HOLTEC INTERNATIONAL

Holtec Center, 555 Lincoln Drive West, Marlton, NJ 08053
Telephone (856) 797-0900
Fax (856) 797-0909

December 30, 2004

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Reference: USNRC Docket No. 71-9261 (HI-STAR 100)
Holtec Project 5014

Subject: Submittal of License Amendment Request 9261-4 to HI-STAR 100 CoC

Dear Sir:

Holtec International herewith submits License Amendment Request (LAR) 9261-4 proposing certain changes to the HI-STAR 100 System 10 CFR 71 Certificate of Compliance (CoC) Number 9261, Revision 2 and its supporting Safety Analysis Report (SAR). The sole focus of this LAR is to bring certain MPCs and HI-STARs previously loaded under a Part 72 certificate into alignment with HI-STAR's Part 71 certification. Most affected MPCs are located at the Trojan site in Oregon. The proposed changes are minor, consisting of incorporating manufacturing deviations for individual units, incorporating design improvements already implemented under the storage license for these systems, and a clarification of the intact fuel definition for Trojan fuel.

The baseline document for this LAR is the currently approved CoC Amendment 2, and the corresponding SAR Rev. 10. Only changed sections and drawings are provided, as outlined below. To facilitate the staff's review, a summary of changes contemplated in this amendment request is provided in a document entitled "Summary of Proposed Changes". This change summary document provides a listing of the proposed changes to the CoC and SAR as well as the reason and a justification for each change.

The following attachments are provided:

Attachment 1: Summary of Proposed Changes.

Attachment 2: Proposed CoC Changes–All changes are marked by vertical bars in the right margin. Note that Appendix A is not provided since there are no changes proposed to this appendix.

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Attachment 3: Proposed Revised FSAR Sections. Only changed sections are provided, and are labeled as "Rev. L4" in the footer. All text changes are marked by vertical bars in the right margin. The following sections are provided:
Chapter 1: Sections 1.0, 1.2, 1.3, 1.4 (including revised drawings), and 1.6
Chapter 4: Sections 4.1 and 4.2
Chapter 7: Section 7.1
Chapter 8: Section 8.1

We request an expedited review of this application in light of its relevance to establishing transportability of the affected MPCs and HI-STARs.

We appreciate the SFPO's attention to this application.

Sincerely,

Stefan Anton, Dr.-Ing.
Licensing Manager
Docket No. 71-9261

Approved:

K.P. Singh, Ph.D, P.E.
President and CEO

Attachments: As Stated above

Distribution (Letter & CD):
Mr. Meraj Rahimi, NRC

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Holtec Groups 1 and 4
HUG Licensing Committees
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Mr. Larry Camper, NRC
Mr. Wayne Hodges, NRC
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LAR 9261-4

DOCUMENT ID 5014551

ATTACHMENT 1

SUMMARY OF PROPOSED CHANGES

SUMMARY OF PROPOSED CHANGES

SECTION I – PROPOSED CHANGE TO CERTIFICATE OF COMPLIANCE

Proposed Change:

Extend the definition of intact fuel to include all Trojan fuel assemblies not loaded into DFCs or FFCs.

Justification for Change:

The justification is given in SAR Section 1.2.3.2, see proposed SAR change #3 below.

SECTION II - PROPOSED CHANGES TO HI-STAR SAR

Proposed Changes:

1. Section 1.0.1 – Engineering Change Orders that are reflected in the following changes are listed.

2. Section 1.2.1.4.1 – A paragraph from this section describing the various sources of hydrogen generation has been removed. A paragraph has been added to explain the uncertainty in predicting hydrogen generation during loading and unloading operation.

3. Section 1.2.3.2 – A new paragraph is added before the last paragraph, addressing Trojan fuel assemblies.

4. Table 1.2.12 – The design basis fuel assembly for the "MPC Density and Heat Capacity" in the MPC-68/68F is changed to "Dresden 6x6".

5. Table 1.2.18 – A table number and table title are added above the table.

6. Table 1.3.2 – List of ASME Code Alternatives – Entry added to support MPC-68 Closure Ring material for Serial #1021-023, -036, and -037.

7. Table 1.3.3 – Various changes as follows:
    a. The material of the Closure Bolt Washer is changed from stainless steel to ASTM A564, 17-7 PH.

b. Table entries for Backing Strips, Relief Device Coupling, and Relief Device Pipe are removed.
c. Materials for Pocket Trunnions are revised
d. Materials for the Relief Device Plate are expanded to include SA 516 Grade 70.
e. Contact Materials for Thermal Expansion Foam are revised

8. Section 1.4 – Changed drawing revision numbers.

9. Section 1.6 – Reference [1.2.16] is added.

10. Section 4.1.4.2 – Added a paragraph and revised another to include an alternative leakage test method.

11. Section 4.2.5.8 – Revised to include an alternative leakage test.

12. Table 4.2.12 – Added a footnote.

13. Section 7.1.1 – Editorial change in the sixth paragraph following the second Note.

14. Section 7.1.3 – A note is added after Step 9b permitting local grinding of the MPC lid below the minimum diameter on the drawing to alleviate interference with the MPC shell in areas of localized contact.

15. Section 7.1.5 – Added a Note in Step 26e and revised Step 26f, Step 27a, and Step 31, added a Note in Step 32 and revised Steps 32i and 32j.

16. Sections 7.1.5 and 7.1.6 – Removed Item #2 from Section 7.1.6 and added in Section 7.1.5 following Step 28b.

17. Figure 7.1.1 – Added a footnote.

18. Section 8.1.1 – Fabrication and Non-Destructive Examination (NDE) – Item 5 is revised to include a combination of examinations and tests in lieu of a visual examination alone.

19. Table 8.1.2 – HI-STAR Overpack Inspection and Test Acceptance Criteria – The change is to implement Change #18 above.

20. Table 8.1.3 – The ASME Code Subsection and Article for the vent and drain port cover plate plug welds is changed from NG to NB.

Reasons and Justification for Changes:

1. This is an editorial change to show the Engineering Change Orders reflected in this HI-STAR SAR revision.

2. This is an editorial change that simplifies the language supporting the requirement discussed in the last paragraph of this section which states that the space beneath the MPC lid be monitored for the potential presence of combustible gases, and either exhausted or purged with inert gas. The monitoring requirement itself remains unchanged.

3. The new paragraph provides justification for classifying some of the Trojan fuel assemblies (found with conditions of minor impairments) as intact assemblies, and supports the corresponding CoC change.

4. The currently listed fuel type is revised to be consistent with the analysis in Chapter 4.

5. The table number and title were inadvertently deleted in the previous revision.

6. The material was procured as Subsection NG material (in stead of NB material) which did not require any UT inspection as required by NB-2531. Table 1.3.2 provides the justification.

7. Reasons and justifications are as follows:
   a. It was previously experienced that some stainless steel washers were damaged during torquing the bolts. The change in material from stainless steel to ASTM A564 makes it structurally stronger, and therefore better for the application.
   b. Editorial. These components are no longer used.
   c. Editorial. Material specifications are expanded to be consistent with the licensing drawing.
   d. Both materials are equally suitable for the application.
   e. Editorial Correction.

8. Editorial changes for drawing revision numbers.

9. The addition of the reference is due to Change #3 above.

10. The revision is made to address the alternative leakage test method. This is consistent with the change related to the optional construction of the closure ring in Drawing 3923. This change brings the leakage rate testing in line with the corresponding FSAR requirements.

11. Same as Item #10 above.

12. Same as Item #10 above. The footnote is added to define the input parameters for the alternative leakage test.

13. Editorial change.

14. The MPC shell is relatively flexible compared to the MPC lid and may create areas of local contact that may impede lid insertion in the shell. The prescription in the note makes the insertion process easier.

15. Same as Item #10. The specific changes in Step 26 are made to include the alternative leakage test. The change in Step 27a eliminates the use of nitrogen which is not used with the FHD system. The changes in Step 31 are editorial to distinguish between the original and the alternative leakage test, and the change in Step 32 is to provide a description of the alternative leakage test.

16. The steps are revised since the FHD system is not capable of heating the MPC to the required limit with water in the annulus.

17. Same as Item #10.

18. The revised examination requirements comply with 10CFR71.85(a) and are adopted for consistency with the requirements in the HI-STAR FSAR for storage.

19. Same as #18 above.

20. The change corrects a typographical error. The text is revised to be consistent with the ASME Code applicability listed in Table 1.3.1 of the HI-STAR SAR.

SECTION III – PROPOSED CHANGES TO HI-STAR 100 LICENSING DRAWINGS

Drawing No. 3913: Licensing Drawing for HI-STAR 100 Overpack

Proposed Changes:

Several changes are made to address three SMDRs:

a) General repair provision for the Impact Limiter attachment and alignment holes (Sheet 2 Note 5, for SMDR-1020-082).
b) One-time (for Serial #1020-005) condition related to the Holtite thickness which was found to be 4-9/32" (in stead of 4.3" min.) in one of the cavities (Sheet 6 Note 1 for SMDR-1020-229).
c) One-time (for Serial #1020-006) condition related to the welding requirement between a radial channel and the intermediate shell (Sheet 6 Note 2 for SMDR-1020-289).

Additionally, editorial clarifications are made to dimensions and weld descriptions.

Reasons and Justification for Changes:

The changes have been evaluated in respective SMDRs and it has been concluded that they have negligible effect in the design function. Reasons and justifications for individual SMDRs are:

a) The change provides a general repair provision for the Impact Limiter attachment and alignment holes.
b) The change allows a specific unit to have a slightly smaller thickness of Holtite compared to that in the current drawing. The thickness (4-9/32") reported in this SMDR is still larger than the thickness of 4.1875" used in the supporting analyses for HI-STAR FSAR.
c) The change allows a length of 4" fillet weld missing from a total weld length of 6880 inches. The SMDR evaluations conclude that the change does not compromise the structural integrity of the attachment of the radial channel, and there is no impact on the thermal performance.

The editorial clarifications do not affect the design function or design analyses.

Drawing No. 3923: Licensing Drawing for MPC Enclosure Vessel

Proposed Changes:

1. The notes (Sheets 3 & 4) to the lid-to-shell welds are revised for clarification. The profile of the MPC lid is changed to have a tapered edge (chamfer).

2. The groove weld (Sheet 2) between the port cover plates and the MPC lid is reduced from 3/16" to 1/8".

3. Several changes are made to incorporate four SMDRs (1021-895, -907, -929, and -1001):

   a) An optional construction for the closure ring (Sheet 3 Note 6, and Detail D) that provides penetrations to allow helium leakage testing of the MPC lid-to-shell and vent/drain port cover plate welds during a single test. Plug welds in the closure ring are identical to the plug welds in the vent/drain portcover plates.
   b) Specific configuration of the MPC lid (Sheet 4 Note 4, and Sheet 6) due to one-time (for MPC-68 Serial #1021-040) condition with respect to the MPC lid thickness.

4. The MPC-68F lid OD is changed (Sheet 4 Note 2) from 66-1/32" to 65.8".

5. Fuel spacer plate dimensions are revised (Sheet 5).

Reasons and Justification for Changes:

1. The notes are revised for clarification and for consistency with the HI-STORM and HI-STAR FSAR Chapter 9, and HI-STAR SAR Chapter 8. The addition of a chamfer to the MPC lids eases fit-up during loading operations.

2. The proposed weld size change provides improved fit-up, minimize welding time and thereby radiation exposure. The reduced weld size still maintains the associated weld stresses below allowable levels.

3. The evaluations for changes needed to incorporate SMDR-1021-895, -907, -929, and -1001 into the HI-STAR SAR concluded that these

changes do not have any adverse impact on the design function. Specifically:

a) Using this change the MPC primary confinement welds can be leakage rate tested as a whole providing a quantified leakage rate that is easily compared to the technical specification requirements. The structural integrity is not compromised by this change. This brings leakage rate testing in line with the HI-STORM FSAR requirements.
b) The MPC lid-to-shell welding for Serial #1021-040 developed many indications, all located at the MPC lid interface. The lid was removed and replaced with a new lid. During the lid-to-shell weld removal process the MPC shell height was reduced by approximately 1-1/2" due to machining. Consequently, the new lid needed to be thinner by 1-1/2" (i.e., 8-1/2" thick). An additional 1-1/2" thick shield disk was installed on top of the new lid. The structural integrity of the new 8-1/2" thick lid is bounded by the existing structural calculations. The new 8-1/2" thick lid and the new 1-1/2" thick shield disk have a combined thickness of 10", providing essentially the same shielding performance as the 10" thick lid. The thermal contact resistance between the lid and the shield disk is negligible compared to the approximately 2" air gap between the top of the MPC and the bottom of the HI-STORM lid, so the thermal analysis of the MPC is not significantly affected. The installation of the vent and drain port cover plates and the closure ring is not affected by this change.

4. The change on the MPC-68F lid OD is needed to correct an inadvertent omission in an earlier version of the licensing drawing.

5. Minor changes for consistency with design drawings.

Drawing No. 3925: Licensing Drawing for MPC-24E/EF Fuel Basket Assembly

Proposed Changes:

The proposed change (Sheet 2 Note 5) addresses a one-time (SMDR-1022-926 forTrojan MPC-24 Serial #1022-029) condition with respect to the orientation of two cell plates (panels) between cell numbers 11 and 17. This change results in the bottom mouse-holes being a semicircular shape instead of the intended rectangular slot and the top mouse-holes being a rectangular slot instead of the intended semicircular shape. The two plates do not have any Boral panels attached.

Reasons and Justification for Changes:

Since the panels do not have Boral installed on them, there is no effect on criticality. The rectangular slots were designed to allow sufficient room at the bottom of the basket for proper axial positioning of Boral panels, but this is not critical on panels without Boral. The structural and shielding analyses neglect the presence of the mouse-holes, so there is no structural and shielding impact. Thermal analyses do not credit the top mouse-holes, but do credit the bottom ones. The semicircular shaped hole has a larger flow area than the rectangular slot, so the thermal analyses are unaffected. In summary, the condition has a negligible effect on the design basis analysis.

Drawing No. 3928: Licensing Drawing for MPC-68/68F/68FF Fuel Basket Assembly

Proposed Changes:

Several changes are made to address three SMDRs:

a) A one-time condition (SMDR-1021-73 for MPC-68F Serial #1021-005) related to the 6.49 +/- .06 cell opening and 6.053 +/- .06 inside cell dimension for cell numbers 68 and 64 (Sheet 3 Note 3). The cell opening is oversized by a maximum of 5/32" along approximately 3 feet of the cell height.
b) A one-time condition (SMDR-1021-577 for MPC-68 Serial #1021-090) related to the width of one Boral panel that has a minimum width of 4.728" in stead of 4.75” (Sheet 2 Note 1).
c) A one-time condition (SMDR-1021-674 for MPC-68 Serial #1021-026) related to the basket height (e.g., one basket cell panel in cell #68 has a height of 175 5/8" in stead of 176”+/- 1/8”, Sheet 2 Note 5).

Reasons and Justification for Changes:

The changes are needed to incorporate SMDR-1021-073, -577, and -674 into the HI-STAR SAR. Reasons and justifications are as follows:

a) The oversize of cells 68 and 64 is limited to a 34" length. The oversized subject cells will not interfere with the assembly of the basket into the shell by virtue of their location. The acceptance of the oversized weld in the 34" length is subject to successful drag test of the cells.
b) The change has negligible impact in the criticality, thermal and shielding analyses due to the magnitude of the deviation (less than 0.5% of the width) only in a single panel. Sufficient conservatism exists in all calculations to bound this condition.
c) The reduction of length at the top of the basket cell plate will not affect the design function of the MPC-68 basket. The structural integrity of the fuel basket is not affected by a reduction in height of 1/4" of one basket cell plate, the criticality is not be affected since the reduction of the basket length is not in the sheathing zone, and the effect on shielding is negligible since the amount of material missing is extremely small compared to the overall weight of the basket.

Drawing No. C1765: HI-STAR 100 Impact Limiter

Proposed Changes:

- The thickness of Holtite in the impact limiters is changed to 2-1/2" minimum from the current 2-1/2" nominal (Sheets 1, 2, & 4).
- Clarification notes (Sheet 2 Note 6, and Sheet 3 Note 5) are added for shimming the 3/16” maximum gap between the overpack outer diameter and impact limiter inner diameter
- Clarification notes (Sheet 2 Note 7, and Sheet 3 Note 7) for rounding of corners moved to “Notes” section of drawing.

Reasons and Justification for Changes:

- The change of the thickness of Holtite from the nominal value to the minimum value makes it consistent with the CoC.
- The change on the note for the shimming provides clarification for the acceptance criteria, and also allows better control over the shim.
- Editorial changes for clarification.

HOLTEC INTERNATIONAL

LAR 9261-4

DOCUMENT ID 5014551

ATTACHMENT 2

PROPOSED COC CHANGES

CERTIFICATE OF COMPLIANCE
FOR RADIOACTIVE MATERIALS PACKAGES

1.a CERTIFICATE NUMBER	b. REVISION NUMBER	c. PACKAGE IDENTIFICATION NUMBER	d. PAGE NUMBER	e. TOTAL NUMBER PAGES
9261	~~2~~*TBD*	USA/9261/B(U)F-85	1	10

2. PREAMBLE

a. This certificate is issued to certify that the packaging and contents described in Item 5 below, meets the applicable safety standards set forth in Title 10, Code of Federal Regulations, Part 71, “Packaging and Transportation of Radioactive Material.”

b. This certificate does not relieve the consignor from compliance with any requirement of the regulations of the U.S. Department of Transportation or other applicable regulatory agencies, including the government of and country through or into which the package will be transported.

3. THIS CERTIFICATE IS ISSUED ON THE BASIS OF A SAFETY ANALYSIS REPORT OF THE PACKAGE DESIGN OR APPLICATION

a. ISSUED TO (*Name and Address)*

Holtec International
Holtec Center
555 Lincoln Drive West
Marlton, NJ 08053

b. TITLE AND IDENTIFICATION OF REPORT OR APPLICATION:

Holtec International application dated October 23, 1995, as supplemented

c. DOCKET NUMBER

71-9261

4. CONDITIONS

This certificate is conditional upon fulfilling the requirements of 10CFR Part 71, as applicable, and the conditions specified below.

5.

5.a. Packaging

(1) Model No.: HI-STAR 100 System

(2) Description

The HI-STAR 100 System is a canister system comprising a Multi-Purpose Canister (MPC) inside of an overpack designed for both storage and transportation (with impact limiters) of irradiated nuclear fuel. The HI-STAR 100 System consists of interchangeable MPCs that house the spent nuclear fuel and an overpack that provides the containment boundary, helium retention boundary, gamma and neutron radiation shielding, and heat rejection capability. The outer diameter of the overpack of the HI-STAR 100 is approximately 96 inches without impact limiters and approximately 128 inches with impact limiters. Maximum gross weight for transportation (including overpack, MPC, fuel, and impact limiters) is 282,000 pounds. Specific tolerances germane to the safety analyses for the package are called out in drawings listed below.

Multi-Purpose Canister

There are five Multi-Purpose Canister (MPC) models, designated the MPC-24, MPC-24E, MPC-24EF, MPC-68, and MPC-68F. All MPCs are designed to have identical exterior dimensions, except those MPC-24E/EFs custom-designed for the Trojan plant, which are approximately nine inches shorter than the generic Holtec MPC design. A single overpack design is provided that is capable of containing each type of MPC. The two digits after the MPC designate the number of reactor fuel assemblies for which the respective MPCs are designed. The MPC-24 series is designed to contain up to 24 Pressurized Water Reactor (PWR) fuel assemblies;

5. a. (2) Description (continued)

and the MPC-68 and MPC-68F are designed to contain up to 68 Boiling Water Reactor (BWR) fuel assemblies. Any MPC-68 loaded with material classified as fuel debris is designated as MPC-68F. Any MPC-24E loaded with material classified as fuel debris is designated as MPC-24EF.

The HI-STAR 100 MPC is a welded cylindrical structure with flat ends. Each MPC is an assembly consisting of a honeycombed fuel basket, baseplate, canister shell, lid, and closure ring. The outer diameter and cylindrical height of each generic MPC is fixed. The outer diameter of the Trojan MPCs is the same as the generic MPC, but the height is approximately nine inches shorter than the generic MPC design. A steel spacer is used with the Trojan plant MPCs to ensure the MPC-overpack interface is bounded by the generic design. The fuel basket designs vary based on the MPC model. For the HI-STAR 100 System transporting fuel debris in a MPC-68F or MPC-24EF, the MPC provides the second inner container, in accordance with 10CFR71.63. The MPC pressure boundary is a strength-welded enclosure constructed entirely of a stainless steel alloy.

Overpack

The HI-STAR 100 overpack is a multi-layer steel cylinder with a welded baseplate and bolted lid (closure plate). The inner shell of the overpack forms an internal cylindrical cavity for housing the MPC. The outer surface of the overpack inner shell is buttressed with intermediate steel shells for radiation shielding. The overpack closure plate incorporates a dual O-ring design to ensure its containment function. The containment system consists of the overpack inner shell, bottom plate, top flange, top closure plate, top closure inner O-ring seal, vent port plug and seal, and drain port plug and seal.

Impact Limiters

The HI-STAR 100 overpack is fitted with two impact limiters fabricated of aluminum honeycomb completely enclosed by an all-welded austenitic stainless steel skin. The two impact limiters are attached to the overpack with 20 and 16 bolts at the top and bottom, respectively.

(3) Drawings

The package shall be constructed and assembled in accordance with the following drawings or figures in Holtec International Report No. HI-951251, Safety Analysis Report for the Holtec International Storage, Transport, And Repository Cask System (HI-STAR 100 Cask System), Revision ~~10~~*TBD*:

(a) HI-STAR 100 MPC-24 Fuel Basket	Drawing 3926, Sheets 1-4, Rev. 5
(b) HI-STAR 100 MPC-24E/EF Fuel Basket	Drawing 3925, Sheets 1-4, Rev. ~~4~~*5*

5. a. (3) Drawings (continued)

(c) HI-STAR 100 MPC-68/68F/68FF Fuel Basket	Drawing 3928, Sheets 1-4, Rev. ~~4~~*5*
(d) HI-STAR 100 MPC Enclosure Vessel	Drawing 3923, Sheets 1-~~5~~*6*, Rev. ~~8~~*11*
(e) HI-STAR 100 Overpack	Drawing 3913, Sheets 1-9, Rev. ~~5~~*7*
(f) HI-STAR 100 Impact Limiters	Drawing C1765, Sheets 1-~~6~~*2*, Rev. ~~1~~*2;* *Sheet 3, Rev. 1;* *Sheet 4, Rev. 2;* *Sheets 5-6, Rev. 1*; and Sheet 7, Rev. 0
(g) HI-STAR 100 Assembly for Transport	Drawing 3930, Sheets 1-3, Rev. 1
(h) Trojan MPC Spacer	Drawing 4111, Sheets 1 and 2, Rev. 0
(i) Trojan Failed Fuel Can	SNC Drawings PFFC-001, Rev. 8 and PFFC-002, Sheets 1 and 2, Rev. 7
(j) Trojan Failed Fuel Can Spacer	Drawing 4122, Sheets 1 and 2, Rev. 0
(k) Holtec Damaged Fuel Container for Trojan plant SNF	Drawing 4119, Sheet 1-4, Rev. 1

5. b. Contents

(1) Type and Form, and Quantity of Material

(a) Fuel assemblies meeting the specifications and quantities provided in Appendix A to this Certificate of Compliance and meeting the requirements provided in Conditions 5.b(1)(b) through 5.b(1)(g) below are authorized for transportation.

(b) The following definitions apply:

Damaged Fuel Assemblies are fuel assemblies with known or suspected cladding defects, as determined by review of records, greater than pinhole leaks or hairline cracks, empty fuel rod locations that are not filled with dummy fuel rods, or those that cannot be handled by normal means. Fuel assemblies which cannot be handled by normal means due to fuel cladding damage are considered fuel debris.

5.b.1.(b) Definitions (continued)

Damaged Fuel Containers (or Canisters) (DFCs) are specially designed fuel containers for damaged fuel assemblies or fuel debris that permit gaseous and liquid media to escape while minimizing dispersal of gross particulates. The DFC designs authorized for use in the HI-STAR 100 are shown in Figures 1.2.10 and 1.2.11 of the HI-STAR 100 System SAR, Rev. ~~10~~*TBD*.

Fuel Debris is 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. Fuel debris also includes certain Trojan plant-specific fuel material contained in Trojan Failed Fuel Cans.

Incore Grid Spacers are fuel assembly grid spacers located within the active fuel region (i.e., not including top and bottom spacers).

Intact Fuel Assemblies are fuel assemblies without known or suspected cladding defects greater than pinhole leaks or hairline cracks and which can be handled by normal means. Fuel assemblies without fuel rods in fuel rod locations shall not be classified as intact fuel assemblies unless dummy fuel rods are used to displace an amount of water greater than or equal to that displaced by the original fuel rod(s). *Trojan fuel assemblies not loaded into DFCs or FFCs are classified as intact assemblies.*

Minimum Enrichment is the minimum assembly average enrichment. Natural uranium blankets are not considered in determining minimum enrichment.

Non-Fuel Hardware is defined as Burnable Poison Rod Assemblies (BPRAs), Thimble Plug Devices (TPDs), and Rod Cluster Control Assemblies (RCCAs).

Planar-Average Initial Enrichment is the average of the distributed fuel rod initial enrichments within a given axial plane of the assembly lattice.

Trojan Damaged Fuel Containers (or Canisters) are Holtec damaged fuel containers custom-designed for Trojan plant damaged fuel and fuel debris as depicted in Drawing 4119, Rev. 0.

Trojan Failed Fuel Cans are non-Holtec designed Trojan plant-specific damaged fuel containers that may be loaded with Trojan plant damaged fuel assemblies, Trojan fuel assembly metal fragments (e.g., portions of fuel rods and grid assemblies, bottom nozzles, etc.), a Trojan fuel rod storage container, a Trojan Fuel Debris Process Can Capsule, or a Trojan Fuel Debris Process Can. The Trojan Failed Fuel Can is depicted in Drawings PFFC-001, Rev. 8 and PFFC-002, Rev. 7.

5.b.1.(b) Definitions (continued)

Trojan Fuel Debris Process Cans are Trojan plant-specific canisters containing fuel debris (metal fragments) and were used to process organic media removed from the Trojan plant spent fuel pool during cleanup operations in preparation for spent fuel pool decommissioning. Trojan Fuel Debris Process Cans are loaded into Trojan Fuel Debris Process Can Capsules or directly into Trojan Failed Fuel Cans. The Trojan Fuel Debris Process Can is depicted in Figure 1.2.10B of the HI-STAR 100 System SAR, Rev. ~~10~~*TBD*.

Trojan Fuel Debris Process Can Capsules are Trojan plant-specific canisters that contain up to five Trojan Fuel Debris Process Cans and are vacuumed, purged, backfilled with helium and then seal-welded closed. The Trojan Fuel Debris Process Can Capsule is depicted in Figure 1.2.10C of the HI-STAR 100 System SAR, Rev. ~~10~~*TBD*.

ZR means any zirconium-based fuel cladding material authorized for use in a commercial nuclear power plant reactor.

(c) For MPCs partially loaded with stainless steel clad fuel assemblies, all remaining fuel assemblies in the MPC shall meet the more restrictive of the two limits for the stainless steel clad fuel assemblies or the applicable ZR clad fuel assemblies.

(d) For MPC-68s and MPC-68Fs partially loaded with damaged fuel assemblies or fuel debris, all remaining ZR clad intact fuel assemblies in the MPC shall meet the more restrictive of the two limits for the damaged fuel assemblies or the intact fuel assemblies.

(e) For MPC-68s partially loaded with array/class 6x6A, 6x6B, 6x6C, 7x7A, or 8x8A fuel assemblies, all remaining Zircaloy-clad intact fuel assemblies in the MPC shall meet the more restrictive of the two limits for the 6x6A, 6x6B, 6x6C, 7x7A, and 8x8A fuel assemblies or the applicable Zircaloy-clad fuel assemblies.

(f) PWR non-fuel hardware and neutron sources are not authorized for transportation except as specifically provided for in Appendix A to this CoC.

(g) BWR stainless-steel channels and control blades are not authorized for transportation.

c. Transport Index for Criticality Control

The minimum transport index to be shown on the label for nuclear criticality control: 0

6. For operating controls and procedures, in addition to the requirements of Subpart G of 10 CFR Part 71:

a. Each package shall be both prepared for shipment and operated in accordance with detailed written operating procedures. Procedures for both preparation and operation shall be developed. At a minimum, those procedures shall include the following provisions:

6.a (continued)

(1) Identification of the fuel to be loaded and independent verification that the fuel meets the specifications of Condition 5.b above.

(2) Before each shipment, the licensee or shipper shall verify and document that each of the requirements of 10 CFR 71.87 has been satisfied.

(3) The package must satisfy the following leak testing requirements:

(a) All overpack containment boundary seals shall be leak tested to show a total leak rate of not greater than 4.3×10^{-6} atm cm^3/sec (helium). The leak test shall have a minimum sensitivity of 2.15×10^{-6} atm cm^3/sec (helium) and shall be performed:

(i) within the 12-month period prior to each shipment;
(ii) after detensioning one or more overpack lid bolts or the vent port plug; and
(iii) After each seal replacement.

(b) Within 30 days before each shipment, all overpack containment boundary seals shall be leak tested using a test with a minimum sensitivity of 1×10^{-3} atm cm^3/sec. If leakage is detected on a seal, then the seal must be replaced and leak tested per Condition 6.a(3)(a) above.

(c) Each overpack containment boundary seal must be replaced after each use of the seal.

(4) The relief devices on the neutron shield vessel shall be replaced every 5 years.

(5) MPC-68F and MPC-24EF shall be leak tested prior to shipment to show a leak rate of no greater than 5×10^{-6} atm cm^3/sec (helium). The leak test shall have a minimum sensitivity of 2.5×10^{-6} atm cm^3/sec (helium).

(6) MPCs deployed at an ISFSI under 10 CFR 72 prior to transportation may be dried using the vacuum drying method or the Forced Helium Dehydration (FHD) method. MPCs placed directly into transportation service under 10 CFR 71 without first being deployed at an ISFSI must be dried using the FHD method. Water and residual moisture shall be removed from the MPC in accordance with the following specifications:

6.a.(6) (continued)

For those MPCs vacuum dried:

(a) The MPC shall be evacuated to a pressure of less than or equal to 3 torr.

(b) The MPC cavity shall hold a stable pressure of less than or equal to 3 torr for at least 30 minutes.

For those MPCs dried using the FHD System:

(a) Following bulk moisture removal, the temperature of the gas exiting the demoisturizer shall be $\leq$ 21^{o}F for $\geq$ 30 minutes.

(7) Following drying, the MPC shall be backfilled with 99.995% minimum purity helium: > 0 psig and $\leq$ 44.8 psig at a reference temperature of 70^{o}F.

(8) Water and residual moisture shall be removed from the HI-STAR 100 overpack in accordance with the following specifications:

(a) The overpack annulus shall be evacuated to a pressure of less than or equal to 3 torr.

(b) The overpack annulus shall hold a stable pressure of less than or equal to 3 torr for at least 30 minutes.

(9) Following vacuum drying, the overpack shall be backfilled with helium to $\geq$ 10 psig and $\leq$ 14 psig.

(10) The following fasteners shall be tightened to the torque values specified below:

Fastener	Torque (ft-lbs)
Overpack Closure Plate Bolts	2985 $\pm$ 90
Overpack Vent and Drain Port Plugs	45 +5/-2
Top Impact Limiter Attachment Bolts	256 +10/-0
Bottom Impact Limiter Attachment Bolts	1500 +45/-0

(11) Verify that the appropriate fuel spacers, as necessary, are used to position the fuel in the MPC cavity.

b. All acceptance tests and maintenance shall be performed in accordance with detailed written procedures. Procedures for fabrication, acceptance testing, and maintenance shall be developed and shall include the following provisions:

(1) The overpack lifting trunnions shall be tested at 300% of the maximum design lifting load.

6.b (continued)

(2) The MPC shall be pressure tested in accordance with ASME Section III, Subsection NB, Article NB-6110 and applicable sub-articles. If hydrostatic testing is used, the MPC shall be pressure tested to 125% of the design pressure. The minimum hydrostastic test pressure shall be 125 psig. If pneumatic testing is used, the MPC shall be pressure tested to 120% of the design pressure. The minimum pneumatic test pressure shall be 120 psig.

(3) The overpack shall be pressure tested to 150% of the Maximum Normal Operating Pressure (MNOP). The minimum test pressure shall be 150 psig.

(4) The MPC lid-to-shell (LTS) weld shall be verified by either volumetric examination using the Ultrasonic (UT) method or multi-layer liquid penetrant (PT) examination. The root and final weld layers shall be PT examined in either case. If PT alone is used, additional intermediate PT examination(s) shall be conducted after each approximately 3/8 inch of the weld is completed. The inspection of the weld must be performed by qualified personnel and shall meet the acceptance requirements of ASME B&PV Section III, NB-5350. The inspection results, including all relevant indications shall be made a permanent part of the licensee's records by video, photographic, or other means providing an equivalent retrievable record of weld integrity.

(5) The radial neutron shield shall have a minimum thickness of 4.3 inches and the impact limiter neutron shields shall have a minimum thickness of 2.5 inches. Before first use, the neutron shielding integrity shall be confirmed through a combination of fabrication process control and radiation measurements with either loaded contents or a check source. Measurements shall be performed over the entire exterior surface of the radial neutron shield and each impact limiter using, at a maximum, a 6 x 6 inch test grid.

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

(7) The first fabricated HI-STAR 100 overpack shall be tested to confirm its heat transfer capability. The test shall be conducted after the radial channels, enclosure shell panels, and neutron shield material have been installed and all inside and outside surfaces are painted per the Design Drawings specified in Section 1.4 of the SAR, Rev. 9. A test cover plate shall be used to seal the overpack cavity. Testing shall be performed in accordance with written and approved procedures. The test must demonstrate that the overpack is fabricated adequately to meet the design heat transfer capability.

6.b (continued)

(8) For each package, a periodic thermal performance test shall be performed every 5 years or prior to next use, if the package has not been used for transport for greater than 5 years, to demonstrate that the thermal capabilities of the cask remain within its design basis.

(9) The MPC neutron absorber's minimum acceptable ^{10}B loading is 0.0267 g/cm^2 for the MPC-24 and 0.0372 g/cm^2 for the MPC-24E, MPC-24EF, and MPC-68; and 0.01 g/cm^2 for the MPC-68F. The ^{10}B loading shall be verified by chemistry or neutron attenuation techniques.

(10) a. The minimum flux trap size for the MPC-24 is 1.09 inches.

b. The minimum flux trap sizes for the generic MPC-24E and MPC-24EF are 0.776 inch for cells 3, 6, 9,and 22; and 1.076 inch for the remaining cells.

c. The minimum flux trap sizes for the Trojan MPC-24E and MPC-24EF are 0.526 inch for cells 3, 6, 9,and 22; and 1.076 inch for the remaining cells.

(11) The minimum fuel cell pitch for the MPC-68 and MPC-68F is 6.43 inches.

(12) The package containment verification leak test shall be per ANSI N14.5-1997.

7. The maximum gross weight of the package as presented for shipment shall not exceed 282,000 pounds.

8. The package shall be located on the transport vehicle such that the bottom surface of the bottom impact limiter is at least 9 feet (along the axis of the overpack) from the edge of the vehicle.

9. The personnel barrier shall be installed at all times while transporting a loaded overpack.

10. The package authorized by this certificate is hereby approved for use under the general license provisions of 10 CFR 71.12.

11. Expiration Date: March 31, 2004

Attachment: Appendix A

REFERENCES:

Holtec International Report No. HI-951251, *Safety Analysis Report for the Holtec International Storage, Transport, And Repository Cask System (HI-STAR 100 Cask System)*, Revision ~~10~~*TBD*, dated TBD.

FOR THE U.S. NUCLEAR REGULATORY COMMISSION

E. William Brach, Director
Spent Fuel Project Office
Office of Nuclear Material Safety
and Safeguards

Date: TBD

HOLTEC INTERNATIONAL

LAR 9261-4

DOCUMENT ID 5014551

ATTACHMENT 3

PROPOSED REVISED FSAR SECTIONS

CHAPTER 1: GENERAL INFORMATION

1.0 GENERAL INFORMATION

This Safety Analysis Report (SAR) for Holtec International's HI-STAR 100 packaging is a compilation of information and analyses to support a United States Nuclear Regulatory Commission (NRC) licensing review as a spent nuclear fuel transportation package (Docket No. 71-9261) under requirements specified in 10CFR71 [1.0.1] and 49CFR173 [1.0.2]. This SAR supports NRC approval and issuance of Certificate of Compliance No. 9261, issued under the provisions and definitions in 10CFR71, Subpart D, for the design Model: HI-STAR 100 as an acceptable Type B(U)F-85 packaging for transport by exclusive use shipment (10CFR71.47).

The HI-STAR 100 packaging complies with the requirements of 10CFR71 for a Type B(U)F-85 package. The HI-STAR 100 packaging does not have a maximum normal operating pressure (MNOP) greater than 700 kPa (100 lb/in^2). The HI-STAR 100 internal design pressure is specified in Table 2.1.1 as 100 psig to calculate bounding stress values. Section 3.4 calculates the MNOP (reported in Table 3.4.15) and demonstrates that the value remains below the design value specified in Table 2.1.1. No pressure relief device is provided on the HI-STAR 100 containment boundary, as discussed in Subsection 1.2.1.8. Therefore, there is no pressure relief device that would allow the release of radioactive material under the tests specified in 10CFR71.73. Analyses that demonstrate that the HI-STAR 100 packaging complies with the requirements of Subparts E and F of 10CFR71 are provided in this SAR. Specific reference to each section of the SAR that is used to specifically address compliance to 10CFR71 is provided in Table 1.0.2. Therefore, the HI-STAR 100 packaging to transport spent nuclear fuel should be designated B(U)F-85.

The HI-STAR 100 transport index for nuclear criticality control is zero, as an unlimited number of packages is subcritical under the procedures specified in 10CFR71.59(a). Section 6.1 provides the determination of the transport index for nuclear criticality control. The transport index based on radiation is in excess of 10 for the HI-STAR 100 Packaging with design basis fuel contents. Therefore, the HI-STAR 100 Packaging must be transported by exclusive use shipment (10CFR71.47).

The HI-STAR 100 packaging design, fabrication, assembly, and testing shall be performed in accordance with Holtec International's quality assurance program. 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. NRC approval of Holtec International's quality assurance program is documented by the Quality Assurance Program Approval for Radioactive material Packages (NRC Form 311), Approval Number 0784, Docket No. 71-0784.

This SAR has been prepared in the format and content suggested in NRC Regulatory Guide 7.9 [1.0.3]. The purpose of this chapter is to provide a general description of the design features and transport capabilities of the HI-STAR 100 packaging including its intended use. This chapter provides a summary description of the packaging, operational features, and contents, and provides reasonable assurance that the package will meet the regulations and operating objectives. Table

1.0.1 contains a listing of the terminology and notation used in preparing this SAR.

This SAR was initially prepared prior to the issuance of the draft version of NUREG-1617 [1.0.5]. To aid NRC review, additional tables and references have been added to facilitate the location of information needed to demonstrate compliance with 10CFR71 as outlined by NUREG-1617. Table 1.0.2 provides a matrix of the 10CFR71 requirements as outlined in NUREG-1617, the format requirements of Regulatory Guide 7.9, and reference to the applicable SAR section(s) that address(es) each topic.

The HI-STAR 100 System is a dual purpose system, certified under 10 CFR 71 and 10 CFR 72. The HI-STAR 100 Final Safety Analysis Report (FSAR) [1.0.6] supports Certificate of Compliance No. 1008 for HI-STAR 100 to store spent nuclear fuel at an Independent Spent Fuel Storage Installation (ISFSI) facility under requirements of 10CFR72, Subpart L [1.0.4] (Docket Number 72-1008).

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 1.1.1 is the first figure in Section 1.1 of Chapter 1 (which is the next section in this chapter).

Revision of this document ~~to Revision 10~~ was made on a section level. Therefore, if any change occurs on a page, the entire section was updated to *the current r*~~R~~evision ~~10~~. The locations of specific text changes are indicated by revision bars in the margin of the page. Figures are controlled individually at the latest SAR revision level for that particular figure. Sections and figures unchanged in the latest SAR revision indicate the revision level corresponding to the last changes made in the section/figure. Drawings are also controlled individually within the Holtec International drawing control system. The revisions of drawings included in *this r*~~R~~evision ~~10~~ of this SAR are the same as those incorporated by reference into CoC No. 9261, Amendment ~~2~~*TBD*.

This r~~R~~evision ~~10~~ of this SAR includes information pertaining to the MPC-32 basket. However, the MPC-32 is not certified for transportation at this time. MPC-32 is under review by the NRC and will be certified in a future CoC amendment.

1.0.1 Engineering Change Orders

The changes authorized by the following Holtec Engineering Change Orders (ECOs) are reflected in *this r*~~R~~evision ~~10~~ of this SAR:

MPC-68/68F: ECOs 1021-*61*.~~1, 3, 4, 7, 8, 13, 14, 16, 18 through 20, 22, 27, 29, 33, 34, 39, 41, 44, 46 through 54, and 56; and 71188-43.~~

MPC-24/24E/24EF: ECOs 1022-~~3, 6, 9, 10 through 13, 16, 19, 21 through 24, 26, 28, 35, 37 through 41, 43 through 46, and 48 through 51; and 1135-24 through 26, 28 through 33, 36, 39, and 40.~~*57*.

MPC-32: ECOs 1023-~~3, 5, 7, 10 through 14, 16, 18 through 21, and 24~~*30*.

HI-STAR overpack: ECOs 1020-~~6, 7, 9, 11, 12, 14, 15, 19, 22, 23, 25, 29, 31, 33, 34 through 36, 38, 41 through 43, and 45 through 47; and 71188-31 and 33~~*49*.

Ancillary Equipment: ECOs 1027-~~27, 31 and 50~~*61*.

General FSAR changes: ECOs 5014-~~36, 49, 54, 57, 62, 67,68, 71, 72, 77, 80, 82, 86 through 88, 91~~*98,99* and ~~94~~*101*.

Table 1.0.1

TERMINOLOGY AND NOTATION

ALARA is an acronym for As Low As Reasonably Achievable.

AL-STAR^{TM} is the trademark name of the HI-STAR 100 impact limiter.

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.

Commercial Spent Fuel or CSF refers to nuclear fuel used to produce energy in a commercial nuclear power plant.

Containment System Boundary means the enclosure formed by the overpack inner shell welded to a bottom plate and top flange plus the bolted closure plate with dual seals and the vent and drain port plugs with seals. It is also called the primary containment boundary when used with the inner (secondary) containment boundary of the MPC-68F and MPC-24EF.

Containment System means the HI-STAR 100 overpack that forms the containment boundary of the packaging intended to contain the radioactive material during transport.

Cooling Time (or post-irradiation cooling time) for a spent fuel assembly is the time between reactor shutdown and the time the spent fuel assembly is loaded into the MPC.

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

Damaged Fuel Container (or Canister) means a specially designed enclosure for damaged fuel assemblies or fuel debris which permits gaseous and liquid media to escape while minimizing dispersal of gross solid particulates.

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

Exclusive use means the sole use by a single consignor of a conveyance for which all initial, intermediate, and final loading and unloading are carried out in accordance with the direction of the consignor or consignee. The consignor and the carrier must ensure that loading or unloading is performed by personnel having radiological training and resources appropriate for safe handling of the consignment. The consignor must issue specific instructions, in writing, for maintenance of exclusive use shipment controls, and include them with the shipping paper information provided to the carrier by the consignor.

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

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

Fuel Debris is 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. Fuel debris also includes certain Trojan plant-specific fuel material contained in Trojan Failed Fuel Cans.

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 containment boundary for radioactive materials, gamma and neutron shielding, and a set of lifting trunnions for handling. Certain overpack models also include optional pocket trunnions for upending and downending.

HI-STAR 100 System or HI-STAR 100 Packaging consists of the MPC sealed within the HI-STAR 100 overpack with impact limiters installed.

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 Holtite R&D program. As such, the terms Holtite and Holtite-A may be used interchangeably throughout this SAR.

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

Impact Limiter means a set of fully-enclosed energy absorbers that are attached to the top and bottom of the overpack during transport. The impact limiters are used to absorb kinetic energy resulting from normal and hypothetical accident drop conditions. The HI-STAR impact limiters are called AL-STAR.

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

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. Fuel assemblies without fuel rods in fuel rod locations shall not be classified as Intact Fuel Assemblies unless dummy fuel rods are used to displace an amount of water greater than or equal to that displaced by the original fuel rod(s).

Load-and-Go is a term used in this SAR that means the practice of loading spent fuel into the HI-STAR 100 System packaging and placing the packaging into transportation service under 10 CFR 71, without first deploying the system at an Independent Spent Fuel Storage Installation (ISFSI) under 10 CFR 72.

Maximum Normal Operating Pressure (MNOP) means the maximum gauge pressure that would develop in the containment system in a period of 1 year under the heat condition specified in 10CFR71.71(c)(1), in the absence of venting, external cooling by an ancillary system, or operational controls during transport.

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.

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 transported. 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.

Multi-Purpose Canister (MPC) means the sealed canister consisting of a honeycombed fuel basket for spent nuclear fuel storage, contained in a cylindrical canister shell (the MPC Enclosure Vessel). There are different MPCs with different fuel basket geometries for storing PWR or BWR fuel. All MPCs except the Trojan plant MPCs have identical exterior dimensions. The Trojan plant MPCs have the same outside diameter, but are approximately nine inches shorter than the generic MPC design. MPC is an acronym for multi-purpose canister. The MPCs used as part of the HI-STAR 100 Packaging are identical to the MPCs authorized for use in the HI-STAR 100 Storage

(Docket No. 72-1008) and HI-STORM 100 Storage (72-1014) [1.0.7] CoCs to the extent that the particular MPC models are authorized for use under both CoCs.

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

Neutron Sources means specially designed inserts for fuel assemblies that produce neutrons for startup of the reactor. The specific types of neutron sources authorized for transportation in the HI-STAR 100 System are discussed in Section 1.2.3.

Non-fuel Hardware, or NFH, means Burnable Poison Rod Assemblies (BPRAs), Thimble Plug Devices (TPDs), Control Rod Assemblies (CRAs), Axial Power Shaping Rods (APSRs), Wet Annular Burnable Absorbers (WABAs), Rod Cluster Control Assemblies (RCCAs), Control Element Assemblies (CEAs),water displacement guide tube plugs, orifice rod assemblies, and vibration suppressor inserts. The specific types of NFH authorized for transportation in the HI-STAR 100 System are discussed in Section 1.2 of this SAR.

Packaging means the HI-STAR 100 System consisting of a single HI-STAR 100 overpack, a set of impact limiters, and a multi-purpose canister (MPC). It excludes all lifting devices, rigging, transporters, saddle blocks, welding machines, and auxiliary equipment (such as the drying and helium backfill system) used during fuel loading operations and preparation for off-site transportation.

Package means the HI-STAR 100 System plus the licensed radioactive contents loaded for transport.

Planar-Average Initial Enrichment is the average of the distributed fuel rod initial enrichments within a given axial plane of the assembly lattice.

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).

Secondary Containment Boundary means the Enclosure Vessel of the “F” model MPC. The secondary containment boundary of the “F” model MPC provides the separate inner container for the transport of fuel debris. The “F” model MPC, in conjunction with the overpack containment system boundary, is designed to meet the double barrier requirement of 10CFR71.63(b) for plutonium shipments.

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.

STP is Standard Temperature (298^{o}K) and Pressure (1 atm) conditions.

Transport index means the dimensionless number (rounded up to the next tenth) placed on the label of a package, to designate the degree of control to be exercised by the carrier during transportation. The transport index is determined for fissile material packages as the number determined by multiplying the maximum radiation level in millisievert per hour at one meter (3.3 ft) from the external surface of the package by 100 (equivalent to the maximum radiation level in millirem per hour at one meter (3.3 ft)), or, for criticality control purposes, the number obtained as described in 10CFR71.59, whichever is larger.

Trojan Damaged Fuel Container (or Canister) is a Holtec damaged fuel container custom-designed for Trojan plant damaged fuel and fuel debris. Trojan plant damaged fuel and fuel debris not loaded into a Trojan Failed Fuel Can must be loaded into a Trojan Damaged Fuel Container.

Trojan Failed Fuel Can (FFC) is a non-Holtec designed Trojan plant-specific damaged fuel container that may be loaded with Trojan plant damaged fuel assemblies, Trojan fuel assembly metal fragments (e.g., portions of fuel rods, grid assemblies, bottom nozzles, etc.), a Trojan fuel rod storage container, a Trojan Fuel Debris Process Can Capsule, or a Trojan Fuel Debris Process Can.

Trojan Failed Fuel Can Spacer is a square, structural steel tube with a baseplate designed to be placed inside one Trojan Failed Fuel Can to occupy any space between the top of the contents and the top of the FFC in order to minimize movement of the FFC contents during transportation.

Trojan Fuel Debris Process Can is a Trojan plant-specific canister containing fuel debris (metal fragments) and was used to process organic media removed from the Trojan plant spent fuel pool during cleanup operations in preparation for spent fuel pool decommissioning. Trojan Fuel Debris Process Cans are loaded into Trojan Fuel Debris Process Can Capsules or directly into Trojan Failed Fuel Cans.

Trojan Fuel Debris Process Can Capsule is a Trojan plant-specific canister that contains up to five Trojan Fuel Debris Process Cans and is vacuumed, purged, backfilled with helium, and then seal-welded closed.

ZR means any zirconium-based fuel cladding material authorized for use in a commercial nuclear power plant reactor. Any reference to Zircaloy fuel cladding in this SAR applies to any zirconium-based fuel cladding material.

Table 1.0.2

HI-STAR 100 SAR CORRELATION WITH 10CFR71 AND REGULATORY GUIDE 7.9

RG 7.9 Section	10CFR Part 71 Section	HI-STAR SAR Section
1.1	71.31(a)(1), 71.31(a)(2), 71.31(a)(3), 71.31(c), 71.33(a)(1), 71.33(a)(3), 71.35(b), 71.37, 71.59	1.0, 1.1, 1.2, 1.5
1.2	71.31(a)(1), 71.33(a)(2), 71.33(a)(4), 71.33(a)(5), 71.33(a)(6), 71.33(b), 71.43(b)	1.2, 1.3, 1.4
None	71.31(a)(2), 71.35(a), 71.41(a)	1.5
1.3	None	Appendices 1.A, 1.B, and 1.C
2.1, 2.2	71.31(a)(1), 71.31(c), 71.33	2.1, 2.2
2.3, 2.4	71.43(d)	2.3, 2.4
2.5	71.45	2.5
2.6, 2.7	71.31(a)(2), 71.35(a), 71.41(a), 71.61, 71.71, 71.73	2.6, 2.7
2.6	71.35(a), 71.41(a), 71.43(f), 71.51(a)(1), 71.55(d)(4), 71.71	2.6
2.7	71.35(a), 71.41(a), 71.73	2.7
None	71.61	2.7
None	71.85(b)	8.1.2.2
2.10	None	2.10
3.1	71.31(a)(1), 71.31(c), 71.33(a)(5), 71.33(a)(6), 71.33(b)(1), 71.33(b)(3), 71.33(b)(5), 71.33(b)(7), 71.33(b)(8), 71.51(c)	Chapters 1 & 2, Sections 3.0, 3.1, 3.4, 3.6
3.2, 3.3	71.31(a)(1), 71.33(a)(5)	Chapters 1 & 2, Sections 3.0, 3.1, 3.4, 3.6
None	71.31(a)(2), 71.35(a), 71.41(a)	3.0, 3.1, 3.4, 3.5, 3.6
None	71.43(g)	3.0, 3.4, 3.6
3.4	71.43(f), 71.51(a)(1), 71.71	3.0, 3.4, 3.6
3.5	71.73	3.0, 3.5, 3.6
3.6	None	N/A
4.1	71.31(a)(1), 71.31(c), 71.33(a)(4), 71.33(a)(5), 71.33(b)(1), 71.33(b)(3), 71.33(b)(5), 71.33(b)(7), 71.43(c), 71.43(d), 71.43(e)	4.0, 4.1, 4.2, 4.3
4.2	71.31(a)(2), 71.35(a), 71.41(a), 71.43(f), 71.43(h), 71.51(a)(1), 71.51(c)	4.2, 4.3
4.3	71.31(a)(2), 71.35(a),	4.2, 4.3

Table 1.0.2 (continued)

HI-STAR 100 SAR CORRELATION WITH 10CFR71 AND REGULATORY GUIDE 7.9

RG 7.9 Section	10CFR Part 71 Section	HI-STAR SAR Section
	71.41(a), 71.51(a)(2), 71.51(c)	
4.4	71.63	4.2, 4.3, 7.1
4.5	None	-
5.1	71.31(a)(1), 71.31(c), 71.33(a)(5)	5.1
5.2	71.31(a)(1), 71.33(b)(1), 71.33(b)(2), 71.33(b)(3)	5.2
5.3	71.31(a), 71.31(b)	5.3
5.4	71.31(a)(2), 71.35(a), 71.41(a), 71.43(f), 71.47(b), 71.51(a)(1), 71.51(a)(2)	5.1, 5.4, 5.5
5.5	None	Appendices 5.A, 5.B, 5.C
6.1	71.31(a)(1), 71.31(c), 71.33(a)(5), 71.35(b), 71.59(b)	6.1
6.2	71.31(a)(1), 71.33(b)(1), 71.33(b)(2), 71.33(b)(3), 71.83	6.2
6.3	71.31(a)(2), 71.35(a), 71.41(a)	6.3
6.4	71.35, 71.43(f), 71.51(a)(1), 71.55(b), 71.55(d), 71.55(e), 71.59	6.4
6.5	71.31(a)(2), 71.35	6.5, Appendix 6.A
6.6	None	6.2, 6.4, Appendices 6.B, 6.C, 6.D
7.1	71.31(c), 71.35(c), 71.43(g), 71.47(b), 71.47(c), 71.47(d), 71.87, 71.89	7.4, 7.1.3, 7.1.7
7.2	71.35(c)	7.1.7
7.3	71.87(i)	7.1.7
None	71.35(c)	7.1.7
7.4	None	-
8.1	71.31(c), 71.37(b), 71.85(a), 71.85(b), 71.85(c), 71.87(g), 71.93(b)	8.1
8.2	71.31(c), 71.37(b), 71.87(b), 71.87(g), 71.93(b)	8.2

Notes:

“-“ There is no HI-STAR SAR section that addresses this.

1.2 PACKAGE DESCRIPTION

1.2.1 Packaging

The HI-STAR 100 System consists of an MPC designed for BWR or PWR spent nuclear fuel, an overpack that provides the containment boundary and a set of impact limiters that provide energy absorption capability for the normal and hypothetical accident conditions of transport. Each of these components is described below, including information with respect to component fabrication techniques and designed safety features. This discussion is supplemented by a set of drawings in Section 1.4. Section 1.3 provides the HI-STAR 100 design code applicability and details any alternatives to the ASME Code.

Before proceeding to present detailed physical data on HI-STAR 100, it is contextual to summarize the design attributes that set it apart from the prior generation of spent fuel transportation packages.

There are several features in the HI-STAR 100 System design that increase its effectiveness with respect to the safe transport of spent nuclear fuel (SNF). Some of the principal features of the HI-STAR 100 System that enhance its effectiveness are:

- the honeycomb design of the MPC fuel basket
- the effective distribution of neutron and gamma shielding materials within the system
- the high heat rejection capability
- the structural robustness of the multi-shell overpack construction

The honeycomb design of the MPC fuel baskets renders the basket into a multi-flanged 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 coplanar (no offset) or orthogonal with each other. There is complete edge-to-edge continuity between contiguous cells.

Among the many benefits of the honeycomb construction is the uniform distribution of the metal mass 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.

The multi-layer shell construction in the overpack provides a natural barrier against crack propagation in the radial direction across the overpack structure. If, during a hypothetical accident (impact) event, a crack was initiated in one layer, the crack could not propagate to the adjacent layer. Additionally, it is highly unlikely that a crack would initiate as the thinner layers are more ductile than a thicker plate.

In this Safety Analysis Report the HI-STAR 100 System design is demonstrated to have predicted responses to accident conditions that are clearly acceptable with respect to certification requirements for post-accident containment system integrity, maintenance of subcriticality margin, dose rates, and adequate heat rejection capability. Table 1.2.18 presents a summary of the HI-STAR 100 System performance against these aspects of post-accident performance at two levels. At the first level, the integrity of the MPC boundary prevents release of radioactive material or helium from the MPC, and ingress of moderator. The integrity of the MPC is demonstrated by the analysis of the response of this high quality, ASME Code, Section III, Subsection NB-designed, pressure vessel to the accident loads while in the overpack. With this demonstration of MPC integrity, the excellent performance results listed in the second column of Table 1.2.18 constitutes an acceptable basis for certification of the HI-STAR 100 System for the safe transport of spent nuclear fuel. However, no credit is taken for MPC integrity for certification of the HI-STAR 100 System for the transport of intact or damaged fuel assemblies. Credit is only taken for the additional containment boundary of the MPC-68F and MPC-24EF for the transport of fuel classified as fuel debris in order to meet the requirements of 10 CFR 71.63(b).

The HI-STAR 100 System provides a large margin of safety. The third column in Table 1.2.18 summarizes the performance if the MPC is postulated to suffer gross failurein the post-accident analysis. Even with this postulated failure, the performance of the HI-STAR 100 System is acceptable for the transport of intact and damaged fuel assemblies, showing the defense-in-depth methodology incorporated into the HI-STAR 100 System.

The containment boundary of the HI-STAR 100 System is shown to satisfy the special requirements of 10CFR71.61 for irradiated nuclear fuel shipments.

To meet the requirements of 10CFR71.63(b) for plutonium shipments, which is considered applicable for the transport of fuel classified as fuel debris, double containment is provided by the containment boundary of the overpack and the secondary containment boundary of the MPC-68F and MPC-24EF, serving as a separate inner container.

1.2.1.1 Gross Weight

The gross weight of the HI-STAR 100 System depends on which of the MPCs is loaded into the HI-STAR 100 overpack for shipment. Table 2.2.1 summarizes the maximum calculated component weights for the HI-STAR 100 overpack, impact limiters, and each MPC loaded to maximum capacity with design basis SNF. The maximum gross transport weight of the HI-STAR 100 System is to be marked on the packaging nameplate.

1.2.1.2 Materials of Construction, Dimensions, and Fabrication

All materials used to construct the HI-STAR 100 System are ASME Code materials, except the neutron shield, neutron poison, optional aluminum heat conduction elements, thermal expansion foam, seals, pressure relief devices, aluminum honeycomb, pipe couplings, and other material classified as Not Important to Safety. The specified materials of construction along with outline dimensions for important-to-safety items are provided in the drawings in Section 1.4.

The materials of construction and method of fabrication are further detailed in the subsections that follow. Section 1.3 provides the codes applicable to the HI-STAR 100 packaging for materials, design, fabrication, and inspection, including NRC-approved alternatives to the ASME Code.

1.2.1.2.1 HI-STAR 100 Overpack

The HI-STAR 100 overpack is a heavy-walled steel cylindrical vessel. A single overpack design is provided that is capable of transporting each type of MPC. The inner diameter of the overpack is approximately 68-3/4 inches and the height of the internal cavity is approximately 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 203-1/4 inches.

Figure 1.2.1 provides a cross sectional elevation view of the overpack containment boundary. The overpack containment boundary is formed by a steel inner shell welded at the bottom to a bottom plate and, at the top, to a heavy top flange with a bolted closure plate. Two concentric grooves are machined into the closure plate for the seals. The closure plate is recessed into the top flange and the bolted joint is configured to protect the closure bolts and seals in the event of a drop accident. The closure plate has test and vent ports that are closed by a threaded port plug with a seal. The bottom plate has a drain port that is also closed by a threaded port plug with a seal. The containment boundary forms an internal cylindrical cavity for housing the MPC.

The outer surface of the overpack inner shell is buttressed with intermediate shells of gamma shielding that 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 puncture or penetration. 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 enclosure shell panels form the overpack outer enclosure shell (Figure 1.2.2). Atop the outer enclosure shell, pressure relief devices (e.g., rupture disks) are positioned in a recessed area. The relief devices relieve internal pressure that 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 in the axial direction. Appendix 1.C provides material information on the thermal expansion foam. Figure 1.2.2 provides a mid-plane cross section view of the overpack, depicting the inner shell, intermediate shells, radial channels, outer enclosure shell, and neutron shield.

The exposed steel surfaces (except seal seating surfaces) of the overpack and the intermediate shell layers are coated to prevent corrosion. Coating materials are chosen based on the expected service conditions, considering the dual purpose certification status of the HI-STAR 100 System under 10 CFR 72 for spent fuel storage as well as transportation. The coatings applied to the overpack exposed exterior and interior surfaces are specified on the drawings in Section 1.4. The material data on the coatings is provided in Appendix 1.C. The inner cavity of the overpack is coated with a material appropriate to its high temperatures and the exterior of the overpack is coated with a material appropriate for fuel pool operations and environmental exposure. The coating applied to the intermediate shells acts as a surface preservative and is not exposed to the fuel pool or ambient environment.

Lifting trunnions are attached to the overpack top flange for lifting and rotating the cask body between vertical and horizontal positions. The lifting trunnions are located 180^{o} apart in the sides of the top flange. On overpack serial numbers 1020-001 through 1020-007, pocket trunnions are welded to the lower side of the overpack 180^{o} apart to provide a pivoting axis for rotation. The pocket trunnions are slightly off-center to ensure proper rotation direction of the overpack. As shown in Figure 1.1.4, the trunnions do no protrude beyond the cylindrical envelope of the overpack outer enclosure shell. This feature reduces the potential for direct impact on a trunnion in the event of an overpack side impact. After fabrication of HI-STAR overpack serial number 1020-007, the pocket trunnions were deleted from the overpack design.

1.2.1.2.2 Multi-Purpose Canisters

1.2.1.2.2.1 General Description

In this subsection, discussion of those attributes applicable to all of the MPC models is provided. Differences among the models are discussed in subsequent subsections. Specifications for the authorized contents of each MPC model, including non-fuel hardware and neutron sources are provided in Section 1.2.3.

The HI-STAR 100 MPCs are welded cylindrical structures with flat ends. Each MPC is an assembly consisting of a honeycombed fuel basket, a baseplate, a canister shell, a lid with vent and drain ports and cover plates, and a closure ring. The outer diameter of all MPCs and cylindrical height of each generic design MPC is fixed (see discussion in Subsection 1.2.1.2.2.3 regarding Trojan plant-specific MPCs). The number of spent nuclear fuel storage locations in each of the MPCs depends on the fuel assembly characteristics. As the generic MPCs are interchangeable, they correspondingly have identical exterior dimensions. The outer dimension of the MPC is nominally 68-3/8 inches and the length is nominally 190-1/4 inches. Figures 1.2.3-1.2.5 depict the cross sectional views of the different MPCs. Drawings of the MPCs are provided in Section 1.4. Key system data for the HI-STAR 100 System are outlined in Tables 1.2.2 and 1.2.3.

The generic MPC-24/24E/24EF and Trojan plant MPC-24E/EF differ in construction from the MPC-32 and MPC-68/68F in one important aspect: the fuel cells are physically separated from one another by a flux trap between each cell for criticality control (Figures 1.2.3 and 1.2.4). All MPC baskets are formed from an array of plates welded to each other, such that a honeycomb structure is created that resembles a multi-flanged, closed-section beam in its structural characteristics.

The MPC fuel basket is positioned and supported within the MPC shell by a series of basket supports welded to the inside of the MPC shell. In the peripheral area created by the basket, the MPC shell, and the basket supports, optional aluminum heat conduction elements are installed in some early production MPC-68 and MPC-68F models (see Figure 1.2.3). These heat conduction elements are fabricated from thin aluminum alloy 1100 in shapes and a design that allow a snug fit in the confined spaces and ease of installation. The heat conduction elements are along the full length of the MPC basket, except at the drain pipe location, to create a nonstructural thermal connection that facilitates heat transfer from the basket to the shell. In their operating condition, the heat conduction elements conform to, and contact the MPC shell and basket walls. In SAR Revision 10, a refined thermal analysis, described in Chapter 3, has allowed the elimination of these heat conduction elements from the MPC design, thus giving this design feature “optional” status.

Lifting lugs attached to the inside surface of the MPC canister shell serve to permit placement of the empty MPC into the overpack, and are considered non-structural, non-pressure retaining attachments to the MPC pressure boundary. The lifting lugs also serve to axially locate the MPC lid prior to welding. These internal lifting lugs are not used to handle a loaded MPC, since the MPC lid blocks access to the lifting lugs.

The top 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 (fabricated from one piece, or two pieces - split top and bottom) that is edge-welded to the MPC shell. If the two-piece lid design is employed, only the top piece is analyzed as part of the enclosure vessel pressure boundary. The bottom piece acts primarily as a radiation shield and is attached to the top piece with a non-structural, non-pressure retaining weld, as depicted on the MPC enclosure vessel drawing in Section 1.4. The MPC lid is equipped with vent and drain ports that are used to remove moisture and gas from the MPC and backfill the MPC with a specified pressure of inert gas (helium). The vent and drain ports are sealed closed by cover plates welded to the MPC lid before the closure ring is installed. The closure ring is a circular ring edge-welded to the MPC shell and MPC lid. The MPC lid provides sufficient rigidity to allow the entire MPC loaded with SNF to be lifted by the threaded holes in the MPC lid during transfer from the storage-only HI-STORM 100 System to the HI-STAR 100 overpack for transportation. Threaded insert plugs are installed to provide shielding when the threaded holes are not in use.

All MPCs are designed to handle intact fuel assemblies, damaged fuel assemblies, and fuel classified as fuel debris. Damaged fuel and fuel debris must be transported in damaged fuel containers or other approved damaged/failed fuel canister. At this time, only BWR damaged fuel and fuel debris from the Dresden Unit 1 and Humboldt Bay plants is certified for transportation in the MPC-68 and the MPC-68F. Similarly, only PWR damaged fuel and fuel debris from the

Trojan plant is certified for transportation in the Trojan plant-specific MPC-24E and the MPC-24EF. The definitions, and applicable specifications for all authorized contents, including the requirements for canning certain fuel, are provided in Subsection 1.2.3.

Intact SNF can be placed directly into the MPC. Damaged SNF and fuel debris must be placed into a Holtec damaged fuel container or other authorized canister for transportation inside the MPC and the HI-STAR 100 overpack. Figures 1.2.10 through 1.2.11 provide sketches of the containers authorized for transportation of damaged fuel and fuel debris in the HI-STAR 100 System. One Dresden Unit 1 Thoria rod canister, shown in Figure 1.2.11A, is also authorized for transportation in HI-STAR 100.

In order to qualify the MPC-68F and MPC-24EF shells as a secondary containment boundary for the transportation of Dresden Unit 1/Humboldt Bay and Trojan plant fuel debris, respectively, the MPC-68 and MPC-24E enclosure vessels have been slightly modified to further strengthen the lid-to-shell joint area. These fuel debris MPCs are given the "F" suffix (hence, MPC-68F and MPC-24EF)[†]. The differences between the standard and "F-model" MPC lid-to-shell joints are shown on Figure 1.2.17, and include a thickened upper shell, a larger lid-to-shell weld size, and a correspondingly smaller lid diameter. The design of the rest of the enclosure vessel is identical between the standard MPC and the "F-model" MPC.

The MPC-68F and MPC-24EF provide the separate inner container per 10CFR71.63(b) for the HI-STAR 100 System transporting fuel classified as fuel debris to ensure double containment. The overpack containment boundary provides the primary containment boundary.

1.2.1.2.2.2 MPC-24/24E/24EF

The MPC-24 is designed to transport up to 24 PWR intact fuel assemblies meeting the limits specified in Subsection 1.2.3. The MPC 24E is designed to transport up to 24 PWR intact and up to four PWR damaged fuel assemblies in damaged fuel containers. The MPC-24EF is designed to transport up to 24 PWR intact fuel assemblies and up to four PWR damaged fuel assemblies or fuel assemblies classified as fuel debris. At this time, however, generic PWR damaged fuel and fuel debris are not authorized for transportation in the MPC-24E/EF.

All MPC-24-series fuel baskets employ the flux trap design for criticality control, as shown in the drawings in Section 1.4. The fuel basket design for the MPC-24E is an enhanced MPC-24 basket layout designed to improve the fuel storage geometry for criticality control. The fuel basket design of the MPC-24EF is identical to the MPC-24E. The MPC-24E/EF basket designs also employ a higher ^{10}B loading than the MPC-24, as shown in Table 1.2.3. The differences between the MPC-24EF enclosure vessel design and the MPC-24/24E enclosure vessel are discussed in Subsection 1.2.1.2.2.1.

† The drawing in Section 1.4 also denotes an MPC-68FF fuel debris canister design. However, the MPC-68FF is not authorized for use in transportation under the HI-STAR 100 10 CFR 71 CoC.

1.2.1.2.2.3 Trojan Plant MPC-24E/EF

The Trojan plant MPC-24E and -24EF models are designs that have been customized for that plant's fuel and the concrete storage cask being used at the Trojan plant Independent Spent Fuel Storage Installation (ISFSI) (Docket 72-0017). The design features that are unique to the Trojan plant MPCs are specifically noted on the MPC enclosure vessel and MPC-24E/EF fuel basket drawings in Section 1.4. These differences include:

- a shorter MPC fuel basket and cavity length to match the shorter Trojan fuel assembly length

- shorter corner fuel storage cell lengths to accommodate the Trojan Failed Fuel Cans

- a different fuel storage cell and flux trap dimension in the corner cells to accommodate the Trojan Failed Fuel Cans

- a different configuration of the flow holes at the bottom of the fuel basket (rectangular vs. semi-circular)

All other design features in the Trojan MPCs are identical to the generic MPC-24E/EF design. The HI-STAR 100 overpack design has not been modified for the Trojan MPC design.

The technical analyses described in this SAR were verified in most cases to bound the Trojan-specific design features. Where necessary, Trojan plant-specific evaluations were performed and are summarized in the appropriate SAR section. To accommodate the shorter Trojan plant MPC length in a standard-length HI-STAR 100 overpack, a spacer was designed for installation into the overpack above the Trojan MPC (see Figure 1.1.5 and the drawing in Section 1.4) for transportation in the standard-length HI-STAR 100 overpack. This spacer prevents the MPC from moving more than the MPC was analyzed to move in the axial direction and serves to transfer the axial loads from the MPC lid to the overpack top closure plate within the limits of the supporting analyses. See Section 2.7.1.1 for additional discussion of the spacer used with the Trojan MPC design. Hereafter in this SAR, the Trojan plant-specific MPC design is only distinguished from the generic MPC-24E/EF design when necessary to describe unique evaluations performed for those MPCs.

1.2.1.2.2.4 MPC-32

NOTE: The MPC-32 is not certified for transportation at this time.

The MPC-32 is designed to transport up 32 PWR intact fuel assemblies meeting the specifications in Subsection 1.2.3. Damaged fuel and fuel debris are not permitted to be transported in the MPC-32. The MPC-32 enclosure vessel design is identical to the MPC-24/24E enclosure vessel design as shown on the drawings in Section 1.4. The MPC-32 fuel basket does not employ flux traps for criticality control. Credit for burnup of the fuel is taken in the criticality analyses for accident conditions and to meet the requirements of 10 CFR 71.55(b). Because the MPC is designed to preclude the intrusion of moderator under all normal and credible accident conditions of transport, the moderator intrusion condition analyzed as required by 10 CFR 71.55(b) is a non-mechanistic event for the HI-STAR 100 System.

1.2.1.2.2.5 MPC-68/68F

The MPC-68 is designed to transport up to 68 BWR intact fuel assemblies and damaged fuel assemblies meeting the specifications in Subsection 1.2.3. Zircaloy channels are permitted. At this time, only damaged fuel from the Dresden Unit 1 and Humboldt Bay plants is authorized for transportation in the MPC-68. The MPC-68F is designed to transport only fuel and other authorized material from the Dresden Unit 1 and Humboldt Bay plants meeting the specifications in Subsection 1.2.3. The sole difference between the MPC-68 and MPC-68F fuel basket design is a reduction in the required ^{10}B areal density in the Boral. A reduction in the required ^{10}B areal density of the Boral is possible for the MPC-68F due to limited types of fuel and low enrichments permitted to be transported in this MPC model. The differences between the MPC-68F enclosure vessel design and the MPC-68 enclosure vessel are discussed in Subsection 1.2.1.2.2.1.

1.2.1.2.2.6 Alloy X

The HI-STAR MPC is constructed entirely from stainless steel alloy materials (except for the neutron absorber and aluminum vent and drain cap seal washers in all MPCs, and the aluminum heat conduction elements in the first several production units of MPC-68 and MPC–68F). No carbon steel parts are used in the design of the HI-STAR 100 MPC. Concerns regarding interaction of coated carbon steel materials and various MPC operating environments [1.2.1] are not applicable to the HI-STAR MPCs. All structural components in a HI-STAR MPC will be fabricated of Alloy X, a designation that warrants further explanation.

Alloy X is a fictitious material that should be acceptable as a Mined Geological Depository System (MGDS) waste package and that 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 that 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 SAR) may be one of the following materials. Any steel part in an MPC may be fabricated from any of the acceptable Alloy X materials listed below, except that all steel pieces comprising the MPC shell (i.e., the 1/2" thick cylinder) must be fabricated from the same Alloy X stainless steel type:

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

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 exceed the analytical predictions contained in this document.

1.2.1.3 Impact Limiters

The HI-STAR 100 overpack is fitted with aluminum honeycomb impact limiters, termed AL-STAR™, one at each end, once the overpack is positioned and secured in the transport frame. The impact limiters ensure the inertia loadings during the normal and hypothetical accident conditions of transport are maintained below design levels. The impact limiter design is discussed further in Chapter 2 and drawings are provided in Section 1.4.

1.2.1.4 Shielding

The HI-STAR 100 System is provided with shielding to minimize personnel exposure. The HI-STAR 100 System will be transported by exclusive use shipment to ensure the external radiation requirements of 10CFR71.47 are met. During transport, a personnel barrier is installed to restrict access to the overpack to protect personnel from the HI-STAR 100 exterior surface temperature in accordance with 10CFR71.43(g). The personnel barrier provides a stand-off equal to the exterior radial dimension of the impact limiters. Figure 1.2.8 provides a sketch of the personnel barrier being installed.

The initial attenuation of gamma and neutron radiation emitted by the radioactive spent fuel is provided by the MPC fuel basket structure built from inter-welded plates and Boral neutron poison panels with sheathing attached to the fuel 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. No shielding credit is taken for the aluminum heat conduction elements installed in some of the early production MPC-68 and MPC-68F units.

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 outside 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 top closure plate. During transport, the impact limiters will provide incremental gamma shielding and provide additional distance from the radiation source at the ends of the package. An additional circular segment of neutron shielding is contained within each impact limiter to provide neutron attenuation.

1.2.1.4.1 <u>Boral Neutron Absorber</u>

Boral is a thermal neutron poison material composed of boron carbide and aluminum alloy 1100. 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 aluminum alloy 1100 is a lightweight metal with high tensile strength that 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 many cask designs.

Boral has been licensed by the NRC 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 the neutron absorbing material can be attributed to its proven performance and several unique characteristics, such as:

- The content and placement of boron carbide provides a very high removal cross section for thermal neutrons.

- Boron carbide, in the form of fine particles, is homogeneously dispersed throughout the central layer of the Boral panels.

- The boron carbide and aluminum materials in Boral do not degrade as a result of long-term exposure to radiation.

- The neutron absorbing central layer of Boral is clad with permanently bonded surfaces of aluminum.

- 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 10CFR71, Subpart H and 10CFR72, Subpart G. Holtec International has procured over 200,000 panels of Boral from AAR Advanced Structures for 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 <u>never</u> 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 with full compliance with the stipulated minimum loading. Furthermore, the surveillance, coupon testing, and material tracking processes that 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.

~~The oxide layer that is created from the reaction of the outer aluminum cladding and the edges of the Boral panels with air and water provides a barrier to further reaction of the aluminum cladding with air or the spent fuel pool water during loading and unloading operations. However, with extended submergence in an MPC filled with water or in the plant's spent fuel pool, the hydrostatic pressure can drive water into the Boral core (comprised of particulate B_4C and aluminum powder) where previously unexposed aluminum powder may react with the water to create hydrogen. The rate of hydrogen generation and the total hydrogen generated is dependent on several variables:~~

- ~~Aluminum particle size: Aluminum particle size in the Boral core and associated porosity affects the amount of aluminum available for reaction with water. Larger aluminum particles yield less surface area for reaction, but higher porosity for aluminum-water interaction; smaller aluminum particles yield more surface area for reaction, but lower porosity for aluminum-water reaction.~~

- ~~Presence of trace impurities: The presence of trace impurities in the Boral core due to the manufacturing process (i.e., sodium hydroxide, boron oxide, and iron oxide) can affect the rate of hydrogen production, both increasing and suppressing the reaction. Sodium dissolved in the water increases the pH and tends to increase the rate of hydrogen production. This is counteracted by the boron oxide, which hydrolyzes to boric acid (H_3BO_3) and reduces the rate of hydrogen production. Trace impurities do not affect the total amount of hydrogen generated.~~

- ~~Pool water chemistry: Chemicals in the plant spent fuel pool water (e.g., copper, boron) can affect the rate of hydrogen production, both increasing (copper) and suppressing (boron) the reaction.~~

- ~~MPC loading operations: Operating needs or preferences by individual utilities as to when, and for how long the MPC is kept at varying water depths in the spent fuel pool, and how long the MPC is kept filled with water outside the spent fuel pool can affect the amount of aluminum in the Boral core that may be exposed to water.~~

Operating experience in nuclear plants with fuel loading of Boral equipped MPCs as well as laboratory test data indicate that the aluminum used in the manufacture of the Boral may react with water, resulting in the generation of hydrogen. The numerous variables (i.e., aluminum particle size, pool temperature, pool chemistry, etc.) that influence the extent of the hydrogen produced make it impossible to predict the amount of hydrogen that may be generated during MPC loading or unloading at a particular plant. Therefore, d~~D~~ue to the variability in hydrogen generation from the Boral-water reaction, the operating procedures in Chapter 7 require monitoring for combustible gases and either exhausting or purging the space beneath the MPC lid during loading and unloading operations when an ignition event could occur (i.e., when the space beneath the MPC lid is open to the welding or cutting operation).

1.2.1.4.2 Holtite-A™ Neutron Shielding

The specification for the overpack and impact limiter 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 that 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 nominal 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 assumed to be 1.61 g/cm^3 to underestimate the shielding capabilities of the neutron shield.

Hydrogen

The nominal 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% (nominal) 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 1.2.2 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 accident analyses.

The Holtite-A neutron shielding material is stable at normal design temperatures over the long term and provides excellent shielding properties for neutrons.

1.2.1.4.3 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 is constructed from two halves. The two halves of the shell are precision sheared, beveled, 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 beveled edges to be joined are positioned to make contact or have a slight 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 1.2.7).

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 used in other designs.

- Post-weld heat treatment is not required by the ASME Code, simplifying fabrication.

1.2.1.5 Lifting and Tie-Down Devices

The HI-STAR 100 overpack is equipped with two lifting trunnions located in the top flange. The lifting trunnions are designed in accordance with 10CFR71.45, NUREG-0612 [1.2.11], and ANSI N14.6 [1.3.3], manufactured from a high strength alloy, and are installed in threaded openings. The lifting trunnions may be secured in position by optional locking pads, shaped to make conformal contact with the curved overpack. Once the locking pad is bolted in position, the inner diameter is sized to restrain the trunnion from backing out. The two off-center pockets located near the overpack bottom plate on overpack serial numbers 1020-001 through 1020-007 are pocket trunnions. The pocket trunnions were eliminated from the design after serial number 1020-007 was fabricated and are no longer considered qualified tie-down devices. However, the pocket trunnions on these overpacks may still be used for normal handling activities such as upending and downending.

The lifting, upending, and downending of the HI-STAR 100 System requires the use of external handling devices. A lifting yoke is utilized when the cask is to be lifted or set in a vertical orientation. For those overpacks that have been fabricated with the pocket trunnions, transport and rotation cradles may include rotation trunnions that interface with the pocket trunnions to provide a pivot axis. A lift yoke may be connected to the lifting trunnions and the crane hook used for upending or downending the HI-STAR 100 System by rotating on the pocket trunnions for these overpacks. For those overpacks fabricated without pocket trunnions, the overpack must be transferred into the transport saddle with appropriate lift rigging. If an overpack having pocket trunnions is secured to the transport vehicle without engaging the pocket trunnions, plugs are required to be installed in the pocket to provide radiation shielding (see the overpack drawing in Section 1.4).

For transportation, the HI-STAR 100 System is engineered to be mounted on a transport frame secured to the transporter bed. Figure 1.2.8 provides a sketch of the HI-STAR 100 System secured for transport and the drawing in Section 1.4 provides additional details. The transport frame has a lower saddle with attachment points for belly slings around the cask body designed to prevent excessive vertical or lateral movement of the cask during normal transportation. The impact limiters affixed to both ends of the cask are designed to transmit the design basis axial loads into the cradle structure. See Section 2.5 for discussion of the qualification of tie-down devices.

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. For users of the HI-STORM 100 Dry Storage System, 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 100 overpack (storage-only) to the HI-STAR 100 overpack, or vice versa. The threaded holes in the MPC lid are designed in accordance with NUREG-0612 and ANSI N14.6 and are plugged during transportation to prevent radiation streaming.

1.2.1.6 Heat Dissipation

The HI-STAR 100 System can safely transport SNF by maintaining the fuel cladding temperature below the limits specified in Table 1.2.3 for normal and accident conditions. These limits have been established consistent with the guidance in NRC Interim Staff Guidance (ISG) document No. 11, Revision 2 (Ref. [1.2.14]). The temperature of the fuel cladding is dependent on the decay heat and the heat dissipation capabilities of the cask. The total heat load per BWR and PWR MPC is identified in Table 1.2.3. The SNF decay heat is passively dissipated without any mechanical or forced cooling.

The HI-STAR 100 System must meet the requirements of 10CFR71.43(g) for the accessible surface temperature limit. To meet this requirement the HI-STAR 100 System is shipped as an exclusive use shipment and includes an engineered personnel barrier during transport.

The primary heat transfer mechanisms in the HI-STAR 100 System are conduction and surface radiation.

The free volume of the MPC and the annulus between the external surface of the MPC and the inside surface of the overpack containment boundary are filled with 99.995% pure helium gas during fuel loading operations. Table 1.2.3 specifies the acceptance criteria for helium fill pressure in the MPC internal cavity. Besides providing an inert dry atmosphere for the fuel cladding, the helium also provides conductive heat transfer across any gaps between the metal surfaces inside the MPC and in the annulus between the MPC and overpack containment boundary. Metal conduction transfers the heat throughout the MPC fuel basket, through the MPC aluminum heat conduction elements (if installed) and shell, through the overpack inner shell, intermediate shells, steel radial connectors and finally, to the outer neutron shield enclosure shell. 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 3. The thermal analysis in Chapter 3 no longer takes credit for the aluminum heat conduction elements and they have been designated as optional equipment.

1.2.1.7 Coolants

There are no coolants utilized in the HI-STAR 100 System. As discussed in Subsection 1.2.1.6 above, helium is sealed within the MPC internal cavity. The annulus between the MPC outer surface and overpack containment boundary is also purged and filled with helium gas.

1.2.1.8 Pressure Relief Systems

No pressure relief system is provided on the HI-STAR 100 packaging containment boundary.

The sole pressure relief devices are provided in the overpack outer enclosure (Figure 1.1.4). The overpack outer enclosure contains the neutron shield material. Normal loadings will not cause the rupture disks to open. The rupture disks are installed to relieve internal pressure in the neutron shield cavities caused by the fire accident. The overpack outer enclosure is not designed as a pressure vessel. Correspondingly, the rupture disks are designed to open at relatively low pressures as stated below.

Relief Device location	Set pressure, psig
Overpack outer enclosure	30, +/- 5

1.2.1.9 Security Seal

The HI-STAR 100 packaging provides a security seal that while intact, provides evidence that the package has not been opened by unauthorized persons. When installed, the impact limiters cover all penetrations into the HI-STAR 100 packaging containment boundary. Therefore, the security seal is placed to ensure that the impact limiters are not removed which thereby ensures that the package has not been opened. As shown on the HI-STAR transport assembly drawing in Section 1.4, security seals are provided on one impact limiter attachment bolt on the top impact limiter and through two adjacent bolts on the bottom impact limiter. A hole is provided in the head of the bolt and the impact limiter. Lockwire shall be threaded through the hole and joined with a security seal.

1.2.1.10 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 8, 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

1.2.2 Operational Features

Table 1.2.7 provides the sequence of basic operations necessary to load fuel and prepare the HI-STAR 100 System for transport. More detailed guidance for transportation-related loading, unloading, and handling operations is provided in Chapter 7 and is supported by the drawings in Section 1.4. A summary of the loading and unloading operations is provided below. Figures 1.2.9 and 1.2.16 provide a pictorial view of the loading and unloading operations, respectively.

1.2.2.1 Applicability of Operating Procedures for the Dual-Purpose HI-STAR 100 System

The HI-STAR 100 System is a dual-purpose system certified for use as a dry storage cask under 10 CFR 72 and a transportation package under 10 CFR 71. In addition, the MPC is certified for use under 10 CFR 72 in the storage-only HI-STORM 100 System (a ventilated concrete cask system). Therefore, it is possible that the HI-STAR 100 overpack and/or the MPC may be loaded, prepared, and sealed under the operating procedures for storage, delineated in the HI-STAR 100 storage FSAR (Docket 72-1008) or the HI-STORM 100 storage FSAR (Docket 72-1014). In those cases, the operating procedures governing MPC and overpack preparation for storage would apply. The MPC and HI-STAR 100 overpack, as applicable, must be confirmed to meet all requirements of the Part 71 Certificate of Compliance before being released for shipment.

For those instances where the MPC is being loaded and shipped off-site in a HI-STAR 100 overpack under 10 CFR 71 without first being deployed at an ISFSI (known as “load-and-go” operations), the operating procedures in Chapter 7 (and summarized below) apply for preparation of the MPC and HI-STAR overpack. For those cases where the MPC is transferred from storage in a HI-STORM overpack to a HI-STAR overpack for shipment, the operating procedures in Chapter 7 (and summarized below) govern the preparation activities for the HI-STAR overpack.

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 (borated as required for MPC-32). 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. 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 (foreign material exclusion). If used, the Automated Welding System (AWS) is installed. The MPC water level is lowered slightly and the space under the MPC lid is purged or exhausted and monitoring is performed. The MPC lid is seal-welded using the AWS. Liquid penetrant examinations are performed on the root and final passes and ultrasonic examination is also performed on the MPC lid-to-shell weld or, in place of the ultrasonic examination, the weld may be inspected by multiple-pass liquid penetrant examination at approximately every 3/8 inch of weld depth. 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 the 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. At the appropriate time in the sequence of activities, based on the type of test performed (hydrostatic or pneumatic), a pressure test of the MPC enclosure vessel is performed.

The Forced Helium Dehydration (FHD) System is connected to the MPC and is used to remove residual water from the MPC and reduce the level of moisture in the MPC to acceptable levels. This is accomplished by recirculating dry, heated helium through the MPC cavity to absorb the moisture. When the helium exiting the MPC is determined to meet the required moisture limit, the MPC is considered sufficiently dried for transportation (see Section 3.4.1.1.16 for a description of the FHD System.

Following MPC drying operations, the MPC is backfilled with a predetermined amount of helium gas. The helium backfill ensures adequate heat transfer, provides an inert atmosphere for fuel cladding integrity, and provides the means of future leakage rate testing of the MPC enclosure vessel 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/or final passes, depending on the number of weld passes required. That is, if only a single weld pass is required, only a final liquid penetrant examination is performed. 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 enclosure vessel closure welds. Tack welds are visually examined, and the root and/or final welds (depending on the number of weld passes required) 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 is removed. The overpack closure plate is installed and the bolts are torqued. The overpack annulus is dried using the vacuum drying system (VDS).

If the MPC being transported is an “F-model” canister, a helium leakage test on the canister must be performed to confirm the integrity of the secondary containment boundary prior to backfilling the overpack annulus.

The overpack annulus is 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 the containment 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 overpack penetrations.

The overpack is surveyed for removable contamination and secured on the transport vehicle with impact limiters installed, the security seals are attached, and the personnel barrier is installed. The HI-STAR 100 packaging is then ready for transport.

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 (if necessary), 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.

After removing the impact limiters, the overpack and MPC are positioned in the designated preparation area. At the site's discretion, a gas sample is drawn from the overpack annulus and analyzed. The gas sample provides an indication of MPC enclosure vessel 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. The MPC closure ring and vent and drain port cover plates are core drilled to the extent necessary to allow access by the Remote Valve Operating Assemblies (RVOAs). Local ventilation is established around the vent and drain ports. The RVOAs are connected to allow access to the MPC cavity for re-flooding operations.

The MPC cavity gas is verified to be below an appropriate temperature (approximately 200^{o}F) to allow water flooding. Depending on the time since initial fuel loading and the age and burnup of the contained fuel, mechanical cooling of the MPC cavity gas may or may not be required to ensure the cavity gas temperature meets the acceptance criterion. A thermal evaluation should be performed to determine the MPC bulk cavity gas temperature at the time of unloading. Based on that thermal evaluation, if the MPC cavity gas temperature does not already meet the acceptance limit, any appropriate means to cool the cavity gas may be employed to reduce the gas temperature to the acceptance criterion. Typically, this may involve intrusive means, such as recirculation cooling of the MPC cavity helium, or non-intrusive means, such as cooling of the exterior surface of the MPC enclosure vessel with water or air. The thermal evaluation should include an evaluation of the cooling process, if required, to determine the appropriate criteria for the cooling process, such as fluid flow rate(s), fluid temperature(s), and the cooling duration required to meet the acceptance criterion. Following fuel cool-down (if required), the MPC is flooded with water. The WRS is positioned for MPC lid-to-shell weld removal. The WRS is then removed with the MPC lid left in place.

The annulus shield is removed and 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. The overpack and MPC are returned to the designated preparation area. The annulus water is drained and the MPC and overpack are dispositioned for re-use or waste.

1.2.3 Contents of Package

The HI-STAR 100 packaging is classified as a Type B package under 10CFR71. As the HI-STAR 100 System is designed to transport spent nuclear fuel, the maximum activity of the contents requires that the HI-STAR 100 packaging be classified as Category I in accordance with Regulatory Guide 7.11 [1.2.10]. This section delineates the authorized contents permitted for shipment in the HI-STAR 100 System, including fuel assembly types; non-fuel hardware; neutron sources; physical parameter limits for fuel assemblies and sub-components; enrichment, burnup, cooling time, and decay heat limits; location requirements; and requirements for canning the material.

1.2.3.1 Determination of Design Basis Fuel

The HI-STAR 100 package is designed to transport most types of fuel assemblies generated in the commercial U.S. nuclear industry. Boiling-water reactor (BWR) fuel assemblies have been supplied by General Electric (GE), Siemens (SPC), Exxon Nuclear, ANF, UNC, ABB Combustion Engineering, Allis-Chalmers (AC) 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. [1.2.6], [1.2.7], and [1.2.15] 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 transported in one of the MPCs.

The cell openings in the fuel basket have been sized to accommodate all BWR and PWR assemblies listed in Refs. [1.2.6], [1.2.7], and [1.2.15], except as noted below. Similarly, the cavity length of the MPC has been set at a dimension that permits transportation of most types of PWR fuel assemblies and BWR fuel assemblies with or without fuel channels. The one exception is 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 1.2.15 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 and hypothetical accident conditions of transport. Due to the shorter, custom MPC design for Trojan plant fuel, only lower fuel spacers are needed for certain fuel assemblies that do not contain integral control rod assemblies. This creates the potential for a slight misalignment between the active fuel region of a fuel assembly and the neutron absorber panels affixed to the cell walls of the Trojan MPCs. This condition is addressed in the criticality evaluations described in Chapter 6.

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, containment, shielding, thermal-hydraulic, and criticality criteria. In fact, the same 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. [1.2.6], [1.2.7], and [1.2.15] that is geometrically admissible in the HI-STAR MPC is precluded from loading, 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 1.2.8 lists the PWR fuel assemblies 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 1.2.9. Tables 1.2.10 and 1.2.11 provide the fuel characteristics determined to be acceptable for transport in the HI-STAR 100 System. Each “array/class” listed in these tables represents a bounding set of parameters for one or more fuel assembly types. The array/classes are defined in SAR Section 6.2. Table 1.2.12 lists the BWR and PWR fuel assembly designs that are found to govern for the qualification criteria, namely reactivity, shielding, and thermal. Thermal is broken down into three criteria, namely: 1) fuel assembly effective planar conductivity, 2) fuel basket effective axial conductivity, and 3) MPC density and heat capacity. Substantiating results of analyses for the governing assembly types are presented in the respective chapters dealing with the specific qualification topic. Tables 1.2.10, 1.2.11, and 1.2.21 through 1.2.36 provide the specific limits for all material authorized to be transported in the HI-STAR 100 System. Additional information on the design basis fuel definition is presented in the following subsections.

1.2.3.2 Design Payload for Intact Fuel

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 intact fuel to be transported in the HI-STAR 100 System is provided in Tables 1.2.10, 1.2.11, and 1.2.22 through 1.2.36. 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. Stainless steel clad fuel assemblies are not authorized for transportation in the MPC-68F or MPC-32.

Fuel assemblies without fuel rods in fuel rod locations cannot be classified as intact fuel unless dummy fuel rods, which occupy a volume equal to or greater than the original fuel rods, replace the missing rods prior to loading. Any intact fuel assembly that falls within the geometric, thermal, and nuclear limits established for the design basis intact fuel assembly can be safely transported in the HI-STAR 100 System.

Some Trojan fuel assemblies not loaded into DFCs or FFCs show conditions of minor impairments on some grid straps [1.2.16]. These conditions, as determined by visual inspection of the assemblies, consist of small portions of grid straps that are missing or bent. The worst condition is the exposure of a single fuel rod on the periphery of one grid strap. These conditions do not meet the definition of damaged fuel in the CoC, since the impairment is minor, no grid spacers are missing, and the overall structural integrity of the assembly is not affected. Such assemblies are therefore classified as intact assemblies.

The fuel characteristics specified in Tables 1.2.10, 1.2.11, and 1.2.21 have been evaluated in this SAR and are acceptable for transport in the HI-STAR 100 System.

1.2.3.3 Design Payload for Damaged Fuel and Fuel Debris

Damaged fuel and fuel debris are defined in Table 1.0.1. The only PWR damaged fuel and fuel debris authorized for transportation in the HI-STAR 100 System is that from the Trojan plant. The only BWR damaged fuel and fuel debris authorized for transportation in the HI-STAR 100 System is that from the Dresden Unit 1 and Humboldt Bay plants.

Damaged fuel may only be transported in the MPC-24E, MPC-24EF, MPC-68, or MPC-68F as shown in Tables 1.2.23 through 1.2.26. Fuel debris may only be transported in the MPC-24EF and the MPC-68F as shown in Tables 1.2.24 and 1.2.26. Damaged fuel and fuel debris must be transported in stainless steel Holtec damaged fuel containers (DFCs) or other approved stainless steel damaged/failed fuel canister in the HI-STAR 100 System. The list of approved damaged/failed fuel canisters and associated SAR figures are provided below:

- Holtec-designed Dresden Unit 1 and Humboldt Bay Damaged Fuel Container(Figure 1.2.10)

- Sierra Nuclear-designed Trojan Failed Fuel Can (Figure 1.2.10A) containing Trojan damaged fuel, fuel debris, or Trojan Fuel debris process cans; or containing Trojan Fuel Debris Process Can Capsules (Figure 1.2.10C), which themselves contain Trojan Fuel Debris Process Cans (Figure 1.2.10B).

- Holtec-designed Damaged Fuel Container for Trojan plan fuel (Figure 1.2.10D)

- Dresden Unit 1's TN Damaged Fuel Container (Figure 1.2.11)

- Dresden Unit 1's Thoria Rod Canister (Figure 1.2.11A)

1.2.3.3.1 BWR Damaged Fuel and Fuel Debris

Dresden Unit 1 (UO_2 fuel rods and MOX fuel rods) and Humboldt Bay fuel arrays (Assembly Classes 6x6A, 6x6B, 6x6C, 7x7A, and 8x8A) are authorized for transportation as damaged fuel in the MPC-68 and damaged fuel or fuel debris in the MPC-68F. No other BWR damaged fuel or fuel debris is authorized for transportation.

The limits for transporting Dresden Unit 1 and Humboldt Bay damaged fuel and fuel debris are given in Table 1.2.23 and 1.2.24. The placement of a single damaged fuel assembly in an MPC-68 or MPC-68F, or a single fuel debris damaged fuel container in an MPC-68F necessitates that all fuel assemblies (intact, damaged, or debris) placed in that MPC meet the maximum heat generation requirements specified in Tables 1.2.23 and 1.2.24.

The fuel characteristics specified in Tables 1.2.11, 1.2.23 and 1.2.24 for Dresden Unit 1 and Humboldt Bay fuel arrays have been evaluated in this SAR and are acceptable for transport as damaged fuel or fuel debris in the HI-STAR 100 System. 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.

As Dresden Unit 1 and Humboldt Bay fuel assemblies classified as fuel debris have significant cladding damage, no cladding integrity is assumed. To meet the double containment criteria of 10CFR71.63(b) for plutonium shipments, the MPC-68F provides the secondary containment boundary (separate inner container), while the overpack provides the primary containment boundary.

The fuel characteristics specified in Table 1.2.11 for the Dresden Unit 1 and Humboldt Bay fuel arrays (Assembly Classes 6x6A, 6x6B, 6x6C, 7x7A, and 8x8A) have been evaluated in this SAR and are acceptable for transport as damaged fuel or fuel debris in the HI-STAR 100 System after being placed in a damaged fuel container.

1.2.3.3.2 PWR Damaged Fuel and Fuel Debris

The PWR damaged fuel and fuel debris authorized for transportation in the HI-STAR 100 System is limited to that from the Trojan plant. The limits for transporting Trojan plant damaged fuel and fuel debris in the Trojan MPC-24E/EF are given in Tables 1.2.10, 1.2.25 and 1.2.26. All Trojan plant damaged fuel, and fuel debris listed below is authorized for transportation in the HI-STAR 100 System [1.2.12]:

- Damaged fuel assemblies in Trojan failed fuel cans

- Damaged fuel assemblies in Holtec's Trojan plant PWR damaged fuel container

- Fuel assemblies classified as fuel debris in Trojan failed fuel cans

- Trojan fuel assemblies classified as fuel debris in Holtec's Trojan damaged fuel container

- Fuel debris consisting of loose fuel pellets, fuel pellet fragments, and fuel assembly metal fragments (portions of fuel rods, portions of grid assemblies, bottom nozzles, etc.) in Trojan failed fuel cans

- Trojan fuel debris process cans loaded into Trojan fuel debris process can capsules and then into Trojan failed fuel cans. The fuel debris process cans contain fuel debris (metal fragments) and were used to process organic media removed from the Trojan spent fuel pool during cleanup operations in preparation for decommissioning the pool. The fuel debris process cans have metallic filters in the can bottom and lid that allowed removal of water and organic media using high temperature steam, while retaining the solid residue from the processed media and fuel debris inside the process can[†]. Up to five process cans can be loaded into a process can capsule, which is vacuumed, purged, backfilled with helium, and seal-welded closed to provide a sealed containment for the fuel debris.

One Trojan Failed Fuel Can is not completely filled with fuel debris. Therefore, a stainless steel failed fuel can spacer is installed in this FFC to minimize movement of the fuel debris during normal transportation and hypothetical accident conditions. The spacer is a long, square tube with a baseplate that rests atop the fuel debris inside the Trojan FFC. A drawing of the Trojan failed fuel can spacer is provided in Section 1.4. A summary of the structural analysis of the FFC spacer is provided in Section 2.6.1.3.1.3.

1.2.3.4 Structural Payload Parameters

The main physical parameters of an 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 1.2.22 through 1.2.27 for the various MPC models. The centers of gravity reported in Chapter 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 spacers are designed to withstand normal and accident conditions of transport. 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 1.2.16 and 1.2.17. Due to the custom design of the Trojan MPCs, only lower fuel spacers are required with Trojan plant fuel assemblies not containing non-fuel hardware or neutron sources. In order to qualify for transport in the HI-STAR 100 MPC, the SNF must satisfy the physical parameters listed in Tables 1.2.21 through 1.2.36, as applicable.

[†] The Trojan Fuel Debris Process Cans were used in the spent fuel pool cleanup effort conducted as part of plant decommissioning. This project is complete and not associated with certification of Trojan fuel debris for transportation in the HI-STAR 100 System under 10 CFR 71.

1.2.3.5 Thermal Payload Parameters

The principal thermal design parameter for the fuel is the peak fuel cladding temperature, which is a function of the maximum heat generation rate per assembly 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 lowest thermal performance characteristics. The parameters that define this decay heat design basis fuel are listed in Table 1.2.12. The governing thermal parameters to ensure that the range of SNF discussed previously are bounded by the thermal analysis discussed in detail and specified in Chapter 3. By utilizing these bounding thermal parameters, the calculated peak fuel rod cladding temperatures are conservative for the actual spent fuel assemblies, which are apt to have a higher thermal conductivity.

The peak fuel cladding temperature limit for normal conditions of transport is 400^{o}C (752^{o}F), which is consistent with the guidance in ISG-11, Revision 2 [1.2.14]. Tables 1.2.21 through 1.2.27 provide the maximum heat generation for all fuel assemblies authorized for transportation in the HI-STAR 100 System. The basis for these limits is discussed in Chapter 3.

Finally, the axial variation in the heat emission rate in the design basis fuel is defined based on the axial burnup distribution. For this purpose, the data provided in Refs. [1.2.8], [1.2.9], and [1.2.12] are utilized and summarized in Table 1.2.15 and Figures 1.2.13, 1.2.13A, and 1.2.14, for reference. These distributions are representative of fuel assemblies with the design burnup levels considered. These distributions are used for analysis only, and do not provide a criteria for fuel assembly acceptability for transport in the HI-STAR 100 System.

1.2.3.6 Radiological Payload Parameters

The principal radiological design criteria are the 10CFR71.47 and 10CFR71.51 radiation dose rate and release requirements for the HI-STAR 100 System. The radiation dose rate 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 cool 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 is, therefore, evaluated for different combinations of maximum burnup, minimum cooling time, and minimum enrichment. The shielding design basis intact fuel assembly thus bounds all other intact fuel assemblies.

The design basis dose rates can be met by a variety of burnup levels, cooling times, and minimum enrichments. Tables 1.2.21 through 1.2.36 include the burnup and cooling time values that meet the radiological dose rate requirements for all authorized contents to be transported in each MPC model. The allowable maximum burnup, minimum cooling time, and minimum enrichment limits were chosen strictly based on the dose rate requirements. All allowable burnup, cooling time, and minimum enrichment combinations result in calculated dose rates less than the regulatory dose rate limits.

Table 1.2.15 and Figures 1.2.13. 1.2.13A, and 1.2.14 provide the axial distribution for the radiological source term for PWR and BWR fuel assemblies, and for Trojan plant-specific fuel, based on the actual burnup distribution. The axial burnup distributions are representative of fuel assemblies with the design basis burnup levels considered. These distributions are used for analysis only, and do not provide criteria for fuel assembly acceptability for transport in the HI-STAR 100 System.

Thoria rods placed in Dresden Unit 1 Thoria Rod Canisters meeting the requirements of Table 1.2.21 and Dresden Unit 1 fuel assemblies with one Antimony-Beryllium neutron source have been qualified for transport. 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 transported.

1.2.3.7 Criticality Payload Parameters

As discussed earlier, the MPC-68/68F and MPC-32 feature a basket without flux traps. In these fuel baskets, there is one panel of neutron absorber between adjacent fuel assemblies. The MPC-24/24E/24EF 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 flux trap basket can accept a much higher enrichment fuel than a non-flux trap basket without taking credit for fuel assembly burnup in the criticality analysis. The maximum initial ^{235}U enrichment for PWR and BWR fuel authorized for transport is specified by fuel array/class in Tables 1.2.10 and 1.2.11, respectively. Trojan plant fuel is limited to a lower maximum initial enrichment of 3.7 wt.% ^{235}U compared to other fuel in its array/class, based on the specific analysis performed for the custom-designed Trojan MPCs containing only Trojan plant fuel.

The MPC-24 Boral ^{10}B areal density is specified at a minimum loading of 0.0267 g/cm^2. The MPC-24E/EF, MPC-32, and 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 loading 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. The reduction in ^{10}B areal density credit meets NUREG-1617 [1.0.5], 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.

Credit for burnup of the fuel, in accordance with the intent of the guidance in Interim Staff Guidance Document 8 (ISG-8) [1.2.13], is taken in the criticality analysis to allow the transportation of certain PWR fuel assemblies in MPC-32. Burnup credit is a required input to qualify PWR fuel for transportation in the MPC-32, considering the inleakage of moderator (i.e., unborated water) under accident conditions. This hypothetical event is non-credible given the double barrier design engineered into the HI-STAR 100 System with the fully welded MPC enclosure vessel (designed for 60 g's) surrounded by the sealed overpack, which is designed for deep submersion under water (greater than 650 feet submersion) without breach. The details of the burnup credit analyses are provided in Chapter 6, including detailed discussion of how the recommendations of ISG-8 were implemented. Exceptions to some of the recommendations in ISG-8 were necessary (e.g., partial credit for fission products) in order to develop burnup versus enrichment curves that can be practically implemented at the plants. These exceptions are described in Chapter 6.

1.2.3.8 Non-Fuel Hardware and Neutron Sources

BWR fuel is permitted to be stored with or without Zircaloy channels. Control blades and stainless steel channels are not authorized for transportation in the HI-STAR 100 System. Dresden Unit 1 (D-1) neutron sources are authorized for transportation a shown in Tables 1.2.23 and 1.2.24. The D-1 neutron sources are single, long rods containing Sb-Be source material that fits into a water rod location in a D-1 fuel assembly.

Except for Trojan plant fuel, no PWR non-fuel hardware or neutron sources are authorized for transportation in the HI-STAR 100 System. For Trojan plant fuel only, the following non-fuel hardware and neutron sources are permitted for transportation in specific quantities as shown in Tables 1.2.25 and 1.2.26:

- Rod Cluster Control Assemblies (RCCAs) with cladding made of Type 304 stainless steel and Ag-In-Cd neutron absorber material.

- Burnable Poison Rod Assemblies (BPRAs) with cladding made of Type 304 stainless steel and borosilicate glass tube neutron poison material.

- Thimble Plug Devices made of Type 304 stainless steel.

- Neutron source assemblies with cladding made of Type 304 stainless steel - two (2) californium primary source assemblies and four (4) antimony-beryllium secondary source assemblies.

These devices are designed with thin rods of varying length and materials as discussed above, that fit into the fuel assembly guide tubes within the fuel rod lattice. The upper fittings for each device can vary to accommodate the handling tool (grapple) design. During reactor operation, the positions of the RCCAs are controlled by the operator using the control rod drive system, while the BPRAs, TPDs, and neutron sources stay fully inserted.

A complete list of the authorized non-fuel hardware and neutron sources, including appropriate limits on the characteristics of this material, is provided in Tables 1.2.23 through 1.2.36, as applicable.

1.2.3.9 Summary of Authorized Contents

The criticality safety index for the HI-STAR 100 Package is zero. A fuel assembly is acceptable for transport in a HI-STAR 100 System if it fulfills the following criteria.

a. It satisfies the physical parameter characteristics listed in Tables 1.2.10 or 1.2.11, as applicable..

b. It satisfies the cooling time, decay heat, burnup, enrichment, and other limits specified in Tables 1.2.21 through 1.2.36, as applicable.

c. Deleted.

d. Deleted.

A damaged fuel assembly shall be transported in a damaged fuel container or other authorized damaged/failed fuel canister, and shall meet the characteristics specified in Tables 1.2.23 through 1.2.26 for transport in the MPC-68, MPC-68F, MPC-24E, or MPC-24EF. Fuel classified as fuel debris shall be placed in a damaged fuel container or other authorized damaged/failed fuel canister and shall meet the characteristics specified in Tables 1.2.24 or 1.2.26 for transport in the MPC-68F or MPC-24EF.

Stainless steel clad fuel assemblies shall meet the characteristics specified in Tables 1.2.22 through 1.2.33 for transport in the MPC-24, MPC-24E, MPC-24EF, or MPC-68.

MOX BWR fuel assemblies shall meet the requirements of Tables 1.2.23 or 1.2.24 for intact and damaged fuel/fuel debris.

Thoria rods placed in Dresden Unit 1 Thoria Rod Canisters meeting the requirements of Table 1.2.21 and Dresden Unit 1 fuel assemblies with one Antimony-Beryllium neutron source have been qualified for transport. 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 transported.

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

Table 1.2.2 summarizes the key system data for the HI-STAR 100 System. Table 1.2.3 summarizes the key parameters and limits for the HI-STAR 100 MPCs. Tables 1.2.10, 1.2.11, and 1.2.21 through 1.2.37 and other tables referenced from these tables provide the limiting conditions for all material to be transported in the HI-STAR 100 System.

Table 1.2.1

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Table 1.2.2

SUMMARY OF KEY SYSTEM DATA FOR HI-STAR 100

PARAMETER	VALUE (Nominal)	
Types of MPCs in this SAR	6	4 for PWR 2 for BWR
MPC capacity	MPC-24	Up to 24 intact ZR or stainless steel clad PWR fuel assemblies
	MPC-24E	Up to 24 intact ZR or stainless steel clad PWR fuel assemblies. Up to four (4) Trojan plant fuel assemblies classified as damaged fuel, each in a Trojan Failed Fuel Can or a Holtec damaged fuel container, and the complement intact fuel assemblies.
	MPC-24EF	Up to 24 intact ZR or stainless steel clad PWR fuel assemblies. Up to four (4) Trojan plant fuel assemblies classified as damaged fuel or fuel debris, each in a Trojan Failed Fuel Can or a Holtec damaged fuel container; or other Trojan fuel debris stored in Trojan Process Cans either placed directly into a Trojan Failed Fuel Can or placed inside Trojan Process Can Capsules and then in Trojan Failed Fuel Cans; and the complement intact fuel assemblies.
	MPC-32	Up to 32 intact ZRclad PWR fuel assemblies.
	MPC-68	Up to 68 intact ZR or stainless steel clad BWR fuel assemblies or damaged ZR clad fuel assemblies* in damaged fuel containers within an MPC-68
	MPC-68F	Up to 4 damaged fuel containers with ZR clad BWR fuel debris* and the complement intact or damaged* ZR clad BWR fuel assemblies within an MPC-68F. *Only damaged fuel and fuel debris from Dresden Unit 1 or Humboldt Bay is authorized for transportation in the MPC-68 and MPC-68F.

Table 1.2.3
KEY PARAMETERS FOR HI-STAR 100 MULTI-PURPOSE CANISTERS

PARAMETER	PWR	BWR
Unloaded MPC weight (lb)	See Table 2.2.1	See Table 2.2.1
Minimum neutron absorber ^{10}B loading (g/cm^2)	0.0267 (MPC-24) 0.0372 (MPC-24E/EF) 0.0372 (MPC-32)	0.0372 (MPC-68) 0.01 (MPC-68F)
Pre-disposal service life (years)	40	40
Design temperature, max./min. (^oF)	$725^{o\dagger}/-40^{o\dagger\dagger}$	$725^{o\dagger}/-40^{o\dagger\dagger}$
Design Internal pressure (psig) Normal Conditions Off-normal Conditions Accident Conditions	 100 100 200	 100 100 200
Total heat load, max. (kW)	20.0	18.5
Maximum permissible peak fuel cladding temperature (^oF)	752^o (normal conditions) 1058^o (accident conditions)	752^o (normal conditions) 1058^o (accident conditions)
MPC internal environment Helium filled (psig)	$\geq$ 0 and $\leq$ 44.8 psig††† at a reference temperature of 70^oF	$\geq$ 0 and $\leq$ 44.8 psig††† at a reference temperature of 70^oF
MPC external environment/overpack internal environment Helium filled initial pressure (psig, at STP)	$\geq$ 10 and $\leq$ 14	$\geq$ 10 and $\leq$ 14
Maximum permissible reactivity including all uncertainty and biases	<0.95	<0.95
End closure(s)	Welded	Welded
Fuel handling	Opening compatible with standard grapples	Opening compatible with standard grapples
Heat dissipation	Passive	Passive

† Maximum normal condition design temperature for the MPC fuel basket. A complete listing of design temperatures for all components is provided in Table 2.1.2

†† Temperature based on minimum ambient temperature (10CFR71.71(c)(2)) and no fuel decay heat load.

††† This value represents the nominal backfill value used in the thermal analysis, plus 2 psig operating tolerance. Based on the MPC pressure results in Table 3.4.15 and the pressure limits specified in Table 2.1.1, there is sufficient analysis margin to accommodate this operating tolerance.

Tables 1.2.4 through 1.2.6

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Table 1.2.7

HI-STAR 100 LOADING OPERATIONS DESCRIPTION

Site-specific handling and operating 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 to 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, examined, pressure tested, and leak tested
5	MPC dewatered, 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 pre-tensioned
8	Overpack cavity dried, backfilled with helium, and helium leak tested
9	HI-STAR 100 System transferred to transport bay
10	HI-STAR 100 placed onto transport saddles, tied down, impact limiters and personnel barrier installed, and package surveyed for release for transport.

Table 1.2.8

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 except System 80™
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, except MOX)	All
Indian Point 1	All

Table 1.2.9

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 1.2.10
PWR FUEL ASSEMBLY CHARACTERISTICS (Note 1)

Fuel Assembly Array/Class	**14x14A**	**14x14B**	**14x14C**	**14x14D**	**14x14E**
Clad Material (Note 2)	ZR	ZR	ZR	SS	SS
Design Initial U (kg/assy.) (Note 3)	≤ 407	≤ 407	≤ 425	≤ 400	≤ 206
Initial Enrichment (MPC-24, 24E, and 24EF) (wt % ^{235}U)	≤ 4.6 (24) ≤ 5.0 (24E/24EF)	≤ 4.6 (24) ≤ 5.0 (24E/24EF)	≤ 4.6 (24) ≤ 5.0 (24E/24EF)	≤ 4.0 (24) ≤ 5.0 (24E/24EF)	≤ 5.0
Initial Enrichment (MPC-32) (wt % ^{235}U) (Note 5)	N/A	N/A	N/A	N/A	N/A
No. of Fuel Rod Locations	179	179	176	180	173
Fuel Clad O.D. (in.)	≥ 0.400	≥ 0.417	≥ 0.440	≥ 0.422	≥ 0.3415
Fuel Clad I.D. (in.)	≤ 0.3514	≤ 0.3734	≤ 0.3880	≤ 0.3890	≤ 0.3175
Fuel Pellet Dia. (in.)	≤ 0.3444	≤ 0.3659	≤ 0.3805	≤ 0.3835	≤ 0.3130
Fuel Rod Pitch (in.)	≤ 0.556	≤ 0.556	≤ 0.580	≤ 0.556	Note 6
Active Fuel Length (in.)	≤ 150	≤ 150	≤ 150	≤ 144	≤ 102
No. of Guide and/or Instrument Tubes	17	17	5 (Note 4)	16	0
Guide/Instrument Tube Thickness (in.)	≥ 0.017	≥ 0.017	≥ 0.038	≥ 0.0145	N/A

Table 1.2.10 (continued)
PWR FUEL ASSEMBLY CHARACTERISTICS (Note 1)

Fuel Assembly Array/Class	**15x15A**	**15x15B**	**15x15C**	**15x15D**	**15x15E**	**15x15F**
Clad Material (Note 2)	ZR	ZR	ZR	ZR	ZR	ZR
Design Initial U (kg/assy.) (Note 3)	≤ 464	≤ 464	≤ 464	≤ 475	≤ 475	≤ 475
Initial Enrichment (MPC-24, 24E, and 24EF (wt % ^{235}U)	≤ 4.1 (24) ≤ 4.5 (24E/24EF)	≤ 4.1 (24) ≤ 4.5 (24E/24EF)	≤ 4.1 (24) ≤ 4.5 (24E/24EF)	≤ 4.1 (24) ≤ 4.5 (24E/24EF)	≤ 4.1 (24) ≤ 4.5 (24E/24EF)	≤ 4.1 (24) ≤ 4.5 (24E/24EF)
Initial Enrichment (MPC-32) (wt % ^{235}U) (Note 5)	N/A	N/A	N/A	≤ 5.0	≤ 5.0	≤ 5.0
No. of Fuel Rod Locations	204	204	204	208	208	208
Fuel Clad O.D. (in.)	≥ 0.418	≥ 0.420	≥ 0.417	≥ 0.430	≥ 0.428	≥ 0.428
Fuel Clad I.D. (in.)	≤ 0.3660	≤ 0.3736	≤ 0.3640	≤ 0.3800	≤ 0.3790	≤ 0.3820
Fuel Pellet Dia. (in.)	≤ 0.3580	≤ 0.3671	≤ 0.3570	≤ 0.3735	≤ 0.3707	≤ 0.3742
Fuel Rod Pitch (in.)	≤ 0.550	≤ 0.563	≤ 0.563	≤ 0.568	≤ 0.568	≤ 0.568
Active Fuel Length (in.)	≤ 150	≤ 150	≤ 150	≤ 150	≤ 150	≤ 150
No. of Guide and/or Instrument Tubes	21	21	21	17	17	17
Guide/Instrument Tube Thickness (in.)	≥ 0.0165	≥ 0.015	≥ 0.0165	≥ 0.0150	≥ 0.0140	≥ 0.0140

Table 1.2.10 (continued)
PWR FUEL ASSEMBLY CHARACTERISTICS (Note 1)

Fuel Assembly Array/Class	**15x15G**	**15x15H**	**16x16A**	**17x17A**	**17x17B**	**17x17C**
Clad Material (Note 2)	SS	ZR	ZR	ZR	ZR	ZR
Design Initial U (kg/assy.) (Note 3)	≤ 420	≤ 475	≤ 443	≤ 467	≤ 467	≤ 474
Initial Enrichment (MPC-24, 24E, and 24EF) (wt % ^{235}U)	≤ 4.0 (24) ≤ 4.5 (24E/24EF)	≤ 3.8 (24) ≤ 4.2 (24E/24EF)	≤ 4.6 (24) ≤ 5.0 (24E/24EF)	≤ 4.0 (24) ≤ 4.4 (24E/24EF)	≤ 4.0 (24) ≤ 4.4 (24E/24EF) (Note 7)	≤ 4.0 (24) ≤ 4.4 (24E/24EF)
Initial Enrichment (MPC-32) (wt % ^{235}U) (Note 5)	N/A	≤ 5.0	N/A	≤ 5.0	≤ 5.0	≤ 5.0
No. of Fuel Rod Locations	204	208	236	264	264	264
Fuel Clad O.D. (in.)	≥ 0.422	≥ 0.414	≥ 0.382	≥ 0.360	≥ 0.372	≥ 0.377
Fuel Clad I.D. (in.)	≤ 0.3890	≤ 0.3700	≤ 0.3320	≤ 0.3150	≤ 0.3310	≤ 0.3330
Fuel Pellet Dia. (in.)	≤ 0.3825	≤ 0.3622	≤ 0.3255	≤ 0.3088	≤ 0.3232	≤ 0.3252
Fuel Rod Pitch (in.)	≥ 0.563	≥ 0.568	≥ 0.506	≥ 0.496	≥ 0.496	≥ 0.502
Active Fuel Length (in.)	≤ 144	≤ 150	≤ 150	≤ 150	≤ 150	≤ 150
No. of Guide and/or Instrument Tubes	21	17	5 (Note 4)	25	25	25
Guide/Instrument Tube Thickness (in.)	≥ 0.0145	≥ 0.0140	≥ 0.0400	≥ 0.016	≥ 0.014	≥ 0.020

Table 1.2.10 (continued)
PWR FUEL ASSEMBLY CHARACTERISTICS

Notes:

1. 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 any zirconium-based fuel cladding material authorized for use in a commercial power reactor.

3. Design initial uranium weight is the nominal uranium weight specified for each 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's tolerances.

4. Each guide tube replaces four fuel rods.

5. Minimum assembly average burnup is required per Table 1.2.34.

6. This fuel assembly array/class includes only the Indian Point Unit 1 fuel assembly. This fuel assembly has two pitches in different sectors of the assembly. These pitches are 0.441 inches and 0.453 inches.

7. Trojan plant-specific fuel is governed by the limits specified for array/class 17x17B and will be transported in the custom-designed Trojan MPC-24E/EF canisters. The Trojan MPC-24E/EF design is authorized to transport only Trojan plant fuel with a maximum initial enrichment of 3.7 wt.% ^{235}U.

Table 1.2.11
BWR FUEL ASSEMBLY CHARACTERISTICS (Note 1)

Fuel Assembly Array/Class	**6x6A**	**6x6B**	**6x6C**	**7x7A**	**7x7B**	**8x8A**
Clad Material (Note 2)	ZR	ZR	ZR	ZR	ZR	ZR
Design Initial U (kg/assy.) (Note 3)	$\leq$ 110	$\leq$ 110	$\leq$ 110	$\leq$ 100	$\leq$ 195	$\leq$ 120
Maximum Planar-Average Initial Enrichment (wt % ^{235}U)	$\leq$ 2.7	$\leq$ 2.7 for the UO_2 rods. See Note 4 for MOX rods.	$\leq$ 2.7	$\leq$ 2.7	$\leq$ 4.2	$\leq$ 2.7
Initial Maximum Rod Enrichment (wt % ^{235}U)	$\leq$ 4.0	$\leq$ 4.0	$\leq$ 4.0	$\leq$ 5.5	$\leq$ 5.0	$\leq$ 4.0
No. of Fuel Rod Locations	35 or 36	35 or 36 (up to 9 MOX rods)	36	49	49	63 or 64
Fuel Clad O.D. (in.)	$\geq$ 0.5550	$\geq$ 0.5625	$\geq$ 0.5630	$\geq$ 0.4860	$\geq$ 0.5630	$\geq$ 0.4120
Fuel Clad I.D. (in.)	$\leq$ 0.5105	$\leq$ 0.4945	$\leq$ 0.4990	$\leq$ 0.4204	$\leq$ 0.4990	$\leq$ 0.3620
Fuel Pellet Dia. (in.)	$\leq$ 0.4980	$\leq$ 0.4820	$\leq$ 0.4880	$\leq$ 0.4110	$\leq$ 0.4910	$\leq$ 0.3580
Fuel Rod Pitch (in.)	$\leq$ 0.710	$\leq$ 0.710	$\leq$ 0.740	$\leq$ 0.631	$\leq$ 0.738	$\leq$ 0.523
Active Fuel Length (in.)	$\leq$ 120	$\leq$ 120	$\leq$ 77.5	$\leq$ 80	$\leq$ 150	$\leq$ 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	$\geq$ 0
Channel Thickness (in.)	$\leq$ 0.060	$\leq$ 0.060	$\leq$ 0.060	$\leq$ 0.060	$\leq$ 0.120	$\leq$ 0.100

Table 1.2.11 (continued)
BWR FUEL ASSEMBLY CHARACTERISTICS (Note 1)

Fuel Assembly Array/Class	**8x8B**	**8x8C**	**8x8D**	**8x8E**	**8x8F**	**9x9A**
Clad Material (Note 2)	ZR	ZR	ZR	ZR	ZR	ZR
Design Initial U (kg/assy) (Note 3)	≤ 185	≤ 185	≤ 185	≤ 185	≤ 185	≤ 177
Maximum Planar-Average Initial Enrichment (wt % ^{235}U)	≤ 4.2	≤ 4.2	≤ 4.2	≤ 4.2	≤ 4.0	≤ 4.2
Initial Maximum Rod Enrichment (wt % ^{235}U)	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0
No. of Fuel Rod Locations	63 or 64	62	60 or 61	59	64	74/66 (Note 5)
Fuel Clad O.D. (in.)	≥ 0.4840	≥ 0.4830	≥ 0.4830	≥ 0.4930	≥ 0.4576	≥ 0.4400
Fuel Clad I.D. (in.)	≤ 0.4295	≤ 0.4250	≤ 0.4230	≤ 0.4250	≤ 0.3996	≤ 0.3840
Fuel Pellet Dia. (in.)	≤ 0.4195	≤ 0.4160	≤ 0.4140	≤ 0.4160	≤ 0.3913	≤ 0.3760
Fuel Rod Pitch (in.)	≤ 0.642	≤ 0.641	≤ 0.640	≤ 0.640	≤ 0.609	≤ 0.566
Design Active Fuel Length (in.)	≤ 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
Water Rod Thickness (in.)	≥ 0.034	> 0.00	> 0.00	≥ 0.034	≥ 0.0315	> 0.00
Channel Thickness (in.)	≤ 0.120	≤ 0.120	≤ 0.120	≤ 0.100	≤ 0.055	≤ 0.120

Table 1.2.11 (continued)
BWR FUEL ASSEMBLY CHARACTERISTICS (Note 1)

Fuel Assembly Array/Class	**9x9 B**	**9x9 C**	**9x9 D**	**9x9 E (Note 13)**	**9x9 F (Note 13)**	**9x9 G**
Clad Material (Note 2)	ZR	ZR	ZR	ZR	ZR	ZR
Design Initial U (kg/assy.) (Note 3)	≤ 177	≤ 177	≤ 177	≤ 177	≤ 177	≤ 177
Maximum Planar-Average Initial Enrichment (wt % ^{235}U)	≤ 4.2	≤ 4.2	≤ 4.2	≤ 4.0	≤ 4.0	≤ 4.2
Initial Maximum Rod Enrichment (wt % ^{235}U)	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0	≤ 5.0
No. of Fuel Rod Locations	72	80	79	76	76	72
Fuel Clad O.D. (in.)	≥ 0.4330	≥ 0.4230	≥ 0.4240	≥ 0.4170	≥ 0.4430	≥ 0.4240
Fuel Clad I.D. (in.)	≤ 0.3810	≤ 0.3640	≤ 0.3640	≤ 0.3640	≤ 0.3860	≤ 0.3640
Fuel Pellet Dia. (in.)	≤ 0.3740	≤ 0.3565	≤ 0.3565	≤ 0.3530	≤ 0.3745	≤ 0.3565
Fuel Rod Pitch (in.)	≤ 0.572	≤ 0.572	≤ 0.572	≤ 0.572	≤ 0.572	≤ 0.572
Design Active Fuel Length (in.)	≤ 150	≤ 150	≤ 150	≤ 150	≤ 150	≤ 150
No. of Water Rods (Note 11)	1 (Note 6)	1	2	5	5	1 (Note 6)
Water Rod Thickness (in.)	> 0.00	≥ 0.020	≥ 0.0300	≥ 0.0120	≥ 0.0120	≥ 0.0320
Channel Thickness (in.)	≤ 0.120	≤ 0.100	≤ 0.100	≤ 0.120	≤ 0.120	≤ 0.120

Table 1.2.11 (continued)
BWR FUEL ASSEMBLY CHARACTERISTICS (Note 1)

Fuel Assembly Array/Class	**10x10 A**	**10x10 B**	**10x10 C**	**10x10 D**	**10x10 E**
Clad Material (Note 2)	ZR	ZR	ZR	SS	SS
Design Initial U (kg/assy.) (Note 3)	$\leq$ 186	$\leq$ 186	$\leq$ 186	$\leq$ 125	$\leq$ 125
Maximum Planar-Average Initial Enrichment (wt % ^{235}U)	$\leq$ 4.2	$\leq$ 4.2	$\leq$ 4.2	$\leq$ 4.0	$\leq$ 4.0
Initial Maximum Rod Enrichment (wt % ^{235}U)	$\leq$ 5.0	$\leq$ 5.0	$\leq$ 5.0	$\leq$ 5.0	$\leq$ 5.0
No. of Fuel Rod Locations	92/78 (Note 8)	91/83 (Note 9)	96	100	96
Fuel Clad O.D. (in.)	$\geq$ 0.4040	$\geq$ 0.3957	$\geq$ 0.3780	$\geq$ 0.3960	$\geq$ 0.3940
Fuel Clad I.D. (in.)	$\leq$ 0.3520	$\leq$ 0.3480	$\leq$ 0.3294	$\leq$ 0.3560	$\leq$ 0.3500
Fuel Pellet Dia. (in.)	$\leq$ 0.3455	$\leq$ 0.3420	$\leq$ 0.3224	$\leq$ 0.3500	$\leq$ 0.3430
Fuel Rod Pitch (in.)	$\leq$ 0.510	$\leq$ 0.510	$\leq$ 0.488	$\leq$ 0.565	$\leq$ 0.557
Design Active Fuel Length (in.)	$\leq$ 150	$\leq$ 150	$\leq$ 150	$\leq$ 83	$\leq$ 83
No. of Water Rods (Note 11)	2	1 (Note 6)	5 (Note 10)	0	4
Water Rod Thickness (in.)	$\geq$ 0.030	> 0.00	$\geq$ 0.031	N/A	$\geq$ 0.022
Channel Thickness (in.)	$\leq$ 0.120	$\leq$ 0.120	$\leq$ 0.055	$\leq$ 0.080	$\leq$ 0.080

Table 1.2.11 (continued)
BWR FUEL ASSEMBLY CHARACTERISTICS

NOTES:

1. 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 any zirconium-based fuel cladding material authorized for use in a commercial power reactor.

3. Design initial uranium weight is the nominal uranium weight specified for each assembly by the fuel manufacturer or reactor user. For each BWR 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 rods; 66 full length rods and 8 partial length rods.

6. Square, replacing nine fuel rods.

7. Variable.

8. This assembly 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 rods dividing the assembly into four quadrants.

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

12. This assembly is known as "QUAD+." It 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 or clad O.D., clad I.D., and pellet diameter.

Table 1.2.12

DESIGN BASIS FUEL ASSEMBLY FOR EACH DESIGN CRITERION

Criterion	MPC-68/68F	MPC-24/24E/24EF/32
Reactivity	SPC 9x9-5 (Array/Class 9x9E/F)	B&W 15x15 (Array/Class 15x15F)
Shielding (Source Term)	GE 7x7	B&W 15x15
Fuel Assembly Effective Planar Thermal Conductivity	GE 11 9x9	W 17x17 OFA
Fuel Basket Effective Axial Thermal Conductivity	GE 7x7	W 14x14 OFA
MPC Density and heat Capacity	~~GE 7x7~~Dresden 6x6	W 14x14 OFA

Tables 1.2.13 and 1.2.14

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Table 1.2.15

NORMALIZED DISTRIBUTION BASED ON BURNUP PROFILE

GENERIC FUEL DISTRIBUTION[†]			
Interval	Axial Distance From Bottom of Active Fuel (% of Active Fuel Length)	PWR Fuel Normalized Distribution	BWR Fuel Normalized Distribution
1	0% to 4-1/6%	0.5485	0.2200
2	4-1/6% to 8-1/3%	0.8477	0.7600
3	8-1/3% to 16-2/3%	1.0770	1.0350
4	16-2/3% to 33-1/3%	1.1050	1.1675
5	33-1/3% to 50%	1.0980	1.1950
6	50% to 66-2/3%	1.0790	1.1625
7	66-2/3% to 83-1/3%	1.0501	1.0725
8	83-1/3% to 91-2/3%	0.9604	0.8650
9	91-2/3% to 95-5/6%	0.7338	0.6200
10	95-5/6% to 100%	0.4670	0.2200

TROJAN PLANT FUEL DISTRIBUTION[††]		
Interval	Axial Distance From Bottom of Active Fuel (% of Active Fuel Length)	Normalized Distribution
1	0% to 5%	0.59
2	5% to 10%	0.89
3	10% to 15%	1.03
4	15% to 20%	1.07
5	20% to 25%	1.09
6	25% to 45%	1.10
7	45% to 70%	1.09
8	70% to 75%	1.07
9	75% to 80%	1.05
10	80% to 85%	1.02
11	85% to 90%	0.96
12	90% to 95 %	0.82
13	95% to 100%	0.56

† References [1.2.8] and [1.2.9]

†† Reference [1.2.12]

Table 1.2.16

SUGGESTED PWR UPPER AND LOWER FUEL SPACER LENGTHS (Note 1)

Fuel Assembly Type	**Assembly Length w/o NFH† (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
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 17x17S	159.8	3.7	144	8.2	8.5
W 17x17V5H	160.1	3.7	144	7.9	8.5
W 15x15	159.8	3.7	144	8.2	8.5
W 14x14S	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
Indian Point 1	137.2	17.705	101.5	18.75	20.0

Notes: 1. These fuel spacer lengths are not applicable to Trojan plant fuel. Trojan plant fuel spacer lengths are determined uniquely for the custom-designed Trojan MPC-24E/EF, as necessary, based on the presence of non-fuel hardware. They are sized to maintain the active fuel within the envelope of the neutron absorber affixed to the cell walls and allow for an approximate 2-inch gap between the fuel and the MPC lid. See Chapter 6 for discussion of potential misalignments between the active fuel and the neutron absorber.

† NFH is an abbreviation for non-fuel hardware, including control components. Fuel assemblies with control components may require shorter fuel spacers.

Table 1.2.17

SUGGESTED BWR UPPER AND LOWER FUEL SPACER LENGTHS (Note 1)

Fuel Assembly 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	28.0
Humboldt Bay	95	8	79	40.5	40.5
Dresden 1 Damaged Fuel or Fuel Debris	142.1†	11.2	110	17	16.9
Humboldt Bay Damaged Fuel or Fuel Debris	105.5†	8	79	35.25	35.25
LaCrosse	102.5	10.5	83	37	37.5

Notes: 1. Each user shall specify the fuel spacer lengths based on their fuel length and allowing an approximate 2-inch gap between the fuel and the MPC lid. See Chapter 6 for discussion of potential misalignments between the active fuel and the neutron absorber.

† Fuel length includes the damaged fuel container.

Table 1.2.18

SUMMARY OF HI-STAR 100 SYSTEM POST-ACCIDENT PERFORMANCE

Aspect of Post-Accident Performance	Results with Demonstrated Integrity of MPC Enclosure Vessel	Results with Postulated Gross Failure of MPC Enclosure Vessel
Containment Boundary Integrity	The MPC enclosure vessel is leak tested to 5.0×10^{-6} atm cm^3/s (helium). The overpack containment boundary is standard air leak tested to 4.3×10^{-6} atm cm^3/s (helium). Both boundaries are shown to withstand all hypothetical accident conditions. Therefore, there will be no detectable release of radioactive materials.	The overpack containment boundary is leak tested to 4.3×10^{-6} atm cm^3/s (helium). The overpack containment boundary is shown to withstand all hypothetical accident conditions. Therefore, the overpack containment boundary meets the accident condition leakage rates.
Maintenance of Subcritical Margins (Maximum k_{eff})	The MPC enclosure vessel is seal welded and there is no breach of the MPC. The bolted closure overpack containment boundary has been shown to prevent water immersion. Therefore, the maximum reactivity of the fuel in a dry MPC is less than 0.5.	The bolted closure overpack containment boundary has been shown to prevent water immersion. Therefore, the maximum reactivity of the fuel in a dry MPC is less than 0.5. Assuming the MPC is fully flooded with water, the reactivity is shown to be below the regulatory requirement of 0.95 including uncertainties and bias.
Adequate Shielding	The MPC enclosure vessel boundary has no effect on the dose rates of the HI-STAR 100 System.	Failure of the MPC enclosure vessel to maintain a release boundary has no effect on the dose rates of the HI-STAR 100 System.
Adequate Heat Rejection (Peak Fuel Cladding Temperature)	The MPC enclosure vessel maintains the helium and the peak fuel cladding temperature is demonstrated to remain below 800^{o}F in the post-fire hypothetical accident condition.	Assuming the MPC internal helium fill pressure is released into the overpack containment, the pressure within the small annulus would rise to equalize with the MPC internal pressure. There would be a corresponding slight pressure decrease in the MPC enclosure vessel. The comparatively small volume of the annulus and pressure differential results in the slight pressure change. This will have a negligibly small effect on the peak fuel cladding temperature. The overpack containment boundary is demonstrated to withstand all hypothetical accident conditions. Therefore, there is no credible mechanism for the release of the helium.

Tables 1.2.19 and 1.2.20

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Table 1.2.21

DESIGN CHARACTERISTICS FOR THORIA RODS IN D-1 THORIA ROD CANISTERS

PARAMETER	MPC-68 or MPC-68F
Cladding Type	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	$\leq$ 18
Decay Heat Per Thoria Canister	$\leq$ 115 watts
Post-Irradiation Fuel Cooling Time and Average Burnup Per Thoria Canister	Cooling time $\geq$ 18 years and average burnup $\leq$ 16,000 MWD/MTIHM
Initial Heavy Metal Weight	$\leq$ 27 kg/canister
Fuel Cladding O.D.	$\geq$ 0.412 inches
Fuel Cladding I.D.	$\leq$ 0.362 inches
Fuel Pellet O.D.	$\leq$ 0.358 inches
Active Fuel Length	$\leq$ 111 inches
Canister Weight	$\leq$ 550 lbs., including Thoria Rods
Canister Material	Type 304 SS

Table 1.2.22

LIMITS FOR MATERIAL TO BE TRANSPORTED IN MPC-24

PARAMETER	VALUE
Fuel Type	Uranium oxide, PWR intact fuel assemblies meeting the limits in Table 1.2.10 for the applicable array/class
Cladding Type	ZR or Stainless Steel (SS) as specified in Table 1.2.10 for the applicable array/class
Maximum Initial Enrichment	As specified in Table 1.2.10 for the applicable array/class
Post-irradiation Cooling Time, Average Burnup, and Minimum Initial Enrichment per Assembly	ZR clad: As specified in Table 1.2.28 or Table 1.2.29, as applicable SS clad: As specified in Table 1.2.30
Decay Heat Per Assembly	ZR clad: $\leq$ 833 Watts SS clad: $\leq$ 488 Watts
Fuel Assembly Length	$\leq$ 176.8 in. (nominal design)
Fuel Assembly Width	$\leq$ 8.54 in. (nominal design)
Fuel Assembly Weight	$\leq$ 1,680 lbs
Other Limitations	▪ Quantity is limited to up to 24 PWR intact fuel assemblies. ▪ Non-fuel hardware and neutron sources not permitted. ▪ Damaged fuel assemblies and fuel debris not permitted. ▪ Trojan plant fuel not permitted.

Table 1.2.23

LIMITS FOR MATERIAL TO BE TRANSPORTED IN MPC-68

PARAMETER	VALUE (Note 1)			
Fuel Type(s)	Uranium oxide, BWR intact fuel assemblies meeting the limits in Table 1.2.11 for the applicable array/class, with or without Zircaloy channels	Uranium oxide, BWR damaged fuel assemblies meeting the limits in Table 1.2.11 for array/class 6x6A, 6x6C, 7x7A, or 8x8A, with or without Zircaloy channels, placed in Damaged Fuel Containers(DFCs)	Mixed Oxide (MOX) BWR intact fuel assemblies meeting the limits in Table 1.2.11 for array/class 6x6B, with or without Zircaloy channels	Mixed Oxide (MOX) BWR damaged fuel assemblies meeting the limits in Table 1.2.11 for array/class 6x6B, with or without Zircaloy channels, placed in Damaged Fuel Containers (DFCs)
Cladding Type	ZR or Stainless Steel (SS) as specified in Table 1.2.11 for the applicable array/class	ZR	ZR	ZR
Maximum Initial Planar-Average and Rod Enrichment	As specified in Table 1.2.11 for the applicable array/class	As specified in Table 1.2.11 for the applicable array/class	As specified in Table 1.2.11 for array/class 6x6B	As specified in Table 1.2.11 for array/class 6x6B
Post-irradiation Cooling Time, Average Burnup, and Minimum Initial Enrichment per Assembly	ZR clad: As specified in Table 1.2.31 except as provided in Notes 2 and 3 SS clad: Note 4	Cooling time $\geq$ 18 years, average burnup $\leq$ 30,000 MWD/MTU, and minimum initial enrichment $\geq$ 1.8 wt. % ^{235}U.	Cooling time $\geq$ 18 years, average burnup $\leq$ 30,000 MWD/MTIHM, and minimum initial enrichment $\geq$ 1.8 wt. % ^{235}U.	Cooling time $\geq$ 18 years, average burnup $\leq$ 30,000 MWD/MTIHM, and minimum initial enrichment $\geq$ 1.8 wt. % ^{235}U.
Decay Heat Per Assembly	ZR clad: $\leq$ 272 Watts (Note 5) SS clad: $\leq$ 83 Watts	$\leq$ 115 Watts	$\leq$ 115 Watts	$\leq$ 115 Watts

Table 1.2.23 (cont'd)

LIMITS FOR MATERIAL TO BE TRANSPORTED IN MPC-68

PARAMETER	VALUE (Note 1)			
Fuel Assembly Length	≤ 176.2 in. (nominal design)	≤ 135.0 in. (nominal design)	≤ 135.0 in. (nominal design)	≤ 135.0 in. (nominal design)
Fuel Assembly Width	≤ 5.85 in. (nominal design)	≤ 4.70 in. (nominal design)	≤ 4.70 in. (nominal design)	≤ 4.70 in. (nominal design)
Fuel Assembly Weight	≤ 700 lbs (including channels)	≤ 550 lbs, (including channels and DFC)	≤ 400 lbs, (including channels)	≤ 550 lbs, (including channels and DFC)
Quantity per MPC	Up to 68 BWR intact fuel assemblies	Up to 68 BWR damaged and/or intact fuel assemblies	Up to 68 BWR intact fuel assemblies	Up to 68 BWR damaged and/or intact fuel assemblies
Other Limitations	▪ Quantity is limited to up to one (1) Dresden Unit 1 thoria rod canister meeting the specifications listed in Table 1.2.21 plus any combination of Dresden Unit 1 or Humboldt Bay damaged fuel assemblies in DFCs and intact fuel assemblies up to a total of 68. ▪ Stainless steel channels are not permitted. ▪ Fuel debris is not permitted. ▪ Dresden Unit 1 fuel assemblies with one antimony-beryllium neutron source are permitted. The antimony-beryllium neutron source material shall be in a water rod location.			

Notes:

1. A fuel assembly must meet the requirements of any one column and the other limitations to be authorized for transportation.

2. Array/class 6x6A, 6x6C, 7x7A, and 8x8A fuel assemblies shall have a cooling time ≥ 18 years, an average burnup ≤ 30,000 MWD/MTU, and a minimum initial enrichment ≥ 1.8 wt. % ^{235}U.

3. Array/class 8x8F fuel assemblies shall have a cooling time ≥ 10 years, an average burnup ≤ 27,500 MWD/MTU, and a minimum initial enrichment ≥ 2.4 wt. % ^{235}U.

4. SS-clad fuel assemblies shall have a cooling time ≥ 16 years, an average burnup ≤ 22,500 MWD/MTU, and a minimum initial enrichment ≥ 3.5 wt. % ^{235}U.

5. Array/class 8x8F fuel assemblies shall have a decay heat ≤ 183.5 Watts.

Table 1.2.24

LIMITS FOR MATERIAL TO BE TRANSPORTED IN MPC-68F

PARAMETER	**VALUE (Notes 1 and 2)**			
Fuel Type(s)	Uranium oxide, BWR intact fuel assemblies meeting the limits in Table 1.2.11 for array/class 6x6A, 6x6C, 7x7A, or 8x8A, with or without Zircaloy channels	Uranium oxide, BWR damaged fuel assemblies or fuel debris meeting the limits in Table 1.2.11 for array/class 6x6A, 6x6C, 7x7A, or 8x8A, with or without Zircaloy channels, placed in Damaged Fuel Containers(DFCs)	Mixed Oxide (MOX) BWR intact fuel assemblies meeting the limits in Table 1.2.11 for array/class 6x6B, with or without Zircaloy channels	Mixed Oxide (MOX) BWR damaged fuel assemblies or fuel debris meeting the limits in Table 1.2.11 for array/class 6x6B, with or without Zircaloy channels, placed in Damaged Fuel Containers (DFCs))
Cladding Type	ZR	ZR	ZR	ZR
Maximum Initial Planar-Average and Rod Enrichment	As specified in Table 1.2.11 for the applicable array/class	As specified in Table 1.2.11 for the applicable array/class	As specified in Table 1.2.11 for array/class 6x6B	As specified in Table 1.2.11 for array/class 6x6B
Post-irradiation Cooling Time, Average Burnup, and Minimum Initial Enrichment per Assembly	Cooling time $\geq$ 18 years, average burnup $\leq$ 30,000 MWD/MTU, and minimum initial enrichment $\geq$ 1.8 wt. % ^{235}U.	Cooling time $\geq$ 18 years, average burnup $\leq$ 30,000 MWD/MTU, and minimum initial enrichment $\geq$ 1.8 wt. % ^{235}U.	Cooling time $\geq$ 18 years, average burnup $\leq$ 30,000 MWD/MTIHM, and minimum initial enrichment $\geq$ 1.8 wt. % ^{235}U.	Cooling time $\geq$ 18 years, average burnup $\leq$ 30,000 MWD/MTIHM, and minimum initial enrichment $\geq$ 1.8 wt. % ^{235}U.
Decay Heat Per Assembly	$\leq$ 115 Watts	$\leq$ 115 Watts	$\leq$ 115 Watts	$\leq$ 115 Watts

Table 1.2.24 (cont'd)

LIMITS FOR MATERIAL TO BE TRANSPORTED IN MPC-68F

PARAMETER	**VALUE (Note 1)**			
Fuel Assembly Length	≤ 135.0 in. (nominal design)	≤ 135.0 in. (nominal design)	≤ 135.0 in. (nominal design)	≤ 135.0 in. (nominal design)
Fuel Assembly Width	≤ 4.70 in. (nominal design)	≤ 4.70 in. (nominal design)	≤ 4.70 in. (nominal design)	≤ 4.70 in. (nominal design)
Fuel Assembly Weight	≤ 400 lbs (including channels)	≤ 550 lbs (including channels and DFC)	≤ 400 lbs (including channels)	≤ 550 lbs (including channels and DFC)
Other Limitations	▪ Quantity is limited to up to four (4) DFCs containing Dresden Unit 1 or Humboldt Bay uranium oxide or MOX fuel debris. The remaining fuel storage locations may be filled with array/class 6x6A, 6x6B, 6x6C, 7x7A, and 8x8A fuel assemblies of the following type, as applicable: - uranium oxide BWR intact fuel assemblies - MOX BWR intact fuel assemblies - uranium oxide BWR damaged fuel assemblies in DFCs - MOX BWR damaged fuel assemblies in DFCs - up to one (1) Dresden Unit 1 thoria rod canister meeting the specifications listed in Table 1.2.21 ▪ Stainless steel channels are not permitted. ▪ Dresden Unit 1 fuel assemblies with one antimony-beryllium neutron source are permitted. The antimony-beryllium neutron source material shall be in a water rod location.			

Notes:

1. A fuel assembly must meet the requirements of any one column and the other limitations to be authorized for transportation.

2. Only fuel from Dresden Unit 1 and Humboldt Bay plant are permitted for transportation in the MPC-68F.

Table 1.2.25

LIMITS FOR MATERIAL TO BE TRANSPORTED IN MPC-24E

PARAMETER	VALUE (Note 1)	
Fuel Type	Uranium oxide PWR intact fuel assemblies meeting the limits in Table 1.2.10 for the applicable array/class	Trojan plant damaged fuel meeting the limits in Table 1.2.10 for array/class 17x17B, placed in a Holtec Damaged Fuel Container (DFC) designed for Trojan plan fuel or a Trojan Failed Fuel Can (FFC)
Cladding Type	ZR or Stainless Steel (SS) assemblies as specified in Table 1.2.10 for the applicable array/class	ZR
Maximum Initial Enrichment	As specified in Table 1.2.10 for the applicable array/class	3.7 wt. % ^{235}U
Post-irradiation Cooling Time, Average Burnup, and Minimum Initial Enrichment per Assembly (except Trojan plant fuel and non-fuel hardware)	ZR clad: As specified in Table 1.2 28 or 1.2.29, as applicable SS clad: As specified in Table 1.2.30	Not applicable
Post-irradiation Cooling Time, Average Burnup, and Minimum Initial Enrichment per Assembly for Trojan plant fuel	As specified in Table 1.2.35	As specified in Table 1.2.35
Post-irradiation Cooling Time and Burnup for Trojan plant Non-fuel Hardware and Neutron Sources	As specified in Table 1.2.36	Not applicable
Decay Heat Per Assembly (except for Trojan plant fuel)	ZR clad: $\leq$ 833 Watts SS clad: $\leq$ 488 Watts	Not applicable
Decay heat per Assembly for Trojan plant fuel	$\leq$ 725 Watts	$\leq$ 725 Watts

Table 1.2.25 (cont'd)

LIMITS FOR MATERIAL TO BE TRANSPORTED IN MPC-24E

PARAMETER	VALUE (Note 1)	
Fuel Assembly Length	≤ 176.8 in. (nominal design)	≤ 169.3 in. (nominal design)
Fuel Assembly Width	≤ 8.54 in. (nominal design)	≤ 8.43 in. (nominal design)
Fuel Assembly Weight	≤ 1680 lbs (including non-fuel hardware)	≤ 1680 lbs (including DFC or Failed Fuel Can)
Other Limitations	▪ Quantity per MPC: up to 24 PWR intact fuel assemblies. For Trojan plant fuel only, up to four (4) damaged fuel assemblies may be stored in fuel storage locations 3, 6, 19, and/or 22. The remaining fuel storage locations may be filled with Trojan plant intact fuel assemblies. ▪ Trojan plant fuel must be transported in the custom-designed Trojan MPCs with the MPC spacer installed (see Figure 1.1.5). Fuel from other plants is not permitted to be transported in the Trojan MPCs. ▪ Except for Trojan plant fuel, the fuel assemblies shall not contain non-fuel hardware. Trojan intact fuel assemblies containing non-fuel hardware may be transported in any fuel storage location. ▪ Trojan plant damaged fuel assemblies must be transported in a Holtec DFC for Trojan plant fuel or a Trojan plant FFC. ▪ One (1) Trojan plant Sb-Be and/or two (2) Cf neutron sources, each in a Trojan plant intact fuel assembly may be transported in any one MPC. Each neutron source may be transported in any fuel storage location. ▪ Fuel debris is not authorized for transportation in the MPC-24E. ▪ Trojan plant non-fuel hardware and neutron sources may not be transported in the same fuel storage location with damaged fuel assemblies.	

Notes:

1. A fuel assembly must meet the requirements of any one column and the other limitations to be authorized for transportation.

Table 1.2.26

LIMITS FOR MATERIAL TO BE TRANSPORTED IN MPC-24EF

PARAMETER	VALUE (Note 1)		
Fuel Type	Uranium oxide PWR intact fuel assemblies meeting the limits in Table 1.2.10 for the applicable array/class	Trojan plant damaged fuel meeting the limits in Table 1.2.10 for array/class 17x17B, placed in a Holtec Damaged Fuel Container (DFC)designed for Trojan plant fuel or a Trojan Failed Fuel Can (FFC)	Trojan plant Fuel Debris Process Can Capsules and/or Trojan plant fuel assemblies classified as fuel debris, for which the original fuel assemblies meet the applicable criteria in Table 1.2.10 for array/class 17x17B, placed in a Holtec Damaged Fuel Container (DFC) designed for Trojan plant fuel or a Trojan Failed Fuel Can (FFC)
Cladding Type	ZR or Stainless Steel (SS) assemblies as specified in Table 1.2.10 for the applicable array/class	ZR	ZR
Maximum Initial Enrichment	As specified in Table 1.2.10 for the applicable array/class	$\leq$ 3.7 wt. % ^{235}U	$\leq$ 3.7 wt. % ^{235}U
Post-irradiation Cooling Time, Average Burnup, and Minimum Initial Enrichment per Assembly (except Trojan plant fuel and non-fuel hardware)	ZR clad: As specified in Table 1.2 28 or 1.2.29, as applicable SS clad: As specified in Table 1.2.30	Not applicable	Not applicable
Post-irradiation Cooling Time, Average Burnup, and Minimum Initial Enrichment per Assembly for Trojan plant fuel	As specified in Table 1.2.35	As specified in Table 1.2.35	As specified in Table 1.2.35

Table 1.2.26 (cont'd)

LIMITS FOR MATERIAL TO BE TRANSPORTED IN MPC-24EF

PARAMETER	VALUE (Note 1)		
Post-irradiation Cooling Time and Burnup for Trojan plant Non-fuel Hardware and Neutron Sources	As specified in Table 1.2.36	As specified in Table 1.2.36	As specified in Table 1.2.36
Decay Heat Per Assembly (except for Trojan plant fuel)	ZR clad: ≤ 833 Watts SS clad: ≤ 488 Watts	Not applicable	Not applicable
Decay heat per Assembly for Trojan plant fuel	≤ 725 Watts	≤ 725 Watts	≤ 725 Watts
Fuel Assembly Length	≤ 176.8 in. (nominal design)	≤ 169.3 in. (nominal design)	≤ 169.3 in. (nominal design)
Fuel Assembly Width	≤ 8.54 in. (nominal design)	≤ 8.43 in. (nominal design)	≤ 8.43 in. (nominal design)
Fuel Assembly Weight	≤ 1680 lbs (including non-fuel hardware(	≤ 1680 lbs (including DFC or Failed Fuel Can)	≤ 1680 lbs (including DFC or Failed Fuel Can)

Table 1.2.26 (cont'd)

LIMITS FOR MATERIAL TO BE TRANSPORTED IN MPC-24EF

Other Limitations	▪ Quantity per MPC: Up to 24 PWR intact fuel assemblies. For Trojan plant fuel only, up to four (4) damaged fuel assemblies, fuel assemblies classified as fuel debris, and/or Trojan Fuel Debris Process Can Capsules may be stored in fuel storage locations 3, 6, 19, and/or 22. The remaining fuel storage locations may be filled with Trojan plant intact fuel assemblies. ▪ Trojan plant fuel must be transported in the custom-designed Trojan MPCs with the MPC spacer installed (see Figure 1.1.5). Fuel from other plants is not permitted to be transported in the Trojan MPCs. ▪ Except for Trojan plant fuel, the fuel assemblies shall not contain non-fuel hardware or neutron sources. Trojan intact fuel assemblies containing non-fuel hardware may be transported in any fuel storage location. ▪ Trojan plant damaged fuel assemblies, fuel assemblies classified as fuel debris, and Fuel Debris Process Can Capsules must be transported in a Trojan Failed Fuel Can or a Holtec DFC for Trojan plant fuel. ▪ One (1) Trojan plant Sb-Be and/or two (2) Cf neutron sources, each in a Trojan plant intact fuel assembly may be transported in any one MPC. Each neutron source may be transported in any fuel storage location.

Notes:

1. A fuel assembly must meet the requirements of any one column and the other limitations to be authorized for transportation.

Table 1.2.27

LIMITS FOR MATERIAL TO BE TRANSPORTED IN MPC-32 (Note 1)

PARAMETER	VALUE
Fuel Type	Uranium oxide, PWR intact fuel assemblies meeting the limits in Table 1.2.10 for array/classes 15x15D, E, F, and H and 17x17A, B, and C
Cladding Type	ZR
Maximum Initial Enrichment	As specified in Table 1.2.10
Post-irradiation Cooling Time, Average Burnup, and Minimum Initial Enrichment per Assembly	As specified in Table 1.2.32 or Table 1.2.33, as applicable
Decay Heat Per Assembly	≤ 625 Watts
Minimum Burnup per Assembly	As specified in Table 1.2.34 for the applicable array/class
Fuel Assembly Length	≤ 176.8 in. (nominal design)
Fuel Assembly Width	≤ 8.54 in. (nominal design)
Fuel Assembly Weight	≤ 1,680 lbs
Other Limitations	▪ Quantity is limited to up to 32 PWR intact fuel assemblies in the above-specified array/classes only. ▪ Non-fuel hardware and neutron sources not permitted. ▪ Damaged fuel assemblies and fuel debris not permitted. ▪ Trojan plant fuel not permitted.

NOTES:

1. The MPC-32 is not authorized for transportation in the HI-STAR 100 System at this time.

Table 1.2.28

FUEL ASSEMBLY COOLING, AVERAGE BURNUP, AND MINIMUM ENRICHMENT LIMITS FOR TRANSPORTATION IN MPC-24/24E/24EF; PWR FUEL WITH ZR CLADDING AND WITH NON-ZIRCALOY IN-CORE GRID SPACERS

ASSEMBLY POST-IRRADIATION COOLING TIME (years)	**ASSEMBLY BURNUP (MWD/MTU)**	**ASSEMBLY ENRICHMENT (wt. % ^{235}U)**
≥ 9	≤ 24,500	≥ 2.3
≥ 11	≤ 29,500	≥ 2.6
≥ 13	≤ 34,500	≥ 2.9
≥ 15	≤ 39,500	≥ 3.2
≥ 18	≤ 44,500	≥ 3.4

Table 1.2.29

FUEL ASSEMBLY COOLING, AVERAGE BURNUP, AND MINIMUM ENRICHMENT LIMITS FOR TRANSPORTATION IN MPC-24/24E/24EF;PWR FUEL WITH ZR CLADDING AND WITH ZIRCALOY IN-CORE GRID SPACERS

ASSEMBLY POST-IRRADIATION COOLING TIME (years)	**ASSEMBLY BURNUP (MWD/MTU)**	**ASSEMBLY ENRICHMENT (wt. % ^{235}U)**
≥ 6	≤ 24,500	≥ 2.3
≥ 7	≤ 29,500	≥ 2.6
≥ 9	≤ 34,500	≥ 2.9
≥ 11	≤ 39,500	≥ 3.2
≥ 14	≤ 44,500	≥ 3.4

Table 1.2.30

FUEL ASSEMBLY COOLING, AVERAGE BURNUP, AND MINIMUM ENRICHMENT LIMITS FOR TRANSPORTATION IN MPC-24/24E/24EF; PWR FUEL WITH STAINLESS STEEL CLADDING

ASSEMBLY POST-IRRADIATION COOLING TIME (years)	**ASSEMBLY BURNUP (MWD/MTU)**	**ASSEMBLY ENRICHMENT (wt. % ^{235}U)**
$\geq$ 19	$\leq$ 30,000	$\geq$ 3.1
$\geq$ 24	$\leq$ 40,000	$\geq$ 3.1

Table 1.2.31

FUEL ASSEMBLY COOLING, AVERAGE BURNUP, AND MINIMUM ENRICHMENT LIMITS FOR TRANSPORTATION IN MPC-68

ASSEMBLY POST-IRRADIATION COOLING TIME (years)	ASSEMBLY BURNUP (MWD/MTU)	ASSEMBLY ENRICHMENT (wt. % ^{235}U)
≥ 8	≤ 24,500	≥ 2.1
≥ 9	≤ 29,500	≥ 2.4
≥ 11	≤ 34,500	≥ 2.6
≥ 14	≤ 39,500	≥ 2.9
≥ 19	≤ 44,500	≥ 3.0

Table 1.2.32

FUEL ASSEMBLY COOLING, AVERAGE BURNUP, AND MINIMUM ENRICHMENT LIMITS FOR TRANSPORTATION IN MPC-32; PWR FUEL WITH ZR CLADDING AND WITH NON-ZIRCALOY IN-CORE GRID SPACERS (Note 1)

ASSEMBLY POST-IRRADIATION COOLING TIME (years)	**ASSEMBLY BURNUP (MWD/MTU)**	**ASSEMBLY ENRICHMENT (wt. % ^{235}U)**
$\geq$ 12	$\leq$ 24,500	$\geq$ 2.3
$\geq$ 14	$\leq$ 29,500	$\geq$ 2.6
$\geq$ 16	$\leq$ 34,500	$\geq$ 2.9
$\geq$ 19	$\leq$ 39,500	$\geq$ 3.2
$\geq$ 20	$\leq$ 42,500	$\geq$ 3.4

NOTES:

1. MPC-32 is not authorized for transportation at this time.

Table 1.2.33

FUEL ASSEMBLY COOLING, AVERAGE BURNUP, AND MINIMUM ENRICHMENT LIMITS FOR TRANSPORTATION IN MPC-32; PWR FUEL WITH ZR CLADDING AND WITH ZIRCALOY IN-CORE GRID SPACERS (Note 1)

ASSEMBLY POST-IRRADIATION COOLING TIME (years)	**ASSEMBLY BURNUP (MWD/MTU)**	**ASSEMBLY ENRICHMENT (wt. % ^{235}U)**
≥ 8	≤ 24,500	≥ 2.3
≥ 9	≤ 29,500	≥ 2.6
≥ 12	≤ 34,500	≥ 2.9
≥ 14	≤ 39,500	≥ 3.2
≥ 19	≤ 44,500	≥ 3.4

NOTES:

1. MPC-32 is not authorized for transportation at this time.

Table 1.2.34

FUEL ASSEMBLY MINIMUM BURNUP REQUIREMENTS FOR TRANSPORTATION IN MPC-32 (Note 1)

FUEL ASSEMBLY ARRAY/CLASS	MINIMUM BURNUP (B) AS A FUNCTION OF INITIAL ENRICHMENT (E) (Note 2) (GWD/MTU)
15x15D, E, F, and H	Later
17x15A, B, and C	Later

Notes:

1. MPC-32 is not authorized for transportation at this time.

2. E = Initial enrichment from the fuel vendor's data sheet, i.e., for 4.05wt. %, E = 4.05.

Table 1.2.35

TROJAN PLANT FUEL ASSEMBLY COOLING, AVERAGE BURNUP, AND MINIMUM ENRICHMENT LIMITS (Note 1)

Post-irradiation Cooling Time (years)	**Assembly Burnup (MWD/MTU)**	**Assembly Minimum Enrichment (wt. % ^{235}U)**
$\geq$ 16	$\leq$ 42,000	$\geq$ 3.09
$\geq$ 16	$\leq$ 37,500	$\geq$ 2.6
$\geq$ 16	$\leq$ 30,000	$\geq$ 2.1

Notes:

1. Each fuel assembly must only meet one set of limits (i.e., one row).

Table 1.2.36

TROJAN PLANT NON-FUEL HARDWARE AND NEUTRON SOURCE COOLING AND BURNUP LIMITS

Type Of Hardware or Neutron Source	**Burnup (MWD/MTU)**	**Post-irradiation Cooling Time (years)**
BPRAs	$\leq$ 15,998	$\geq$ 24
TPDs	$\leq$ 118,674	$\geq$ 11
RCCAs	$\leq$ 125,515	$\geq$ 9
Cf neutron source	$\leq$ 15,998	$\geq$ 24
Sb-Be neutron source with 4 source rods, 16 burnable poison rods, and 4 thimble plug rods	$\leq$ 45,361	$\geq$ 19
Sb-Be neutron source with 4 source rods and 20 thimble plug rods	$\leq$ 88,547	$\geq$ 9

1.3 DESIGN CODE APPLICABILITY

The ASME Boiler and Pressure Vessel Code (ASME Code), 1995 Edition with Addenda through 1997 [1.3.1], is the governing code for the construction of the HI-STAR 100 System, as clarified in Table 1.3.2. The ASME Code is applied to each component consistent with the function of the component. Table 1.3.3 lists each structure, system and component (SSC) of the HI-STAR 100 System that are labeled Important to Safety (ITS), 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" [1.3.2] 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 1.3.3. Table 1.3.3 may not include all NITS items associated with the HI-STAR 100 Package.

Table 1.3.1 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 1.3.2 lists the alternatives to the ASME Code for the HI-STAR 100 System and the justification for those alternatives.

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, with certain NRC-approved alternatives, as discussed in Table 1.3.2. 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, with certain NRC-approved alternatives, as discussed in Table 1.3.2. 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 Table 1.3.2. In addition, the threaded holes in the MPC lid are designed in accordance with the requirements of ANSI N14.6 [1.3.3] 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 2. The MPC closure ring welds are inspected by performing a liquid penetrant examination of the root pass (if more than one weld pass is required) and final weld surface, in accordance with the requirements contained in Section 8.1. The MPC lid weld may be examined by either volumetric or multi-layer liquid penetrant examination. If volumetric examination is used, it shall be the ultrasonic method and shall include a liquid penetrant examination of the root and final weld layers. If multi-layer liquid penetrant examination is used alone, at a minimum, it must include the root and final weld layers and each approximately 3/8 inch of weld to detect critical weld flaws. The integrity of the MPC lid weld is further verified by performing a pressure test (hydrostatic or pneumatic) and a helium leak test in accordance with the requirements contained in Section 8.1.

The structural analysis of the MPC, in conjunction with the redundant closures and nondestructive examination, 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.

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 Table 1.3.2). 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 Table 1.3.2).

Table 1.3.1

HI-STAR 100 ASME BOILER AND PRESSURE VESSEL CODE APPLICABILITY

HI-STAR 100 Component	Material Procurement	Design	Fabrication	Inspection
Overpack containment boundary	Section II; and 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; and Section III, Subsection NF	Section III, Subsection NF, NF-3300	Section III, Subsection NF, NF-4000	Section III, Subsection NF, NF-5360 and Section V
MPC helium retention boundary	Section II; and 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; and Section III, Subsection NG, NG-2000 for core support structures (NG-1121)	Section III, Subsection NG, NG-3300 and NG-3200 for core support structures (NG-1121)	Section III, Subsection NG, NG-4000 for core support structures (NG-1121)	Section III, Subsection NG, NG-5000 and Section V for core support structures (NG-1121)
Lifting Trunnions	Section II; and Section III, Subsection NF, NF-2000	ANSI N14.6	Section III, Subsection NF, NF-4000	ANSI 14.6 See Chapter 8
MPC Basket Supports (Angled Plates)	Section II, and Section III, Subsection NG, NG-2000 for internal structures (NG-1122)	Section III, Subsection NG, NG-3300 and NG-3200 for internal structures (NG-1122)	Section III, Subsection NG, NG-4000 for internal structures (NG-1122)	Section III, Subsection NG, NG-5000 and Section V for internal structures (NG-1122)
Damaged Fuel Container	Section II, and 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 1.3.2

LIST OF ASME CODE ALTERNATIVES FOR HI-STAR 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	Alternative, Justification & Compensatory Measures
MPC, MPC basket assembly, and HI-STAR overpack steel structure.	Subsection NCA	General Requirements. Requires preparation of a Design Specification, Design Report, Overpressure Protection Report, Certification of Construction Report, Data Report, and other administrative controls for an ASME Code stamped vessel.	Because the MPC and overpack are not ASME Code stamped vessels, none of the specifications, reports, certificates, or other general requirements specified by NCA are required. In lieu of a Design Specification and Design Report, the HI-STAR SAR includes the design criteria, service conditions, and load combinations for the design and operation of the HI-STAR 100 System as well as the results of the stress analyses to demonstrate that applicable Code stress limits are met. Additionally, the fabricator is not required to have an ASME-certified QA program. All important-to-safety activities are governed by the NRC-approved Holtec QA program. Because the cask components are not certified to the Code, the terms "Certificate Holder" and "Inspector" are not germane to the manufacturing of NRC-certified cask components. To eliminate ambiguity, the responsibilities assigned to the Certificate Holder in the various articles of Subsections NB, NG, and NF of the Code, as applicable, shall be interpreted to apply to the NRC Certificate of Compliance (CoC) holder (and by extension, to the component fabricator) if the requirement must be fulfilled. The Code term "Inspector" means the QA/QC personnel of the CoC holder and its vendors assigned to oversee and inspect the manufacturing process.
MPC	NB-1100	Statement of requirements for Code stamping of components.	MPC 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.

Table 1.3.2 (continued)

LIST OF ASME CODE ALTERNATIVES FOR HI-STAR 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	Alternative, Justification & Compensatory Measures
MPC basket supports and lift lugs	NB-1130	NB-1132.2(d) requires that the first connecting weld of a nonpressure-retaining structural attachment to a component shall be considered part of the component unless the weld is more than 2t from the pressure-retaining portion of the component, where t is the nominal thickness of the pressure-retaining material. NB-1132.2(e) requires that the first connecting weld of a welded nonstructural attachment to a component shall conform to NB-4430 if the connecting weld is within 2t from the pressure-retaining portion of the component.	The MPC basket supports (nonpressure-retaining structural attachments) and lift lugs (nonstructural attachments used exclusively for lifting an empty MPC) are welded to the inside of the pressure-retaining MPC shell, but are not designed in accordance with Subsection NB. The basket supports and associated attachment welds are designed to satisfy the stress limits of Subsection NG and the lift lugs and associated attachment welds are designed to satisfy the stress limits of Subsection NF, as a minimum. These attachments and their welds are shown by analysis to meet the respective stress limits for their service conditions. Likewise, non-structural items, such as shield plugs, spacers, etc. if used, can be attached to pressure-retaining parts in the same manner.
MPC, MPC basket assembly, and HI-STAR overpack steel structure.	NB-3100 NG-3100 NF-3100	Provides requirements for determining design loading conditions, such as pressure, temperature, and mechanical loads.	These requirements are not applicable. The HI-STAR SAR, serving as the Design Specification, establishes the service conditions and load combinations for the storage system.

Table 1.3.2 (continued)

LIST OF ASME CODE ALTERNATIVES FOR HI-STAR 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	Alternative, Justification & Compensatory Measures
MPC	NB-3350	NB-3352.3 requires, for Category C joints, that the minimum dimensions of the welds and throat thickness shall be as shown in Figure NB-4243-1.	The MPC shell-to-baseplate weld joint design (designated Category C) may not include a reinforcing fillet weld or a bevel in the MPC baseplate, which makes it different than any of the representative configurations depicted in Figure NB-4243-1. The transverse thickness of this weld is equal to the thickness of the adjoining shell (1/2 inch). The weld is designed as a full penetration weld that receives VT and RT or UT, as well as final surface PT examinations. Because the MPC shell design thickness is considerably larger than the minimum thickness required by the Code, a reinforcing fillet weld that would intrude into the MPC cavity space is not included. Not including this fillet weld provides for a higher quality radiographic examination of the full penetration weld. From the standpoint of stress analysis, the fillet weld serves to reduce the local bending stress (secondary stress) produced by the gross structural discontinuity defined by the flat plate/shell junction. In the MPC design, the shell and baseplate thicknesses are well beyond that required to meet their respective membrane stress intensity limits.
MPC, MPC basket assembly, and HI-STAR overpack steel structure	NB-4120 NG-4120 NF-4120	NB-4121.2, NG-4121.2, and NF-4121.2 provide requirements for repetition of tensile or impact tests for material subjected to heat treatment during fabrication or installation.	In-shop operations of short duration that apply heat to a component, such as plasma cutting of plate stock, welding, machining, coating, and pouring of Holtite are not, unless explicitly stated by the Code, defined as heat treatment operations. For the steel parts in the HI-STAR 100 System components, the duration for which a part exceeds the off-normal temperature limit shall be limited to 24 hours in a particular manufacturing process (such as the Holtite pouring process).

Table 1.3.2 (continued)

LIST OF ASME CODE ALTERNATIVES FOR HI-STAR 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	Alternative, Justification & Compensatory Measures
MPC and HI-STAR overpack steel structure	NB-4220 NF-4220	Requires certain forming tolerances to be met for cylindrical, conical, or spherical shells of a vessel.	The cylindricity measurements on the rolled shells are not specifically recorded in the shop travelers, as would be the case for a Code-stamped pressure vessel. Rather, the requirements on inter-component clearances (such as the MPC-to-overpack) are guaranteed through fixture-controlled manufacturing. The fabrication specification and shop procedures ensure that all dimensional design objectives, including inter-component annular clearances are satisfied. The dimensions required to be met in fabrication are chosen to meet the functional requirements of the dry storage components. Thus, although the post-forming Code cylindricity requirements are not evaluated for compliance directly, they are indirectly satisfied (actually exceeded) in the final manufactured components.
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.
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.

Table 1.3.2 (continued)

LIST OF ASME CODE ALTERNATIVES FOR HI-STAR 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	Alternative, Justification & Compensatory Measures
MPC Enclosure Vessel and Lid	NB-6111	All completed pressure retaining systems shall be pressure tested.	The MPC vessel is seal welded in the field following fuel assembly loading. The MPC vessel shall then be pressure tested as defined in Chapter 8. Accessibility for leakage inspections preclude a Code compliant pressure test. All MPC vessel welds (except closure ring and vent/drain cover plate) are inspected by volumetric examination, except that 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 than the critical flaw size. The critical flaw size must be determined in accordance with ASME Section XI methods. The critical flaw size shall not cause the primary stress limits of NB-3000 to be exceeded. The inspection results, including relevant findings (indications) shall be made a permanent part of the user's records by video, photographic, or other means which provide an equivalent retrievable record of weld integrity. The video or photographic records should be taken during the final interpretation period described in ASME Section V, Article 6, T-676. The vent/drain cover plate welds are confirmed by helium leakage testing and liquid penetrant examination and the closure ring weld is confirmed by liquid penetrant examination. The inspection of the weld must be performed by qualified personnel and shall meet the acceptance requirements of ASME Code Section III, NB-5350 for PT or NB-5332 for UT.
MPC Enclosure Vessel	NB-7000	Vessels are required to have overpressure protection.	No overpressure protection is provided. The function of MPC vessel is as a helium retention boundary. MPC vessel is designed to withstand maximum internal pressure considering 100% fuel rod failure and maximum accident temperatures.

Table 1.3.2 (continued)

LIST OF ASME CODE ALTERNATIVES FOR HI-STAR 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	Alternative, Justification & Compensatory Measures
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.
Overpack Containment Boundary	NB-1100	Statement of requirements for Code stamping of components.	Overpack containment 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 Containment 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 Containment Boundary	NB-7000	Vessels are required to have overpressure protection.	No overpressure protection is provided. Function of overpack vessel is as a radionuclide containment boundary under normal and hypothetical accident conditions. Overpack vessel is designed to withstand maximum internal pressure and maximum accident temperatures.
Overpack Containment Boundary	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'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 requirements.

Table 1.3.2 (continued)

LIST OF ASME CODE ALTERNATIVES FOR HI-STAR 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	Alternative, Justification & Compensatory Measures
MPC Basket Assembly	NG-4420	NG-4427(a) allows a fillet weld in any single continuous weld to be less than the specified fillet weld dimension by not more than 1/16 inch, provided that the total undersize portion of the weld does not exceed 10 percent of the length of the weld. Individual undersize weld portions shall not exceed 2 inches in length.	Modify the Code requirement (intended for core support structures) with the following text prepared to accord with the geometry and stress analysis imperatives for the fuel basket: For the longitudinal MPC basket fillet welds, the following criteria apply: 1) The specified fillet weld throat dimension must be maintained over at least 92 percent of the total weld length. All regions of undersized weld must be less than 3 inches long and separated from each other by at least 9 inches. 2) Areas of undercuts and porosity beyond that allowed by the applicable ASME Code shall not exceed 1/2 inch in weld length. The total length of undercut and porosity over any 1-foot length shall not exceed 2 inches. 3) The total weld length in which items (1) and (2) apply shall not exceed a total of 10 percent of the overall weld length. The limited access of the MPC basket panel longitudinal fillet welds makes it difficult to perform effective repairs of these welds and creates the potential for causing additional damage to the basket assembly (e.g., to the neutron absorber and its sheathing) if repairs are attempted. The acceptance criteria provided in the foregoing have been established to comport with the objectives of the basket design and preserve the margins demonstrated in the supporting stress analysis. From the structural standpoint, the weld acceptance criteria are established to ensure that any departure from the ideal, continuous fillet weld seam would not alter the primary bending stresses on which the design of the fuel baskets is predicated. Stated differently, the permitted weld discontinuities are limited in size to ensure that they remain classifiable as local stress elevators (“peak stress”, F, in the ASME Code for which specific stress intensity limits do not apply).
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	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.

Table 1.3.2 (continued)

LIST OF ASME CODE ALTERNATIVES FOR HI-STAR 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	Alternative, Justification & Compensatory Measures
Overpack Containment 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 containment boundary components.
Overpack Containment Boundary	NF-3320 NF-4720	NF-3324.6 and NF-4720 provide requirements for bolting.	These Code requirements are applicable to linear structures wherein bolted joints carry axial, shear, as well as rotational (torsional) loads. The overpack bolted connections in the structural load path are qualified by design based on the design loadings defined in the SAR. Bolted joints in these components see no shear or torsional loads under normal storage conditions. Larger clearances between bolts and holes may be necessary to ensure shear interfaces located elsewhere in the structure engage prior to the bolts experiencing shear loadings (which occur only during side impact scenarios). Bolted joints that are subject to shear loads in accident conditions are qualified by appropriate stress analysis. Larger bolt-to-hole clearances help ensure more efficient operations in making these bolted connections, thereby minimizing time spent by operations personnel in a radiation area. Additionally, larger bolt-to-hole clearances allow interchangeability of the lids from one particular fabricated cask to another.

Table 1.3.2 (continued)

LIST OF ASME CODE ALTERNATIVES FOR HI-STAR 100 SYSTEM

Component	Reference ASME Code Section/Article	Code Requirement	Alternative, Justification & Compensatory Measures
MPC-68 Serial #1021-023, 036, 037 Closure Rings	*NB-2531*	*Requires UT inspection of plate.*	*The sole deviation of the 3/8" thick austenitic stainless steel material used for the MPC closure ring is the omission of a straight beam UT inspection as required by NB-2531. The ASME Code required straight beam inspection for vessels because the predominant indication in plates is laminations. Straight beam inspection cannot detect indications perpendicular to the surface of the plate. With respect to maintaining confinement, an indication perpendicular to the surface of the plate is the most critical. Laminations in the plate parallel to the surface of the plate cannot cause leakage through the plate. Therefore, the straight beam UT inspection does not add any value for detecting a defect in the thin closure ring with respect to its confinement function.*

Table 1.3.3

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)**
Containment	Inner Shell	A	ASME Section III; Subsection NB	SA203-E	Table 2.3.4	Paint inside surface with Thermaline 450 (Note 5). External surface to be coated with a surface preservative.	NA
Containment	Bottom Plate	A	ASME Section III; Subsection NB	SA350-LF3	Table 2.3.4	Paint inside surface with Thermaline 450 (Note 5).	NA
Containment	Top Flange	A	ASME Section III; Subsection NB	SA350-LF3	Table 2.3.4	Paint inside surface with Thermaline 450. Paint outside surface with Carboline 890 (Note 5).	NA
Containment	Closure Plate	A	ASME Section III; Subsection NB	SA350-LF3	Table 2.3.4	Paint inside surface with Thermaline 450. Paint outside surface with Carboline 890 (Note 5).	NA
Containment	Closure Plate Bolts	A	ASME Section III; Subsection NB	SB637-N07718	Table 2.3.5	NA	NA
Containment	Port Plug	A	Non-code	SA193-B8	Not required	NA	NA
Containment	Port Plug Seal	A	Non-code	Alloy X750	Not required	NA	NA

Notes:
1) There are no known residuals on finished component surfaces.
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III. For parts beyond the purview of ASME Section III, compliance with Section IX and Section II of the Code shall be observed to the extent practicable.
3) Component nomenclature taken from drawings in Chapter 1.
4) A,B and C denote important to safety classifications as described in NUREG/CR-6407. NITS stands for Not Important To Safety.
5) Thermaline 450 and Carboline 890 were the product names at the time of initial licensing. Chemically identical products with different names are permitted. For example, Carboline 890 was re-named Carboguard 890 in 2000, with no change to the coating material and is , therefore, acceptable for use where Carboline 890 is specified.

TABLE 1.3.3 (continued)

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)**
Containment	Closure Plate Seal	A	Non-code	Alloy X750	Not required	NA	NA
Containment	Port Cover Seal	B	Non-code	Alloy X750	Not required	NA	NA
Shielding	Intermediate Shells	B	ASME Section III; Subsection NF	SA516-70	Table 2.3.2	Internal surfaces to be coated with a silicone encapsulant (Dow-Corning SYLGARD 567 or equivalent) for surface preservation. Exposed areas of fifth intermediate shell to be painted with Carboline 890 (Note 5).	NA
Shielding	Neutron Shield	B	Non-code	Holtite-A	Not required	NA	Holtite/CS
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 2.3.4	Paint external surface with Carboline 890 (Note 5).	NA
Shielding	Pocket Trunnion Plug Plate	C	Non-code	SA240-304	Not required	NA	NA

Notes:
1) There are no known residuals on finished component surfaces.
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III. For parts beyond the purview of ASME Section III, compliance with Section IX and Section II of the Code shall be observed to the extent practicable.
3) Component nomenclature taken from drawings in Chapter 1.
4) A,B and C denote important to safety classifications as described in NUREG/CR-6407. NITS stands for Not Important To Safety.
5) Thermaline 450 and Carboline 890 were the product names at the time of initial licensing. Chemically identical products with different names are permitted. For example, Carboline 890 was re-named Carboguard 890 in 2000, with no change to the coating material and is , therefore, acceptable for use where Carboline 890 is specified.

TABLE 1.3.3 (continued)

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)
Heat Transfer	Radial Channels	B	ASME Section III; Subsection NF	SA515-70	Table 2.3.3	Paint outside surface with Carboline 890 (Note 5).	NA
Rotation Pivot and Shielding	Pocket Trunnion	B	Non-Code	SA705-630 *17-4 PH* or SA564-630 *17-4 PH*	Table 2.3.5	NA	NA
Structural Integrity	Lifting Trunnion	A	ANSI N14.6	SB637-N07718	Table 2.3.5	NA	NA
~~Structural Integrity~~	~~Backing Strip~~	~~B~~	~~Non-code~~	~~A569~~	~~Not required~~	~~NA~~	~~NA~~
~~Structural Integrity~~	~~Relief DeviceCoupling~~	~~NITS~~	~~Non-code~~	~~C/S~~	~~Not required~~	~~NA~~	~~NA~~
Structural Integrity	Relief Device	C	Non-code	Commercial	Not required	NA	Brass-C/S
~~Structural Integrity~~	~~Relief Device Pipe~~	~~C~~	~~Non-code~~	~~SA-106~~	~~Not required~~	~~NA~~	~~NA~~
Structural Integrity	Relief Device Plate	C	Non-code	*SA 516 Grade 70 or* A569	Not required	NA	NA
Structural Integrity	Removable Shear Ring Bolt	C	Non-code	SA193-B7	Not required	NA	NA

Notes:
1) There are no known residuals on finished component surfaces.
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III. For parts beyond the purview of ASME Section III, compliance with Section IX and Section II of the Code shall be observed to the extent practicable.
3) Component nomenclature taken from drawings in Chapter 1.
4) A,B and C denote important to safety classifications as described in NUREG/CR-6407. NITS stands for Not Important To Safety.
5) Thermaline 450 and Carboline 890 were the product names at the time of initial licensing. Chemically identical products with different names are permitted. For example, Carboline 890 was re-named Carboguard 890 in 2000, with no change to the coating material and is , therefore, acceptable for use where Carboline 890 is specified.

TABLE 1.3.3 (continued)

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	Thermal Expansion Foam	NITS	Non-code	Silicone Foam	Not required	NA	~~NA~~*Silicone with CS, brass, and Holtite*
Structural Integrity	Closure Bolt Washer	NITS	Non-code	~~SA240-304~~*ASTM A564, 17-7 PH*	Not required	NA	NA
Structural Integrity	Enclosure Shell Panels	B	ASME Section III; Subsection NF	SA515-70	Table 2.3.3	Paint outside surface with Carboline 890 (Note 5).	NA
Structural Integrity	Enclosure Shell Return	B	ASME Section III; Subsection NF	SA515-70	Table 2.3.3	Paint outside surface with Carboline 890 (Note 5).	NA
Structural Integrity	Port Cover	B	ASME Section III; Subsection NF	SA203E	Table 2.3.4	Paint outside surface with Carboline 890 (Note 5).	NA
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 or SA515 Gr. 70	Table 2.3.2	Paint exposed surfaces with Carboline 890 (Note 5).	NA

Notes:
1) There are no known residuals on finished component surfaces.
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III. For parts beyond the purview of ASME Section III, compliance with Section IX and Section II of the Code shall be observed to the extent practicable.
3) Component nomenclature taken from drawings in Chapter 1.
4) A,B and C denote important to safety classifications as described in NUREG/CR-6407. NITS stands for Not Important To Safety.
5) Thermaline 450 and Carboline 890 were the product names at the time of initial licensing. Chemically identical products with different names are permitted. For example, Carboline 890 was re-named Carboguard 890 in 2000, with no change to the coating material and is , therefore, acceptable for use where Carboline 890 is specified.

TABLE 1.3.3 (continued)

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)**
Operations	Lifting Trunnion Locking Pad	C	Non-code	SA516-70	Table 2.3.2	Paint exposed surfaces with Carboline 890 (Note 5).	NA
Operations	Nameplate	NITS	Non-code	S/S	Not required	NA	NA

Notes:
1) There are no known residuals on finished component surfaces.
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III. For parts beyond the purview of ASME Section III, compliance with Section IX and Section II of the Code shall be observed to the extent practicable.
3) Component nomenclature taken from drawings in Chapter 1.
4) A,B and C denote important to safety classifications as described in NUREG/CR-6407. NITS stands for Not Important To Safety.
5) Thermaline 450 and Carboline 890 were the product names at the time of initial licensing. Chemically identical products with different names are permitted. For example, Carboline 890 was re-named Carboguard 890 in 2000, with no change to the coating material and is , therefore, acceptable for use where Carboline 890 is specified.

Table 1.3.3 (cont'd)

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)
Helium Retention (Secondary Containment)	Shell	A	ASME Section III; Subsection NB	Alloy X (5)	See Appendix 1.A	NA	NA
Helium Retention (Secondary Containment)	Baseplate	A	ASME Section III; Subsection NB	Alloy X	See Appendix 1.A	NA	NA
Helium Retention (Secondary Containment)	Lid (One-piece design and top portion of optional two-piece design)	A	ASME Section III; Subsection NB	Alloy X	See Appendix 1.A	NA	NA
Helium Retention (Secondary Containment)	Closure Ring	A	ASME Section III; Subsection NB	Alloy X	See Appendix 1.A	NA	NA
Helium Retention (Secondary Containment)	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; core support structures (NG-1121)	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

Notes:
1) There are no known residuals on finished component surfaces.
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III. For parts beyond the purview of ASME Section III, compliance with Section IX and Section II of the Code shall be observed to the extent practicable.
3) Component nomenclature taken from Bill of Materials in Chapter 1.
4) A,B and C denote important to safety classifications as described in NUREG/CR-6407. NITS stands for Not Important To Safety.
5) For details on Alloy X material, see Appendix 1.A.

TABLE 1.3.3 (continued)

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)
Shielding	Bottom portion of optional two-piece MPC lid design	B	Non-code	Alloy X	See Appendix 1.A	NA	NA
Heat Transfer	Optional 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
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; internal structures (NG-1122)	Alloy X	See Appendix 1.A	NA	NA
Structural Form	Basket Supports (Flat Plates)	NITS	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

Notes:
1) There are no known residuals on finished component surfaces.
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III. For parts beyond the purview of ASME Section III, compliance with Section IX and Section II of the Code shall be observed to the extent practicable.
3) Component nomenclature taken from Bill of Materials in Chapter 1.
4) A,B and C denote important to safety classifications as described in NUREG/CR-6407. NITS stands for Not Important To Safety.
5) For details on Alloy X material, see Appendix 1.A.

TABLE 1.3.3 (continued)

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	Lower Fuel Spacer Column	B	ASME Section III; Subsection NG (only for stress analysis)	S/S	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
Structural Integrity	Trojan MPC Spacer	B	Non-code	304 S/S	Per ASME Section II	NA	NA
Structural Integrity	Trojan Failed Fuel Can Spacer	B	ASME Section III, Subsection NF	304 or 304LN S/S	Per ASME Section II	NA	NA
Operations	Vent and Drain Tube	C	Non-code	S/S	Per ASME Section II	Thread area surface hardened	NA
Operations	Vent & Drain Cap	C	Non-code	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
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

Notes:
1) There are no known residuals on finished component surfaces.
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III. For parts beyond the purview of ASME Section III, compliance with Section IX and Section II of the Code shall be observed to the extent practicable.
3) Component nomenclature taken from Bill of Materials in Chapter 1.
4) A,B and C denote important to safety classifications as described in NUREG/CR-6407. NITS stands for Not Important To Safety.
5) For details on Alloy X material, see Appendix 1.A.

TABLE 1.3.3 (continued)

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	Damaged Fuel Container	C	ASME Section III; Subsection NG	Primarily 304 S/S	See Appendix 1.A	NA	NA
Operations	Trojan Failed Fuel Can	C	ASME Section III; Subsection NG	304 S/S	Per ASME Section II	NA	NA
Operations	Drain Line Guide Tube	NITS	Non-code	S/S	NA	NA	NA

Notes:
1) There are no known residuals on finished component surfaces.
2) All welding processes used in welding the components shall be qualified in accordance with the requirements of ASME Section IX. All welds shall be made using welders qualified in accordance with ASME Section IX. Weld material shall meet the requirements of ASME Section II and the applicable Subsection of ASME Section III. For parts beyond the purview of ASME Section III, compliance with Section IX and Section II of the Code shall be observed to the extent practicable.
3) Component nomenclature taken from Bill of Materials in Chapter 1.
4) A,B and C denote important to safety classifications as described in NUREG/CR-6407. NITS stands for Not Important To Safety.
5) For details on Alloy X material, see Appendix 1.A.

1.4 DRAWINGS

The following drawings provide sufficient detail to describe the HI-STAR 100 packaging.

The classification of all components important to safety in accordance with Regulatory Guide 7.10 and NUREG/CR-6407 is provided in Table 1.3.3. Operational information, such as bolt torque and pressure-relief specifications are provided in Chapters 7 and 8. The maximum weight of the package and the maximum weight of the contents is provided in Table 2.2.1.

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

Drawing Number/Sheet	Description	Rev.
3913	Licensing Drawing for HI-STAR 100 Overpack Assembly	~~5~~*7*
3923	Licensing Drawing for MPC Enclosure Vessel	~~8~~*11*
3925	Licensing Drawing for MPC-24E/EF Fuel Basket Assembly	~~4~~*5*
3926	Licensing Drawing for MPC-24 Fuel Basket Assembly	5
3927	Licensing Drawing for MPC-32 Fuel Basket Assembly	6
3928	Licensing Drawing for MPC-68/68F/68FF Fuel Basket Assembly	~~4~~*5*
5014-C1765 Sht 1/7†	HI-STAR 100 Impact Limiter	~~1~~*2*
5014-C1765 Sht 2/7†	HI-STAR 100 Bottom Impact Limiter	~~1~~*2*
5014-C1765 Sht 3/7†	HI-STAR 100 Top Impact Limiter	1
5014-C1765 Sht 4/7†	HI-STAR 100 Top Impact Limiter	~~1~~*2*
5014-C1765 Sht 5/7†	HI-STAR 100 Top Impact Limiter Detail of Item #6	1
5014-C1765 Sht 6/7†	HI-STAR 100 Impact Limiter Honeycomb Details	1
5014-C1765 Sht 7/7†	HI-STAR 100 Bottom Impact Limiter	0
3930	HI-STAR 100 Assembly For Transport	1
4111	Licensing Drawing for Trojan MPC Spacer Ring	0
4119	Licensing Drawing for Holtec Damaged Fuel Container for Trojan Plant Fuel	1

† These drawing titles include the term "CoC No. 9261, Appendix B." Rather than appending the drawings directly to the CoC, they are incorporated into the CoC by reference. The "Appendix B" will be removed from each drawing as part of its next normal revision.

Drawing Number/Sheet	Description	Rev.
4122	Licensing Drawing for Trojan FFC Spacer	0
PFFC-001	Failed Fuel Can Assembly	8
PFFC-002	Failed Fuel Can Shell and Lid Assembly	7

Figure Withheld Under 10 CFR 2.390

HOLTEC INTERNATIONAL HOLTEC CENTER 555 LINCOLN DRIVE WEST MARLTON, NJ 08053	GENERAL HI-STAR 100 OVERPACK
1020	3913	1	9
N/A	

Figure Withheld Under 10 CFR 2.390

HOLTEC INTERNATIONAL HOLTEC CENTER 555 LINCOLN DRIVE WEST MARLTON, NJ 08053	GENERAL			
	HI-STAR 100 OVERPACK ELEVATION VIEW			
	D	3913	2	7
	NTS			

2 1

Figure Withheld Under 10 CFR 2.390

HOLTEC INTERNATIONAL HOLTEC CENTER 555 LINCOLN DRIVE WEST MARLTON, NJ 08053	GENERAL HI-STAR 100 OVERPACK DETAIL OF TOP FLANGE AT 0° & 180°		
	D	3913	3	7
	NTS			

2 1

Figure Withheld Under 10 CFR 2.390

HOLTEC INTERNATIONAL	GENERAL		
	HI-STAR 100 OVERPACK CLOSURE PLATE BOLT HOLE & BOLT		
	D	3913	4	7
	NTS		

Figure Withheld Under 10 CFR 2.390

HOLTEC INTERNATIONAL HOLTEC CENTER 555 LINCOLN DRIVE WEST MARLTON, NJ 08053	GENERAL			
	HI-STAR 100 OVERPACK TOP PLAN VIEW "D" - "D"			
	D	3913	5	7
	NTS			

Figure Withheld Under 10 CFR 2.390

HOLTEC INTERNATIONAL HOLTEC CENTER 555 LINCOLN DRIVE WEST MARLTON, NJ 08053	GENERAL HI-STAR 100 OVERPACK MID-PLANE SECTION "E" - "E"			
	D	3913	6	7
	NTS			

2 1

Figure Withheld Under 10 CFR 2.390

HOLTEC INTERNATIONAL HOLTEC CENTER 555 LINCOLN DRIVE WEST MARLTON, NJ 08053	GENERAL HI-STAR 100 OVERPACK TEST, VENT AND DRAIN PORT DETAILS			
	D	3913	7	7
	NTS			

2 1 1

Figure Withheld Under 10 CFR 2.390

HOLTEC INTERNATIONAL HOLTEC CENTER 555 LINCOLN DRIVE WEST MARLTON, NJ 08053	GENERAL HI-STAR 100 OVERPACK DETAIL "H"			
	D	3913	8	7
	NTS			

2 1

Figure Withheld Under 10 CFR 2.390

HOLTEC INTERNATIONAL HOLTEC CENTER 555 LINCOLN DRIVE WEST MARLTON, NJ 08053	GENERAL			
	POCKET TRUNNION DETAIL			
	D	3913	9	7
	NTS			

2 1

Figure Withheld Under 10 CFR 2.390

HOLTEC INTERNATIONAL

GENERA

MPC ENCLOSURE VESSEL

5014

N/A

3923

1

2

1

Figure Withheld Under 10 CFR 2.390

HOLTEC INTERNATIONAL

3925 3926 3927 3928

GENERAL

MPC ENCLOSURE VESSEL GENERAL ARRANGEMENT

D	3923	2	11

Figure Withheld Under 10 CFR 2.390

HOLTEC INTERNATIONAL	GENERAL
	MPC ENCLOSURE ENCLOSURE VESSEL ELEVATION DETAILS
	D	3923	3	11

2 1

Figure Withheld Under 10 CFR 2.390

HOLTEC INTERNATIONAL	GENERAL	
3925 3926 3927 3928	MPC ENCLOSURE VESSEL LID DETAILS	
	D 3923	4 11

2 1

Figure Withheld Under 10 CFR 2.390

HOLTEC INTERNATIONAL	GENERAL			
	FUEL SPACER DETAILS			
3925 3926 3927 3928	D	3923	5	11
	NONE			

2 1

Figure Withheld Under 10 CFR 2.390

HOLTEC INTERNATIONAL	GENERAL			
	MPC SERIAL #1021 040 ENCLOSURE VESSEL LID DETAILS			
	D	3923	6	11

2 1

Figure Withheld Under 10 CFR 2.390

HOLTEC INTERNATIONAL

GENERAL

MPC-24E/EF
FUEL BASKET
ASSEMBLY

1022	3925	1	
N/A			

Figure Withheld Under 10 CFR 2.390

HOLTEC INTERNATIONAL

MPC-24E/EF FUEL BASKET ARRANGEMENT

D	3925	2	5

2

1

Figure Withheld Under 10 CFR 2.390

HOLTEC INTERNATIONAL	GENERAL	
	MPC-24E/EF FUEL BASKET LAYOUT AND WELD DETAILS	
	D 3925	3 5

2 1

Figure Withheld Under 10 CFR 2.390

HOLTEC INTERNATIONAL	GENERAL MPC-24E/24EF FUEL BASKET SUPPORTS			
	D	3925	4	5

Figure Withheld Under 10 CFR 2.390

TRANSPORTATION UNDER 10CFR71

HOLTEC INTERNATIONAL

GENERAL

MPC-68/68F/68FF FUEL BASKET

1021	3928	1	1
N/A			

2 1

Figure Withheld Under 10 CFR 2.390

HOLTEC INTERNATIONAL

GENERAL

MPC-68 68F 68FF FUEL BASKET

D 3928 2 5

2 1

Figure Withheld Under 10 CFR 2.390

HOLTEC INTERNATIONAL

GENERAL

MPC 68 68F 68FF
FUEL BASKET
LAYOUT AND WELD DETAILS

D | 3928 | 3 | 5

Figure Withheld Under 10 CFR 2.390

HOLTEC INTERNATIONAL

GENERAL

MPC 68/68FF/68F
FUEL BASKET
SUPPORTS

D 3928 4 5

Figure Withheld Under 10 CFR 2.390

HI-STAR 100 IMPACT LIMITER CoC No. 9261, APPENDIX B	
LIENT VARIOUS	
OMPANION DRAWINGS NONE	REV [illegible]
ROJECT No 5014	DRAWING No C1765 (E I D 4420) SHT 1 OF 7
I. No. VARIOUS	

@\DRAWINGS\5014\5014\IMPACT\C1765-1R1

Figure Withheld Under 10 CFR 2.390

CLIENT	VARIOUS
COMPANION DRAWINGS NONE	
PROJECT No 5014	DRAWING No C1765
P.O. No VARIOUS	

Figure Withheld Under 10 CFR 2.390

VARIOUS	
COMPANION DRAWINGS NONE	REV.
PROJECT No. 5014	DRAWING No
P.C. No VARIOUS	C1765 (E12-442E) SHT 4 3

P:\DRAWINGS\5014\5014\IMPACT\C1765-4

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4.1 CONTAINMENT BOUNDARIES

The primary containment system boundary for the HI-STAR 100 packaging consists of the overpack inner shell, the bottom plate, the top flange, the top closure plate, closure bolts, the overpack vent and drain port plugs, and their respective mechanical seals. The primary containment boundary system components for the HI-STAR 100 system are designed and fabricated in accordance with the requirements of ASME Code, Section III, Subsection NB [4.1.1], to the maximum extent practicable. Chapter 1 provides design criteria for the containment design. Section 1.3 provides applicable Code requirements. Exceptions to specific Code requirements with complete justifications are presented in Table 1.3.2. The primary containment boundary components are shown on Figure 4.1.1 with additional details provided in Figures 4.1.2 and 4.1.3.

The secondary containment system boundary for a HI-STAR 100 packaging containing fuel debris in the MPC-24EF or the MPC-68F consists of the enclosure vessel including the MPC shell, the MPC bottom plate, the MPC lid, vent and drain port cover plates and MPC closure ring. The secondary containment boundary system components for the HI-STAR 100 system are designed and fabricated in accordance with the requirements of ASME Code, Section III, Subsection NB, to the maximum extent practicable. Chapter 2 provides design criteria for the containment design. Section 1.3 provides applicable Code requirements. Alternatives to specific Code requirements with complete justifications are presented in Table 1.3.2. The secondary containment boundary components are shown in Figure 4.1.4. The use of two independent and testable containment boundaries provides the capability to load and transport the specified fuel debris in accordance with the requirements of 10CFR71.63(b) [4.0.1]. The MPC-24EF or MPC-68F each provide the separate inner container per 10CFR71.63(b) for the HI-STAR 100 System transporting fuel classified as fuel debris. The other MPC designs (MPC-24, MPC-24E, MPC-32 and MPC-68) are not currently evaluated for secondary containment requirements.

4.1.1 Containment Vessel

The primary containment vessel for the HI-STAR 100 packaging consists of the overpack components which form the inner cavity volume used to house any of the MPC designs which contain spent nuclear fuel. The primary containment vessel is represented by the overpack inner shell, bottom plate, the top flange, and the closure plate. These components create an enclosed cylindrical cavity sufficient for insertion and enclosure of an MPC. The materials of construction for the packaging primary containment vessel are specified in the drawings in Section 1.4.

The secondary containment vessel for the HI-STAR 100 packaging consists of either the MPC-24EF or the MPC-68F enclosure vessel complete with field-installed MPC lid, closure ring, vent and drain port cover plates. The enclosure vessel components create an enclosed cylindrical cavity sufficient for insertion and enclosure of fuel debris. The materials of construction for the secondary containment vessel are specified in the drawings in Section 1.4.

Table 4.1.1 provides a summary of the containment boundary design specifications.

4.1.2 Containment Penetrations

The primary containment system boundary penetrations for the HI-STAR 100 package include the closure plate test port plug, the vent port plug, the drain port plug, and their respective mechanical seals. Each penetration has redundant mechanical seals. The vent port is located in the closure plate and the drain port is located in the bottom plate. The closure configuration of the vent and drain ports is essentially identical (See Figure 4.1.3). The primary containment penetrations are designed and tested to ensure that the radionuclide release rates specified in 10CFR71.51 will not be exceeded.

The secondary containment boundary for the HI-STAR 100 packaging is the either the MPC-24EF or the MPC-68F. The penetrations on the MPC include the MPC vent and drain port cover plates. The MPC penetrations are designed to prevent the release of radionuclides. Two penetrations (the MPC vent and drain ports) are provided in the MPC lid for MPC draining, vacuum drying and backfilling during MPC loading operations, and for fuel cool-down and MPC flooding during unloading operations. No other confinement penetrations exist in the MPC. The MPC vent and drain ports are equipped with metal-to-metal seals to minimize leakage and withstand the long-term effects of temperature and radiation. No containment credit is taken for the vent and drain mechanical seals. The vent and drain connectors allow the vent and drain ports to be operated like valves and prevent the need to hot tap into the penetrations during unloading operations. The vent and drain port covers are sealed with the fully welded vent and drain port cover plates. The MPC closure ring covers the vent and drain port cover plate welds, and the MPC lid-to-shell weld providing redundant closure of the MPC vessel. Both the MPC-24EF and MPC-68F are designed and tested to ensure that the radionuclide release rates specified in 10CFR71.63(b) will not be exceeded.

4.1.3 Seals and Welds

The HI-STAR 100 primary containment vessel uses a combination of seals and welds designed and tested during normal transport conditions, and during and after the hypothetical transport accident conditions. The secondary containment boundary utilizes a fully welded vessel to prevent the release of radioactive materials. Seals and welds are individually discussed below.

The seals and welds discussed below provide containment systems which are securely closed, cannot be opened unintentionally or by an internal pressure within the package as required in 10CFR71.43(c).

4.1.3.1 Containment Seals

The HI-STAR 100 closure plate uses two concentric metallic seals to form the closure between the top flange surface and the closure plate. To protect the sealing surfaces against corrosion, a stainless steel weld inlay is provided during manufacturing on both the closure plate and mating overpack surfaces. The closure plate inner seal is tested for leakage through a small test port in the overpack closure plate (See Figure 4.1.2). The test port provides access to the volume between the two mechanical lid seals for leakage testing of the closure plate inner seal. Following leakage testing, a threaded plug with a metallic seal is installed in the test port hole to provide redundant closure.

Primary closure of the vent and drain ports is achieved via a threaded plug with a single metallic seal. The metallic seal is compressed between the underside of the threaded plug head and the overpack body to form the seal. The sealing surfaces are not subject to corrosion due to the presence of the cover plates and their seals preventing exposure of the seal surfaces to the elements. Each port plug seal is independently tested for leakage to verify containment performance. A bolted cover plate, with a machined seal groove, is installed over the vent and drain ports. A metallic seal, installed in the cover plate groove, is compressed between the cover plate and the overpack body during cover plate bolt torquing. These cover plates provide redundant closure of the drain and vent port penetrations.

Details on the seals are provided in the drawings in Section 1.4 and in Appendix 4.B. Table 4.1.1 contains reference information for the seals from the selected supplier. Note that the seals selected are designed and fabricated to meet the design requirements of the HI-STAR 100 System. The Chapter 7 procedures require replacement of any used seal after closure opening except for transportation of an empty overpack.

There are no seals on the secondary containment boundary.

4.1.3.2 Containment Welds

The primary containment boundary welds of the HI-STAR 100 overpack body include the welds forming the inner closure shell, the weld connecting the inner shell to the top flange, and the weld connecting the bottom plate to the inner shell. All primary containment boundary welds are fabricated and inspected in accordance with ASME Code Section III, Subsection NB (no stamp required). Full-penetration welds are specified for the plates that form the overpack inner shell. Full-penetration welds are also specified for the inner shell to the top flange and bottom plate welds. The weld details are shown in the drawings in Section 1.4. The containment boundary welds are volumetrically examined by radiography (RT) as described in Chapter 8.

The secondary containment boundary welds of the MPC-24EF and MPC-68F include the welds forming the MPC shell, the weld connecting the shell to the MPC baseplate, and the final field closure welds described in Section 4.1.4.2. All secondary containment welds are fabricated and inspected in accordance with ASME Code Section III, Subsection NB, except for the field installed closure welds. The alternatives to the ASME Code for the secondary containment are detailed in Table 1.3.2. The weld details are shown on the MPC-24EF and MPC-68F drawings in Section 1.4. The secondary containment boundary welds are volumetrically examined by radiography (RT) or ultrasonic (UT) inspection methods as described in Chapter 8.

4.1.4 Closure

4.1.4.1 Primary Closure

The HI-STAR 100 packaging closure plate is secured using multiple closure bolts around the perimeter. Torquing of the closure plate bolts compresses the closure plate concentric mechanical seals between the closure plate and the overpack flange forming the closure plate seal.

Closure of the overpack vent and drain ports is provided by a single threaded plug installed in each penetration (see Figure 4.1.3). The mechanical seal is compressed between the underside of the port plug head and the overpack body forming the primary port closure. A cover plate, containing a single metallic seal, is installed over each of the ports forming the redundant closure of the vent and drain port penetrations. The cover plate is secured by bolts. The closure plate test port is sealed using a port plug and mechanical seal in the same manner as the vent and drain port penetrations (see Figure 4.1.2).

The installation procedures, bolt torquing patterns, required lubrication, and torque values are provided in Table 7.1.3. The torque values are established to maintain containment during normal and accident conditions of transport. Torque values for the closure plate bolts were determined to preclude separation of the closure plate from the overpack flange. Appendix 4.A contains the calculations for the test, vent and drain port plugs and the vent and drain port cover plates bolt torques.

Table 4.1.2 provides a summary of the containment closure bolting for the HI-STAR 100 overpack penetrations.

4.1.4.2 Secondary Closure

The secondary closure of the HI-STAR 100 packaging is provided by the MPC lid which is welded to the MPC shell. Following fuel loading and MPC lid welding, the MPC lid to shell weld may be examined by either volumetric or multi-layer liquid penetrant examination. If volumetric examination is used, it shall be the ultrasonic method and shall include a PT of the root and final weld layers. If PT alone is used, at a minimum, it must include the root and final weld layers and sufficient intermediate layers to detect critical weld flaws.

Then ~~T~~*t*he *MPC* lid to shell weld is ~~also volumetrically examined,~~ helium leakage tested~~,~~ and hydrostatic tested. If the MPC lid weld is acceptable, the vent and drain port cover plates are welded in place, examined by the liquid penetrant method (root and final), and a leakage rate test is performed. Finally, the MPC closure ring *(with no closure ring penetrations)* is installed, welded and inspected by the liquid penetrant method (root and final).

Alternatively, the MPC lid to shell weld is only hydrostatic tested. If the MPC lid weld is acceptable, the vent and drain port cover plates are welded in place, examined by liquid penetrant method (root and final). The MPC closure ring, with the closure ring penetrations, is installed, welded and inspected by the liquid penetrant method (root and final) and a leakage rate test is performed on the MPC lid-to-shell weld and vent and drain port cover plates. The closure ring penetrations are welded and inspected by the liquid penetrant method (final).

4.1.5 Damaged Fuel Container

Fuel assemblies classified as damaged fuel or fuel debris (assembly array/class 6x6A, 6x6B, 6x6C, 7x7A, and 8x8A for BWR fuel as specified in Table 1.2.11 and Trojan damaged fuel and fuel debris for PWR fuel as specified in Table 1.2.10) have been evaluated.

The MPC is designed to transport damaged fuel, fuel debris, or intact fuel. The sole additional requirement imposed on an MPC to load fuel debris is an additional leakage rate criteria test just prior to shipment. Therefore, an MPC which is to transport fuel debris will be designated to ensure the proper leakage rate test criteria is applied. To distinguish an MPC which is fabricated to transport fuel debris, the MPC will be designated with an "F" after the MPC designation (i.e. MPC-68F or MPC-24EF)

To aid in loading and unloading, damaged fuel assemblies and fuel debris will be loaded into stainless steel DFCs prior to placement in the HI-STAR 100 System. The damaged fuel container (DFC) is shown in the drawings in Section 1.4. The DFC is designed to provide SNF loose component retention and handling capabilities. The DFC consists of a smooth-walled, welded stainless steel square canister with a removable lid. The canister lid provides the means of DFC closure and handling. The DFC is provided with stainless steel wire mesh screens in the top and bottom for draining, vacuum drying and helium backfill operations. The screens are specified as a 250-by-250-mesh with an effective opening of 0.0024 inches. There are no other openings in the DFC. Chapter 1 specifies the fuel assembly characteristics for damaged fuel acceptable for loading in the MPC-68, MPC-68F, or MPC-24EF and for fuel debris acceptable for loading in the MPC-68F or MPC-24EF.

Up to four (4) DFCs containing specified fuel debris may be placed in a custom-designed Trojan MPC-24EF (Trojan PWR fuel debris) or an MPC-68F (BWR fuel debris). Up to 4 PWR damaged fuel assemblies in DFCs may be transported in a custom-designed Trojan MPC-24EF or up to 68 BWR damaged fuel assemblies in DFCs may be transported in an MPC-68 or MPC-68F, respectively. The quantity of fuel debris is limited to meet the off-site transportation requirements of 10CFR71, specifically, 10CFR71.63(b). Analyses provided in this chapter conservatively assume 100% of the rods of the fuel debris are breached under normal conditions of transport. Therefore, 100% of the contents of the DFCs are available for release.

Table 4.1.1

SUMMARY OF CONTAINMENT BOUNDARY DESIGN SPECIFICATIONS

Design Attribute	Design Rating	
	Primary (Overpack) 10CFR71.51	Secondary (MPC) 10CFR71.63(b)
Closure Plate Mechanical Seals:†† Design Temperature Pressure Rating Design Leakage Rate	 $1200^{o}F$ 1,000 psig $1x10^{-6}$ cm^3/s, Helium	N/A
Overpack Vent and Drain Port Cover Plate Mechanical Seals: †,†† Design Temperature Pressure Rating Design Leakage Rate	 $1200^{o}F$ 1,000 psig $1x10^{-6}$ cm^3/sec, Helium	N/A
Overpack Vent and Drain Port Plug Mechanical Seals: †† Design Temperature Pressure Rating Design Leakage Rate	 $1200^{o}F$ 1,000 psig $1x10^{-6}$ cm^3/sec, Helium	N/A
Leakage Rate Acceptance Criterion	4.3×10^{-6} atm cm^3/s, He	5.0×10^{-6} atm cm^3/s, He
Leakage Rate Test Sensitivity	2.15×10^{-6} atm cm^3/s, He	2.5×10^{-6} atm cm^3/s, He

† No credit is taken for the overpack vent and drain port cover plate seals as part of the containment boundary. Specifications are provided for information.

†† Per manufacturer's recommended operating limits.

Table 4.1.2

CONTAINMENT CLOSURE BOLTING SUMMARY

Item	Qty	Type	Material
Closure Plate Bolt (Long)	52	1-5/8"-8 UNC x 7-3/8" LG Cap Screw	SB-637-N07718
Closure Plate Bolt (Short)	2	1-5/8"-8 UNC x 7-1/8" LG Cap Screw	SB-637-N07718
Vent/Drain Port Cover Plate Bolt	4 ea	3/8 -16 UNC x 5/8" LG Cap Screw	SA-193 GRADE B7
Vent/Drain/Closure Plate Test Port Plugs	1 ea	7/8" diameter Fabricated Plug	SA-193 GRADE B8

4.2 REQUIREMENTS FOR NORMAL AND HYPOTHETICAL ACCIDENT CONDITIONS OF TRANSPORT

Chapter 2 shows that all primary and secondary containment components are maintained within their code-allowable stress limits during all normal and hypothetical accident conditions of transport as defined in 10CFR71.71 and 10CFR71.73 [4.0.1]. Chapter 3 shows that the peak containment component temperatures and pressure are within the design basis limits for all normal and hypothetical accident conditions of transport as defined in 10CFR71.71 and 10CFR71.73. Since the primary and secondary containment vessels remain intact, and the temperature and pressure design bases are not exceeded, the design basis leakage rate (see Table 4.1.1) will not be exceeded during normal or hypothetical accident conditions of transport.

4.2.1 Containment Criteria

The allowable leakage rates presented in this chapter were determined in accordance with ANSI N14.5-1997 [4.0.2] and shall be used for containment system fabrication verification and containment system periodic verification tests of the HI-STAR 100 containment boundaries. Measured leakage rates shall not exceed the values presented in Table 4.1.1. Compliance with these leakage rates ensures that the radionuclide release rates specified in 10CFR71.51 and 10CFR71.63(b) will not be exceeded during normal or hypothetical accident conditions of transport.

4.2.2 Containment of Radioactive Material

The HI-STAR 100 packaging allowable leakage rate (See Table 4.1.1) ensures that the requirements of 10CFR71.51 and 10CFR71.63(b) are met. Section 4.2.5 determines the maximum leakage rate for normal and hypothetical accident conditions of transport and the allowable leakage rate criterion for the HI-STAR 100 packaging containing each of the MPC types. The maximum calculated leakage rates for normal transport conditions assume a full complement of design basis fuel assembly types with bounding radiological source terms. The calculations also assume 3% fuel rod rupture for normal conditions. This bounds all possible MPC fuel loading configurations. For calculating the maximum leakage rates for normal conditions of transport, the internal pressure is conservatively assumed to be greater than the MPC internal pressure for the most limiting MPC type determined in Chapter 3. Following testing, no credit is taken for the MPC as a containment boundary for the transport of intact fuel. The MPC enclosure vessel is identified as the secondary containment boundary for the transport of the specified fuel debris in accordance with the 10CFR71.63(b) requirements for a separate inner container.

The allowable leakage rate is then conservatively chosen to be less than the calculated maximum leakage rates from all MPC types for normal conditions of transport. This ensures that the 10CFR71.51(a)(1) and 71.63(b) limits for radionuclide release are not exceeded.

4.2.3 Pressurization of Containment Vessel

The HI-STAR 100 overpack contains a sealed MPC during normal conditions of transport. Except for the small space between the MPC and overpack, the overpack internal cavity is essentially filled. This space (annulus) is drained, dried, evacuated and backfilled with helium gas prior to final closure of the overpack; therefore, no vapors or gases are present which could cause a reaction or explosion inside the overpack. Procedural steps (Chapter 7) prevent overpack over-pressurization during closure operations. The enclosed MPC is also drained, dried, and backfilled with helium gas prior to final closure; therefore, any MPC leak would not introduce any explosive gases into the overpack cavity. Since the exterior of the MPC is entirely composed of stainless steel, there is no possibility of chemical reaction that would produce gas or vapor. The overpack accident condition design basis internal pressure analysis assumes a non-mechanistic event resulting in the loss of MPC closure welds, a full-complement of design basis fuel with 100% fill gas and 30% of significant fission gas release, and the hypothetical 10CFR71.73(c)(4) fire condition. Even in this event, structural integrity and containment of the HI-STAR 100 packaging are maintained.

As the MPC is drained, dried, evacuated and backfilled with helium gas, no vapors or gases are present which could cause a reaction or explosion inside the MPC. Procedural steps (Chapter 7) prevent MPC over-pressurization during closure operations. The interior of the MPC contains stainless steel, Boral, and optional aluminum heat conductive inserts. There is no possibility of chemical reaction that would produce gas or vapor.

4.2.4 Assumptions

The HI-STAR 100 System is designed to meet the radioactive release limit requirements of 10CFR71.51 and 10CFR71.63(b). Allowable leakage rates are determined in accordance with the requirements of ANSI N14.5, and utilizing NUREG/CR-6487, *Containment Analysis for Type B Packages Used to Transport Various Contents* [4.0.3] and Regulatory Guide 7.4, *Leakage Tests on Packages for Shipment of Radioactive Materials* [4.0.4] as guides.

The following assumptions have been used in determining the allowable leakage rates:

1. For MPCs other than the MPC-24EF with Trojan fuel debris and MPC-68F, three percent of the fuel rods are assumed to have failed during normal conditions of transportation. One-hundred percent of the fuel rods are assumed to have failed during hypothetical accident conditions.

2. Thirty percent of the radioactive gases are assumed to escape each failed fuel rod.

3. Fifteen percent of the ^{60}Co from the crud on the surface of the fuel rods is released as an aerosol in normal conditions of transport. One-hundred percent of the ^{60}Co is released as an aerosol from the surfaces of the fuel assemblies during accident conditions.

4. Since the overpack internals are never exposed to contaminants, the residual activity on the overpack interior surface and the MPC exterior surface is negligible compared to crud deposits on the fuel and is neglected as a source term.

5. Up to four (4) DFCs containing specified fuel debris may be placed in an MPC-24EF (only the custom-designed Trojan MPC-24EF) or an MPC-68F.

6. Crud spallation and cladding breaches occur instantaneously after fuel loading and container closure operations.

7. The calculation for normal transport conditions of an MPC containing fuel debris assumes 100% of the rods of the fuel debris are breached.

8. For containment analysis purposes, the MPC-24, MPC-24E or MPC-24EF contain up to 24 PWR assemblies, of which 4 of these in the custom-designed Trojan MPC-24EF may be DFCs with Trojan fuel debris, the MPC-32 contains up to 32 PWR assemblies, the MPC-68 contains up to 68 BWR assemblies, and the MPC-68F contains up to 68 intact BWR fuel assemblies, of which 4 of those may be specified BWR fuel debris in damaged fuel containers.

9. 0.003% of the total fuel mass contained in a rod is assumed to be released as fines if the cladding on the rod ruptures (i.e., f_f=3x10^{-5}).

10. Bounding values for the crud surface activity for PWR rods is 140x10^{-6} Ci/cm^2 and for BWR rods is 1254x10^{-6} Ci/cm^2.

11. The rod surface area per assembly is 3x10^5 cm^2 for PWR and 1x10^5 cm^2 for BWR fuel assemblies. These surface areas are also conservatively used for the surface area of damaged fuel or fuel debris..

12. The release fractions for volatiles (^{89}Sr, ^{90}Sr, ^{103}Ru, ^{106}Ru, ^{134}Cs, ^{135}Cs, and ^{137}Cs) are all assumed to be 2x10^{-4} (f_V =2x10^{-4}).

13. In the analysis of the primary containment boundary, the MPC is assumed to rupture. In the analysis of the secondary containment boundary, the primary containment is assumed to fail.

14. In calculating the leakage rates of the primary containment for normal conditions of transport, the internal pressure of the overpack is conservatively assumed to be larger than the maximum internal pressure of all MPC types determined in Chapter 3.

15. The average cavity temperature for all analyses is conservatively assumed to be the design basis peak cladding temperature.

16. All of the activity associated with crud is assumed to be Cobalt-60.

17. It is assumed that the flow is unchoked for all leakage analyses.

18. In the evaluation to demonstrate compliance with 10CFR71.63(b), the source activity due to Plutonium was determined by conservatively assuming that all of the rods develop cladding breaches during normal transportation and hypothetical accident conditions (i.e., f_B=1.0).

19. In the evaluation to demonstrate compliance with 10CFR71.63(b), the assumption was also made that roughly 0.003% of the plutonium is released from a fuel rod (i.e., $f_{Pu}=3x10^{-5}$).

4.2.5 Analysis and Results

The allowable leakage rates for the primary and secondary containment boundaries under normal and hypothetical accident conditions of transport at operating conditions for the HI-STAR 100 packaging containing each of the MPC types were determined and are presented in this chapter. To calculate the leakage rates for a particular contents type and transportation condition, the following were determined: the source term concentration for the releasable material; the effective A_2 of the individual contributors; the releasable activity; the effective A_2 for the total source term; the allowable radionuclide release rates; and the allowable leakage rates at transport (operating) conditions. Using the equations for continuum and molecular flow, the corresponding leakage hole diameters were calculated. Then, using these leak hole diameters, the corresponding allowable leakage rates at test conditions were calculated. Parameters were utilized in a way that ensured conservatism in the final leakage rates for the conditions, contents, and package arrangements considered.

The methodology and analysis results are summarized below.

4.2.5.1 Volume in the Containment Vessel

As discussed above, the primary containment system boundary for the HI-STAR 100 packaging consists of the overpack inner shell and associated components and the secondary containment system boundary consists of the MPC enclosure vessel and associated components. The MPC provides the separate inner container per 10CFR71.63(b) for the HI-STAR 100 System transporting fuel classified as fuel debris.

Except for a small volume between the MPC and the overpack (the annulus), the overpack internal cavity is essentially filled. Therefore, the free gas volume for the primary containment boundary includes the free gas volume for the MPC plus the overpack annulus volume. The free gas volume in each of the MPC types is presented in Chapter 3. The free gas volumes of the primary and secondary containment are repeated in Table 4.2.1 for completeness. The MPC-24E and MPC-24EF basket designed for Trojan are shorter to allow for storage in their overpacks. These shorter baskets are designated as the Trojan MPC-24E and Trojan MPC-24EF, respectively, where necessary. For calculating the free volume in the primary containment (overpack) with either of the Trojan MPCs, the annulus space is assumed to be the same as that for the larger generic MPCs (i.e. the larger annulus space between the Trojan MPC and HI-STAR overpack is neglected). This will conservatively underestimate the free volume inside the primary containment.

4.2.5.2 Source Terms For Spent Nuclear Fuel Assemblies

In accordance with NUREG/CR-6487 [4.0.3], the following contributions are considered in determining the releasable source term for packages designed to transport irradiated fuel rods: (1)

the radionuclides comprising the fuel rods, (2) the radionuclides on the surface of the fuel rods, and (3) the residual contamination on the inside surfaces of the vessel. NUREG/CR-6487 goes on to state that a radioactive aerosol can be generated inside a vessel when radioactive material from the fuel rods or from the inside surfaces of the container become airborne. The sources for the airborne material are (1) residual activity on the cask interior, (2) fission and activation-product activity associated with corrosion-deposited material (crud) on the fuel assembly surface, and (3) the radionuclides within the individual fuel rods. In accordance with NUREG/CR-6487, contamination due to residual activity on the cask interior surfaces is negligible as compared to crud deposits on the fuel rods themselves and therefore may be neglected. The source term considered for this calculation results from the spallation of crud from the fuel rods and from the fines, gases and volatiles which result from cladding breaches.

The inventory for isotopes other than ^{60}Co is calculated with the SAS2H and ORIGEN-S modules of the SCALE 4.3 system as described in Chapter 5. The inventory for the MPC-24, MPC-24E, MPC-24EF, and MPC-32 was conservatively based on the B&W 15x15 fuel assembly with a burnup of 45,000 MWD/MTU, 5 years of cooling time, and an enrichment of 3.6%. The inventory for the Trojan MPCs (Trojan MPC-24E, Trojan MPC-24EF) was based on the Westinghouse 17x17 fuel assembly with a burnup of 42,000 MWD/MTU, 9 years cooling time, and an enrichment of 3.09% . The inventory for the MPC-68 was based the GE 7x7 fuel assembly with a burnup of 45,000 MWD/MTU, 5 years of cooling time, and 3.2% enrichment. The inventory for the MPC-68F was based on the GE 6x6 fuel assembly with a burnup of 30,000 MWD/MTU, 18 years of cooling time, and 1.8% enrichment. Additionally, an MPC-68F was analyzed containing 67 GE 6x6 assemblies and a DFC containing 18 thorium rods. Finally, an Sb-Be source stored in one fuel rod in one assembly with 67 GE 6x6 assemblies was analyzed. The isotopes which contribute greater than 0.01% to the total curie inventory for the fuel assembly are considered in the evaluation as fines. Additionally, isotopes with A_2 values less than 1.0 in Table A-1, Appendix A, 10CFR71 are included as fines. Isotopes which contribute greater than 0.01% but which do not have an assigned A_2 value in Table A-1 are assigned an A_2 value based on the guidance in Table A-2, Appendix A, 10CFR71. Isotopes which contribute greater than 0.01% but have a radiological half life less than 10 days are neglected. Table 4.2.2 presents the isotope inventory used in the calculation.

A. Source Activity Due to Crud Spallation from Fuel Rods

The majority of the activity associated with crud is due to ^{60}Co [4.0.3]. The inventory for ^{60}Co was determined by using the crud surface activity for PWR rods (140×10^{-6} Ci/cm^2) and for BWR rods (1254×10^{-6} Ci/cm^2) provided in NUREG/CR-6487 [4.0.3] multiplied by the surface area per assembly (3×10^5 cm^2 and 1×10^5 cm^2 for PWR and BWR, respectively, also provided in NUREG/CR-6487).

The source terms were then decay corrected (5 years for the MPC-24, MPC-24E, MPC-24EF, MPC-32 and the MPC-68; 18 years for the MPC-68F; 9 years for the Trojan MPCs) using the basic radioactive decay equation:

$$A(t) = A_0 e^{-\lambda t} \tag{4-1}$$

where:

A(t) is activity at time t [Ci]
A_o is the initial activity [Ci]
λ is the ln2/$t_{1/2}$ (where $t_{1/2}$ = 5.272 years for ^{60}Co)
t is the time in years (5 years for the MPC-24, MPC-24E, MPC-24EF, MPC-32 and the MPC-68; 18 years for the MPC-68F; 9 years for the Trojan MPCs)

The inventory for ^{60}Co was determined using the methodology described above with the following results:

PWR
Surface area per Assy = 3.0E+05 cm^2
140 μCi/cm^2 x 3.0E+05 cm^2 = 42.0 Ci/assy

BWR
Surface area per Assy = 1.0E+05 cm^2
1254 μCi/cm^2 x 1.0E+05 cm^2 = 125.4 Ci/assy

$^{60}Co(t) = {}^{60}Co_0\, e^{-(\lambda t)}$, where $\lambda = \ln 2/t_{1/2}$, t = 5 years (for the MPC-24, MPC-24E, MPC-24EF, MPC-32 and MPC-68), t = 18 years (MPC-68F), t = 9 years (Trojan MPCs), $t_{1/2}$ = 5.272 years for ^{60}Co [4.2.4]

MPC-24, MPC-24E, MPC-24EF, MPC-32
$^{60}Co(5) = 42.0\ Ci\ e^{-(\ln 2/5.272)(5)}$
$^{60}Co(5)$ = 21.77 Ci/assy

MPC-68
$^{60}Co(5) = 125.4\ Ci\ e^{-(\ln 2/5.272)(5)}$
$^{60}Co(5)$ = 64.98 Ci/assy

Trojan MPC-24E, Trojan MPC-24EF
$^{60}Co(5) = 42.0\ Ci\ e^{-(\ln 2/5.272)(9)}$
$^{60}Co(5)$ = 12.86 Ci/assy

MPC-68F
$^{60}Co(18) = 125.4\ Ci\ e^{-(\ln 2/5.272)(18)}$
$^{60}Co(18)$ = 11.76 Ci/assy

A summary of the ^{60}Co inventory available for release is provided in Table 4.2.2.

The activity density that results inside the containment vessel as a result of crud spallation from spent fuel rods can be formulated as:

$$C_{crud} = \frac{f_C\, M_A\, N_A}{V} \qquad \textbf{(4-2)}$$

where:

C_{crud} is the activity density inside the containment vessel as a result of crud spallation [Ci/cm^3],
M_A is the total crud activity inventory per assembly [Ci/assy],
f_C is the crud spallation fraction,
N_A is the number of assemblies, and
V is the free volume inside the containment vessel [cm^3].

NUREG/CR-6487 states that measurements have shown 15% to be a reasonable value for the percent of crud spallation for both PWR and BWR fuel rods under normal transportation conditions. For hypothetical accident conditions, it is assumed that there is 100% crud spallation [4.0.3].

B. <u>Source Activity Due to Releases of Fines from Cladding Breaches</u>

A breach in the cladding of a fuel rod may allow radionuclides to be released from the resulting cladding defect into the interior of the MPC. If there is a leak in the primary or secondary containment vessels, then the radioisotopes emitted from a cladding breach that were aerosolized may be entrained in the gases escaping from the package and result in a radioactive release to the environment.

NUREG/CR-6487 suggests that a bounding value of 3% of the rods develop cladding breaches during normal transportation (i.e., f_B=0.03). For hypothetical accident conditions, it is assumed that all of the rods develop a cladding breach (i.e., f_B=1.0). These values were used for both PWR and BWR fuel rods. As described in NUREG/CR-6487, roughly 0.003% of the fuel mass contained in a rod is released as fines if the cladding on the rod ruptures (i.e., f_f=3x10^{-5}).

The calculation for normal transport conditions of either a Trojan MPC-24EF or an MPC-68F containing four (4) DFCs containing fuel debris assumes that for the four DFCs, 100% of the rods of the fuel debris are breached. The remaining 20 or 64 assemblies in either the Trojan MPC-24EF or the MPC-68F, respectively, were assumed to have a 3% cladding rupture. Therefore, f_B for a Trojan MPC-24EF or an MPC-68F containing fuel debris is:

$$f_B = (0.03)\frac{20}{24} + (1.0)\frac{4}{20}$$
$$f_B = 0.192 \qquad \textbf{(4-3a)}$$

$$f_B = (0.03)\frac{64}{68} + (1.0)\frac{4}{68} \qquad \textbf{(4-3b)}$$
$$f_B = 0.087$$

The activity concentration inside the containment vessel due to fines being released from cladding breaches is given by:

$$C_{fines} = \frac{f_f\, I_{fines}\, N_A\, f_B}{V} \qquad \textbf{(4-4)}$$

where:

C_{fines} is the activity concentration inside the containment vessel as a result of fines released from cladding breaches [Ci/cm^3],
f_f is the fraction of a fuel rod's mass released as fines as a result of a cladding breach (f_f=3x10^{-5}),
I_{fines} is the total activity inventory [Ci/assy],
N_A is the number of assemblies,
f_B is the fraction of rods that develop cladding breaches, and
V is the free volume inside the containment vessel [cm^3].

C. Source Activity from Gases due to Cladding Breaches

If a cladding failure occurs in a fuel rod, a large fraction of the gap fission gases will be introduced into the free volume of the system. Tritium and Krypton-85 are typically the major sources of radioactivity among the gases present [4.0.3]. NUREG/CR-6487 suggests that a bounding value of 30% of the fission product gases escape from a fuel rod as a result of a cladding breach (i.e., f_g=0.3).

The activity concentration due to the release of gases form a cladding breach is given by:

$$C_{gases} = \frac{f_g \, I_{gases} \, N_A \, f_B}{V} \qquad \textbf{(4-5)}$$

where:

C_{gases} is the releasable activity concentration inside the containment vessel due to gases released from cladding breaches [Ci/cm^3],
f_g is the fraction of gas that would escape from a fuel rod that developed a cladding breach,
I_{gases} is the gas activity inventory [^{3}H, ^{129}I, ^{85}Kr, ^{81}Kr, ^{127}Xe] [Ci/assy],
N_A is the number of assemblies,
f_B is the fraction of rods that develop cladding breaches, and
V is the free volume inside the containment vessel [cm^3].

D. Source Activity from Volatiles due to Cladding Breaches

Volatiles such as cesium, strontium, and ruthenium, can also be released from a fuel rod as a result of a cladding breach. NUREG/CR-6487 estimates that $2x10^{-4}$ is a conservative bounding value for the fraction of the volatiles released from a fuel rod (i.e., $f_V=2x10^{-4}$).

The activity concentration due to the release of volatiles is given by:

$$C_{vol} = \frac{f_v \, I_{vol} \, N_A \, f_B}{V} \qquad \textbf{(4-6)}$$

where:

C_{vol} is the releasable activity concentration inside the containment vessel due to volatiles released from cladding breaches [Ci/cm^3],
f_V is the fraction of volatiles that would escape from a fuel rod that developed a cladding breach,
I_{vol} is the volatile activity inventory [^{89}Sr, ^{90}Sr, ^{134}Cs, ^{135}Cs, ^{137}Cs, ^{134}Cs, ^{103}Ru, ^{106}Ru] [Ci/assy],
N_A is the number of assemblies,
f_B is the fraction of rods that develop cladding breaches, and
V is the free volume inside the containment vessel [cm^3].

E. Total Source Term for the HI-STAR 100 System

The total source term was determined by combining Equations 4-2, 4-4, 4-5, and 4-6:

$$C_{total} = C_{crud} + C_{fines} + C_{gases} + C_{vol} \quad \textbf{(4-7)}$$

where C_{total} has units of Ci/cm^3.

Table 4.2.3 presents the total source term determined using the above methodology. Table 4.2.4 summarizes the parameters from NUREG/CR-6487 used in this analysis.

4.2.5.3 Effective A_2 of Individual Contributors (Crud, Fines, Gases, and Volatiles)

The A_2 of the individual contributions (i.e., crud, fines, gases, and volatiles) were determined in accordance with NUREG/CR-6487. As previously described, the majority of the activity due to crud is from Cobalt-60. Therefore, the A_2 value of 10.8 Ci used for crud for both PWR and BWR fuel is the same as that for Cobalt-60 found in 10CFR71, Appendix A.

In accordance with 10CFR71.51(b) the methodology presented in 10CFR71, Appendix A for mixtures of different radionuclides was used to determine the A_2 values for the gases, fines and volatiles.

$$A_2 \text{ for a mixture} = \frac{1}{\sum_{i=1}^{I} \frac{f_i}{(A_2)_i}} \quad \textbf{(4-8)}$$

Where f(i) is the fraction of activity of nuclide I in the mixture and $A_2(i)$ is the appropriate A_2 value for the nuclide I.

10CFR71.51(b) also states that for Krypton-85, an effective A_2 value equal to 10 A_2 may be used. Table 4.2.5 summarizes the effective A_2 for all individual contributors.

4.2.5.4 Releasable Activity

The releasable activity is the product of the respective activity concentrations (C_{fines}, C_{gas}, C_{crud}, and C_{vol}) and the respective MPC volume. The releasable activity of fines, volatiles, gases, and crud were determined using this methodology.

$$\text{Releasable Activity [Ci]} = \text{Activity Concentration } [\frac{Ci}{cm^3}] \text{ x Volume } [cm^3] \quad \textbf{(4-9)}$$

4.2.5.5 Effective A_2 for the Total Source Term

Using the releasable activity and the effective A_2 values from the individual contributors (i.e., crud, fines, gases, and volatiles), the effective A_2 for the total source term was calculated for each MPC type, for normal transportation and hypothetical accident conditions. The methodology used to determine the effective A_2 is the same as that used for a mixture, which is provided in Equation 4-8.

The results are summarized in Table 4.2.6. As stated in 4.2.5.3, the effective A_2 used for Krypton-85 is 10 A_2 (2700 Ci).

4.2.5.6 Allowable Radionuclide Release Rates

The containment criterion for the HI-STAR 100 System under normal conditions of transport is given in 10CFR71.51(a)(1). This criterion requires that a package have a radioactive release rate less than $A_2 \times 10^{-6}$ in one hour, where A_2 is the effective A_2 for the total source term in the packaging determined in 4.2.5.5. Additionally, 10CFR71.51(b)(2) specifies that for hypothetical accident conditions, the quantity that may be released in one week is A_2 (effective A_2 for the total source term determined in 4.2.5.5).

NUREG/CR-6487 and ANSI N14.5 provides the following equations for the allowable release rates.

Release rate for normal conditions of transport:

$$R_N = L_N C_N \leq A_2 \times 2.78\text{x}10^{-10}/\text{second} \qquad \textbf{(4-10)}$$

where:

R_N is the release rate for normal transport [Ci/s]
L_N is the volumetric gas leakage rate [cm^3/s]
C_N is the total source term activity concentration [Ci/cm^3]
A_2 is the appropriate effective A_2 value [Ci].

Release rate for hypothetical accident conditions:

$$R_A = L_A C_A \leq A_2 \times 1.65\text{x}10^{-6}/\text{second} \qquad \textbf{(4-11)}$$

where:

R_A is the release rate for hypothetical accident conditions [Ci/s]
L_A is the volumetric gas leakage rate [cm^3/s]
C_A is the total source term activity concentration [Ci/cm^3]
A_2 is the appropriate effective A_2 value [Ci].

Equations 4-10 and 4-11 were used to determine the allowable radionuclide release rates for each MPC type and transport condition. The release rates are summarized in Table 4.2.7.

4.2.5.7 Allowable Leakage Rates at Operating Conditions

The allowable leakage rates at operating conditions were determined by dividing the allowable release rates by the appropriate source term activity concentration (modifying Equations 4-10 and 4-11).

$$L_N = \frac{R_N}{C_N} \text{ or } L_A = \frac{R_A}{C_A} \qquad \textbf{(4-12)}$$

where,

L_N or L_A is the allowable leakage rate at the upstream pressure for normal (N) or accident (A) conditions [cm^3/s],
R_N or R_A is the allowable release rate for normal (N) or accident (A) conditions [Ci/s], and
C_N or C_A is the allowable release rate for normal (N) or accident (A) conditions [Ci/cm^3].

The allowable leakage rates determined using Equation 4-12 are the allowable leakage rates at the upstream pressure. Table 4.2.9 summarizes the allowable leakage rates at the upstream pressures. The most limiting allowable leakage rate presented in Table 4.2.9 was conservatively selected and used to determine the leakage rate acceptance criterion .

Equation deleted **(4-13)**

4.2.5.8 Leakage Rate Acceptance Criteria for Test Conditions

The leakage rates discussed thus far were determined at operating conditions (see normal and accident conditions in Table 4.2.12). The following provides details of the methodology used to convert the allowable leakage rate at operating conditions to a leakage rate acceptance criterion at reference test conditions.

For conservatism, unchoked flow correlations were used as the unchoked flow correlations better approximate the true measured flow rate for the leakage rates associated with transportation packages. Using the equations for molecular and continuum flow provided in NUREG/CR-6487, the corresponding leak hole diameter was calculated by solving Equation 4-14a for D, the leak hole diameter. The capillary length required for Equation 4-14a for the primary containment was conservatively chosen as the closure plate inner seal seating width which is 0.25 cm; for the secondary containment, the capillary length was conservatively chosen to be the MPC lid closure weld thickness which is 1.25 inches thick (3.175 cm).

$$L_{@P_u} = \left[\frac{2.49x10^6\ D^4}{a\ u} + \frac{3.81x10^3\ D^3 \sqrt{\frac{T}{M}}}{a\ P_a} \right] \left[P_u - P_d \right] \frac{P_a}{P_u} \qquad \textbf{(4-14a)}$$

where:

$L_{@Pu}$ is the allowable leakage rate at the upstream pressure for normal and accident conditions [cm^3/s],
a is the capillary length [cm],
T is the temperature for normal and accident conditions [K],
M is the gas molecular weight [g/mole] = 4.0 from ANSI N14.5, Table B1 [4.0.2],
u is the fluid viscosity for helium [cP] from Rosenhow and Hartnett [4.2.3]
P_u is the upstream pressure [ATM],
D leak hole diameter [cm],
P_d is the downstream pressure for normal and accident conditions [ATM], and
P_a is the average pressure; $P_a = (P_u + P_d)/2$ for normal and accident conditions [ATM].

The actual leakage tests performed on the primary and secondary confinement boundary welds are typically not performed under exactly the same conditions every time. Therefore, reference test conditions are specified to provide a consistent comparison of the measured leakage rate to the leakage rate acceptance criterion. For example, the MPC Lid-to-Shell weld is performed with *either* an elevated pressure (85 psig min) inside the MPC cavity to magnify the leakage rate in the event of a leak *or with a vacuum pulled on the area between the MPC lid and the cover ring and the helium backfill pressure inside the MPC cavity*. The reference test conditions, and approximate actual test conditions are specified in Table 4.2.12.

The corresponding leak hole diameter at operating conditions was determined by solving Equation 4-14a for 'D' where $L_{@Pu}$ is equal to 1.03×10^{-5} cm^3/s and using the parameters for normal conditions of transport presented in Table 4.2.12.

Using this leak hole diameter and the temperature and pressure specified for reference test conditions provided in Table 4.2.12, Equation 4-14a was solved for the volumetric leakage rate at reference test conditions.

Equation B-1 of ANSI N14.5-1997 [4.0.2] is used to express this volumetric leakage rate into a mass-like helium flow rate (Q_u) as follows:

$$Q_u = L_u * P_u \text{ (atm-cm}^3\text{/sec)} \qquad \textbf{(4-14b)}$$

where:

L_u is the upstream volumetric leakage rate [cm^3/sec],
Q_u is the mass-like helium leak rate [atm-cm^3/sec], and
P_u is the upstream pressure [atm].

Using Equation 4-14b to convert the volumetric flow rate into a mass-like flow, the leakage rate acceptance criteria is calculated to be 5.41×10^{-6} atm-cm^3/sec, which has been conservatively reduced and is presented in Table 4.1.1.

Table 4.2.12 provides additional parameters used in the analysis.

4.2.5.9 10CFR71.63(b) Plutonium Leakage Verification

The HI-STAR 100 System configured to transport fuel debris must meet the criteria of 10CFR71.63(b) for plutonium shipments. This criteria specifies that for normal conditions of transport, the separate inner container must not release plutonium as demonstrated to a sensitivity of $A_2 \times 10^{-6}$ in one hour, where A_2 is the effective A_2 for the plutonium inventory in the damaged fuel (up to four DFCs containing specified fuel debris). Additionally, 10CFR71.63(b) specifies that for hypothetical accident conditions, the separate inner container must restrict the loss of plutonium to not more than A_2 in one week (effective A_2 for the plutonium inventory determined using the methodology described in Section 4.2.5.3).

To demonstrate compliance with this requirement, the leakage rate acceptance criterion was determined following the basic methodology described above. To determine this leakage rate, the plutonium inventory for the GE 6x6 MOX fuel assembly and the plutonium inventories for the assemblies described in Section 4.2.5.2 was analyzed. Table 4.2.11 contains the plutonium inventory for the MOX fuel used in this evaluation.

As discussed in 4.2.5.2, Equation 4-3a and Equation 4-3b presents the methodology to determine f_B for a Trojan MPC-24EF and an MPC-68F containing fuel debris, respectively. This f_B was applied in determining the source activity due to Plutonium. The calculation for normal transport conditions of an MPC containing four (4) DFCs containing fuel debris assumes that for the four DFCs, 100% of the rods of the fuel debris are breached. The remaining assemblies in the MPC were assumed to have a 3% cladding rupture. The source activity due to Plutonium was determined by conservatively assuming that all of the rods develop cladding breaches during hypothetical accident conditions (i.e., f_B=1.0). The assumption was also made that roughly 0.003% of the plutonium is released from a fuel rod (i.e., $f_{Pu}=3\times10^{-5}$). Therefore, the activity concentration inside the containment vessel due to plutonium is given by:

$$C_{Pu} = \frac{f_{Pu}\, I_{Pu}\, N_A\, f_B}{V} \tag{4-15}$$

where:

C_{Pu} is the activity concentration inside the containment vessel from Plutonium [Ci/cm^3],
f_{Pu} is the fraction of a fuel rod's mass released as Plutonium ($f_f = 3\times10^{-5}$),
I_{Pu} is the total Plutonium inventory of one assembly [Ci/assy],
N_A is the number of assemblies,
f_B is the fraction of rods that develop cladding breaches (f_B=0.087 for BWR fuel and f_B=0.192 for PWR fuel under normal conditions of transport and f_B=1.0 for accident conditions), and
V is the free volume inside the containment vessel [cm^3] from Table 4.2.1.

The methodology described in 4.2.5.3 for mixtures was used to calculate the effective A_2 for Plutonium. The methodology in 4.2.5.4 was used to determine the releasable activity. The allowable radionuclide release rates were determined using the methodology presented in 4.2.5.6 and are summarized in Table 4.2.13. The allowable leakage rates at the upstream pressure were determined as discussed in 4.2.5.7 (using Equation 4-12). The allowable leakage rates are presented in Table 4.2.14. As in 4.2.5.7, the most limiting allowable leakage rate presented in Table 4.2.14 was conservatively selected and used to determine the leakage rate acceptance criterion for the MPC.

As discussed in 4.2.5.8, the allowable leakage rate was then converted to a leakage rate acceptance criterion at test conditions using the equations for molecular and continuum flow provided in NUREG/CR-6487 (Equation 4-14a). The capillary length required for Equation 4-14a for the secondary containment was conservatively chosen to be the MPC lid closure weld thickness which is assumed to be 1.25 inches thick (3.175 cm). Equation 4-14a was solved for D, the leak hole diameter and then using this leak hole diameter, and the temperature and pressures for test conditions (Table 4.1.12), Equation 4-14a was solved for the volumetric leakage rate acceptance criterion at test conditions. Equation 4-14b is used to convert the volumetric flow rate into the mass-like flow rate, resulting in an acceptance criterion leakage rate of 8.94×10^{-6} atm-cm^3/sec. For additional conservatism to ensure compliance with 10CFR71.63(b), this leakage rate acceptance criterion was conservatively reduced and is presented in Table 4.1.1.

4.2.5.10 Leak Test Sensitivity

The sensitivity for the overpack leakage test procedures is equal to one-half of the allowable leakage rate. The HI-STAR 100 containment packaging tests in Chapter 8 incorporate the appropriate leakage test procedure sensitivity. The leakage rates for the HI-STAR 100 containment packaging with its corresponding sensitivity are presented in Table 4.1.1.

Table 4.2.1

FREE GAS VOLUME OF THE PRIMARY AND SECONDARY CONTAINMENT

MPC Type	Primary Containment Volume (overpack) (cm^3)	Secondary Containment Volume (MPC) (cm^3)
MPC-24	6.70×10^6	N/A
MPC-24E MPC-24EF	6.55×10^6	N/A
Trojan MPC-24E Trojan MPC-24EF	6.12×10^6	5.96×10^6
MPC-32	6.35×10^6	N/A
MPC-68	6.15×10^6	N/A
MPC-68F	6.15×10^6	5.99×10^6

Table 4.2.2

ISOTOPE INVENTORY
Ci/Assembly

Nuclide	PWR MPCs Ci/Assembly	MPC-68 Ci/Assembly	MPC-68F Ci/Assembly	Trojan MPCs Ci/Assembly
Gases				
^{3}H	2.76E+02	1.09E+02	1.78E+01	1.75E+02
^{129}I	2.17E-02	8.66E-03	3.49E-03	1.93E-02
^{85}Kr	4.69E+03	1.79E+03	2.37E+02	2.76E+03
^{81}Kr	7.97E-08	3.50E-08	1.19E-08	6.80E-08
^{127}Xe	5.95E-11	2.05E-11	1.62E-17	3.39E-29
Crud				
^{60}Co	2.18E+01	6.50E+01	1.18E+01	1.29E+01
Volatiles				
^{90}Sr	4.53E+04	1.76E+04	4.29E+03	3.36E+04
^{106}Ru	4.97E+04	1.74E+04	2.30E-01	7.99E+02
^{134}Cs	4.43E+04	1.66E+04	3.16E+01	5.14E+03
^{137}Cs	6.76E+04	2.68E+04	7.21E+03	5.20E+04
^{89}Sr	1.25E-01	3.47E-02	2.41E-35	1.01E-14
^{103}Ru	3.65E-03	1.13E-03	0.00E+00	5.47E-20
^{135}Cs	2.79E-01	1.11E-01	4.54E-02	2.16E-01
Fines				
^{225}Ac*	3.05E-08	2.14E-08	9.69E-09	9.89E-13
^{227}Ac*	2.36E-06	1.18E-06	1.45E-06	2.56E-08
^{110m}Ag	1.73E+02	6.58E+01	4.97E-06	2.04E-07
^{241}Am	4.76E+02	1.61E+02	2.52E+02	1.17E+00

Table 4.2.2 (continued) ΙΣΟΤΟΠΕ ΙΝςΕΝΤΟΡΨ				
	MPC-24 Ci/Assembly	MPC-68 Ci/Assembly	MPC-68F Ci/Assembly	Trojan MPCs Ci/Assembly
^{242M}Am*	5.60E+00	1.94E+00	9.35E-01	5.06E-03
^{243}Am*	2.23E+01	9.42E+00	3.30E+00	2.53E-02
^{137m}Ba	6.39E+04	2.53E+04	6.81E+03	0.00E+00
^{210M} Bi*	0.00E+00	0.00E+00	0.00E+00	1.38E-10
^{247}Bk*	2.82E-08	1.32E-08	5.94E-08	7.06E-24
^{144}Ce	4.77E+04	1.45E+04	7.33E-03	2.62E-04
^{248}Cf*	0.00E+00	0.00E+00	0.00E+00	0.00E+00
^{249}Cf*	8.01E-05	4.47E-05	3.62E-06	7.20E-08
^{250}Cf*	2.92E-04	1.86E-04	6.69E-06	7.73E-08
^{251}Cf*	3.40E-06	2.06E-06	1.36E-07	2.84E-09
^{252}Cf*	4.11E-04	3.14E-04	3.64E-07	1.52E-08
^{254}Cf*	1.19E-13	1.05E-13	0.00E+00	5.32E-28
^{240}Cm*	0.00E+00	0.00E+00	0.00E+00	0.00E+00
^{242}Cm*	3.21E+02	1.26E+02	7.71E-01	8.42E-05
^{243}Cm*	1.61E+01	6.51E+00	1.54E+00	9.51E-03
^{244}Cm	3.26E+03	1.43E+03	2.17E+02	1.42E+00
^{245}Cm*	3.25E-01	1.23E-01	2.48E-02	3.21E-04
^{246}Cm*	1.06E-01	5.40E-02	1.01E-02	1.14E-04
^{247}Cm*	7.07E-07	3.72E-07	5.26E-08	7.01E-10
^{248}Cm*	4.20E-06	2.43E-06	2.53E-07	1.56E-08

Table 4.2.2 (continued)

ISOTOPE INVENTORY

Ci/Assembly

	MPC-24 Ci/Assembly	MPC-68 Ci/Assembly	MPC-68F Ci/Assembly	Trojan MPCs Ci/Assembly
^{253}Es*	6.35E-20	4.62E-20	0.00E+00	0.00E+00
^{254}Es*	1.93E-08	1.96E-08	8.05E-16	5.24E-15
^{154}Eu	4.03E+03	1.47E+03	1.44E+02	1.01E-03
^{155}Eu	1.34E+03	5.46E+02	2.23E+01	6.06E-05
^{55}Fe	6.98E+01	3.23E+01	2.94E-01	1.11E-07
^{257}Fm*	4.26E-07	1.69E-07	0.00E+00	2.35E-26
^{148}Gd*	0.00E+00	0.00E+00	0.00E+00	0.00E+00
^{182}Hf*	0.00E+00	0.00E+00	0.00E+00	0.00E+00
^{236}Np*	9.77E-06	3.29E-06	7.30E-07	1.78E-09
^{237}Np*	2.33E-01	8.07E-02	2.55E-02	2.33E-04
^{239}Np	2.23E+01	9.42E+00	3.30E+00	1.01E-05
^{231}Pa*	1.82E-05	8.17E-06	3.16E-06	3.26E-08
^{210}Pb*	4.30E-09	2.17E-09	1.17E-08	3.77E-13
^{147}Pm	4.28E+04	1.52E+04	1.18E+02	2.17E-03
^{208}Po*	0.00E+00	0.00E+00	0.00E+00	0.00E+00
^{209}Po*	0.00E+00	0.00E+00	0.00E+00	0.00E+00
^{210}Po*	3.92E-09	1.98E-09	1.08E-08	1.49E-13
^{144}Pr	4.77E+04	1.45E+04	7.33E-03	0.00E+00
^{144m}Pr	6.68E+02	2.04E+02	1.03E-04	0.00E+00
^{236}Pu*	2.04E-01	6.32E-02	3.66E-04	1.26E-05

Table 4.2.2 (continued) ISOTOPE INVENTORY Ci/Assembly				
	MPC-24 Ci/Assembly	MPC-68 Ci/Assembly	MPC-68F Ci/Assembly	Trojan MPCs Ci/Assembly
^{238}Pu	2.56E+03	9.55E+02	2.50E+02	2.37E+00
^{239}Pu	1.91E+02	6.24E+01	2.95E+01	2.00E-01
^{240}Pu	3.27E+02	1.34E+02	6.81E+01	3.70E-01
^{241}Pu	7.55E+04	2.47E+04	5.16E+03	1.21E+00
^{242}Pu*	1.65E+00	7.05E-01	3.06E-01	1.97E-03
^{244}Pu*	1.11E-13	6.58E-14	3.73E-14	2.87E-16
^{223}Ra*	2.37E-06	1.18E-06	1.45E-06	1.70E-11
^{225}Ra*	3.05E-08	2.14E-08	9.69E-09	4.94E-13
^{226}Ra*	2.82E-08	1.32E-08	5.94E-08	1.38E-12
^{106}Rh	4.97E+04	1.74E+04	2.30E-01	0.00E+00
^{222}Rn*	2.82E-08	1.32E-08	5.94E-08	6.89E-12
^{125}Sb	2.87E+03	1.15E+03	8.02E+00	1.59E-04
^{151}Sm	2.60E+02	7.92E+01	2.53E+01	1.24E-05
^{119m}Sn	5.46E+02	3.08E+02	1.07E-06	4.23E-05
^{125m}Te	6.99E+02	2.82E+02	1.96E+00	1.89E-03
^{227}Th*	2.33E-06	1.16E-06	1.43E-06	5.05E-11
^{228}Th*	8.56E-03	3.40E-03	1.71E-03	8.06E-06
^{229}Th*	3.05E-08	2.14E-08	9.69E-09	3.29E-10
^{230}Th*	2.16E-05	8.26E-06	1.29E-05	5.40E-08
^{230}U*	1.33E-23	4.74E-24	0.00E+00	0.00E+00

Table 4.2.2 (continued) ISOTOPE INVENTORY Ci/Assembly				
	MPC-24 Ci/Assembly	MPC-68 Ci/Assembly	MPC-68F Ci/Assembly	Trojan MPCs Ci/Assembly
^{232}U*	1.51E-02	5.58E-03	1.69E-03	1.21E-05
^{233}U*	1.41E-05	4.20E-06	3.03E-06	3.94E-09
^{234}U*	4.97E-01	1.70E-01	7.26E-02	1.08E-04
^{236}U*	1.60E-01	5.85E-02	1.84E-02	3.18E-05
^{90}Y	4.53E+04	1.76E+04	4.29E+03	4.13E-02

Note: The isotopes which contribute greater than 0.01% to the total curie inventory for the fuel assembly are considered in the evaluation as fines. Additionally, isotopes with A_2 values less than 1.0 in Table A-1, Appendix A, 10CFR71 are included as fines and are designated in the table by an "*".

Table 4.2.3

TOTAL SOURCE TERM FOR THE HI-STAR 100 SYSTEM (Ci/cm^3)

	C_{crud} (Ci/cm^3)	C_{fines} (Ci/cm^3)	C_{vol} (Ci/cm^3)	C_{gas} (Ci/cm^3)	Total (Ci/cm^3)
Normal Transport Conditions					
MPC-24	1.17E-05	1.26E-07	4.45E-06	1.60E-04	1.77E-04
MPC-24E, MPC-24EF	1.20E-05	1.29E-07	4.55E-06	1.64E-04	1.82E-04
Trojan MPC-24E	7.56E-06	5.31E-07	2.15E-06	1.04E-04	1.14E-04
Trojan MPC-24EF Secondary	7.77E-06	3.49E-06	1.42E-05	6.81E-04	7.06E-04
Trojan MPC-24EF Primary	7.56E-06	3.40E-06	1.38E-05	6.63E-04	6.88E-04
MPC-32	1.64E-05	1.77E-07	6.26E-06	2.25E-04	2.50E-04
MPC-68	1.08E-04	1.36E-07	5.20E-06	1.89E-04	3.03E-04
MPC-68F Secondary	2.00E-05	5.16E-07	2.28E-06	7.55E-05	9.83E-05
MPC-68F Primary	1.95E-05	5.02E-08	2.22E-06	7.35E-05	9.58E-05
Accident Conditions					
MPC-24	7.79E-05	4.20E-05	1.48E-04	5.34E-03	5.60E-03
MPC-24E, MPC-24EF	7.97E-05	4.29E-05	1.52E-04	5.46E-03	5.73E-03
Trojan MPC-24E	5.04E-05	1.77E-05	7.18E-05	3.45E-03	3.59E-03
Trojan MPC-24EF Secondary	5.18E-05	1.82E-05	7.37E-05	3.55E-03	3.69E-03
Trojan MPC-24EF Primary	5.04E-05	1.77E-05	7.18E-05	3.45E-03	3.59E-03
MPC-32	1.10E-04	5.90E-05	2.09E-04	7.51E-03	7.88E-03
MPC-68	7.18E-04	4.52E-05	1.73E-04	6.30E-03	7.23E-03
MPC-68F Secondary	1.34E-04	5.93E-06	2.62E-05	8.68E-04	1.03E-03
MPC-68F Primary	1.30E-04	5.77E-06	2.55E-05	8.45E-04	1.01E-03

Table 4.2.4

VARIABLES FOUND IN NUREG/CR-6487 USED IN THE LEAKAGE RATE ANALYSIS

Variable	PWR		BWR	
	Normal	Accident	Normal	Accident
Fraction of crud that spalls, f_C	0.15	1.0	0.15	1.0
Crud surface activity (Ci/cm^2)	140×10^{-06}	140×10^{-06}	1254×10^{-06}	1254×10^{-06}
Surface area per assembly, cm^2	3×10^5	3×10^5	1×10^5	1×10^5
Fraction of rods that develop cladding breach, f_B†	0.03	1.0	0.03	1.0
Fraction of fines that are released, f_f	3×10^{-5}	3×10^{-5}	3×10^{-5}	3×10^{-5}
Fraction of gases that are released, f_G	0.3	0.3	0.3	0.3
Fraction of volatiles that are released, f_V	2×10^{-04}	2×10^{-04}	2×10^{-04}	2×10^{-04}

† The calculation for normal transport conditions of the Trojan MPC-24EF and MPC-68F each containing four (4) DFCs with fuel debris assumes that for the four DFCs, 100% of the rods of the fuel debris are breached. The remaining 20 or 64 assemblies in the Trojan MPC-24EF and MPC-68F, respectively, were assumed to have a 3% cladding rupture. Therefore, f_B for the Trojan MPC-24EF and the MPC-68F containing fuel debris is 0.192 and 0.087, respectively.

Table 4.2.5

INDIVIDUAL CONTRIBUTOR EFFECTIVE A_2
FOR GASES, CRUD, FINES, AND VOLATILES

MPC Type	A_2 (Ci)
Gases	
PWR MPCs	282
MPC-68	282
MPC-68F	285
Trojan MPCs	478
Crud	
All MPCs	10.8
Fines	
PWR MPCs	0.308
MPC-68	0.284
MPC-68F	0.115
Trojan MPCs	0.147
Volatiles	
PWR MPCs	6.04
MPC-68	6.05
MPC-68F	5.43
Trojan MPCs	5.44

Table 4.2.6

TOTAL SOURCE TERM EFFECTIVE A_2 FOR
NORMAL AND HYPOTHETICAL
ACCIDENT CONDITIONS

Normal Transport Conditions	
	Effective A_2 (Ci)
MPC-24	27.4
MPC-24E MPC-24EF	27.4
Trojan MPC-24E	23.1
Trojan MPC-24EF	24.7
MPC-32	27.4
MPC-68	18.6
MPC-68F	14.0
Accident Conditions	
MPC-24	30.0
MPC-24E MPC-24EF	30.0
Trojan MPC-24E	24.6
Trojan MPC-24EF	24.6
MPC-32	30.0
MPC-68	26.2
MPC-68F	14.4

Table 4.2.7

RADIONUCLIDE RELEASE RATES

	Allowable Release Rate (R_N or R_A) (Ci/s)
Normal Conditions	
MPC-24	7.62E-09
MPC-24E, MPC-24EF	7.62E-09
Trojan MPC-24E	6.41E-09
Trojan MPC-24EF	6.87E-09
MPC-32	7.62E-09
MPC-68	5.18E-09
MPC-68F	3.88E-09
Accident Conditions	
MPC-24	4.94E-05
MPC-24E, MPC-24EF	4.94E-05
Trojan MPC-24E	4.06E-05
Trojan MPC-24EF	4.06E-05
MPC-32	4.94E-05
MPC-68	4.32E-05
MPC-68F	2.37E-05

Table 4.2.8

Table Deleted

Table 4.2.9

ALLOWABLE LEAKAGE RATES AT UPSTREAM PRESSURE

	C_{total} (Ci/cm^3)	Allowable Leakage Rate at P_u L_N or L_A (cm^3/s)
Normal Transport Conditions		
MPC-24	1.77E-04	4.29E-05
MPC-24E, MPC-24EF	1.82E-04	4.20E-05
Trojan MPC-24E	1.14E-04	5.63E-05
Trojan MPC-24EF Secondary	7.06E-04	9.73E-06
Trojan MPC-24EF Primary	6.88E-04	1.00E-05
MPC-32	2.50E-04	3.05E-05
MPC-68	3.03E-04	1.71E-05
MPC-68F Secondary	9.83E-05	3.95E-05
MPC-68F Primary	9.58E-05	4.05E-05
Accident Conditions		
MPC-24	5.60E-03	8.82E-03
MPC-24E, MPC-24EF	5.73E-03	8.62E-03
Trojan MPC-24E	3.59E-03	1.13E-02
Trojan MPC-24EF Secondary	3.69E-03	1.10E-02
Trojan MPC-24EF Primary	3.59E-03	1.13E-02
MPC-32	7.88E-03	6.27E-03
MPC-68	7.23E-03	5.96E-03
MPC-68F Secondary	1.03E-03	2.29E-02
MPC-68F Primary	1.01E-03	2.35E-02

Table 4.2.10

Table Deleted

Table 4.2.11

PLUTONIUM INVENTORY
(Ci/assembly)

Nuclide	MPC-68F MOX fuel Ci/Assy	MPC-68F UO_2 fuel Ci/Assy	Trojan MPC-24EF UO_2 fuel Ci/Assy
Pu-236	4.92E-04	3.66E-04	2.04E-01
Pu-237	0.00E+00	0.00E+00	3.04E-07
Pu-238	1.11E+03	2.50E+02	2.56E+03
Pu-239	3.29E+01	2.95E+01	1.91E+02
Pu-240	7.83E+01	6.81E+01	3.27E+02
Pu-241	6.15E+03	5.16E+03	7.55E+04
Pu-242	3.44E-01	3.06E-01	1.65E+00
Pu-244	0.0	3.73E-14	1.11E-13
Total	**7.37E+03**	**5.51E+03**	**7.86E+04**

Table 4.2.12

PARAMETERS FOR NORMAL, HYPOTHETICAL ACCIDENT AND TEST CONDITIONS

Parameter	Normal Conditions	Hypothetical Accident Conditions	Reference Test Conditions	Actual Test Conditions[1]
P_u	104 psia[2] (7.07 ATM)	214.7 psia (14.61 ATM)	Primary: 1.68 ATM	Primary: 1.68 ATM (min)
			Secondary: 2.0 ATM	Secondary: 6.78 ATM (min)
P_d	14.7 psia (1 ATM)	14.7 psia (1 ATM)	14.7 psia (1 ATM)	14.7 psia (1 ATM)
T	495°F (530 K)	1058°F (843 K)	373 K	373 K (max)
M	4 g/mol	4 g/mol	4 g/mol	4 g/mol
u	0.0293 cP	0.0397 cP	0.0231 cP	0.0231 cP
a	Primary: 0.25 cm	Primary: 0.25 cm	Primary: 0.25 cm	Primary: 0.25 cm
	Secondary: 3.175 cm	Secondary: 3.175 cm	Secondary: 3.175 cm	Secondary: 3.175 cm

[1] *For the leakage rate test performed by drawing a vacuum between the MPC lid and the cover ring, P_u is 2.0 ATM (min) and P_d is 0.01 ATM.*
[2] The maximum upstream pressure for normal operating conditions in the Trojan MPCs is 83.2 psia (5.66 ATM). This value has been used to determine the maximum allowable leakage rate from the Trojan MPCs.

Table 4.2.13

RADIONUCLIDE RELEASE RATES
FOR PLUTONIUM (SECONDARY CONTAINMENT)

	Effective A_2 (Ci)	Allowable Release Rate (R_N or R_A) (Ci/s)
Normal Transport Conditions		
MPC-68F MOX Fuel	0.0297	8.24E-12
MPC-68F UO_2 Fuel	0.0660	1.84E-11
Trojan MPC-24EF UO_2 Fuel	0.0926	2.57E-11
Accident Conditions		
MPC-68F	0.0297	4.89E-08
MPC-68F UO_2 Fuel	0.0660	1.09E-07
Trojan MPC-24EF UO_2 Fuel	0.0926	1.53E-07

Table 4.2.14

ALLOWABLE LEAKAGE RATES AT UPSTREAM PRESSURE FOR PLUTONIUM (SECONDARY CONTAINMENT)

	C_{Pu} (Ci/cm^3)	Allowable Leakage Rate at P_u L_N or L_A (cm^3/s)
Normal Transport Conditions		
MPC-68F MOX Fuel	2.18E-07	3.77E-05
MPC-68F UO_2 Fuel	1.63E-07	1.12E-04
Trojan MPC-24EF UO_2 Fuel	1.82E-06	1.41E-05
Accident Conditions		
MPC-68F	2.51E-06	1.95E-02
MPC-68F UO_2 Fuel	1.88E-06	5.81E-02
Trojan MPC-24EF UO_2 Fuel	9.49E-06	1.61E-02

7.1 PROCEDURE FOR LOADING THE HI-STAR 100 SYSTEM IN THE SPENT FUEL POOL AND PREPARATION FOR SHIPMENT

7.1.1 Overview of Loading Operations

Note:
The MPC loading operations described herein are for HI-STAR 100 systems prepared for "load-and-go" directly into transportation under 10CFR71. HI-STAR 100 systems that are loaded and stored on an ISFSI site must be prepared in accordance with the procedures detailed in the applicable Part 72 HI-STAR or HI-STORM FSAR and CoC. Any HI-STAR 100 overpack and/or MPC deployed at an ISFSI must be confirmed to meet all conditions of the 10CFR71 CoC prior to shipment.

The HI-STAR 100 System is used to load and transport spent fuel. Specific steps are performed to prepare the HI-STAR 100 System for fuel loading, to load the fuel, to prepare the system for transport and to ship the HI-STAR 100 System. The HI-STAR 100 overpack may be transported off-site using a rail car or a specially designed heavy haul trailer, or any other load handling equipment designed for such applications. Users shall develop detailed written procedures to control on-site transport operations. Section 7.1.2 provides the general procedures for handling of the HI-STAR 100 overpack and MPC both with and without fuel loaded inside.

Figure 7.1.1 shows a flow diagram of the HI-STAR 100 System loading operations. Figure 7.1.2 illustrates some of the major HI-STAR 100 System loading operations. The HI-STAR 100 overpack and empty MPC may arrive together or separately. The procedures provided assume that these components arrive separately. If the HI-STAR 100 overpack and MPC arrive together, certain steps of the procedure may be omitted.

Note:
The procedures describe plant facilities, functions, and processes in general terms. Each site is different with regard to layout, organization and nomenclature. Users shall interpret the nomenclature used herein to suit their particular site, organization, and methods of operation.

Refer to the boxes of Figure 7.1.2 for the following description. The HI-STAR 100 overpack is received and the personnel barrier is removed. Receipt inspection and radiological surveys are performed. The impact limiters are removed and the HI-STAR 100 overpack is upended. At the start of loading operations, an empty MPC is upended (Box 1). The empty MPC is raised and inserted into the HI-STAR 100 overpack (Box 2). The annulus is filled with clean (uncontaminated) water and an inflatable seal is installed in the annulus between the MPC and the HI-STAR 100 overpack to prevent spent fuel pool water from contaminating the exterior surface of the MPC. The MPC is filled with either spent fuel pool water or clean water (Box 3). The HI-STAR 100 overpack and the MPC are then raised and lowered into the spent fuel pool for fuel loading using the lift yoke (Box 4). Pre-selected assemblies are loaded into the MPC and a visual verification of the assembly identification is performed (Box 5).

While still underwater, a thick shielded lid (the MPC lid) is installed using either slings attached to the lift yoke or the lid retention system (Box 6). The lift yoke remotely engages to the HI-STAR 100 overpack lifting trunnions to lift the HI-STAR 100 overpack and loaded MPC close to the spent fuel pool surface (Box 7). The cask is removed from the spent fuel pool. If the lid retention system is being used, the bolts are installed to the lid retention system to secure the MPC lid for the transfer to the cask preparation area. The lift yoke and HI-STAR 100 overpack are sprayed with clean water to help remove contamination as they are removed from the spent fuel pool.

The HI-STAR 100 overpack is placed in the designated preparation area and the lift yoke and lid retention system retention disk are removed. The next phase of decontamination is then performed. The top surfaces of the MPC lid and the upper flange of the HI-STAR 100 overpack are decontaminated. The temporary shield ring (if used) is installed and filled with water. The inflatable annulus seal is removed, and the annulus shield is installed. The temporary shield ring provides additional personnel shielding around the top of the HI-STAR 100 overpack during MPC closure operations. 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 at the MPC lid and around the mid-height circumference of the HI-STAR 100 overpack to establish appropriate radiological control.

The MPC water level is lowered slightly, the MPC is vented or purged and checked for combustible gas concentrations, and the MPC lid is seal welded using the Automated Welding System (AWS) (Box 8), by manual welding, or a combination of the two. Visual examinations are performed on the tack welds. Liquid penetrant examinations are performed on the root and final passes. A volumetric examination is performed on the MPC welds to ensure that the completed weld is satisfactory. As an alternative to volumetric examination of the MPC lid-to-shell weld, a multi-layer PT may be performed including intermediate examinations after approximately every three-eighth inch of weld depth. At the appropriate time in the sequence of activities, based on the type of test performed (hydrostatic or pneumatic), a pressure test of the MPC enclosure vessel is performed. The area below the MPC lid is filled with helium gas for leakage testing. A leakage rate test is performed on the MPC lid-to-shell weld to verify weld integrity and to ensure that leakage rates are within acceptance criteria.

The MPC water is displaced from the MPC by blowdown of the water using pressurized helium or nitrogen gas introduced into the vent port of the MPC thus displacing the water through the drain line. The Forced Helium Dehydration (FHD) is connected to the MPC and is used to remove all liquid water from the MPC (Box 9). After the bulk water has been removed, the helium exiting the FHD demoisturizer is cooled to a temperature of less than or equal to 21 °F and circulated through the MPC for greater than or equal to 30 minutes to ensure that the MPC cavity is suitably dry.

Following the drying operations, the MPC is backfilled with a predetermined pressure of helium gas. The helium backfill ensures adequate heat transfer during transport. Cover plates are installed and seal welded over the MPC vent and drain ports and liquid penetrant examinations are performed on the root (for multi-pass welds) and final passes (Box 10). The cover plates *and*

MPC lid to shell weld are leakage tested to confirm that they meet the established leakage rate criteria.

The MPC closure ring is then placed on the MPC and dose rates are measured. The closure ring is aligned, tacked in place and seal welded providing redundant closure of the MPC confinement boundary closure welds. Tack welds are visually examined, and the root (for multi-pass welds) 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 temporary shield ring is drained and removed. The MPC lid and accessible areas at the top of the MPC shell are smeared for removable contamination. The HI-STAR 100 overpack closure plate is installed (Box 11) and the bolts are torqued. The HI-STAR 100 overpack annulus is dried. If the package contains an MPC-68F or MPC-24EF, a secondary leakage verification test is performed. The overpack is then backfilled with helium gas. The HI-STAR 100 overpack mechanical seals and the vent and drain plug seals are leakage tested to assure they will provide long-term retention of the annulus helium. The HI-STAR 100 overpack vent and drain port cover plates are installed. The HI-STAR 100 overpack is surveyed for removable contamination.

The HI-STAR 100 overpack is moved to the transport location. An inspection for signs of impaired condition is performed. Contamination surveys are performed. The AL-STAR impact limiters are installed and the HI-STAR 100 system is placed on the transport vehicle, the tie-down system is installed and a shielding effectiveness test is performed to ensure that the HI-STAR 100 shielding has been manufactured and is functioning as designed. Radiation levels are verified to be within acceptable limits. The assembled package is given a final inspection to verify that all conditions for transport have been met (e.g., all mechanical seals have been installed and tested, relief devicesare intact, installed and not covered. The carrier is provided with the appropriate paperwork and the receiver is notified of the impending shipment) and the personnel barrier is installed (Box 12). The package is then labeled, placarded and released for transport.

7.1.2 HI-STAR 100 System Receiving and Handling Operations

Note:
The HI-STAR 100 overpack may be received and handled in several different configurations and may be transported on-site in a horizontal or vertical orientation. This section provides general guidance for the HI-STAR 100 overpack and MPC rigging and handling. Site-specific procedures shall specify the required operational sequences based on the design of the overpack (i.e., with or without pocket trunnions) and site capabilities.

Note:
Steps 1 through 4 describe the handling operations using a lift yoke. Specialty rigging may be substituted if the lift complies with NUREG-0612 [7.1.1].

1. Vertical Handling of the HI-STAR 100 overpack:

Note:
Prior to performing any lifting operation, the removable shear ring segments under the two lifting trunnions must be removed.

Caution:
Users shall maintain controls to ensure that heights to which the loaded HI-STAR 100 is lifted outside the fuel building are limited to ensure that the structural integrity of the MPC and overpack is not compromised should the overpack be dropped.

a. Verify that the lift yoke load test certifications are current.

b. Visually inspect the lift yoke and the lifting trunnions for gouges, cracks, deformation or other indications of damage.

c. Engage the lift yoke to the lifting trunnions. See Figure 7.1.3.

d. Apply lifting tension to the lift yoke and verify proper engagement of the lift yoke.

Note:
Refer to the site's heavy load handling procedures for lift height, load path, floor loading and other applicable load handling requirements.

e. Raise the HI-STAR 100 overpack and position it accordingly.

2. Upending of the HI-STAR 100 overpack

Warning:
Personnel shall remain clear of the unshielded bottom of the loaded overpack. Users shall coordinate operations to keep the bottom cover installed to the maximum extent practicable whenever when the loaded overpack is downended.

a. Position the HI-STAR 100 overpack under the lifting device.

b. Verify that the lift yoke load test certifications are current.

c. Visually inspect the lift yoke and the lifting trunnions for gouges, cracks, deformation or other indications of damage.

d. Place a light layer of Fel-Pro Chemical Products, N-5000, Nuclear Grade Lubricant (or equivalent) on the cask lifting trunnions and the palms of the lift yoke.

e. Engage the lift yoke to the lifting trunnions. See Figure 7.1.3.

f. Apply lifting tension to the lift yoke and verify proper engagement of the lift yoke.

g. Slowly rotate the HI-STAR 100 overpack to the vertical position keeping all rigging as close to vertical as practicable. See Figure 7.1.4.

h. Lift the overpack clear of the transport vehicle.

i. Position the HI-STAR 100 overpack per site direction.

3. Downending of the HI-STAR 100 overpack.

a. Position the transport vehicle under the lifting device.

b. Verify that the lift yoke load test certifications are current.

c. Visually inspect the lift yoke and the lifting trunnions for gouges, cracks, deformation or other indications of damage.

d. Place a light layer of Fel-Pro Chemical Products, N-5000, Nuclear Grade Lubricant (or equivalent) on the cask trunnions and the palms of the lift yoke.

e. Deleted.

f. Engage the lift yoke to the lifting trunnions. See Figure 7.1.3.

g. Apply lifting tension to the lift yoke and verify proper lift yoke engagement.

h. Deleted.

i. Slowly rotate the HI-STAR 100 overpack to the horizontal position keeping all rigging as close to vertical as practicable.

j. Disengage the lift yoke.

Warning:
Personnel shall remain clear of the unshielded bottom of the loaded overpack. Users shall coordinate operations to keep the bottom cover installed to the maximum extent practicable whenever when the loaded overpack is downended.

k. If necessary for radiation shielding, install the overpack bottom cover. Rigging points are provided.

4. Horizontal handling of the HI-STAR 100 overpack.

   a. Deleted..

   b. Downend the HI-STAR 100 overpack per Step 3, if necessary.

   c. Rig the overpack as shown in Figure 7.1.5.

   d. Position the overpack accordingly.

5. Empty MPC Installation in the HI-STAR 100 overpack:

Note:
To avoid side loading the MPC lift lugs, the MPC must be upended in the MPC Upending Frame (or equivalent). See Figure 7.1.6.

   a. If necessary, remove any MPC shipping covers and rinse off any road dirt with water. Be sure to remove any foreign objects from the MPC internals.

   b. Upend the MPC as follows:

      1. Visually inspect the MPC upending frame for gouges, cracks, deformation or other indications of damage.

      2. Install the MPC on the upending frame. Make sure that the banding straps are secure around the MPC shell. See Figure 7.1.6.

      3. Inspect the upending frame slings in accordance with the site's lifting equipment inspection procedures. Rig the slings to the bar. See Figure 7.1.6.

      4. Attach the MPC upper end slings of the upending frame to the main overhead lifting device. Attach the bottom-end slings to a secondary lifting device (or a chain fall attached to the primary lifting device).

      5. Raise the MPC in the upending frame.

Warning:
The upending frame corner should be kept close to the ground during the upending process.

6. Slowly lift the upper end of the upending frame while lowering the bottom end of the Upending Frame.

7. When the MPC approaches the vertical orientation, release the tension on the lower slings.

8. Place the MPC in a vertical orientation on a level surface.

9. Disconnect the MPC straps and disconnect the rigging.

c. Install the MPC in the HI-STAR 100 overpack as follows:

1. Install the four point lift sling to the lift lugs inside the MPC. See Figure 7.1.7.

Caution:
Be careful not to damage the overpack seal seating surface during MPC installation.

2. Raise and place the MPC inside the HI-STAR 100 overpack.

Note:
An alignment punch mark is provided on the HI-STAR 100 overpack and the top edge of the MPC. Similar marks are provided on the MPC lid and closure ring. See Figure 7.1.8.

3. Rotate the MPC so the alignment marks agree and seat the MPC inside the HI-STAR 100 overpack. Disconnect the MPC rigging or the MPC lift rig.

7.1.3 <u>HI-STAR 100 Overpack and MPC Receipt Inspection and Loading Preparation</u>

1. Recover the shipping documentation from the carrier.

a. If necessary, recover the keys to the personnel barrier locks from the carrier.

b. Record the impact limiter security seal serial numbers and verify that they match the corresponding shipping documentation, as applicable.

c. Perform a receipt radiation and contamination survey in accordance with 49CFR173.443 [7.1.3] and 10CFR20.1906 [7.1.4].

2. If necessary, remove the personnel barrier as follows:

Note:
The personnel barrier is a ventilated enclosure cage that fits over the main body of the HI-STAR 100 overpack. The personnel barrier is designed to restrict personnel accessibility to the surfaces of the HI-STAR 100 overpack. The personnel barrier in conjunction with the impact limiters restrict accessibility to all surfaces of the HI-STAR 100 overpack during transport. The personnel barrier is equipped with locks to prevent unauthorized access.

a. Remove the locks securing the personnel barrier and remove the personnel barrier.

b. Remove any fasteners securing the personnel barrier to the transport frame.

c. Rig the personnel barrier to the lifting device.

d. Remove the personnel barrier as shown on Figure 7.1.9.

e. Perform a partial visual inspection of the overpack surfaces to verify that there is no outward indication that would suggest impaired condition of the overpack in accordance with 10CFR71.87(b) [7.0.1]. Identify any significant indications to the cognizant individual for evaluation and resolution and record on the receiving documentation.

3. If necessary, remove the impact limiters as follows:

Note:
To prevent damage to the impact limiters, the impact limiter handling frame must be used to remove, install, handle and store the impact limiters.

a. Clip the security seal wires and remove the security seals and wires.

b. Attach the impact limiter handling frame as shown on Figure 7.1.10. The rigging arms secure the impact limiter and maintain it at the proper orientation during rigging.

c. Using a load measuring device, apply the correct lift load. See Table 7.1.1 for approximate weights.

d. Remove the bolts securing the impact limiter to the overpack. See Figure 7.1.11.

e. Remove the impact limiter and store the impact limiter and bolts in a site-approved location.

f. Repeat Steps 3.c. through 3.e. for the other impact limiter

g. Remove the alignment pins from the bottom of the HI-STAR 100 overpack. See Figure 7.1.11.

h. Complete the visual inspection to verify that there is no outward indication that would suggest impaired condition of the overpack. (10CFR71.87(b)) [7.0.1]. Identify any significant indications to the cognizant individual for evaluation and resolution.

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

ALARA Note:
A bottom protective cover may be attached to the HI-STAR 100 overpack bottom or placed in the designated preparation area or spent fuel pool. This will help prevent embedding contaminated particles in the HI-STAR 100 overpack bottom surface and ease the decontamination effort.

4. Upend the HI-STAR 100 and place the overpack in the cask receiving area in accordance with Section 7.1.2.

5. If necessary, remove the buttress plate bolts and remove the buttress plate. See Figure 7.1.11. See Figure 7.1.12 for rigging. Store these components in a site-approved storage location.

6. If necessary, remove the HI-STAR 100 overpack closure plate by removing the closure plate bolts and using the dedicated lift sling. See Figure 7.1.12 for rigging.

    a. Place the closure plate on cribbing that protects the seal seating surfaces and allows access for seal replacement.

    b. Store the closure plate and bolts in a site-approved location.

    c. Install the seal surface protector on the HI-STAR 100 overpack seal seating surface. See Figure 7.1.13.

7. Install the MPC inside the HI-STAR 100 overpack as follows:

    a. Rinse off any MPC road dirt with water. Inspect all cavity locations for foreign objects. Remove any foreign objects.

    b. At the site's discretion, perform an MPC receipt inspection and cleanliness inspection in accordance with a site-specific inspection checklist.

    c. Install the MPC in the HI-STAR 100 taking care not to damage the overpack seal surface. See Figure 7.1.7 for rigging requirements.

    d. Place the HI-STAR 100 overpack in the designated preparation area.

Note:
Upper fuel spacers are fuel-type specific. Not all fuel types require fuel spacers. See Figure 7.1.14. Upper fuel spacers may be loaded any time prior to placement of the MPC lid in the spent fuel pool for installation in the MPC.

8. Install the upper fuel spacers in the MPC lid as follows:

Warning:
Never work under a suspended load.

    a. Position the MPC lid on supports to allow access to the underside of the MPC lid.

b. Thread the fuel spacers into the holes provided on the underside of the MPC lid. See Figure 7.1.14 and Table 7.1.3 for torque requirements.

c. Install threaded plugs in the MPC lid where and when spacers will not be installed, if necessary. See Table 7.1.3 for torque requirements.

9. At the user's discretion, perform an MPC lid and closure ring fit test:

Note:
It will be necessary to perform the MPC installation and inspection in a location that has sufficient crane clearance to perform the operation.

a. Visually inspect the MPC lid rigging (See Figure 7.1.12).

b. Raise the MPC lid such that the drain line can be installed. Install the drain line to the underside of the MPC lid. See Figure 7.1.15.

Note:
The MPC Shell is relatively flexible compared to the MPC Lid and may create areas of local contact that impede Lid insertion in the Shell. Grinding of the MPC Lid below the minimum diameter on the drawing is only permitted to alleviate interference with the MPC Shell in areas of localized contact. Care should be taken to minimize the amount and depth of grinding. If the amount of material removed from the surface exceeds 1/8", the surface shall be examined by a liquid penetrant method (NB-2546). The weld prep for the Lid-to-Shell weld shall be maintained after grinding.

c. Align the MPC lid and lift yoke so the drain line will be positioned in the MPC drain location. See Figure 7.1.16. Install the MPC lid. Verify that the MPC lid fit and weld prep are in accordance with the approved design drawings.

ALARA Note:
The closure ring is installed by hand. No tools are required.

d. Install the closure ring.

e. Verify that closure ring fit and weld prep are in accordance with the approved design drawings.

f. Remove the closure ring and the MPC lid. Disconnect the drain line. Store these components in an approved plant storage location.

Note:
Fuel spacers are fuel-type specific. Not all fuel types require fuel spacers. Lower fuel spacers are set in the MPC cells manually. No restraining devices are used. Fuel spacers may be loaded any time prior to insertion of the fuel assemblies in the MPC.

10. Install lower fuel spacers in the MPC (if required for the fuel type). See Figure 7.1.14.

11. Fill the MPC and annulus as follows:

Caution:
Do not use any sharp tools or instruments to install the inflatable seal. Some air in the inflatable seal helps in the installation.

a. Remove the HI-STAR 100 overpack drain port cover and port plug and install the drain connector. Store the drain port cover plate and port plug in an approved storage location.

b. Fill the annulus with clean water to just below the inflatable seal seating surface.

c. Manually insert the inflatable annulus seal around the MPC. See Figure 7.1.13.

d. Ensure that the seal is uniformly positioned in the annulus area.

e. Inflate the seal to between 30 and 35 psig or as directed by the manufacturer.

f. Visually inspect the seal to ensure that it is properly seated in the annulus. Deflate, adjust and inflate the seal as necessary. Replace the seal as necessary.

ALARA Note:
Waterproof tape placed over empty bolt holes, and bolt plugs may reduce the time required for decontamination.

12. At the user's discretion, install the HI-STAR 100 overpack closure plate bolt plugs and/or apply waterproof tape over any empty bolt holes.

ALARA Note:
Keeping the water level below the top of the MPC prevents splashing during handling.

13. Fill the MPC with either clean water or spent fuel pool water to approximately 12 inches below the top of the MPC shell.

14. Place the HI-STAR 100 overpack in the spent fuel pool as follows:

ALARA Note:
The Annulus Overpressure System is used to provide further protection against MPC external shell contamination during in-pool operations. The Annulus Overpressure System is equipped with design features to prevent inadvertent draining. The reservoir valve must be closed to ensure that the annulus is not inadvertently drained through the Annulus Overpressure System when the cask is raised above the level of the annulus reservoir.

a. If used, fill the Annulus Overpressure System lines and reservoir with clean water and close the reservoir valve. Attach the Annulus Overpressure System to the HI-STAR 100 overpack. See Figure 7.1.17.

b. Engage the lift yoke to the HI-STAR 100 overpack lifting trunnions and position the HI-STAR 100 overpack over the cask loading area.

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

c. Wet the surfaces of the HI-STAR 100 overpack and lift yoke with clean water while slowly lowering the HI-STAR 100 overpack into the spent fuel pool.

d. When the top of the HI-STAR 100 overpack reaches the elevation of the reservoir, start the Annulus Overpressure System water flow. Maintain the reservoir water level at approximately 3/4 full the entire time the cask is in the spent fuel pool.

e. Place the HI-STAR 100 overpack on the floor of the cask loading area and disengage the lift yoke. Visually verify that the lift yoke is fully disengaged. Remove the lift yoke from the spent fuel pool while spraying the crane cables and yoke with clean water.

7.1.4 MPC Fuel Loading

Note:
An underwater camera or other suitable viewing device may be used for monitoring underwater operations.

1. Perform a fuel assembly selection verification using plant fuel records to ensure that only fuel assemblies that meet all the conditions for loading as specified in the Certificate of Compliance have been selected for loading into the MPC.

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

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

7.1.5 MPC Closure

Note:
The user may elect to use the optional Lid Retention System (See Figure 7.1.18) to assist in the installation of the MPC lid and attachment of the lift yoke, and to provide the means to secure the MPC lid in the event of a drop or tip-over accident during loaded cask handling operations outside of the spent fuel pool. The user is responsible for evaluating the additional weight imposed on the cask, lift yoke, crane and floor prior to use to ensure that its use does not exceed the crane capacity, heavy loads handling restrictions, or 250,000 pounds. See Tables 7.1.1 and 7.1.2.

1. Visually inspect the MPC lid rigging or Lid Retention System in accordance with site-approved rigging procedures. Attach the MPC lid to the lift yoke so that MPC lid, drain line and trunnions will be in relative alignment. Raise the MPC lid and adjust the rigging so the MPC lid hangs level as necessary.

2. Install the drain line to the underside of the MPC lid. See Figure 7.1.15.

3. Align the MPC lid and lift yoke so the drain line will be positioned in the MPC drain location and the cask trunnions will also engage. See Figure 7.1.16 and 7.1.19.

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

4. Slowly lower the MPC lid into the pool and insert the drain line into the drain access location and visually verify that the drain line is correctly oriented. See Figure 7.1.16.

5. Lower the MPC lid while monitoring for any hang-up of the drain line. If the drain line becomes kinked or disfigured for any reason, remove the MPC lid and inspect and replace the drain line as necessary.

Note:
The upper surface of the MPC lid will seat approximately flush with the top edge of the MPC shell when properly installed.

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

7. Engage the lift yoke to the HI-STAR 100 overpack lifting trunnions.

8. Apply a slight tension to the lift yoke and visually verify proper engagement of the lift yoke to the lifting trunnions.

ALARA Note:
Activated debris may have settled on the top face of the HI-STAR 100 overpack and MPC during fuel loading. The cask top surface should be kept under water until a preliminary dose rate scan clears the cask for removal.

9. Raise the HI-STAR 100 overpack until the MPC lid is just below the surface of the spent fuel pool. Survey the area above the cask lid to check for hot particles. Raise and flush the upper surface of the HI-STAR 100 overpack and MPC as necessary to remove any activated particles from the HI-STAR 100 overpack or the MPC lid.

10. Visually verify that the MPC lid is properly seated. Lower the HI-STAR 100 overpack, reinstall the MPC lid, and repeat Step 9, as necessary.

11. If the Lid Retention System is used, inspect the closure plate bolts for general condition. Replace worn or damaged bolts with new bolts.

12. Install the Lid Retention System bolts if the Lid Retention System is used.

Warning:
Cask removal from the spent fuel pool is typically the heaviest lift that occurs during HI-STAR 100 loading operations. The HI-STAR 100 trunnions must not be subjected to lifted loads in excess of 250,000 lbs. . Users must ensure that plant-specific lifting equipment is qualified to lift the expected load. Users may elect to pump a measured quantity of water from the MPC prior to removing the HI-STAR 100 from the spent fuel pool. See Tables 7.1.1 and 7.1.2 for weight information.

13. If necessary for lifted weight conditions, pump a measured amount of water from the MPC. See Figure 7.1.22 and Tables 7.1.1 and 7.1.2.

14. Continue to raise the HI-STAR 100 overpack under the direction of the plant's radiological control personnel. Continue rinsing the surfaces with clean water. When the top of the HI-STAR 100 overpack reaches the approximate elevation of the reservoir, stop the Annulus Overpressure System water flow. See Figure 7.1.17.

Caution:
Users are required to take necessary actions to prevent boiling of the water in the MPC. This may be accomplished by performing a site-specific analysis to identify a time limitation to ensure that water boiling will not occur in the MPC prior to the initiation of draining operations. Chapter 3 of this SAR provides some sample time limits for the time to initiation of draining for various spent fuel pool water temperatures using design basis heat loads. These time limits may be adopted if the user chooses not to perform a site-specific analysis. If time limitations are imposed, users shall have appropriate procedures and equipment to take action if time limits are approached or exceeded. One course of action involves initiating an MPC water flush for a certain duration and flow rate. Any site-specific analysis shall identify the methods to respond should it become likely that the imposed time limit could be exceeded.

ALARA Note:
To reduce decontamination time, the surfaces of the HI-STAR 100 overpack and lift yoke should be kept wet until decontamination begins.

15. Remove the HI-STAR 100 overpack from the spent fuel pool while spraying the surfaces with clean water. Record the time.

ALARA Note:
Decontamination of the HI-STAR 100 overpack bottom should be performed using pole-mounted cleaning devices.

16. Decontaminate the HI-STAR 100 overpack bottom and perform a contamination survey of the HI-STAR 100 overpack bottom. Remove the bottom protective cover, if used.

17. If used, disconnect the Annulus Overpressure System from the HI-STAR 100 overpack. See Figure 7.1.17.

18. Set the HI-STAR 100 overpack in the designated cask preparation area.

19. Disconnect the lifting slings or Lid Retention System (if used) from the MPC lid and disengage the lift yoke. Decontaminate and store these items in an approved storage location.

Warning:
MPC lid dose rates are measured to provide assurance that the dose rates at the lid are reasonable to allow worker access.

   a. Measure the dose rates at the MPC lid..

20. Perform decontamination of the HI-STAR 100 overpack.

21. Prepare the MPC for MPC lid welding as follows:

   a. Decontaminate the area around the HI-STAR 100 overpack top flange and install the Temporary Shield Ring, (if used). See Figure 7.1.20.

   b. Fill the Temporary Shield Ring with water (if used).

   c. Carefully decontaminate the MPC lid top surface and the shell area above the inflatable annulus seal.

   d. Deflate and remove the annulus seal.

ALARA Note:
The water in the HI-STAR 100 overpack-to-MPC annulus provides personnel shielding. The level should be checked periodically and refilled accordingly.

22. Attach the drain line to the HI-STAR 100 overpack drain port connector and lower the annulus water level approximately 6 inches.

ALARA Note:
The MPC exterior shell survey is performed to evaluate the performance of the inflatable annulus seal. Indications of contamination could require the MPC to be unloaded.

   a. Survey the MPC lid top surfaces and the accessible areas of the top two inches of the MPC shell.

ALARA Note:
The annulus shield is used to prevent objects from being dropped into the annulus and helps reduce dose rates directly above the annulus region. The annulus shield is hand installed and requires no tools.

23. Install the annulus shield. See Figure 7.1.13.

24. Prepare for MPC lid welding as follows:

Note:

The following steps use two identical Remote Valve Operating Assemblies (RVOAs) (See Figure 7.1.21) to engage the MPC vent and drain ports. The MPC vent and drain ports are equipped with metal-to-metal seals to minimize leakage during vacuum drying, and to withstand the long-term effects of temperature and radiation. The RVOAs allow the vent and drain ports to be operated like valves and prevent the need to hot tap into the penetrations during unloading operations. The RVOAs are purposely not installed until the cask is removed from the spent fuel pool to reduce the amount of decontamination.

Note:

The vent and drain ports are opened by pushing the RVOA handle down to engage the square nut on the cap and turning the handle fully in the counter-clockwise direction. The handle will not turn once the port is fully open. Similarly, the vent and drain ports are closed by turning the handle fully in the clockwise direction. The ports are closed when the handle cannot be turned further.

a. Clean the vent and drain ports to remove any dirt. Install the RVOAs (See Figure 7.1.21) to the vent and drain ports leaving caps open.

ALARA Warning:

Personnel should remain clear of the drain lines any time water is being pumped or purged from the MPC. Assembly crud, suspended in the water, may create a radiation hazard to workers. Controlling the amount of water pumped from the MPC prior to welding keeps the fuel assembly cladding covered with water yet still allows room for thermal expansion.

b. Connect the water pump to the drain port (See Figure 7.1.22) and pump between 50 and 120 gallons to the spent fuel pool or liquid radwaste system. The water level is lowered to keep moisture away from the weld region.

c. Disconnect the water pump.

25. Weld the MPC lid as follows:

ALARA Warning:

Grinding of MPC welds may create the potential for contamination. All grinding activities shall be performed under the direction of radiation protection personnel.

Caution:

Oxidation of Boral panels contained in the MPC may create hydrogen gas while the MPC is filled with water. Appropriate monitoring for combustible gas concentrations shall be performed prior to, and during MPC lid welding operations. The space below the MPC lid shall be exhausted or purged with inert gas prior to, and during MPC lid welding operations to provide additional assurance that flammable gas concentrations will not develop in this space.

Note:
Exhausting or purging may help improve the weld quality by keeping moist air from condensing on the MPC lid weld area. The vacuum source can be supplied from a wet/dry vacuum cleaner or small vacuum pump.

a. Attach a vacuum source to the vent port or inert the gas space under the MPC lid and begin monitoring for combustible gas concentrations.

ALARA Warning:
It may be necessary to rotate or reposition the MPC lid slightly to achieve uniform weld gap and lid alignment. A punch mark is located on the outer edge of the MPC lid and shell. These marks are aligned with the alignment mark on the top edge of the HI-STAR 100 overpack (See Figure 7.1.8). If necessary, the MPC lid lift should be performed using a hand operated chain fall to closely control the lift to allow rotation and repositioning by hand. If the chain fall is hung from the crane hook, the crane should be secured to prevent inadvertent use during this operation. Continuous radiation monitoring is recommended.

b. If necessary center the lid in the MPC shell using a hand-operated chain fall.

Note:
The MPC is equipped with lid shims that serve to close the gap in the joint for MPC lid closure weld.

c. As necessary, install the MPC lid shims around the MPC lid to make the weld gap uniform.

ALARA Note:
The optional AWS Baseplate shield is used to further reduce the dose rates to the operators working around the top cask surfaces.

d. Install the Automated Welding System baseplate shield (if used). See Figure 7.1.12 for rigging.

e. Install the Automated Welding System Robot (if used). See Figure 7.1.12 for rigging.

f. Tack weld the MPC lid.

g. Visually inspect the tack welds.

h. Lay the root weld.

Note:

The Lid-to-Shell weld may be examined by either volumetric examination (UT) or multi-layer liquid penetrant examination. If volumetric examination is used, it shall be the ultrasonic method and shall include a liquid penetrant (PT) of the root and final weld layers. If PT alone is used, at a minimum, it must include the root and final weld layers and one intermediate PT after approximately every 3/8 inch weld depth.

The methods and acceptance criteria for MPC welding examinations are specified in Section 8.1.1.

i. Disconnect the vacuum /purge source from the MPC and terminate combustible gas monitoring.

j. Perform a liquid penetrant examination of the weld root.

k. Complete the MPC lid welding, performing at least one intermediate layer liquid penetrant examination after approximately every 3/8 inch weld depth if the multi-layer liquid penetrant method is used.

l. Perform a liquid penetrant examination on the MPC lid final pass and UT (if required).

Note:

The timing of the ASME Code pressure test may depend on the type of test used (hydraulic or pneumatic). The test shall be performed at any time after welding is complete and prior to installation of the MPC closure rings.

26. Perform an ASME Code pressure test and MPC leakage rate testing as follows:

ALARA Note:

The leakage rates may be determined before the MPC is drained for ALARA reasons. A weld repair is a lower dose activity if water remains inside the MPC.

a. Attach the drain line to the vent port and route the drain line to the spent fuel pool or the plant liquid radwaste system. See Figure 7.1.23 for an example of a pressure test arrangement.

ALARA Warning:

Water and gas flowing from the MPC may carry activated particles and fuel particles. Apply appropriate ALARA practices around the drain line.

b. Fill the MPC with the pressure test fluid.

c. Perform a pressure test of the MPC as follows:

   1. Close the outlet valve and pressurize the MPC to the appropriate pressure as dictated by the requirements contained in Section 8.1.2. .

   2. Close the inlet valve and monitor the pressure for a minimum of 10 minutes. The pressure shall not drop during the performance of the test.

3. Following the 10-minute hold period, visually examine the MPC lid-to-shell weld for leakage. The acceptance criteria is no observable leakage.

d. Release the MPC internal pressure, disconnect the fill line and drain line from the vent and drain port RVOAs leaving the vent and drain port caps open.

e. Perform required NDE inspections on the MPC lid-to-shell weld.

Note:
There are two options for performing the leakage test of the MPC secondary containment boundary. The first method, "Option A", involves using a tracer-gas sniffer test of the MPC lid-to-shell weld and an evacuated envelope-gas detector test of the vent and drain port cover plates. The second method, "Option B", utilizes the penetration in the MPC closure ring to perform a helium leakage rate test of vent and drain cover plate welds and MPC lid-to-shell weld simultaneously, using the evacuated envelope-gas detector method in accordance with the Mass Spectrometer Leak Detector (MSLD) manufacturer's instructions and ANSI N14.5 [7.1.5].

f. *If performing "Option A" helium leakage test method,*

1. Attach a regulated helium supply to the vent port and attach the drain line to the drain port as shown in Figure 7.1.24

~~g.~~*2.* Verify the correct pressure on the helium supply and open the helium supply valve. Drain approximately 5 to 10 gallons.

~~h.~~*3.* Close the drain port valve and pressurize the MPC to a mininum of 85 psig with helium.

~~i.~~*4.* Close the vent port.

Note:
The leakage test is performed to provide the user with an indication of the integrity of the weld for all MPC types. The CoC required secondary containment helium leakage test for the MPC-68F and MPC-24EF is performed after MPC closure operations are completed. (See Step 7.1.6.5) The leakage detector may detect residual helium in the atmosphere. If the leakage test detects a leak, the area should be flushed with nitrogen or compressed air and the location should be retested.

~~j.~~*5.* Perform a helium leakage rate test of the MPC lid-to shell weld using the tracer gas-sniffer method in accordance with the Mass Spectrometer Leak Detector (MSLD) manufacturer's instructions and ANSI N14.5 [7.1.5]. The sum of the MPC Helium Leak Rates shall meet the requirements of Section 8.1.3.

~~k.~~*6.* Repair any weld defects in accordance with the site's approved weld repair procedures. Re-perform the Ultrasonic, Liquid Penetrant, Hydrostatic and Helium Leakage tests if weld repair is performed.

27. Drain the MPC as follows:

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

a. Attach a regulated *high purity* helium supply to the vent port.

b. Attach a drain line to the drain port shown on Figure 7.1.24.

c. Deleted.

d. Open the gas supply valve and record the time at the start of MPC draindown.

e. Deleted.

f. Blow the water out of the MPC until water ceases to flow out of the drain line. Shut the gas supply valve.

g. Disconnect the gas supply line from the MPC.

h. Disconnect the drain line from the MPC.

28. Dry the MPC as follows:

Note:
When the MPC is dried under the "load and go" operations, The Forced Helium Dehydrator (FHD) will be used to remove water to the levels required in the CoC. The FHD operates in two distinct phases. In Phase 1, liquid water is removed through a forced evaporation process. In Phase 2, heated, dry helium is circulated through the MPC to reduce the remaining water vapor to below required limits. It is recognized that certain MPCs may have been prepared for storage at an ISFSI under 10 CFR 72 where drying was performed using the vacuum drying technique. If vacuum drying was used, the MPC shall have been held at a pressure of $\leq$ 3 torr for $\geq$ 30 minutes to be considered adequately dried prior to helium backfill operations.

a. Connect the FHD to the MPC vent and drain port RVOAs. See Figure 7.1.25.

b. Purge the FHD and connecting piping to remove oxygen from the lines.

c. *Attach a drain line to the HI-STAR 100 overpack drain connector and drain the remaining water from the annulus to the spent fuel pool or the plant liquid radwaste system (See Figure 7.1.17).*

~~c.~~*d.* Operate the FHD through Phase 1 to remove liquid water.

~~d.~~*e.* Operate the FHD through Phase 2 to remove the water vapor. Helium shall be circulated though the MPC for greater than or equal to 30 minutes with the temperature at the demoisturizer outlet held less than or equal to 21 °F.

29. Backfill the MPC as follows:

> **Note:**
> Backfill requires use of 99.995% (minimum) purity helium.

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

b. While monitoring the temperatures into and out of the MPC, adjust the helium pressure in the MPC to provide a fill pressure as required in Table 1.2.3.

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

d. Disconnect the FHD from the MPC.

30. Weld the vent and drain port cover plates as follows:

a. Wipe the inside area of the vent and drain port recesses to dry and clean the surfaces.

b. Place the cover plate over the vent port recess.

c. Deleted.

> **Note:**
> The vent and drain port cover plates are provided with two small threaded holes with set screws for the injection of helium. The set screws may be installed or removed during welding.

d. Deleted

e. Tack weld the cover plate.

f. Visually inspect the tack welds.

g. Weld the root pass on the vent port cover plate.

h. Perform a liquid penetrant examination on the vent port cover plate root weld.

i. If required, complete the vent port cover plate welding and perform a liquid penetrant examination on the final weld pass.

j. Repeat Steps 30.a through 30.i for the drain port cover plate.

31. *If performing “Option A” leakage test method, p*~~P~~erform a leakage test of the MPC vent and drain port cover plates as follows:

Note:
The leakage test is performed to provide the user with an indication of the integrity of the weld for all MPC types. The CoC required secondary containment helium leakage test for the MPC-68F and MPC-24EF is performed after MPC closure operations are completed. (See Step 7.1.6.5) The leakage detector may detect residual helium in the atmosphere from the helium injection process. If the leakage test detects a leak, the area should be blown clear with compressed air or nitrogen and the location should be retested. The following process provides a high concentration of helium gas into the cavity. Other methods that ensure a high concentration of helium gas are also acceptable.

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

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

c. Plug weld the recess above each set screw to complete the penetration closure welding.

d. Perform a liquid penetrant examination on the plug weld.

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

f. Perform a helium leakage rate test of vent and drain cover plate welds using the evacuated envelope-gas detector method in accordance with the Mass Spectrometer Leak Detector (MSLD) manufacturer's instructions and ANSI N14.5 [7.1.5]. The sum of the MPC Helium Leak Rates shall meet the requirements of Section 8.1.3.

g. Repair any weld defects in accordance with the site's approved code weld repair procedures. Re-perform the leakage test as required.

32. Weld the MPC closure ring as follows:

ALARA Note:
The closure ring is installed by hand. No tools are required. The closure ring may be provided as a complete ring or in multiple sections. In the case of the single ring, no radial connecting welds are needed. Portions of the closure ring may be installed while the MPC is filled with water and after the lid-to-shell weld is complete to reduce dose.

a. Install and align the closure ring. See Figure 7.1.8.

b. Tack weld the closure ring to the MPC shell and the MPC lid.

c. Visually inspect the tack welds.

d. Lay the root weld between the closure ring and the MPC.

e. Perform a liquid penetrant examination on the closure ring root welds.

f. If necessary, complete the closure ring welding and perform a liquid penetrant examination on the closure ring final welds.

g. Remove the Automated Welding System.

h. If used, remove the AWS baseplate shield. See Figure 7.1.12 for rigging.

Note:
The leakage test is performed to provide the user with an indication of the integrity of the weld for all MPC types. The CoC required secondary containment helium leakage test for the MPC-68F and MPC-24EF is performed after MPC closure operations are completed. The leakage detector may detect residual helium in the atmosphere. If the leakage test detects a leak, the area should be flushed with nitrogen or compressed air and the MPC should be retested.

i. If performing the "Option B" leakage test method,

1. Using the penetrations in the closure ring, perform a helium leakage rate test of the MPC lid to shell weld and vent and drain port cover plate welds using the evacuated envelope-gas detector method in accordance with the Mass Spectrometer Leak Detector (MSLD) manufacturer's instructions and ANSI N14.5 [7.1.5]. The MPC Helium Leak Rate shall meet the requirements of Section 8.1.3.

j. Install the set screws at least 1/8" below flush and plug weld the penetrations. Inspect the plug welds with a visual and liquid penetration examination.

7.1.6 Preparation for Transport

1. Remove the annulus shield and seal surface protector and store it in an approved plant storage location

ALARA Warning:
Dose rates will rise around the top of the annulus as water is drained from the annulus. Apply appropriate ALARA practices.

2. ~~Attach a drain line to the HI-STAR 100 overpack drain connector and drain the emaining water from the annulus to the spent fuel pool or the plant liquid radwaste system (see Figure 7.1.17).~~*DELETED*

3. Install the overpack closure plate as follows:

a. Remove any waterproof tape or bolt plugs used for contamination mitigation and ensure that the threaded holes in the MPC lid are plugged to prevent radiation streaming.

b. Clean the closure plate seal seating surface and the HI-STAR 100 overpack seal seating surface and install new overpack closure plate mechanical seals.

c. Remove the test port plug and store it in a site-approved location. Discard any used metallic seals.

Note:
Care should be taken to protect the overpack seal seating surface from scratches, nicks or dents.

d. Install the closure plate (see Figure 7.1.12). Disconnect the closure plate lifting eyes and install the bolt hole plugs in the empty bolt holes.

e. Install and torque the closure plate bolts. See Table 7.1.3 for torque requirements.

f. Remove the vent port cover plate and remove the port plug and seal. Discard any used mechanical seals.

4. Dry the overpack annulus as follows:

a. Disconnect the drain connector from the overpack.

b. Install the drain port plug with a new seal and torque the plug. See Table 7.1.3 for torque requirements. Discard any used metallic seals.

Note:
Preliminary annulus vacuum drying may be performed using the test cover to improve flow rates and reduce vacuum drying time. Dryness testing and helium backfill shall use the backfill tool.

c. Load the backfill tool with the HI-STAR 100 overpack vent port plug and the vent port with a new plug seal. Attach the backfill tool to the HI-STAR 100 overpack vent port with the plug in the open position. See Figure 7.1.28. See Table 7.1.3 for torque requirements.

d. Connect the vacuum pump and evacuate the HI-STAR 100 overpack pressure to below 3 torr.

Note:
The annulus pressure may rise due to the presence of water in the HI-STAR 100 overpack. The dryness test may need to be repeated several times until all the water has been removed. Leaks in the Vacuum Drying System, damage to the vacuum pump, and improper vacuum gauge calibration may cause repeated failure of the dryness verification test. These conditions should be checked as part of the corrective actions if repeated failure of the dryness verification test is occurring.

e. Perform a HI-STAR 100 overpack Annulus Dryness Verification. The overpack annulus shall hold stable vacuum drying pressure of $\leq$ 3 torr for $\geq$ 30 minutes.

5. Perform a leakage test of the MPC-68F/24EF as follows:

   a. Evacuate the annulus per the MSLD manufacturer's instructions and isolate the vacuum pump from the backfill tool.

   b. Connect the MSLD to the backfill tool and perform a leakage rate test of MPC-68F/24EF using the evacuated envelope-gas detector method in accordance with the MSLD manufacturer's instructions and ANSI N14.5 [7.1.5]. The total MPC Helium Leak Rate shall meet the requirements of Section 8.1.3.

Note:
The sum of the helium leak rates from the overpack penetrations (i.e. the overpack closure plate inner mechanical seal and vent and drain port plugs) shall meet the limit established in Section 8.1.3.

6. Backfill, and leakage test the overpack as follows:

   a. Attach the helium supply to the backfill tool.

   b. Verify the correct pressure on the helium supply and open the helium supply valve.

   c. Backfill the HI-STAR 100 overpack annulus to the pressure required by Table 1.2.3.

   d. Install the overpack vent port plug and torque. See Table 7.1.3 for torque requirements.

   e. Disconnect the overpack backfill tool from the vent port.

   f. Flush the overpack vent port recess with compressed air to remove any standing helium gas.

   g. Install the overpack test cover to the overpack vent port as shown on Figure 7.1.27. See Table 7.1.3 for torque requirements.

   h. Evacuate the test cavity per the MSLD manufacturer's instructions and isolate the vacuum pump from the overpack test cover.

i. Perform a leakage rate test of overpack vent port plug using the evacuated envelope-gas detector method in accordance with the MSLD manufacturer's instructions and ANSI N14.5 [7.1.5].

j. Remove the overpack test cover and install a new metallic seal on the overpack vent port cover plate. Discard any used metallic seals.

k. Install the vent port cover plate and torque the bolts. See Table 7.1.3 for torque requirements.

l. Repeat Steps 6.f through 6.k for the overpack drain port.

7. Leak test the overpack closure plate inner mechanical seal as follows:

   a. Attach the closure plate test tool to the closure plate test port with the MSLD attached. See Figure 7.1.29. See Table 7.1.3 for torque requirements.

   b. Evacuate the closure plate test port tool and closure plate inter-seal area per the MSLD manufacturer's instructions.

   c. Perform a leakage rate test of overpack closure plate inner mechanical seal using the evacuated envelope-gas detector method in accordance with the MSLD manufacturer's instructions and ANSI N14.5 [7.1.5].

   d. Remove the closure plate test tool from the test port and install the test port plug with a new mechanical seal. See Table 7.1.3 for torque requirements. Discard any used metallic seals.

8. Sum the individual leak rates for the closure plate inner mechanical seal and the vent and drain port plugs and ensure that they meet the requirements of Section 8.1.3.

9. Drain the temporary shield ring (Figure 7.1.20), if used. Remove and store in an approved plant storage location.

ALARA Warning:
For ALARA reasons, decontamination of the overpack bottom shall be performed using pole-mounted cleaning tools or other remote cleaning devices.

ALARA Warning:
If the overpack is to be downended on the transport frame, the bottom shield should be installed quickly. Personnel should remain clear of the bottom of the unshielded overpack.

7.1.7 Placement of the HI-STAR 100 Overpack on the Transport Vehicle

1. Position the transport vehicle under the overhead lifting device.

2. Install the HI-STAR 100 overpack buttress plate on the HI-STAR 100 overpack. See Figure 7.1.11 and 7.1.12 for rigging. See Table 7.1.3 for torque requirements.

3. Downend the HI-STAR 100 overpack . See Section 7.1.2.

4. Install the removable shear ring segments. See Table 7.1.3 for torque requirements.

5. Ensure that pocket trunnions are plugged if present and not in use on the transport vehicle.

Note:
To prevent damage to the impact limiters, the impact limiter handling frame must be used to remove, install, handle and store the impact limiters.

6. Install the impact limiters as follows:

    a. Install the alignment pins in the bottom of the HI-STAR 100 overpack. See Figure 7.1.11. See Table 7.1.3 for torque requirements.

    b. Using the impact limiter handling frame, raise and position the impact limiter over the end of HI-STAR 100. See Figure 7.1.10.

    c. Install the impact limiter bolts. See Table 7.1.3 for torque requirements.

    d. Repeat for the other impact limiter.

Note:
The impact limiters cover all the HI-STAR 100 penetrations. The security seals are used to provide tamper detection.

    e. Install a security seal (one per impact limiter) through the threaded hole in the top and bottom impact limiter bolts. Record the security seal number on the shipping documentation.

f. Perform final radiation surveys of the package surfaces per 10CFR71.47 [7.0.1] and SAR Section 8.1.5.2 and 49CFR173.443 [7.1.3]. Record the results on the shipping documentation.

Note:
The HI-STAR shall be secured and positioned in the transport vehicle in accordance with the drawing in Section 1.4.

7. Place the overpack in the transport vehicle. See Figure 7.1.5

8. Perform a final inspection of the HI-STAR 100 overpack as follows:

ALARA Warning:
Dose rates around the unshielded bottom end of the HI-STAR 100 overpack may be higher that other locations around the overpack. Workers should exercise appropriate ALARA controls when working around the bottom end of the HI-STAR 100 overpack.

Note:
Prior to shipment of the HI-STAR 100 package, the accessible external surfaces of the HI-STAR 100 packaging (HI-STAR 100 overpack, impact limiters, personnel barrier, and transport vehicle) shall be surveyed for removable radiological contamination in accordance with 49CFR173.428 [7.1.3].

a. Perform a final decontamination of the HI-STAR 100 overpack, and survey for removable contamination.

b. Perform a visual inspection of the HI-STAR 100 overpack to verify that there are no outward visual indications of impaired physical condition. Identify any significant indications to the cognizant individual for evaluation and resolution and record on the shipping documentation.

c. Verify that the HI-STAR 100 overpack neutron shield relief devicesare installed, intact and not covered by tape or other covering.

9. Secure the HI-STAR 100 to the transport vehicle using the tie-downs.

10. Install the personnel barrier as follows:

a. Rig the personnel barrier as shown in Figure 7.1.9 and position the personnel barrier over the frame.

b. Remove the personnel barrier rigging and install the personnel barrier locks.

c. Transfer the personnel barrier keys to the carrier.

11. Perform a final check to ensure that the package is ready for release as follows:

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

b. Perform a HI-STAR 100 overpack surface temperature check. The accessible surfaces of the HI-STAR 100 Package (impact limiters and personnel barrier) shall not exceed the Exclusive Use temperature limits of 49CFR173.442 [7.1.3].

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

d. Verify that the receiver has been notified of the impending shipment and that the receiver has the appropriate procedures and equipment available to safely receive and handle the HI-STAR 100 System (10CFR20.1906(e)) [7.1.4].

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

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

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

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

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

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

12. Release the HI-STAR 100 System for transport.

Table 7.1.1

ESTIMATED HI-STAR 100 SYSTEM COMPONENT AND HANDLING WEIGHTS

Component	Weight (lbs)			Case Applicability †			
	MPC-24/24E/24EF	MPC-32	MPC-68/68F	1	2	3	4
Empty HI-STAR Overpack (without Closure Plate)	145,726	145,726	145,726	1	1	1	1
HI-STAR Closure Plate (without rigging)	7,984	7,984	7,984		1	1	1
Empty MPC (without Lid or Closure Ring)	31,000	24,700	27,300	1	1	1	1
MPC Lid (without Fuel Spacers or Drain Line)	9,677	9,677	10,113	1	1	1	1
MPC Closure Ring	145	145	145		1	1	1
MPC Fuel Spacers††	1,256	1,440	1,904	1	1	1	1
MPC Drain Line	50	50	50	1	1	1	1
Fuel and non-fuel components (Design Basis)	40,320	53,760	47,600	1	1	1	1
Damaged Fuel Container (Dresden 1)	N/A	N/A	150				
Damaged Fuel Container (Humboldt Bay)	N/A	N/A	120				
Damaged Fuel Container (Trojan)	276	N/A	N/A				
MPC Water ††† (with Fuel in MPC)	17,630	17,630	16,957	1			
Annulus Water	280	280	280	1			
HI-STAR Lift Yoke (with slings)	3600	3600	3600	1	1		
Annulus Seal	50	50	50	1			
Lid Retention System	2300	2300	2300				
Transport Frame	9000	9000	9000			1	
Temporary Shield Ring	2500	2500	2500				
Automated Welding System Baseplate Shield	2000	2000	2000				
Automated Welding System Robot	1900	1900	1900				
Top Impact Limiter (without Buttress Plate)	19,187	19,187	19,187			1	1
Bottom Impact Limiter	17,231	17,231	17,231			1	1
Impact Limiter Handling Frame	1980	1980	1980				
Buttress Plate	2520	2520	2520			1	1
Tie-Down	995	995	995			1	
Personnel Barrier	1500	1500	1500			1	

Note: These weights are estimated from the design drawings and assuming maximum design weight in each fuel cell location. Actual weights will vary based on component as-built conditions and actual contents of each fuel cell location (i.e., fuel assembly, non-fuel hardware, DFC, etc.). Licensees shall confirm weights for lifting and handling operations. MPC-24/24E/24EF weights are bounding for Trojan design MPC-24E/EF.

† See Table 7.1.2.

†† The fuel spacers referenced in this table are for the heaviest fuel assembly for each MPC. This yields the maximum weight of fuel assemblies and spacers.

††† Varies by fuel type and loading configuration. Users may opt to pump some water from the MPC prior to removal from the spent fuel pool to reduce the overall lifted weight.

TABLE 7.1.2
ESTIMATED MAXIMUM HANDLING WEIGHTS
HI-STAR 100 SYSTEM

Caution:
The maximum weight supported by the HI-STAR 100 overpack lifting trunnions (not including the lift yoke) cannot exceed 250,000 lbs. Users should determine their specific handling weights based on the MPC contents and the expected handling modes.

Note:
The weight of the fuel spacers and the damaged fuel container are less than the weight of the design basis fuel assembly for each MPC and are therefore not included in the maximum handling weight calculations.

Case No.	Load Handling Evolution	Weight (lbs)		
		MPC-24/24E/24EF	MPC-32	MPC-68/68F
1	Loaded HI-STAR Removal from Spent Fuel Pool	249,589	256,913	253,580
2	Loaded HI-STAR During Movement through Hatchway	239,758	247,082	244,422
3	Weight on Transport Vehicle	286,591	293,915	291,255
4	Gross HI-STAR 100 Package Weight	275,096	282,420	279,760

Note: These weights are estimated from the design drawings. Actual weights may vary based on as-built conditions. Licensee shall confirm weights based on actual equipment received. MPC-24/24E/24EF weights are bounding for Trojan design MPC-24E/EF.

Table 7.1.3
HI-STAR 100 SYSTEM TORQUE REQUIREMENTS

Fastener	Torque (ft-lbs)	Pattern
Overpack Closure Plate Bolts†, ††	First Pass – Hand Tight Second Pass – Wrench Tight Third Pass – 860 +25/-25 Fourth Pass – 1725 +50/-50 Final Pass - 2895 +90/-90	Figure 7.1.30
Overpack Vent and Drain Port Cover Plate Bolts††	12+2/-0	X-pattern
Overpack Vent and Drain Port Plugs	45+5/-2	None
Closure Plate Test Port Plug	45+5/-2	None
Backfill Tool Test Cover Bolts††	16+2/-0	X-pattern
Shear Ring Segments	22+2/-0	None
Overpack Bottom Cover Bolts	200+20/-0	None
Pocket Trunnion Plugs	Hand Tight	None
Threaded Fuel Spacers	Hand Tight	None
MPC Lid Threaded Plugs	Hand Tight	None
Impact Limiter Alignment Pin	Hand Tight	None
Top Impact Limiter Attachment Bolt	256+10/-0	None
Bottom Impact Limiter Attachment Bolt	1500+45/-0	None
Buttress Plate Bolts	150 +10-0	None

† Detorquing shall be performed by turning the bolts counter-clockwise in 1/3 turn +/- 30 degrees increments per pass according to Figure 7.1.30 for three passes. The bolts may then be removed.

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

Table 7.1.4
HI-STAR 100 SYSTEM ANCILLARY EQUIPMENT OPERATIONAL DESCRIPTION

Equipment	Important To Safety Classification	Reference Figure	Description
Annulus Overpressure System (optional)	Not Important To Safety	7.1.17	The Annulus Overpressure System is used for supplemental protection against spent fuel pool water contamination of the external MPC shell and baseplate surfaces by providing a slight annulus overpressure. The Annulus Overpressure System consists of the quick disconnects water reservoir, reservoir valve and annulus connector hoses. User is responsible for supplying clean water to the location of the Annulus Overpressure System.
Annulus Shield (optional)	Not Important To Safety	7.1.13	A shield that is placed at the top of the annulus to provide supplemental shielding to the operators performing cask loading and closure operations.
Automated Welding System (optional)	Not Important To Safety	7.1.2b	Used for remote welding of the MPC lid, vent and drain port cover plates and the MPC closure ring. The AWS consists of the robot, wire feed system, torch system, weld power supply and gas lines.
AWS Baseplate Shield (optional)	Not Important To Safety	7.1.2b	The AWS baseplate shield provides supplemental shielding to the operators during the cask closure operations.
Backfill Tool	Not Important to Safety	7.1.28	Used to dry, backfill the HI-STAR 100 annulus and install the HI-STAR 100 overpack vent and drain port plugs. The backfill tool uses the same bolts as the HI-STAR 100 overpack vent and drain cover plates.
Closure Plate Test Tool	Not Important to Safety	7.1.29	Used to helium leakage test the HI-STAR 100 overpack Closure Plate inner mechanical seal.
Cool-Down System	Not Important To Safety	7.2.5	The Cool-Down System is a closed-loop forced ventilation cooling system used to gas-cool the MPC fuel assemblies down to a temperature water can be introduced without the risk of thermally shocking the fuel assemblies or flashing the water, causing uncontrolled pressure transients. The Cool-Down System is attached between the MPC drain and vent ports The CDS consists of the piping, blower, heat exchanger, valves, instrumentation, and connectors. The CDS is used only for unloading operations.
Forced Helium Dehydration System	Not Important To Safety	7.1.25	Used for drying the MPC cavity. Consists of a circulating blower, heat exchangers, heater and associated piping and controls.

Table 7.1.4 (Continued)
HI-STAR 100 SYSTEM ANCILLARY EQUIPMENT OPERATIONAL DESCRIPTION

Equipment	Important To Safety Classification	Reference Figure	Description
Four Legged Sling and Lifting Rings	Not Important To Safety (controlled under the user's rigging equipment program)	7.1.12	Used for rigging the HI-STAR 100 overpack upper shield lid, MPC lid, Automated Welding System Baseplate shield, Automated Welding System Baseplate Shield and other ancillary equipment. Consists of a four legged sling, lifting rings, shackles and a main lift link.
Helium Backfill System	Not Important To Safety	7.1.26	Used for helium backfilling of the MPC. System consists of the gas lines regulator and measurement equipment used to backfill the MPC with helium.
Code Pressure Test System	Not Important to Safety	7.1.23	Used to perform a Code pressure test on the MPC primary welds. The test system consists of the gauges, piping, pressure protection system piping and connectors.
Impact Limiter Handling Frame	Not Important to Safety	7.1.10	The impact limiter handling frame is used for installing, removing, handling and storing the impact limiters. The impact limiter handling frame consists of the handling frame and rigging.
Impact Limiters	Important to Safety	7.1.11	The impact limiters are used to limit the HI-STAR 100 decelerations to less than 60 g during postulated transportation accidents. The impact limiters consist of the top and bottom impact limiter and the connecting fasteners.
Inflatable Annulus Seal	Not Important To Safety	7.1.13	Used to prevent spent fuel pool water from contaminating the external MPC shell and baseplate surfaces during in-pool operations.
Lid Retention System (optional)	User designated	7.1.18	The Lid Retention System provides three functions; it guides the MPC lid into place during underwater installation, establishes lift yoke alignment with the HI-STAR 100 overpack trunnions, and locks the MPC lid in place during cask handling operations between the pool and decontamination pad. The device consists of the retention disk, alignment pins, lift yoke connector links and lift yoke attachment bolts.
Lift Yoke	User designated	7.1.3	Used for HI-STAR 100 overpack cask handling when used in conjunction with the overhead crane. The lift yoke consists of the lift yoke assembly and crane hook engagement pin(s). The lift yoke is a modular design that allows inspection, disassembly, maintenance and replacement of components.
MPC Upending Frame	Not Important to Safety	7.1.6	A welded steel frame used to evenly support the MPC during upending operations. The frame consists of the main frame, MPC support saddles, two rigging bars, wrap around-straps, and strap attachment lugs.

Table 7.1.4 (Continued)
HI-STAR 100 SYSTEM ANCILLARY EQUIPMENT OPERATIONAL DESCRIPTION

Equipment	Important To Safety Classification	Reference Figure	Description
MSLD (Helium Leakage Detector)	Not Important To Safety	Not shown	Used for helium leakage testing of the MPC closure welds.
Overpack Bottom Cover (optional)	Not Important to Safety	Not shown	A cup-shaped shield used to reduce dose rates around the HI-STAR 100 overpack bottom end when operated in the horizontal orientation.
Overpack Test Cover	Not Important to Safety	7.1.27	Used to helium leakage test the HI-STAR 100 overpack vent and drain port plug seals.
Personnel Barrier	Not Important to Safety	7.1.9	The personnel barrier is a ventilated enclosure cage that fits over the main body of the HI-STAR 100 overpack. The personnel barrier is designed to restrict personnel accessibility to the potentially hot surfaces of the HI-STAR 100 overpack. The personnel barrier in conjunction with the impact limiters restrict accessibility to all surfaces of the HI-STAR 100 overpack during transport. The personnel barrier is equipped with locks to prevent unauthorized access. The personnel barrier is equipped with a four-legged bridle sling used for installation and removal.
Seal Surface Protector (optional)	Not Important to Safety	7.1.13	Used to protect the HI-STAR 100 overpack mechanical seal seating surface during loading and MPC closure operations.
Temporary Shield Ring (optional)	Not Important To Safety	7.1.20	A water-filled tank that fits on the cask neutron shield around the upper forging and provides supplemental shielding to personnel performing cask loading and closure operations.
Threaded Inserts	Not Important To Safety	Not shown	Used to fill the empty threaded holes in the HI-STAR 100 overpack and MPC.
Tie-Down	Not Important to Safety	Not shown	The tie-down is a horse-shoe shaped collar that secures the HI-STAR 100 top end to the transport frame. The tie-down is secured by multiple bolts.
Transport Frame	Not Important To Safety	Not shown	A welded steel frame used to support the HI-STAR 100 overpack during on-site movement.

Table 7.1.4 (Continued)
HI-STAR 100 SYSTEM ANCILLARY EQUIPMENT OPERATIONAL DESCRIPTION

Equipment	**Important To Safety Classification**	**Reference Figure**	**Description**
Transport Vehicle	Not Important to Safety	Not Shown	Any flatbed rail car, heavy haul trailer or other device used to transport the loaded HI-STAR 100 overpack.
Vacuum Drying System	Not Important To Safety	Not shown	Used for removal of residual moisture from the HI-STAR 100 Overpack annulus following water draining. May be used for evacuation of the MPC to support backfilling operations. Used to support test volume samples for MPC unloading operations. The VDS consists of the vacuum pump, piping, skid, gauges, valves, inlet filter, flexible hoses, connectors, control system.
Vent and Drain RVOAs (optional)	Not Important To Safety	7.1.21	Used to drain, dry, inert and fill the MPC through the vent and drain ports. The vent and drain RVOAs allow the vent and drain ports to be operated like valves and prevent the need to hot tap into the penetrations during unloading operation.
Weld Removal System (optional)	Not Important To Safety	7.2.2b	Semi-automated weld removal system used for removal of the MPC to shell weld, MPC to closure ring weld and closure ring to MPC shell weld. The WRS mechanically removes the welds using a high-speed cutter.

Table 7.1.5
HI-STAR 100 SYSTEM INSTRUMENTATION SUMMARY FOR LOADING AND UNLOADING OPERATIONS†

Note:
The following list summarizes the instruments identified in the procedures for cask loading and unloading operations. Alternate instruments are acceptable as long as they can perform appropriate measurements.

Instrument	Function
Dose Rate Monitors/Survey Equipment	Monitors dose rate and contamination levels and ensures proper function of shielding. Ensures assembly debris is not inadvertently removed from the spent fuel pool during overpack removal.
Flow Rate Monitor (Optional)	Monitors the gas flow rate during assembly cool-down.
Helium Mass Flow Monitor (Optional)	Determines the amount of helium introduced into the MPC during backfilling operations. Includes integrator.
Helium Mass Spectrometer Leak Detector (MSLD)	Ensures leakage rates of welds are within acceptance criteria.
Helium Pressure Gauges	Ensures correct helium backfill pressure during backfilling operation.
Moisture Monitoring Instrument	Used to measure the moisture out of the MPC to determine the end of Phase 1 operation of the FHD.
Volumetric Testing Rig (Optional)	Used to assess the integrity of the MPC lid-to-shell weld.
Pressure Gauge	Ensures correct helium pressure during fuel cool-down operations.
Test Pressure Gauges	Used for during the Code pressure testing of MPC lid-to-shell weld and back filling operations.
Temperature Gauge	Monitors the MPC temperature during FHD operations and th state of fuel cool-down prior to MPC flooding.
Temperature Probe	For fuel cool-down operations
Vacuum Gauges	Used for vacuum drying operations and to prepare an MPC evacuated sample bottle for MPC gas sampling for unloading operations.

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

Table 7.1.6
HI-STAR 100 OVERPACK SAMPLE INSPECTION CHECKLIST

Note:
This checklist provides the basis for establishing a site-specific inspection checklist for the HI-STAR 100 overpack. Specific findings shall be brought to the attention of the appropriate site organizations for assessment, evaluation and potential corrective action prior to use.

<u>HI-STAR 100 Overpack Closure Plate:</u>

1. Lifting rings shall be inspected for general condition and date of required load test certification.
2. The test port shall be inspected for dirt and debris, hole blockage, thread condition, presence or availability of the port plug and replacement mechanical seals.
3. The mechanical seal grooves shall be inspected for cleanliness, dents, scratches and gouges and the presence or availability of replacement mechanical seals.
4. The painted surfaces shall be inspected for corrosion and chipped, cracked or blistered paint.
5. All closure plate surfaces shall be relatively free of dents, scratches, gouges or other damage.
6. The vent port plug shall be inspected for thread condition, and sealing surface condition (scratches, gouges).
7. Overpack vent port shall be inspected for presence or availability of port plugs, hole blockage, and plug seal seating surface condition.
8. Overpack vent port cover plate shall be inspected for cleanliness, scratches, dents, and gouges, availability of retention bolts, availability of replacement mechanical seals.

<u>HI-STAR 100 Overpack Main Body:</u>

1. The impact limiter attachment bolt holes shall be inspected for dirt and debris and thread condition.
2. The mechanical seal seating surface shall be inspected for cleanliness, scratches, and dents or gouges.
3. The drain port plug shall be inspected for thread condition, and sealing surface condition (scratches, gouges).
4. The closure plate bolt holes shall be inspected for dirt, debris and thread damage.
5. Painted surfaces shall be inspected for corrosion and chipped, cracked or blistered paint.
6. Trunnions shall be inspected for deformation, cracks, thread damage, end plate damage, corrosion, excessive galling, damage to the locking plate, presence or availability of locking plate and end plate retention bolts.

Table 7.1.6
HI-STAR 100 OVERPACK SAMPLE INSPECTION CHECKLIST
(continued)

7. Deleted.
8. Overpack drain port cover plate shall be inspected for cleanliness, scratches, dents, and gouges, availability of retention bolts, and availability of replacement mechanical seals.
9. Overpack drain port shall be inspected for presence or availability of port plug, availability of replacement mechanical seals, hole blockage, plug seal seating surface condition.
10. Annulus inflatable seal groove shall be inspected for cleanliness, scratches, dents, gouges, sharp corners, burrs or any other condition that may damage the inflatable seal.
11. The overpack relief devicesshall be inspected for presence or availability and the general condition.
12. The nameplate shall be inspected for presence and general condition.
13. The removable shear ring shall be inspected for fit and thread condition.

Table 7.1.7
MPC SAMPLE INSPECTION CHECKLIST

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

MPC Lid and Closure Ring:

1. The MPC lid and closure ring surfaces shall be relatively free of dents, gouges or other shipping damage.
2. The drain line shall be inspected for straightness, thread condition, and blockage.
3. Upper fuel spacers (if used) shall be inspected for availability and general condition. Plugs shall be available for non-used spacer locations.
4. Lower fuel spacers (if used) shall be inspected for availability and general condition.
5. Drain and vent port cover plates shall be inspected for availability and general condition.
6. Serial numbers shall be inspected for readability.

MPC Main Body:

1. All visible MPC body surfaces shall be inspected for dents, gouges or other shipping damage.
2. Fuel cell openings shall be inspected for debris, dents and general condition.
3. Lift lugs shall be inspected for general condition.
4. Verify proper MPC basket type for contents.
5. Inspect drain guide tube for debris, dents, and general condition.

LOCATION: CASK RECEIVING AREA	LOWER ANNULUS WATER LEVEL SLIGHTLY
REMOVE PERSONNEL BARRIER	SMEAR MPC LID TOP SURFACES
PERFORM RECEIPT INSPECTION	INSTALL ANNULUS SHIELD
SURVEY HI-STAR 100 OVERPACK	LOWER MPC WATER LEVEL
REMOVE IMPACT LIMITERS	WELD MPC LID
REMOVE TIE-DOWN	PERFORM NDE ON MPC LID WELD
UPEND HI-STAR 100 OVERPACK	PERFORM CODE PRESSURE TEST ON MPC
REMOVE HI-STAR CLOSURE PLATE	PERFORM LEAKAGE TESTING
INSTALL MPC	DRAIN MPC
INSTALL UPPER FUEL SPACERS	DRY MPC
INSTALL LOWER FUEL SPACERS	BACKFILL MPC
FILL ANNULUS	WELD VENT AND DRAIN PORT COVER PLATES
INSTALL ANNULUS SEAL	PERFORM NDE ON COVER PLATE WELDS
FILL MPC	PERFORM LEAKAGE TEST ON COVER PLATES
PLACE HI-STAR IN SPENT FUEL POOL	WELD MPC CLOSURE RING
LOCATION: SPENT FUEL POOL	PERFORM NDE ON CLOSURE RING WELDS[1]
LOAD FUEL ASSEMBLIES INTO MPC	DRAIN ANNULUS
PERFORM ASSEMBLY IDENTIFICATION VERIFICATION	PERFORM SURVEYS ON HI-STAR
INSTALL DRAIN LINE TO MPC LID	INSTALL HI-STAR CLOSURE PLATE
ALIGN MPC LID AND LIFT YOKE	REMOVE TEMPORARY SHIELD RING
INSTALL MPC LID	PERFORM FINAL SURVEYS ON HI-STAR
REMOVE HI-STAR FROM SPENT FUEL POOL AND PLACE IN PREPARATION AREA	**LOCATION: SHIPPING FACILITY**
LOCATION: CASK PREPARATION AREA	PERFORM SHIELDING EFFECTIVENESS TEST
DECONTAMINATE HI-STAR 100 BOTTOM	DOWNEND HI-STAR 100 OVERPACK
SET HISTAR 100 IN CASK PREPARATION AREA	INSTALL IMPACT LIMITERS
MEASURE DOSE RATES AT MPC LID	SURVEY HI-STAR 100 OVERPACK
DECONTAMINATE HI-STAR 100 AND LIFT YOKE	INSTALL TIE-DOWN
INSTALL TEMPORARY SHIELD RING, IF USED	PERFORM FINAL INSPECTION
REMOVE INFLATABLE ANNULUS SEAL	INSTALL PERSONNEL BARRIER.

FIGURE 7.1.1; Loading Operations Flow Diagram

[1] *If "Option B" leakage rate test is utilized, it is performed after welding and NDE of the closure ring.*

CHAPTER 8: ACCEPTANCE CRITERIA AND MAINTENANCE PROGRAM

8.0 INTRODUCTION

This chapter identifies the fabrication, inspection, test, and maintenance programs to be conducted on the HI-STAR 100 Package to verify that the structures, systems and components (SSCs) classified as important to safety have been fabricated, assembled, inspected, tested, accepted, and maintained in accordance with the requirements set forth in this Safety Analysis Report (SAR), the applicable regulatory requirements, and the Certificate of Compliance (CoC).

The controls, inspections, and tests set forth in this chapter, in conjunction with the design requirements described in previous chapters, ensure that the HI-STAR 100 Package will maintain containment of radioactive material; will maintain subcriticality control; will properly transfer the decay heat of the contained radioactive materials; and that radiation doses will meet regulatory requirements under all normal and hypothetical accident conditions of transport in accordance with 10CFR71 [8.0.1].

Both pre-operational and operational tests and inspections are performed throughout HI-STAR 100 loading operations to assure that the HI-STAR 100 Package is functioning within its design parameters. These include receipt inspections, nondestructive weld inspections, pressure tests, radiation shielding tests, thermal performance tests, dryness tests, and others. Chapter 7 identifies the sequence of the tests and inspections. "Pre-operation", as referred to in this chapter, defines that period of time from receipt inspection of a HI-STAR 100 Package until the empty MPC is loaded into a HI-STAR overpack for fuel assembly loading.

The HI-STAR 100 Package is classified as important to safety (ITS). Therefore, the individual structures, systems, and components (SSCs) that make up the HI-STAR 100 Package shall be designed, fabricated, assembled, inspected, tested, accepted, and maintained in accordance with a quality program commensurate with the particular SSC's graded quality category. Table 1.3.3 provides the safety classification and quality category, as applicable, for each major item or component of the HI-STAR 100 Package and required ancillary equipment and systems.

The acceptance criteria and maintenance program described in this chapter fully comply with the requirements of 10CFR Part 71.

8.1 ACCEPTANCE CRITERIA

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

Noncompliances encountered during the required inspections and tests shall be corrected or dispositioned to bring the item into compliance with this SAR prior to use. Identification and resolution of noncompliances shall be performed in accordance with the Holtec International

Quality Assurance Program [8.1.1] or the licensee's NRC-approved Quality Assurance Program. The testing and inspection acceptance criteria applicable to the MPCs and the HI-STAR overpack are listed in Tables 8.1.1 and 8.1.2, respectively, and discussed in more detail in the sections that follow. These inspections and tests are intended to demonstrate that the HI-STAR 100 Package has been fabricated, assembled, and examined in accordance with the design evaluated in this SAR.

This section summarizes the test program established for the HI-STAR 100 Package.

8.1.1 Fabrication and Nondestructive Examination (NDE)

The design, material procurement, fabrication, and inspection of the HI-STAR 100 Package is performed in accordance with applicable codes and standards, including NRC-approved alternatives to the ASME Code, as specified in Tables 1.3.1 and 1.3.2, respectively, and on the drawings in Section 1.4. Additional details on specific codes used are provided below.

The following fabrication controls and required inspections shall be performed on the HI-STAR 100 Package, including the MPCs, in order to assure compliance with this SAR and the Certificate of Compliance.

1. Materials of construction specified for the HI-STAR 100 Package are identified in the drawings in Chapter 1. Important-to-safety materials shall be procured with certification and supporting documentation as required by ASME Code [8.1.2] Section II (when applicable); the applicable subsection of ASME Code Section III (when applicable); Holtec procurement specifications; and 10CFR71, Subpart H. Materials and components shall be receipt inspected for visual and dimensional acceptability, material conformance to specification requirements, and traceability markings, as applicable. Controls shall be in place to assure material traceability is maintained throughout fabrication for ITS items. Materials for the primary containment boundary of the HI-STAR overpack (bottom plate, inner shell, top flange, closure plate, port plugs, and closure plate bolts) and for the secondary containment boundary provided by the MPC (for the MPC-24EF and MPC-68F), shall also be inspected per the requirements of ASME Section III, Article NB-2500 Subsection NB.

2. The HI-STAR 100 Package primary containment boundary and the MPC (secondary containment boundary for MPC-24EF and MPC-68F) shall be fabricated and inspected in accordance with ASME Code Section III, Subsection NB (see approved Code alternatives in Table 1.3.2). Other portions of the HI-STAR 100 Package shall be fabricated and inspected in accordance with ASME Code Section III, Subsection NF (see approved Code alternatives in Table 1.3.2). The MPC basket and certain basket supports shall be fabricated and inspected in accordance with ASME Code Section III, Subsection NG (see Tables 1.3.1, 1.3.2, and 1.3.3 for Code applicability and approved Code alternatives).

3. Welding shall be performed using welders and weld procedures that have been qualified in accordance with ASME Code Section IX and the applicable ASME Section III Subsections (e.g., NB, NG, or NF, as applicable to the SSC).

4. Welds shall be visually examined in accordance with ASME Code Section V, Article 9 with acceptance criteria per ASME Code Section III, Subsection NF, Article NF-5360, except the MPC fuel basket cell plate-to-cell plate welds and fuel basket support-to-canister welds, which shall have acceptance criteria to ASME Code Section III, Subsection NG, Article NG-5360, except as clarified by the Code alternatives in Table 1.3.2. Table 8.1.3 identifies additional nondestructive examination (NDE) requirements to be performed on specific welds, and the applicable codes and acceptance criteria to be used in order to meet the requirements of the applicable portions of Section III of the ASME Code. Acceptance criteria for NDE shall be in accordance with the applicable Code for which the item was fabricated, except as modified by the Code alternatives in Table 1.3.2. These additional NDE criteria are also specified in the drawings provided in Chapter 1 for the specific welds. Weld inspections shall be detailed in a weld inspection plan that identifies the weld and the examination requirements, the sequence of examination, and the acceptance criteria. The inspection plan shall be reviewed and approved by Holtec International in accordance with its QA program. NDE inspections shall be performed in accordance with written and approved procedures by personnel qualified in accordance with SNT-TC-1A [8.1.3] or other site-specific, NRC-approved program for personnel qualification.

5. The HI-STAR 100 ~~containment boundary shall be visually examined in accordance with ASME Code Section V, Article 9, to verify that each packaging is free of cracks, pin holes, uncontrolled voids, or other defects that could significantly reduce its effectiveness.~~ *system containment boundary shall be examined and tested by a combination of methods (including helium leak test, pressure test, UT, MT and/or PT, as applicable) to verify that it is free of cracks, pinholes, uncontrolled voids or other defects that could significantly reduce the effectiveness of the packaging.*

6. Any welds requiring weld repair shall be repaired in accordance with the requirements of the ASME Code Section III, Article NB-4450, NG-4450, or NF-4450, as applicable to the SSC, and examined after repair in the same manner as the original weld.

7. Any base metal repairs shall be performed and examined in accordance with the applicable fabrication Code.

8. Grinding and machining operations of the HI-STAR 100 overpack primary containment boundary and the MPC shall be controlled through written and approved procedures and quality assurance oversight to ensure grinding and machining operations do not reduce base metal wall thicknesses of the boundaries beyond that allowed by the design. The thicknesses of base metals shall be

ultrasonically tested, as necessary, in accordance with written and approved procedures to verify base metal thickness meets design requirements. A nonconformance shall be written for areas found to be below allowable base metal thickness and shall be evaluated and repaired as necessary per the ASME Code Section III, Subsection NB requirements.

9. Dimensional inspections of the HI-STAR 100 Package shall be performed in accordance with written and approved procedures in order to verify compliance to design drawings and fit-up of individual components. All dimensional inspections and functional fit-up tests shall be documented.

10. All required inspections, examinations, and tests shall be documented. The inspection, examination, and test documentation shall become part of the final quality documentation package.

11. The HI-STAR 100 Package shall be inspected for cleanliness and proper preparation for shipping in accordance with written and approved procedures.

12. Each HI-STAR overpack shall be durably marked with the CoC identification number assigned by the NRC, trefoil radiation symbol, gross weight, model number, and unique identification serial number in accordance with 10CFR71.85(c) at the completion of the acceptance test program.

13. Deleted.

14. A completed quality documentation record package shall be prepared and maintained during fabrication of each HI-STAR 100 Package to include detailed records and evidence that the required inspections and tests have been performed for ITS items. The quality document record package shall be reviewed to verify that the HI-STAR 100 Package or component has been properly fabricated and inspected in accordance with the design and Code construction requirements. The quality documentation record package shall include, but not be limited to:

    - Completed Weld Records
    - Inspection Records
    - Nonconformance Reports
    - Material Test Reports
    - NDE Reports
    - Dimensional Inspection Reports

8.1.1.1 <u>MPC Lid-to-Shell Weld Volumetric Inspection</u>

1. The MPC lid-to-shell (LTS) weld (the confinement boundary closure per 10CFR72, and secondary containment (inner container) boundary per 10CFR71 for the MPC-68F and MPC-24EF) shall be volumetrically or multi-layer liquid penetrant examined following completion of field welding. If volumetric

examination is used, the ultrasonic test (UT) method shall be employed. Ultrasonic techniques (including, as appropriate, Time-of-Flight Diffraction, Focussed Phased Array, and conventional pulse-echo) shall be supplemented, as necessary, to ensure substantially complete coverage of the examination volume.

2. If volumetric examination is used, then a liquid penetrant (PT) examination of the root and final pass of the LTS weld shall be performed and unacceptable indications shall be documented, repaired and re-examined.

3. If a volumetric examination is not used, a multi-layer PT examination shall be employed. The multi-layer PT must, at a minimum, include the root and final weld layers and one intermediate PT after each approximately 3/8 inch weld depth has been completed. The 3/8-inch weld depth corresponds to the maximum allowable flaw size.

4. The overall minimum thickness of the LTS weld has been increased by 0.125 inch over the size credited in the structural analyses to provide additional structural capacity (actual weld to be 0.75 inch for the standard MPC model and 1.25 inches for the "F" model). A J-groove weld 1/8" less was assumed in the structural analyses in Chapter 2.

5. For either UT or PT, the maximum undetectable flaw size must be demonstrated to be less than the critical flaw size. The critical flaw size must be determined in accordance with ASME Section XI methods. The critical flaw size shall not cause the primary stress limits of NB-3000 to be exceeded. The inspection process, including findings (indications) shall be made a permanent part of the user's records by video, photographic, or other means which provide an equivalent retrievable record of weld integrity. The video or photographic records should be taken during the final interpretation period described in ASME Section V, Article 6, T-676. The inspection of the weld shall be performed by qualified personnel and shall meet the acceptance requirements of ASME Section III, NB-5350 for PT and NB-5332 for UT.

6. Evaluation of any indications shall include consideration of any active flaw mechanisms. However, cyclic loading on the LTS weld is not significant, so fatigue will not be a factor. The LTS weld is protected from the external environment by the closure ring and the root of the LTS weld is dry and inert (He atmosphere), so stress corrosion cracking is not a concern for the LTS weld.

7. The volumetric or multi-layer PT examination of the LTS weld, in conjunction with other examinations that will be performed on this weld (PT of root and final pass, pressure test, and helium leakage test); the use of the ASME Code Section III acceptance criteria; and the additional 1/8th-inch of weld material conservatively not credited in the structural analyses, in total, provide reasonable assurance that the LTS weld is sound and will perform its secondary containment boundary function under all loading conditions. The volumetric (or multi-layer

PT) examination and evaluation of indications provides reasonable assurance that leakage of the weld or structural failure under normal or hypothetical accident conditions of transport will not occur.

8.1.2 Structural and Pressure Tests

8.1.2.1 Lifting Trunnions

Two trunnions (located near the top of the HI-STAR overpack) are provided for vertical lifting and handling of the HI-STAR 100 Package without the impact limiters installed. The trunnions are designed and shall be inspected and tested in accordance with ANSI N14.6 [8.1.5]. The trunnions are fabricated using a high-strength and high-ductility material (see overpack drawing in Section 1.4). The trunnions contain no welded components. The maximum design lifting load of 250,000 pounds for the HI-STAR 100 Package will occur during the removal of the HI-STAR overpack from the spent fuel pool after the MPC has been loaded, flooded with water, and the MPC lid is installed. The high material ductility, absence of materials vulnerable to brittle fracture, excellent stress margins, and a carefully engineered design to eliminate local stress risers in the highly-stressed regions (during lift operations) ensure that the lifting trunnions will work reliably. However, pursuant to the defense-in-depth approach of NUREG-0612 [8.1.6], acceptance criteria for the lifting trunnions have been established in conjunction with other considerations applicable to heavy load handling.

Section 5 of NUREG-0612 calls for measures to "provide an adequate defense-in-depth for handling of heavy loads...". The NUREG-0612 guidelines cite four major causes of load handling accidents, of which rigging failure (including trunnion failure) is one:

i. operator errors
ii. rigging failure
iii. lack of adequate inspection
iv. inadequate procedures

The cask loading and handling operations program shall ensure maximum emphasis to minimize the potential of load drop accidents by implementing measures to eliminate shortcomings in all aspects of the operation including the four aforementioned areas.

In order to ensure that the lifting trunnions do not have any hidden material flaws, the trunnions shall be tested at 300% of the maximum design (service) lifting load. The load (750,000 lbs) shall be applied for a minimum of 10 minutes to the pair of lifting trunnions. The accessible parts of the trunnions (areas outside the HI-STAR overpack), and the local HI-STAR 100 cask areas shall then be visually examined to verify no deformation, distortion, or cracking has occurred. Any evidence of deformation, distortion or cracking of the trunnion or adjacent HI-STAR 100 cask areas shall require replacement of the trunnion and/or repair of the HI-STAR 100 cask. Following any replacements and/or repair, the load testing shall be re-performed and the components re-examined in accordance with the original procedure and acceptance criteria. Testing shall be performed in accordance with written and approved procedures. Certified material test reports verifying trunnion material mechanical properties meet ASME Code Section

II requirements provide further verification of the trunnion load capabilities. Test results shall be documented and shall become part of the final quality documentation package.

The acceptance testing of the trunnions in the manner described above provide reasonable assurance that a handling accidents will not occur due to trunnion failure.

8.1.2.2 Pressure Testing

8.1.2.2.1 HI-STAR 100 Containment Boundary

The containment boundary of the HI-STAR Package shall be hydrostatically or pneumatically pressure tested to 150 psig +10,-0 psig, in accordance with the requirements of the ASME Code Section III, Subsection NB, Article NB-6000. The test pressure of 150 psig is 150% of the Maximum Normal Operating Pressure (established per 10CFR71.85(b) requirements). This bounds the ASME Code Section III requirement (NB-6221) for hydrostatic testing to 125% of the design pressure (100 psig). The test shall be performed in accordance with written and approved procedures. The written and approved test procedure shall clearly define the test equipment arrangement.

The overpack pressure test may be performed at any time during fabrication after the containment boundary is complete. Preferably, the pressure test should be performed after overpack fabrication is complete, including attachment of the intermediate shells. The HI-STAR overpack shall be assembled for this test with the closure plate mechanical seal (only one required) or temporary test seal installed. Closure bolts shall be installed and torqued to a value less than or equal to the value specified in Table 7.1.3.

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

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

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

8.1.2.2.2 MPC Secondary Containment Boundary

Pressure testing (hydrostatic or pneumatic) of the MPC secondary containment boundary shall be performed in accordance with the requirements of the ASME Code Section III, Subsection NB, Article NB-6000 and applicable sub-articles, when field welding of the MPC lid-to-shell weld is completed. If hydrostatic testing is used, the MPC shall be pressure tested to 125% of design pressure. If pneumatic testing is used, the MPC shall be pressure tested to 120% of the design pressure. The MPC vent and drain ports are used for pressurizing the MPC cavity. The loading procedures in Chapter 7 define the test equipment arrangement. The calibrated test pressure gage installed on the MPC pressure boundary shall have an upper limit of approximately twice that of the test pressure. Following completion of the required hold period at the test pressure, and after determining the leakage acceptance criterion is met, the surface of the MPC lid-to-shell weld shall be re-examined by liquid penetrant examination performed in accordance with ASME Code Section V, Article 6, with acceptance criteria per ASME Code Section III, Subsection NB, Article NB-5350. Any unacceptable areas shall require repair in accordance with the ASME Code Section III, Subsection NB, Article NB-4450. Any evidence of cracking or deformation shall be cause for rejection, or repair and retest, as applicable. The performance and sequence of the test is described in Section 7.1 (loading procedures).

If a leak is discovered, the test pressure shall be reduced, the MPC cavity water level lowered, if applicable, the MPC cavity vented, and the weld shall be examined to determine the cause of the leakage and/or cracking. Repairs to the weld shall be performed in accordance with approved written procedures prepared in accordance with the ASME Code Section III, Subsection NB, NB-4450.

The MPC pressure boundary pressure test shall be repeated until all required examinations are found to be acceptable. Test results shall be documented and shall be maintained as part of the loaded MPC quality documentation package.

8.1.2.3 Materials Testing

The majority of materials used in the HI-STAR overpack are ferritic steels. ASME Code Section III and Regulatory Guides 7.11 [8.1.7] and 7.12 [8.1.8] require that certain materials be tested in order to assure that these materials are not subject to brittle fracture failures.

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

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

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

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

8.1.2.4 Pneumatic Testing of the Neutron Shield Enclosure Vessel

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

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

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

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

8.1.3 Leakage Testing

Leakage testing shall be performed in accordance with the requirements of ANSI N14.5 [8.1.9]. Testing shall be performed in accordance with written and approved procedures.

8.1.3.1 HI-STAR Overpack

A Containment System Fabrication Verification Leakage test of the welded structure shall be performed at any time after the containment boundary fabrication is complete. Preferably, this test should be performed at the completion of overpack fabrication, after all intermediate shells have been attached. The leakage test instrumentation shall have a minimum test sensitivity of 2.15×10^{-6} atm cm^3/s (helium). Containment boundary welds shall have indicated leakage rates not exceeding 4.3×10^{-6} atm cm^3/s (helium). If a leakage rate exceeding the acceptance criterion is detected, the area of leakage shall be determined using the sniffer probe method or other means, and the area shall be repaired per ASME Code Section III, Subsection NB, NB-4450 requirements. Following repair and appropriate NDE, the leakage testing shall be re-performed until the test acceptance criterion is satisfied.

At the completion of overpack fabrication, the total helium leakage through all helium retention penetrations (consisting of the inner mechanical seal between the closure plate and the top flange and the vent and drain port plug seals) shall be demonstrated to not exceed the leakage rate of 4.3×10^{-6} atm cm^3/sec (helium) at a minimum test sensitivity of 2.15×10^{-6} atm cm^3/sec (helium). This may be performed simultaneously with the Containment System Fabrication Verification Leakage test or may be performed separately using the methods described in the paragraph below.

At the completion of fabrication, a Containment System Fabrication Verification Leakage test shall be performed on the HI-STAR overpack closures. Helium leakage through the containment penetrations (consisting of the inner mechanical seal between the closure plate and top flange, and the vent and drain port plug seals) shall be demonstrated to not exceed a leakage rate of 4.3×10^{-6} atm cm^3/s (helium) at a minimum test sensitivity of 2.15×10^{-6} atm cm^3/s (helium).

The leakage testing of the penetrations is performed by evacuating and backfilling the overpack with helium gas to an appropriate pressure. A helium Mass Spectrometer Leak Detector (MSLD) with a minimum calibrated sensitivity of 2.15×10^{-6} atm cm^3/s (helium) shall be used in parallel with a vacuum pump and a test cover (see Chapter 7 for details) designed for testing the penetration seals. The test cover is connected. The cavity on the external side of the port plug to be tested is evacuated and the vacuum pump is valved out. The MSLD detector measures the leakage rate of helium into the test cavity. If the leakage rate exceeds a leakage rate of 4.3×10^{-6} atm cm^3/s (helium), the test chamber is vented and removed. The corresponding plug seal is removed, seal seating surfaces are inspected and cleaned, and the plug with a new seal is reinstalled and torqued to the required value. The test process is then repeated until the seal leakage rate is successfully achieved. The same process is repeated for the remaining overpack vent or drain port. The process is used for the closure plate seals except the closure plate test tool (see Chapter 7 for details) is used in lieu of the test cover.

If the total measured leakage rate for all tested penetrations does not exceed 4.3×10^{-6} atm cm^3/sec, the leakage tests are successful. If the total leakage rate exceeds 4.3×10^{-6} atm cm^3/sec, an evaluation should be performed to determine the cause of the leakage, repairs made as necessary, and the overpack must be re-tested until the total leakage rate is within the required acceptance criterion. Leak testing results for the HI-STAR overpack shall become part of the quality record documentation record package.

8.1.3.2 MPC Secondary Containment Boundary

After the completion of welding the MPC shell to the baseplate, a confinement boundary weld leakage test shall be performed using a helium MSLD as described in Chapter 7.. These leakage tests are performed on all MPCs as a good practice to confirm the CoC leakage rate limits are not exceeded. However, the MPC only performs a secondary containment function for MPC-68F and MPC-24EF, which transport fuel debris. The MPC leakage test used to demonstrate compliance with the CoC leakage acceptance criterion for MPC-68F and MPC-24EF is performed prior to shipment as later in this section. The pressure boundary welds of the MPC canisters shall have indicated leakage rates not exceeding $5x10^{-6}$ atm cm^3/s (helium) with a minimum test sensitivity of $2.5x10^{-6}$ atm cm^3/sec (helium). If leakage rates exceeding the test criteria are detected, then the area of leakage shall be determined and the area repaired per ASME Code Section III, Subsection NB, NB-4450, requirements. Re-testing of the MPC shall be performed until the leakage rate acceptance criterion is met.

Leakage testing of the field welded MPC lid-to-shell weld shall be performed following completion of the MPC pressure test performed per Subsection 8.1.2.2.2. Leakage testing of the vent and drain port cover plate welds shall be performed after welding of the cover plates and subsequent NDE. The description and procedures for these field tests are provided in Section 7.1.

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

Prior to the transport of an MPC-68F or MPC-24EF containing fuel debris in the HI-STAR 100 Package, a Containment Fabrication Verification Leakage Test shall be performed on the secondary containment boundary of the MPC. The test is performed with the MPC loaded into the HI-STAR overpack. The HI-STAR overpack annulus is sampled to inspect for radioactive material and then evacuated to an appropriate vacuum condition. The HI-STAR overpack annulus is then isolated from the vacuum pump. Following an appropriate isolation period, the HI-STAR overpack annulus atmosphere is sampled for helium leakage from the MPC. The test is considered acceptable if the detected leakage from the MPC does not exceed $5x10^{-6}$ atm cm^3/s (helium) with a test sensitivity of $2.5x10^{-6}$ atm cm^3/s (helium). If the acceptance criterion is not met, transport of the MPC-68F or MPC-24EF is not authorized. Corrective actions from re-testing, up to and including off-loading of the MPC, shall be taken until the leakage rate acceptance criterion is met.

8.1.4 Component Tests

8.1.4.1 Valves, Relief Devices, and Fluid Transport Devices

There are no fluid transport devices associated with the HI-STAR 100 Package. The only valve-like components in the HI-STAR 100 Package are the specially designed caps installed in the MPC lid for the drain and vent ports. These caps are recessed inside the MPC lid and covered by the fully-welded vent and drain port cover plates. No credit is taken for the caps' ability to confine helium or radioactivity. After completion of drying and backfill operations, the drain and vent port cover plates are welded in place on the MPC lid and are leak tested to verify the MPC secondary containment (MPC-68F and MPC-24EF) boundary.

The vent and drain ports in the HI-STAR overpack are accessed through port plugs specially designed for removal and installation using connector tools. The tools are described and presented in figures in Chapter 7.

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

8.1.4.2 Seals and Gaskets

Two concentric mechanical seals are provided on the HI-STAR overpack closure plate to provide containment boundary sealing. Mechanical seals are also used on the overpack vent and drain port plugs of the HI-STAR overpack containment boundary. Each primary seal is individually leak tested in accordance with Subsection 8.1.3.1. prior to the HI-STAR 100 Package's first use and during each loading operation. An independent and redundant seal is provided for each penetration (e.g., closure plate, port cover plates, and closure plate test plug). No containment credit is taken for these redundant seals and they are not leakage tested. Details on these seals are provided in Chapter 4.

8.1.4.3 Transport Impact Limiter

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

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

8.1.5 Shielding Integrity

The HI-STAR 100 System has three specifically designed shields for neutron and gamma ray attenuation. For gamma shielding, there are successive carbon steel intermediate shells attached onto the outer surface of the overpack inner shell. The details of the manufacturing process are discussed in Chapter 1. Holtite-A neutron shielding is provided in the outer enclosure of the overpack. Additional neutron attenuation is provided by the encased Boral neutron absorber attached to the fuel basket cell surfaces inside the MPCs. Test requirements for each of the three shielding items are described below.

8.1.5.1 Fabrication Testing and Controls

Holtite-A:

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

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

Steel:

The steel plates utilized in the construction of the HI-STAR 100 Package shall be dimensionally inspected to assure compliance with the drawings in Section 1.4.

The total measured thickness of the inner shell plus intermediate shells shall be nominally 8.5 inches over the total surface area of the overpack shell. The top flange, closure plate, and bottom plate of the overpack shall be measured to confirm their thicknesses meet drawing requirements of Section 1.4. Measurements shall be performed in accordance with written and approved procedures. Measurements shall be made through a combination of receipt inspection thickness measurements on individual plates and actual measurements taken prior to welding the forgings and shells. Any area found to be under the specified minimum thickness shall be repaired in accordance with applicable ASME Code requirements.

No additional gamma shield testing of the HI-STAR 100 Package is required. A shielding effectiveness test as described in Subsection 8.1.5.2 shall be performed on each fabricated HI-STAR 100 Package after the first fuel loading.

General Requirements for Shield Materials:

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

2. Dimensional inspections of the cavities containing poured neutron shielding materials shall assure that the amount of shielding material specified in the design documents is incorporated into the fabricated item.

8.1.5.2 Shielding Effectiveness Tests

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

Following the first fuel loading of each HI-STAR 100 Package, a shielding effectiveness test shall be performed to verify the effectiveness of the neutron shield. This test shall be performed either with a check source or with loaded contents. If the test is performed using loaded contents, the test shall be performed after the HI-STAR 100 Package has been, drained, sealed, and backfilled with helium.

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

8.1.5.3 Neutron Absorber Tests

Each plate of Boral shall be visually inspected by the manufacturer for damage (e.g., scratches, cracks, burrs, and peeled cladding) and foreign material embedded in the surfaces. In addition, the MPC fabricator shall visually inspect the Boral plates on a lot sampling basis. The sample size shall be determined in accordance with MIL-STD-105D or equivalent. The selected Boral plates shall be inspected for damage such as inclusions, cracks, voids, delamination, and surface finish.

After manufacturing, a statistical sample of each lot of Boral shall be tested using wet chemistry and/or neutron attenuation techniques to verify a minimum ^{10}B content at the ends of the panel. The minimum ^{10}B loading of the Boral panels for each MPC model is provided in Table 1.2.3 Any panel in which ^{10}B loading is less than the minimum allowed per the drawings in Section 1.4 shall be rejected.

Tests shall be performed using written and approved procedures. Results shall be documented and become part of the quality records documentation package.

Installation of Boral panels into the fuel basket shall be performed in accordance with written and approved procedures (or shop travelers). Travelers and/or quality control procedures shall be in place to assure each required cell wall of the MPC basket contains a Boral panel in accordance with the drawings in Section 1.4. These quality control processes, in conjunction with Boral manufacturing testing, provide the necessary assurances that the Boral will perform its intended function. The criticality design for the HI-STAR 100 System is based on favorable geometry and fixed neutron poisons. The inert helium environment inside the MPC cavity where the Boral is located ensures that the poisons will remain effective for the life of the canister. Given the design and service conditions, there are no credible means to lose the fixed neutron poisons. Therefore, no additional testing is required to ensure the Boral is present and in proper condition per 10 CFR 71.87(g).

8.1.6 Thermal Acceptance Test

The first fabricated HI-STAR overpack shall be tested to confirm its heat transfer capability. The test shall be conducted after the radial channels, enclosure shell panels, and neutron shield material have been installed and all inside and outside surfaces are painted per the drawings in Section 1.4. A test cover plate shall be used to seal the overpack cavity. Testing shall be performed in accordance with written and approved procedures.

Steam heating of the overpack cavity surfaces is the preferred method for this test instead of electric heating. There are several advantages with steam heated testing as listed below:

(i) Uniform cavity surface temperatures are readily achieved as a result of high steam condensation heat transfer coefficient (about 2,000 Btu/ft^2 hr-^{o}F compared to about 1 Btu/ft^2 hr-^{o}F for air) coupled with the steam's uniform distribution throughout the cavity.

(ii) A reliable constant temperature source (steam at atmospheric pressure condenses at 212^{o}F compared to variable heater surface temperatures in excess of 1,000^{o}F) eliminates concerns of overpack cavity surface overheating.

(iii) Interpretation of isothermal test data is not susceptible to errors associated with electric heating systems due to heat input measurement uncertainties, leakage of heat from electrical cables, thermocouple wires, overpack lid, bottom baseplate, etc.

(iv) The test setup is simple requiring only a steam inlet source and drain compared to numerous power measurement and control instruments, switchgear and safety interlocks required to operate an electric heater assembly.

Twelve (12) calibrated thermocouples shall be installed on the external walls of the overpack as shown in Figure 8.1.2. Three calibrated thermocouples shall be installed on the internal walls of the overpack in locations to be determined by procedure. Additional temperature sensors shall be used to monitor ambient temperature, steam supply temperature, and condensate drain temperature. The thermocouples shall be attached to strip chart recorders or other similar mechanism to allow for continuous monitoring and recording of temperatures during the test. Instrumentation shall be installed to monitor overpack cavity internal pressure.

After the thermocouples have been installed, dry steam will be introduced through an opening in the test cover plate previously installed on the overpack and the test initiated. Temperatures of the thermocouples, plus ambient, steam supply, and condensate drain temperature shall be recorded at hourly intervals until thermal equilibrium is reached. Appropriate criteria defining when thermal equilibrium is achieved shall be determined based on a variety of potential ambient test conditions and incorporated into the test procedure. In general, thermal equilibrium is expected approximately 12 hours after the start of steam heating. Air will be purged from the overpack cavity via venting during the heatup cycle. During the test, the steam condensate flowing out of the overpack drain shall be collected and the mass of the condensate measured with a precision weighing instrument.

Once thermal equilibrium is established, the final ambient, steam supply, and condensate drain temperatures and temperatures at each of the thermocouples shall be recorded. The strip charts, hand-written logs, or other similar readout shall be marked to show the point when thermal equilibrium was established and final test measurements were recorded. The final test readings along with the hourly data inputs and strip charts (or other similar mechanism) shall become part of the quality records documentation package for the HI-STAR 100 Package.

The heat rejection capability of the overpack at test conditions shall be computed using the following formula:

$$Q_{hm} = (h_1 - h_2)\, m_c \tag{8-1}$$

Where:

Q_{hm} = Heat rejection rate of the overpack (Btu/hr)

h_1 = Enthalpy of steam entering the overpack cavity (Btu/lbm)

h_2 = Enthalpy of condensate leaving the overpack cavity (Btu/lbm)

m_c = Average rate of condensate flow measured during thermal equilibrium conditions (lbm/hr)

Based on the HI-STAR 100 overpack thermal model, a design basis minimum heat rejection capacity (Q_{hd}) shall be computed at the measured test conditions (i.e., steam temperature in the overpack cavity and ambient air temperature). The thermal test shall be considered acceptable if the measured heat rejection capability is greater than the design basis minimum heat rejection capacity ($Q_{hm} > Q_{hd}$).

The summary of reference ambient inputs that define the thermal test environment are provided in Table 8.1.4. In Figure 8.1.3, a steady-state temperature contour plot of a steam heated overpack is provided based on the thermal analysis methodology described in SAR Chapter 3. Transient heating of the overpack is also determined to establish the time required to approach (within 2^{o} F) the equilibrium temperatures. The surface temperature plot shown in Figure 8.1.4 demonstrates that a 12-hour steam heating time is adequate to closely approach the equilibrium condition.

If the acceptance criteria above are not met, then the HI-STAR 100 Package shall not be accepted until the root cause is determined, appropriate corrective actions are completed, and the overpack is re-tested with acceptable results.

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

8.1.7 Cask Identification

Each HI-STAR 100 Package shall be provided with unique identification plates with appropriate markings per 10CFR71.85(c) and 10CFR72.236(k). The identification plates shall not be installed until each HI-STAR 100 Package component has completed the fabrication acceptance test program and been accepted by authorized Holtec International personnel. A unique identifying serial number shall also be stamped on the MPC to provide traceability back to the MPC specific quality records documentation package.

Table 8.1.1

MPC INSPECTION AND TEST ACCEPTANCE CRITERIA

Function	Fabrication	Pre-operation	Maintenance and Operations
Visual Inspection and Nondestructive Examination (NDE)	a) Examination of MPC components per ASME Code Section III, Subsections NB, NF, and NG, , per NB-5300, NF-5300, and NG-5300, as applicable. b) A dimensional inspection of the fuel basket assembly and canister shall be performed to verify compliance with design requirements. c) A dimensional inspection of the MPC lid and MPC closure ring shall be performed prior to inserting into the canister shell to verify compliance with design requirements. d) NDE of weldments are defined on the drawings using standard American Welding Society NDE symbols and/or notations. e) Cleanliness of the MPC shall be verified upon completion of fabrication. f) The packaging of the MPC at the completion of fabrication shall be verified prior to shipment.	a) The MPC shall be visually inspected prior to placement in service at the licensee's facility. b) MPC protection at the licensee's facility shall be verified. c) MPC cleanliness and exclusion of foreign material shall be verified prior to placing in the spent fuel pool.	a) None.

Table 8.1.1 (continued)

MPC INSPECTION AND TEST ACCEPTANCE CRITERIA

Function	Fabrication	Pre-operation	Maintenance and Operations
Structural	a) Assembly and welding of MPC components shall be performed per ASME Code Section IX and III, Subsections NB, NF, and NG, as applicable. b) Materials analysis (steel, Boral, etc.), shall be performed and records shall be kept in a manner commensurate with "important to safety" classifications.	a) None.	a) An ultrasonic (UT) examination or multi-layer liquid penetrant (PT) examination of the MPC lid-to-shell weld shall be performed per ASME Section V, Article 5 (or ASME Section V, Article 2). Acceptance criteria for the examination are defined in Subsection 8.1.1.1. b) ASME Code NB-6000 pressure test shall be performed after MPC closure welding. Acceptance criteria are defined in Subsection 8.1.2.2.2.
Leak Tests	a) Helium leak rate testing shall be performed on all MPC pressure boundary shop welds.	a) None.	a) Helium leak rate testing shall be performed on MPC lid-to-shell, and vent and drain ports-to-MPC lid field welds after closure welding. Acceptance criteria are defined in Subsection 8.1.3.2. b) A Containment System Fabrication Verification Leakage Test shall be performed on the MPC-68F and MPC-24EF prior to the transport of the HI-STAR 100 Package containing fuel debris. Acceptance criteria are defined in Subsection 8.1.3.2.

Table 8.1.1 (continued)

MPC INSPECTION AND TEST ACCEPTANCE CRITERIA

Function	Fabrication	Pre-operation	Maintenance and Operations
Criticality Safety	a) The boron content shall be verified at the time of neutron absorber material manufacture. b) The installation of Boral panels into MPC basket plates shall be verified by inspection.	a) None.	a) None.
Shielding Integrity	a) Material compliance shall be verified through CMTRs. b) Dimensional verification of MPC lid thickness shall be performed.	a) None.	a) None.
Thermal Acceptance	a) None.	a) None.	a) None.
Fit-Up Tests	a) Fit-up of the following components is to be tested during fabrication. - MPC lid - vent/drain port cover plates - MPC closure ring b) A gauge test of all basket fuel compartments.	a) Fit-up of the following components is to be verified during pre-operation. - MPC lid - MPC closure ring vent/drain cover plates	a) None.
Canister Identification Inspections	a) Verification of identification marking applied at completion of fabrication.	a) Identification marking shall be checked for legibility during pre-operation.	a) None.

Table 8.1.2

HI-STAR OVERPACK INSPECTION AND TEST ACCEPTANCE CRITERIA

Function	Fabrication	Pre-operation	Maintenance and Operations
Visual Inspection and Nondestructive Examination (NDE)	a) Examination of the HI-STAR overpack shall be performed per ASME Code, Subsection NB, NB-5300 for containment boundary components, and Subsection NF, NF-5300 for non-containment boundary components. b) A dimensional inspection of the overpack internal cavity, external dimensions, and closure plate shall be performed to verify compliance with design requirements. c) The HI-STAR overpack ~~shall be visually examined in accordance with the ASME Code Section V, Article 9, to verify that the overpack is free of cracks, pinholes, uncontrolled voids, or other defects that could significantly reduce its effectiveness.~~ *system containment boundary shall be examined and tested by a combination of methods (including helium leak test, pressure test, UT, MT and/or PT, as applicable) to verify that it is free of cracks, pinholes, uncontrolled voids or other defects that could significantly reduce the effectiveness of the packaging.* d) NDE of weldments shall be defined on drawings using standard American Welding Society NDE symbols and/or notations. e) Cleanliness of the HI-STAR overpack shall be verified upon completion of fabrication. f) Packaging of the HI-STAR overpack at the completion of fabrication shall be verified prior to shipment. g) Examination of the AL-STAR impact limiters shall be performed per ASME Code, Subsection NF, NF-5300.	a) The HI-STAR overpack shall be visually inspected prior to placement in service at the licensee's facility. b) HI-STAR overpack protection at the licensee's facility shall be verified. c) HI-STAR overpack cleanliness and exclusion of foreign material shall be verified prior to use.	a) Inspect overpack cavity and accessible external surfaces prior to each fuel loading. b) Visually inspect impact limiters for damage and compliance to drawing requirements prior to each transport.

Table 8.1.2 (continued)

HI-STAR OVERPACK INSPECTION AND TEST ACCEPTANCE CRITERIA

Function	Fabrication	Pre-operation	Maintenance and Operations
Structural	a) Assembly and welding of HI-STAR overpack components shall be performed per ASME Code, Subsection NB and NF, as applicable. b) Verification of structural materials shall be performed through receipt inspection and review of certified material test reports (CMTRs) obtained in accordance with the item's quality classification category. c) A load test of the lifting trunnions shall be performed during fabrication. d) A pressure test of the containment boundary in accordance with ASME Code Section III, Subsection NB-6000 and 10CFR71.85(b) shall be performed. e) A pneumatic pressure test of the neutron shield enclosure shall be performed during fabrication.	a) None.	a) The relief devices on the neutron shield vessel shall be replaced every 5 years.

Table 8.1.2 (continued)

HI-STAR OVERPACK INSPECTION AND TEST ACCEPTANCE CRITERIA

Function	Fabrication	Pre-operation	Maintenance and Operations
Leak Tests	a) Containment Fabrication Verification Leakage rate testing of the HI-STAR containment boundary welds shall be performed in accordance with ANSI N14.5. b) A Containment System Fabrication Verification Leakage rate test shall be performed on all HI-STAR overpack containment boundary mechanical seal boundaries in accordance with ANSI N14.5 at the completion of fabrication.	a) None.	a) Containment System Periodic Verification Leakage Test of the HI-STAR 100 Package shall be performed prior to each loaded transport (if not previously tested within 12 months). b) Containment System Fabrication Verification Leakage Test of the HI-STAR 100 Package shall be performed after the third use.
Criticality Safety	a) None.	a) None.	a) None.
Shielding Integrity	a) Material verifications (Holtite-A, shell plates, etc.), shall be performed in accordance with the item's safety classification. The required material certifications shall be obtained. b) The placement of Holtite-A shall be controlled through written special process procedures.	a) None.	a) A shielding effectiveness test of the neutron shield shall be performed every five years while in service. b) Verify the integrity of the Holtite-A neutron shield once at first use or with a check source.

Table 8.1.2 (continued)

HI-STAR OVERPACK INSPECTION AND TEST ACCEPTANCE CRITERIA

Function	Fabrication	Pre-operation	Maintenance and Operation
Thermal Acceptance	a) A thermal acceptance test is performed at completion of fabrication of the first HI-STAR overpack to confirm the heat transfer capabilities.	a) None.	a) An in-service thermal test shall be performed every five years during transport operations, or prior to transport if period exceeds five years from previous test. Acceptance criteria are defined in Section 8.2.6.
Cask Identification Inspection	a) Identification plates shall be installed on the HI-STAR overpack at completion of the acceptance test program.	a) The identification plates shall be checked prior to loading.	a) The identification plates shall be periodically inspected per licensee procedures and shall be repaired or replaced if damaged.
Fit-Up Tests	a) Fit-up tests of HI-STAR 100 Package components (closure plates, port plugs, cover plates impact limiters (if available)), shall be performed during fabrication.	a) Fit-up test of the HI-STAR overpack lifting trunnions with the lifting yoke shall be performed. b) Deleted c) Fit-up test of the MPC into the HI-STAR overpack shall be performed prior to loading.	a) Fit-up of all removable components shall be verified during each loading operation.

Table 8.1.3

HI-STAR 100 NDE REQUIREMENTS

MPC			
Weld Location	**NDE Requirement**	**Applicable Code**	**Acceptance Criteria (Applicable Code)**
Shell longitudinal seam	RT PT (surface)	ASME Section V, Article 2 (RT) ASME Section V, Article 6 (PT)	RT: ASME Section III, Subsection NB, Article NB-5320 PT: ASME Section III, Subsection NB, Article NB-5350
Shell circumferential seam	RT PT (surface)	ASME Section V, Article 2 (RT) ASME Section V, Article 6 (PT)	RT: ASME Section III, Subsection NB, Article NB-5320 PT: ASME Section III, Subsection NB, Article NB-5350
Baseplate-to-shell	RT or UT PT (surface)	ASME Section V, Article 2 (RT) ASME Section V, Article 5 (UT) ASME Section V, Article 6 (PT)	RT: ASME Section III, Subsection NB, Article NB-5320 UT: ASME Section III, Subsection NB, Article NB-5330 PT: ASME Section III, Subsection NB, Article NB-5350

Table 8.1.3 (continued)

HI-STAR 100 NDE REQUIREMENTS

MPC

Weld Location	**NDE Requirement**	**Applicable Code**	**Acceptance Criteria (Applicable Code)**
Lid-to-shell	PT (root and final pass) and multi-layer PT (if UT is not performed). PT (surface following pressure test) UT (if multi-layer PT is not performed)	ASME Section V, Article 6 (PT) ASME Section V, Article 5 (UT)	PT: ASME Section III, Subsection NB, Article NB-5350 UT: ASME Section III, Subsection NB, Article NB-5332
Closure ring-to-shell	PT (final pass)	ASME Section V, Article 6 (PT)	PT: ASME Section III, Subsection NB, Article NB-5350
Closure ring-to-lid	PT (final pass)	ASME Section V, Article 6 (PT)	PT: ASME Section III, Subsection NB, Article NB-5350
Closure ring radial welds	PT (final pass)	ASME Section V, Article 6 (PT)	PT: ASME Section III, Subsection NB, Article NB-5350
Port cover plates-to-lid	PT (root and final pass)	ASME Section V, Article 6 (PT)	PT: ASME Section III, Subsection NB, Article NB-5350
Vent and drain port cover plate plug welds	PT (surface)	ASME Section V, Article 6 (PT)	PT: ASME Section III, Subsection ~~NG~~*NB*, Article ~~NG~~*NB*-5350

Table 8.1.3 (continued)

HI-STAR 100 NDE REQUIREMENTS

HI-STAR OVERPACK			
Weld Location	**NDE Requirement**	**Applicable Code**	**Acceptance Criteria (Applicable Code)**
Inner shell-to-top flange	RT MT or PT (surface)	ASME Section V, Article 2 (RT) ASME Section V, Article 7 (MT) ASME Section V, Article 6 (PT)	RT: ASME Section III, Subsection NB, Article NB-5320 MT: ASME Section III, Subsection NB, Article NB-5340 PT: ASME Section III, Subsection NB, Article NB-5350
Inner shell-to-bottom plate	RT MT or PT (surface)	ASME Section V, Article 2 (RT) ASME Section V, Article 7 (MT) ASME Section V, Article 6 (PT)	RT: ASME Section III, Subsection NB, Article NB-5320 MT: ASME Section III, Subsection NB, Article NB-5340 PT: ASME Section III, Subsection NB, Article NB-5350
Inner shell longitudinal seam	RT MT or PT (surface)	ASME Section V, Article 2 (RT) ASME Section V, Article 7 (MT) ASME Section V, Article 6 (PT)	RT: ASME Section III, Subsection NB, Article NB-5320 MT: ASME Section III, Subsection NB, Article NB-5340 PT: ASME Section III, Subsection NB, Article NB-5350

Table 8.1.3 (continued)

HI-STAR 100 NDE REQUIREMENTS

HI-STAR OVERPACK			
Weld Location	**NDE Requirement**	**Applicable Code**	**Acceptance Criteria (Applicable Code)**
Inner shell circumferential seam	RT MT or PT (surface)	ASME Section V, Article 2 (RT) ASME Section V, Article 7 (MT) ASME Section V, Article 6 (PT)	RT: ASME Section III, Subsection NB, Article NB-5320 MT: ASME Section III, Subsection NB, Article NB-5340 PT: ASME Section III, Subsection NB, Article NB-5350
Intermediate shell welds (as noted on drawings)	MT or PT (surface)	ASME Section V, Article 6 (PT) ASME Section V, Article 7 (MT)	PT: ASME Section III, Subsection NF, Article NF-5350 MT ASME Section III, Subsection NF, Article NF-5340

Table 8.1.4

SUMMARY OF OVERPACK THERMAL ANALYSIS
REFERENCE AMBIENT INPUTS

PARAMETER	VALUE
Steam Temperature	212^{o}F
Ambient Temperature	70^{o}F
Radiative Blocking	None[1]
Exposed Surfaces Insolation	None

1 The test shall be performed on an isolated overpack. Thus, cask radiation blocking at an ISFSI array is not applicable to test conditions.