclude a Code compliant hydrostatic test. All MPC enclosure vessel welds (except the closure ring and vent/drain cover plate welds) are inspected by volumetric examination, except the MPC lid-to shell weld shall be verified by volumetric or multi-layer PT examination. If PT alone is used, at a minimum, it must include the root and final layers and each approximately 3/8 inch of weld depth. For either UT or PT, the maximum undetectable flaw size must be demonstrated to be less

Table 2.2.15 (continued)

LIST OF ASME CODE EXCEPTIONS FOR HI-STAR 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification & Compensatory Measures
			than the critical flaw size. The critical flaw size must be determined in accordance with ASME XI methods. The critical flaw size shall not casue the primary stress limits of NB-3000 to be exceeded. examined. The vent/drain cover plate weld is confirmed by leakage testing and liquid penetrant examination and the closure ring weld is confirmed by liquid penetrant examination.
MPC Enclosure Vessel	NB-7000	Vessels are required to have overpressure protection.	No overpressure protection is provided. Function of MPC enclosure vessel is to contain radioactive contents under normal, off-normal, and accident conditions of storage. MPC vessel is designed to withstand maximum internal pressure considering 100% fuel rod failure and maximum accident temperatures.
MPC Enclosure Vessel	NB-8000	States requirements for nameplates, stamping and reports per NCA-8000.	HI-STAR 100 System to be marked and identified in accordance with 10CFR71 and 10CFR72 requirements. Code stamping is not required. QA data package to be in accordance with Holtec approved QA program.

Table 2.2.15 (continued)

LIST OF ASME CODE EXCEPTIONS FOR HI-STAR 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification & Compensatory Measures
Overpack Helium Retention Boundary	NB-1100	Statement of requirements for Code stamping of components.	Overpack helium retention boundary is designed, and will be fabricated in accordance with ASME Code, Section III, Subsection NB to the maximum practical extent, but Code stamping is not required.
Overpack Helium Retention Boundary	NB-2000	Requires materials to be supplied by ASME approved Material Supplier.	Materials will be supplied by Holtec approved suppliers with CMTRs per NB-2000.
Overpack Helium Retention Boundary	NB-7000	Vessels are required to have overpressure protection.	No overpressure protection is provided. Function of overpack vessel is to contain helium contents under normal, off-normal, and accident conditions. Overpack vessel is designed to withstand maximum internal pressure and maximum accident temperatures.
Overpack Helium Retention Boundary	NB-8000	Statement of Requirements for nameplates, stamping and reports per NCA-8000.	HI-STAR 100 System to be marked and identified in accordance with 10CFR71 and 10CFR72 requirements. Code stamping is not required. QA data package to be in accordance with Holtec's approved QA program.
MPC Basket Assembly	NG-2000	Requires materials to be supplied by ASME approved Material Supplier.	Materials will be supplied by Holtec approved supplier with CMTRs in accordance with NG-2000

Table 2.2.15 (continued)

LIST OF ASME CODE EXCEPTIONS FOR HI-STAR 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification & Compensatory Measures
			requirements.
MPC Basket Assembly	NG-8000	States requirements for nameplates, stamping and reports per NCA-8000.	The HI-STAR 100 System will be marked and identified in accordance with 10CFR71 and 10CFR72 requirements. No Code stamping is required. The MPC basket data package will be in conformance with Holtec's QA program.
Overpack Intermediate Shells	NB-4622	All welds, including repair welds, shall be post-weld heat treated (PWHT).	PWHT of intermediate shell-to-top flange and intermediate shell-to-bottom plate welds do not require PWHT. These welds attach non-pressure retaining parts to pressure retaining parts. The pressure retaining parts are > 7 inches thick. Localized PWHT will cause material away from the weld to experience elevated temperatures which will have an adverse effect on the material properties.
Overpack Helium Retention Boundary	NG-2000	Perform radiographic examination after post-weld heat treatment (PWHT).	Radiography of the helium retention boundary welds after PWHT is not required. All welds (including repairs) will have passed radiographic examination prior to PWHT of the entire containment boundary. Confirmatory radiographic examination

Table 2.2.15 (continued)

LIST OF ASME CODE EXCEPTIONS FOR HI-STAR 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification & Compensatory Measures
			after PWHT is not necessary because PWHT is not known to introduce new weld defects in nickel steels.
Overpack Intermediate Shells	NF-2000	Requires materials to be supplied by ASME approved Material Supplier.	Materials will be supplied by Holtec approved supplier with CMTRs in accordance with NF-2000 requirements.
Overpack Helium Retention Boundary	NB-2330	Defines the methods for determining the T_{NDT} for impact testing of materials.	T_{NDT} shall be defined in accordance with Regulatory Guides 7.11 and 7.12 for the helium retention boundary components.

Table 2.2.16

NON-ASME CODE STRESS ALLOWABLE CRITERIA

OVERPACK CLOSURE BOLTS[†]:

STRESS CATEGORY	NORMAL AND OFF-NORMAL CONDITIONS	ACCIDENT CONDITIONS
Average Tensile Stress	$2/3\ S_y$	$AMIN(S_y, 0.7\ S_u)$
Average Shear Stress	$0.6\ (2/3\ S_y)$	$AMIN(0.6\ S_y, 0.42\ S_u)$
Combined Tensile and Shear Stress[††]	$R_t^2 + R_s^2 < 1.0$	$R_t^2 + R_s^2 < 1.0$

LIFTING TRUNNIONS AND LIFTING BOLTS:

The lifting trunnions and the lifting bolts, for the overpack closure plate and for the MPC lid, are designed in accordance with NUREG-0612 and ANSI N14.6. Specifically, the design must meet factors of safety of six based on the material yield stress and ten based on the material ultimate stress for non-redundant lifting devices.

[†] The overpack closure bolts are designed in accordance with NUREG/CR-6007, "Stress Analysis of Closure Bolts for Shipping Casks".

[††] R_t and R_s are the ratios of actual stress to allowable tensile and shear stress, respectively.

Table 2.2.17

ALLOWABLE CARRY HEIGHTS

Cask Orientation	Height (Inches)
Vertical	21
Horizontal	72

<u>Note:</u> The carry height is measured from the lowest surface of the overpack to the potential impact surface.

2.3 SAFETY PROTECTION SYSTEMS

2.3.1 General

The HI-STAR 100 System is a storage and transport cask engineered to provide safe long-term storage of spent nuclear fuel. The HI-STAR 100 System will withstand all normal, off-normal, and postulated accident conditions without any uncontrolled release of radioactive material or excessive radiation exposure to workers or members of the public. Special considerations in the design have been made to ensure long-term integrity and confinement of the stored SNF throughout all cask operating conditions. The design considerations which have been incorporated into the HI-STAR 100 System to ensure safe long-term fuel storage are:

1. The MPC confinement barrier is an enclosure vessel designed in accordance with the ASME Code, Subsection NB with most confinement welds inspected by radiography (RT) or ultrasonic testing (UT). Where RT or UT is not possible, a redundant closure system is provided. The MPC closure ring and vent and drain port cover plates are not inspected by UT or RT, but the closure ring provides an independent redundant closure for the vent and drain cover plates. The MPC lid-to-shell weld will be examined by PT (root and final weld layers) and UT or multi-layer PT.

2. The MPC confinement barrier is encapsulated by the overpack helium retention boundary.

3. The HI-STAR 100 System is designed to meet the requirements of storage while maintaining the safety of the spent nuclear fuel.

4. The spent nuclear fuel once initially loaded in the MPC and overpack does not require any further canister transfer or fuel handling operations for storage or transport.

5. The decay heat emitted by the spent nuclear fuel is rejected from HI-STAR 100 through passive means. No active cooling systems are employed.

It is recognized that a rugged design with large safety margins is essential, but not sufficient to ensure acceptable performance over the service life of any system. A carefully planned oversight and surveillance plan which does not diminish system integrity but provides reliable information on the effect of passage of time on the performance of the system is essential. Such a surveillance and performance assay program will be developed to be compatible with the specific conditions of the licensee's facility where the HI-STAR 100 System is installed. The general requirements for the acceptance testing and maintenance programs are provided in Chapter 9. Surveillance requirements are specified in Technical Specifications.

The structures, systems, and components of the HI-STAR 100 System designated as important to safety are identified in Table 2.2.6. Similar categorization of structures, systems, and components, which are part of the ISFSI, but not part of the HI-STAR 100 System, will be the responsibility of the 10CFR72 licensee.

2.3.2 Protection by Multiple Confinement Barriers and Systems

2.3.2.1 Confinement Barriers and Systems

The radioactivity which the HI-STAR 100 must confine originates from the spent fuel assemblies and, to a lesser extent, the contaminated water in the fuel pool. This radioactivity is confined by multiple confinement barriers.

Radioactivity from the fuel pool water is minimized by preventing contact, removing the contaminated water, and decontamination.

An inflatable seal in the annular gap between the MPC and overpack prevents the fuel pool water from contacting the exterior of the MPC and interior of the overpack while submerged for fuel loading. The fuel pool water is drained from the interior of the MPC, and the MPC internals are dried. The exterior of the overpack has a painted surface which is decontaminated to acceptable levels. Any residual radioactivity deposited by the fuel pool water is confined by the MPC confinement boundary along with the spent nuclear fuel.

The HI-STAR 100 is designed with several confinement barriers for the radioactive fuel contents. Fuel assemblies classified as damaged fuel or fuel debris are placed within a damaged fuel container which restricts the release of fuel debris. Intact fuel assemblies have cladding which provides the first boundary preventing release of the fission products. The MPC is a seal welded enclosure which provides the confinement boundary. The MPC confinement boundary is defined by the MPC baseplate, shell, lid, closure ring, and port cover plates. An entirely redundant boundary is provided by the overpack helium retention boundary; however, no credit is taken for the overpack helium retention boundary other than its ability to retain a helium atmosphere.

The MPC confinement boundary has been designed to withstand any postulated off-normal operations, internal change, or external natural phenomena. The MPC is designed to endure normal, off-normal, and accident conditions of storage with the maximum decay heat loads without loss of confinement. Designed in accordance with the ASME Code, Section III, Subsection NB, the MPC confinement boundary provides assurance that there will be no release of radioactive materials from the cask under the specified loading conditions. Therefore, no monitoring system for the confinement boundary is required.

Confinement is discussed further in Chapter 7. MPC field weld examinations, hydrostatic testing, and helium leak testing are performed to verify the confinement function in accordance with the operating procedures in Chapter 8 and the testing and acceptance requirements in Chapter 9.

2.3.2.2 Cask Cooling

To facilitate the passive heat removal capability of the HI-STAR 100, several thermal design criteria are established for normal and off-normal conditions. They are as follows:

- A concentric set of metallic seals in the overpack closure plate contain the helium atmosphere between the exterior of the MPC and the interior of the overpack. A maximum steady-state temperature limit is conservatively set for the seals in Table 2.2.3 based on the manufacturer's specifications. The seals can also withstand the pressures specified in Table 2.2.1.

- The overpack helium retention boundary ensures that the helium atmosphere in the overpack annulus is maintained during normal, off-normal, and accident conditions.

- The MPC confinement boundary ensures that the helium atmosphere inside the MPC is maintained during normal and off-normal conditions. The MPC confinement boundary maintains the helium confinement atmosphere below the design temperatures and pressures stated in Table 2.2.3 and Table 2.2.1, respectively.

- The MPC thermal design maintains the fuel rod cladding temperatures below the values stated in Chapter 4 such that fuel cladding is not degraded during the normal storage period.

- The fabrication method used for layering of the intermediate shells will assure contact between layers. However, the thermal evaluation is conservatively based on small uniform gaps between each shell. During normal conditions, the internal heat source (decay heat from the fuel) acts to provide further assurance of inter-shell contact due to thermal expansion. Likewise, during the fire accident, the outermost intermediate shell would tend to expand more than the inner intermediate shells, possibly reducing the inter-surface contact between them. Such a reduction in contact would tend to insulate the cask during the fire accident. However, no credit is taken for this differential thermal expansion in the thermal analyses. Differential thermal expansion and the resultant stresses caused by restriction of free expansion are, however, accounted for in the structural analyses.

- The heat rejection capacity of the HI-STAR 100 is deliberately understated by conservatively determining the design basis fuel. The decay heat value in Table 2.1.6 is prepared by computing the decay heat from the design basis fuel assembly which produces the highest heat generation rate for a given burnup. Additional margin is built into the calculated cask cooling rate by using a fictitious fuel assembly which offers maximum resistance to the transmission of heat (minimum thermal conductivity).

2.3.3 Protection by Equipment and Instrumentation Selection

2.3.3.1 Equipment

Design criteria for the HI-STAR 100 System is described in Section 2.2. The HI-STAR 100 System may include support equipment. The lifting equipment used to handle the HI-STAR 100 System in and out of the pool is classified as Important to Safety. The lifting equipment is designed in accordance with ANSI N14.6. Other important to safety support equipment is listed in Table 8.1.4.

Auxiliary operational equipment (e.g., trailers, skids, portable cranes, transporters, or air pads) are Not Important to Safety, as the HI-STAR 100 is designed to withstand the failure of any of these components provided the requirements of this FSAR are met.

2.3.3.2 Instrumentation

As a consequence of the passive nature of the HI-STAR 100 System, instrumentation which is Important to Safety is not necessary. No instrumentation is required for HI-STAR 100 storage operations.

2.3.4 Nuclear Criticality Safety

The criticality safety criterion stipulates that the effective neutron multiplication factor, k_{eff}, including statistical uncertainties and biases, is less than 0.95 for all postulated arrangements of fuel within the cask under all credible conditions.

2.3.4.1 Control Methods for Prevention of Criticality

The control methods and design features used to prevent criticality for all MPC configurations are the following:

a. Incorporation of permanent neutron absorbing material (Boral) in the MPC fuel basket walls.

b. Favorable geometry provided by the MPC fuel basket

Administrative controls will be used to ensure that fuel placed in the HI-STAR 100 System meets the requirements of the Certificate of Compliance. All appropriate criticality analyses are presented in Chapter 6.

2.3.4.2 Error Contingency Criteria

Provision for error contingency is built into the criticality analyses performed in Chapter 6. Because biases and uncertainties are explicitly evaluated in the analysis, it is not necessary to introduce additional contingency for error.

2.3.4.3 Verification Analyses

In Chapter 6, critical experiments are selected which reflect the design configurations. These critical experiments are evaluated using the same calculation methods, and a suitable bias is incorporated in the reactivity calculation.

2.3.5 Radiological Protection

2.3.5.1 Access Control

As required by 10CFR72, uncontrolled access to the ISFSI will be prevented through physical means. A peripheral fence with an appropriate monitoring system is a standard approach to limit access. The details of the access control systems and procedures, including division of the site into radiation protection areas, will be developed by the licensee.

2.3.5.2 Shielding

The shielding design is governed by 10CFR72.104 and 10CFR72.106 which provide radiation dose limits for any real individual located at or beyond the nearest boundary of the controlled area. The individual must not receive an annual dose equivalent greater than the values stated in Table 2.3.1 for normal and off-normal conditions. Further, an individual located at the site boundary must not receive a dose to the whole body or any organ from any design basis accident greater than the values listed in Table 2.3.1.

The objective of shielding is to assure that radiation dose rates at key locations are below acceptable levels for those locations. Three locations are of particular interest in the storage mode:

- immediate vicinity of the cask
- restricted area boundary
- controlled area (site) boundary

Dose rates in the immediate vicinity of the cask are important in consideration of occupational exposure. A design objective for the radial neutron shield mid-height surface dose rate has been established as 125 mrem/hr. Dose rates above and below the neutron shield may be further reduced by temporary shielding as detailed in Chapter 10. Areas above and below the neutron shield in the radial direction are limited to 375 mrem/hr. Chapter 5 of this FSAR presents the analyses and evaluations to establish HI-STAR 100 compliance with these design objectives.

Because of the passive nature of the HI-STAR 100, human activity related to the system is infrequent and of short duration. Personnel exposures due to operational and maintenance activities are discussed in Chapter 10. Chapter 10 also provides information concerning temporary shielding which may be utilized to reduce the personnel dose during loading, unloading, and handling operations. The estimated occupational doses for personnel must comply with the requirements of 10CFR20.

Dose rates at the restricted area and site boundaries shall be in accordance with applicable regulations. Licensees are required to demonstrate compliance with 10CFR72.104 and 10CFR72.106 for the actual fuel being stored, ISFSI storage array, and controlled area boundary.

The analyses presented in Chapters 5, 10 and 11 demonstrate that the HI-STAR 100 System meets the above radiation dose limits and design objectives.

2.3.5.3 Radiological Alarm System

There are no credible events which could result in release of radioactive materials or unacceptable increases in direct radiation. In addition, the releases postulated as the result of the hypothetical accidents described in Chapter 11 are of a very small magnitude. Therefore, radiological alarm systems are not necessary.

2.3.6 Fire and Explosion Protection

There are no combustible or explosive materials associated with the HI-STAR 100 System. No such materials would be stored within an ISFSI. However, for conservatism we have analyzed the fire accident as a bounding condition for HI-STAR 100 System. An evaluation of the HI-STAR 100 System in a fire accident is discussed in Chapter 11.

Small overpressures are the result of accidents involving explosive materials which are stored or transported near the site. Explosion is a load considered in Chapter 11.

Table 2.3.1

RADIOLOGICAL SITE BOUNDARY REQUIREMENTS

BOUNDARY OF CONTROLLED AREA (m) (minimum)	100
NORMAL AND OFF-NORMAL CONDITIONS:	
Whole Body (mrem/yr)	25
Thyroid (mrem/yr)	75
Any Other Organ (mrem/yr)	25
DESIGN BASIS ACCIDENT:	
Whole Body-Total Effective Dose (rem)	5
Deep Dose Equivalent and Any Organ or Tissue (rem)	50
Lens of Eye (rem)	15
Skin or Extremity (rem)	50

2.4 DECOMMISSIONING CONSIDERATIONS

Efficient decommissioning of the ISFSI is a paramount objective of the HI-STAR 100 System. The HI-STAR 100 System is ideally configured to facilitate rapid, safe, and economical decommissioning of the storage site.

The MPC which holds the SNF assemblies is engineered to be suitable as a waste package for permanent internment in a deep Mined Geological Disposal System (MGDS). The materials of construction permitted for the MPC are known to be highly resistant to severe environmental conditions. No carbon steel, paint, or coatings are used or permitted in the MPC. Therefore, the SNF assemblies stored in the MPC should not need to be removed. However, to ensure a practical, feasible method to defuel the HI-STAR 100 MPC, the top of the MPC is equipped with sufficient gamma shielding and markings locating the drain and vent locations to enable semiautomatic (or remotely actuated) boring of the MPC lid to provide access to the MPC vent and drain. The circumferential welds of the MPC lid and closure ring can be removed by semiautomatic or remotely actuated means, providing access to the SNF.

Likewise, the overpack consists of alloy materials rendering it suitable for permanent burial. Alternatively, the MPC can be removed from the overpack, and the latter reused for storage or transportation of other MPCs.

In either case, the overpack would be expected to have only minimal interior or exterior radioactive surface contamination. Any neutron activation of the metal cask walls and neutron shielding is expected to be extremely small, and the assembly would qualify as Class A waste in a stable form based on definitions and requirements in 10CFR61.55. As such, the material would be suitable for burial in a near-surface disposal site as Low Specific Activity (LSA) material.

If the HI-STAR 100 MPC needs to be opened and separated from the SNF before the fuel is placed into the MGDS, the MPC interior metal surfaces will be decontaminated using existing mechanical or chemical methods. This will be facilitated by the MPC fuel basket and interior structures' smooth metal surfaces designed to minimize crud traps. After the surface contamination is removed, the MPC radioactivity will be diminished significantly, allowing near-surface burial or secondary applications at the licensee's facility.

It is also likely that both the overpack and MPC, or extensive portions of both, can be further decontaminated to allow recycle or reuse options. After decontamination, the only radiological hazard the HI-STAR 100 System may pose is slight activation of the HI-STAR 100 materials caused by irradiation over a 40-year storage period. Table 2.4.1 provides the conservatively determined quantities of the major nuclides after 40 years of irradiation.

The calculation of the material activation is based on the following:

- Beyond design basis fuel assemblies (B&W 15x15, 3.7% enrichment, 47,500 MWD/MTU, and eight-year cooling time) stored for 40 years.
- Cask material quantities based on the Design Drawings in Chapter 1.
- A constant flux equal to the initial loading condition is conservatively assumed.
- Material activation is based on MCNP-4A calculations.

As can be seen by the material activation results presented in Table 2.4.1, the HI-STAR 100 System total activation is very low.

Due to the design of the HI-STAR 100 System, no residual contamination is expected to be left behind on the concrete ISFSI pad. The base pad, fence, and peripheral utility structures will require no decontamination or special handling after the last cask is removed.

In any case, the HI-STAR 100 System would not impose any additional decommissioning requirements on the licensee of the ISFSI facility per 10CFR72.30, since the HI-STAR 100 System could eventually be shipped from the site as a complete assembly.

Table 2.4.1

HI-STAR 100 SYSTEM ACTIVATION

HI-STAR 100 Component	**Nuclide**	**Curies After 40-Year Storage**
MPC	^{54}Mn	1.434e-3
	^{55}Fe	2.30e-3
	^{59}Ni	1.89e-3
	^{60}Co	2.02e-3
	^{63}Ni	6.43e-3
	Total	1.41e-2
Overpack	^{54}Mn	1.788e-3
	^{55}Fe	8.887e-3
	^{59}Ni	N/A
	^{60}Co	N/A
	^{63}Ni	N/A
	Total	1.0675e-2
Total HI-STAR 100 System		2.48e-2

2.5 REGULATORY COMPLIANCE

Chapter 2 provides the principal design criteria related to structures, systems, and components important to safety. These criteria include specifications regarding the fuel, as well as, external conditions that may exist in the operating environment during normal and off-normal operations, accident conditions, and natural phenomena events. The chapter has been written to provide sufficient information to allow verification of compliance with 10CFR72, NUREG-1536, and Regulatory Guide 3.61. A more detailed evaluation of the design criteria and an assessment of compliance with those criteria is provided in Chapters 3 through 13.

2.6 REFERENCES

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[2.0.3] American Society of Mechanical Engineers, "Boiler and Pressure Vessel Code", 1995 with Addenda through 1997.

[2.0.4] ANSI N14.6-1993, "Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4500 Kg) or More", June 1993.

[2.0.5] Levy, et al., "Recommended Temperature Limits for Dry Storage of Spent Light Water Reactor Zircaloy - Clad Fuel Rods in Inert Gas," Pacific Northwest Laboratory, PNL-6189, 1987.

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[2.0.7] PNL-4835, "Technical Basis for Storage of Zircaloy-Clad Spent Fuel in Inert Gases", A.B. Johnson and E.R. Gilbert, Pacific Northwest Laboratories, September 1983.

[2.1.1] ORNL/TM-10902, "Physical Characteristics of GE BWR Fuel Assemblies", by R.S. Moore and K.J. Notz, Martin Marietta (1989).

[2.1.2] U.S. DOE SRC/CNEAF/96-01, Spent Nuclear Fuel Discharges from U.S. Reactors 1994, Feb. 1996.

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[2.1.4] Commonwealth Edison Company, Letter No. NFS-BND-95-083, Chicago, Illinois.

[2.1.5] NUREG-1536, SRP for Dry Cask Storage Systems, USNRC, Washington, DC, January 1997.

[2.1.6] DOE Multi-Purpose Canister Subsystem Design Procurement Specification.

[2.2.1] Crane Manufacturer's Association of America (CMAA), Specification #70, 1988, Section 3.3.

[2.2.2] Cunningham, et als., "Evaluation of Expected Behavior of LWR Stainless-Clad Fuel in Long-Term Dry Storage", EPRI TR-106440, April 1996.

[2.2.3] ASCE 7-88 (formerly ANSI A58.1), "Minimum Design Loads for Buildings and Other Structures", American Society of Civil Engineers, New York, NY, 1990.

[2.2.4] "Debris Collection System for Boiling Water Reactor Consolidation Equipment", EPRI Project 3100-02 and ESEERCO Project EP91-29, October 1995.

[2.2.5] Design Basis Tornado for Nuclear Power Plants, Regulatory Guide 1.76, U.S. Nuclear Regulatory Commission, April 1974.

[2.2.6] ANSI/ANS 57.9-1992, "Design Criteria for an Independent Spent Fuel Storage Installation (dry type)", American Nuclear Society, LaGrange Park, Illinois.

[2.2.7] NUREG-0800, SRP 3.5.1.4, USNRC, Washington, DC.

[2.2.8] 10CFR 100, "Reactor Site Criteria", Title 10 of the Code of Federal Regulations.

[2.2.9] Regulatory Guide 1.59, "Design Basis Floods for Nuclear Power Plants", U.S. Nuclear Regulatory Commission, Washington, D.C., August 1997.

[2.2.10] Regulatory Guide 1.102, "Flood Protection for Nuclear Power Plants", U.S. Nuclear Regulatory Commission, Washington, D.C.

[2.2.11] NUREG/CR-6407, "Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety", U.S. Nuclear Regulatory Commission, Washington, D.C., February 1996.

[2.2.12] NUREG/CR-6007, "Stress Analysis of Closure Bolts for Shipping Casks", U.S. Nuclear Regulatory Commission, Washington, D.C., January 1993.

[2.2.13] NUREG-0612, "Control of Heavy Loads at Nuclear Power Plants", U.S. Nuclear Regulatory Commission, Washington, D.C., July 1980.

CHAPTER 3: STRUCTURAL EVALUATION

In this chapter, the structural components of the HI-STAR 100 System that are important to safety (ITS) are identified and all structural analyses to demonstrate their compliance with the provisions of 10CFR72 are presented. The objective of the structural analyses is to ensure that the integrity of the HI-STAR 100 System is maintained under all credible loads for normal and off-normal conditions, and design basis accident/natural phenomena. The results in this chapter support the conclusion that the confinement, criticality control, radiation shielding, and retrievability criteria set forth by 10CFR72.236(l), 10CFR72.124(a), 10CFR72.104, 10CFR72.106, and 10CFR72.122(l) are met. In particular, the design basis information contained in the previous two chapters and in this chapter provides sufficient data to permit the necessary structural evaluations to demonstrate compliance with the requirements of 10CFR72.24. To facilitate regulatory review, the assumptions and conservatism inherent in the analyses are identified along with a complete description of the analytical methods, models, and acceptance criteria. A summary of other considerations germane to satisfactory structural performance, such as corrosion and material fracture toughness, is also provided.

Detailed numerical computations supporting the conclusions in the main body of this chapter are presented in a series of appendices. Where appropriate, the subsections make reference to results in the appendices. Section 3.6.3 contains the complete list of appendices that support this chapter.

The organization of technical information in this chapter follows the format and content guidelines of USNRC Regulatory Guide 3.61 (February 1989). This revision of this FSAR ensures that the responses to the review requirements listed in NUREG-1536[2.1.5] are complete and comprehensive. It is noted that the areas of NRC staff technical inquiries, with respect to structural evaluation in NUREG-1536, span a wide array of technical topics within and beyond the material in this chapter. To facilitate staff review to ascertain compliance with the stipulations of NUREG-1536, Table 3.0.1 "Matrix of NUREG-1536 Compliance - Structural Evaluation", is included in this chapter. A comprehensive cross-reference of the topical areas set forth in NUREG-1536 and the location of the required compliance information is contained in Table 3.0.1.

Sections 3.1 through 3.6 provide technical information in the formatting sequence set forth in Regulatory Guide 3.61. Section 3.7 describes in detail HI-STAR 100 System's compliance to NUREG-1536 Structural Evaluation Requirements.

Table 3.0.1 MATRIX OF NUREG-1536 COMPLIANCE ITEMS – STRUCTURAL EVALUATION †

PARAGRAPH IN NUREG-1536	NUREG-1536 COMPLIANCE ITEM	LOCATION IN FSAR CHAPTER 3	LOCATION OUTSIDE OF FSAR CHAPTER 3
IV.1.a	ASME B&PV Compliance		
	NB	3.1.1	Tables 2.2.6,2.2.7
	NG	3.1.1	Tables 2.2.6,2.2.7
V.	Identification of SSC that are ITS		Table 2.2.6
"	Applicable Codes/Standards	3.6.1	Table 2.2.6
"	Loads	3.1.2.1.1	Table 2.2.13
"	Load Combinations	3.1.2.1.2; Table 3.1.1, Tables 3.1.3-3.1.5	Table 2.2.14
"	Summary of Safety Factors	3.4.3; 3.4.4.3.1-2; 3.4.6-3.4.8; Tables 3.4.3-3.4.19	
"	Design/Analysis Procedures	Chapter 3 plus Appendices	
"	Structural Acceptance Criteria		Tables 2.2.10-2.2.12
"	Material/QC/Fabrication	Table 3.4.2	Chap. 9; Chap. 13
"	Testing/In-Service Surveillance		Chap. 9; Chap. 12

Table 3.0.1 MATRIX OF NUREG-1536 COMPLIANCE ITEMS – STRUCTURAL EVALUATION † (Continued)

PARAGRAPH IN NUREG-1536	NUREG-1536 COMPLIANCE ITEM	LOCATION IN FSAR CHAPTER 3	LOCATION OUTSIDE OF FSAR CHAPTER 3
"	Conditions for Use		Table 1.2.6; Chaps. 8,9,12
V.1.a	Description of SSC	3.1.1	1.2; Table 2.2.6
V.1.b.i.(2)	Identification of Codes & Standards		Tables 2.2.6, 2.2.7
V.1.b.ii	Drawings/Figures		1.5
"	Identification of Confinement Boundary		1.5; 2.3.2; 7.1; Table 7.1.1
"	Boundary Weld Specifications	3.3.1.4	1.5; Table 7.1.2
"	Boundary Bolt Torque	NA	
"	Weights and C.G. Location	Tables 3.2.1-3.2.4	
"	Chemical/Galvanic Reactions	3.4.1; Table 3.4.2	
V.1.c	Material Properties	3.3; Tables 3.3.1-3.3.5	1.A; Figures 1.A.1-1.A-5; 1.C
"	Allowable Strengths	3.1.2.2; Tables 3.1.6-3.1.17	Tables 2.2.10-2.2.12
"	Suitability of Materials	3.3; Table 3.4.2	1.A; 1.B
"	Corrosion	3.4.1; Table 3.4.2	
"	Material Examination before Fabrication		9.1.1

Table 3.0.1 MATRIX OF NUREG-1536 COMPLIANCE ITEMS – STRUCTURAL EVALUATION † (Continued)

PARAGRAPH IN NUREG-1536	NUREG-1536 COMPLIANCE ITEM	LOCATION IN FSAR CHAPTER 3	LOCATION OUTSIDE OF FSAR CHAPTER 3
"	Material Testing and Analysis		9.1; Table 9.1.1; Table 9.1.2
"	Material Traceability		9.1.1
"	Material Long Term Performance	3.4.10; 3.4.11	9.2
"	Materials Appropriate to Load Conditions		Chap. 1
"	Restrictions on Use		Chap. 12
"	Temperature Limits	Table 3.1.17	Table 2.2.3
"	Creep/Slump	NA	
"	Brittle Fracture Considerations	3.1.2.3; Table 3.1.18-19	
"	Low Temperature Handling	NA	NA
V.1.d.i.(1)	Normal Load Conditions		2.2.1; Tables 2.2.13,2.2.14
"	Fatigue	3.1.2.4	
"	Internal Pressures/Temperatures for Hot and Cold Conditions	3.4.4.1	Tables 2.2.1,2.2.3
"	Required Evaluations		

Table 3.0.1 MATRIX OF NUREG-1536 COMPLIANCE ITEMS – STRUCTURAL EVALUATION † (Continued)

PARAGRAPH IN NUREG-1536	NUREG-1536 COMPLIANCE ITEM	LOCATION IN FSAR CHAPTER 3	LOCATION OUTSIDE OF FSAR CHAPTER 3
"	Weight+Pressure	3.4.4.3.1.2; Table 3.4.7	
"	Weight+Pressure+Temp.	3.4.4.3.1.2; Table 3.4.8	
"	Free Thermal Expansion	3.4.4.2; 3.U; 3.W; 3.AD	Tables 4.4.16, 4.4.22; Table 11.2.5
V.1.d.i.(2)	Off-Normal Conditions		2.2.2; Tables 2.2.13, 2.2.14; 11.1
V.1.d.i.(3)	Accident Level Events and Conditions	Table 3.1.2	2.2.3; Tables 2.2.13, 2.2.14; 11.2
V.1.d.i.(3).(a)	Storage Cask Vertical Drop	3.1.2.1.1.2; 3.4.9; 3.A	
"	Storage Cask Tipover	3.1.2.1.1.1; 3.4.9; 3.A	2.2.3.2
"	Storage Horizontal Drop	3.1.2.1.1.2; 3.A	
V.1.d.i.(3).(b)	Explosive Overpressure	3.1.2.1.1.4	2.2.3.10
V.1.d.i.(3).(c)	Fire		
"	Structural Evaluations	3.4.4.2.2	2.2.3.3
"	Material Properties	3.4.4.2.2	
"	Material Suitability	3.3.1.1; 3.4.4.2.2	Table 2.2.3
V.1.d.i.(3).(d)	Flood		

Table 3.0.1 MATRIX OF NUREG-1536 COMPLIANCE ITEMS – STRUCTURAL EVALUATION † (Continued)

PARAGRAPH IN NUREG-1536	NUREG-1536 COMPLIANCE ITEM	LOCATION IN FSAR CHAPTER 3	LOCATION OUTSIDE OF FSAR CHAPTER 3
"	Identification	3.1.2.1.1.3; 3.4.6	2.2.3.6
"	Cask Tipover	3.4.6	
"	Cask Sliding	3.4.6	
"	Hydrostatic Loading	3.1.2.1.1.3; 3.4.6; 3.H	
"	Consequences	3.4.6	11.2
V.1.d.i.(3).(e)	Tornado Winds		
"	Specification	3.1.2.1.1.5	2.2.3.5; Table 2.2.4
"	Drag Coefficients	3.4.8; 3.C	
"	Load Combination	3.4.8; 3.C	
"	Overturning	3.4.8; 3.C	
"	Overturning –Transfer Cask	NA	
V.1.d.i.(3).(f)	Tornado Missiles		
"	Missile Parameters	3.1.2.1.1.5	Table 2.2.5
"	Tipover	3.4.8; 3.C	
"	Damage	3.G; 3.H	

Table 3.0.1 MATRIX OF NUREG-1536 COMPLIANCE ITEMS – STRUCTURAL EVALUATION † (Continued)

PARAGRAPH IN NUREG-1536	NUREG-1536 COMPLIANCE ITEM	LOCATION IN FSAR CHAPTER 3	LOCATION OUTSIDE OF FSAR CHAPTER 3
"	Consequences	3.4.8	11.2
V.1.d.i.(3).(g)	Earthquakes		
"	Definition of DBE	3.1.2.1.1.6; 3.4.7	2.2.3.7; Table 2.2.8
"	Sliding	3.4.7.1	
"	Overturning	3.4.7.1	
"	Structural Evaluations	3.4.7.2	
V.1.d.i.(4).(a)	Lifting Analyses		
"	Trunnions		
"	Requirements	3.1.1; 3.4.3.1	
"	Analyses	3.4.3.1; 3.D	
"	Other Lift Analyses	3.4.3.2-3.4.3.4; 3.D; 3.E; 3.I; 3.K; 3.Y; 3.AC	
V.1.d.i.(4).(b)	Fuel Basket		
"	Requirements	3.1.2.1.2; Table 3.1.3	

Table 3.0.1 MATRIX OF NUREG-1536 COMPLIANCE ITEMS – STRUCTURAL EVALUATION † (Continued)

PARAGRAPH IN NUREG-1536	NUREG-1536 COMPLIANCE ITEM	LOCATION IN FSAR CHAPTER 3	LOCATION OUTSIDE OF FSAR CHAPTER 3
"	Specific Analyses	3.4.4.2; 3.4.4.3.1; 3.4.4.4.1; 3.B; 3.M; 3.N; 3.R; 3.U; 3.W; 3.AA; 3.AD; 3.AI;Table 3.4.3, Table 3.4.9; Table 3.4.11	
"	Dynamic Amplifiers	3.X	
"	Stability	3.4.4.3.1.3; Figures 3.4.27-32	
V.1.d.i.(4).(c)	Confinement Closure Lid Bolts		
"	Pre-Torque	NA	
"	Analyses	NA	
"	Engagement Length	NA	
"	Miscellaneous Bolting		
"	Pre-Torque	3.F; 3.K	Table 8.1.3
"	Analyses	3.4.4.3.2.3; 3.F; 3.K; 3.Z; Tables 3.4.17, 3.4.18; 3.AE; 3.AF	
"	Engagement Length	3.K	

Table 3.0.1 MATRIX OF NUREG-1536 COMPLIANCE ITEMS – STRUCTURAL EVALUATION † (Continued)

PARAGRAPH IN NUREG-1536	NUREG-1536 COMPLIANCE ITEM	LOCATION IN FSAR CHAPTER 3	LOCATION OUTSIDE OF FSAR CHAPTER 3
V.1.d.i.(4)	Confinement		
"	Requirements	3.1.2.1.2; Table 3.1.4	Chap. 7
"	Specific Analyses	3.4.4.2; 3.4.4.3.1; 3.4.4.4.1; 3.E; 3.H; 3.I; 3.O; 3.S; 3.U; 3.W; 3.Y; 3.AA; 3.AC; 3.AD; Tables 3.4.4, 3.4.7-3.4.9,3.4.11-3.4.15	
"	Dynamic Amplifiers	3.X	
"	Stability	3.4.4.3.1.7; 3.H	
"	Overpack		

Table 3.0.1 MATRIX OF NUREG-1536 COMPLIANCE ITEMS – STRUCTURAL EVALUATION † (Continued)

PARAGRAPH IN NUREG-1536	NUREG-1536 COMPLIANCE ITEM	LOCATION IN FSAR CHAPTER 3	LOCATION OUTSIDE OF FSAR CHAPTER 3
“	Requirements	3.1.2.1.2; Tables 3.1.1, 3.1.5	
“	Specific Analyses	3..4.4.3.2; 3.4.4.4.2; 3.L; 3.T; 3.Y; 3.AB; 3.AG; Tables 3.4.5, 3.4.6, 3.4.10, 3.4.16	
“	Dynamic Amplifiers	3.X	
“	Stability	3.4.4.3.2.5; 3.H	

† Legend for Table 3.0.1

Per the nomenclature defined in Chapter 1, the first digit refers to the chapter number, the second digit is the section number within the chapter; an alphabetic character in the second place means it is an appendix to the chapter.

NA	Not Applicable for this item

3.1 STRUCTURAL DESIGN

3.1.1 Discussion

The HI-STAR 100 System consists of two principal components: the Multi-Purpose Canister (MPC), and the overpack. The MPC is a hermetically sealed, welded structure of cylindrical profile with flat ends and a honeycomb fuel basket. A complete description is provided in Section 1.2.1.1 wherein the anatomy of the MPC and its fabrication details are presented with the aid of figures. A detailed discussion of the HI-STAR 100 overpack geometry is presented in Section 1.2. Detailed design drawings for the HI-STAR 100 System are provided in Section 1.5. In this section, the discussion is confined to characterizing and establishing the structural features of the MPC and the storage overpack.

The design of the MPC seeks to attain three objectives which are central to its functional adequacy, namely;

- Ability to Dissipate Heat: The thermal energy produced by the stored spent fuel must be transported to the outside surface of the MPC such that the prescribed temperature limits for the fuel cladding and for the fuel basket metal walls are not exceeded.

- Ability to Withstand Large Impact Loads: The MPC, with its payload of nuclear fuel, must be sufficiently robust to withstand large impact loads associated with the postulated handling accident events. Furthermore, the strength of the MPC must be sufficiently isotropic to meet structural requirements under a variety of handling and tip-over accidents.

- Restraint of Free End Expansion: The membrane and bending stresses produced by restraint of free-end expansion of the fuel basket are conservatively categorized as primary stresses. In view of the concentration of heat generation in the fuel basket, it is necessary to ensure that structural constraints to its external expansion do not exist.

Where the first two criteria call for extensive inter-cell connections, the last criterion requires the opposite. The design of the MPC seeks to realize all of the above three criteria in an optimal manner.

As the description presented in Chapter 1 indicates, the MPC enclosure vessel is the confinement vessel designed to meet ASME Code, Section III, Subsection NB stress limits. The enveloping canister shell, the baseplate, and the lid system form a complete confinement boundary for the stored fuel which is referred to as the "enclosure vessel". Within this cylindrical shell confinement vessel is an integrally welded assemblage of cells comprised of square cross sectional openings for fuel storage, referred to herein as the "fuel basket". The fuel basket is analyzed under the provisions of Subsection NG of Section III of the ASME Code. There are two different multi-purpose canisters which are exactly alike in their external dimensions. The essential difference between the MPCs lies in the fuel baskets. Each fuel storage MPC is designed to house fuel assemblies with different characteristics. Although all fuel baskets are configured to maximize structural ruggedness through extensive inter-cell connectivity, they are sufficiently dissimilar in structural details to warrant separate evaluations. Therefore, analyses for each of the two MPC types are presented, as appropriate, throughout this chapter.

Components of the HI-STAR 100 System that are important to safety and their applicable design codes are defined in Chapter 2.

The structural function of the MPC in the storage mode is:

1. To maintain position of the fuel in a subcritical configuration, and
2. To provide a radiological confinement boundary.

The structural function of the overpack in the storage mode is:

1. To serve as a missile barrier for the MPC
2. To ensure stability of the HI-STAR 100 System, and
3. To provide a structurally robust support for the radiation shielding,and
4. To provide a helium retention boundary

Some structural features of the MPCs which allow the system to perform these functions are summarized below:

- There are no gasketed ports or openings in the MPC. The MPC does not rely on any sealing arrangement except welding. The absence of any gasketed or flanged joints precludes joint leaks. The confinement boundary contains no valves or other pressure relief devices.
- The closure system for the MPCs consists of two components, namely, the MPC lid and closure ring. The MPC lid is a thick circular plate continuously welded to the MPC shell along its circumference. The MPC closure system is shown in the Design Drawings in Section 1.5. The MPC lid-to-MPC shell weld is a J-groove weld which is subject to root and final pass liquid penetrant examinations and finally, a volumetric examination to ensure the absence of unacceptable flaws and indications. The MPC lid is equipped with vent and drain ports which are utilized for evacuating moisture and air from the MPC following fuel loading, and

subsequent backfilling with an inert gas (helium) in a specified quantity. The vent and drain ports are covered by a cover plate and welded before the closure ring is installed. The closure ring is a circular annular plate edge-welded to the MPC shell. The two closure members are interconnected by welding around the inner diameter of the ring. Lift points for the MPC are provided in the MPC lid.

- The MPC fuel baskets consist of an array of interconnecting plates (Figure 3.1.1). The number of storage cells formed by this interconnection process varies depending on the type of fuel being stored. Basket designs containing 24 (PWR), and 68 (BWR) cell configurations have been designed and are explained in detail in Section 1.2. Both baskets are designed to fit into the same MPC shell. Welding of the basket plates along their edges essentially renders the fuel basket into a multiflange beam. Figure 3.1.1 provides an isometric illustration of a fuel basket for the MPC-68 design.

- The MPC basket is separated from the longitudinal supports installed in the enclosure vessel shell by a small gap. The gap size decreases as a result of thermal expansion (depending on the magnitude of internal heat generation from the stored spent fuel). The provision of a small gap between the basket and the basket support structure is consistent with the natural thermal characteristics of the MPC. The planar temperature distribution across the basket, as shown in Section 4.4, approximates a shallow parabolic profile. This profile will create high thermal stresses unless structural constraints at the interface between the basket and the basket support structure are removed.

The MPCs will be loaded with fuel with widely varying heat generation rates. The basket/basket support structure gap tends to be reduced due to thermal expansion from decay heat generation. Gaps between the fuel basket and the basket support structure are specified to be sufficiently large such that a gap will exist around the periphery under any normal or off-normal operating or accident conditions (such as the postulated fire event).

A small number of flexible thermal conduction elements (thin aluminum tubes) are interposed between the basket and the MPC shell. The elements are designed to be resilient. They do not provide structural support for the basket, and thus their resistance to thermal growth is negligible.
It is quite evident from the geometry of the MPC that a critical loading event pertains to the drop condition, when the MPC is postulated to undergo a handling side drop (the longitudinal axis of the MPC is horizontal) or tip-over. Under the side drop or tip-over condition the flat panels of the fuel basket are subject to an equivalent pressure loading that simulates the deceleration magnified inertia load from the stored fuel and the MPC's own metal mass.

The MPC fuel basket maintains the spent nuclear fuel in a subcritical arrangement. Its safe operation is assured by maintaining the physical configuration of the storage cell cavities intact in the aftermath of a drop event. This requirement is considered to be satisfied if the MPC fuel basket meets the stress intensity criteria set forth in the ASME Code, Section III, Subsection NG. Therefore, the demonstration that the fuel basket meets Subsection NG limits ensures that there is no impairment of ready retrievability (as required by NUREG-1536), that there is no unacceptable release of radioactive materials, and that there is no unacceptable radiation level.

The MPC confinement boundary contains no valves or other pressure relief devices. The MPC enclosure vessel will be shown to meet the stress intensity criteria of the ASME Code, Section III, Subsection NB for all service conditions.

Structural features of the overpack that allow the system to perform its structural function are summarized below:

- The HI-STAR 100 overpack is a missile barrier, radiation shield, and helium retention boundary in the storage mode. The overpack provides kinematic stability to the system, and acts as a cushion for the MPC in the event of a postulated tip-over accident. The overpack features a thick inner shell welded to a bottom plate which forms the load bearing surface (foundation interface) for the HI-STAR 100 System. A solid metal top flange welded at the top of the inner shell provides the attachment location for lifting trunnions. The top flange is also designed to provide a recessed ledge for the closure plate to protect the bolts from direct shear loadings resulting from an impulsive load at the top edge of the overpack. The helium retention boundary of the HI-STAR 100 overpack is subject to the stress limits of the ASME Code, Section III, Subsection NB.

- The inner shell is reinforced by multilayered intermediate shells. The multi layer approach eliminates the potential for a crack in any one layer, developed by any postulated mechanical loading or material flaw, to travel uninterrupted through the vessel wall. The intermediate shells also buttress the overpack inner shell against buckling. The intermediate shells of the HI-STAR 100 overpack are subject to the stress limits of the ASME Code, Section III, Subsection NF, Class 3.

- To facilitate handling of the loaded system, the HI-STAR 100 overpack is equipped with lifting trunnions and pocket trunnions. The pocket trunnions are located on the overpack intermediate shells just above the bottom plate. The centerline through the pocket trunnion recess is offset from a vertical plane containing the overpack's center of gravity to ensure a stable rotation direction during upending and down ending operations. Lifting trunnions are conservatively designed to meet the design safety factor requirements of NUREG-0612 [3.1.1] and ANSI N14.6-1993 [3.1.2] for single failure proof lifting equipment.

Table 2.2.6 provides a listing of the applicable design codes for all structures, systems, and components which are designated as "Important to Safety"(ITS).

3.1.2 Design Criteria

This subsection provides information requested in Subsection 3.1.2 of Regulatory Guide 3.61. Principal design criteria for normal, off-normal, and accident/environmental events are discussed in Section 2.2 in Chapter 2. In this section, the loads, load combinations, and allowable stresses used in the structural evaluation of the HI-STAR 100 System are presented.

Consistent with the provisions of NUREG-1536, the central objective of the structural analysis presented in this chapter is to ensure that the HI-STAR 100 System possesses sufficient structural capability to withstand normal and off-normal loads and the worst case loads under natural phenomenon events. Withstanding such loadings enables the HI-STAR 100 System to successfully preclude the following negative consequences:

- risk of criticality
- release of radioactive materials
- unacceptable radiation levels
- impairment of ready retrievability of the SNF

The design objectives for the HI-STAR 100 are particularized for individual components as follows:

- The objective of the structural analysis of the MPC is to demonstrate that:

    1. Confinement of radioactive material is maintained under normal, off-normal, accident conditions, and natural phenomenon events.

    2. The MPC basket does not deform under credible loading conditions such that the sub-criticality or retrievability of the SNF is jeopardized.

- The objective of the structural analysis of the storage overpack is to demonstrate that:

    1. Tornado-generated missiles do not compromise integrity of the MPC confinement boundary.

    2. The integrity of the helium retention boundary is not compromised.

    3. The radiation shielding remains properly positioned in the case of a natural phenomenon or accident event.

The aforementioned objectives are deemed to be satisfied for the MPC, and the overpack, if stresses (or stress intensities, as applicable) calculated by the appropriate structural analyses are less than the allowables defined in Subsection 3.1.2.2.

Stresses arise in the components of the HI-STAR 100 System due to various loads which originate under normal, off-normal, or accident conditions. These individual loads are combined to form load combinations. Stresses and stress intensities resulting from the load combinations are compared to allowable stresses and stress intensities. The following subsections present loads, load combinations, and allowable strengths for use in the structural analyses of the MPC and the HI-STAR 100 overpack.

3.1.2.1 Loads and Load Combinations

The individual loads are defined in Section 2.2 of this report (Table 2.2.13). Load combinations are developed by appropriately combining the individual loads (Table 2.2.14). Load combinations are applied to the mathematical models of the MPCs, and the overpack. Results of the analyses carried out under bounding load combinations are compared to allowable stresses or stress intensities, as applicable.

3.1.2.1.1 Individual Load Cases

The individual load cases which address each design criterion applicable to the structural design of the HI-STAR 100 System are catalogued in Table 2.2.13. Each load is given a symbol for subsequent use in the load combination listed in Table 2.2.14.

Accident condition and natural phenomena-induced events, collectively referred to as the "Level D" condition in Section III of the ASME Boiler & Pressure Vessel Codes, *in general* do not have a universally prescribed limit. For example, the impact load from a tornado borne missile, or the overturning load under flood or tsunami, cannot be prescribed as design basis values with absolute certainty that all ISFSI sites will be covered. Therefore, as applicable, allowable magnitudes of such loadings are postulated for the HI-STAR system. The allowable values are drawn from ANSI documents (such as for tornado and wind) or from an intrinsic limitation in the system (such as the permissible "drop height" under a postulated handling accident). In the following, the essential characteristic of each "Level D" type loading is explained.

3.1.2.1.1.1 Tip-Over

It is required to demonstrate that the HI-STAR 100 System will not tip over as a result of a postulated natural phenomenon event, including tornado wind, a tornado-generated missile, a seismic or a hydrological event (flood). However, to demonstrate the defense-in-depth features of the design, a non-mechanistic tip-over scenario per NUREG-1536 (page 3-11) is analyzed. Table 3.1.2 lists the design basis deceleration limit.

3.1.2.1.1.2 Handling Accident

The design basis handling accident during transport of a loaded HI-STAR 100 storage overpack results in either a vertical or horizontal drop. Table 3.1.2 lists the design basis deceleration limit.

3.1.2.1.1.3 Flood

The postulated flood event results into two discrete scenarios which must be considered; namely,

1. Stability of the HI-STAR 100 System due to flood water velocity, and

2. Structural effects of hydrostatic pressure and water velocity induced lateral pressure.

The maximum design external pressure for the overpack is 300 psi (Table 2.2.1). The maximum design flood water depth of 656 ft. (Table 2.2.8) corresponds to an external pressure that is bounded by the design external pressure in Table 2.2.1.

3.1.2.1.1.4 Explosion

Explosive materials are not permitted within the protective boundary of an ISFSI where a loaded HI-STAR 100 System is maintained in normal storage. The accident condition overpack external pressure specified in Table 2.2.1 is also set as the overall external pressure that bounds all credible external explosion events. There are no credible internal explosion events.

3.1.2.1.1.5 Tornado

The three components of a tornado load are:

1. Pressure changes,
2. Wind loads, and
3. Tornado-generated missiles.

Wind speeds and tornado-induced pressure drop are specified in Table 2.2.4. Tornado missiles are listed in Table 2.2.5. Potential consequences of a tornado on the cask system are:

- Instability (tip-over) due to tornado missile impact plus either steady wind or impulse from sudden pressure drop.

- Stress in the overpack induced by the lateral force caused by the steady wind or missile impact.

3.1.2.1.1.6 Earthquake

Subsections 2.2.3.7 and 3.4.7 contain the detailed specification of the seismic inputs applied to the HI-STAR 100 System. The design basis earthquake is assumed to be applied at the top of the ISFSI pad. Potential consequences of a seismic event are sliding/overturning of the loaded overpack, and stresses in the overpack arising from the inertia forces on the system.

3.1.2.1.1.7 Lightning

The HI-STAR 100 overpack contains many thousands of pounds of highly conductive carbon steel with over 400 square feet of external surface area. Such a large surface area and metal mass is adequate to dissipate any lightning which may strike the HI-STAR 100 System. There are no combustible materials on the HI-STAR 100 surface. Therefore, lightning will not impair the structural performance of components of the HI-STAR 100 System that are important to safety.

3.1.2.1.2 Load Combinations

Load combinations are created by summing the effects of all applicable individual loads which can act concurrently. The load combinations are selected for the normal, off-normal, and accident conditions. The loadings appropriate for HI-STAR 100 under the various conditions are presented in Table 2.2.14. These loadings are combined into meaningful combinations for the various HI-STAR 100 System components in Tables 3.1.1, and 3.1.3-3.1.5. Table 3.1.1 lists the load combinations that address overpack stability. Tables 3.1.3 through 3.1.5 list the applicable load combinations for the fuel basket, the enclosure vessel, and the overpack, respectively.

As discussed in Section 2.2.7, the number of discrete load combinations for each situational condition (i.e., normal, off-normal, etc.) is consolidated by defining bounding loads for certain groups of loadings. Thus, the accident condition pressure P_0^* bounds the surface loadings arising from accident and extreme natural phenomenon events, namely tornado wind W', flood F, and explosion E^*.

As noted previously, certain loads, namely earthquake E, flowing water under flood condition F, and tornado missile M, act to destabilize a cask. Additionally, these loads act on the overpack and produce localized stresses at the HI-STAR 100 System to ISFSI interface. Table 3.1.1 provides the load combinations which are relevant to the stability analyses. The site ISFSI DBE zero period acceleration (ZPA) must be bounded by the design basis seismic ZPA defined by the Load Case C of Table 3.1.1 to demonstrate that the margins against tip-over and inter-cask collision during a seismic event are maintained.

As noted at the beginning of this section, there are two principal components to the HI-STAR 100 System: the multi-purpose canister (MPC) and the overpack. The MPC is made up of the fuel basket and the enclosure vessel. A complete account of analyses and results for all load cases for all three constituent parts: (i) the fuel basket, (ii) the enclosure vessel, and (iii) the overpack is provided in Section 3.4, as required by Regulatory Guide 3.61.

In the following, the loadings listed as applicable for each situational condition in Table 2.2.14 are addressed in meaningful load combinations for the fuel basket, enclosure vessel, and the overpack. Each component is considered separately. It is noted that off-normal condition pressure temperatures for structural analyses are conservatively bounded by the specified design pressures and temperatures. Therefore, load combinations for normal and off-normal condition are subsumed into a consolidated set of bounding load combinations.

Fuel Basket

Table 3.1.3 summarizes all loading cases (derived from Table 2.2.14) which are germane to demonstrating compliance of the fuel baskets to Subsection NG when these baskets are housed within the HI-STAR 100 overpack.

Normal Condition

- The fuel basket is not a pressure vessel; therefore, the pressure loadings are not meaningful loads for the basket. Further, the basket is structurally decoupled from the enclosure vessel. The gap between the basket and the enclosure vessel is sized to ensure that no constraint of free-end thermal expansion of the basket occurs. The demonstration of the adequacy of the basket to the enclosure vessel (EV) gap to ensure absence of interference is a physical problem which must be analyzed. Temperature, like pressure, is not a source of loading for the fuel basket. All loadings on the fuel basket, therefore, arise from handling and postulated handling accident conditions.

- Normal handling encompasses both vertical and horizontal orientation. When the cask is being handled in the vertical orientation, the vertical load produces a strictly axial compressive stress. When the cask is being lifted from the horizontal orientation, the amplified dead load may cause flexing of the fuel basket panels.

Off-Normal Conditions

- The off-normal condition handling loads are identical to the normal condition, and therefore, a separate analysis is not required.

Accident Condition

- Three accident condition scenarios must be considered: (i) drop with the storage overpack axis vertical; (ii) drop with the storage overpack axis horizontal; and (iii) storage overpack tip-over.

- The vertical drop scenario induces compression in the longitudinal panel of the fuel basket.

- The horizontal drop and tip-over must consider multiple orientations of the fuel basket as the fuel basket is not radially symmetric. Heretofore, two horizontal drop orientations are considered which are referred to as the 0-degree drop and 45-degree drop, respectively. In the 0-degree drop, the basket drops with its panels oriented parallel and normal to the vertical (see Figure 3.1.2). The 45-degree drop implies that the basket's honeycomb section is rotated meridionally by 45 degrees (Figure 3.1.3).

Enclosure Vessel

Table 3.1.4 summarizes all load cases that are applicable to structural analysis of the enclosure vessel to ensure integrity of the confinement boundary.

Normal Conditions

- The enclosure vessel is a pressure vessel consisting of a cylindrical shell, a thick circular baseplate at the bottom, and a thick circular lid at the top. This pressure vessel must be shown to meet the primary stress intensity limits for ASME Section III Class 1 at the design temperature and primary plus secondary stress intensity limits under the combined action of pressure plus thermal loads.

- The MPC lid system of the enclosure vessel is equipped with tapped holes for lifting operations. A normal handling operation is defined to encompass a vertical lift where the MPC is supported by threaded inserts in the MPC lid. Stress intensities in the MPC lid, must satisfy Level A limits for Class 1 components. The threaded inserts (i.e., the lifting eye bolts) and the internal threads in the tapped holes must meet NUREG-0612 stress limits. Further discussion on design criteria applicable to lifting operations is presented in Subsection 3.4.3 herein, as required by Regulatory Guide 3.61.

Off-Normal Conditions

- The off-normal condition loads are identical to the normal condition, and therefore, a separate analysis is not required.

Accident Conditions

- The design basis deceleration for the MPC in the HI-STAR 100 System is 60g's. The deceleration loading developed in the enclosure vessel during a horizontal drop event must be combined with those due to P_i (internal pressure) acting alone. The accident condition pressure is bounded by P_i^*. During a vertical drop scenario, the axial buckling of the enclosure vessel shell is the item of principal concern. To render the loading combination most adverse, the vertical deceleration load is assumed to act in the absence of P_i, which produces tensile stresses (and thus counteracts the loads which produce buckling).

- The fire event (T^* loading) is considered for ensuring absence of interference between the enclosure vessel and the fuel basket and between the enclosure vessel and the overpack. The metal temperatures of the "NB pressure parts" (defined by the ASME Code, loc. cit.) are required to remain in the range of temperatures permitted by the ASME Code.

Storage Overpack

Table 3.1.5 identifies the load cases to be considered for the overpack. These are in addition to the kinematic criteria listed in Table 3.1.1. Within these load cases and kinematic criteria, the following items must be addressed:

Normal Conditions

- The inner shell, the bottom plate, the top flange, and the closure plate of the overpack constitute a pressure vessel and must be engineered to meet ASME Code requirements for helium pressure retention.

- In the normal handling condition, the most adverse configuration is the vertical lift. The top flange/closure plate region and the bottom plate are most affected by the handling loads acting in concert with design internal or external pressure. The specific stress limits which must be satisfied under normal handling are discussed in depth in Subsection 3.4.3, as required by Regulatory Guide 3.61.

Off-Normal Conditions

- The off-normal condition loads are identical to the normal condition, and therefore, a separate analysis is not required.

Accident Conditions

- Maximum flood water velocity for the overpack with an empty MPC (to minimize system weight and thus maximize the potential for kinematic instability) must be specified to ensure that no sliding or tip-over occurs.

- Tornado missile plus wind on an overpack with an empty MPC must be specified to demonstrate that no cask tip-over occurs.

- Tornado missile penetration analysis must demonstrate that the postulated penetrant missiles cannot reach the MPC stored inside the HI-STAR 100 overpack.

- Under seismic conditions, a fully loaded HI-STAR 100 overpack must not tip over under the maximum ZPA event. The maximum sliding of the overpack must demonstrate that casks will not impact each other.

- Under a non-mechanistic postulated tip-over or a drop accident with a full HI-STAR 100 overpack, the overpack structure must meet faulted (Level D) requirements of the ASME Code.

3.1.2.2 Allowables

The important to safety components of the HI-STAR 100 System are listed in Table 2.2.6. Allowable stresses, as appropriate, are tabulated for these components for all service conditions in Tables 3.1.6 through 3.1.16.

In Subsection 2.2.5, the applicable service level from the ASME Code for determination of allowables is listed. Table 2.2.14 provides a tabulation of normal, off-normal, and accident conditions and the service levels defined in the ASME Code, along with the applicable loadings for each service condition.

Allowable stresses and stress intensities are calculated using the data provided in the ASME Code and Tables 2.2.10 through 2.2.12. Tables 3.1.6 through 3.1.16 contain numerical values of the stresses/stress intensities for all MPC and overpack load bearing materials as a function of temperature.

In all tables the terms S, S_m, S_y, and S_u, respectively, denote the design stress, design stress intensity, minimum yield strength, and the ultimate strength. Property values at intermediate temperatures which are not reported in the ASME Code are obtained by linear interpolation. Property values are not extrapolated beyond the limits of the Code in any structural calculation.

Additional terms relevant to the analyses are extracted from the ASME Code (Figure NB-3222-1, for example) as follows:

Symbol	Description	Notes
P_m	Average primary stress across a solid section.	Excludes effects of discontinuities and concentrations. Produced by pressure and mechanical loads.
P_L	Average stress across any solid section.	Considers effects of discontinuities but not concentrations. Produced by pressure and mechanical loads, including inertia earthquake effects.
P_b	Primary bending stress.	Component of primary stress proportional to the distance from the centroid of a solid section. Excludes the effects of discontinuities and concentrations. Produced by pressure and mechanical loads, including inertia earthquake effects.
P_e	Secondary expansion stress.	Stresses which result from the constraint of free-end displacement. Considers effects of discontinuities but not local stress concentration. (Not applicable to vessels.)
Q	Secondary membrane plus bending stress.	Self-equilibrating stress necessary to satisfy continuity of structure. Occurs at structural discontinuities. Can be caused by pressure, mechanical loads, or differential thermal expansion.
F	Peak stress.	Increment added to primary or secondary stress by a concentration (notch), or, certain thermal stresses which may cause fatigue but not distortion. This value is not used in the tables.

It is shown that there is no interference between component parts due to free thermal expansion. Therefore, P_e does not develop within any HI-STAR 100 component.

It is recognized that the planar temperature distribution in the fuel basket and the overpack under the maximum heat load condition is the highest at the cask center and drops monotonically, reaching its lowest value at the outside surface. Strictly speaking, the allowable stresses/stress intensities at any location in the basket, the enclosure vessel, or the overpack should be based on the coincident metal temperature under the specific operating condition. However, in the interest of conservatism, reference temperatures are established for each component which are upper bound on the metal temperature for each situational condition. Table 3.1.17 provides the reference temperatures for the fuel basket and the MPC canister and, utilizing Tables 3.1.6

through 3.1.16, provides conservative numerical limits for the stresses and stress intensities for all loading cases. Reference temperatures for the MPC baseplate and the MPC lid are 400°F and 550°F, respectively, as specified in Table 2.2.3.

Finally, the lift devices in the HI-STAR 100 overpack and the multi-purpose canisters, collectively referred to as "trunnions", are subject to specific limits set forth by NUREG-0612: the primary stresses in a trunnion must be less than the smaller of 1/10 of the material ultimate strength and 1/6 of the material yield strength under a normal handling condition (Load Cases F2, E2, and 03 in Tables 3.1.3 through 3.1.5, respectively. The load combination D+H in Table 3.1.5 is equivalent to 1.15D. This is further explained in Subsection 3.4.3.

The region around the trunnions is part of the NF structure in HI-STAR 100 and an NB pressure boundary in the MPC, and as such, must satisfy the applicable stress (or stress intensity) limits for the load combination. In addition to meeting the applicable Code limits, it is further required that the local primary stresses at the trunnion/mother structure interface must not exceed the material yield stress at three times the handling condition load (1.15D). This criterion, mandated by Regulatory Guide 3.61, Section 3.4.3, eliminates the potential of local yielding at the trunnion/structure interface.

3.1.2.3 Brittle Fracture

The MPC canister and basket are constructed from a series of stainless steels termed Alloy X. These stainless steel materials do not undergo a ductile-to-brittle transition in the minimum temperature range of the HI-STAR 100 System. Therefore, brittle fracture is not a concern for the MPC components. However, the HI-STAR 100 overpack is composed of ferritic steel materials which will be subject to impact loading in a cold environment and, therefore, must be evaluated and/or subjected to impact testing in accordance with the ASME Code to ensure protection against brittle fracture.

Tables 3.1.18 and 3.1.19 provide the fracture toughness test criteria for the HI-STAR 100 components in accordance with the applicable ASME Code and Regulatory Guide requirements for prevention of brittle fracture. Regulatory Guides 7.11 [3.1.3] and 7.12 [3.1.4] are used to determine drop test requirements for the helium retention boundary components, as discussed below.

All helium retention boundary materials subject to impact loading in a cold environment must be evaluated and/or tested for their propensity for brittle fracture. The overpack baseplate, top flange, and closure plate have thicknesses greater than four inches. Table 1 of Regulatory Guide 7.12

requires that the Nil Ductility Transition temperature, T_{NDT}, (for the lowest service temperature of -20°F) be -129°F for 6-in. thick material, and linear interpolation of the table shows that for 7-inch thick material, the T_{NDT} is -132°F. SA350-LF3 has been selected as the material for these overpack components based on the material's capability to perform at low temperatures with excellent ductility properties

The overpack inner shell has a thickness of 2.5 inches. SA203-E has been selected as the material for this item due to its capability to perform at low temperatures (see Table A1.15 of ASME Section IIA). Regulatory Guide 7.11 requires that the T_{NDT} for this material be less than -70°F.

The overpack closure plate bolts are fabricated from SB-637 Grade N07718, a high strength nickel alloy material. Section 5 of NUREG/CR-1815 [3.1.5] indicates that bolts are generally not considered a fracture critical component. Nevertheless, this material has a high resistance to fracture at low temperatures, as can be shown by calculating the transition temperature of the material and assessing its performance as indicated in NUREG/CR-1815.

The Aerospace Structural Metals Handbook [Ref. 3.1.6] shows that a minimum impact absorption energy for SB-637 Grade N07718 at -320°F is 18.5 ft-lb. This may be transferred into a fracture toughness value by using the relationship (presented in Section 4.2 of NUREG/CR-1815) between Charpy impact measurement, C_v (ft-lb), and dynamic fracture toughness, K_{ID} (psi $\sqrt{\text{in.}}$)

$$K_{ID} = (5\,E\,C_v)^{1/2}$$

where $E \approx 31 \times 10^6$ psi at -320°F and C_v (minimum) = 18.5 ft-lb. Therefore,

$$K_{ID} = 53.5 \text{ ksi} \sqrt{\text{in.}}$$

Using Figure 2 of NUREG/CR-1815 yields

$$(T - T_{NDT}) \approx 32°F$$

Since the data used is for T = -320°F, then $T_{NDT} = -320° - 32° = -352°F$

Using Figure 3 of NUREG/CR-1815 where thickness is defined as the bolt diameter (1.5 inch), and $\sigma/\sigma_{yd} = 1$ per Regulatory Guide 7.11, A (°F) is found to be 60°F. Therefore, the required maximum nil ductility transition temperature per NUREG/CR-1815 for the closure bolts is

$$T_{NDT} = T_{LT} - A$$
$$= -40^\circ - 60^\circ = -100^\circ F$$

where $T_{LT} = -40^\circ F$.

The large margin between the calculated T_{NDT} and the required maximum nil ductility transition temperature leads to the conclusion that SB-637 Grade N07718 possesses appropriate fracture toughness for use as closure lid bolting.

ASME Code Section III, Subsection NF requires Charpy V-notch tests for materials of certain non-helium retention boundary components of the overpack. The intermediate shells used for gamma shielding are fabricated from normalized SA516-70. Table A1.15 of ASME Section IIA shows that normalized SA516-70 should have a minimum energy absorption of 12 ft-lb at -40°F for a Charpy V-notch test. The lowest service temperature for the overpack is -40°F. Therefore, these tests on the normalized SA516-70 materials of the intermediate shells will confirm the minimum energy absorption of 12 ft-lb at -40°F and the ability of the intermediate shells to perform their intended function at the lowest service temperature.

The pocket trunnions are fabricated from 17-4PH material that is precipitation hardened to condition H1150. ARMCO Product Data Bulletin S-22 [Ref. 3.1.7] shows that Charpy V-notch testing of 17-4PH H1150 material at -110°F gives energy absorption values of approximately 48 ft-lb. Using the same methodology as used for the closure plate bolts,

$$K_{ID} = 83 \text{ ksi}\sqrt{\text{in.}}$$

where $E = 28.7 \times 10^6$ psi and $C_v = 48$ ft-lbs.

Using Figure 2 of NUREG/CR-1815 yields

$$T - T_{NDT} = 65^\circ F$$

and therefore

$$T_{NDT} = -110^\circ F - 65^\circ F = -175^\circ F$$

While the pocket trunnions are not part of the helium retention boundary for the overpack, Regulatory Guide 7.12 is used to define the required T_{NDT} for the trunnion pocket thickness ($T_{NDT} = -140^\circ F$). The 35°F margin between the calculated T_{NDT} and the T_{NDT} defined in Regulatory

Guide 7.12 provides assurance that brittle fracture failure of the 17-4PH material will not occur at the lowest service temperature.

3.1.2.4 Fatigue

In storage, the HI-STAR 100 System is not subject to significant cyclic loads. Failure due to fatigue is not a concern for the HI-STAR 100 System.

The system is subject to cyclic temperature fluctuations. These fluctuations result in small changes of thermal expansions and pressures in the MPC. The loads resulting from these changes are small and do not significantly contribute to the "usage factor" of the cask.

The closure plate bolts will be installed with a specified pre-load and, therefore, will be subject to little fluctuation in their state of stress due to small variations in overpack internal pressure.

Inspection of the trunnions specified in Chapter 9 will preclude use of a trunnion which exhibits visual damage.

3.1.2.5 Buckling

Certain load combinations subject structural sections with relatively large slenderness ratios (such as the enclosure vessel shell) to compressive stresses which may actuate buckling instability *before* the allowable stress is reached. Tables 3.1.4 and 3.1.5 list load combinations for the enclosure vessel and the HI-STAR 100 structure; the cases which warrant stability (buckling) check are listed therein.

Table 3.1.1

LOAD COMBINATIONS SIGNIFICANT TO HI-STAR 100 OVERPACK KINEMATIC STABILITY ANALYSIS

Load Case	**Combinations**[†]	**Comment**	**Analysis of this Load Case Presented in:**
A	D + F	This case establishes flood water flow velocity with a minimum safety factor of 1.1 against overturning and sliding.	Subsection 3.4.6
B	D + M + W'	Demonstrate that the HI-STAR 100 overpack with minimum SNF stored (minimum D) will not tip over.	Appendix 3.C
C	D + E	Establish the value of ZPA[††] which will not cause the overpack to tip over.	Subsection 3.4.7

[†] Loading symbols are defined in Table 2.2.13.

[††] ZPA is zero period acceleration.

Table 3.1.2

DESIGN BASIS DECELERATIONS FOR THE DROP AND TIP-OVER EVENTS

Case	**Value (in multiples of acceleration due to gravity)**
Vertical axis drop	60
Horizontal axis (side) drop and tip-over	60

Table 3.1.3
LOADING CASES FOR THE FUEL BASKET

Load Case I.D.	**Loading**[†]	**Notes**	**Location Where this Case is Evaluated**
F1	T, T'	Demonstrate that the most adverse of the temperature distributions in the basket will not cause fuel basket to expand and contact the enclosure vessel wall.	Appendices 3.AA, 3.AD, 3.U, 3.W; Subsection 3.4.4.2
F2	D + H	For a lateral handling load, a 2g deceleration is imposed on the stored fuel.	Appendix 3.AA
F3			
F3.a	D + H'	Vertical axis drop event	Subsections 3.4.4.3.1.6, 3.4.4.3.1.3
F3.b	D + H'	Side Drop, 0° orientation (Figure 3.1.2)	Appendix 3.AA
F3.c	D + H'	Side Drop, 45° orientation (Figure 3.1.3)	Appendix 3.AA

[†] The symbols used for the loadings are defined in Table 2.2.13.

Table 3.1.4

LOADING CASES FOR THE ENCLOSURE VESSEL (CONFINEMENT BOUNDARY)

Load Case I.D.	Load Combination[†]	Notes	Comments and Location in FSAR Where this Case is Analyzed
E1.a	Design internal pressure, P_i	Primary stress intensity limits in the shell, baseplate, and closure ring	Lid 3.E.8.1.1 Baseplate 3.I.8.1 Shell 3.4.4.3.1.2 Supports N/A
E1.b	Design external pressure, P_o	Primary stress intensity limits, buckling stability	Lid P_i bounds Baseplate P_i bounds Shell 3.H (Case 7) Supports N/A
E1.c	Design internal pressure, P_i, plus Temperature, T	Primary plus secondary stress intensity under Level A condition	Subsection 3.4.4.3.1.2
E2	$D + H + (P_i, P_o)$[††] For elastic stability, only D+H is considered.	Vertical lift, internal operating pressure conservatively assumed to be equal to the normal design pressure.	Lid 3.E.8.1.2 Baseplate 3.I.8.2 Shell 3.AA (stress) 3.H (Case 4) (buckling) Supports 3.AA

[†] The symbols used for the loadings are defined in Table 2.2.13.

[††] The notation (P_i, P_o) means that both cases are checked for stresses with either P_o or P_i applied.

Table 3.1.4 (continued)

LOADING CASES FOR THE ENCLOSURE VESSEL (CONFINEMENT BOUNDARY)

Load Case I.D.	**Load Combination**[†]	**Notes**	**Comments and Location in FSAR Where this Case is Analyzed**	
E3				
E3.a	$D + H' + (P_o, P_i)$ For elastic stability, only D+H' is considered.	Vertical axis drop event	Lid Baseplate Shell Supports	3.E.8.2.1 3.I.8.3 3.H (Case 5) (Buckling) N/A
E3.b	$D + H' + (P_i, P_o)$	Side drop, 0° orientation (Figure 3.1.2)	Lid Baseplate Shell Supports	End drop bounds End drop bounds Appendix 3.AA Appendix 3.AA, 3.M
E3.c	$D + H' + (P_i, P_o)$	Side drop, 45° orientation (Figure 3.1.3)	Lid Baseplate Shell Supports	End drop bounds End drop bounds Appendix 3.AA Appendix 3.AA, 3.M
E4	T	Demonstrate that interference with the overpack will not develop for T.	Subsection 3.4.4.2 Appendices 3.U; 3.V; 3.W; 3.AD	

[†] The symbols used for the loadings are defined in Table 2.2.13.

Table 3.1.4 (continued)

LOADING CASES FOR THE ENCLOSURE VESSEL (CONFINEMENT BOUNDARY)

Load Case I.D.	Load Combination†	Notes	Comments and Location in FSAR Where this Case is Analyzed
E5	P_i^* or P_o^* + D + T^*	Demonstrate compliance with Level D stress limits - buckling stability.	Lid 3.E.8.2.1.3 Baseplate 3.I.8.4 Shell 3.H (Case 6) (buckling) 3.4.4.3.1.5 (thermal stress) Supports N/A

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† The symbols used for the loadings are defined in Table 2.2.13.

Table 3.1.5
LOAD CASES FOR THE HI-STAR 100 OVERPACK

Load Case I.D.	**Loading[†]**	**Notes**	**Location in FSAR Where this Case is Analyzed**
01	(P_i, P_o)	Compliance with NB stress intensity limits	3.4.4.4.2; 3.AB
02	$(P_i^*, P_o^*) + D + T^*$	Compliance with NB Level D stress intensity limits	3.4.4.4.2; 3.AB
03	$D + H + T + (P_o, P_i)$	Vertical load handling of HI-STAR 100 Overpack	3.4.4.4.2; 3.AB; 3.D
04			
04.a	$D + H' + (P_o, P_i)$	End drop; primary stress intensities must meet Level D limits.	3.4.4.4.2; 3.AB
04.b	$D + H' + (P_o, P_i)$	Horizontal (side) drop; meet Level D limits for NF components away from the impacted zone	3.4.4.4.2; 3.AB
05	T	Satisfy primary membrane plus bending stress limits for NB components	3.4.4.4.2; 3.AB
06	M (small and medium penetrant missiles)	Demonstrate that no thru-wall breach of the overpack occurs, no loss of helium retention boundary occurs, and that primary stress levels are not exceeded.	3.G

Notes:

1. Under each of these load cases, different regions of the structure are analyzed to demonstrate compliance.

[†] The symbols used for the loadings are defined in Table 2.2.13.

Table 3.1.6

DESIGN, LEVELS A AND B: STRESS INTENSITY

Code:	ASME NB
Material:	SA203-E
Service Conditions:	Design, Levels A and B
Item:	Stress Intensity

Temp. (°F)	Classification and Value (ksi)					
	S_m	P_m[†]	P_L[†]	$P_L + P_b$[†]	$P_L + P_b + Q$[††]	P_e[††]
-20 to 100	23.3	23.3	35.0	35.0	69.9	69.9
200	23.3	23.3	35.0	35.0	69.9	69.9
300	23.3	23.3	35.0	35.0	69.9	69.9
400	22.9	22.9	34.4	34.4	68.7	68.7
500	21.6	21.6	32.4	32.4	64.8	64.8

Definitions:

S_m = Stress intensity values per ASME Code
P_m = Primary membrane stress intensity
P_L = Local membrane stress intensity
P_b = Primary bending stress intensity
P_e = Expansion stress
Q = Secondary stress
$P_L + P_b$ = Either primary or local membrane plus primary bending

Definitions for Table 3.1.6 apply to all following tables unless modified.

Notes:

1. Limits on values are presented in Table 2.2.10.

[†] Evaluation required for Design condition only.

[††] Evaluation required for Levels A and B conditions only. P_e not applicable to vessels.

Table 3.1.7

LEVEL D: STRESS INTENSITY

Code:	ASME NB
Material:	SA203-E
Service Condition:	Level D
Item:	Stress Intensity

Temp. (°F)	Classification and Value (ksi)		
	P_m	P_L	$P_L + P_b$
-20 to 100	49.0	70.0	70.0
200	49.0	70.0	70.0
300	49.0	70.0	70.0
400	48.2	68.8	68.8
500	45.4	64.9	64.9

Notes:

1. Level D allowables per NB-3225 and Appendix F, Paragraph F-1331.
2. Average primary shear stress across a section loaded in pure shear may not exceed 0.42 S_u.
3. Limits on values are presented in Table 2.2.10.
4. P_m, P_L, and P_b are defined in Table 3.1.6.

Table 3.1.8

DESIGN, LEVELS A AND B: STRESS INTENSITY

Code:	ASME NB
Material:	SA350-LF3
Service Conditions:	Design, Levels A and B
Item:	Stress Intensity

Temp. (°F)	Classification and Value (ksi)					
	S_m	P_m[†]	P_L[†]	$P_L + P_b$[†]	$P_L + P_b + Q$[††]	P_e[††]
-20 to 100	23.3	23.3	35.0	35.0	69.9	69.9
200	22.8	22.8	34.2	34.2	68.4	68.4
300	22.2	22.2	33.3	33.3	66.6	66.6
400	21.5	21.5	32.3	32.3	64.5	64.5
500	20.2	20.2	30.3	30.3	60.6	60.6
600	18.5	18.5	27.75	27.75	55.5	55.5
700	16.8	16.8	25.2	25.2	50.4	50.4

Notes:

1. Source for S_m is ASME Code.
2. Limits on values are presented in Table 2.2.10.
3. S_m, P_m, P_L, P_b, Q, and P_e are defined in Table 3.1.6.

[†] Evaluation required for Design condition only.

[††] Evaluation required for Levels A and B conditions only. P_e not applicable to vessels.

Table 3.1.9

LEVEL D, STRESS INTENSITY

Code:	ASME NB
Material:	SA350-LF3
Service Conditions:	Level D
Item:	Stress Intensity

Temp. (°F)	Classification and Value (ksi)		
	P_m	P_L	$P_L + P_b$
-20 to 100	49.0	70.0	70.0
200	48.0	68.5	68.5
300	46.7	66.7	66.7
400	45.2	64.6	64.6
500	42.5	60.7	60.7
600	38.9	58.4	58.4
700	35.3	53.1	53.1

Notes:

1. Level D allowables per NB-3225 and Appendix F, Paragraph F-1331.
2. Average primary shear stress across a section loaded in pure shear may not exceed 0.42 S_u.
3. Limits on values are presented in Table 2.2.10.
4. P_m, P_L, and P_b are defined in Table 3.1.6.

Table 3.1.10

DESIGN AND LEVEL A: STRESS

Code:	ASME NF
Material:	SA516, Grade 70, SA515, Grade 70
Service Conditions:	Design and Level A
Item:	Stress

Temp. (°F)	Classification and Value (ksi)		
	S	Membrane Stress	Membrane plus Bending Stress
-20 to 650	17.5	17.5	26.3
700	16.6	16.6	24.9

Notes:

1. S = Maximum allowable stress values from Table 1A of ASME Code, Section II, Part D.

2. Stress classification per Paragraph NF-3260.

3. Limits on values are presented in Table 2.2.12.

Table 3.1.11

LEVEL B: STRESS

Code:	ASME NF
Material:	SA516, Grade 70, SA515, Grade 70
Service Conditions:	Level B
Item:	Stress

Temp. (°F)	Classification and Value (ksi)	
	Membrane Stress	Membrane plus Bending Stress
-20 to 650	23.3	34.9
700	22.1	33.1

Notes:

1. Limits on values are presented in Table 2.2.12 with allowables from Table 3.1.10.

Table 3.1.12

LEVEL D: STRESS INTENSITY

Code:	ASME NF
Material:	SA516, Grade 70, SA515, Grade 70
Service Conditions:	Level D
Item:	Stress Intensity

Temp. (°F)	Classification and Value (ksi)		
	S_m	P_m	$P_m + P_b$
-20 to 100	23.3	45.6	68.4
200	23.1	41.5	62.3
300	22.5	40.4	60.6
400	21.7	39.1	58.7
500	20.5	36.8	55.3
600	18.7	33.7	50.6
650	18.4	33.1	49.7
700	18.3	32.9	49.3

Notes:

1. Level D allowable stress intensities per Appendix F, Paragraph F-1332.
2. S_m = Stress intensity values per Table 2A of ASME, Section II, Part D.
3. Limits on values are presented in Table 2.2.12.
4. P_m and P_b are defined in Table 3.1.6.

Table 3.1.13

DESIGN, LEVELS A AND B: STRESS INTENSITY

Code:	ASME NB
Material:	Alloy X
Service Conditions:	Design, Levels A and B
Item:	Stress Intensity

Temp. (°F)	Classification and Numerical Value					
	S_m	P_m†	P_L†	$P_L + P_b$†	P_L+ P_b+Q††	P_e††
-20 to 100	20.0	20.0	30.0	30.0	60.0	60.0
200	20.0	20.0	30.0	30.0	60.0	60.0
300	20.0	20.0	30.0	30.0	60.0	60.0
400	18.7	18.7	28.1	28.1	56.1	56.1
500	17.5	17.5	26.3	26.3	52.5	52.5
600	16.4	16.4	24.6	24.6	49.2	49.2
650	16.0	16.0	24.0	24.0	48.0	48.0
700	15.6	15.6	23.4	23.4	46.8	46.8
750	15.2	15.2	22.8	22.8	45.6	45.6
800	14.9	14.9	22.4	22.4	44.7	44.7

Notes:

1. S_m = Stress intensity values per Table 2A of ASME II, Part D.
2. Alloy X S_m values are the lowest values for each of the candidate materials at temperature.
3. Stress classification per NB-3220.
4. Limits on values are presented in Table 2.2.10.
5. P_m, P_L, P_b, Q, and P_e are defined in Table 3.1.6.

---

† Evaluation required for Design condition only.

†† Evaluation required for Levels A, B conditions only. P_e not applicable to vessels.

Table 3.1.14

LEVEL D: STRESS INTENSITY

Code:	ASME NB
Material:	Alloy X
Service Conditions:	Level D
Item:	Stress Intensity

Temp. (°F)	Classification and Value (ksi)		
	P_m	P_L	$P_L + P_b$
-20 to 100	48.0	72.0	72.0
200	48.0	72.0	72.0
300	46.2	69.3	69.3
400	44.9	67.4	67.4
500	42.0	63.0	63.0
600	39.4	59.1	59.1
650	38.4	57.6	57.6
700	37.4	56.1	56.1
750	36.5	54.8	54.8
800	35.8	53.7	53.7

Notes:

1. Level D stress intensities per ASME NB-3225 and Appendix F, Paragraph F-1331.
2. The average primary shear strength across a section loaded in pure shear may not exceed 0.42 S_u.
3. Limits on values are presented in Table 2.2.10.
4. P_m, P_L, and P_b are defined in Table 3.1.6.

Table 3.1.15

DESIGN, LEVELS A AND B: STRESS INTENSITY

Code:	ASME NG
Material:	Alloy X
Service Conditions:	Design, Levels A and B
Item:	Stress Intensity

Temp. (°F)	Classification and Value (ksi)				
	S_m	P_m	P_m+P_b	P_m+P_b $+Q$	P_e
-20 to 100	20.0	20.0	30.0	60.0	60.0
200	20.0	20.0	30.0	60.0	60.0
300	20.0	20.0	30.0	60.0	60.0
400	18.7	18.7	28.1	56.1	56.1
500	17.5	17.5	26.3	52.5	52.5
600	16.4	16.4	24.6	49.2	49.2
650	16.0	16.0	24.0	48.0	48.0
700	15.6	15.6	23.4	46.8	46.8
750	15.2	15.2	22.8	45.6	45.6
800	14.9	14.9	22.4	44.7	44.7

Notes:

1. S_m = Stress intensity values per Table 2A of ASME, Section II, Part D.
2. Alloy X S_m values are the lowest values for each of the candidate materials at temperature.
3. Classifications per NG-3220.
4. Limits on values are presented in Table 2.2.11.
5. P_m, P_b, Q, and P_e are defined in Table 3.1.6.

Table 3.1.16

LEVEL D: STRESS INTENSITY

Code:	ASME NG
Material:	Alloy X
Service Conditions:	Level D
Item:	Stress Intensity

Temp. (°F)	Classification and Value (ksi)		
	P_m	P_L	$P_L + P_b$
-20 to 100	48.0	72.0	72.0
200	48.0	72.0	72.0
300	46.2	69.3	69.3
400	44.9	67.4	67.4
500	42.0	63.0	63.0
600	39.4	59.1	59.1
650	38.4	57.6	57.6
700	37.4	56.1	56.1
750	36.5	54.8	54.8
800	35.8	53.7	53.7

Notes:

1. Level D stress intensities per ASME NG-3225 and Appendix F, Paragraph F-1331.
2. The average primary shear strength across a section loaded in pure shear may not exceed 0.42 S_u.
3. Limits on values are presented in Table 2.2.11.
4. P_m, P_L and P_b are defined in Table 3.1.6.

Table 3.1.17

REFERENCE TEMPERATURES AND STRESS LIMITS FOR THE VARIOUS LOAD CASES

Load Case I.D.	**Material**	**Reference Temperature,**[†] **°F**	**Stress Intensity Allowables, ksi**		
			P_m	$P_L + P_b$	$P_L + P_b + Q$
F1	Alloy X	725	15.4	23.1	46.2
F2	Alloy X	725	15.4	23.1	46.2
F3	Alloy X	725	36.9	55.4	NL[††]
E1	Alloy X	450	18.1	27.2	54.3
E2	Alloy X	450	18.1	27.2	54.3
E3	Alloy X	450	43.4	65.2	NL
E4	Alloy X	450	18.1	27.2	54.3
E5	Alloy X	775	36.15	54.25	NL

Note:

1. Q, P_m, P_L and P_b are defined in Table 3.1.6.

[†] Values for reference temperatures are taken as the design temperatures (Table 2.2.3).

[††] NL: No specified limit in the Code.

Table 3.1.17 (continued):
REFERENCE TEMPERATURES AND STRESS LIMITS FOR THE VARIOUS LOAD CASES

Load Case I.D.	**Material**	**Reference Temperature,†,†† °F**	**Stress Intensity Allowables, ksi**		
			P_m	**$P_L + P_b$**	**$P_L + P_b + Q$**
O1	SA203-E	400	22.9	34.4	68.7
	SA350-LF3	400	21.5	32.3	64.5
	SA516 Gr. 70 SA515 Gr. 70	400	17.5	26.3	NL†††
O2	SA203-E	400	48.2	68.8	NL
	SA350-LF3	400	45.2	64.6	NL
	SA516 Gr. 70 SA515 Gr. 70	400	39.1	58.7	NL
O3	SA203-E	400	22.9	34.4	68.7
	SA350-LF3	400	21.5	32.3	64.5
	SA516 Gr. 70 SA515 Gr. 70	400	17.5	26.3	NL
O4	SA203-E	400	48.2	68.8	NL
	SA350-LF3	400	45.2	64.6	NL
	SA516 Gr. 70 SA515 Gr. 70	400	39.1	58.7	NL
O5	SA203-E	400	22.9	34.4	68.7
	SA350-LF3	400	21.5	32.3	64.5
	SA516 Gr. 70 SA515 Gr. 70	400	17.5	26.3	NL
O6	SA203-E	400	48.2	68.8	NL
	SA350-LF3	400	45.2	64.6	NL
	SA516 Gr. 70 SA515 Gr. 70	400	39.1	58.7	NL

Note: 1. P_m, P_L, P_b, and Q are defined in Table 3.1.6.

---

† Values for reference temperatures are taken as the design temperatures (Table 2.2.3).

†† For storage fire analysis, temperatures are defined by thermal solution.

††† NL: No specified limit in the Code.

Table 3.1.18
FRACTURE TOUGHNESS TEST CRITERIA: HELIUM RETENTION BOUNDARY

Item	**Material**	**Thickness (in.)**	**Charpy V-Notch Temperature**[†]	**Drop Test Temperature**[††]
Weld Metal for NB Welds	As required	NA	As required per ASME Section III, Subsection NB, Article NB-2430 and Article NB-2330 Min. test temperature = -40°F	As required per ASME Section III, Subsection NB, Articles NB-2430 and Article NB-2330
Shell	SA203E	2-1/2	$T_{NDT} \leq -70°F$ with testing and acceptance criteria per ASME Section III, Subsection NB, Article NB-2330	$T_{NDT} \leq -70°F$ per Reg. Guide 7.11
Top Flange	SA350-LF3	8-3/4	$T_{NDT} \leq -136°F$ with testing and acceptance criteria per ASME Section III, Subsection NB, Article NB-2330	$T_{NDT} \leq -136°F$ per Reg. Guide 7.12
Bottom Plate	SA350-LF3	6	$T_{NDT} \leq -129°F$ with testing and acceptance criteria per ASME Section III, Subsection NB, Article NB-2330	$T_{NDT} \leq -129°$ per Reg. Guide 7.12

[†] Temperature is T_{NDT} unless noted.

[††] Materials to be tested in accordance with ASTM E208-87a.

Table 3.1.19

FRACTURE TOUGHNESS TEST CRITERIA MISCELLANEOUS ITEMS

Item	Material	Thickness (in.)	Charpy V-Notch Temperature[†]	Drop Test Temperature
Closure Plate	SA350-LF3	6	$T_{NDT} \leq$ -129°F with testing and acceptance criteria per ASME Section III, Subsection NB, Article NB-2330	$T_{NDT} \leq$ -129°F per Reg. Guide 7.12
Intermediate Shells	SA516 Grade 70	1-1/4 and 1	Test temperature = -40°F with acceptance criteria per ASME Section III, Subsection NF, Table NF-2331(a)-3 and Figure NF-2331(a)-2	Not Required
Port Cover Plates	SA203-E	1-1/2	Test temperature = -40°F with acceptance criteria per ASME Section III, Subsection NF, Table NF--2331(a)-3 and Figure NF-2331(a)-2	Not Required
Weld Metal for NF Welds	As required	NA	As required per ASME Section III, Subsection NF, Article NF-2430 and Article NF-2330 Test temperature = -40°F	Not Required

---

[†] Temperature is T_{NDT} unless noted.

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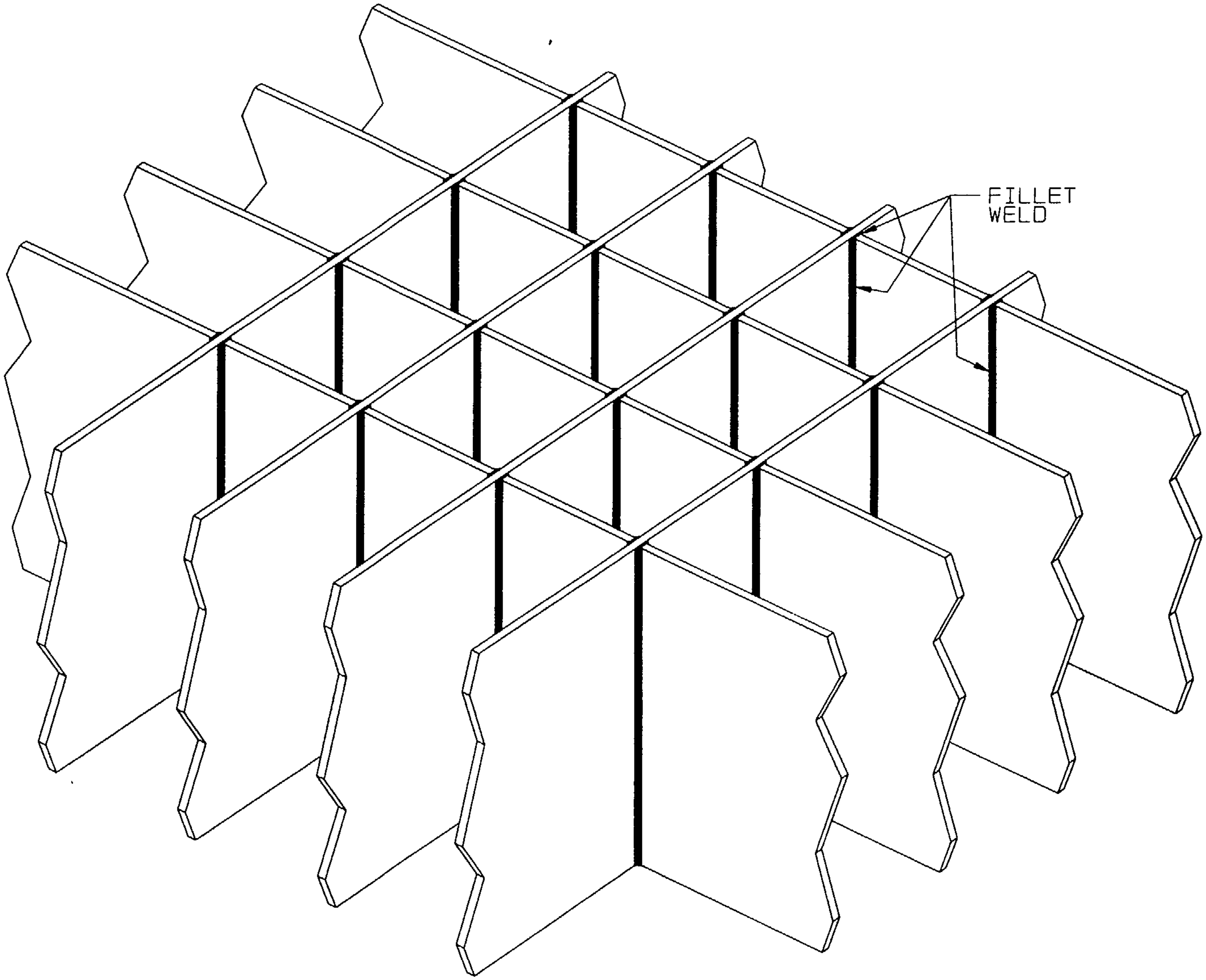

FIGURE 3.1.1; MPC FUEL BASKET GEOMETRY

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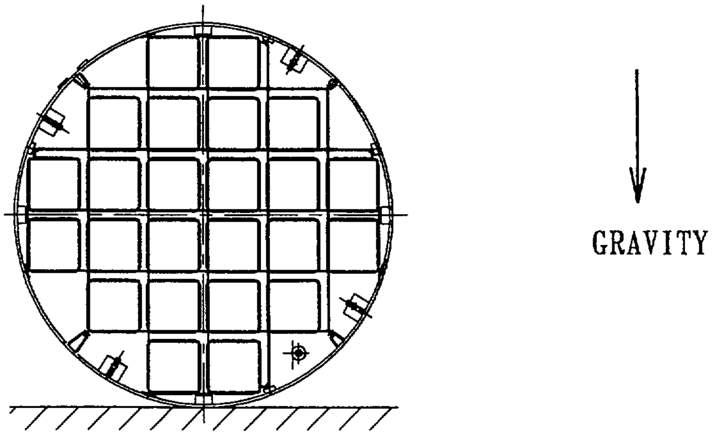

MPC-24

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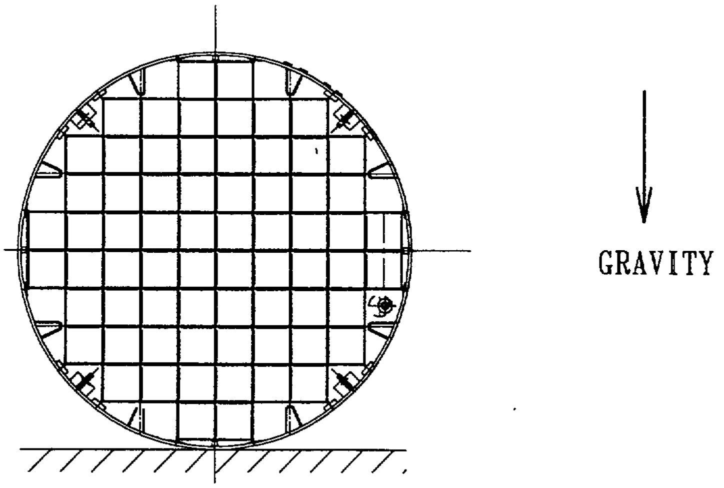

MPC-68

FIGURE 3.1.2; 0° DROP ORIENTATIONS FOR THE MPCs

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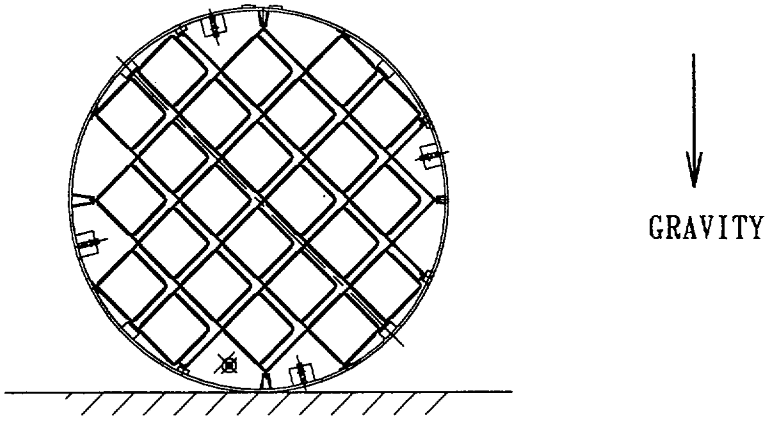

MPC-24

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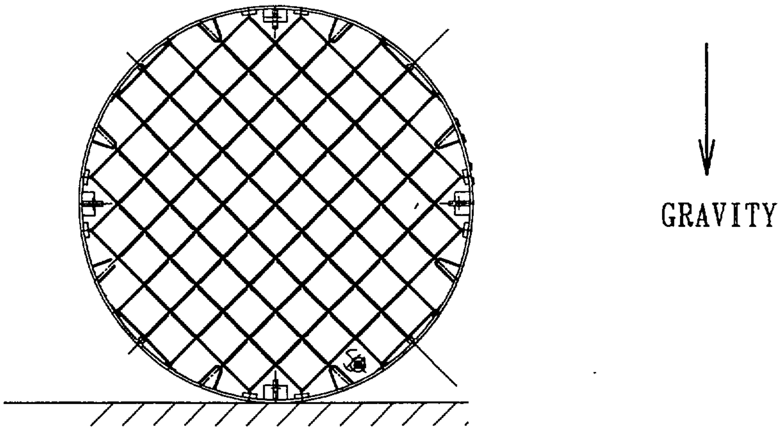

MPC-68

FIGURE 3.1.3; 45° DROP ORIENTATIONS FOR THE MPCs

3.2 WEIGHTS AND CENTERS OF GRAVITY

Table 3.2.1 provides the weights of the individual HI-STAR 100 components as well as the total system weights. Contained water during loading is not included in this table.

The location of the calculated centers of gravity (CGs) are presented in Table 3.2.2. All centers of gravity are located on the cask centerline, since the non-axisymmetry effects of the cask system plus contents are negligible.

Table 3.2.3 provides the lift weight when the HI-STAR 100 System with the heaviest fully loaded MPC is being lifted from the fuel pool. The effect of buoyancy is neglected, and the weight of rigging is set at a conservative value.

Table 3.2.4 provides a set of bounding weights that may be used in analytical calculations.

Table 3.2.1

HI-STAR 100 WEIGHT DATA[1]

	CALCULATED WEIGHT (lb)	
Item	Component	Assembly
• Overpack		153,710
• Overpack closure plate	7,984	
• MPC-24		
• Fuel basket	17,045	
• Without SNF		39,667
• Fully loaded with SNF		79,987
• Overpack with loaded MPC-24		233,697
• MPC-68		
• Fuel basket	15,263	
• Without SNF		39,641
• Fully loaded with SNF		87,241
• Overpack with fully loaded MPC-68		240,951
• Overpack with minimum weight MPC without SNF (Value listed is lower bound to actual minimum weight of 193351 lb.)		189,000

---

[1] All calculated weights are rounded to the nearest pound

Table 3.2.2

CENTERS OF GRAVITY OF HI-STAR 100 CONFIGURATIONS

Component	Height of CG Above Datum[1], inches
Overpack empty	99.7
MPC-24 empty	108.9
MPC-68 empty	109.9
MPC-24 with fuel in overpack	101.8
MPC-68 with fuel in overpack	101.8

---

[1] The datum used for calculations involving the overpack is the bottom of the overpack bottom plate. The datum used for calculations involving the MPC only is the bottom of MPC baseplate (see Figure 3.2.1).

Table 3.2.3

LIFT WEIGHT ABOVE POOL

Item	**Calculated Weight (lb.)**
Total weight of overpack	153,710
Total weight of an MPC (Upper Bound) + fuel	89,057[1]
Overpack closure plate	-7,984
Water in MPC and overpack	16,384
Lift yoke	3,600
Inflatable annulus seal	50
TOTAL	254,816[2]

---

[1] Includes MPC closure ring.

[2] Trunnion rating and crane limits at certain sites may require temporary water removal from the HI-STAR 100 System during removal from the pool (See Chapter 8).

Table 3.2.4
COMPONENT WEIGHTS AND DIMENSIONS FOR ANALYTIC CALCULATIONS[1]

Component	Weight (lbs)
MPC baseplate	3,000
MPC closure lid	10,400
MPC shell	5,900
MPC basket supports and fuel spacers	3,700
Fuel basket	13,000
Fuel	54,000
Total MPC package	90,000
Overpack bottom plate	10,000
Overpack closure plate	8,000
Overpack shell	137,000
Total overpack	155,000
Total HI-STAR 100 lift weight	250,000
Item	**Dimension (inch)**
Overpack Outer Diameter	96
Overpack Length	203.125
MPC Outer Diameter	68.375
MPC Length	190.5
Overpack Inner Diameter	68.75

---

[1] Analytic calculations may use the weights and dimensions in Table 3.2.4 or actual weights and dimensions for conservatism in calculation of safety factors. Finite element analyses use other bounding weights or weights calculated based on input weight densities.

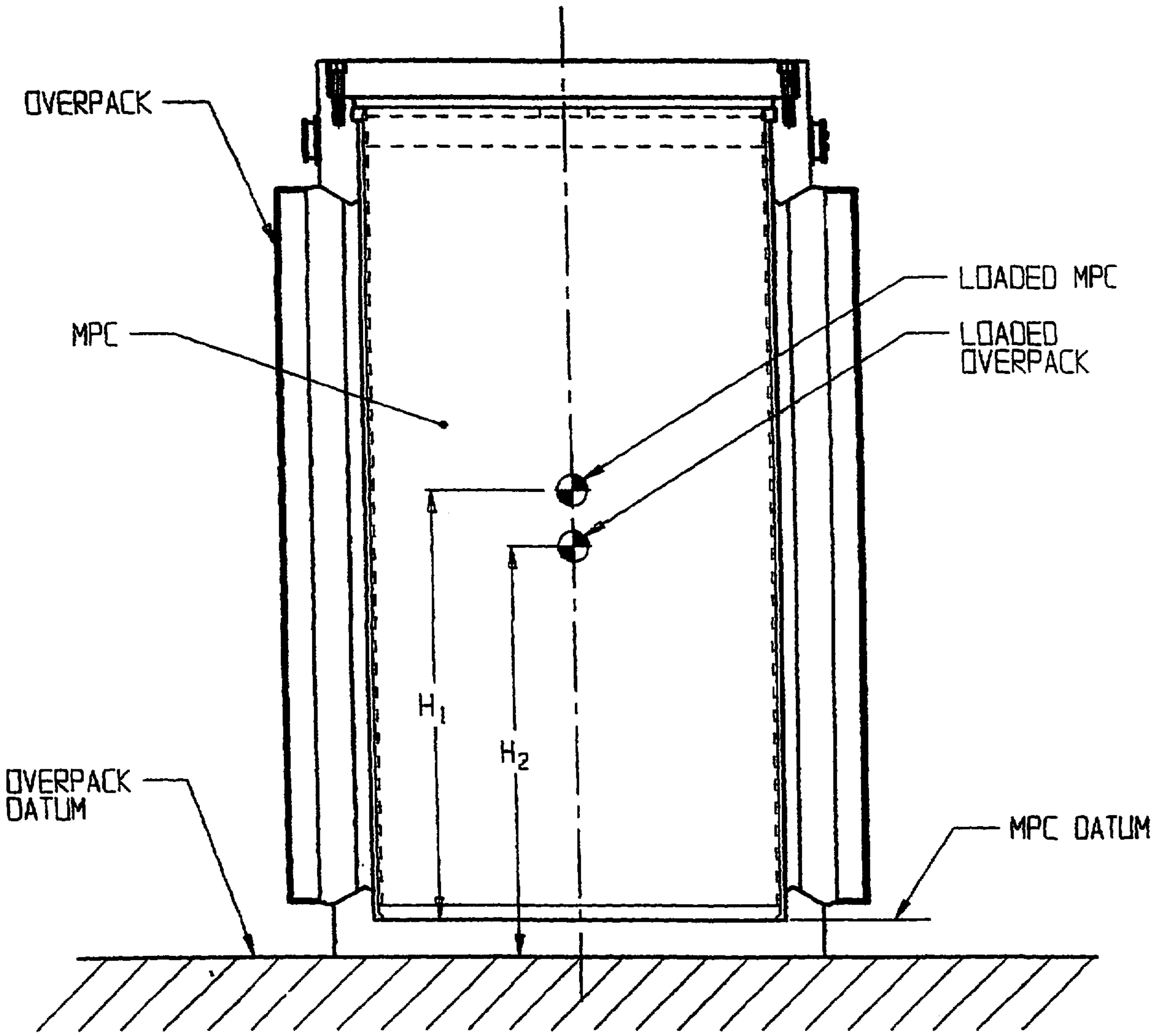

FIGURE 3.2.1; HI-STAR 100 DATUM DEFINITION FOR TABLE 3.2.2

3.3 MECHANICAL PROPERTIES OF MATERIALS

This section provides the mechanical properties used in the structural evaluation. The properties include yield stress, ultimate stress, modulus of elasticity, Poisson's ratio, weight density, and coefficient of thermal expansion. Values are presented for a range of temperatures; the limits of which are below the off-normal environmental temperature and above the off-normal design temperature.

The materials selected for use in the HI-STAR 100 MPC and overpack are presented on the Bills-of-Material in Section 1.5. In this chapter, the materials are divided into two categories, structural and nonstructural. Structural materials are materials that act as load bearing members in the analysis. Materials that do not support mechanical loads are considered nonstructural. For example, while the overpack inner shell is a structural material, Holtite-A (neutron shield) is a nonstructural material.

3.3.1 Structural Materials

3.3.1.1 Alloy X

A hypothetical material termed Alloy X is defined for all MPC structural components. The material properties of Alloy X are the least favorable values from the set of candidate stainless alloys. The purpose of a least favorable material definition is to ensure that all structural analyses are conservative, regardless of the actual MPC material. For example, when evaluating the stresses in the MPC, it is conservative to work with the minimum values for yield strength and ultimate strength. This guarantees that the material used for fabrication of the MPC is of equal or greater strength than the hypothetical material used in the analysis. In the structural evaluation, the only property for which it is not always conservative to use the set of minimum values is the coefficient of thermal expansion. Two sets of values for the coefficient of thermal expansion are specified, a minimum set and a maximum set. For each analysis, the set of coefficients, minimum or maximum, that causes the most adverse result for the cask system is used. Table 3.3.1 lists the numerical values for the material properties of Alloy X versus temperature. These values, taken from the ASME Code, Section II, Part D [3.3.1], are used to complete all structural analyses. The maximum temperatures in some MPC components may exceed the allowable limits of temperature during short time duration loading operations, off-normal transfer operations, or storage accident events. However, under no scenario does the maximum temperature of Alloy X material used in the confinement boundary exceed 1000°F. 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°F temperature for up to 10,000 hours. Therefore, there is no significant effect on mechanical properties of the confinement or basket material during the short time duration loading. A further description of Alloy X, including the materials from which it is derived, is provided in Appendix 1.A.

Two properties of Alloy X which are not included in Table 3.3.1 are weight density and Poisson's ratio. These properties are assumed constant for all structural analyses because there is no significant variation with temperature. The values used are shown in the table below.

PROPERTY	VALUE
Weight Density (lb/in^3)	0.290
Poisson's Ratio	0.30

3.3.1.2 Carbon Steel, Low-Alloy and Nickel Alloy Steel

The carbon steels in the HI-STAR 100 System are SA516 Grade 70 and SA515 Grade 70. The nickel alloy and low alloy steels are SA203-E and SA350-LF3, respectively. These steels are not constituents of Alloy X. The material properties of SA516 Grade 70 and SA515 Grade 70 are presented in Tables 3.3.2 and 3.3.3, respectively. The material properties of SA203-E and SA350-LF3 are given in Table 3.3.4.

Two properties of these steels which are not included in Tables 3.3.2, 3.3.3, and 3.3.4 are weight density and Poisson's ratio. These properties are assumed constant for all structural analyses because there is no significant variation with temperature. The values used are shown in the table below.

PROPERTY	VALUE
Weight Density (lb/in^3)	0.283
Poisson's Ratio	0.30

3.3.1.3 Bolting Materials

Material properties of the bolting materials used in the HI-STAR 100 System are given in Table 3.3.5.

3.3.1.4 Weld Material

All weld materials utilized in the welding of the Code components will comply with the provisions of the appropriate ASME subsection (e.g., Subsection NB for the enclosure vessel) and Section IX. All non-code welds shall also be made using weld procedures which meet Section IX of the ASME Code. The minimum tensile strength of the weld wire and filler material (where applicable) will be equal to or greater than the tensile strength of the base metal listed in the ASME Code.

3.3.2 Nonstructural Materials

3.3.2.1 Neutron Shield

The neutron shield in the overpack is not considered as a structural member of the HI-STAR 100 System. Its load carrying capacity is neglected in all structural analyses except where such omission would be nonconservative. The only material property of the neutron shield which is important to the structural evaluation is its weight density ($1.63 g/cm^3$).

3.3.2.2 Boral Neutron Absorber

Boral is not a structural member of the HI-STAR 100 System. Its load carrying capacity is neglected in all structural analyses. The only material property of Boral which is important to the structural evaluation is its weight density. As the MPC fuel baskets can be constructed with Boral panels of variable areal density, the weight that produces the most severe cask load is assumed in each analysis (density $2.644 g/cm^3$).

3.3.2.3 Aluminum Conduction Inserts

Aluminum conduction inserts are located between the fuel basket and MPC vessel. They are thin, flexible elements whose sole function is to transmit heat. They are not credited with any structural load capacity, and are shaped to provide negligible resistance to basket thermal expansion. The total weight of the aluminum inserts is less than 1,000 lb. per MPC.

Table 3.3.1
ALLOY X MATERIAL PROPERTIES

Temp. (°F)	Alloy X				
	S_y	S_u	α_{min}	α_{max}	E
-40	30.0	75.0	8.54	8.55	28.14
100	30.0	75.0	8.54	8.55	28.14
150	27.5	73.0	8.64	8.67	27.87
200	25.0	71.0	8.76	8.79	27.6
250	23.75	68.5	8.88	8.9	27.3
300	22.5	66.0	8.97	9.0	27.0
350	21.6	65.2	9.10	9.11	26.75
400	20.7	64.4	9.19	9.21	26.5
450	20.05	64.0	9.28	9.32	26.15
500	19.4	63.5	9.37	9.42	25.8
550	18.8	63.3	9.45	9.50	25.55
600	18.2	63.1	9.53	9.6	25.3
650	17.8	62.8	9.61	9.69	25.05
700	17.3	62.5	9.69	9.76	24.8
750	16.9	62.2	9.76	9.81	24.45
800	16.6	61.7	9.82	9.90	24.1

Definitions:

S_y = Yield Stress (ksi)
α = Mean Coefficient of thermal expansion (in./in. per degree F x 10^{-6})
S_u = Ultimate Stress (ksi)
E = Young's Modulus (psi x 10^6)

Notes:

1. Source for S_y values is Table Y-1 of [3.3.1].
2. Source for S_u values is Table U of [3.3.1].
3. Source for α_{min} and α_{max} values is Table TE-1 of [3.3.1].
4. Source for E values is material group G in Table TM-1 of [3.3.1].

Table 3.3.2
SA516, GRADE 70 MATERIAL PROPERTIES

Temp. (°F)	SA516, Grade 70			
	S_y	S_u	α	E
-40	38.0	70.0	5.53	29.34
100	38.0	70.0	5.53	29.34
150	36.3	70.0	5.71	29.1
200	34.6	70.0	5.89	28.8
250	34.15	70.0	6.09	28.6
300	33.7	70.0	6.26	28.3
350	33.15	70.0	6.43	28.0
400	32.6	70.0	6.61	27.7
450	31.65	70.0	6.77	27.5
500	30.7	70.0	6.91	27.3
550	29.4	70.0	7.06	27.0
600	28.1	70.0	7.17	26.7
650	27.6	70.0	7.30	26.1
700	27.4	70.0	7.41	25.5
750	26.5	69.3	7.50	24.85

Definitions:

S_y = Yield Stress (ksi)
α = Mean Coefficient of thermal expansion (in./in. per degree F x 10^{-6})
S_u = Ultimate Stress (ksi)
E = Young's Modulus (psi x 10^6)

Notes:

1. Source for S_y values is Table Y-1 of [3.3.1].
2. Source for S_u values is Table U of [3.3.1].
3. Source for α values is material group C in Table TE-1 of [3.3.1].
4. Source for E values is "Carbon steels with C≤0.30%" in Table TM-1 of [3.3.1].

Table 3.3.3
SA515, GRADE 70 MATERIAL PROPERTIES

Temp. (°F)	SA515, Grade 70			
	S_y	S_u	α	E
-40	38.0	70.0	5.53	29.34
100	38.0	70.0	5.53	29.34
150	36.3	70.0	5.71	29.1
200	34.6	70.0	5.89	28.8
250	34.15	70.0	6.09	28.6
300	33.7	70.0	6.26	28.3
350	33.15	70.0	6.43	28.0
400	32.6	70.0	6.61	27.7
450	31.65	70.0	6.77	27.5
500	30.7	70.0	6.91	27.3
550	29.4	70.0	7.06	27.0
600	28.1	70.0	7.17	26.7
650	27.6	70.0	7.30	26.1
700	27.4	70.0	7.41	25.5
750	26.5	69.3	7.50	24.85

Definitions:

S_y = Yield Stress (ksi)
α = Mean Coefficient of thermal expansion (in./in. per degree F x 10^{-6})
S_u = Ultimate Stress (ksi)
E = Young's Modulus (psi x 10^6)

Notes:

1. Source for S_y values is Table Y-1 of [3.3.1].
2. Source for S_u values is Table U of [3.3.1].
3. Source for α values is material group C in Table TE-1 of [3.3.1].

4. Source for E values is "Carbon steels with C≤0.30%" in Table TM-1 of [3.3.1].

Table 3.3.4

SA350-LF3 AND SA203-E MATERIAL PROPERTIES

Temp. (°F)	SA350-LF3			SA350-LF3/SA203-E		SA203-E		
	S_m	S_y	S_u	E	α	S_m	S_y	S_u
-120	23.3	37.5	70.0	28.5	6.20	23.3	40.0	70.0
100	23.3	37.5	70.0	27.6	6.27	23.3	40.0	70.0
200	22.8	34.2	68.5	27.1	6.54	23.3	36.5	70.0
300	22.2	33.2	66.7	26.7	6.78	23.3	35.4	70.0
400	21.5	32.2	64.6	26.1	6.98	22.9	34.3	68.8
500	20.2	30.3	60.7	25.7	7.16	21.6	32.4	64.9
600	18.5	-	-	-	-	-	-	-
700	16.8	-	-	-	-	-	-	-

Definitions:

S_m = Design Stress Intensity (ksi)
S_y = Yield Stress (ksi)
S_u = Ultimate Stress (ksi)
α = Coefficient of Thermal Expansion (in./in. per degree F x 10^{-6})
E = Young's Modulus (psi x 10^{6})

Notes:

1. Source for S_m values is ASME Code, Table 2A of [3.3.1].
2. Source for S_y values is ASME Code, Table Y-1 of [3.3.1].
3. Source for S_u values is ratioing S_m values.
4. Source for α values is material group E in Table TE-1 of [3.3.1].
5. Source for E values is material group B in Table TM-1 of [3.3.1].

Table 3.3.5
SB637-N07718, SA564-630, AND SA705-630 MATERIAL PROPERTIES

Temp. (°F)	SB637-N07718				
	S_y	S_u	E	α	S_m
-100	150.0	185.0	29.9	---	50.0
-20	150.0	185.0	---	---	50.0
70	150.0	185.0	29.0	6.7	50.0
100	150.0	185.0	---	7.08	50.0
200	144.0	177.6	28.3	7.22	48.0
300	140.7	173.5	27.8	7.33	46.9
400	138.3	170.6	27.6	7.45	46.1
500	136.8	168.7	27.1	7.57	45.6
600	135.3	166.9	26.8	7.67	45.1
SA705-630/SA564-630 (Age Hardened at 1075°F)					
Temp. (°F)	S_y	S_u	E	α	-
200	115.6	145.0	28.5	5.9	-
300	110.7	145.0	27.9	5.9	-
SA705-630/SA564-630 (Age Hardened at 1150°F)					
200	97.1	135.0	28.5	5.9	-
300	93.0	135.0	27.9	5.9	-

Definitions:

S_m = Design stress intensity (ksi)
S_y = Yield Stress (ksi)
α = Mean Coefficient of thermal expansion (in./in. per degree F x 10^{-6})
S_u = Ultimate Stress (ksi)
E = Young's Modulus (psi x 10^{6})

Notes:

1. Source for S_m values is Table 4 of [3.3.1].
2. Source for S_y values is ratioing design stress intensity values.
3. Source for S_u values is ratioing design stress intensity values.
4. Source for α values is Tables TE-1 and TE-4 of [3.3.1], as applicable.
5. Source for E values is Table TM-1 of [3.3.1].