UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

October 16, 2018

Mr. Royston Ngwayah
Licensing Engineer
Holtec International
1 Holtec Blvd
Camden, NJ 08104

SUBJECT: CERTIFICATE OF COMPLIANCE NO. 9261, REVISION NO. 10, FOR THE MODEL NO. HI-STAR 100 PACKAGE

Dear Mr. Ngwayah:

As requested by your amendment request dated January 29, 2016, as supplemented on August 22, 2016, May 1 and July 11, 2017, January 17 and June 22, 2018, enclosed is the Certificate of Compliance No. 9261, Revision No. 10, for the Model No. HI-STAR 100 package. Changes made to the enclosed certificate are indicated by vertical lines in the margin. The staff's safety evaluation report is also enclosed.

The approval constitutes authority to use the package for shipment of radioactive material and for the package to be shipped in accordance with the provisions of Title 49 of the *Code of Federal Regulations* 49 (CFR) 173.471. If you have any questions regarding this certificate, please contact Pierre Saverot of my staff at (301) 415-7505.

Sincerely,

/RA/

John McKirgan, Chief
Spent Fuel Licensing Branch
Division of Spent Fuel Management
Office of Nuclear Material Safety
and Safeguards

Docket No. 71-9261
EPID No.L-2017-LLA-0007 (Previously CAC No. L25080)

Enclosures:
1. Certificate of Compliance No. 9261, Rev. No. 10
2. Safety Evaluation Report
3. Registered Users

Upon removal of Enclosure 3, this document is uncontrolled.

cc w/encls 1 & 2: R. Boyle, Department of Transportation
J. Shuler, Department of Energy, c/o L. Gelder
Registered Users

SUBJECT: CERTIFICATE OF COMPLIANCE NO. 9261, REVISION NO. 10, FOR THE MODEL NO. HI-STAR 100 PACKAGE DOCUMENT DATE: <u>October 16, 2018</u>

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OFC:	SFM E	SFM E	SFM	SFM	SFM	SFM
NAME:	PSaverot	JWise	ARigato	CHrabal	JBorowski	ZLi
DATE:	11/6/2017	08/06/2018	12/19/2017	08/18/2016	02/07/2018	02/06/2018
OFC:	SFM E	SFM E	SFM	SFM	SFM	SFM
NAME:	JSolis	MRahimi	TTate	YDiaz-Sanabria	SFigueroa	JMcKirgan
DATE:	09/19/2017	08/06/2018	10/01/2018	02/07/2018	10/15/2018	10/16/2018

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SAFETY EVALUATION REPORT
Docket No. 71-9261
Model No. HI-STAR 100
Certificate of Compliance No. 9261
Revision No. 10

SUMMARY

By letter dated January 29, 2016, Holtec International (Holtec) submitted an amendment request for the Model No. HI-STAR 100 Transportation Package to add (i) an MPC-32 designed for the Diablo Canyon spent fuel, and (ii) a HI-STAR 100 Version Humboldt Bay for BWR fuel and Greater than Class C waste. Licensing drawings were also updated with various proposed design changes.

Staff issued a first request for additional information (RAI) letter dated May 18, 2016. Holtec provided RAI responses on August 22, 2016. By letter dated February 7, 2017, staff documented a second request for additional information to which the applicant responded on May 1, 2017. The applicant revised its criticality RAI responses and submitted, on July 10, 2017, new criticality calculations, including the Holtec report HI-2156611 “Burnup Credit for the MPC-32 with MCNP5 and CASMO5”.

By letter dated February 22, 2018, Holtec advised staff that modifications had to be done to ensure the transportability of the Humboldt Bay GTCC waste canister (GWC-HB). Holtec provided the necessary information and structural calculations on June 22, 2018, along with a position paper “Acceptable Flaw Size for MPC Transportability Inspection.” Holtec also submitted a revised application “Safety Analysis Report on the HI-STAR 100 Cask System”, Holtec report HI-951251, Revision No. 18, now referenced in Revision No. 10 of the certificate of compliance.

NRC staff reviewed the applicant’s successive requests and found that the package meets the requirements of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 71.

1.0 GENERAL INFORMATION

The Model No. HI-STAR 100 package is a canister based spent fuel transportation system with a design that relies on the geometry of the fuel basket, fuel enrichment limits, and poison plates for criticality safety, with burnup credit being also implemented for criticality safety of the package with certain PWR fuel canisters.

This amendment request seeks approval of variants of the HI-STAR 100 model: the HI-STAR version Humboldt Bay (HB) package with the MPC-HB for BWR spent fuel, the version HB GTCC for Greater-Than-Class C waste, and the HI-STAR 100 loaded with the Diablo Canyon (DC) MPC-32 for moderate burnup PWR spent fuel.

The HI-STAR 100 HB GTCC utilizes a new overpack design that is nearly identical to the HI-STAR 100 except that it is shorter in height, weighs less, and does not serve as the primary containment boundary. The licensing drawings provide tolerances for components; the GWC-HB canister, inserted into the GTCC overpack, is a new design and acts as primary containment boundary.

The GWC generic canister is similar to the generic MPC used in the HI-STAR 100 and HI-STAR 100 HB, but is shorter when compared to the currently approved MPCs. This amendment also requested the use of impact material (honeycomb blocks) characterized by one set of material properties versus the original four sets of properties, to lower fabrication costs.

The Diablo Canyon MPC-32 canister is shorter than the generic MPC-32, employs a spacer ring, has a thicker bottom plate, and a thicker inner shell. The applicant provided licensing drawings for the MPC-32 Diablo Canyon Enclosure Vessel Drawing 4459, Sheets 1-6, Rev. 14 and Diablo Canyon MPC-32 Fuel Basket Drawing 4458, Sheets 1-3, Rev. 11. The Diablo Canyon MPC-32 canister can accommodate 32 undamaged PWR fuel assemblies (with a burnup less than or equal to 45 GWD/MTU) with non-fuel hardware and neutron sources. The spent fuel cladding type, assembly average burnup, and enrichment of the Diablo Canyon MPC-32 contents are bounded by the spent fuel contents previously approved for transport in the generic MPC-32. The applicant added new drawings for the proposed HB and DC packages and made several editorial changes to the existing design drawings of the Model No. HI-STAR 100 package.

The GWC-HB canister contains solid activated metals (e.g., reactor internals) and process wastes (spent fuel pool cleanup material) that are confined in a "not-important-to-safety" process waste canister. The process wastes, thermally processed to remove organics and other hydrogen-bearing compounds that could create flammable gases, are loaded into the waste canister, which is vacuum-dried, helium-backfilled, sealed, and leak-tested. The applicant stated that the thermal processing reduces the potential for hydrogen gas concentration within the waste canister to less than 5 percent by volume.

The applicant requested to change the thoria rod material composition from 98.2 to 98.5 wt% ThO_2 and UO_2 from 1.8 wt% to 1.5 wt% with a 93.5 wt% U^{235} enrichment for packages that ship the MPC-68 or MPC-68F containing the thoria rods. The applicant also requested to be able to use one of the two burnup verification methods for the MPC-32 spent fuel, i.e., (1) burnup verification through quantitative burnup measurement or (2) burnup verification through an administrative procedure and qualitative measurements. The first method relies on actual measurement of fuel burnup for every fuel assemblies to be loaded into the basket and the second method relies on a positive verification of the fuel inventory in the pool and reactor operating history data.

The staff concludes that the information presented in this section of the application provides an adequate basis for the evaluation of the Model No. HI-STAR 100 package against 10 CFR Part 71 requirements for each technical discipline.

2.0 STRUCTURAL AND MATERIALS EVALUATIONS

2.1 Structural Evaluation

2.1.1 Lifting and Tie-Down Standards

Revision 9 of the Model No. HI-STAR 100 package system examined the lifting trunnions for the package focusing on both the 1/3rd yield criteria to satisfy 10 CFR Part 71.45 and 1/10th of ultimate strength as per NUREG 0612 *Control of Heavy Loads at Nuclear Power Plants* for storage applications, rather than the typically more stringent NUREG 0612 criteria alone. For this amendment request, i.e., Revision No. 10 of the certificate, the applicant did not make any changes to the design of the trunnions, but did re-examine the lifting analysis taking into account the requirements of 10 CFR Part 71.45 only, since the 1/10th of ultimate strength is not a regulatory requirement. Specifically, the package was re-examined assuming that a safety factor of three against yielding must be satisfied, rather than using the factor of six in the previous amendment request. As a result, the trunnion safety factors for lifting have doubled to a minimum value of 2.83, with an effective safety factor of 8.49 vs yielding.

Because the previously approved trunnion design is unmodified and, when compared to the current lifting criteria in 10 CFR Part 71, the resultant safety factors are greater than one, the staff agrees that the lifting requirements in 10 CFR 71.45(a) will continue to be maintained for the package and will be continued to be maintained with respect to the tests and conditions in 10 CFR 71.45(a).

The applicant removed superfluous calculations related to tie-downs in Sections 2.5.2.2 to 2.5.2.6 of the application which remained as artifacts from previous amendment requests. No part of the package is directly tied-down, as shown in Figure 1.2.8 of the application: thus, no analysis under 10 CFR Part 71.45(b) is necessary.

2.1.2 HI-STAR 100 Overpack Pressure Changes

The applicant revised the overpack calculations originally performed, assuming an internal pressure of 30 psi, to accommodate an increased pressure of 45 psi. The applicant stated that the pressure increase is the result of off-gassing from the neutron shield material combined with a reduced external pressure. Specifically, the applicant examined the ½" shell and the welds used to encase the neutron absorber material, as depicted in Licensing Drawing 3913 on the exterior of the overpack. The applicant determined the minimum safety factor to be 4.88 as tabulated in Section 2.6.1.3.2.5 of the application (also found in calculation supplement No. 32) which bounds both normal conditions of transport (NCT) and hypothetical accident conditions (HAC).

The applicant determined the minimum safety factor for the annular plate welds and gamma shell weld to be 1.57 at a minimum. NRC staff did not agree with the applicant's choice of some of the geometric parameters used in the analysis of these welds and had reservations on how the pressure was incorporated into the calculations, as presented in the application; however, an independent evaluation of these welds confirmed that safety factors are still greater than one.

As a result of calculated safety factors being greater than one, the staff agrees that the enclosure (outer) shell of the HI-STAR 100 package will continue to perform satisfactorily when subjected to the tests and conditions in 10 CFR Part 71.71 and 10 CFR 71.73.

2.1.3 HI-STAR 100 Overpack Closure Bolts and Flange

The applicant re-examined a portion of the analyses of the overpack closure bolts using the criteria provided in NUREG CR-6007 *Stress Analysis of Closure Bolts for Shipping Casks* along with a revised finite element analysis completed by the applicant using the ANSYS analysis software correcting for new pressure inputs. The additional analysis performed in ANSYS was to better estimate shear loads. The applicant examined combined tension, shear, torsion and bending of the bolts and flange as described in calculation supplement No. 31 and determined that the minimum safety factor for the enclosure bolts for NCT (load case 1 of Table 2.6.4) to be 1.57, while the flange itself had a safety factor of 1.13. For HAC (load cases 1, 2, 3 of Table 2.7.3 of the application), the applicant determined that the enclosure bolts had a minimum safety factor of 1.05, which occurred during the HAC fire scenario.

2.1.4 HI-STAR 100 Overpack Closure Bolts and Impact Limiter Closure Bolt Fatigue Analysis

With regards to fatigue of the overpack closure bolts, the applicant re-calculated the number of cycles that the overpack closure bolts could be torqued due to use of the package as described in Section 2.6.1.3.3 of the application, with supporting calculations in supplement No. 31B. The methodology is unchanged; yet, supporting calculations were revised since the applicant relied on bolt stresses observed due to NCT. As a result, the applicant determined that the overpack closure bolts may be torqued a total of 339 times with the bolts not observing more than 80ksi.

Impact limiter bolts were evaluated in essentially the same fashion as the overpack closure bolts. Torqueing loads on these bolts are very small when compared to those on the overpack closure bolts and, as a result, the number of cycles that the bolts may experience prior to needing to be replaced due to torqueing alone was determined by the applicant to be more than 78,000 cycles, assuming a conservative 10g acceleration loading, where the top impact limiter bolts (rather than the bottom set of impact limiter bolts) where found to be the limiting case assuming a conservative stress concentration factor of 4.

Since the applicant revised existing calculations for fatigue in the overpack closure bolts and impact limiter bolts, the staff agrees that the bolts analyzed for the Model No. HI-STAR 100 package will continue to perform satisfactorily when subjected to the tests and conditions in 10 CFR 71.71.

2.1.5 Lifting Standards for the Multi-Purpose Canister (MPC)

The applicant re-examined the lifting analysis for the MPC, and specifically for both 1/3rd yield criteria to satisfy 10 CFR 71.45 and 1/10th of ultimate strength as per NUREG 0612 for storage applications, rather than the typically more stringent NUREG 0612 criteria alone. The material properties assumed by the applicant were based on the lid material at 475°F. The applicant examined combined shear and tension, appropriate thread length of the bolts, and shear failure of the bolt threads. The applicant determined that the minimum safety factor for the lid is 1.67 for the allowable thread shear stress.

Since the previously approved design is unmodified, and because, when compared to the 10 CFR Part 71 lifting criteria, the resultant safety factors are greater than one, the staff agrees that lifting standards for the Model No. HI-STAR 100 package will continue to be maintained with respect to the tests and conditions in 10 CFR 71.45(a).

2.1.6 Impact Limiter Modifications

Both the Model Nos. HI-STAR 100 HB and HI-STAR 100 HB GTCC packages use the same impact limiter. The applicant requested the use of impact material (honeycomb blocks) characterized by one set of material properties versus the original four sets of properties, to lower fabrication costs. The applicant calculated the effect of having one consistent honeycomb material and demonstrated that uniform honeycomb material, with an allowable crush strength of between 800-1100 psi, would impart a maximum of 57.5g for the evaluation of the 9 meter drop test in 10 CFR 71.73, which is bounded by the previously calculated g-load of 60g.

The staff agrees that the proposed impact limiter material modification will support package performance with respect to the tests and conditions in 10 CFR 71.71 and 71.73.

2.1.7 Changes Related to MPC Models 24, 24E, 24EF, 32, 68, and 68F

The applicant modified the optional, 5" diameter, 5/8" deep drain in the base plate of the MPCs to be free of shape restriction (such as a circular shape), while maintaining its current depth of 5/8" as shown on sheet 2 of licensing drawing 3923. The applicant stated that this modification would have no adverse effect on the package as the base plate was originally analyzed as being only as thick as its thinnest section (where the 5/8" thick cutout is located).

NRC staff agrees that the thinnest section already bounds the bottom plate analysis. The staff noted that the applicant modified the analysis related to the secondary containment, but this was not reviewed as part of 10 CFR 71.63(b) since this regulation no longer exists.

Therefore, the staff agrees that MPC models 24, 24E, 24EF, 32, 68, and 68F will continue to meet the requirements of 10 CFR 71 with regards to the proposed modification.

2.1.8 Changes Related to MPC Models 24, 24E, 24EF, 32, 68, 68F, and MPC-HB

The applicant revised the existing internal pressure calculations assuming a 225 psig internal pressure rather than 200 psig for all MPC canisters for the HAC fire scenario. The applicant's revised calculations showed that the minimum safety factor was 1.05 as a result of bending at the baseplate of the MPC.

Since updated calculations still support a safety factor greater than unity, the staff agrees that the increased internal pressure of the MPCs will not adversely affect the HI-STAR 100 system's ability to meet the requirements of 10 CFR Part 71.73.

2.1.9 Partially Loaded MPCs Used in Conjunction with the HI-STAR 100

The applicant described how the structural performance of partially loaded MPCs (50% capacity or more, all MPC types) will not diminish the performance of the package. Specifically, the applicant indicated that the overall weight of the package is less (and therefore would result in less impact energy for the NCT and HAC test in 10 CFR Part 71.71 and 71.73), while maintaining the original center of gravity. Given a lower mass, and a negligible potential change in the center of gravity, the fully loaded, previously approved HI-STAR 100 MPCs will bound the deceleration rates of the partially loaded MPCs.

Since deceleration forces are lower due to the reduction in the number of fuel assemblies in the MPCs and impact forces are not appreciably redirected by changes in the package's center of gravity, the staff agrees that the partially loaded MPCs will not adversely affect the ability of the HI-STAR 100 system to perform satisfactorily when subjected to the tests and conditions found in 10 CFR Part 71.71 and 71.73.

2.1.10 HI-STAR 100 HB GTCC Package with GWC-HB Canister

The HI-STAR 100 HB GTCC utilizes a new overpack design that is nearly identical to the HI-STAR 100 except that it is shorter in height, weighs less, and does not serve as the primary containment boundary. The licensing drawings provide tolerances for components that are key to licensing, while weights for package components are clearly denoted in the application. The GWC-HB canister, inserted into the GTCC overpack, is new to this amendment request and acts as a primary containment boundary. The GWC canister is similar to the MPC used in the

HI-STAR 100 and HI-STAR 100 HB, but is shorter when compared to the currently approved MPCs.

Because the GTCC overpack with a loaded GWC-HB canister weighs less than the HI-STAR 100 HB, the g-forces experienced under drop scenarios for NCT and HAC are bounded by the HI-STAR 100 HB. Specifically, the applicant conducted analyses similar to previously submitted and approved analyses and demonstrated that the GWC-HB experiences decelerations of 13.5g for NCT, and 32.3g for HAC. These results are bounded by MPC results of 17g for NCT and 60g for HAC. For fire conditions cited under HAC, the applicant described the GWC-HB canister (shell) as experiencing the following:

- a higher temperature than the MPC (775°F vs. 550°F), but
- less than half the internal pressure that the MPC experiences (100 psig vs 225 psig),

This results in safety margins larger than the previously approved MPC, as the material properties of the GWC-HB shell do not change to the same degree.

Given a similar construction, lower overall package weight, and less canister pressure, the GTCC package safety margins are bounded by the previously approved HI-STAR 100 HB. Therefore, the staff agrees that the HI-STAR 100 HB GTCC Package with a GWC-HB canister meets the requirements of 10 CFR Part 71.71 and 71.73.

2.1.11 HI-STAR 100 with Diablo Canyon MPC-32

The HI-STAR 100 also accommodates the Diablo Canyon MPC-32 where the overpack of the HI-STAR 100 is unchanged. The Diablo Canyon MPC-32 is similar to the previously approved MPC-32, with the exception that it is shorter, employs a spacer ring, has a thicker bottom plate, and a thicker inner shell. The spacer ring is inserted into the HI-STAR 100 to help maintain the same internal gap between the Diablo Canyon MPC-32 canister and HI-STAR 100 overpack as it currently exists between the HI-STAR 100 overpack and MPC-32. Combined, the HI-STAR 100 system loaded with the Diablo Canyon MPC-32 is lighter than if loaded with the previously approved MPC-32. The applicant states that the impact forces that would be observed during the drop tests specified in 10 CFR Part 71 for the Diablo Canyon MPC-32 would be bounded by the standard MPC-32 for both NCT and HAC due to less impact energy (less package mass) and a negligible change in the center of gravity for the package (similar construction as the MPC-32).

Section 2.7.1.1 of the application summarizes the applicant's analysis which results in a safety factor of 2.2. This scenario is a result of the end drop scenario of the package for HAC which induces a compressive loading.

Therefore, due to a lower weight (less impact energy), and similar construction, the staff agrees that the HI-STAR 100 with Diablo Canyon MPC-32 meets the requirements of 10 CFR 71.

2.2 Materials Evaluation

The staff's materials review evaluated the materials of construction, welding practices, and inspections performed on the Humboldt Bay and Diablo Canyon packages. The staff also evaluated the integrity of the spent fuel cladding in those packages and whether the applicant appropriately considered the potential for adverse chemical reactions and generation of hydrogen gas for both the spent fuel and GTCC waste contents.

2.2.1 Mechanical Properties

The staff reviewed the drawings and the structural analyses and verified that the materials and mechanical properties used in the design of the proposed Humboldt Bay and Diablo Canyon packages have been previously approved for use in the HI-STAR 100 CoC. The applicant did not introduce any new structural materials in the amendment request. The staff also reviewed the thermal and shielding analyses, and verified that the thermal and radiation environments for the proposed packages are bounded by the environments previously evaluated for the HI-STAR 100 CoC. As a result, no mechanical property changes are expected to occur that have not been previously evaluated.

The staff notes that the aluminum honeycomb structure in the proposed HB impact limiter is a modified version of the honeycomb structure in the previously approved HI-STAR 100 impact limiter. The new and existing honeycomb structures are constructed of the same aluminum alloy; however, the material thickness and honeycomb dimensions are tailored to each design to meet the crush strengths specified in the impact limiter drawings. Section 8.1.5.3 of the application states that each batch of honeycomb material is tested to ensure that the crush strength meets the specification in the drawings. Appendix 2.A details the static and dynamic testing and numerical simulations that were used to demonstrate the performance of the impact limiters. Dimensional differences in the honeycomb structures do not influence the existing thermal analysis because thermal calculations conservatively assume the impact limiters contain solid aluminum in a fire event (for maximum heat input) and air during normal conditions of transport (for minimum heat dissipation), as described in Table 3.2.2 of the application.

The staff finds the mechanical properties of materials used in the structural analyses of the proposed Humboldt Bay and Diablo Canyon packages to be acceptable because they are consistent with those used in the previously-approved HI-STAR 100 CoC, and, in the case of the aluminum honeycomb structure in the HB impact limiter, each batch of honeycomb material is tested to ensure that the required crush strengths are achieved.

2.2.2 Brittle Fracture

The applicant revised Section 2.1.2.3, “Brittle Fracture Failure,” to include an option to qualify the impact properties of ferritic components to a lowest service temperature of -40°F, rather than -20°F as required by 10 CFR 71.73 for accident conditions. The staff’s evaluation of this approach is documented in SER Section 8.1.2, “Impact Testing.”

2.2.3 Weld Design and Examinations

The applicant added new drawings for the proposed Humboldt Bay and Diablo Canyon packages and made several editorial changes to existing design drawings for the HI-STAR 100. The applicant also revised Sections 8.1.2 and 8.II.1.2, “Weld Examinations”, to expand the discussion of the code and code-alternative welding requirements.

The staff reviewed the drawings and welding criteria to verify that the welding code information is appropriately identified and that the design, inspection, and testing of the welds are performed in accordance with ASME Code criteria, as described in NUREG/CR-3019, “Recommended Welding Criteria for Use in the Fabrication of Shipping Containers for Radioactive Materials” (NRC, 1984).

Diablo Canyon Package and Humboldt Bay GTCC Overpack and HB Impact Limiter

The ASME Code criteria for the welding design, fabrication, and inspection of the Diablo Canyon MPC-32 and spacer ring and the Humboldt Bay GTCC overpack and HB impact limiter are identical to the welding criteria in the previously approved HI-STAR 100 CoC. The staff verified that the weld design and inspections are in accordance with the recommendations in NUREG/CR-3019, which includes the use of ASME Code Section III, Subsection NB for containment boundary welds; Subsection NF for the impact limiters, MPC spacers, and non-containment cask welds; and Subsections NB, NF, and NG for other code welds (MPC enclosure vessel, fuel basket), as appropriate. The staff notes that the Humboldt Bay GTCC overpack is not credited as the containment boundary (the canister is credited for containment of GTCC waste); however, the overpack welds will be examined in a manner consistent with the containment boundary of the previously approved HI-STAR 100 overpack.

The staff finds the welding criteria for the Diablo Canyon package and the Humboldt Bay GTCC overpack and HB impact limiter to be acceptable because they are in accordance with NRC recommendations in NUREG/CR-3019 and are consistent with the previously-approved HI-STAR 100 CoC.

Humboldt Bay GTCC Waste Canister

The welding criteria for the Humboldt Bay GTCC waste canister (GWC-HB) are unique in that the welds of the containment boundary are fabricated and examined with acceptance criteria per ASME Code Section III, Division 1, Subsection ND, "Class 3 Components." The staff notes that Subsection ND is the recommended welding criteria in NUREG/CR-3019 for Category II containment-related welds, and Section 1.II.2.3 of the application states that the Humboldt Bay GTCC waste is Category II (as defined in Table 2-1 of NRC Regulatory Guide 7.9 (NRC, 2005)).

In Sections 2.II.6.1 and 2.II.7.7, the applicant provided the bases for using a partial penetration weld in the lid-to-shell joint of the GWC-HB. To demonstrate that the weld is in compliance with Subsection ND of the ASME Code, the applicant provided calculations to show that the thickness of the weld conforms to the requirements in Paragraphs ND-3224 and ND-3225 for a corner joint between a flat head and cylindrical shell. The ASME Code calculations establish the minimum wall and weld thicknesses, based on the internal and external pressurization of the component. The staff notes that Subsection ND does not require full penetration welds for austenitic stainless steels in this joint configuration.

In addition, to demonstrate that the lid-to-shell weld can perform its containment function, the applicant provided calculations to show that the weld has significant margins in strength under normal conditions of transport and hypothetical accident conditions, including loading due to internal pressurization during a thermal accident and inertial loading of the lid in a drop accident. The applicant also provided calculations to show that a hypothetical crack present around the entire circumference of the weld would not propagate in a drop accident. The flaw size for this calculation was chosen as 10 mm (about 3/8 inch), the maximum depth between the multilayer liquid penetrate examinations for the lid-to-shell weld.

The staff reviewed the applicant's bases for the lid-to-shell weld and found them to be acceptable because the applicant demonstrated that the weld conforms to Subsection ND of the ASME Code (and thus the recommendations in NUREG/CR-3019) and the weld has sufficient strength and tolerance to a maximum hypothetical flaw in accident conditions.

Section 1.II.2.1.2.2 of the application states that the Humboldt Bay GTCC waste basket does not serve a safety function and the package would comply with regulatory radiation limits if it was not present. However, the applicant stated that the basket is conservatively classified as important-to-safety and it is welded in accordance with ASME Code Section III, Subsection ND, "Class 3 Components." The staff finds the GTCC waste basket welding criteria to be acceptable because fabrication and examination consistent with Class 3 nuclear facility component welds are sufficiently rigorous to ensure that the basket can fulfill its role in maintaining the position of the GTCC waste contents.

2.2.4 Content Reactions

As described in Section 1.II, the Humboldt Bay GTCC waste canister contains solid activated metals (e.g., reactor internals) and process wastes (spent fuel pool cleanup material) that reside in a "not-important-to-safety" process waste canister. The process wastes are thermally processed (e.g., by dry-ashing) to remove organics and other hydrogen-bearing compounds that could create flammable gases. The process wastes are then loaded into the waste canister, which is vacuum-dried, helium-backfilled, sealed, and leak-tested. The applicant stated that the thermal processing reduces the potential for hydrogen gas concentration within the waste canister to less than 5 percent by volume.

After loading the activated metal and process waste canister, the GWC-HB undergoes forced helium dehydration (FHD) and helium backfill to 10-15 psig before closure welding. The dryness criteria is defined by the Humboldt Bay storage license. The staff notes that the Humboldt Bay storage safety analysis report states that the FHD dryness criteria is a partial pressure of entrained water vapor of less than 3 torr, which is achieved by maintaining a FHD system demoisturizer exit temperature of less than or equal to 21°F for at least 30 minutes (PG&E, 2013).

Because the GWC-HB contents are dried and inerted (and the secondary process waste canister is independently dried and inerted), the staff finds that the GTCC waste contents would not be susceptible to adverse chemical reactions or generation of hydrogen gas.

The Diablo Canyon MPC-32 canister can accommodate 32 undamaged PWR moderate burnup fuel assemblies (less than or equal to 45 GWD/MTU) with non-fuel hardware and neutron sources, as described in Table 1.II.2. The spent fuel cladding type, assembly average burnup, and enrichment of the Diablo Canyon MPC-32 contents are bounded by the spent fuel contents previously approved for transport in the generic MPC-32 under the HI-STAR 100 CoC. The staff notes that, while the application describes the cladding only as being "zirconium," the Diablo Canyon ISFSI safety analysis report for storage further defines the allowable zirconium alloys as Zircaloy-2, Zircaloy-4, or ZIRLO. After loading of the fuel, the Diablo Canyon MPC-32 undergoes forced helium dehydration and helium backfill in a manner similar to that for the previously approved generic MPC-32. Therefore, the staff finds that the addition of the Diablo Canyon MPC-32 canister does not introduce any adverse chemical reactions or potential for generation of hydrogen gas.

The applicant also revised the allowable contents of the generic MPC-32 canister to include non-fuel hardware and neutron sources. Table 1.2.27 of the application lists these authorized contents, and the allowable combinations of hardware burnup and cooling time are provided in Table 1.2.38. The staff reviewed these additional contents and did not identify any potential for adverse chemical reactions or generation of hydrogen gas in the dried and inerted helium environment.

2.2.5 Spent Fuel Cladding Integrity

The spent fuel contents of the Diablo Canyon MPC-32 canister are described in Table 1.2.3 (cladding temperature limits for all MPC-32 canisters), Table 1.2.10 (assembly characteristics), Tables 1.2.32 and 1.2.33 (cooling time, burnup, enrichment for all MPC-32 canisters) and Tables 1.II.1 and 1.II.2 (specific parameters and limits for the Diablo Canyon MPC-32). The staff notes that the Diablo Canyon fuel assembly array/class 17x17A and 17x17B characteristics, such as cladding dimensions, are bounded by those currently approved.

In Section 2.III.9, the applicant stated that the Diablo Canyon fuel is a shorter version of the design basis fuel in the current HI-STAR 100 CoC, and thus the computations and conclusions for the structural integrity of the fuel rods during transportation remain the same. Section 2.9 provides the analysis of the integrity of the cladding under hypothetical accident conditions for all fuel transported under the HI-STAR CoC, and the applicant did not make any revisions to this analysis in the amendment. The maximum peak cladding temperatures for the Diablo Canyon fuel are 400°C (752°F) under normal conditions and 570°C (1058°F) under accident conditions. These limits are identical to those of the fuel currently approved for transport in the HI-STAR 100 CoC and are consistent with the recommended cladding temperature limits during storage in NRC Interim Staff Guidance - 11 to minimize the effects of creep and hydride reorientation.

The staff finds that the applicant has adequately demonstrated the integrity of the spent fuel cladding, as the structural analyses previously reviewed and approved by the NRC are considered bounding of the Diablo Canyon fuel.

2.2.6 Other Materials Evaluation Criteria

The staff did not identify any significant materials-related changes to bolting, neutron poison materials, gamma shielding materials, or seals. The Humboldt Bay GTCC Waste package does not employ seals, neutron poisons within the canister, nor the Holtite neutron shield material that is present in the generic HI-STAR 100 overpack. The Diablo Canyon MPC-32 basket can use either Boral or Metamic neutron absorber panels, consistent with the generic MPC-32 canister in the previously approved HI-STAR 100 CoC. As the Diablo Canyon MPC-32 will be transported in the previously approved HI-STAR 100 overpack, no new seals were introduced.

The staff's materials review evaluated the materials of construction, welding practices, and inspections performed on the Humboldt Bay and Diablo Canyon packages. The staff also evaluated the integrity of the spent fuel cladding in those packages and whether the applicant appropriately considered the potential for adverse chemical reactions and generation of hydrogen gas for the spent fuel and GTCC waste contents.

2.3 Conclusion

Based on the staff's review of the statements and representations in the application, the staff concludes that the Model No. HI-STAR 100 package meets the requirements of 10 CFR Part 71.

3.0 THERMAL EVALUATION

The objective of the review is to verify that the thermal performance of the Model No. HI-STAR 100 package has been adequately evaluated for the tests specified under both NCT and HAC, and that the package design satisfies the thermal requirements of 10 CFR Part 71.

This amendment request seeks approval of two variants of the HI-STAR 100 package: the HI-STAR HB package with an MPC-HB for BWR spent fuel and a GWC-HB for Greater-Than-Class C waste, and the HI-STAR 100 package with the Diablo Canyon (DC) MPC-32 for moderate burnup PWR spent fuel.

3.1 Description of the Thermal Design

The HI-STAR HB overpack design features a neutron shield placed in the annulus region between the multi-layered shells and enclosure shell without connecting ribs. Except for this difference, the thermal design of the HI-STAR HB and HI-STAR DC MPC-32 is identical to the generic HI-STAR 100 package design which has been reviewed and approved previously.

3.1.1 Packaging Design Features

Except for the contents which can be transported in the HI-STAR 100 transportation cask, the packaging design features are documented in the HI-STAR 100 application. The design features have been reviewed and approved previously.

3.1.2 Codes and Standards

Appropriate codes and standards are referenced by the applicant throughout the application.

3.1.3 Content Heat Load Specification

The HI-STAR HB package is designed to transport HB spent fuel with a maximum decay heat load of 2 kW. The applicant states that the Humboldt Bay Greater-Than Class C (GTCC) waste contained in the GTCC Waste Canister (GWC-HB) has a negligible heat source term, particularly as compared to that of a fuel-bearing cask. As such, the heat load of the HI-STAR HB GTCC cask is limited to insolation heat. The HI-STAR DC MPC-32 maximum heat load is limited to 18 kW.

The thermal loads are different for NCT and HAC: the surface thermal load (insolation) is applied continuously during NCT, while the surface thermal load (combustion heat) is external during the HAC fire accident.

The staff reviewed all the external heat loads on the package. These heat loads are expected and acceptable based on the proposed heat loads and the thermal loads described in 10 CFR 71.71 and 71.73.

3.1.4 Summary Tables of Temperatures and Pressures

The staff verified that summary tables of the package component temperatures and pressures were included in the application. Tables 3.I.3 and 3.I.5 provide maximum temperatures and operating pressures for the HI-STAR HB package. Maximum temperatures and pressures for the HI-STAR HB GTCC are bounded by the HI-STAR HB package.

Components include spent fuel cladding, MPC shell, overpack inner shell, overpack top plate, overpack bottom plate, and overpack outer shell. The staff confirmed that the temperatures are consistently presented throughout the application for both NCT and HAC conditions.

For HAC, the applicant stated that because of small differences between the generic HI-STAR 100 thermal design and the HI-STAR HB GTCC package, the generic HI-STAR 100 maximum temperatures and pressure are bounding. The same statement applies to the HI-STAR DC MPC-32 package.

The staff confirmed that all components remain below their material property limits specified in the application. Therefore, the staff finds that the summary tables of temperatures and pressures in the application are consistent with NUREG-1617, "*Standard Review Plan for Transportation Packages for Spent Nuclear Fuel*," and are acceptable.

3.2 Material Properties and Component Specifications

Except for the thermal conductivity of Holtite, the material properties compiled in Section 3.2 of the application provide the required materials information. This information has been reviewed and previously accepted by the staff. Holtite conductivity data is provided in Table 3.I.1.

The staff finds that the properties used for the analysis of the package are appropriate for the materials specified, and for the package conditions required by 10 CFR Part 71 during NCT and HAC.

3.3 Thermal Design Limits of Package Materials and Components

Maximum pressure and temperature limits of package materials and components are provided by the applicant. The staff verified that they are used consistently throughout the application. The applicant states that components and materials would not degrade under an extreme low temperature of -40°C (-40°F). The application also describes the long-term stability of Holtite-A under NCT. The applicant demonstrated that peak cladding temperatures are in compliance with the recommended limits specified in NUREG-1617.

The staff reviewed and confirmed that the maximum allowable temperatures for components critical to the package containment, radiation shielding, and criticality are specified. The staff verified that the spent fuel cladding temperature limit of 570ºC (1058°F) for accident conditions is observed. This temperature limit is based on the Pacific Northwest National Laboratory (PNNL) report, PNL-4835, which is a methodology accepted by the staff.

3.4 Thermal Evaluation Methods

3.4.1 Evaluation by Analyses

The thermal evaluation methods are the same than those considered in the generic HI-STAR 100 package which have been reviewed and previously accepted by the staff.

3.4.2 Evaluation by Tests

Section 8.1.7 of the application provides a basic description of the testing sequence and the condition for its acceptability. Section 8.2.4 of the application specifies that, for each package, a periodic thermal performance test is also performed at least once within the 5-years prior to each shipment to demonstrate that the thermal capabilities of the package remain within its design basis.

3.4.3 Temperatures

See Section 3.1.4

3.4.4 Pressures

See Section 3.1.4

3.4.5 Thermal Stresses

Thermal stresses during NCT are evaluated in Chapter 2 of the application.

3.4.6 Confirmatory Analyses

The staff reviewed the thermal models used in the applicant's analyses. The engineering drawings were also consulted to verify that drawing dimensions were properly translated to the analytical model. The staff reviewed the material properties presented in the application and verified that they are appropriately referenced and used.

3.5 Evaluation of Accessible Surface Temperature

The accessible surface temperatures calculated for the generic HI-STAR 100 package are bounding; therefore no additional analyses are necessary for the new contents and package designs. The generic HI-STAR 100 package accessible surface temperature calculations have been reviewed and previously accepted by the staff.

3.6 Thermal Evaluation under Normal Conditions of Transport

The applicant employed the same thermal analysis methods, previously used to evaluate the generic HI-STAR 100, for both the HI-STAR HB package and the HI-STAR DC MPC-32 package. The applicant did not develop any thermal models for the HI-STAR WGC-HB due to the negligible decay heat from the GTCC waste proposed as contents. These methods have been reviewed and previously accepted by the staff.

The staff finds the applicant's approach of performing the NCT evaluation acceptable because the developed thermal model is adequate to capture the heat transfer characteristics expected for these packages.

3.6.1 Heat

For the HI-STAR HB package under a 38ºC (100°F) ambient temperature, still air, and solar heat, the applicant predicted the maximum temperatures of the fuel cladding, MPC shell, overpack inner shell, overpack top plate, overpack bottom plate, and overpack outer shell. These temperatures are listed in Table 3.I.3 of the application.

The staff confirms that these maximum temperatures are below the material temperature limits with sufficient margin and find them acceptable. The applicant stated that the generic HI-STAR maximum temperatures are bounding for the HI-STAR DC MP-32 package. The generic HI-STAR analysis and maximum temperatures had been reviewed and previously accepted by the staff.

3.6.2 Cold

With no decay heat and an ambient temperature of -40°C (-40°F), the entire package approaches uniformly the steady-state ambient temperature. Package components, including the seals, are not adversely affected by exposure to cold temperatures. The staff finds these arguments acceptable because the materials of construction are designed to operate at this low temperature.

3.6.3 Maximum Normal Operating Pressure (MNOP)

Based on the heat condition, 38ºC (100°F), still air, and insolation specified in 10 CFR 71.71(c)(1) and the design heat load, the HI-STAR-HB package MNOP is calculated and reported in Table 3.I.5 of the application. Since the DC MPC-32 canister is shorter than the generic HI-STAR 100, the applicant also calculated and reported MNOP for the HI-STAR DC MPC-32 package. These pressures are reported in Table 3.III.2 of the application. The staff verified that the calculated pressures are below the allowable limit specified in the application.

3.7 Thermal Evaluation for Short Term Operations

3.7.1 Time-to-Boil Limits

The applicant calculated the thermal inertia and heat load specifications for the contents described in the application, and determined that the generic HI-STAR bounds the additional contents, heat loads, and packages. The applicant used these parameters to calculate time limits that can be used during loading operations to avoid boiling in the cask cavity. The staff reviewed the calculations provided in the application, and finds the applicant's arguments acceptable as the decay heat of some of the contents is negligible when compared to the generic HI-STAR 100 package. The staff also reviewed the applicant's calculations of the thermal inertia for the HI-STAR DC MPC-32 and determined the HI-STAR 100 generic package bounds those of the HI-STAR DC MP-32.

3.7.2 Cask Drying

The temperatures calculated for the generic HI-STAR 100 during package drying are bounding. Therefore, no analyses are necessary for the additional contents and packages. The generic HI-STAR 100 package analysis and results had been reviewed and previously accepted by the staff.

3.8 Thermal Evaluation under Hypothetical Accident Conditions

The applicant stated that the generic HI-STAR 100 HAC results are bounding for these packages. Given the lower decay heat of the contents, the staff finds this argument acceptable. The generic HI-STAR 100 HAC analysis and results had been reviewed and previously accepted by the staff.

3.8.3 Maximum Thermal Stresses

Thermal stresses during HAC are evaluated in Chapter 2 of the application.

3.9 Evaluation Findings

The staff reviewed the package description, the material properties, the component specifications and the methods used in the thermal evaluation, and found reasonable assurance that they are sufficient to provide a basis for evaluation of the package against the thermal requirements of 10 CFR Part 71.

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

The staff also found reasonable assurance that the package material and component temperatures will not exceed the specified allowable short-term temperature limits during hypothetical accident conditions, consistent with the tests specified in 10 CFR Part 71.73.

4.0 CONTAINMENT EVALUATION

4.1 Review Objective

The objective of the review was to verify that the containment-related changes to the Model No. HI-STAR 100 package described in the application were adequately evaluated under NCT and HAC, as required per 10 CFR Part 71.

The containment-related changes included the following: (i) containment analysis of the HI-STAR 100 with a Diablo Canyon MPC-32, and (ii) containment analysis of the HI-STAR HB GTCC with the GWC-HB. In addition, there were miscellaneous content changes and pressure changes for previously approved contents; however, the responses to staff's RAI, and particularly RAIs 4-11 and 4-12, indicated that content and pressure changes did not affect previously submitted containment release estimates. Regulations applicable to the containment review include 10 CFR 71.31, 71.33, 71.35, 71.43, and 71.51.

4.1 Description of Containment Systems

4.1.1 HI-STAR HB GTCC

The HI-STAR HB GTCC package is used for transport of GTCC waste. As noted on page 4.II-1 of the application, the HI-STAR 100 package, which has a bolted lid (lid bolt torque requirements are provided in Table 7.II.1.2), is not considered part of the containment boundary, but serves a defense-in-depth "non-quantified" containment function.

Section 4.II.0 of the application indicated that the GTCC waste, which has been loaded at Humboldt Bay, consists of non-dispersible solids, e.g., activated stainless steel core components, and dispersible solids, e.g., up to 50 kg of dried and thermally treated processing waste. Section 4.II.0.B discusses the bases for the GWC-HB content, including the determination of content properties, e.g., total activity of process waste, total surface activity, activity fraction of surface contamination that spalls-off, total aerosol density, weight of process waste, and the fact that the dominant content contributor (Co^{60}) activity has reduced by a factor of 2 since the content activity was first measured and documented.

Table 4.II.2.6 and page 7.A-32 of the application provide the total source term effective A_2 for the content and quantity of radioactive material, respectively. As stated in Supplement 7.II.1.3.1 and Section 7.II.3 of the application, the dispersible and non-dispersible activity placed within the GWC-HB canister is to be confirmed to meet the allowable values defined in the CoC and Sections 4.II.2.4, 4.II.2.5, and Appendix 7A of the application. The process waste content would be placed within a Process Waste Container (PWC) stainless steel secondary container, which

is then placed within the GWC-HB. Although not the containment boundary and considered a not-important-to-safety component, pages 1.II- and 4.II-1 of the application indicate that the PWC is vacuum dried, helium backfilled, and leak-tested. In addition, it is stated, on page 4.II-1, that the PWC provides an additional, unquantifiable containment function.

According to Section 4.II.0 of the application, the containment boundary for GTCC contents will be the multipurpose canister (GWC-HB) rather than the HI-STAR 100 GTCC package. Section 4.II.1 indicated that the GWC-HB enclosure vessel is credited as the containment boundary, which is a welded enclosure (no seals) consisting of base plate, top and bottom lids, upper and lower outer GWC-HB canister shell plates, closure ring, vent and drain port cover plates, and associated welds; Figure 4.II.1.1 provides a pictorial description of the containment boundary. Table 8.II.1 states that the various aspects associated with the GWC-HB containment boundary, including material procurement, design, stress and deformation analysis, welding, inspection, and testing are per American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section III, Subsection ND.

Regarding the GWC-HB welds, page 8.II-2 of the application states the welds are to be examined in accordance with ASME Code Section V, with acceptance criteria per ASME Code Section III, Subsection ND. A discussion on the relevance of Subsection ND is provided in the Materials section of this SER. Section 4.II.1.3.2 of the application lists the welds that form the containment boundary, including the welds forming the shell plates, welds connecting the shell plates to the top lid, welds connecting the shell plates to the base plate, and welds connecting the vent and drain port cover plates.

Although Section 4.II.1.3.2 states full-penetration welds are specified for the shell to the top lid, Drawing 10316 (sheet 1 of 4) indicates a fillet weld is associated with the closure ring and shell top. The Materials section of this SER provides further discussion about the GWC-HB closure weld.

According to Section 4.II.1, the HI-STAR HB GTCC system is designed and fabricated as a Class 1 component pressure vessel in accordance with Section III, Subsection NB of the ASME Boiler and Pressure Vessel Code.

4.1.2 HI-STAR 100 with Diablo Canyon MPC-32

The HI-STAR 100 with the Diablo Canyon MPC-32 is used for transporting the contents described in Section 1.III of the application. According to Section 4.III.0, the Diablo Canyon MPC-32 is identical, from a perspective of limiting contents, to the current standard length MPC-32; the total source term effective A_2 and radionuclide release rates were provided in Table 4.III.2.4 and Table 4.III.2.5, respectively. Likewise, Section 4.III of the application stated that the HI-STAR 100 with the Diablo Canyon MPC-32, including the HI-STAR 100 containment system, is essentially identical to the previously approved HI-STAR 100 package.

Table 8.1.4 states that the various aspects associated with the HI-STAR 100 containment boundary, including material procurement, design, stress and deformation analysis, welding, inspection, and testing is per ASME Boiler and Pressure Vessel Code, Section III, Subsection NB. Page 4.1-1 of the application states that the containment boundary includes the overpack inner shell, bottom plate, top flange, top closure plate, closure bolts, overpack vent and drain port plugs, and their respective welds and mechanical seals.

According to page 4.1-2, the containment welds include the welds forming the inner closure shell, the inner shell to the top flange, and the weld connecting the inner shell to the bottom plate. Likewise, the seals include an inner metallic seal that forms the closure between the top flange surface and closure plate; an outer metallic seal forms a redundant closure. In addition, the vent port and drain port closures include a threaded plug with a metallic seal. A cover plate, with a machined seal groove and metallic seal, is placed over each vent port and drain port; a closure ring is welded over the cover plates.

Table 7.1.1 provides the closure lid bolt torque values, required lubrication, bolt torqueing patterns, and installation procedures while page 4.1-3 indicates that the bolt torque values preclude the separation of the closure plate from the overpack flange.

4.2 Containment under NCT

4.2.1 Pressurization of Containment Vessel

Table 1.II.2 of the application indicates that the MNOP for the GWC-HB is 17.94 psig. The pressure is less than the 100 psig design pressure stated in Table 1.II.2 and Table 2.1.1. Section 4.II.2.3 indicates that there is less than 5% (by volume) of hydrogen gas within the GWC-HB because the GWC is drained, dried, backfilled with helium and, for process wastes, there is no organic material in the content.

Supplement 2.III of the application indicates that the pressure for the HI-STAR 100 package with the Diablo Canyon MPC-32 is bounded by the previously analyzed HI-STAR 100 packages for the other MPC designs, e.g., MPC-24, MPC-68, MPC-24E, and MPC-32. In addition, Section 3.4.4 indicates the HI-STAR 100 package MNOP values are bounded by the MPC pressures.

According to Table 3.4.15, these pressures are less than 89.3 psig, which is less than the NCT design pressure of 100 psig, as provided in Table 2.1.1. Section 4.2.3 of the application indicates that the HI-STAR 100 package and the (Diablo Canyon) MPC-32 are each drained, dried, evacuated, and backfilled with helium, that no vapors or gases are present which could cause a reaction or explosion, and that the hydrogen concentration remains below 5 percent by volume.

4.2.2 Containment Criteria

4.2.2.1 HI-STAR HB GTCC

Supplement 4.II of the application performed calculations, in accordance with ANSI N14.5-2014 and using NUREG/CR-6487 "Containment Analysis for Type B Packages Used to Transport Various Contents", to show that a leakage rate acceptance criterion of 2.10^{-2} atm-cm^3/sec (He) at upstream pressure would satisfy 10 CFR 71.51. The bases for the leakage rate acceptance criterion included the use of the values and assumptions in Section 4.II.B.0 and retaining the GWC-HB containment integrity during NCT and HAC conditions.

Sections 8.II.1.4 and 8.II.2.2 describe the fabrication, maintenance, and pre-shipment leakage tests for the GWC-HB containment boundary. Tables 8.II.2 and 8.II.3 indicate that the fabrication leakage rate test, which includes the shell, baseplate, shell welds, and shell-to-baseplate weld must satisfy a 1.25 10^{-6} ref-cm^3/s (air) leakage rate with a 0.625 10^{-6} ref-cm^3/sec (air) sensitivity and follow ANSI N14.5-2014; this bounds the 2 10^{-2} atm-cm^3/sec (He) condition discussed above.

Table 8.II.2 indicates that the complete canister, which includes the enclosure vessel and the closure assembly (lid, vent and drain port cover plates, welds), has a 10^{-2} ref-cm^3/sec (air) leakage rate acceptance criterion with a 5 10^{-3} ref-cm^3/sec (air) sensitivity. A maintenance leakage rate test is to be performed for any part of the containment boundary that undergoes maintenance and must satisfy a 10^{-2} ref-cm^3/s (air) leakage rate with a 5 10^{-3} ref-cm^3/sec (air) sensitivity.

A pre-shipment leakage rate test of the entire containment boundary (shell, baseplate, top closure assembly, shell welds, shell to baseplate weld, closure assembly welds) must satisfy a 10^{-2} ref-cm^3/s (air) leakage rate acceptance criterion with a 5 10^{-3} ref-cm^3/sec sensitivity prior to shipment. Table 8.II.5 of the application states that the pre-shipment leakage rate test will be performed following the loading of the GWC-HB (per Table 8.II.5, this test may be performed under the Part 72 docket) and prior to transport. The GWC-HB, which is seal welded, is a one-time use system. Therefore, according to Section 8.II.2.2, there is no periodic leak test; however, per Table 8.II.5, the pre-shipment leakage rate test would be repeated if transport does not occur within a year. As noted in Section 4.II.1.4, the leakage rate testing of field welds performed under the 10 CFR 72 docket is not credited for transport. As noted above, the leakage rate test sensitivity for all leakage tests is half of the leakage rate acceptance criteria.

According to Section 8.II.2.2, the leakage rate test procedures are to be approved by an ASNT Level III specialist and leakage rate testing is to be performed by personnel who is qualified and certified in accordance with the requirements in SNT-TC-1A.

4.2.2.2 HI-STAR 100 with Diablo Canyon MPC-32

Supplement 4.III of the application indicates that the containment evaluation of the HI-STAR 100 with the Diablo Canyon MPC-32 was similar to the evaluation analyzed for the HI-STAR 100 package with the other MPC designs, e.g., MPC-24, MPC-68, MPC-24E, and MPC-32. Supplement 4.III also included calculations, in accordance with ANSI N14.5-2014 and using NUREG/CR-6487, to show that a leakage rate acceptance criterion of 6.54 10^{-5} cm^3/sec (upstream conditions per Table 4.III.2.6) would satisfy 10 CFR 71.51.

According to Table 8.1.1, the leakage rate acceptance criterion is 2.15 10^{-6} ref cm^3/sec (air). The bases for the leakage rate acceptance criterion included using the release fractions (in Table 4.2.4) and source terms (in Tables 4.III.2.2 and 4.III.2.4) provided in the calculations. The basis for the release fractions is described in NUREG/CR-6487.

Table 8.1.2 indicated that the fabrication, pre-shipment, maintenance, and periodic leakage rate tests are as defined by ANSI N14.5-2014. Section 8.1.4 indicated that leakage rate tests of the HI-STAR 100 package containment system will be performed per written and approved procedures in accordance with the requirements of ANSI N14.5-2014.

The personnel approving leakage testing procedures will be qualified and, according to Section 8.1.4, will be approved by an ASNT Level III specialist. Leakage rate testing will be performed per written and approved procedures by qualified and certified personnel in accordance with the requirements of SNT-TC-1A. Likewise, Section 8.1.4 stated that leakage rate testing is performed in accordance with a written quality assurance program.

4.2.3 Compliance with Containment Criteria

4.2.3.1 HI-STAR HB GTCC

Supplement 2.II of the application indicated that the HI-STAR HB GTCC package with the GWC-HB canister is essentially identical to the already-approved HI-STAR HB transport package; therefore, the package's response to the NCT tests was considered in the previous safety evaluations.

With regard to the GWC-HB canister and its containment boundary, previously submitted structural analyses in Chapters 2.6 and 2.7 showed that the integrity of an MPC boundary is maintained during the NCT and HAC tests and that their safety factors associated with the stresses relative to yield were greater than one. Specifically, the applicant's response to the first round of RAIs, i.e., RAIs 2-16 and 4-1, (Enclosure 1 to Holtec Letter 5014814), indicated that the results from these previous analyses bound those for the GWC-HB canister because of the GWC-HB's reduced size and mass; therefore, the containment boundary would maintain the capability to satisfy the containment criteria leakage rate.

Further discussion on the structural and thermal integrity of the HI-STAR 100 package's containment boundary is discussed in the structural and thermal sections of this SER. In addition, discussion of long-term maintenance and aging management of the GWC-HB canister in storage and subsequent transportation is provided in Section 8.A of the application, and in the materials section of the SER.

4.2.3.2 HI-STAR 100 with Diablo Canyon MPC-32

Section 2.III of the application states that the Diablo Canyon MPC-32 is similar to the previously analyzed MPC-32 designs except for its shorter length; a spacer ring ensures that the weight and center of gravity of the two packages are similar with the Diablo Canyon MPC-32 being slightly lower in weight. As a result, Sections 2.III.6 and 2.III.7 indicate that the Diablo Canyon MPC-32 is bounded by the previous MPC analyses per Section 2.III of the application.

With regard to the HI-STAR 100 with the Diablo Canyon MPC-32, previously submitted structural and thermal analyses indicated that the HI-STAR 100 package's containment boundary would be maintained after undergoing the conditions specified in 10 CFR 71.71.

Further discussion on the structural and thermal integrity of the HI-STAR 100 package's containment boundary is discussed in the structural and thermal sections of the SER. In addition, discussion of long-term maintenance and aging management of the MPC in storage and subsequent transportation is provided in Section 8A of the application, and in the materials section of the SER.

4.3 Containment under Hypothetical Accident Conditions

4.3.1 Pressurization of Containment Vessel

4.3.1.1 HI-STAR HB GTCC

Page 3.II-3 and Table 3.II.3 of Supplement 3.II of the application indicated that the pressure within the GWC-HB canister, as a result of the HAC fire, is 36 psig. This pressure is within the 100 psig design pressure stated in Tables 1.II.2 and 2.1.1 of the application. Section 4.II.2.3

indicated that there is less than 5% (by volume) of hydrogen gas within the GWC-HB canister because the canister is drained, dried, backfilled with helium and, for process wastes, there is no organic material in the content.

4.3.1.2 HI-STAR 100 with the Diablo Canyon MPC-32

Table 3.III.3 of Supplement 3.III indicates that the pressure for the HI-STAR 100 package with the Diablo Canyon MPC-32 under HAC fire test conditions and 100% fuel rod rupture is 214.7 psig. This is bounded by the 225 psig HAC pressure presented in Table 2.1.1. Section 4.2.3 of the application indicated that the HI-STAR 100 package and the (Diablo Canyon) MPC-32 are each drained, dried, evacuated, and backfilled with helium, that no vapors or gases are present which could cause a reaction or explosion, and that the hydrogen concentration remains below 5 percent by volume.

4.3.2 Compliance with Containment Criteria

4.3.2.1HI-STAR HB GTCC

Supplement 2.II of the application indicated that the HI-STAR HB GTCC package with the GWC-HB canister is essentially identical to the already-approved HI-STAR HB transport package; therefore, the package's response to HAC tests was previously considered. With regard to the GWC-HB and its containment boundary, previously submitted structural analyses (in Chapter 2.7) showed that the integrity of an MPC boundary is maintained during the HAC tests and that the safety factors associated with the MPC stresses relative to yield were greater than one. The response to the first round of RAIs (RAIs 2-16 and 4-1 in Enclosure 1 to Holtec Letter 5014814) indicated that the results from these previous analyses bound those for the GWC-HB because of the GWC-HB's reduced size and mass.

4.3.2.2 HI-STAR 100 with the Diablo Canyon MPC-32

Section 2.III stated that the Diablo Canyon MPC-32 is similar to the previously analyzed MPC-32 designs except for its shorter length; a spacer ring ensures that the weight and center of gravity of the two packages are similar with the Diablo Canyon MPC-32 being slightly lower in weight. As a result, Sections 2.III.6 and 2.III.7 indicate that the Diablo Canyon MPC-32 is bounded by the previous MPC analyses, with safety factors associated with the MPC stresses relative to yield being greater than one.

With regard to the HI-STAR 100 with the Diablo Canyon MPC-32, Supplement 2.II indicates that the HI-STAR 100 transporting the Diablo Canyon MPC-32 is bounded by the previously analyzed HI-STAR 100 packages with the other MPC designs, e.g., MPC-24, MPC-68, MPC-24E, and MPC-32. Specifically, previous structural and thermal analyses indicated that the HI-STAR 100 transportation package's containment boundary would be retained after undergoing the conditions specified in 10 CFR 71.73.

4.4.4 Evaluation Findings

4.4.1 Description of Containment System

The staff reviewed the description and evaluation of the containment system for the HI-STAR 100 transporting either the Diablo Canyon MPC-32 or the GWC-HB and concludes that the application identifies established codes and standards for the containment system. The package containment system will remain securely closed by a positive fastening device and cannot be opened unintentionally by any external means nor by pressure that may arise within the package. The Diablo Canyon MPC-32 includes port plugs that are protected against unauthorized operation and are provided with an enclosure to retain any leakage.

4.4.2 Containment under Normal Conditions of Transport

The staff reviewed the evaluation of the containment system under NCT and concludes that the package is designed, constructed, and prepared for shipment so that, under the tests specified in 10 CFR 71.71, the package satisfies the containment requirements of 10 CFR 71.43(f) and 10 CFR 71.51(a)(1) for normal conditions of transport with no dependence on filters or a mechanical cooling system.

4.4.3 Containment under Hypothetical Accident Conditions

The staff reviewed the evaluation of the containment system under HAC and concludes that the package satisfies the containment requirements of 10 CFR 71.51(a)(2) for hypothetical accident conditions, with no dependence on filters or a mechanical cooling system.

Based on review of the statements and representations in the application and the conditions stated in the CoC, 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.

5.0 SHIELDING EVALUATION

The staff reviewed the application to revise the Model No. HI-STAR 100 package to verify that the shielding design has been described and evaluated under NCT and HAC, as required in 10 CFR Part 71. This application was also reviewed to determine whether the package fulfills the acceptance criteria listed in Section 5 (Shielding Review) of NUREG-1617, "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel."

5.1 Description of Shielding Design

5.1.1 Packaging Design Features

Staff reviewed the changes to the design features proposed in the amendment request with the addition of the MPC-32 designed for the Diablo Canyon spent fuel assemblies and the HB GTCC version of the HI-STAR 100 package designed for reactor-related waste.

The shielding analysis provided in the application bounds the Diablo Canyon HI-STAR 100 MPC fuel configuration since:

1. The PWR fuel analyzed has the highest UO_2, and thus bounds PWR fuel assemblies for Diablo Canyon.

2. The number of non-fuel hardware devices that can be loaded into the HI-STAR 100 System with a Diablo Canyon MPC-32 is limited, and is less than the number of non-fuel hardware devices previously analyzed in the application.

No other proposed changes affect the shielding design. The staff reviewed the licensing drawings and descriptions of the HI-STAR 100 system, as modified in the proposed amendment, and finds there is sufficient detail to perform a shielding evaluation. The staff reviewed the proposed changes and finds them to be described in sufficient detail to perform an evaluation of the shielding design.

5.1.2 Codes and Standards

The applicant continues to use the flux-to-dose conversion factors from ANSI 6.1.1-1977. The staff finds the use of these conversion factors to be acceptable.

5.1.3 Summary Table of Maximum Radiation Levels

The summary dose rate tables for the HI-STAR HB GTCC with a GWC-HB MPC are provided in the Supplement 5.II of the application. The tables show maximum dose rates for the side, top, and base of the HI-STAR 100 to be below the 10 CFR Part 71 regulatory dose rate limits. Staff reviewed the dose rates presented in the Supplement 5.II and finds they are consistent with those reported in the rest of the analysis and are the maximum dose rates.

5.2 Source Specification

NUREG-1617 states that "In general, only gammas from approximately 0.8 MeV-2.5 MeV will contribute significantly to the external radiation levels." Cobalt-60 is the most substantial high-activity gamma emitter in this gamma energy range. Table 5.II.4 of the application lists the Co-60 source that is used in the MCNP calculations. The Co-60 used in the applicant's shielding analysis bounds the authorized Co-60 activity limit stated in Supplement 1.II.

5.3 Model Specification

The applicant uses the same shielding models as for the analyses performed in the previously approved amendment, except that the end plate/shielding disk of the impact limiter is added to the bottom of HI-STAR HB GTCC as a shielding material (this disk is attached to the bottom plate of the HISTAR HB GTCC using screws; and therefore, the disk remains in place after an accident). The GTCC waste is modeled as homogenized material, with densities provided in Table 5.II.4.

Chapters 2 and 3 of this SER describe staff's evaluations of the structural and thermal performance of the HI-STAR 100 system as proposed in the amendment. None of the proposed changes were found to exceed the bounding conditions affecting shielding as evaluated in the previously approved amendment. Based on its review of these proposed changes, the staff finds that the shielding models, with the correction to the impact limiters, remain appropriate.

5.4 Evaluation

The applicant performed the shielding analysis with MCNP-4A, the same code used by the applicant for the shielding analyses in the previously approved amendment. The applicant calculated the dose rates for a Co-60 source with the source strengths identified in Table 5.II.4. These dose rates are presented in Tables 5.II.1 and 5.II.2 for the surface dose rates and two-meter dose rates for normal conditions, respectively, and Table 5.II.3 for the one-meter dose rates for hypothetical accident conditions.

The staff reviewed this information and also created a model of the HI-STAR HB GTCC using the MAVRIC/MONACO shielding code as part of SCALE 6.1. The staff used the source term used by the applicant in its MAVRIC/MONACO model. The staff's dose rates were within 15% of the applicant's. This comparison helps to demonstrate that the applicant's model and methods calculate an appropriate dose rate.

5.5 Conclusion

Based on its review of the information and representations provided by the applicant in this amendment request and the staff's independent analyses, the staff has reasonable assurance that the changes to the package design and contents satisfy the shielding requirements and dose limits in 10 CFR Part 71.

6.0 CRITICALITY EVALUATION

The applicant requested additional fuel and canister designs as authorized contents. The applicant also revised its criticality safety analyses in its report referenced HI-2012630 Revision 2, "Burnup Credit for the MPC 32." to use the method recommended by Interim Staff Guidance 8, Revision 3, "Burnup Credit in the Criticality Safety Analyses of PWR Spent Fuel in Transport and Storage Casks," (ISG-8, Rev. 3 thereafter) for criticality safety analysis computer code validation to determine the worth, bias, and bias uncertainty of the minor actinides and fission products (MAFPs) for part of the isotopes, as listed in ISG-8, Rev. 3. Other changes in the designs that do not affect the criticality safety features of the package design are not discussed in this chapter.

The purpose of this review is to verify that the proposed amendment request meets the criticality safety requirements of 10 CFR 71.55 and 71.59. The staff performed its review following the guidance of NUREG-1617, "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel" (NUREG-1617 thereafter) and ISG-8, Rev. 3. The staff's evaluations and findings of the criticality safety of this package with new contents and a new burnup credit analysis approach are documented in the following sections of the SER.

6.1 Description of Criticality Safety Design

6.1.1 Package Criticality Safety Design Features

The HI-STAR 100 is a canister based spent fuel transportation packaging system. The package design relies on the combination of the geometry of the fuel basket, fuel enrichment limits, and poison plates for criticality safety. The package containing the MPC-32 canister also relies on burnup credit for criticality safety of the package for the PWR fuel assembly designs that are listed in the CoC.

The requested changes that impact the criticality safety of the package include: (1) revising the material composition of the BWR thoria rod in the MPC 68/68F canisters; (2) revising the burnup credit methodology for MPC-32 PWR fuel canister; (3) adding a new fuel basket, MPC-32s; and (4) revising the fuel burnup verification method for the MPC-32 spent fuel with the submittal of the report HI-2156611, Revision 1, "Burnup Credit for the MPC-32 with MCNP5 and CASMO5," July, 2017.

In the first requested change, the applicant proposed to change the thoria rod material composition from 98.2 weight percent (wt%) of ThO_2 and 1.8 wt% UO_2 to 98.5 wt% ThO_2 and 1.5% UO_2. The enrichment of U-235 in the UO_2 compound is at 93.5 wt%. This change is only applicable to the packages that ship the MPC-68 or MPC-68F canister containing the thoria rods.

In the second requested change, the applicant proposed to revise the code benchmarking analysis method to use the recommendation of ISG-8, Rev. 3, i.e., specifically, the use of 1.5% of the reactivity worth of the MAFPs, as the bias and bias uncertainty of the computer code and cross section used for criticality safety analyses, in lieu of performing explicit code benchmarking analyses using critical experiments.

The third requested change is to add the MPC-32s canister as an authorized content. The MPC-32s is essentially the same as the currently authorized MPC-32 canister except that it is 9 inches shorter and is designed specifically for the Diablo Canyon Nuclear Power Reactor fuels. The applicant provided drawings for the MPC-32s canister in the Diablo Canyon Enclosure Vessel Drawing 4459, Sheets 1-6, Rev. 14 and the Diablo Canyon MPC-32 Fuel Basket Drawing 4458, Sheets 1-3, Rev. 11.

The fourth requested change is the use of one of the two burnup verification methods, as recommended in ISG-8, Rev. 3 for the spent fuel to be loaded in the MPC-32 canister: (1) burnup verification through quantitative burnup measurement; or (2) burnup verification through an administrative procedure control of fuel selection supplemented with misloading analyses. The first method relies on actual physical measurement of fuel burnup for every fuel assembly to be loaded into the canister, whereas the second method relies on a positive verification of the fuel inventory in the pool based on reactor operating history data and misload analyses.

The criticality safety design of the package relies on favorable geometry, fixed neutron poisons, and administrative limits on the maximum allowable enrichment. The criticality safety design of the package containing the MPC-32 basket also relies on burnup credit that accounts for the reactivity reduction based on the net loss of fissile materials and accumulation of fission products and transuranic absorbers.

For the package containing the MPC-32 canister, the applicant took burnup credit in the criticality safety analyses. Based on the criticality safety analyses, the applicant determined the minimum required assembly average burnup as a function of initial enrichment.

Table 1.2.34 of the application provides the equations that the package user needs to determine the minimum required burnup for the fuel as a function of the maximum initial enrichment for all authorized fuel in the MPC-32. The fuel loading functions are also captured in Table C.7 and C.8 of Report HI-2156611 for fuel selection instructions during loading operations.

The staff reviewed the description of the package design and finds that the applicant has appropriately identified and adequately described the package design features that are important to criticality safety.

The engineering drawings and other information are sufficient for the staff to perform a safety evaluation. The results of the structural and thermal analyses demonstrate that the packaging design features important to criticality safety are not adversely affected by the tests prescribed in 10 CFR 71.71 and 71.73.

6.1.2 Summary Table of Criticality Evaluations

The applicant provided a summary of its criticality safety evaluation results in Table 6.1.4 of the application for the new basket design and revised thorium-uranium ratio. Table 6.1.4 includes results of the criticality safety analyses for a single package and arrays of undamaged and damaged packages that contain intact fuel, damaged fuel and/or fuel debris being transported in the HI-STAR 100 package. The maximum reactivity (k_{eff}) of all the packages is 0.9486, which corresponds to the package containing the MPC-68 canister loaded with the 9x9E or 9x9F class fuel assemblies.

The staff reviewed the applicant's summary table for criticality safety analyses for the package with the new contents, i.e., MPC-68, MPC-68F or MPC-32s. The staff finds that the results show that the package design meets the requirements of 10 CFR Part 71 for criticality safety, i.e., all values of k_{eff}, after being adjusted with uncertainty and biases, are below the acceptance criterion (i.e., $k_{eff} \leq 0.95$) set in the NUREG-1617. The staff also finds that the MPC-32s, a shorter version of MPC-32, is bounded by the criticality safety analyses for the MPC-32 canister because there is less fuel in the package containing the MPC-32s canister. For this reason, the rest of the SER does not provide separate discussions on the criticality safety of the MPC-32s. The discussions and conclusions on the safety evaluation of the MPC-32 are all applicable to the MPC-32s.

6.1.3 Criticality Safety Index

The applicant analyzed an infinite array of packages under normal conditions of transport and hypothetical accident conditions. The results showed that, in both cases, the k_{eff} values are below the acceptable limit, $k_{eff} < 0.95$, as set in NUREG-1617. Based on these results, the applicant determined that the Criticality Safety Index (CSI) is 0 for the HI-STAR 100 package loaded with the new contents.

6.2 Spent Nuclear Fuel Contents

The new authorized contents of this package include 18 irradiated thoria rods per package in an MPC-68 or MPC-68F canister. The thorium rods contains 98.5 wt.% ThO_2 and 1.5 wt. % UO_2. The enrichment of U-235 in the UO_2 compound is 93.5 wt%. The thorium rods are loaded in thorium rod container. The thorium rod container is a square stainless tube with 20 cells in a 4x5 array. However, only 18 irradiated thorium rods are loaded per container. Figure 1.2.11B of the application shows the geometric configuration and dimensions of the thoria rod container.

The new authorized contents also include the MPC-32s canister. The MPC-32s canister is designed specifically for the Diablo Canyon fuel with a 17x17 array configuration and 144 inches in active fuel length. The staff reviewed the description of the spent fuel contents and concludes that it provides adequate data and analyses for the staff to perform criticality safety evaluation, in accordance to NUREG-1617.

6.3 General Considerations for Criticality Safety Evaluations

6.3.1 Model Configuration

The applicant used the same general conservative assumptions and modeling methods, such as assumed flooded pellet to clad gap, omitting the impact limiters, as previously reviewed and approved package containing intact fuel, damaged fuel, and fuel debris in various canister designs. The criticality safety analyses conservatively credit only 75% of minimum B-10 content for the Boral fixed neutron absorber or 90% of minimum B-10 content for the Metamic fixed neutron absorber. This also is the same assumption as previously approved. For this reason, the staff did not perform a further detailed review on the model assumptions.

6.3.2 Material Properties

The applicant used the same material properties as those that were used in previous applications. The staff, therefore, did not perform further evaluations of the material properties for the new canister. However, the applicant revised the applications to include calculations of the U-233 content in the thoria rods as a result of irradiation of thorium in the reactor.

The staff reviewed the assumed conversion ratio (also known as breeding ratio, BR) used for determining the U-233 quantity in the thoria rods and finds it to be bounding based on the known BR in typical thorium cycle reactors.

However, the applicant did not take burnup credit for the BWR fuel and the thoria rod. It used unirradiated U-235 and U-233 that were produced by irradiation of thoria in the reactor in its criticality safety analysis models for packages containing the thoria rods. This is a significant conservatism because this assumption does not take into account of the net loss of the fissile materials and the accumulation of the fission products that are all neutron absorbers.

On this basis, the staff determines that the applicant's calculations of the fissile materials, including U-233, in the package are conservative and acceptable.

6.3.3 Computer Codes and Cross Section Libraries

The applicant used CASMO5 and 586 group cross section library that is derived from the ENDF/B-VII.0 cross section database "ENDF/B-VII.0 586 Group Neutron Data Library for CASMO-5 and CASMO-5M", SSP-07/402 Rev 5, to calculate the spent fuel composition that are used in burnup credit analyses.

The applicant used the three-dimensional continuous energy code Monte Carlo N-Particle MCNP5, "MCNP – A General Monte Carlo N-Particle Transport Code, Version 5," Los Alamos National Laboratory, LA-UR-03-1987, April 24, 2003 (Revised 2/1/2008), and ENDF/B-VII cross section library for the criticality analyses of the packages.

The staff finds that the codes and cross-section sets used in the analyses are appropriate for this application and fuel designs because the CASMO code is widely used in nuclear reactor safety analyses and MCNP5 and the cross section library have been well tested and widely used in national laboratories and the nuclear industry for criticality safety analyses. The MCNP code is also one of the acceptable codes identified in NUREG-1617 for criticality safety analysis.

On this basis, the staff determined that the computer codes and cross section libraries used by the applicant for criticality safety analyses for the revised U-233 contents of the thoria rods in the MPC-68 or MPC-68F are adequate and acceptable.

Since the computer codes and cross section libraries have been determined to be acceptable in the review of the HI-STAR 190 application for UO_2 fuel, the staff did not perform a further detailed review of the adequacy of the codes and the libraries for UO_2 fuel for this application.

6.3.4 Demonstration of Maximum reactivity

In the criticality safety analysis, the applicant used fuel and basket dimensions with the tolerance limits to maximize the k_{eff} , as done in previous amendment applications. These optimum conditions are: maximum active fuel length, maximum fuel pellet diameter, minimum cladding outer diameter, maximum cladding inner diameter, minimum guide tube thickness, maximum channel thickness, minimum cell pitch, minimum cell inner dimensions, and nominal cell wall thickness. All of these conditions will lead to an increase of reactivity. Table 6.1.2 and Table 6.1.3 show the bounding reactivity values for each fuel classes that are to be loaded in the MPC-68 or MPC-68F, respectively. For the package containing the MPC-68 canister, the maximum reactivity is 0.9486, which is the canister containing the class 9x9E or 9x9E fuel. For the package containing the MPC-68F canister, the maximum reactivity is 0.8021, which is the canister containing the class 6x6C fuel.

Table 6.1.7 of the application shows the bounding reactivity values for each fuel classes that are to be loaded in the MPC-32 canister. For the package containing the MPC-32 canister, the maximum reactivity is 0.9462, which is the canister containing the class 15x15D, 15x15E, 15x15F, or 15x15H fuel with an initial U-235 enrichment of 4.0 wt% at a burnup of 38.32 GWd/MTU.

The staff reviewed the applicant’s approach for search for the maximum reactivity and finds the methods used to identify the parameters values that maximize k_{eff} to be appropriate and the set of parameters used in the analyses to be acceptable in accordance to the guidance provided in NUREG-1617.

The staff notes that the calculated maximum reactivity of the package containing the MPC-32 cask is based on burnup credit. A detailed evaluation of the new burnup credit analysis, including the code benchmarking for MAFPs in particular, is documented in Section 6.3.5.2.2 of this SER.

6.3.5 Analysis Approaches

6.3.5.1 Analysis approach for BWR fuel package

The applicant performed criticality safety analyses for the package containing revised thoria and high enriched uranium rod in a MPC-68 and MPC-68F canister. Because these canisters contain irradiated thorium rods, the applicant analyzed the U-233 content using the output of the depletion analysis model. The applicant determined that the maximum conversion of thorium to U-233 with a conservative conversion ratio in comparison with the research result published by Carrall, “The effects of reactor irradiation on Thorium-Uranium alloy fuel plates,” Oak Ridge National Laboratory, August 23, 1955. The applicant then calculated the k_{eff} value of a package containing this calculated U-233 quantity with the rest as fresh UO_2 fuel.

The staff reviewed the applicant’s calculations of the U-233 content in the thoria rods and each canister and finds that the assumed conversion rate is very conservative based on the experimental results published by R. M. Carrall and the assumed burnup is consistent with the requested thoria rods.

On this basis, the staff determined that the approach used by the applicant for criticality safety analyses of the package containing the irradiated thoria rods, which contains the U-233 that is created by irradiation of the thorium in the thoria rod, is conservative and hence acceptable.

6.3.5.2 Analysis approaches for PWR fuel package

6.3.5.2.1 Analysis approaches for non-burnup credit PWR fuel package

The applicant performed criticality safety analyses for the packages containing the requested new PWR spent fuel canister types. The criticality safety of the HI-STAR 100 System does not rely on credit of: (1) fuel burnup; (2) fuel-related burnable absorbers; or (3) more than 75% of the manufacturer's minimum B-10 content for the fixed neutron absorber when subject to standard acceptance tests.

These are very conservative assumptions for a spent fuel transportation package design because these assumptions do not account for the reactivity reduction resulting from fuel irradiation. However, this conclusion does not apply to a package containing the MPC-32 canister which takes burnup credit.

6.3.5.2.2 Analysis approaches for burnup credit of MPC-32 PWR fuel package

The applicant states that the overall process of determined burnup credit for the package containing the MPC-32 remains essentially identical to the previously used method with the exception of how the biases of the criticality safety analysis code are determined. Furthermore, the applicant states that the safety analyses that are not impacted by the code version changes are not revised, since the results of the evaluations in the previous versions of the application remain applicable.

For the package containing the MPC-32 canister, the applicant revised its method for code benchmarking analysis for MAFPs. Instead of performing code benchmarking analyses using the critical experiments to determine the bias and bias uncertainty of the code in predicting the burnup credit of MAFPs, the applicant chose to use the recommendation provided in ISG-8, Rev. 3 for code benchmarking, which allows the users to use 1.5% of the reactivity worth of the MAFPs as the bias and bias uncertainty of the certain codes under certain conditions. For this reason, the staff did not review the parts that had been accepted in the previous review.

The staff's review focused on evaluation of the adequacy of using the recommendation for code benchmarking for burnup credit analysis of the MAFPs. Details of the staff's evaluation of the applicability of the recommendation of ISG-8, Rev. 3 to the HI-STAR 100 package containing the MPC-32 canister are discussed in Section 6.8 of this SER; Section 6.8 is dedicated to an evaluation of burnup credit analyses.

6.4 Single Package Evaluation

The applicant's criticality safety analyses remain the same as previously approved for the package containing all canister designs except the MPC-68 and MPC-68F. The applicant performed additional calculations for the revised thoria and U-235 contents in the MPC-68 or MPC-68F. Based on the criticality safety analysis of a single package under NCT or HAC, the applicant demonstrated that the MPC-68 package containing 5 wt% fresh fuel bounds the MPC-68 or MPC-68F that contains the thoria rods.

For the packages containing the MPC-32s, the applicant has demonstrated that the analysis for a single package is bounded by the package containing the MPC-32 canister under NCT or HAC. The results show that the k_{eff} values for all packages are below the acceptance criterion as specified in NUREG-1617, i.e., $k_{eff} \leq 0.95$. For the package containing the MPC-32 canister, the applicant revised the code benchmarking part of the MAFP burnup credit analyses; all other analyses remain the same. The revised loading curves in the form of burnup and enrichment equations are provided in Chapter 7 of the application.

The staff reviewed the applicant's analyses and the results presented in the application and finds that the applicant has demonstrated that a single package, containing either a MPC-32, MPC-32s, MPC-68 or MPC-68F, remains subcritical under either NCT or HAC. The maximum k_{eff} value is 0.9462 and 0.9486 for a package containing MPC-32 and MPC-68 canister respectively. The staff finds that this package meets the requirements of 10 CFR 71.55(b) based on the acceptance criterion provided in NUREG-1617, i.e., $k_{eff} \leq 0.95$.

6.5 Evaluation of Array of Packages under Normal Conditions of Transport

Based on the results of the criticality safety analysis of a single package under NCT, the applicant determined that the MPC-68 package containing 5 wt% fresh fuel bounds the MPC-68 or MPC-68F that contains the thoria rods. Therefore, the calculated k_{eff} of the array of packages containing the MPC-68 canister under NCT bounds the array of packages containing the MPC-68 or MPC-68F canister that includes thoria rods under NCT.

For the packages containing the MPC-32s, the analysis for an array of packages under NCT is bounded by the analysis of the array of packages containing the MPC-32 canister under NCT. For these reasons, the applicant chose to perform criticality safety for an array of packages using the bounding package design. All of the applicant's results show that the k_{eff} of an infinite array of packages below 0.95.

The staff reviewed the applicant's analyses and finds that the conclusions that the package MPC-68 containing UO_2 fuel with 5.0 wt% U-235 bounds the MPC-68 or MPC-68F canister containing thoria rods and the package containing the MPC-32 bounds the package containing the MPC-32s are acceptable for two reasons: (1) the quantity of U-235 and U-233 in the thoria rods is much less than the quantity of U-235 in a full BWR fuel assembly at 5 wt% U-235 enrichment, and (2) the MPC-32s contains 6% less fuel than the MPC-32 does, because the fuel in the MPC-32s is 9 inches shorter than the fuel in an MPC-32.

Based on its review, the staff finds that the assumptions used in the models are consistent with conditions of the package under the tests prescribed in 10 CFR 71.71 and the conclusion that an infinite array packages under NCT remains subcritical to be acceptable.

6.6 Evaluation of Array of Packages under Hypothetical Accident Conditions

Based on the safety analysis of single package under HAC, the applicant determined that the MPC-68 package containing 5 wt% fresh fuel bounds the MPC-68 or MPC-68F containing thoria rods. For the packages containing MPC-32s, the analysis for an array of packages under HAC is bounded by the analysis of the packages containing the MPC-32 canister under HAC. The applicant chose to use the bounding cases to perform safety analyses for the respective array of packages under HAC.

The applicant used these bounding package designs to develop models for arrays of packages under NCT and HAC. The applicant further demonstrated that an infinite array of packages under HAC remains subcritical with a maximum k_{eff} of 0.9450.

The staff reviewed the applicant's analyses and finds that the assumptions used in the models are consistent with damage conditions of the package under the tests prescribed in 10 CFR 71.73 and, therefore, are acceptable.

The applicant further calculated the Criticality Safety Index (CSI) following the method prescribed in 10 CFR 71.59. The result shows that the CSI of 0 is appropriate for the HI-STAR 100 with the canister containing the revised thoria rod parameters or the MPC-32s canister.

The staff reviewed the applicant's calculation of the CSI for the package and finds that the applicant followed the method as defined in 10 CFR 71.59 and the result is correct. On this basis, the staff finds that applicant has demonstrated that the package design meets the requirement of 10 CFR 71.59 and the CSI value of 0 is acceptable.

6.7 Computer Codes and Cross Section Library

The applicant used the MCNP 5.0 computer code and the ENDF/B-VII cross section library in its criticality safety analyses. Since this computer code and the cross section library are widely used in criticality safety analyses and MCNP is one of recommended computer code of the SRP, the staff finds them to meet the acceptance criteria and, therefore, to be acceptable.

In its burnup credit analyses for the package containing MPC-32, the applicant used data from the ENDF/B-VII cross section library. Since this cross section library is also widely used in criticality safety analyses and is one of most up to date cross section library, the staff finds that it meets the acceptance criteria of NUREG-1617 and, therefore, is acceptable.

6.8 Code Benchmark Evaluations

The applicant revised its code benchmarking analyses for the MAFPs for the package containing the MPC-32 canister. There is no other changes in the code benchmarking analyses and the results for the major actinides of the package. As such, the staff's evaluation of the code benchmarking analyses is limited to the new method for the MAFPs of the spent fuel contained in the MPC-32 canister. The staff did not perform any further review of the previously approved method and results.

The applicant revised the code benchmarking analyses with the recommendation of ISG-8, Rev. 3, which allows the applicant to use the bias (β_i) and bias uncertainty (Δk_i) values estimated in NUREG/CR-7108, in lieu of explicit code benchmarking and the estimated bias value is 1.5% of the reactivity worth of MAFPs under a set of specific conditions. Specifically, ISG-8, Rev. 3 states:

"In lieu of an explicit benchmarking analysis, the applicant may use the bias (β_i) and bias uncertainty (Δk_i) values estimated in NUREG/CR-7108 using the Monte Carlo uncertainty sampling method, as shown in Tables 3 and 4 below. These values may be used directly, provided that:

- the applicant uses the same depletion code and cross section library as was used in NUREG/CR-7108 (SCALE/TRITON and the ENDF/B-V or -VII cross section library),

- the applicant can justify that its design is similar to the hypothetical GBC-32 system design used as the basis for the NUREG/CR-7108 isotopic depletion validation, and credit is limited to the specific nuclides listed in Tables 1 and 2,

- the applicant demonstrates that the credited minor actinide and fission product worth is no greater than 0.1 in k_{eff}."

The staff reviewed the information presented in the application. The staff finds that the applicant used CASMO computer code to calculate the isotope concentrations of the spent fuel and the MCNP 5.0 computer code and ENDF/B-V cross section library to determine the k_{eff} of the package containing the MPC-32 canister.

The staff notes that the MPC-32 can contain up to 32 PWR fuel assemblies in 7 classes. These assembly classes include 15x15D, E, F, H and 17x17A, B, C fuel designs from Westinghouse Electric and B&W Company or other vendors with the same fuel specification. Other major differences include different poison plate types and B-10 areal densities, and different fuel lengths. For these reasons, the staff requested the applicant to provide information that demonstrates the similarity of the neutronic characteristics of the two packages, as required by ISG-8, Rev. 3 for using the recommendation because the intent of the ISG is to make the recommendations useful to a broad range of package designs that are different from the GBC-32 cask. In its response, the applicant provided comparisons of the H/X (moderator to fuel) ratio, EALF, neutron spectrum, and fission reaction rates between the GBC-32 cask and the HI-STAR 100 package containing MPC-32 canister loaded with 17x17 fuel assemblies. The comparisons show that there are fair similarities in most of these parameters. The applicant did not provide similar comparisons or justification for the applicability of the analyses to the package containing other fuel designs, i.e., 15x15. However, the staff determined that the H/X ratio between the 15x15 and 17x17 is very close.

The applicant did not take credit for Eu-151, which is one of the isotopes listed in ISG-8, Rev. 3. Since Eu-151 has a large absorption cross section, based on the calculated quantity of Eu-151 in the spent fuel, the staff finds that not taking credit for it in the burnup credit analysis for MAFPs would be sufficient to support use of the 1.5% of the reactivity worth the MAFPs as the bias and bias uncertainty of the code as analyzed in NUREG/CR-7109 "An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses—Criticality (keff) Predictions," Oak Ridge National Laboratory, Oak Ridge, TN, April 2012, and NUREG/CR-7205 "Bias Estimates Used in Lieu of Validation of Fission Products and Minor Actinides in MCNP Keff Calculations for PWR Burnup Credit Casks," Oak Ridge National Laboratory, Oak Ridge, TN, September 2015.

On this basis, the staff finds it acceptable to use 1.5% of the reactivity worth the MAFPs as the bias and bias uncertainty of the code in lieu of code benchmarking.

6.9 Confirmatory Analysis

The staff calculated the material composition of a WE17x17 fuel assembly with the ORIGEN/ARP computer code of the SCALE 6.1 computer code suite. The input parameters for fuel assembly is 4.0% U-235 enrichment, 40 GWd/MTU burnup and 5 year cooling time. The material composition is very close to that used in the MCNP input file provided by the applicant (Input file name = 7aahuf4040, Flat, Report HI-2156611).

The staff also examined the fuel qualification equations developed to determine the minimum burnup for a given fuel design, enrichment, and irradiation history. The staff finds that for a fuel assembly at an initial enrichment of 5 wt% U-235 and without any history of control rod or burnable poison rod insertion, the minimum burnup is 48.4 GWd/MTU. This is consistent with the results of the design basis burnup credit analysis (5 wt% U-235 and 50 GWd/MTU). The results confirmed that there is a reasonable assurance that the applicant's burnup credit analyses are reliable.

6.10 Burnup verification method

One of the requirements for applying burnup credit is to provide a mean to verify that the burnup of the selected fuel meets the required minimum burnup assumed in burnup credit analyses. In the proposed the new method for burnup verification, the applicant implemented the recommendation of ISG-8, Rev. 3, performed a misloading analysis to demonstrate that, even with accident misload, the cask remains subcritical. The applicant performed misload analyses for several scenarios and demonstrated the under these highly unlikely scenarios, the package remains subcritical. The staff evaluated the applicant's misload analysis method and results and finds that the applicant's misload analyses with a high confidence encompasses the possible misload scenarios. As such, the applicant's analyses meet the acceptance criteria of ISG-8, Rev. 3. On this basis, the staff finds the applicant's burnup verification method to be acceptable.

6.11 Evaluation Findings

The staff has reviewed the design description of and criticality analyses for the package. Based on its review of the application, the applicant's responses to the staff's requests for additional information, the staff finds that the HI-STAR 100 package containing the MPC-68 or MPC-68F canister with revised thoria and UO_2 content and enrichment, or the package containing MPC-32s canister for the Diablo Canyon Power Plant spent fuel, meets the regulatory requirements of 10 CFR 71.55 and 71.59. The staff also finds that the applicant's use of the 1.5% of the reactivity of the MAFPs as the bias and bias uncertainty of the MCNP code to be acceptable for this specific application This meets the acceptance criteria specified in the SRP.

6.12 Conclusions

The staff has reviewed the requested amendments to the HI-STAR 100 package. Based on the statements and representations in the application, as supplemented, and Revision 18 of the application, the staff concludes that the package with the requested changes continues to meet the requirements of 10 CFR Part 71.55 and 71.59 if the intact and damaged fuels meet the conditions defined in Interim Staff Guidance 1, Revision 2, and if the minimum fuel burnup is determined using one of the equations as presented in Table C.7 and C.8 of Report HI-2156611, "Burnup Credit for the MPC-32 with MCNP5 and CASMO5," Revision 1, Holtec, July 10, 2017.

7.0 PACKAGE OPERATIONS

The package operating procedures describe the general procedures for loading and unloading of the package. Changes were made to this Section to reflect the correction of editorial errors, updates to licensing drawings and revision numbers, and also clarification of procedure terminology.

Based on these findings, the staff concludes that the operating procedures both meet the requirements of 10 CFR Part 71 and are adequate to assure the package will be operated in a manner consistent with its evaluation for approval.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.1 Acceptance Tests

8.1.1 Weld Examinations

The applicant revised Sections 8.1.2 and 8.II.1.2, "Weld Examinations", to expand the discussion of the code and code-alternative welding requirements. The staff's evaluation of the welding examination criteria for the proposed Humboldt Bay and Diablo Canyon packages is documented in SER Section 2.3.2, "Weld Design and Examinations."

8.1.2 Impact Testing

The applicant revised the impact testing requirements for ferritic components in Table 8.1.6 to include an option to qualify the impact properties for a lowest service temperature (LST) of -40°F, rather than -20°F as required by 10 CFR 71.73 for accident conditions. The staff notes that this option was previously approved by the NRC for the HI-STAR 180 CoC 71-9325, HI-STAR 180D CoC 71-9367, and HI-STAR 190 CoC 71-9373.

When qualifying to -40°F, the applicant proposed to establish the required material nil ductility transition temperatures (T_{NDT}) with the "fracture initiation" criterion described in NUREG/CR-3826, "Recommendations for Protecting Against Failure by Brittle Fracture in Ferritic Steel Shipping Containers Greater than Four Inches Thick." As stated in Table 8.1.6, the use of this method requires the ferritic components to be volumetrically examined to verify that they do not contain flaws that exceed the criteria in the ASME Boiler and Pressure Vessel Code, Section XI, Table IWB-3510-1, "Allowable Planar Flaws." If cask operations experience impact loadings that exceed normal conditions of transport, re-examination is required.

The staff reviewed the proposed fracture toughness testing to ensure that the testing is capable of evaluating the toughness of ferritic steels under accident conditions at the LST of -20°F, as required by 10 CFR 71.73. The staff notes that the SAR requirements for qualifying the impact properties of ferritic steels to -20°F have not changed since the previously approved amendment to the HI-STAR 100 CoC. Thus, the staff's review focused on whether a material qualified to an LST of -40°F using the fracture initiation criterion to establish T_{NDT} would be acceptable to demonstrate performance at an LST of -20°F.

The staff finds the proposed testing for an LST of -40°F acceptable to meet the requirements of 10 CFR 71.73 because (1) if the fraction initiation criterion is used to define T_{NDT}, the applicant will perform 100 percent volumetric inspection of ferritic components to demonstrate that flaws exceeding a critical size are not present, (2) the volumetric inspections will be re-performed if the cask experiences loadings in excess of normal conditions of transport, and (3) using T_{NDT} test acceptance thresholds for -40°F provides additional margin to demonstrate reasonable assurance of performance at the required LST of -20°F.

8.1.3 Humboldt Bay GTCC Waste Canister Acceptance Tests

The GWC-HB canister is unique compared to the other canisters approved under the HI-STAR 100 CoC in that the canister is the containment boundary during transportation. The HI-STAR HB GTCC overpack does not include seals and is present only for shielding and structural protection of the canister. The following evaluation addresses the aspects of the GTCC package loading, closure, and testing that differ from the spent fuel packages that have been previously-approved under the CoC.

Section 8.II describes the acceptance tests to demonstrate the integrity of the GWC-HB containment boundary during normal conditions of transport and hypothetical accident conditions. After the GWC-HB is loaded in the spent fuel pool and the closure lid is welded, the canister is subjected to an ASME Code Section III, Subsection NB or ND pressure test to verify structural integrity. The staff finds the pressure testing per Subsection NB or ND acceptable because, as a Category II package, testing to either of these requirements is consistent with the guidance in NUREG/CR-3019, "Recommended Welding Criteria for Use in the Fabrication of Shipping Containers for Radioactive Materials." (NRC, 1984).

The GWC-HB subsequently undergoes forced helium dehydration in a manner identical to spent fuel canisters, and the GWC-HB is helium backfilled to 10-15 psig. The staff notes that this backfill pressure is bounded by the allowable pressures for the spent fuel canisters (0-48 psig) and similar to the allowable pressures in the spent fuel transportation overpacks (10-14 psig) approved under the HI-STAR 100 CoC.

To demonstrate the integrity of the containment boundary during transportation, all GWC-HB canisters are leakage tested, and, as discussed below, the containment boundaries of older canisters are inspected prior to shipment to ensure that no flaws exist that could compromise containment under HAC. The staff notes that this approach to demonstrate the integrity of the canister during transport is similar to that previously approved by the NRC staff for the transport of high burnup fuel in the Model No. HI-STAR 190 package (Docket No: 71-9373).

Within one year prior to package shipment, the complete GWC-HB containment boundary is leakage tested in accordance with ANSI N14.5-2014 to a rating of $1x10^{-2}$ cm^3/s air. Also, for any GWC-HBs stored at an ISFSI for more than 5 years under 10 CFR Part 72, the GWC-HB enclosure vessel must be inspected with eddy current techniques to verify the absence of age-related surface defects with greater than 2 mm depth. The applicant provided an evaluation to demonstrate that a GWC-HB with the maximum-allowable 2 mm deep flaw would be able to sustain HAC loads. Any flaw detected on the GWC-HB surface that exceeds the maximum-allowable depth shall not be accepted for transport.

The staff evaluated the proposed acceptance tests for the Humboldt Bay GTCC package and finds them to be acceptable because the combination of the ASME pressure test (general structural integrity of both the canister and overpack), leaking testing (canister containment verification following closure), and eddy current testing (absence of age-related flaws for canisters stored for greater than 5 years) supports the demonstration that the GTCC contents will be maintained within a containment boundary under NCT and HAC.

8.1.4 Diablo Canyon MPC-32 Acceptance Tests

Section 8.III states that the acceptance tests and maintenance for the HI-STAR 100 package with the Diablo Canyon MPC-32 are identical to those for the previously approved HI-STAR 100 CoC. However, the loading procedures of the Diablo Canyon MPC-32 canister that are stored under a Part 72 license before transport are governed by that license's safety analysis report (PG&E, 2016). The staff reviewed those loading procedures and did not identify any significant differences compared to those of the currently approved HI-STAR 100 transportation package; therefore, the staff finds them to be acceptable.

Sections 8.II.1.4 and 8.II.2.2 describe the fabrication, maintenance, and pre-shipment leakage tests for the GWC-HB containment boundary. Tables 8.II.2 and 8.II.3 indicate that the fabrication leakage rate test, which includes the shell, baseplate, shell welds, and shell-to-baseplate weld must satisfy a 1.25 10^{-6} ref-cm^3/s (air) leakage rate with a 0.625 10^{-6} ref-cm^3/sec

(air) sensitivity and follow ANSI N14.5-2014; this bounds the 2 10^{-2} atm-cm^3/sec (He) condition discussed above.

8.2 Leak Tests

For the HB-GTCC, a maintenance leakage rate test is to be performed for any part of the containment boundary that undergoes maintenance and must satisfy a 10^{-2} ref-cm^3/s (air) leakage rate with a 5 10^{-3} ref-cm^3/sec (air) sensitivity. A pre-shipment leakage rate test of the entire containment boundary (shell, baseplate, top closure assembly, shell welds, shell to baseplate weld, closure assembly welds) must satisfy a 10^{-2} ref-cm^3/s (air) leakage rate acceptance criterion with a 5 10^{-3} ref-cm^3/sec sensitivity prior to shipment. Table 8.II.5 of the application states that the pre-shipment leakage rate test will be performed following the loading of the GWC-HB (per Table 8.II.5, this test may be performed under the Part 72 docket) and prior to transport.

The GWC-HB, which is seal welded, is a one-time use system. Therefore, there is no periodic leak test but the pre-shipment leakage rate test would be repeated if transport does not occur within a year. The leakage rate testing of field welds performed under the 10 CFR 72 docket is not credited for transport. The leakage rate test procedures are to be approved by an ASNT Level III specialist and leakage rate testing is to be performed by personnel who is qualified and certified in accordance with the requirements in SNT-TC-1A. In addition, discussion of long-term maintenance and aging management of the GWC-HB canister in storage and subsequent transportation is provided in Section 8.A of the application, and in the materials section of the SER.

For the Diablo Canyon MPC-32, the leakage rate acceptance criterion is 2.15 10^{-6} ref cm^3/sec (air). Table 8.1.2 indicated that the fabrication, pre-shipment, maintenance, and periodic leakage rate tests are as defined by ANSI N14.5-2014. Section 8.1.4 indicated that leakage rate tests of the HI-STAR 100 package containment system will be performed per written and approved procedures in accordance with the requirements of ANSI N14.5-2014. The personnel approving leakage testing procedures will be qualified and, according to Section 8.1.4, will be approved by an ASNT Level III specialist. Leakage rate testing will be performed per written and approved procedures by qualified and certified personnel in accordance with the requirements of SNT-TC-1A. Likewise, Section 8.1.4 stated that leakage rate testing is performed in accordance with a written quality assurance program. In addition, discussion of long-term maintenance and aging management of the MPC in storage and subsequent transportation is provided in Section 8A of the application, and the materials section of the SER.

References

Holtec, Report No. HI-2033042, “Miscellaneous Calculations for the HI-STAR HB,” Revision 7, June 21, 2018.

Holtec, Position Paper DS-438, “Acceptable Flaw Size for MPC Transportability Inspection”, Revision 1, May 21, 2018b.

NRC, NUREG/CR-3019, “Recommended Welding Criteria for Use in the Fabrication of Shipping Containers for Radioactive Materials,” 1984.

NRC, Spent Fuel Project Office, Interim Staff Guidance – 11 (ISG-11), “Cladding Considerations for the Transportation and Storage of Spent Fuel,” Revision 3, November, 2003.

NRC, Regulatory Guide 7.9, “Standard Format and Content of Part 71 Applications for Approval of Packages for Radioactive Material,” Revision 2, March 2005.

NRC, Division of Spent Fuel Storage and Transportation Division, Interim Staff Guidance – 18 (ISG-18), "The Design and Testing of Lid Welds on Austenitic Stainless Steel Canisters as the Confinement Boundary for Spent Fuel Storage," Revision 1, October, 2008.

NRC, Safety Evaluation Report for the Model No. HI-STAR 190 Package, Revision 0, Docket No. 71-9373, 2017.

PG&E, Diablo Canyon Spent Fuel Storage Installation Final Safety Analysis Report Update, Revision 6, Docket No. 72-26, Pacific Gas and Electric Company, March 2016.

PG&E, Humboldt Bay Spent Fuel Storage Installation Final Safety Analysis Report Update, Revision 4, Docket No. 72-27, Pacific Gas and Electric Company, November 2013.

CONDITIONS

The conditions specified in the CoC have been revised to incorporate several changes as indicated below:

Item No. 3.a has been revised to identify the new address of Holtec International

Item No. 3.b and the references section have been revised to identify Holtec application, Revision No. 18, dated June 22, 2018.

Condition No. 5(a)(2) was completely rewritten for clarity.

Condition No. 5(a)(3) has been revised to include new drawings for the HI-STAR 100 Overpack, the MPC Enclosure Vessel, the MPC-24, 24E, 68/68F/68FF Fuel Baskets, the HI-STAR 100 Impact Limiters, the HI-STAR HB Overpack, the Diablo Canyon Enclosure Vessel and MPC-32 Fuel Basket, the MPC Spacer Ring the HI-STAR HB Overpack, the GWC-HB canister and the HB Impact Limiter.

Condition No. 5(b)(1)(a) has been revised to include the Diablo Canyon irradiated fuel as authorized contents.

Condition No. 5(b)(1)(b) has been added to include Humboldt Bay GTCC waste and reactor related waste as authorized contents.

Condition No. 5(b)(2)(a) has been revised to indicate the maximum number of fuel assemblies authorized for shipment in the MPCs.

Condition No. 5(b)(2)(b) has been added to indicate the maximum quantity of reactor-related hardware, the Co-60 maximum activity and specific activity, the process waste effective A2 value and specific activity, the post-irradiation minimum cooling time, and the maximum decay heat.

Condition No. 5(b)(3) has been added to indicate the maximum weights of the HI-STAR 100 with the various MPCs, of the HI-STAR 100 HB GTCC, and the maximum fissile material mass limit.

Condition No. 11 was modified to authorize continued use of Revision No. 9 of the certificate up until the expiration date.

The expiration date of the certificate was not modified.

CONCLUSION

Based on the statements and representations in the application, as supplemented, and the conditions listed above, the staff concludes that the Model HI-STAR 100 package design has been adequately described and evaluated and that these changes do not affect the ability of the package to meet the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9261, Revision No. 10, on October 16, 2018.