SAFETY EVALUATION REPORT

Docket No. 71-9261
Model No. HI-STAR 100
Certificate of Compliance No. 9261
Revision 2

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SUMMARY

By application dated May 31, 2002, as supplemented[1], Holtec International (the applicant) requested an amendment to Certificate of Compliance (CoC) No. 9261 for the Model No. HI-STAR 100 system.

The applicant requested that the certificate be amended to incorporate the following major changes:

1. allow the use of the generic Multi-Purpose Canister (MPC)-24E/EF for transporting intact PWR fuel assemblies with higher initial enrichments,
2. allow the use of the Trojan plant-specific MPC-24E/EF for transporting all Trojan plant intact fuel, damaged fuel, and fuel debris removed from the spent fuel pool in support of decommissioning,
3. allow the use of modified method of securing the overpack to the transport vehicle,
4. replace detailed certificate drawings of the MPCs and overpack with less detailed licensing drawings,
5. incorporate design changes, which had been made to the storage cask design under the provision of 10 CFR 72.48, into the licensing drawings for the transportation design, and
6. remove detailed calculations contained in the appendices to SAR Chapter 2, and place them in the supporting calculation packages which can be made available to staff upon request.

Furthermore, the staff identified additional changes which were not specifically highlighted by Holtec. These changes are:

7. changing to a new basket layout for MPC-24,
8. having two MPC lid fabrication options; (1) as one piece with the specified thickness or (2) two pieces with each piece being half of the specified thickness,
9. increasing the MPC accident internal pressure from 125 psig to 200 psig in order to be consistent with HI-STORM storage CoC Amendment 1,
10. reducing the torque for overpack closure plate bolts, and
11. making Aluminum Heat Conduction Elements (AHCE) optional.

The staff has listed the minor changes with regard to each discipline in the following respective chapters .

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[1]Supplements dated October 24, 2002, May 23 and 29, June 6 and 13, July 11, 18, and 31, August 21, and September 4, 10, and 17, 2003

In support of its application, Holtec provided the necessary engineering analyses and drawing changes. Holtec also submitted Revision 10 to the Safety Analysis Report (SAR) for the HI-STAR 100 System on August 21, 2003. Revision 10 incorporates and consolidates the changes proposed by the applicant, as supplemented, and supersedes the previous revisions to the SAR. Although, Revision 10 of the SAR contains information regarding the MPC-32, the staff excluded the MPC-32 from its evaluation, as requested by Holtec in its May 23, 2003 letter due to unavailability of RAI responses related to Burnup Credit use in designing MPC-32. Therefore, no approval is granted for transporting the MPC-32 in the HI-STAR 100 overpack at this time.

Based on the statements and representations in the application, as supplemented, and Revision 10 of the SAR, the staff concludes, per its evaluation described in Chapter 2 through Chapter 8 of this Safety Evaluation Report (SER), that the requested changes do not affect the ability of the package to meet the requirements of 10 CFR Part 71.

1.0 GENERAL INFORMATION

As indicated in the Summary Section, the applicant's change requests fall within the elevn major groups listed above. The following sections summarize the applicant's change requests with respect to the packaging and its contents.

1.1 Packaging

With respect to the overpack, the applicant has requested the certificate to be amended to:

1. allow the use of modified method of securing the HI-STAR 100 overpack to the transport vehicle,
2. replace detailed certificate drawings of the overpack with less detailed licensing drawings,
3. incorporate design changes, which had been made to the storage cask design under the provision of 10 CFR 72.48, into the licensing drawings for the transportation design, and
4. remove detailed calculations contained in the appendices to SAR Chapter 2, and place them in the supporting calculation packages which can be made available to staff upon request.

With respect to the MPC, the applicant has requested the following changes/additions:

1. allow the use of the generic MPC-24E/EF for transporting intact PWR fuel assemblies with higher initial enrichments,
2. allow the use of the Trojan plant-specific MPC-24E/EF for transporting all Trojan plant intact fuel, damaged fuel, and fuel debris removed from the spent fuel pool in support of decommissioning,
3. replace detailed certificate drawings of the MPCs with less detailed licensing drawings,
4. incorporate design changes, which had been made to the storage cask design under the provision of 10 CFR 72.48, into the transportation licensing drawings,
5. new basket layout for MPC-24, MPC-24E, MPC-24EF, and Trojan plant-specific MPC-24E and MPC-24EF,
6. option of MPC lid to be fabricated as one piece with the specified thickness, or two

pieces with each piece of half the specified thickness,

7. increase the MPC accident internal pressure from 125 psig to 200 psig to be consistent with HI-STORM storage CoC Amendment 1, and
8. make Aluminum Heat Conduction Elements (AHCE) optional.

Based on the statements and representations in the application, as supplemented, and Revision 10 of the SAR, the staff concludes that Holtec has described the changes in the HI-STAR 100 overpack and MPC designs in sufficient detail to provide an adequate basis for its evaluation against 10 CFR Part 71.

1.2 Contents

The applicant has requested additions of or changes to the following fuel forms to the list of the approved contents:

1. PWR intact zircaloy and stainless steel clad fuel assemblies with initial maximum enrichment of 5 %wt placed in MPC-24E,
2. Trojan's intact fuel placed in Trojan plant specific MPC-24E,
3. Trojan's Failed Fuel Can containing Trojan damaged fuel, fuel debris, or Trojan Fuel debris process cans; or Trojan Fuel Debris Process Can Capsules, which themselves contain Trojan Fuel Debris Process Cans,
4. Holtec's Trojan plant PWR Damaged Fuel Container,
5. Trojan plant non-fuel hardware which consists of:
   - Rod Cluster Control Assemblies (RCCAs),
   - Burnable Poison Rod Assemblies (BPRAs),
   - Thimble Plug Devices (TPDs), and
   - Neutron source assemblies
6. PWR 14X14E, BWR 9X9G, and BWR 7X7A fuel which had been deleted inadvertently, and
7. increase of the initial enrichment of the 8x8F fuel type to 4% in the MPC-68.

Based on the statements and representations in the application, as supplemented, and Revision 10 of the SAR, the staff concludes that Holtec has described the changes in the HI-STAR 100 contents in sufficient detail to provide an adequate basis for its evaluation against 10 CFR Part 71.

1.3 Materials

With respect to material for the overpack, the applicant included changes describing the specified protective coatings used for the transportation overpack. These changes reflect trade name changes by the coating manufacturers. The "new" coatings are identical to the previously used coatings, but are now referenced by their new trade names. The staff finds these changes acceptable.

In addition, the applicant proposed to eliminate the use of one of two previously approved neutron absorber materials, NS-4-FR, and employ only the remaining approved material, Holtite. The staff finds this to be acceptable.

The approved materials of construction for the MPC are referred to as “alloy x”. “Alloy x” is the applicant’s term for certain ASME Code grades of 304, 304L, 316, and 316L stainless steels which have similar mechanical and welding properties. Any cask may be fabricated from any of the “alloy x” group of materials.

Previously, any one cask was specified to be made entirely from one grade of the “alloy x” materials. The applicant has proposed that this requirement be changed to permit any single cask to be fabricated from any combination of the “alloy x” grades, with the provison that the shell plates of any single cask all be of a single grade of stainless steel, not a combination of grades.

From the strength standpoint, the lowest bounding value of Code allowable stresses is adopted for design purposes, regardless of which “alloy x” material is actually used. This provides a conservative lower bound on material properties and meets the Code design stress allowable values, regardless of which material of the “alloy x” group may be used.

Through choice of the specified alloys, welding compatibility was assured. The four grades of stainless steel have very similar welding characteristics and may all be welded with the same welding procedure and filler metal, irrespective of which base material is used or which different grades are being joined. Previously, only one grade was joined to itself.

Since the various grades of stainless steel are so similar in mechanical properties, possess similar corrosion resisting ability under the design environmental conditions (atmospheric exposure), and have virtually identical welding properties, the staff finds the expanded use of the “alloy x” concept to be acceptable.

With respect to the content material, the applicant has proposed the addition of certain PWR non-fuel hardware, specifically burnable poison rod assemblies (BPRA’s), thimble plug devices (TPD’s), rod cluster control assemblies (RCCA’s), thoria rods, and fuel assembly neutron sources from the Trojan plant. These non-fuel components are composed of either zircalloy or stainless steel tubular cladding, identical to that used for fuel pins. These pins are filled with various metal oxides. For the proposed amendment, all such assemblies are intact, i.e., without any breaches of the cladding. Thus, no escape of the contents into the general cask environment would occur, and no adverse chemical, corrosion or galvanic reaction could occur. Since the metal oxides that make up the contents of this hardware are either largely inert or similar to fuel oxides, no previously unanalyzed reactions would occur even if a breach of the non-fuel element cladding did occur. Thus, the staff finds that inclusion of these non-fuel assemblies is acceptable.

The applicant has also proposed to add damaged fuel assemblies from Trojan to the list of approved contents for their respective casks. Damaged fuel, as defined by the staff guidance contained in ISG-1, is first placed into a damaged fuel can prior to the canned assembly being loaded into the MPC. The damaged fuel can is constructed of stainless steel and acts to confine the damaged assembly to its specific fuel compartment within the MPC. This aids criticality control and shielding design, minimizes adverse thermal effects, and provides additional confinement of any fuel fines that may escape from a cladding breach. Since the proposed damaged fuel can design and use is in compliance with the staff guidance contained in ISG-1, this change is acceptable.

This amendment adds several fuel types (i.e., different manufacturers) to the list of approved fuel types that may be stored. Included among the additional fuel types is stainless steel clad fuel 14X14E from Indian Point Unit 1. Since the additional fuel types are all constructed of the same materials as previously evaluated or licensed fuel types, no change in the materials to be stored has occurred. Thus, no unanalyzed or adverse chemical, galvanic, or corrosion reactions will occur between the new fuel types and the cask materials. Consequently, the staff finds that the proposed new fuel types to be stored are acceptable.

1.4 Transport Index for Criticality Control (Criticality Safety Index)

The applicant has added the criticality safety index for the HI-STAR 100 package, which is zero, in Section 1.2.3.9 of the SAR.

Condition No. 5(c) of the certificate was revised to clarify that the Transport Index for criticality control is the same as the Criticality Safety Index as defined in the International Atomic Energy Agency Regulations for the Safe Transport of Radioactive Material (TS-R-1).

1.5 Drawings

The applicant requested in its application dated May 31, 2002, as supplemented in October 24, 2002, and July 11, 2003, that the engineering drawings referenced in the certificate be replaced with a revised set of licensing drawings. The revised set of drawings has less details and incorporates changes implemented for storage under the provisions of 10 CFR 72.48.

The applicant indicated on the drawings deviations due to fabrication restrictions or errors. Other changes such as the new basket layout for MPC-24, 24E, 24EF, and Trojan plant-specific MPC-24E/EF are shown in the revised set of licensing drawings. New drawings, regarding fuel spacers for generic MPCs, Trojan plant-specific MPC, Holtec-designed Damaged Fuel Containers for Trojan, and Sierra Nuclear-designed Failed Fuel Cans for Trojan, were also added to the licensing drawings.

The staff reviewed the revised set of licensing drawings and finds that the information on the drawings provides an adequate basis for its evaluation against 10 CFR Part 71 requirements. The information on the drawings is consistent with the package as described and evaluated in the SAR.

2.0 STRUCTURAL

2.1 Description of Changes

The following proposed changes were evaluated for their impact on the structural adequacy of the HI-STAR 100 system:

1. addition of new generic multi-purpose canisters, MPC-24E and MPC-24EF, for transportation of PWR intact fuel and up to four damaged fuel assemblies or fuel debris in canisters. The fuel basket layout and structural details are modified from the currently approved fuel basket cell layout and structural details for MPC-24;
2. addition of the Trojan plant-specific MPC-24E and MPC-24EF designs for transporting

Trojan plant intact fuel, damaged fuel, and fuel debris derived from the Trojan plant spent fuel pool;

3. modification of MPC-24 fuel basket cell layout and structural details. The fuel basket cell layout and structural details for MPC-24 are modified in order to make it similar to that for MPC-24E/24EF;
4. allow the option of the MPC lid to be fabricated as one piece with the specified thickness or two pieces with each piece being half of the specified thickness for all MPCs;
5. modification of the tie-down system. The Pocket Trunnions used for the previous tie-down system design are eliminated for future designs on the HI-STAR 100 system, and are substituted with a different tie-down system;
6. revision of the currently approved drawings to incorporate changes to the storage cask design resulting from the 10 CFR 72.48 process implementation and deletion of unnecessary details.

2.2 Structural Evaluation

2.2.1 MPC-24E/EF

These MPCs are structurally identical to the MPC-24, except that the Boral Neutron Absorber plates and sheathing materials are thicker for the MPC-24E and MPC-24EF, and contain greater B^{10} loading, to reflect the change in fuel content. Additionally, the weld size for connecting the lid to the shell, and the shell thickness at the weld for the MPC-24EF are larger than that for the MPC-24 and MPC-24E. The weld changes were made to provide a separate inner container for meeting 10 CFR 71.63(b) requirements. The weld details are the same as for the currently approved MPC-68F. The currently approved fuel basket cell layout for MPC-24 is modified to be similar to the cell layout for the MPC-24E and MPC-24EF.

The MPC-24E and MPC-24EF are heavier (85,188 lbs) than the currently approved MPC-24 (82,494 lbs). However, the HI-STAR 100 system is designed for a bounding MPC weight of 90000 lbs (Tables 2.2.1 and 2.2.4 of the SAR). Additionally, changes in the center of gravity locations of the MPC-24E and MPC-24EF are minimal when compared to the MPC-24 (SAR Table 2.2.2). The weight of the transport package with the MPC-24E/24EF (275,316 lbs) is bounded by the weight of 282,000 lbs used by the applicant for evaluation of the package to meet 10 CFR Part 71 requirements (SAR Table 2.2.4). Additionally, the fuel baskets in the MPC-24E and MPC-24EF are structurally similar in design as the MPC-24 fuel basket. Therefore, the HI-STAR 100 system with the MPC-24E and MPC-24EF would perform similarly as the approved system with the MPC-24 under normal conditions of transport and hypothetical accident conditions, as required in 10 CFR 71.71 and 10 CFR 71.73 regulations.

Trojan-specific MPC-24E and MPC-24EF are similar to the generic MPC-24E and MPC-24EF, except that the Trojan-specific MPCs are shorter than the generic MPCs by 9 inches. The space between the MPC and the overpack closure plate is made up by a stainless steel spacer ring to transfer the loads from the MPC to the closure plate during the 30-foot drop for hypothetical accident conditions. The applicant has evaluated the spacer ring for the 30-foot drop hypothetical accident loads to demonstrate structural adequacy of the spacer ring. The staff reviewed the applicant's calculations and results and agrees with the applicant's conclusion that the spacer ring will adequately perform the function of transferring the MPC loads to the overpack closure plate. Based on this, the staff concludes that the HI-STAR 100

system with the Trojan-specific MPC-24E and MPC-24EF meet the structural requirements of 10 CFR Part 71.

To verify the structural adequacy of the fuel baskets and the MPC components (shell, base plate, lid) for the MPC-24, MPC-24E and MPC-24EF, the applicant has analyzed the MPC shell and the fuel basket by using the computer code ANSYS and a finite-element method of structural analysis. A two-dimensional basic model of the fuel basket cross-section and the MPC shell is used to determine the clearances required to limit the thermal stresses, and two additional similar models with the overpack are used to determine stresses in the basket and the shell for drop events under normal condition of transport. The ANSYS analyses were performed assuming the connections between the cell plates to be pinned instead of being clamped. Based on the ANSYS analyses, weld sizes for some connections have been changed. The stresses from the computer analyses have been verified to be reasonable based on comparison with the closed-form calculations using the formulas. Calculations supporting the analyses and the results of the analyses were reviewed by the staff to verify that the analyses results and conclusions are reasonable. Details of the analyses for normal conditions of transport loads (§ 71.71) are discussed in SAR Sections 2.6.1.3.1 and 2.6.1.4.1 and the results are provided in Tables 2.6.2, 2.6.3, 2.6.7, and 2.6.8.

Using the same finite-element models as for the normal conditions of transport loads, the applicant has evaluated the MPC shell and the fuel basket for load conditions associated with the hypothetical accident conditions. Additionally, the applicant has computed the buckling strength of the fuel cell plate for the 30-foot end drop by using closed-form solutions to demonstrate that the cell plate has significant margin of safety against buckling. Results of the analyses/evaluation are summarized in Tables 2.7.1, 2.7.2, 2.7.4 and 2.7.7 of the HI-STAR SAR.

The staff reviewed the applicant's evaluation, including the method of analysis, and assumptions, and concluded that the fuel basket designs for MPC-24E and MPC-24EF meet the 10 CFR Part 71 structural requirements.

The applicant has provided a list of damaged fuel or failed fuel canisters in Appendix 2.B of the SAR. These canisters are used in the HI-STAR 100 transport system in the generic and Trojan-specific MPC-24E and MPC-24EF. The Appendix also includes a general method of analysis and table of the minimum safety factors for all canisters. The Holtec-designed Damaged Fuel Container and the Sierra-designed Failed Fuel Can for Trojan fuel are the only structural components. The applicant evaluated these components using formulas for loads during the lifting and the 30-foot end drop under hypothetical accident conditions. The American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NG was used for the acceptance criteria and computation of safety factors. The staff reviewed the applicant's calculations and agrees with the method of analysis and results of the calculations. Based on this review, it is concluded that the Holtec-designed Damaged Fuel Container and the Sierra-designed Failed Fuel Can for Trojan fuel meet the 10 CFR Part 71 structural requirements.

Based on the evaluation discussed above, the staff concludes that the MPC-24, MPC-24E, and MPC-24EF meet the 10 CFR Part 71 structural requirements.

2.2.2 MPC top lid thickness

The MPC top lid thickness design has been changed for all MPCs to allow the use of two equal thickness lids, welded around the periphery, instead of a single thickness top lid employed in the currently approved MPC designs. The applicant has evaluated the top lid design using the thickness equal to 0.5 times the thickness of the currently approved top lid, and has concluded that the top lid with a reduced thickness would meet the currently approved design codes and standards. The staff reviewed the applicant's method of analysis, assumptions, and acceptance criteria, and agrees that the change in using two equal thickness lids instead of a single thickness lid would meet the structural design criteria for the MPC. Based on this, the staff agrees that the MPC designs are not adversely impacted by having two equal thickness top lids instead of a single thickness lid, and that the package meets 10 CFR Part 71 structural requirements.

2.2.3 Tie-down system changes

The applicant has changed the tie-down system to include a saddle and three straps instead of the pocket trunnion and a shear ring. Calculations for the forces in the straps are performed for 10 g axial, 5 g lateral, and 2 g vertical loads in accordance with 10 CFR 71.45(b)(1). The staff reviewed the calculations, and agrees with the method of analysis, assumptions, and results. The new tie-down system is not a structural part of the package. However, the use of the new system requires a minimum number of three straps, and a minimum width of each strap of 6 inches, to satisfy 10 CFR 71.45(b) requirements. These requirements are included in the Drawing No. 3930, sheet 1.

2.3 Evaluation Findings

Based on the review of the statements and representations in the application, as supplemented and revised by the applicant, the staff concludes that the changes in the structural design of the package have been adequately described and evaluated, and the changes do not adversely affect the ability of the package to meet the 10 CFR Part 71 structural requirements.

3.0 THERMAL

The staff reviewed the HI-STAR Transportation Package thermal design and evaluation to assess whether the package and fuel material temperatures will remain within their allowable values or criteria for normal conditions of transport and hypothetical accident conditions (HAC) as required in 10 CFR Part 71 (Ref. 1). This case was also reviewed to determine whether the package fulfills the acceptance criteria listed in Section 3 of NUREG-1617, "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel," as well as associated SFPO ISG documents (Refs. 2 and 3).

3.1 Description of Changes

The principal changes affecting the thermal performance of the HI-STAR 100 System are listed as follows:

1. the AHCE in the MPC are treated as optional hardware,

2. the nominal helium fill pressure is raised to 42.8 psig,
3. the thermal calculations used realistic assumptions to increase the thermal loading of the cask,
4. the thermal evaluation is revised to comply with ISG-11 (Ref. 3), Revision 2 temperature limits, and
5. the Forced Helium Dehydrator (FHD) system is used during drying operations of an MPC which is loaded for direct off-site shipment in a HI-STAR transport cask.

3.2 Description of the Thermal Design

3.2.1 Packaging design features

The calculated maximum normal operating pressure (MNOP) for horizontal transport conditions is provided in Table 3.4.15 of the SAR. The MNOP for the HI-STAR 100 packaging is below 100 psig. The complete cell-to-cell connectivity inherent in the honeycomb basket structure provides an uninterrupted heat transmission path. Vertically welded radial channels act as fins for improved heat conduction to the overpack outer enclosure shell surfaces. Optional AHCEs can be installed along the full length of the MPC to create a nonstructural connection to further enhance heat transfer from the basket to the shell. The spent nuclear fuel (SNF) decay heat is passively dissipated without mechanical or forced cooling. To meet the requirements of 10 CFR 71.43(g) for accessible surface temperature limit, 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 package are conduction and radiation for the surface of the cask. The MPC is initially filled with 99.995% pure helium gas at the initial backfill pressure specified in Table 3.4.15 of the SAR. The helium cover gas provides conductive heat transfer across any gap between the metal surfaces inside the MPC and in the annulus between the MPC and overpack. Metal conduction transfers the heat throughout the MPC fuel basket, through the MPC AHCEs (if installed) and MPC shell, through the overpack inner shell, intermediate shells, steel connectors and Holtite-A (neutron shield) and finally, to the outer neutron shield enclosure shell.

3.2.2 Codes and standards

Where appropriate, codes and standards were referenced by the applicant. For standard structural materials, the ASME code is referenced by the applicant.

3.2.3 Content heat load specification

Design payload for the HI-STAR is intact zircaloy or stainless steel clad fuel assemblies with the characteristics listed in Tables 1.2.10, 1.2.11, and 1.2.22 through 1.2.36 of the SAR. The limits for transporting Dresden Unit 1 and Humboldt Bay damaged fuel and fuel debris are given in Tables 1.2.23 and 1.2.24 of the SAR. The limits for transporting Trojan plant damaged fuel and fuel debris are given in Tables 1.2.10, 1.2.25, and 1.2.26 of the SAR. Decay heat design basis fuel is listed in Table 1.2.12 of the SAR. Axial variation in the heat emission rate in the design basis fuel is defined based on the axial burnup distribution. These distributions are summarized in Table 1.2.15 and Figures 1.2.13, 1.2.13A, and 1.2.14 of the SAR.

3.2.4 Summary tables of temperatures

The HI-STAR System material temperature limits are given in Table 3.3.1 of the SAR for fuel cladding (both Zircaloy and Stainless Steel), Boral, Aluminum Alloy 5052, Holtite-A, and AHCEs (Alloy 1100). Material temperature limits for the overpack closure plate mechanical seals and overpack vent and drain port plug seals are given in Table 4.1.1 of the SAR. The HI-STAR System package components maximum temperatures for normal conditions of transport are listed in Tables 3.4.10 and 3.4.11 of the SAR. Maximum calculated HI-STAR System component and material temperatures during and after hypothetical fire conditions are provided in Table 3.5.4 of the SAR. All temperatures during normal conditions of transport, hypothetical fire accident conditions, and design limit criteria for the package components are consistent throughout the SAR and are within allowable limits.

3.2.5 Summary tables of pressures in the containment vessel

The MNOP for horizontal transport conditions are given in Table 3.4.15 of the SAR. Maximum HI-STAR System hypothetical fire condition event pressures are provided in Table 3.5.3 of the SAR. These pressures are consistent with the pressures presented throughout the SAR.

3.3 Material Properties and Component Specifications

3.3.1 Material thermal properties

Thermal properties necessary to calculate transport of heat in the package, as well as from the package to the environment, are provided in the application for normal conditions of transport and for the hypothetical fire conditions. These properties include temperature-dependent properties of thermal conductivity, viscosity, and a parameter for natural convection properties for air. Temperature-dependent effective thermal conductivities based on the basic material thermal conductivities are calculated and used in the thermal analysis of the HI-STAR System for the different components of the thermal model. Effective thermal conductivities include fuel region, sheathing/boral/cell wall sandwich, basket region, overpack multi-layered intermediate shell region, radial steel connectors-Holtite region, eccentric MPC to overpack gap, and MPC basket-to-shell AHCEs. Other material thermal properties used in the analysis include density, specific heat, and emissivity. Closed cavity temperature-dependent Nusselt number results for helium filled MPC peripheral voids are also provided. All material thermal properties are appropriately used in the analysis of the HI-STAR System response to the different thermal loads applied during normal condition of transport and for hypothetical accident fire condition.

3.3.2 Technical specifications of components

Temperature constraints on the function of the different HI-STAR components is adequately described and identified in the SAR. Operating temperature ranges to ensure safe operation of components are summarized in Table 3.3.1 of the SAR. Design temperature limits for the overpack metallic seals are provided in Table 4.1.1 of the SAR.

3.3.3 Thermal design limits of package materials and components

Maximum allowable temperatures for each safety related component of the package are identified and adequately described in the SAR. Maximum allowable temperature is justified by considering the fuel and clad materials, irradiation conditions, shipping environments, and fill

gas. Cladding temperature limits for normal condition of transport and for hypothetical accident conditions are based on SFPO ISG-11, Rev. 2 guidance (Ref. 3). These limits are applicable to all fuel types, burnup levels, and cladding materials approved by the NRC for power generation.

3.4 Thermal Evaluations

3.4.1 Evaluations by analyses

A detailed analytic model for the thermal design of the HI-STAR 100 System was developed by the applicant using the FLUENT® finite volume computational fluid dynamics code and the ANSYS® modeling package. Transport of heat from the basket interior to the basket periphery is accomplished by conduction through the MPC basket metal grid structure and the narrow helium gaps between the fuel assemblies and the fuel cell walls. Heat dissipation from the MPC basket periphery to the MPC shell gap occurs through a combination of helium conduction, radiation across the gap, and conduction through the aluminum heat conduction elements. Heat is conducted from the outer periphery of the MPC shell to the overpack inner shell through a helium-filled gap and then through the overpack layers to the exterior surface of the overpack. Cooling of the exterior system surfaces occurs by natural convection and radiation to the environment.

3.4.2 Evaluation by tests

The applicant demonstrated the thermal performance of the transport cask by analysis which is acceptable to the staff. The thermal acceptance test required before the first use of the HI-STAR overpack is described in SAR Section 8.1.6, Thermal Acceptance Test. This test is performed at completion of fabrication of the first HI-STAR overpack to confirm its heat transfer capabilities. A HI-STAR overpack in-service thermal test is required every five years during transport operations, or prior to transport, if the period exceeds five years from previous test. The acceptance criteria for this periodic test are defined in the SAR Section 8.2.6. No thermal acceptance test is performed to the MPC.

3.4.3 Confirmatory analyses

Previous SERs of CoC No. 9261 (Ref. 4) have indicated that the staff performed confirmatory analysis by developing a detailed model of the fuel and basket geometry using the ANSYS® finite element code. These analyses were performed to provide added assurances that the analytic models referenced in the SAR were acceptable.

3.5 Evaluation of Accessible Surface Temperatures

Under normal conditions, the package is designed and constructed such that the accessible surface temperatures are 142°F (61.1°C) for the MPC-24 and 139°F (59.5°C) for the MPC-68, assuming design basis heat load and no solar insolation. These temperatures are in compliance with the 10 CFR 71.43(g) requirement, under the condition that the package will be shipped as exclusive-use.

3.6 Evaluation Under Normal Conditions of Transport

3.6.1 Heat and cold

For both the MPC-24 and the MPC-68, the applicant performed steady state calculations for normal conditions of transport at 100°F still air conditions, maximum design basis decay heat and full insolation. Table 3.4.10 and 3.4.11 of the SAR for the PWR MPCs and the MPC-68 respectively, summarize the maximum calculated temperatures at different locations of the HI-STAR System. All materials remained below their temperature limit under normal conditions of transport. The HI-STAR System was analyzed for a cold environment of -40°F with zero decay heat load and no solar input. The above analyzed conditions will result in temperature distributions which are equal to the imposed minimum ambient temperature of -40°F. All materials of construction would perform their intended function at this minimum operating temperature.

3.6.2 Maximum normal operating pressure

See SER Section 3.2.5

3.6.3 Maximum thermal stress

Maximum thermal stresses are evaluated in Section 2.6 of the SAR. Tables 3.4.17 and 3.4.18 of the SAR summarize the HI-STAR System components temperatures under steady-state hot conditions for structural evaluation.

3.7 Thermal Evaluation Under Hypothetical Accident Conditions (HAC)

3.7.1 Initial conditions

For thermal evaluations under HAC conditions, the HI-STAR System was analyzed to a 30-minute fire at 1475°F. The initial condition prior to the start of the fire is based on the bounding normal transport condition MPC basket temperature distribution at an ambient temperature of 100°F and full insolation prior to and following the fire. The impact limiter is assumed to be crushed to the bounding maximum condition of a solid block of highly conducting aluminum, resulting in increased heat input to the overpack ends through the reduced impact limiter thickness during the duration of the fire. The effects of the puncture bar are included by conservatively reducing by 10% the neutron shield region effective thermal conductivity during the post fire cooldown phase. During the initial 30-minute fire event, a conservative value maximizing the heat input to the system is applied for the neutron shield thermal conductivity. During the post-fire cooldown phase, no credit is considered for conduction through the neutron shield material. The FLUENT® model developed for normal condition of transport is also used to determine the thermal response during the fire transient conditions.

3.7.2 Fire test

No fire test is performed to determine the transient thermal response of the HI-STAR System. Thermal evaluation of the system is performed by analysis.

3.7.3 Maximum temperatures and pressures

The maximum HI-STAR System components and materials temperatures during and after HAC conditions are summarized in Table 3.5.4 of the SAR. The calculated results demonstrate that the HI-STAR System is in compliance with 10 CFR Part 71 thermal requirements for HAC of transport. All temperatures are below the allowable limit for accident conditions. Maximum calculated cask internal pressures are reported in Table 3.5.3 of the SAR. The pressure analysis is based on release of 100% of the rod fill gas and 30% of the significant radioactive gases from a ruptured rod. Maximum calculated pressures are below the pressure design limit of 200 psig for accident conditions.

3.7.4 Maximum thermal stresses

Maximum thermal stresses during HAC conditions are reported in Chapter 2 of the SAR.

3.8 Evaluation Findings

3.8.1 Description of the thermal design

The staff has reviewed the package description and evaluation, and concludes that they satisfy the thermal requirements of 10 CFR Part 71.

3.8.2 Material properties and component specifications

The staff has reviewed the material properties and component specifications used in the thermal evaluation and concludes that they are sufficient to provide a basis for evaluation of the package against the thermal requirements of 10 CFR Part 71.

3.8.3 General considerations for thermal evaluations

The staff has reviewed the methods used in the thermal evaluation and concludes that they are described in sufficient detail to permit an independent review, with confirmatory calculations, of the package thermal design.

3.8.4 Evaluation of accessible surface temperature

The staff has reviewed the accessible surface temperatures of the package as it will be prepared for shipment and concludes that they satisfy 10 CFR 71.43(g) for packages transported by exclusive-use vehicle.

3.8.5 Evaluation under normal conditions of transport

The staff has reviewed the package thermal design and concludes that the package material and component temperatures will not extend beyond the specified allowable limits during normal conditions of transport consistent with the tests specified in 10 CFR 71.71.

3.8.6 Evaluation under hypothetical accident conditions

The staff has reviewed the package thermal design and concludes that the package material and component temperatures will not exceed the specified allowable short time limits during hypothetical accident conditions consistent with the tests specified in 10 CFR 71.73.

3.9 References

1. U. S. Code of Federal Regulations, "Packaging and Transportation of Radioactive Material," Part 71, Title 10, "Energy."

2. U. S. Nuclear Regulatory Commission, "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel," NUREG-1617, March 2000.

3. U.S. Nuclear Regulatory Commission, Interim Staff Guidance No. 11, Revision 2, “Cladding Considerations for the Transportation and Storage of Spent Fuel,” July 30, 2002.

4. Safety Evaluation Report, Model No. HI-STAR 100 Cask System, Certificate of Compliance No. 9261, Revision 0.

4.0 CONTAINMENT

This section presents the results of the staff evaluation of the HI-STAR 100 containment design and analyses. The purpose of this review is to verify that the package design has been described and evaluated to satisfy the containment requirements of 10 CFR Part 71 (Ref. 1) under normal conditions of transport and hypothetical accident conditions.

Only those changes that have bearing on the containment evaluation are discussed in this section. The following proposed changes were considered for their impact on the containment evaluation.

Proposed Changes:

1. add the MPC-24E and MPC-24EF and the Trojan plant-specific MPC-24E/EF to the HI-STAR cask system and revise the basket configuration of the MPC-24. Authorize damaged fuel, fuel debris, non-fuel hardware, and neutron sources from the Trojan plant for the Trojan plant-specific MPC-24E/EF, and authorization for specific limits on cooling time, burnup, and decay heat of the SNF for transport in the generic MPC-24E/EF is requested;
2. delete item 6.a.(3)(i) and modify item (ii) of the same section in the Certificate of Compliance to clarify the requirements for overpack seal leak rate testing. Modify item 6.a.(3)(b) to establish a specific time frame defining “before each shipment.” Modify items 6.a(3)(b) and (c) to add the word “overpack;”
3. change the units of the leak test sensitivity from “std cm^3/sec” to “atm cm^3/sec;”
4. modify the helium backfill pressure requirements;
5. correct the specification for the leak test standard to read ANSI N14.5 and add the applicable edition;

6. change “MPC” and “overpack cavity” to “overpack annulus” in Sections (a) and (b) of the CoC; and
7. revise the phrase “inspection process including all findings (indications)” to read “inspection results, including all relevant indications.”

4.1 Description of the Containment System

4.1.1 Containment criteria

The allowable leakage rates presented in the SAR were determined in accordance with ANSI N14.5-1997 (Ref. 2) and will be used for the containment system fabrication verification tests of the HI-STAR 100 containment boundaries. Measured leakage rates are not to exceed the values in the following:

Design Attribute	Design Rating- Primary (Overpack) 10 CFR71.51	Design Rating Secondary (MPC) 10 CFR71.63(b)
Closure Plate Mechanical Seals: Design Temperature Pressure Rating Design Leakage Rate	 1200^0F 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	 1200^0F 1,000 psig $1x10^{-6}$ cm^3/s, Helium	N/A
Overpack Vent and Drain Port Plug Mechanical Seals: Design Temperature Pressure Rating Design Leakage Rate	 1200^0F 1,000 psig $1x10^{-6}$ cm^3/s, Helium	N/A
Leakage Rate Acceptance Criterion	$4.3x10^{-6}$ atm cm^3/s, Helium	$5.0x10^{-6}$ atm cm^3/s, Helium
Leakage Rate Test Sensitivity	$2.15x10^{-6}$ atm cm^3/s, Helium	$2.5x10^{-6}$ atm cm^3/s, Helium

Compliance with these leakage rates ensures that the radionuclide release rates specified in 10 CFR 71.51 and 10 CFR 71.63(b) will not be exceeded during normal or hypothetical conditions of transport.

4.1.2 Containment boundary

The applicant indicated the primary and secondary containment boundaries system components for the package are designed and fabricated in accordance with the requirements of ASME Code, Section III, Subsection NB (Ref. 3), to the maximum extent practicable. The applicant defined the primary containment system boundary for the package to be the overpack inner shell, the bottom plate, the top flange, the closure plate, closure bolts, the overpack vent and drain port plugs, and their respective mechanical seals. The applicant defined the secondary containment system boundary for the package containing BWR fuel debris in the MPC-68F or Trojan PWR fuel debris in the MPC-24EF to be the MPC enclosure vessel, which includes the MPC shell, the MPC bottom plate, the MPC lid, closure ring, and vent and drain port cover plates. The MPC-24EF and MPC-68F each provide the separate inner container per 10 CFR 71.63(b) for the HI-STAR 100 system transporting fuel classified as fuel debris. The applicant proposed an additional requirement imposed on MPC-24EF and MPC-68F for transporting fuel debris which calls for an additional leakage rate test on the MPCs prior to shipping.

The staff reviewed the description of the containment boundary and containment criteria and found it acceptable. The package containment design and criteria are described and evaluated to demonstrate that they meet the containment requirements of 10 CFR Part 71.

4.2 Compliance with Containment Criteria

The applicant performed containment calculations for the maximum release rates under normal and accident conditions and determined that the package meets the leakage requirements of 10 CFR 71.51. The applicant used the SAS2H and ORIGEN-S module of the SCALE 4.3 code (Ref. 4) to determine containment source terms. The source term inventory for the MPC-24, MPC-24E, and MPC -24EF were based on the B&W 15x15 fuel assembly with a burnup of 45,000 MWD/MTU, 5 years cooling time, and an enrichment of 3.64%. The inventory for the Trojan MPCs 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%.

Because the Trojan plant-specific MPC 24-E/EF are shorter baskets, the applicant assumed the annulus space to be the same as the larger MPC-24 for calculating the free volume for normal conditions. The applicant calculated a maximum release rate of 7.62×10^{-9} Ci/s as shown in Tables 4.2.6 and 4.2.7 in the SAR for normal conditions. For accident conditions, the applicant calculated a maximum release rate of 4.94×10^{-5} Ci/s. The applicant calculated the allowable leak rate for the package to be 8.94×10^{-6} atm cm^3/s in accordance with ANSI N14.5-1997 standards. The applicant also performed a representative calculation that showed the proposed leak test results in a sensitivity of at least 2.5×10^{-6} atm-cm^3/s.

Based on a review of the analyses, the staff has reasonable assurance that the applicant demonstrated the package meets the containment requirements of 10 CFR 71.51(a)(1) under normal conditions of transport and 10 CFR 71.51(a)(2) under hypothetical accident conditions. The containment analyses were similar to the containment analyses previously approved in the Amendment 1 to the CoC.

4.3 Leakage Rate Tests

The applicant stated that the seals and welds of the package containment system are securely closed and cannot be opened unintentionally or by an internal pressure within the package as required in 10 CFR 71.43. The secondary containment boundary system will be subject to the fabrication verification leakage testing as described in ANSI N14.5-1997. Prior to transporting an MPC containing fuel debris, the user will perform a periodic leakage test of the MPC secondary containment boundary.

Based on review of the proposed leakage test and associated containment calculations, the staff has reasonable assurance that the package can satisfy the testing requirements of ANSI N14.5-1997. The CoC is modified to reflect the required leakage tests in accordance with the analyses and ANSI N14.5-1997.

4.4 Evaluation Findings

Based on the review of the statements and representations in the application, the staff concludes that the containment design has been adequately described and evaluated and that the package design meets the containment requirements of 10 CFR Part 71.

4.5 References

1. U.S. Code of Federal Regulations, "Packaging and Transportation of Radioactive Material," Title 10, Part 71, January 1, 2003.

2. ANSI N14.5-1997. “American National Standard for Radioactive Materials Leakage Tests on Packages for Shipment.”

3. American Society of Mechanical Engineers (ASME), Boiler and Pressure Vessel Code, Section III, Division I, Subsection NB, Class 1 Components, 1995 Edition.

4. U.S. Nuclear Regulatory Commission, "SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation," NUREG/CR-0200, Vol. 1-5, Rev. 6, May, 2000.

5.0 SHIELDING

This section presents the results of the staff evaluation of the HI-STAR 100 shielding design and analyses. The purpose of this review is to verify that the package design has been described and evaluated to the shielding requirements of 10 CFR Part 71 (Ref. 1) under normal conditions of transport and hypothetical accident conditions.

Only those changes that have bearing on the shielding evaluation are discussed in this section. The following proposed changes were considered for their impact on the shielding evaluation.

Proposed Changes:

1. add the MPC-24E and MPC-24EF and the Trojan plant-specific MPC-24E/EF to the HI-

STAR cask system and revise the basket configuration of the MPC-24. Authorize damaged fuel, fuel debris, non-fuel hardware, and neutron sources from the Trojan plant for the Trojan plant-specific MPC-24E/EF and authorize specific limits on cooling time, burnup, and decay heat for the SNF for transport in the generic MPC-24E/EF,

2. revise the minimum cooling times, maximum burnups, and minimum enrichments for the MPC-24 and MPC-68 canisters,
3. authorize specific non-fuel hardware and neutron sources as listed in Appendix A to the CoC,
4. add fuel assembly array/class 7x7A to the CoC,
5. authorize Indian Point Unit 1 fuel assembly array/class 14x14E and include fuel assembly array/class 9x9G to represent the ANF-9X fuel assembly, and
6. modify item I.C. in Table A.1 of the CoC to refer to non-fuel hardware and neutron sources rather than control components, and add item "E" in Table A.1 to prohibit Trojan plant fuel from being transported in the generic MPC-24.

5.1 Description of the Shielding Design

5.1.1 Packaging design features

The applicant did not request significant changes to the HI-STAR 100 shielding design features in the SAR amendment, as currently approved in Revision 1 of the CoC. The HI-STAR 100 package is designed to transport different MPC designs in a single overpack design with impact limiters. Each MPC is identified by the maximum number of fuel assemblies that it is capable of accommodating. The MPC-24, -24E, and -24EF each can contain and transport up to 24 PWR assemblies, and the MPC-68 and -68F can each contain and transport up to 68 BWR fuel assemblies. The Trojan plant specific MPC-24E/EF is nine inches shorter than the generic MPC-24E/EF and requires a spacer when placed into the overpack. The Trojan MPC is properly placed in the bottom portion of the HI-STAR, and the spacer is placed between the top of the MPC and the underside of the lid.

The HI-STAR 100 system is also designed to transport fuel debris and damaged BWR fuel assemblies loaded into Damaged Fuel Containers (DFCs). The MPC-68 and MPC-68F can also transport Dresden Unit 1 antimony-beryllium neutron sources and the single Thoria rod canister which contains 18 thoria rods that were irradiated in two separate fuel assemblies. The Trojan MPC-24E/EF is analyzed for the inclusion of Trojan specific non-fuel hardware, damaged fuel, and Antimony-Beryllium and Californium neutron sources.

The steel structure from the MPC and overpack provide primary gamma shielding. Holtite-A is Holtec's neutron shielding material that serves to thermalize the neutrons and then capture them with embedded Boron-10 and hydrogen.

The staff reviewed the description of package design features related to the amendment request and found it acceptable. The design of the shielding features did not significantly change and have been previously approved in Amendment 1 to the CoC. The staff did not review nor approve changes related to the new MPC-32 canister that is discussed and analyzed in Chapter 5 of the SAR amendment.

5.1.2 Summary of table of shielding evaluations for normal operations

A summary of the shielding evaluation results is presented in Section 5 of the SAR. The applicant calculated dose rates for normal conditions of transport (NCT) for the new canisters and revised combinations of burnup, cooling time, and enrichment. The flux-to-dose conversion factors used in the dose calculations were taken from ANSI/ANS 6.1.1, 1977 (Ref. 2), which has been previously approved for the HI-STAR shielding calculations. The applicant determined that the calculated dose rates are less than the regulatory limits in 10 CFR 71.47. The highest dose rates calculated for surface normal, 2-meter normal, and 1-meter accident conditions are reported in Tables 5.1.1 - 5.1.15 of the SAR. For the non-fuel Trojan plant specific hardware, the dose rates were calculated and are reported in Tables 5.4.26 through 5.4.28 of the SAR at the package surface and 2 meters from the package under normal condition and at 1 meter from the package surface under accident conditions.

The applicant requested the HI-STAR 100 personnel barrier be qualified as a package in a closed vehicle in accordance with 10 CFR 71.47(b)(2), thereby allowing dose rates up to 1000 mrem/hr on the cask external surface. The exclusive use shipment requirements of 10 CFR 71.47 apply to shipments in which the dose rate on the external surface of the package during normal transport operations is between 200 mrem/hr and 1000 mrem/hr.

The staff reviewed the maximum dose rates for normal conditions of transport and determined the reported values were below the regulatory limit in 10 CFR 71.47. The shielding evaluation is consistent with the appropriate codes and standards for shielding analyses and NRC guidance. The staff determined the use of the personnel barrier to be acceptable for the MPC-24, MPC-68, MPC-24E/F, and Trojan-specific MPC.

5.1.3 Summary of table of shielding evaluations for hypothetical accident conditions

The applicant calculated dose rates for hypothetical accident conditions (HAC) for the new canisters and revised combinations of burnup, cooling time, and enrichment. Analyses for hypothetical accident conditions serve to demonstrate HI-STAR 100's compliance with 10 CFR 71.51. The HAC shielding analyses assumes that the neutron shield is not present and is replaced by void. For the damaged or MOX fuel accident, the shielding analyses assume that the fuel collapses and the pellets rest in the bottom of the fuel container. Section 5.4 of the SAR demonstrates that the damaged fuel post-accident dose rates are bounded by the BWR intact fuel post-accident dose rates. The applicant determined that the calculated accident dose rates are less than regulatory limits in 10 CFR 71.51. The calculated highest dose rates at one meter for accident conditions are reported in Section 5.1 of the SAR.

The staff reviewed the maximum dose rates for hypothetical accident conditions and determined the reported values were below the regulatory limit in 10 CFR 71.51.

5.2 Source Specification

The applicant calculated design-basis SNF source terms for the new and revised burnup and cooling times requested in the amendment. The applicant used a previously approved method to calculate the source terms. The total dose rates for all approved burnup and cooling times are reported in SAR Section 5.4., which includes a bounding analysis for the Dresden Unit 1

fuel assemblies containing antimony-beryllium neutron sources; the results of the Trojan contents in the MPC-24E/EF; and the gamma and neutron sources for the design basis intact stainless-steel clad fuels.

The applicant requested approval of certain non-fuel Trojan plant specific hardware in the Trojan MPC. This hardware includes RCCAs, BPRAs, and TPDs specific to the Trojan plant. SAS2H and ORIGEN-S were used to calculate a radiation source term for the BPRAs and TPDs. Table 5.2.37 shows the curies of Co-60 that were calculated in each region of the fuel assembly. RCCAs are used for many years before discharge to the spent fuel pools. The cladding is typically stainless steel or inconel. The absorber can be a single material or a combination of materials, typically AgInCd, B_4C, or hafnium. The applicant calculated design-basis Trojan neutron and non-fuel hardware source terms for the Trojan MPC configuration. The stainless-steel clad BPRAs create a significant radiation source (Co-60) while the zircaloy clad BPRAs create a negligible radiation source. TPDs are made of stainless steel and may contain a small amount of inconel, and there is a significant amount of Co-60 produced during irradiation. The source terms are described and listed in Chapter 5.2 of the SAR.

The analyses of the Trojan secondary antimony-beryllium neutron sources was performed in a similar manner. The secondary sources are basically BPRAs with four rods containing antimony-beryllium with a length of 88 inches in each rod. The antimony-beryllium source is a regenerative source in which the antimony is activated and the gammas released from the antimony induce a gamma, *n* reaction in the beryllium. The analysis of the dose rates for these sources is described in Section 5.4.8 of the SAR.

The staff reviewed the revised and new source term analyses of the SAR. Based on information provided in the SAR amendment, the staff has reasonable assurance that the source terms for the new and revised fuels are acceptable for the shielding analysis. The source term method used for SNF is similar to the method previously approved in Amendment No. 1 of the CoC. The staff notes that only Trojan specific hardware is authorized for the Trojan MPC and the generic PWR non-fuel hardware is not authorized.

5.3 Model Specification

5.3.1 Configuration of source and shielding

The applicant used MCNP to calculate bounding dose rates for the different configurations and fuel conditions. The applicant used similar MCNP models as previously approved in Amendment 1 of the CoC. However, the applicant revised the shielding geometry of the MPC-24 based on the revised design of the basket cells and modeled the new MPC-24E/F and Trojan plant-specific MPC with associated fuel.

The staff reviewed the configuration of source and shielding, and found it acceptable because the methods used are consistent with the accepted industry practice and standards. In addition, the configuration of source and shielding, and modeling techniques, are similar to the model specification and techniques previously approved in Revision 1 of the CoC.

5.3.2 Material properties

The composition and densities of the materials used in the shielding analysis are presented in Tables 5.2.1 through 5.2.45 of the SAR. As discussed in Chapter 8 of the SAR, the neutron shielding material's integrity must be confirmed through a combination of fabrication process control and radiation measurements before its first use. Periodic verification of the integrity must also be confirmed within 5 years of each shipment.

The applicant submitted a supplementary proprietary report which contained some of the actual MCNP input files that give more detailed information of the material properties and dimensions. Figures 5.3.1 through 5.3.12 of the SAR and design drawings in the revised CoC provide additional design details on all dimensions and materials. Specifications of important material properties of Holtite-A used in the shielding analyses are listed on Drawing No. 3913.

The staff reviewed the materials properties and found them acceptable. The materials and dimensions are consistent with the specifications previously approved in Revision 1 of the CoC, and the dose rates satisfy the limits of 10 CFR Part 72.

5.4 Evaluation Findings

Based on its review of the statements and representations provided in the application, including revisions and supplements, the staff has reasonable assurance that the changes to the package design and changes to contents satisfy the shielding and dose limits in 10 CFR Part 71. The staff does not approve changes related to the new MPC-32 canister that is discussed and analyzed in Chapter 5 of the SAR amendment.

5.5 References

1. U.S. Code of Federal Regulations, "Packaging and Transportation of Radioactive Material," Title 10, Part 71, January 1, 2003.

2. "American National Standard Neutron and Gamma-Ray Flux-to-Dose Rate Factors," ANSI/ANS-6.1.1-1977.

6.0 CRITICALITY

The following requested changes required an update of the criticality evaluation for the HI-STAR 100:

1. modify the dimensions and configuration of the MPC-24 basket,
2. add a generic MPC-24E and MPC-24EF basket for intact fuel assemblies with enrichment limits higher than those in the MPC-24,
3. add a special design MPC-24E and MPC-24EF basket for Trojan plant-specific fuel with authorization to transport intact fuel, damaged fuel, fuel debris, non-fuel hardware, and neutron sources from the Trojan plant,
4. add the 14x14E fuel type as authorized contents in the MPC-24,

5. modify the authorized fuel types as authorized contents in the MPC-68 to add the 7x7A (previously omitted by mistake), add a new 9x9G, and raise the enrichment of the 8x8F, and
6. provide an allowance for minor damage to the boron poison plates.

The applicant provided supporting analyses using a methodology which is fairly similar to the analyses previously reviewed by the staff for the HI-STAR 100 transportation package. The staff's criticality review and confirmatory analyses are based on the information provided in the consolidated Revision 10 of the SAR. The applicant's evaluation and the staff's confirmatory review of the requested changes are described below. Changes in the applicant's analysis methodology from that provided in the previously approved application are noted where applicable.

The applicant's original amendment submitted also requested the addition of the MPC-32 canister where the criticality safety analysis included a calculation of the change in fuel reactivity resulting from irradiation in a reactor (i.e., burnup credit). While preparing its response to staff's request for additional information (RAI) to support inclusion of the MPC-32, the applicant decided to submit the responses related to the MPC-32 at a later date. Therefore, this SER does not address the MPC-32 canister and none of the conclusions and review findings given in this section are intended to apply to the requested action regarding the MPC-32.

6.1 Description of Criticality Design

6.1.1 Packaging design features

The design continues to rely on the geometry of the fuel basket, the use of Boral neutron-absorbing panels, and fuel enrichment limits for criticality control.

In this request, the MPC-24 basket configuration was changed to have an alternating placement of the fuel cells instead of a regular array. For the MPC-24, the minimum flux trap width continues to be 1.09 inches, the minimum poison plate content remains at 0.0267 g $^{10}B/cm^2$, but the cell inner dimensions have been increased slightly to 8.92 inches square.

The generic MPC-24E/EF baskets use the same general fuel cell pattern of the MPC-24. Both baskets have 20 fuel cells for intact fuel with four additional cells in the outside corners that can hold intact fuel but these corner cells have been enlarged so they can also hold special cans containing fuel that is not fully intact (damaged in some way). The inside dimension of the intact-fuel cells is 8.75 inches square while the cells for non-intact fuel are 9.05 inches square inside. The flux traps between the intact-fuel cells have a minimum width of 1.076 inches and the flux traps between the intact-fuel cells and the non-intact-fuel cells have a minimum width of 0.776 inches. All poison plates in the basket have a minimum content of 0.0372 g $^{10}B/cm^2$. Authorization to transport damaged fuel and fuel debris in the generic design was not part of the current request (will be requested at a later date); and thus, was not reviewed.

The Trojan specific MPC-24E/EF baskets are the same as the generic MPC-24E/EF except for the following changes: (1) a larger internal dimension of 9.30 inches square for the four corner fuel cells which can hold containers of damaged fuel or fuel debris, (2) a smaller minimum flux

trap width of 0.526 inches between the intact-fuel cells and the cells which can contain non-intact fuel, and (3) a shorter basket length by about 9 inches. The applicant requested authorization to transport intact fuel, damaged fuel, fuel debris, non-fuel hardware, and neutron sources from the Trojan plant in the Trojan specific MPCs. Damaged fuel and fuel debris must be canned in the Holtec Damaged Fuel Container (DFC), shown in Holtec Drawing No. 4119, or the Sierra Nuclear-designed Trojan Failed Fuel Can (FFC), shown in SNC Drawing Nos. PFFC-001 and PFFC-002. While the baskets in the MPC-24E and MPC-24EF are the same, the upper portion of the canister wall in the MPC-24EF is thicker to provide the necessary performance as a containment boundary under the hypothetical accident conditions. Therefore, fuel debris can be transported only in the Trojan MPC-24EF.

The MPC-68 basket design was not changed.

Results of the structural and thermal analyses show that the packaging design features important to criticality safety are not adversely affected by the tests specified in 10 CFR 71.71 and 71.73 (Ref.1). The staff reviewed the description of the package design and found that the important features were appropriately identified and adequately described. The SAR drawings and other information are sufficient to permit an independent evaluation.

6.1.2 Codes and standards

The criticality evaluation is consistent with the appropriate codes and standards for criticality safety analyses, and NRC guidance (Ref. 2).

6.1.3 Summary of table of criticality evaluations

A summary of the criticality evaluation results is reported in Section 6.1 of the SAR. Numerous tables are presented which provide results for the MPC-24, generic MPC-24E/EF, Trojan MPC-24E/EF and MPC-68. The tables include results for a single package and arrays of undamaged and damaged packages including damaged fuel and fuel debris being transported in the Trojan MPC-24E/EF.

The results show that the package meets the requirements of 10 CFR Part 71 (Ref. 1) for criticality safety. All values of k_{eff}, after being adjusted for uncertainty and biases, fall below the acceptance limit of 0.95 given in the Standard Review Plan (SRP) (Ref. 3).

6.1.4 Transport index (transport index for criticality)

The applicant's analyses considered an infinite array of packages under both normal conditions of transport and hypothetical accident conditions. Therefore, the Transport Index based on nuclear criticality safety continues to be 0 for the package. Condition No. 5(c) of the certificate was revised to clarify that the Transport Index for criticality control is the same as the Criticality Safety Index as defined in the International Atomic Energy Agency Regulations for the Safe Transport of Radioactive Material (TS-R-1).

6.2 Spent Nuclear Fuel Contents

The applicant requested the following changes to the contents authorized for transport in the HI-STAR 100:

1. addition of the 14x14E fuel type in the MPC-24,
2. addition of the generic MPC-24E/EF containing intact fuel of the assembly types 14x14A, 14x14B, 14x14C, 14x14D, 14x14E, 15x15A, 15x15B, 15x15C, 15x15D, 15x15E, 15x15F, 15x15G, 15x15H, 16x16A, 17x17A, 17x17B, and 17x17C,
3. addition of the Trojan MPC-24E/EF containing Trojan plant-specific fuel of the 17x17B type (maximum enrichment of 3.7% ^{235}U) as intact fuel, damaged fuel and fuel debris (MPC-24EF only), and non-fuel hardware and neutron sources from the Trojan plant,
4. addition of the 7x7A and 9x9G fuel types in the MPC-68, and
5. increase of the initial enrichment of the 8x8F fuel type to 4% in the MPC-68.

The damaged fuel and fuel debris from the Trojan plant must be canned in a Holtec-designed DFC or Sierra Nuclear-designed Trojan FFC.

During the review, staff questioned the fact that the fuel specifications have only a maximum limit on the fuel pellet outer diameter. A reduced pellet diameter coupled with flooding of the pellet-to-clad gap could cause k_{eff} to increase for some fuel designs. The applicant argued that if the pellet diameter were to decrease, the diameter of the cladding is expected to decrease also because a survey of pellet-to-cladding gaps has shown that this gap size varies only slightly among fuel types. Therefore, a smaller pellet diameter is expected to be accompanied by a smaller inside diameter for the cladding. Staff notes that a minimum value is specified for the outer diameter of the cladding, and thus, the cladding thickness would typically increase with decreasing pellet diameter or the fuel would no longer meet the minimum limit on the outer cladding diameter and could not be transported. It is expected that this increase in cladding thickness would provide sufficient moderator displacement to maintain adequate criticality control. Therefore, based on risk informed considerations, staff accepts the applicant's argument and concludes that the proposed combination of parameter specifications for the fuel will provide a reasonable assurance of criticality safety.

6.3 General Considerations for Criticality Evaluations

6.3.1 Model configuration

The applicant used the same general assumptions and modeling methods as previously reviewed for intact fuel, damaged fuel, and fuel debris. Notable changes are: (1) remodeling of the MPC-24 to reflect the change in basket design, (2) adding cases where the fuel assemblies are shifted toward the center and the periphery of the canister when analyzing the effect of eccentric positioning of the fuel in the basket cells, (3) adding a fuel debris case for the Trojan MPC-24E/EF that considered bare fragments of fuel, (4) modeling all of the basket's peripheral poison plates as 6.25 inches wide even though just 16 of the 24 poison plates on the periphery of the MPC-24 are 6.25 inches wide as opposed to 7.5 inches, and (5) simulating fabrication damage to the poison plates of a hole up to 1-inch diameter in the center or up to 5 square inches of damage around the periphery of the poison plates in the MPC-24E/EF.

In order to provide a limiting configuration that covers both normal conditions of transport and the hypothetical accident conditions, the applicant modeled the package without the external neutron shield in place. Also, because the MPC-24E and MPC-24EF baskets are identical, duplicate calculations were not provided for each basket.

An analysis of transporting damaged fuel and fuel debris (collectively called failed fuel) in the Trojan MPC-24E/EF was added to Section 6.4 of the SAR. Failed fuel must be placed inside the DFC or FFC which is then placed in one of the four corner positions of the basket. The applicant performed an analysis to identify the most reactive intact fuel type and modeled this fuel in the other 20 positions in the basket. The failed fuel was modeled in the poison plate axial region of the basket based on an evaluation by the applicant which showed a negligible increase in reactivity if the failed fuel were to shift above the poison plates in the four corners of the basket. As a bounding analysis, the applicant modeled the failed fuel as a regular array of bare fuel rods without any cladding or other assembly structural material. The amount of fuel per unit length was varied over a wide range by changing the number of rods in the array and the rod pitch. The applicant also analyzed variations in the failed fuel pellet diameters for minimum, maximum, and typical values. To show that the failed fuel analysis is bounding, the applicant compared those results with the results for sample cases where the failed fuel was replaced with all intact assemblies, assemblies with missing fuel rods, and collapsed assemblies. In the response to the RAIs, the applicant also provided an analysis which modeled the fuel debris as an array of bare fuel cubes where the size and pitch of the cubes was varied to maximize k_{eff}. In all cases, k_{eff} remained below the acceptance limit of 0.95.

6.3.2 Material properties

The material properties remained the same as before except for the higher boron areal density in the poison plates in the MPC-24E/EF (generic and Trojan).

6.3.3 Computer codes and cross section libraries

The applicant used the three-dimensional continuous energy code Monte Carlo N-Particle (MCNP4a) for the criticality analysis. In addition, selected results using the KENOV.a multigroup Monte Carlo code with 238-group cross-sections developed at the Oak Ridge National Laboratory (Ref. 4) were reported as an independent check.

The staff agrees that the codes and cross-section sets used in the analysis are appropriate for this application and fuel system.

6.3.4 Demonstration of maximum reactivity

The applicant varied the fuel and packaging parameters over their possible ranges to determine those values which maximized the value of k_{eff} using the method described in a previous SER except for the changes noted in Section 6.3.1 above. This search for the maximizing parameters included an evaluation of: (1) the optimum dimensions within manufacturing tolerances, (2) the optimum cask internal and external moderation, (3) partial and preferential flooding of the canister, (4) eccentric positioning of the fuel assemblies in their cells, (5) single packages versus arrays, (6) reflection versus no reflection for the single package, (7) flooding of the pellet-to-clad gap, (8) different package spacing in an array, (9) internal cask temperature

sensitivity, and (10) the optimum fuel parameters within a fuel type except as discussed in Section 6.2 above.

Staff found the methods used to identify the parameters values which maximize k_{eff} to be appropriate and found the set of parameters used in the analysis to be acceptable.

6.3.5 Confirmatory analyses

The staff used the CSAS/KENO-Va code in the SCALE suite of analytical codes to perform confirmatory analyses. These calculations used the 44-group cross-section set in SCALE. The CSAS/KENO code was developed by the Oak Ridge National Laboratory for performing criticality analyses and is appropriate for this particular application and fuel system.

The staff's calculational model of the packaging used the information provided in the SAR drawings combined with supplemental information in Chapter 6 of the SAR. Fuel parameter values were taken from the tables in Section 6.2 of the SAR. Staff performed calculations of selected fuel types in the MPC-24, generic MPC-24E/EF, Trojan MPC-24E/EF (with 24 intact fuel assemblies, as well as 20 intact and 4 damaged fuel assemblies), and MPC-68 canisters.

The results of the applicant's calculations are within acceptable agreement with the staff's results for the corresponding canister and fuel type. Staff's results were all below the acceptance limit.

6.4 Single Package Evaluation

The applicant performed calculations for the MPC-24 and MPC-68 which show that both the flux trap and non-flux trap designs are more reactive when internally flooded with full density water versus partial flooding or flooding with lower density water. Thus, a fully flooded package was used in the subsequent package analyses. The applicant then performed a series of calculations for single packages containing the MPC-24, generic MPC-24E/EF, Trojan MPC-24E/EF, MPC-68, and MPC-68F canisters and for each case of an unreflected package, full reflection by water, and full reflection of the containment only. No statistical difference was found between these cases for each canister type. Therefore, most of the subsequent single package calculations were performed on a single unreflected package with full internal moderation in lieu of a reflected package. All of the applicant's results were below the acceptance level of 0.95 for k_{eff}.

6.5 Evaluation of Package Arrays Under Normal Conditions of Transport

The applicant performed calculations for an infinite array of undamaged packages containing the MPC-24, generic MPC-24E/EF, Trojan MPC-24E/EF, MPC-68, and MPC-68F and found values of k_{eff}, as adjusted, which were 0.3950, 0.4026, 0.3518, 0.3808, and 0.3034, respectively. In these calculations, the packages were internally dry and had no moderator between packages. All of the applicant's results are below the acceptance level of 0.95 for k_{eff}.

6.6 Evaluation of Package Arrays Under Hypothetical Accident Conditions

The applicant performed calculations for an infinite array of damaged packages containing the MPC-24, generic MPC-24E/EF, Trojan MPC-24E/EF, MPC-68, and MPC-68F with the limiting case of full internal moderation as found for the single package. The applicant found the damaged array results to be statistically equivalent to the results for the corresponding single package cases discussed in Section 6.4 above.

Because of its finding of statistical equivalency, the applicant provided results from a combination of calculations for fully flooded single packages and infinite arrays of damaged packages. All of the applicant's results are well below the acceptance level of 0.95 for k_{eff}.

6.7 Benchmark Evaluations

The applicant's benchmarking procedures and methods have not changed and staff's evaluation is provided in a previous SER.

6.8 Burnup Credit

Burnup credit is not included in any of the evaluations for the amendments addressed in this SER.

6.9 Evaluation Findings

Based on its review of the presentations and information supplied by the applicant, and the analyses performed by the staff, the staff finds reasonable assurance that the proposed amendments meet the criticality safety requirements of 10 CFR Part 71.

6.10 References

1. U.S. Code of Federal Regulations, "Packaging and Transportation of Radioactive Material," Title 10, Part 71, January 1, 2003.

2. U.S. Nuclear Regulatory Commission, "Recommendations for Preparing the Criticality Safety Evaluation of Transportation Packages," NUREG/CR-5661, April, 1997.

3. U.S. Nuclear Regulatory Commission, "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel," NUREG-1617, March, 2000.

4. U.S. Nuclear Regulatory Commission, "SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation," NUREG/CR-0200, Vol. 1-5, Rev. 6, May, 2000.

7.0 OPERATING PROCEDURES

The applicant has requested the following major changes with respect to the operating procedure:

1. making the bottom trunnions optional, providing an upending/downending frame, and providing a modified method of securing the HI-STAR 100 overpack to the transport vehicle,
2. including hydrogen gas generation monitoring as part of loading and unloading operation, and
3. replacing Vaccum Drying System (VDS) with Forced Helium Dehydrator (FHD) system during drying operations of an MPC for “load-and-go.”

Other minor changes have been made to the text in Chapter 7 of the SAR in order to provide further clarifications

7.1 Package Loading

All three major changes listed above impact the loading operation of the HI-STAR 100 transport package. The use of upending/downending frame, instead of the bottom trunnions, provides additional protection and flexibility in handling and pivoting the package during loading and unloading operations. The staff believes the use of upending/downending frame does not have any adverse impact on the HI-STAR 100 transport package operability.

As part of the modified method for securing the package to the transport, a saddle and three straps, instead of the pocket trunnion and a shear ring, are used. As evaluated in Section 2.2.3, the new system of tie-downs meet the structural requirement of 10 CFR Part 71 and does not have any adverse impact on the operability of the package.

With respect to hydrogen gas generation, Holtec’s operational experience with the MPC revealed that the cask interior may produce some hydrogen during the loading or unloading process when the MPC is full of water. The applicant previously stated that no hydrogen would be generated during the wet phases of the loading or unloading operations. When the error in this assertion was discovered, the applicant changed the storage cask design, under the provisions of 72.48, to require monitoring or mitigation of hydrogen during the wet phases of the operations. As part of the overall license amendment review for the transport package design, the staff reviewed the hydrogen mitigation operating procedures. The staff finds the procedures to be adequate and has added a new condition to the CoC to address this issue.

Adoption of the staff guidance for a 400 °C temperature limit for all cladding types during loading created a need for a revised drying method. This is to avoid the frequently observed temperature excursion above 400 °C that may result from the use of vacuum drying. In place of a Vacuum Drying System, the applicant proposed a Forced Helium Dehydrator system that would maintain the peak cladding temperature below the allowable limit. The new drying method involves the use of a forced helium flow through the MPC after the bulk de-watering step. The helium exiting the cask is tested for moisture content. Acceptance criteria are specified to ensure that any residual moisture meets the requirements for storage and transport. The staff finds the proposed forced drying process to be acceptable.

7.2 Package Unloading

The use of upending/downending frame and monitoring the hydrogen gas generation also pertain to the unloading operation. The staff considered these changes during its evaluation for

unloading as well, and approves these changes for unloading operation.

Furthermore, the applicant has added to the SAR, the need for fuel assembly cool-down during unloading if the helium gas inside the MPC exceeds 200°F. As indicated in Section 3.4.1.1.15 of the SAR, the helium gas temperature below 200°F is an indication of clad temperature that would not create the risk of boiling, when water is injected into the MPC, and the associated thermal stresses, flashing, or over pressurization during unloading operation. The staff agrees with the temperature limit criterion for the purpose of cooling down the HI-STAR 100 transport package as part of the unloading operation.

7.3 Preparation of Empty Package for Transport

The only significant change made in the SAR with respect to the preparation of the empty HI-STAR 100 transport package is revising the procedure in order to reflect use of the modified tie-down system instead of the pocket trunnions. In addition, the applicant has deleted the specific contamination limits cited in the procedure, and has substituted them with citations from the relevant sections of 49 CFR Part 173. The staff finds these changes acceptable and believes the package performance requirements in 10 CFR Part 71 are met.

7.4 Preparation of Loaded Package for Transport Following a Period of Storage

No significant changes have been made to this part of the SAR. However, the applicant has added that 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" of the SAR. The procedure outlined in Section 7.4 of the SAR which describes the procedure for preparing the loaded HI-STAR 100 package for transport following a period storage is acceptable to the staff.

7.5 Evaluation Findings

Based on the information regarding the requested changes supplied by the applicant, with respect to HI-STAR 100 package loading, unloading, and its preparation for shipment after loading, emptying, or following a period of storage, the staff finds the changes acceptable in accordance with the requirements of 10 CFR Part 71.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

The applicant requested some changes to the acceptance tests. These changes are discussed in the following section. No major changes to the maintenance program is requested by the applicant.

8.1 Acceptance Tests

The applicant requested the following major changes with respect to acceptance tests:

1. allowing the option for choosing other relief devices, in addition to the rupture disks, for pressure testing of the neutron shield enclosure vessel,
2. removing the requirement for nonconformance report in the case of the package failing

any of the acceptance tests, and

3. allowing the use of pneumatic method as a second option for pressure testing the MPC.

The “rupture disks” are replaced with “relief devices” in order to provide a flexibility with respect to choosing other appropriately engineered relief devices if desired. The relief device are installed in the upper edge surface of the neutron shield enclosure vessel of the HI-STAR overpack. The 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). The staff finds this change acceptable with respect to 10 CFR Part 71 requirements.

The applicant has revised Section 8.1 of the SAR throughout to remove the notes requiring a nonconformance report to be issued if certain acceptance tests are not completed successfully. The applicant has indicated that such issues are governed by the Holtec or licensee corrective action program. The staff agrees with the applicant provided proper documentations are provided as required by 10 CFR 71.131.

In addition to the hydrostatic pressure test for the MPC, which is used as a secondary containment barrier when transporting fuel debris, the applicant has requested for the flexibility to use a pneumatic pressure test. If pneumatic testing is used, the MPC shall be pressure tested to 120 psig. Under the provisions of the ASME Code, a fabricator may employ either a hydrostatic (water) or pneumatic pressure test as part of the fabrication and testing requirements. Presently, the applicant is using a hydrostatic test. As an aide to the fabrication process, the applicant has chosen to exercise the Code-specified option of using a pressurized air (pneumatic) test instead. Since the staff recommends the use of the ASME Code for fabrication, the staff finds this change acceptable with respect to the 10 CFR Part 71 requirements.

8.2 Maintenance Program

No significant changes have been requested with respect to the maintenance program.

8.3 Evaluation Findings

Based on the information regarding the applicant’s requested changes with respect to HI-STAR 100 package acceptance tests and maintenance program, the staff finds the proposed changes acceptable in accordance with the requirements of 10 CFR Part 71.

CONCLUSION

The staff has reviewed the requested amendment to Certificate of Compliance No. 9261. Based on the statements and representations in the application, as supplemented, and revision 10 of the SAR, the staff concludes that the requested changes do not affect the ability of the package to meet the requirements of 10 CFR Part 71. Certificate of Compliance No. 9261 for the HI-STAR 100 transport package has been amended as requested by Holtec International.

Issued with Certificate of Compliance No. 9261, Revision No. 2,
on September 24, 2003 .