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

May 4, 2020

Mr. Luis Hinojosa
Corporate Adjunct Licensing Manager
Holtec International
1 Holtec Blvd
Camden, NJ 08104

SUBJECT: CERTIFICATE OF COMPLIANCE NO. 9325, REVISION NO. 3, FOR THE MODEL NO. HI-STAR 180 PACKAGE

Dear Mr. Hinojosa:

As requested by your application dated June 21, 2019, supplemented on January 16 and March 25, 2020, enclosed is Certificate of Compliance No. 9325, Revision No. 3, for the Model No. HI-STAR 180 package. Changes made to the enclosed certificate are indicated by vertical lines in the margin. The U.S. Nuclear Regulatory Commission 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* 173.471.

If you have any questions regarding this certificate, please contact Pierre Saverot of my staff at 301-415-7505.

Sincerely,

John B. McKirgan Digitally signed by John B. McKirgan Date: 2020.05.07 09:52:08 -04'00'

John B. McKirgan, Chief
Storage and Transportation Licensing Branch
Division of Fuel Management
Office of Nuclear Material Safety
and Safeguards

Docket No. 71-9325
EPID L-2019-LLA-0122

Enclosures:

1. Certificate of Compliance No. 9325, Rev. No. 3
2. Safety Evaluation Report

cc w/encls.: R. Boyle, Department of Transportation
J. Shuler, Department of Energy, c/o L. Gelder

SUBJECT: CERTIFICATE OF COMPLIANCE NO. 9325, REVISION NO. 3, FOR THE MODEL NO. HI-STAR 180 PACKAGE

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OFC	DFM	E	DFM	C	DFM		DFM	C	DFM	C	DFM	C
NAME	PSaverot		PKoch		JSolis		TAhn		CKenny		ASotomayor	
DATE	12/18/2019		03/10/2020		02/13/2019		02/25/2019		02/25/2019		11/27/2019	
OFC	DFM	C	DFM		DFM		DFM		DFM		DFM	
NAME	ABarto		MRahimi		YDiaz-Sanabria		KArmstrong		SFigueroa		JBMcKirgan	
DATE	02/25/2019		03/18/2020		04/24/2020		02/27/2020		04/03/2020		05/04/2020	

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SAFETY EVALUATION REPORT
Docket No. 71-9325
Model No. HI-STAR 180 Package
Certificate of Compliance No. 9325
Revision No. 3

SUMMARY

By letter dated June 19, 2019, Holtec International (Holtec or the applicant) submitted an amendment request for Certificate of Compliance (CoC) No. 9325 for the Model No. HI-STAR 180 package. The applicant also requested renewal of the CoC. On January 16, 2020, Holtec responded to staff's request for additional information letter dated October 30, 2019. The applicant submitted a revised application on March 25, 2020.

The applicant made several changes to the design of the packaging, including:

Adding separated spent fuel rods to the allowable contents of the package. The rods are inserted in quivers, positioned in specific peripheral cell locations of either the F-32 or F-37 basket.

Reducing the minimum cooling time of spent fuel assemblies from 3 years to 2 years and adding new MOX vectors to the allowable contents.

Developing a new Holtite-B Sourcebook with defined Holtite-B characteristics such as an increased minimum bulk density and a reduced minimum hydrogen density now specified as a limiting material property.

Designing engineered gaps for lead and Holtite components to ensure that their respective enclosures are not overstressed due to differential thermal expansion.

Modifying the design of the top and bottom trunnions by removing the trunnion threads and replacing them with an anti-rotation locking system. Increasing the bearing contact area between the trunnion and the flange to improve margins against local bearing failure.

Providing cyclic vacuum drying as an alternative to forced helium dehydration when a fuel cladding temperature limit of 400°C is required.

Adding a new material for the Inner Closure Lid Port Cover Bolts (Vent and Drain Ports), the Outer Closure Lid Bolts and the Outer Closure Lid Access Port Cover Bolt.

Using the latest edition of ANSI N14.5 (2014) for leak testing.

Revising the Metamic-HT sourcebook to introduce a fracture toughness program to replace the Charpy test program. Updating brittle fracture requirements for ferritic steel components.

Revising the thermal accident temperature limit for baseplate and closure flange to provide a temperature limit for structural accidents and another separate temperature limit for the fire accident.

Providing impact limiter crush material reference density range for type 1 and type 2 crush materials to replace the singular reference density value and adding a discussion on the temperature dependence of impact limiter crush material properties.

Replacing the seal design featuring an aluminum jacket with a seal design featuring a silver sealing liner.

Adding fuel spacers in the form of fuel shims to control the axial gap between a fuel assembly and the cask cavity length.

Based on the statements and representations in the application, and the conditions listed in the CoC, the U.S. Nuclear Regulatory Commission staff (the staff) concludes that the package meets the requirements of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 71.

EVALUATION

1.0 GENERAL INFORMATION

The Model No. HI-STAR 180 package is designed for transportation of undamaged irradiated Uranium Oxide (UO_2) and Mixed Oxide (MOX) fuel assemblies in baskets, or of individual UO_2 fuel rods in quivers. The outer diameter of the HI-STAR 180 packaging is approximately 2700 mm without impact limiters and approximately 3250 mm with impact limiters. The maximum gross weight of the loaded package is 140 Metric Tons.

Two interchangeable fuel basket models, designated F-32 and F-37, contain either 32 or 37 Pressurized Water Reactor (PWR) fuel assemblies respectively, in regionalized and uniform loading patterns. The minimum cooling time of spent fuel assemblies has been reduced from 3 years to 2 years and new MOX vectors were added to the allowable contents. The fuel basket, made of Metamic-HT both as a structural and neutron absorber material, features a honeycomb structure and flux traps between some, but not all, cells.

The applicant has added separated spent fuel rods to the allowable contents of the package: these rods are inserted in quivers (positioned in specific peripheral cell locations of either the F-32 or F-37 basket) which are hermetically sealed containers for leaking, broken, punctured or fragmented fuel rods.

The cylindrical steel shell containment system is welded to a bottom steel baseplate and a top steel forging machined to receive two independent steel closure lids, with each lid being individually designated as a containment boundary component. The outer surface of the the cask inner shell is buttressed with a monolithic shield cylinder for gamma and neutron shielding.

Each closure lid features a dual metallic self-energizing seal system designed to ensure its containment and moderator exclusion functions. For this package, the inner closure lid inner seal and the inner closure lid vent/drain port cover inner seals are the containment boundary components on the inner lid; the outer closure lid inner seal and the outer closure lid access port plug seal are the containment boundary components on the outer lid.

The Model No. HI-STAR 180 package is fitted with two impact limiters fabricated of aluminum honeycomb crush material completely enclosed by an all-welded austenitic stainless-steel skin. Both impact limiters are attached to the cask with 16 bolts. The design of the top and bottom trunnions includes now an anti-rotation locking system.

The packaging is constructed and assembled in accordance with the following Holtec International Drawings Numbers:

(a) HI-STAR 180 Cask	Drawing No. 4845, Sheets 1-7, Rev. 14
(b) F-37 Fuel Basket	Drawing No. 4847, Sheets 1-4, Rev. 9
(c) F-32 Fuel Basket	Drawing No. 4848, Sheets 1-4, Rev. 9
(d) HI-STAR 180 Impact Limiter	Drawing No. 5062, Sheets 1-5, Rev. 7

2.0 STRUCTURAL AND MATERIALS EVALUATION

The staff has reviewed the proposed changes to the Model No. HI-STAR 180 package to verify that the applicant has adequately evaluated the structural performance of the package and demonstrated that it meets the regulations of 10 CFR Part 71.

While the applicant has made numerous changes affecting the previously approved design, the staff's structural review focused primarily on those changes which impacted the structural performance of the package. These include changes to the design of the trunnions and the lifting analysis, the specifications of the impact limiters, the bolting analyses, the containment seal specifications, certain welds; the addition of the use of quivers, dummy fuel assemblies, and fuel shims; and changes affecting the structural integrity of the neutron shielding components.

2.1 Trunnion Design and Lifting Analysis

The applicant proposed a new design of the HI-STAR 180 lifting devices. The threads of the top and bottom trunnions have been replaced with an anti-rotation locking system and the bearing contact area between the trunnions and flanges has been increased. Holtec evaluated these changes as reported in Calculation 24 of the structural calculation package for the HI-STAR 180 transportation package, Holtec Report No. HI-2063552. This structural evaluation ensures the stresses in the trunnions meet the acceptance criteria of NUREG-0612.

The calculated stresses and safety factors for the trunnions are presented in Table 2.5.1 of the application. Drawing No. 4845 has been updated to reflect the new trunnion design. The analysis shows that the proposed trunnion design is sufficient to meet the structural requirements of 10 CFR 71.45(a).

2.2 Impact Limiters

The applicant proposed to include a range for the density of the crush material used in the HI-STAR 180 impact limiters to replace the single reference value previously reported in the application.

The application already contained a range for the material's crush strength, which is a related value. Holtec has conducted a sensitivity study, documented in the HI-STAR 180 Finite Element Analyses report, Holtec Report No. HI-2063584, and in the Holtec Report No. HI-2178010 which examines the results of finite element analyses of certain cask drops using different material densities for the impact limiter crush material. Holtec uses the study to support its assumption that changes in the density of the crush material have a negligible effect on the structural performance of the impact limiters.

The results of the study are presented in Section 2.7 of the application and the proposed density range is updated in Table 2.2.10. Based on the results of the structural analyses and the conclusions of the sensitivity study, the staff finds the proposed range for the density of the crush material used in the HI-STAR 180 impact limiters acceptable.

2.3 Bolting Analyses

The applicant proposed adding the option to repair cask bolt holes by installing threaded inserts in place of damaged bolt holes. As specified in Holtec Drawing No. 4845 and Chapter 8 of the application, the repaired fasteners, including the threaded inserts, are evaluated to ensure they meet the safety category and applicable stress limits used to qualify the original fastener.

The materials and testing are required to comply with the requirements of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code Section III, Division I, Subsection NB or Subsection NF, as applicable. Based on the repaired joint configuration meeting the requirements of the original, the staff finds the use threaded inserts to repair cask bolt holes acceptable.

The applicant has revised the evaluation of temperature changes on the preload of inner and outer closure lid bolts. This evaluation, reported in Calculation 12 of Holtec Report No. HI-2063552 and discussed in Section 2.7.4 of the application, shows there is little change in the bolt load from an increased temperature change. The evaluation demonstrates that there is no loss of seal integrity in either lid. Based on the results of the structural evaluation, the staff finds the preload of the inner and outer closure lid bolts to be sufficient to maintain positive closure under the revised temperature changes.

Holtec revised the preloads and torques for the Inner and Outer Closure Lid Bolts, the Inner Closure Lid Port Cover Plate Bolts, and the Outer Closure Lid Access Port Plug. The calculations in Holtec Report No. HI-2063552 have been revised to be fully compliant with the requirements of the design code, ASME B&PV Code Section III, Division I, Subsection NB. The revised calculations demonstrate that the design capacities of the bolts and port plug are greater than the corresponding loads under Normal Conditions of Transport (NCT) and Hazardous Accident Conditions (HAC). The revised calculations also demonstrate that the minimum bolt preloads are sufficient to maintain a compressive seal and that fatigue failure of the bolts is not credible. The application has been updated to include the preload results from the bolt calculations in Table 2.2.12. Based on the analysis in the structural calculations and a review of the calculations for consistency with the design code, the staff finds revised preloads and corresponding torques for the HI-STAR 180 containment boundary bolts to be acceptable.

2.4 Containments Seals

The applicant proposed changing the specifications for a containment boundary seal option. The seal design option with an aluminum jacket is changed to feature now a silver sealing liner. This change did not affect the inputs for any structural calculations. The staff finds that the change to the containment seal specifications does not impact the structural safety of the HI-STAR 180 package.

2.5 Welds

The applicant proposed removing a weld between the Bottom Ring Forging and Monolithic Shield Cylinder in Holtec Drawing No. 4845 to avoid potential fabrication issues. This weld is not credited in any structural analysis and, thus, is not necessary for the structural safety basis of the HI-STAR 180 package. Because the removal of this weld has no effect on the previously approved structural safety basis of the HI-STAR 180 package, the staff finds the removal of the weld between the Bottom Ring Forging and Monolithic Shield Cylinder acceptable.

The applicant revised the structural calculations and drawings for the HI-STAR 180 package to more accurately represent the Friction Stir Welds (FSWs) along the length of the exterior of the fuel basket corners. The revision changes the effective throat of these FSWs to a more accurate dimension that is less than full penetration. Holtec has updated the structural calculations in Holtec Report No. HI-2063552 to reflect the less than full penetration effective throat of the basket corner FSWs. The updated calculations also include an analysis of the FSWs considering a weld quality factor associated with a partial penetration, Type VI, single groove weld with visual examination per Table NG-3352-1 of the ASME B&PV Code. These calculations demonstrate that the welds meet the applicable stress limits. Holtec also revised the F-37 Basket drawing, Holtec Drawing No. 4847, and the F-32 Basket drawing, Holtec Drawing No. 4848, to reflect the more accurate effective throat of the FSWs.

Based on revisions to the basket drawings and the results of the updated structural calculations, the staff finds the revisions to the fuel basket corner FSWs acceptable.

2.6 Quivers, Dummy Fuel Assemblies, and Fuel Shims

Holtec proposed the addition of the use of quivers to contain damaged fuel in the F-32 and F-37 fuel baskets. As described in the application, the quiver is a hermetically sealed container for damaged fuel rods that have been removed from a fuel assembly. The quiver consists of a rectangular body cavity and a bolted-on lid. The external dimensions and weight of a loaded quiver emulate a PWR fuel assembly. The previously approved structural analyses of the HI-STAR 180 package are unaffected by the use of quivers because of the physical similarities between the loaded quivers and the fuel assemblies which were included in the previously approved analyses.

The quivers, themselves, have been designed for NCT and HAC. The structural capacity of a quiver is calculated in Revision 1 of Westinghouse Report SEA 18-001, "Structural Verification of 14x14 LTS PWR Quiver Design," which is incorporated in the application by reference. Table 2.2.14 of the application lists the structural characteristics of a quiver obtained from Westinghouse Report SEA 18-001. As discussed in Section 2.7 of the application, the design acceleration capacity of a loaded quiver is less than the maximum accelerations determined for the package, which are reported in Table 2.7.3A and 2.7.3B of the application. Based on the structural analysis of the quivers and their physical similarity to the fuel assemblies used in the previously accepted structural evaluations of the HI-STAR 180 package, the staff finds the use of quivers, as described in the HI-STAR 180 application, acceptable.

Holtec proposed allowing partial loading of the HI-STAR 180 casks and the addition of the use of dummy fuel assemblies. Holtec has performed calculations, reported in Calculation 29 of Holtec Report No. HI-2063552, to determine a minimum package weight for partially loaded HI-

STAR 180 casks, which would experience higher decelerations than a fully loaded package. From this calculation, Holtec is requiring a maximum number of empty basket cells derived from the minimum package weight, and is proposing to use dummy fuel assemblies as an option to achieve the maximum number of empty basket cells. As described in the application, dummy fuel assemblies are Not-Important-to-Safety weights made of stainless steel. Dummy fuel assemblies are fabricated to emulate the weight and exterior dimensions of a fuel assembly. Based on the calculation of the maximum number of empty basket cells and the description of the proposed dummy fuel assemblies, the staff finds the partial loading of the HI-STAR 180 cask and use of dummy fuel assemblies acceptable.

Holtec proposed to use fuel shims as spacers between the contents of a HI-STAR 180 package and the boundary of the cask cavity. Fuel shims are described as metallic compression elements used, if necessary, to minimize the clearance between the bottom of a fuel assembly and the inside of the closure lid. The applicant has performed an additional finite element analysis, reported in Holtec Report No. HI-2063584, to show that the peak deceleration and stress limits of the HI-STAR 180 package remain within the previously established structural design parameters.

Based on the use of fuel shims as a simple compressive shim, a detailed stress analysis of the fuel shims is not necessary. The staff concludes that the results from the additional finite element analysis are sufficient to demonstrate that the use of fuel shims is acceptable in the HI-STAR 180 package.

2.7 Shielding Components

The applicant proposed changes to the shielding of the package including the use of a new composition of the Holtite-B neutron shielding material. In support of this change to the package shielding, Holtec updated calculations in Holtec Report No. HI-2063552 for the differential thermal expansion of both the lead shielding components and Holtite shielding components and evaluated the structural components that form the cavity spaces to determine their allowable stresses. Holtec has also performed finite element analyses of the structural components surrounding the shielding material to support the calculations. Where the cavities are determined to be stressed by the differential thermal expansion of the enclosure shielding material, the updated calculations demonstrate that applicable stress limits will not be exceeded.

The updated calculations in Holtec Report No. HI-2063552 also determine the maximum allowable internal pressure for the neutron shielding enclosure cavities. Holtec has performed structural analyses to determine these maximum pressures for each Holtite-B enclosure that would ensure the plates and welds forming the cavities do not undergo plastic deformation. These analyses are reported in Calculation 27 of Holtec Report No. HI-2125252. The HI-STAR 180 package uses pressure relief devices in neutron shielding enclosure cavities which are set to ensure that the structural components and welds bounding the cavities are not overstressed by the buildup of internal pressure. Holtec describes the pressure relief devices and lists the maximum pressure at which the relief devices are to be set for the different Holtite-B enclosures in Note 17 of Holtec Drawing No. 4845. These set pressures are based on the maximum allowable pressures determined in Calculation 27.

Based on the structural analyses of the neutron shielding cavities and the requirements of the pressure relief devices in the licensing drawings, the staff finds the proposed structural changes supporting the use of a new composition of the Holtite-B neutron shielding material to be acceptable and sufficient to meet the requirements of 10 CFR 71.51(a).

2.8 Seal

The closure seals the applicant used previously are cladded, coated, plated with silver or aluminum for the best possible long-term performance. In this application, the applicant used silver plating only (Tables 4.A-1 to 4.A-4). Because the two plating materials have been optional, the staff finds the change acceptable.

The applicant provided conditions under which seal tests are performed. The conditions include HAC in temperature and impact. The applicant also numerically analyzed the seal integrity with LS-DYNA exercises. The staff determines the standard tests and model validations to be acceptable.

2.9 Weld and Brittle Fracture

The applicant made changes for Fracture Toughness Test Criteria (Dose Blocker Steel Parts, Table 2.1.10A) to remove the requirement to measure the Charpy absorbed energy with ASME B&PV Code Section II. Instead, the applicant adopted the requirements of ASME Section III, Subsection NF for the brittle fracture testing. The applicant provided the basis for this change: (1) the two materials specified are selected to provide a shielding function, not for pressure retaining in a structural function. The shielding material is also not connected to modify the pressure retaining structure; and (2) the NF test has a higher absorbed energy value (i.e., it is conservative) in the operational temperature range of this application. Therefore, the staff concludes the changes made to be acceptable.

The applicant also uses FSWs that provide less than full penetration, about 85% to 100% of the panel thickness to prevent the flow of Metamic HT material into the cell opening while welding the cell panels. Unlike traditional arc welding using a lower quality factor, the FSW process results in a fully formed weld which slightly exceeds the tool length. Therefore, the applicant utilizes the weld quality factor for a type III full penetration. The staff concludes the basis for using the weld quality factor for a type III full penetration to be acceptable.

The applicant clarified, after a question from the staff on the weld classification change from NITS to ITS, that the licensing drawing indicated that no changes were made for either NITS or ITS. Further, the applicant added a statement to avoid any confusion in the licensing drawing. The staff find the applicant’s clarification to be acceptable.

The staff asked about the use of lateral expansion in energy absorption. The applicant explained that the use of lateral expansion is an option included because that is the criteria used for qualification for materials under Section III, Subsection NF. The selection of absorbed energy and lateral expansion values used for acceptance are somewhat arbitrary since there is not a well-defined relationship between absorbed energy values or lateral expansion values and how much energy the piece could endure before failure. Since NF allows for the use of either value, the applicant wanted to be consistent with the Code in using the option for either acceptance criteria to be used. The staff find the rationales with flexible Code statements to be acceptable.

2-10 Quiver

The quiver is a damaged fuel container for individual fuel rods which have been removed from their assemblies. Fuel debris are loaded into quivers. The quiver maintains its contents (fuel rods) in an inert (helium filled) environment, thus precluding the risk of in-service corrosion of its contents. In response to a staff’s question on how the inert environment is maintained in a quiver to avoid corrosion, the applicant provided details of the quiver operational requirements in Table 7.1.5 of the application, including lid seal and tight, drain, dry, vacuum, and inert environment. The required pressure is measured. The staff finds the details the applicant added to be acceptable.

2-11 Fuel Impact Attenuator (FIA)

The FIA closes the gap between a stored fuel and the closure lid to eliminate axial rattling of fuel during transport. FIAs are optional and fuel shims may be used instead with a further elaboration on how the gap between fuel assemblies and the cask inner closure lid is controlled. The FIAs consist of stainless steel and/or nickel-based alloy components which are installed at the bottom of the fuel assembly. The applicant conducted an LS-DYNA model evaluation of the use of FIA. The staff determined the materials assumption for the standard numerical model evaluation to be acceptable.

2-12 Impact Limiter

Regarding the justifications on the density range limitation of impact limiter crush material, the applicant provided the reference density range limitations of impact limiter crush material for type 1 (higher density) and type 2 crush materials. The applicant stated that Holtec QI-2535 is not intended to be a supporting document. The applicant documented a sensitivity study to show that the change in the density of impact limiter crush material is inconsequential to the results in Sections 2.6 and 2.7 of the application. Therefore, the staff determines that the changes made are acceptable.

2-13 Metamic-HT

The applicant has revised the Metamic-HT sourcebook to introduce a fracture toughness program to study the crack propagation in the material assumed to contain flaws or defects. The licensing basis is Revision 14 of the sourcebook, where three samples satisfied the crack front uniformity requirements and were assigned as KJ1C. The applicant stated that these values provide comparable information about the fracture toughness of Metamic-HT material. Also, the applicant adopted density and specific heats, both bounded by the sourcebook. Therefore, the staff finds the use of Revision 14 of the sourcebook acceptable for Metamic-HT fracture toughness.

2-14 Holtite-B Hydrogen Content

Table 1.2.16 of the application presents the minimum hydrogen density of Holtite-B, specified as a limiting material property. This value is a critical characteristic for the shielding function, and based on the Holtite-B Sourcebook, Rev. 5. The staff has confirmed that the hydrogen content used does not modify the thermal and radiation stability (based on open literature information) of the material. Therefore, the staff determines the hydrogen content presented acceptable.

2-15 Bolt

In addition to the SB-637 bolt material, the applicant added SA-193 B7, SA-320 L7 and SA-564/705 630 (H1025) as permissible bolt material options for the outer closure lid per the licensing drawing package in Section 1.3, while SA-564/705 630 (H1025) is an optional bolt material for the inner closure lid. For assurance, the applicant imposed additional requirements which the NRC staff approved in the CoC HI STAR 180 (Tables 2.1.8 and 2.2.2). Therefore, the staff determines this addition acceptable.

2-16 Trunnion

The applicant added NUREG-0612 to ASME Code Section II for applicable codes and reference standard for the trunnions. Lifting trunnions are manufactured from a high strength alloy and designed in accordance with 10 CFR 71.45 and NUREG-0612 with loading testing performed in accordance with ANSI N14.6. The staff determines that the addition of NUREG-0612 acceptable because it supplements ASME Code Section II.

2-17 Aluminum Basket Shim Temperature Limit

The applicant corrected the normal condition temperature limit for the aluminum basket shims in Table 3.2.10 of the application. The applicant cited existing Table 2.2.9, which is consistent with the approved CoC. The staff determined the citing to be acceptable based on the literature data used by the staff in recent reviews of the applicant' submittals.

2.18 Evaluation Findings

Based on the review of the statements and representations in the application, the NRC staff concludes that the changes to the structural design have been adequately described and evaluated and that the package has adequate structural integrity to meet the requirements of 10 CFR Part 71. Most relevant to this amendment are the following findings:

- The staff reviewed the package structural design description and concludes that the contents of the application satisfy the requirements of 10 CFR 71.31(a)(1), (a)(2), and 10 CFR 71.33(a) and (b).
- The staff reviewed the structural codes and standards used in the package design and finds that they satisfy the requirements of 10 CFR 71.31(c).
- The staff reviewed the lifting system for the package and concludes that it satisfies the standards of 10 CFR 71.45(a) for lifting attachments.
- The staff reviewed the package closure system and the applicant's analysis for normal and accident pressure conditions and concludes that the containment system is securely closed by a positive fastening device and cannot be opened unintentionally or by a pressure that may arise within the package and therefore satisfies the requirements of 10 CFR 71.43(c) for positive closure.
- The staff reviewed the structural performance of the packaging under NCT prescribed in 10 CFR 71.71 and concludes that there will be no substantial reduction in the effectiveness of the packaging that would prevent it from satisfying the requirements of 10 CFR 71.51(a)(1).
- The staff reviewed the structural performance of the packaging under HAC conditions prescribed in 10 CFR 71.73 and concludes that there will be no substantial reduction in the effectiveness of the packaging that would prevent it from satisfying the requirements of 10 CFR 71.51(a)(2).

Regarding materials as proposed in the application, the applicant described the materials used in the transportation package in sufficient detail to support the staff's evaluation. The applicant has met the requirements of 10 CFR 71.31(c) and identified the applicable codes and standards for the design, fabrication, testing, and maintenance of the package and, in the absence of codes and standards, has adequately described controls for material qualification and fabrication. The staff has reviewed the package and concludes that the applicant has met the requirements of 10 CFR 71.43(f) and 10 CFR 71.51(a). The applicant demonstrated effective materials performance of packaging components under NCT and HAC. Based on the review of the statements and representations in the application, the staff concludes that the materials used in the transportation package design have been adequately described and evaluated and that the 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 180 transport 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.

Specifically, the amendment request includes the following changes that may affect the spent fuel package thermal performance:

1) Addition of quivers to the allowable contents for both F-32 and F-37 fuel baskets.
2) Use of enhanced Holtite-B properties and engineered gaps for lead and Holtite-B components.
3) Use of cyclic vacuum drying.
4) Correction of the basket shim temperature limit.
5) Revision of the containment base plate and containment closure flange temperature limit.
6) Use of partial cask loading and dummy fuel assemblies.
7) Providing impact limiter crush material reference density range for type 1 and type 2 crush materials and updating thermal conductivity value.
8) Revision of the containment seal options and specifications.

The applicant performed the necessary analyses and concluded the changes have a minor or no impact in the package thermal performance. In some cases, based on the thermal analysis results the applicant concluded that the previous analyses continue to be bounding.

3.1 Summary of Thermal Results

3.1.1 Summary Tables of Temperatures

The summary tables of the package component temperatures, i.e., Tables 3.1.1 and 3.1.3 of the application, were verified. The components include spent fuel cladding, spent fuel basket, containment shell, neutron shield, cask surface, impact limiters, primary closure lid, secondary closure lid, containment base plate, primary and secondary lid seals and aluminum basket shims. The temperatures are consistently presented throughout the application for NCT and HAC conditions. For HAC, the applicant presented the pre-fire, during-fire, and post-fire component temperatures. Except for the impact limiters the (structural integrity of the crush material is not relied on to comply with regulations during or after the fire accident) and neutron shield (during a fire, no reduction in the Holtite-B heat conduction effectiveness is assumed; during a post-fire cooldown, the conductivity of air is assumed), all components remain below their material property limits listed in Tables 3.2.10 to 3.2.12 of the application.

3.1.2 Summary Tables of Pressures in the Containment System

The summary tables of the containment pressure under NCT and HAC (i.e., Tables 3.1.2 and 3.1.4 of the application) were reviewed and found consistent with the pressures presented in the General Information, Structural Evaluation, and Containment Evaluation chapters of the application. These tables report the Maximum Normal Operating Pressure (MNOP) for NCT and pressure during HAC (fire).

3.2 Material Properties and Component Specifications

3.2.1 Material Properties

Except for updated thermal conductivity values for the impact limiter crush material, the proposed changes do not impact this section which was previously reviewed by the staff. Therefore, the previous evaluation continues to be acceptable to the staff and an evaluation is not required.

3.2.2 Technical Specifications of Components

The package materials and components are summarized in Chapter 2 and Chapter 3 of the application. These materials are required to be maintained below maximum pressure and temperature limits for safe operation. The staff reviewed and accepts these specifications.

3.2.3 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 in 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-B under NCT and the leaktightness of the closure lids through the use of metallic seals. Peak cladding temperature compliance for moderate and high burnup spent fuel is demonstrated.

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 design basis spent fuel cladding temperature 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.

3.3 Thermal Evaluation Methods

A detailed three dimensional (3-D) thermal model of the HI-STAR 180 system was developed by the applicant using FLUENT finite volume and ANSYS finite element codes. For NCT, the maximum bounding cladding temperature is obtained for the F-32 basket under the pattern A/B heat load. The steady-state analysis produces a maximum cladding temperature which is below the allowable limit of 400°C. For HAC, the analysis shows the maximum cladding temperature occurs during the post-fire cooldown which is below the allowable limit of 570°C for accident conditions with adequate of margin. The staff also reviewed all component temperature limits and maximum temperatures. All the maximum temperatures comply with the temperature limits for both normal conditions of transport and accident scenario.

3.4 Thermal Stresses

Thermal stresses are evaluated in Section 3.4.4 of the application. The applicant uses high conductivity materials to minimize temperature gradients and large fit-up gaps to allow unrestrained thermal expansion of the cask internals during NCT. The differential thermal expansion is evaluated in Section 7.4 of the Holtec Report No. HI-2073649 “Thermal Analysis for HI-STAR 180.” Basket-to-cavity radial and axial growths are evaluated based on the thermal expansion coefficients at the worst conditions. The evaluation results are presented in Table

3.4.2 of the application. For HAC fire conditions, the gap growth in the radial and axial directions is bounded by the NCT.

The methods presented are standard and the evaluation is done under the worst operating conditions (maximum temperature gradients to minimize gas gaps). The results show adequate margin to exclude any safety concern. The staff finds the evaluation methods acceptable.

3.5 Confirmatory Analyses

The staff reviewed the applicant's thermal models used in the analyses. The staff checked the code input in the calculation packages and confirmed that the proper material properties and boundary conditions are used. The engineering drawings were also consulted to verify that proper geometry dimensions were translated to the analysis model. The material properties presented in the application were reviewed to verify that they are appropriately referenced and used.

3.6 Evaluation of Accessible Surface Temperature

Under NCT, the package is designed and constructed such that the surface temperature is 105°C, with the design basis heat load and no solar insolation. This temperature is above 85°C specified in 10 CFR 71.43(g). According to Section 7.1.3 of the application, a personnel barrier is installed if the package surface temperature and the dose rates are within 10 CFR 71.43 and 10 CFR 71.47 requirements.

3.7 Thermal Evaluation under Normal Conditions of Transport

The applicant performs the thermal evaluation using the FLUENT Computational Fluid Dynamics (CFD) code: 3-D models were developed to analyze the F-32 and F-37 spent fuel baskets and various heat loading patterns, i.e., uniform and regionalized, were experimented to establish a bounding configuration.

The bounding configuration conservatively assumes high heat UO_2 fuel in the interior cells and high heat MOX in the Region 1 peripheral fuel locations. Inside a spent fuel cell, the detailed PWR spent fuel assembly is replaced with an equivalent square section characterized by an effective thermal conductivity in the planar and axial directions.

The temperature dependent thermal conductivities are obtained using a two-dimensional conduction-radiation ANSYS thermal model. The turbulent condition is satisfied based on the product of Grashof and Prandtl numbers and a temperature difference of about 10°F between the package surface and the ambient. Therefore, applicable turbulent heat transfer coefficient correlations are chosen to model the cask convective heat transfer to the ambient. For solar heating, the applicant used the 12-hour daytime insolation, as specified in 10 CFR 71, averaged over a 24-hour period to account for the dynamic time lag. A solar absorption coefficient of 1.0 is applied to the cask exterior surface.

The HI-STAR 180 package 3-D thermal model includes several features to conservatively predict the maximum temperature, e.g. a half-symmetric array of fuel storage cells, a uniform gap between the fuel rods in the basket cells, 3 mm helium gaps for shims-to-basket and shims-to-cavity, detailed 3-D components (i.e., neutron shield pockets, lids, base plates, impact limiters, etc.), no internal convection in cask cavity, and FLUENT discrete ordinates radiation model. The applicant also used an adequate number of cells to model the cask, particularly in the areas of high thermal resistance, i.e., spent fuel region and basket shims. The staff finds the approach acceptable.

3.7.1 Heat

Under a 38ºC (100°F) ambient temperature, still air, and solar heat, the applicant predicted the maximum temperatures of the fuel cladding, fuel basket, containment boundary and lid seals, and aluminum basket shim and neutron shielding. These temperatures are listed in Table 3.1.1 of the application. The staff confirms that these maximum temperatures are below the material temperature limits with a sufficient margin and finds them acceptable.

3.7.2 Cold

With no decay heat and an ambient temperature of -40°C (-40°F), the entire package approaches uniformly the steady-state ambient temperature. Cask components, including the seals, are not adversely affected by exposure to cold temperatures.

3.7.3 Maximum Normal Operating Pressure (MNOP)

The MNOP is determined by different sources of gases – initial backfill helium, water vapor, release of fission products, and spent fuel rod failures. Generation of flammable gas is not considered. 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 MNOP is 67.6 kPa (9.8 psia) for normal conditions and 89.6 kPa (13 psia) for 3% rod rupture. The MNOP is well below the containment design pressure of 552 kPa (80 psig), as reported in Table 2.1.1 of the application.

3.8 Thermal Evaluation for Short Term Operations

3.8.1 Time-to-Boil Limits

The applicant determined time limits for completion of wet operations upon removal of a loaded HI-STAR 180 package from the pool to prevent water boiling inside the HI-STAR 180 cavity. The applicant performed an adiabatic heat up using the combined thermal inertia of the package. Table 3.3.5 of the application provides a summary of the maximum allowable time limits at several representative pool initial temperatures.

To verify the time limits based on the adiabatic heat up approach, the applicant performed a CFD analysis using the design basis decay heat and the bounding heat load pattern. The applicant's CFD results confirmed that the approach outlined in the application is conservative.

Based on the application, the staff finds the applicant's approach for obtaining the time-to-boil limits acceptable for this package application.

3.8.2 Cask Drying

The application provides two methods for drying the cask cavity: a conventional vacuum drying (including cyclic vacuum drying) approach for packages containing moderate burnup assemblies only and forced helium dehydration (FHD) for packages with high burnup fuel.

Table 3.3.6 of the application presents the maximum fuel cladding temperature of 485ºC (905ºF), under vacuum drying operations, which is below the ISG-11 limit with adequate margin. The applicant's methodology for performing cyclic vacuum drying is summarized in Section

3.3.5 of the application. The applicant also provided a calculation using the F-32 basket based on the bounding heat load pattern described in the application. Analysis results are provided in the calculation package accompanying the application and the criteria to be consistent with ISG-11 are demonstrated.

The enhanced heat transfer occurring during operation of the FHD system ensures that the fuel cladding temperature will remain well below the peak cladding temperature under NCT, which is itself below the high burnup cladding temperature limit of 400ºC (752ºF) for all loading combinations authorized in the package. Thus, the fuel cladding temperature will remain below the ISG-11 limits for high burnup fuel.

The staff reviewed the applicant's approach to perform the thermal evaluation of the Model No. HI-STAR 180 package short-term operations and finds it acceptable.

3.9 Thermal Evaluation under Hypothetical Accident Conditions

The staff evaluated all proposed changes presented in Section 3.0 and applicant's justification providing reasons why the changes have minimal or no impact during accident conditions and found the changes and justification acceptable. Based on the review and evaluation, the staff concludes the proposed changes do not impact this section. Therefore, the previous evaluation continues to be acceptable to the staff and an evaluation is not required.

3.10 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 prepared for shipment, and found reasonable assurance that the temperatures comply with 10 CFR 71.43(g) for packages transported by exclusive-use vehicle. The staff reviewed the package preparations for shipment and found reasonable assurance 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 limits during hypothetical accident conditions, consistent with the tests specified in 10 CFR Part 71.73.

4.0 CONTAINMENT EVALUATION

The objective of the review is to verify that the Model No. HI-STAR 180 package containment design is adequately described and evaluated under NCT and HAC, as required per 10 CFR Part 71.

4.1 Description of the Containment System

The staff verified the containment boundary for the Model No. HI-STAR 180 package has changed from the previous CoC approval (ML14281A559); changes were made to the design of the seal options. Specifically, the applicant requested the revision of the containment boundary Technetics metallic seal design, "Option 2," with critical parameters for each of the containment boundary seals included in Appendix 4.A of the application.

The applicant proposed to change seal, "Option 2," to replace the seal design featuring an aluminum jacket with a seal design featuring a silver sealing liner. The applicant revised Note 41 of Drawing No. 4845 Rev. 13 to solely refer to Appendix 4.A and Table 2.2.12 which define critical characteristics of the new seal.

4.1.1 Technetics Seal, "Option 2"

The applicant introduced information in Appendix 4.A for the Technetics seal, "Option 2," new seal design, that includes:

i. the seal manufacturer,
ii. the part / drawing number,
iii. the seal and groove dimensions with tolerances,
iv. the seal seating load with tolerances,
v. the surface finish for sealing surfaces, and
vi. component materials for the spring, inner lining, and sealing lining.

The staff verified that the Technetics seal design, "Option 2," had been completely described both in Appendix 4.A and on the licensing drawings. The Technetics seal design included Nimonic-90 for the spring, 304L SS for the inner lining, and silver for the sealing lining. The Technetics seal, "Option 2," includes: the inner closure lid seals, the outer closure lid seals, the inner port cover seals, and the outer lid access port plug seal. The seals that are part of the containment boundary include: the inner closure lid inner seal, the outer closure lid inner seal, the vent and drain port cover inner seals, and the outer lid access port plug seal.

The staff reviewed the seal and groove dimensions presented in Appendix 4.A to verify the seals described would properly fit within the seal grooves as designed. The applicant presented revised seal temperature limits in Table 3.2.12 of the application in a response to the staff's request for supplemental information (RSI) 4-1 (ADAMS Accession No. ML19255F141).

Based on the staff's review of the Technetics Group and applicant's response to the staff's RSI 4-1, the staff finds the seal temperature limits to be acceptable. The staff concluded that there is no chemical, galvanic, or other reactions when using a silver jacketed seal material; therefore, based on the staff's review of the applicant's response to RSI 4-1, the staff finds the use of the silver jacketed seal material to be acceptable.

The applicant described, in Table 8.1.1 of the application, the seal acceptance criterion as leaktight, which is defined as a leakage rate of no greater than $1x10^{-7}$ reference cubic centimeter per second (ref-cm^3/s) of air, in accordance with American National Standards Institute (ANSI) N14.5, "American National Standard for Radioactive Materials – Leakage Tests on Packages for Shipment." The applicant also addressed in Section 2.2.1.1.6 of the application that the seal assembly springback is a critical parameter that provides for maintaining the leaktight acceptance criterion and protection from degradation, which the staff verified had not changed.

Similarly, the seal seating load for the Technetics seal, "Option 2," inner and outer closure lid seals, remains bounded by the seating load for seal, "Option 1," which was shown in Appendix E of Holtec Report No. HI-2063584, and therefore the staff finds this acceptable.

The seal seating loads for the Technetics seal, "Option 2," inner port cover seal and outer lid access port plug seal were revised, as described in Tables 4.A-3 and 4.A-4 of the application, and the staff verified the bounding value was used in Calculation 21 of Holtec Report No. HI-2063552, to demonstrate that the minimum total bolt preload in Table 7.1.1 of the application is adequate.

The staff verified these parameters are provided in Table 2.2.12 of the application and referenced in Appendix 4.A of the application. The staff also verified that Appendix 4.A is incorporated by reference on the licensing drawings. Therefore, based on the staff's review of the seal design changes, the staff finds the seal design changes acceptable.

4.1.2 Containment Boundary

The containment boundary includes the: containment shell, containment baseplate, the containment closure flange, inner closure lid, inner closure lid inner metallic seal, outer closure lid, outer closure lid inner metallic seal, inner closure lid port covers (vent and drain), inner closure lid port covers (vent and drain) inner metallic seals, outer closure lid access port plug, outer closure lid access port plug seal, and associated welds and closure bolts.

The staff verified that all the containment system components are shown in the licensing drawings. The staff verified containment system component information presented in the drawings is consistent with the information presented in the Structural and Thermal Evaluation sections of the application. The staff finds that the applicant has adequately demonstrated, in Section 4.1.4 of the application, that the containment system for the HI-STAR 180 package cannot be opened unintentionally or by an internal pressure within the package and therefore, the requirement in 10 CFR 71.43(c) is met.

The American Seal & Engineering metallic seal, "Option 1," critical parameters for each of the containment boundary seals have also been included in Appendix 4.A and have been previously approved; there are no changes to seal, "Option 1." The two seal designs described in Appendix 4.A of the application are each unique designs and other seal designs cannot be used, neither can seal field changes be made for the Model No. HI-STAR 180 package without prior approval from the NRC because containment boundary seals are important to safety components and modifying an important to safety component would result in an unanalyzed condition.

4.2 Containment Under NCT

Under NCT, the containment system of the package is designed to be leaktight as defined in ANSI N14.5-2014, i.e., there is no leakage greater than 1×10^{-7} ref-cm^3/s of air with a test sensitivity of 5×10^{-8} ref-cm^3/s of air, as described in Table 8.1.1 of the application. The staff verified the applicant provided a definition of leaktight in the glossary of the application and it was consistent with the definition in ANSI N14.5-2014.

The staff verified that the thermal and structural evaluations, presented in the application, demonstrate that there is no release of radioactive material under NCT.

The seal temperature limit for NCT specified in Table 3.2.12 of the SAR is revised from 371ºC to 200 ºC. The applicant provided, and staff reviewed, additional information from the seal manufacturer that demonstrated the physical characteristics of the seal were appropriate for the intended application during transportation. Staff finds the thermal safety analysis remains unaffected and the lid seal temperature remains below the maximum allowable temperature limit.

The applicant stated, in Section 3.3.2 and Table 3.1.2 of the application, that the maximum normal operating pressure (MNOP) of the HI-STAR 180 is 89.6 kPa with 3 percent rod rupture. This is lower than the design internal pressure for the cavity space of 552 kPa, which is provided in Table 2.1.1 of the application; therefore, the staff finds the MNOP to be acceptable.

In Table 3.1.2 of the application, the applicant demonstrated that the pressure in the inter-lid space is 163.4 kPa absolute, which is equal to the cask inter-lid space maximum operating pressure of 62 kPa gauge which is also provided in Table 2.1.1 of the application; therefore, the staff finds the cask inter-lid space pressure to be acceptable.

The applicant reported the maximum NCT temperatures for the containment shell, inner closure lid, outer closure lid, containment baseplate, and inner and outer lid seals in Table 3.1.1 of the application. The staff confirmed that the NCT containment boundary NCT temperatures do not exceed the temperature limits presented in Tables 3.2.10 and 3.2.12 of the application; therefore, the staff finds the containment boundary temperatures acceptable.

In Section 2.6.1.4.2 of the application, the applicant summarized that the containment boundary seals, which includes the closure lid seals and the vent and drain port cover seals, do not unload beyond the minimum force required to maintain leaktight conditions during NCT. Additional sealing critical parameters, i.e., “Containment Boundary Bolted Joint Data,” are included in Table 2.2.12 of the application and incorporated in the CoC by reference.

The staff finds that this proposed change in seal design has no impact on the structural safety analysis since the critical characteristics of the revised option, such as seating load, does not change the inputs used in the structural analysis. The staff concludes that the results of the structural and thermal analyses, as well as the proposed leakage rate testing, conducted during fabrication to the ANSI N14.5 containment leaktight acceptance criterion and before every shipment to the ANSI N14.5 containment leaktight acceptance criterion, demonstrates compliance with 10 CFR 71.51(a)(1) and the safety case remains unaffected due to the change in seal design, “Option 2.”

4.3 Containment Under HAC

As described in Table 8.1.1 of the application, the containment system of the package is designed to be leaktight as defined in ANSI N14.5-2014 under HAC of transport. The staff verified that the thermal and structural evaluations demonstrate no expected release of radioactive material under HAC.

In Section 2.7.8 of the application, the applicant concluded that both lids will maintain a positive contact load at their interface after each hypothetical accident event, which indicates that both the primary and secondary lid seals will remain functional to contain radioactive material. The applicant summarized, in the same section, that the sealing function is maintained at the end of each accident event and at the end of the HAC sequence and demonstrated that the bolted joint performance average service stress during the fire event for the inner and outer closure lids remain below the allowable stresses. Further, the applicant stated that the inner closure lid port cover bolt torque requirement was sufficient to maintain closure under HAC.

The applicant reported, in Table 3.1.4 of the application, that the maximum cavity accident pressure, with assumed 100 percent fuel rod rupture, is 883.7 kPa absolute, which bounds the inter-lid pressure and is lower than the accident condition internal pressure (design pressure limit) of 963.3 kPa absolute, provided in Table 2.1.1 of the application; therefore, the staff finds the maximum cavity accident pressure to be acceptable.

Table 3.1.3 of the application lists the maximum HAC temperatures calculated by the applicant for the containment shell, inner closure lid, outer closure lid, containment baseplate, and inner and outer lid seals and the staff confirmed that the reported HAC temperatures do not exceed the temperature limits presented in Tables 3.2.10 and 3.2.12 of the application; therefore, the staff finds the containment boundary temperatures for HAC acceptable. In Section 2.7.4 of the application, the applicant summarized that the fire event, which occurs after either the 9-meter drop accident or a puncture event, does not lead to loss of seal integrity in either lid.

The staff concludes that the results of the structural and thermal analyses, as well as the proposed leakage rate testing to the ANSI N14.5 containment leaktight acceptance criterion, demonstrates compliance with 10 CFR 71.51(a)(2).

4.4 Leakage Rate Tests for Type B Packages

The applicant adopted the latest edition of ANSI N14.5 (2014). There is no containment analysis associated with the HI-STAR 180 application, and leak testing shall be performed per the 2014 edition of ANSI N14.5. The applicant included information from the 2014 edition of ANSI N14.5 into the application, which include new definitions and updated guidance on package design considerations, leak testing, and quality assurance. The applicant's definition of leaktight in the application aligned with the definition from ANSI N14.5-2014 and the applicant specified an American Society of Nondestructive Testing (ASNT) Nondestructive Testing (NDT) Level III leak testing specialist will be used to write and approve leak testing procedures, as described in ANSI N14.5-2014.

The applicant described, in Sections 8.1.4 and 8.2.2 of the application, that leakage rate testing shall be performed by personnel who are qualified and certified in accordance with ASNT Recommended Practice No. SNT-TC-1A, "Personnel Qualification and Certification in Nondestructive Testing," the 2006 edition as cited in reference 8.1.2 of the application. The staff finds this to be acceptable based on its review of ANSI N14.5-2014.

The staff finds that these changes associated with the new edition of ANSI N14.5 do not change the cask design, and incorporates guidance for including leak testing expertise during the development and performance of leak test procedures.

The applicant also proposed to revise the conversion factor from air reference conditions to helium reference conditions from a factor of 2 to a factor of 1.85 to be consistent with ANSI N14.5-2014. The staff verified that multiplying the leakage rate acceptance criterion and leakage rate test sensitivity when using air as a tracer gas by a factor of 1.85 when using helium as a tracer gas as specified in Note 1 of Table 8.1.1 of the application, is acceptable.

The staff finds that these proposed changes update the SAR to be consistent with the latest edition of ANSI N14.5, and have been carried out appropriately throughout the SAR, including in the glossary, and Chapters 1, 4, 7, and 8.

The staff verified that fabrication, pre-shipment, maintenance, and periodic leakage rate tests are performed on all containment components and seals and the associated the allowable leakage rates and test sensitivities as stated and described in Table 8.1.2 of the application.

The staff verified that Condition 6(a) of the Certificate of Compliance (CoC) states, "The package shall be prepared for shipment and operated in accordance with Chapter 7 of the application." The staff also verified that Condition 6(b) of the CoC states, "The package shall meet the acceptance tests and be maintained in accordance with Chapter 8 of the application." These two conditions of the CoC are necessary to ensure that all portions of Chapters 7 and 8 of the application are complied with. The staff ensured that the language in Chapters 7 and 8 of the application was consistent with these two conditions of the CoC; therefore, any changes to Chapters 7 and 8 of the application necessitate the NRC's approval.

The staff concludes the fabrication, pre-shipment, periodic, and maintenance leakage rate tests verify the integrity of the containment boundary, and that the containment components will maintain their leaktight containment function during transport operations. The staff concludes the leakage rate tests are consistent with the guidelines of ANSI N14.5-2014.

4.5 Evaluation Findings

4.5.1 Description of Containment System

The staff has reviewed the description and evaluation of the containment system and concludes that:

i. the application identifies established codes and standards for the containment system;

ii. the package includes a containment system securely closed by a positive fastening device that cannot be opened unintentionally or by a pressure that may arise within the package during transport;

iii. the package is made of materials and construction that assure that there will be no significant chemical, galvanic, or other reaction.

4.5.2 Containment under Normal Conditions of Transport

The staff has reviewed the evaluation of the containment system under normal conditions of transport and concludes that the package is designed, constructed, and prepared for shipment so that under the tests specified in 10 CFR 71.71 (normal conditions of transport) 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.

4.5.3 Containment under Hypothetical Accident Conditions

The staff has reviewed the evaluation of the containment system under hypothetical accident conditions 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.

In summary, the staff has reviewed the Containment Evaluation section of the SAR and concludes that the package has been described and evaluated to demonstrate that it satisfies the containment requirements of 10 CFR Part 71, and that the package meets the containment criteria of ANSI N14.5-2014.

5.0 SHIELDING EVALUATION

The objective of the review is to verify that the shielding design of the Model No. HI-STAR 180 package provides adequate protection against direct radiation from its contents and that the package design meets the external radiation limits of 10 CFR Part 71 under NCT and HAC. The applicant has made a number of significant changes directly related to shielding, including the:

- Addition of quivers to the allowable contents for both F-32 and F-37 fuel baskets.
- Reduction of the minimum cooling time of spent fuel assemblies from 3 to 2 years.
- Addition of new MOX Vectors to the allowable contents.
- Modification of Holtite-B Properties.
- Specification of minimum hydrogen density of Holtite-B.
- Partial Cask Loading and Dummy Fuel Assemblies

5.1 Shielding Evaluation

5.1.1 Addition of quivers to the allowable contents for both the F-32 and F-37 fuel baskets.

The transport of separated fuel rods within the package requires a container, called “quiver”, to store loose spent fuel rods. The applicant has provided general information such as nominal width, maximum length, maximum loaded quiver weight, maximum allowable quiver weight, material of construction for a quiver, as shown in Figure 1.2.5 of the application.

The maximum quiver heat load is set in accordance with the basket cell heat loads in Table 1.2.8 and Table 1.2.9 of the application. Up to two quivers, each containing up to 48 fuel rods, are allowed in cell locations 1 and 32, or 10 and 23.

The staff reviewed the description of the quiver in Section 5.4.7 of the application and confirmed that the dose rates from a package loaded with quivers are less than the dose rates of the cask loaded with design basis undamaged fuel assemblies.

5.1.2 Reduction of the minimum cooling time of spent fuel assemblies from 3 years to 2 years

The applicant stated that the allowable burnup and cooling time combinations for transportation were determined by calculating the resulting dose rates for various combinations and comparing the calculated dose rates to the regulatory limits for transportation specified in Section 4 of Report HI-2073655R13. Burnup and cooling time combination were considered acceptable if the calculated dose rates were less than the regulatory limits.

Also, the applicant analyzed the regionalized loading patterns to allow for the placement of both MOX and UO2 fuel assemblies within the F-32 and F-37 baskets. Regions for the F-32 and F-37 baskets were identified in Figure 1 and Figure 2 of the Report Hi-2073655R13. According to the applicant, for each basket, several loading patterns are defined.

The applicant analyzed two bounding cases to demonstrate compliance with the regulations:

- The maximum burnups of all equivalent loading conditions in a loading pattern, together with each corresponding cooling time, to maximize the neutron source terms in the basket, thus resulting in bounding dose rates at the locations that are more neutron dominated.

- The condition with the minimum cooling times for all equivalent loading conditions, together with each corresponding burnup, to maximize the gamma source term in the basket, thus resulting in bounding dose rates at the locations that are more gamma dominated.

Total dose rates on the surface of the HI-STAR 180 Package for NCT, with the F-32 or F-37 baskets, are presented in Tables 5.4.2 of the application. Table 5.4.3 of the application shows total dose rates at 2 meters from the package for NCT with the F-32 or F-37 baskets. Table 5.4.5 of the application shows the total dose rates at one meter from the package under HAC. Table 5.4.6 shows the total dose rates at one meter from the HI-STAR 180 package for hypothetical fuel reconfiguration.

For each basket, several loading patterns are defined in Subsection 1.2.2 of the application. These loading patterns allow flexibility in loading the cask, while at the same time ensuring that the regulatory dose rate limits are met. For each of the loading patterns A, B and C, the burnup, cooling time and location of the MOX assembly from the loading plan is modeled. The remaining UO_2 assemblies are always modeled with a bounding burnup and cooling time. Table 5.4.7 shows the bounding scenarios with maximum burnup and minimum cooling time combinations for the F-37 basket with loading pattern B. Table 5.4.8 of the application shows dose rates values for NCT and HAC for bounding scenarios with maximum burnup and minimum cooling time combinations for the F-37 basket, loading pattern B.

The staff performed confirmatory analyzes for source terms using ORIGEN-ARP code and found the source terms calculated by the applicant are similar to the staff's calculated values. The staff reviewed the maximum dose rates for both NCT and HAC and determined that reducing the minimum cooling time from 3 years to 2 years, the dose rates will not exceed the regulatory limits in 10 CFR 71.47 and 71.51(a)(2).

5.1.3 - Addition of new MOX Vectors to allowable contents.

The applicant states that a significant number of conservative assumptions are applied throughout the shielding calculations. These assumptions will ensure that the actual dose rates will always be below the calculated dose rates, and below the regulatory limits. For MOX fuel, these assumptions are:

1. In the source term calculation for the MOX assemblies, an infinite array of MOX assemblies in the core is assumed. A more realistic configuration where UO_2 assemblies surround MOX assemblies would result in lower source terms.

2. For normal conditions, the axial profile of the neutron sources for both UO_2 and MOX assemblies is based on the UO_2 behavior, i.e. for the source strength increasing with the burnup to the power of 4.2. This is conservative for MOX assemblies, since their source term only increases with the burnup to the power of about 1.7.

According to the applicant, for the MOX assemblies, four limiting isotope vectors are specified in Section 5.2 of the application. Dose rate comparisons for cases with different MOX vectors show that the dose rates from MOX vectors MV1 and MV4 are essentially the same, while dose rates from the MOX vectors MV2 and MV3 are lower. Therefore, all calculations were performed using MOX vector MV1.

The staff reviewed the burnup vs cooling times section described in HI-2073555 Report, “Shielding Analysis for he HI-STAR 180”. The applicant determined the allowable burnup and cooling time combinations for the allowable spent fuel contents of the package by calculating the resulting dose rates for various combinations and comparing the calculated dose rates to the regulatory limits specified in 10 CFR 71.

The applicant stated that If the calculated limits were less than the limits, the burnup and cooling time combination was considered acceptable. Regionalized loading patterns were analyzed to allow for the placement of both MOX and UO_2 fuel assemblies within the F-32 or F-37 baskets. Figures 1 and 2 of the Report HI-2073655, identify regions 1 through 8 of the F-32 and F-37 baskets.

The staff reviewed the shielding analysis and the calculations for source terms for the HI-STAR 180 package and found them acceptable based on the dose rates results presented in the application.

5.1.4 Enhanced Holtite-B Properties

In Section 5.1.1, the applicant states that the main neutron shielding is provided by the Holtite-B neutron shield embedded in the cask body and inner lid. The staff evaluated the characteristics of the Holtite-B presented in HI-2167314 Report, “HOLTITE-B SOURCEBOOK.”

The staff found that Holtite-B may experience some minor long-term weight loss from exposure to the temperatures; however, the applicant considered these situations in the model by utilizing a reduced density for the material, and a composition that is adjusted for the weight loss.

The composition of Holtite is also updated considering the weight loss is only applied to the Nylon-66 portion of Holtite-B; 3) the minimum Holtite-B mass in the modeled MSC Holtite-B cavity thickness is used. For Holtite-B in the baseplate and lid, the minimum Holtite-B mass is considered; 4) Holtite-B items are modeled with no gaps, but with reduced densities.

The staff reviewed the material composition of the Holtite-B neutron shield materials, as described in HI-2167314 Report, and found them acceptable based on the fact that the improved Holtite-B composition provides shielding capabilities for high and low burnup fuel contents. Also, the Holtite positions within the monolithic cylinders are offset to minimize any streaming through the side of the cask.

Based on previous analyses performed by the staff, using dummy rods reduced the source terms and therefore the dose rates is bounded by the design basis fuel content. Thus, the staff found that the addition of dummy rods in fuel assemblies does not impact the dose rates of the package.

The staff reviewed the description of the changes for the HI-STAR 180 package related to shielding and the source terms for the design basis fuel and found them acceptable.

5.2 Shielding Evaluation

The MCNP-4A code, a continuous energy, three-dimensional, coupled neutron-photon-electron Monte Carlo transport code, is used for all of the shielding analyses, including for the addition of quivers to the allowable contents, the reduction of the minimum cooling time from 3 years to 2 years, the addition of new MOX Vectors to allowable contents, the revised Holtite-B properties, and the specification of minimum hydrogen density of Holtite-B and partial cask loading and dummy fuel assemblies for the F37 and F-32 baskets. The calculated energy dependent source term is used explicitly represented in the MCNP model, but separate calculations are performed for each of the three source terms (i.e., decay gamma, neutron (including subcriticality multiplication), and Co^{60}).

The total dose rates on the surface of the HI-STAR 180 Package under NCT with the F-32 or F-37 baskets are presented in Tables 5.4.2 of the application. Table 5.4.3 of the application shows total dose rates at 2 meters from the HI-STAR 180 package under NCT with the F-32 or F-37 baskets. Table 5.4.5 of the application shows the total dose rates at one meter from the HI-STAR 180 package under HAC.

Table 5.4.6 shows the total dose rates at one meter from the HI-STAR 180 package with hypothetical fuel reconfiguration. Table 5.4.7 shows the bounding scenarios with maximum burnup and minimum cooling time combinations for the F-37 basket with loading pattern B. Table 5.4.8 of the application shows dose rate values for package under NCT and HAC for bounding scenarios with maximum burnup and minimum cooling time combinations for the F-37 basket, loading pattern B.

Dose rates are calculated using a two-step process: the dose rate is first calculated for each location for each energy group per particle, then the resulting dose rate is multiplied by the source strength in each group and the sum is taken for all groups and basket locations in each detector location.

These results and the standard deviations of the various results are statistically combined to determine the standard deviation of the total dose rate in each detector location. This 2-step process allows for the consideration of the neutron and gamma source spectra, the axial segment of, and the location of the individual assemblies in the package.

The staff reviewed the description of the changes related to shielding and the source terms for the design basis fuel and found them acceptable. The methods used are consistent with accepted industry practices and standards. The staff reviewed the maximum dose rates for both NCT and HAC and determined that the reported values were below the regulatory limit in 10 CFR 71.47 and 71.51.

5.3 Evaluation findings

Based on its review of the statements and representations provided in the application, the staff has reasonable assurance that the shielding evaluation is consistent with the appropriate codes and standards for shielding analyses and NRC guidance. On these bases, the staff finds that the revised HI-STAR 180 package design meets dose rate limits of 10 CFR Part 71.

6.0 CRITICALITY EVALUATION

The applicant requested several changes to the Certificate of Compliance for the Model No. HI-STAR 180 (see Enclosure 1 to Holtec letter dated June 21, 2019). Two of the requested changes to the Certificate of Compliance required changes to the criticality safety analysis for the package:

1) addition of an additional F-32 or F-37 basket configuration which includes the quiver containing fuel debris as allowable spent fuel contents in specific locations, and

2) addition of dummy fuel assemblies for partial loading configurations of the F-32 or F-37 basket.

The applicant added loading configurations which include up to two quivers in opposite corners of the basket, as described in Table 6.1.2 of the application for the F-37 basket, and Table 6.1.3 of the application for the F-32 basket. A quiver consists of sealed housing containing tubes for storing damaged fuel rods or fuel debris. Figure 1.2.5 shows the typical configuration of a quiver. Each quiver may contain the equivalent of a maximum of 48 fuel rods.

The applicant modeled fuel in the quiver as a rectangular array of bare fuel rods (i.e., without cladding), with fresh, 5.0 weight percent enriched uranium oxide (UO_2), and with varying pitch constrained by the outer dimension of the quiver housing. The applicant varied the pitch by changing the number of rods, evaluating between 16 rods in a 4 x 4 array and 400 rods in a 20 x 20 array, to determine the most reactive configuration. The most reactive quiver configuration is used in all subsequent calculations.

The applicant assumed all rods are the same height as the active length of undamaged fuel rods. The applicant assumed all quiver structural material, including the housing, is replaced by water. The fuel in all other locations of each basket is modeled the same as for the previously approved configurations. The applicant also used the cask and basket material and fabrication tolerances previously determined to be most reactive. The staff reviewed the applicant's criticality model for F-32 and F-37 configurations containing quivers and agrees that the applicant has identified the most reactive configuration, and that the model is conservative.

Using the most reactive configuration determined above, the applicant determined a maximum fresh undamaged fuel enrichment of 4.7 weight percent allowed in the other locations of the F-32 basket in Configuration 2. Similarly, the applicant determined a maximum fresh undamaged fuel enrichment of 2.55 weight percent allowed in the other locations of the F-37 basket in Configuration 10.

Additionally, for Configuration 10 of the F-37 basket, the applicant determined a minimum burnup of 29 GigaWatt days per metric ton of uranium (GWd/MTU) required for 5.0 weight percent initial enrichment undamaged fuel in all other locations of the basket, using the previously approved burnup credit methodology outlined in Appendix 6.B of the application.

The zero burnup, 2.55 weight percent enrichment and 29 GWd/MTU burnup, 5.0 weight percent enrichment points form the end points of the loading curve for Configuration 10 of the F-37 basket, as shown in Figure 6.B.7 of the application. The maximum calculated k-effectives (keff) for Configuration 2 of the F-32 basket and Configuration 10 of the F-37 basket are shown in Table 6.2.4 of the application, and are less than the previously calculated maximum system keff shown in Table 6.1.1 of the application (0.9487).

The applicant is also requesting a change to allow the loading of dummy fuel assemblies in any basket cell location of either the F-32 or F-37 basket. The applicant states in Section 6.3.6 that the reactivity of the cask with dummy assemblies will be reduced due to the reduction of fissile material in the system, and that no further evaluations are necessary.

The staff agrees with the applicant that the package with dummy fuel assemblies in any location of the basket will be bounded by the package with fuel assemblies in all locations of the basket.

The staff reviewed the applicant's requested changes to the Certificate of Compliance, initial assumptions, model configurations, analyses, and results. The staff agrees that the applicant has identified the most reactive configuration of the Model No. HI-STAR 180 with the requested changes, and that the criticality results are conservative. Therefore, the staff finds with reasonable assurance that the package, with the requested changes, continues to meet the criticality safety requirements of 10 CFR Part 71.

7.0 OPERATING PROCEDURES

The operating procedures have been revised to allow fuel spacers such as fuel shims or FIAs, if needed. In addition, operational requirements for quivers are provided in Table 7.1.5 including the condition of fuel rods, dryness, backfill gas, backfill pressure, and leaktightness.

The package operations presented in Chapter 7 of the application, allow for cyclic vacuum with cask dryness criteria and operational criteria presented in Table 7.1.2 and Table 7.1.3, respectively. The applicant presented, in Table 3.3.6 of the application, the results of the thermal evaluation showing that the maximum fuel cladding temperature is below the temperature limits of moderate burnup fuel with robust margins. The resulting data supports vacuum drying of moderate burnup fuel without time limits.

For high burnup fuel, if the computed cladding temperature exceeds those determined in ISG 11, Rev. 3, high burnup fuel temperature limits: (i) the demoisturization is required following the cyclic vacuum drying method articulated in Section 3.3.5, or (ii) optionally using Forced Helium Dehydration as stated in Section 3.3.4.2. The staff determined this vacuum process acceptable because the mandated temperature limits for moderate and high burnup fuels are met. The user must verify that the thermal evaluations have been performed to determine the correct cyclic vacuum drying time limits.

Explicit operational steps to the cask loading/closure procedures for the removal of standing water from closure lid bolts holes have been provided in Chapter 7. The additional procedure ensures ALARA.

The staff verified that the pre-shipment and periodic leakage rate tests do verify the integrity of the containment boundary, and that the containment components will maintain their leaktight containment function during transport operations. The staff concludes the leakage rate tests are consistent with the guidelines of ANSI N14.5-2014.

The staff also verified that Condition 6(a) of the CoC states: “The package shall be prepared for shipment and operated in accordance with Chapter 7 of the application.” This condition of the CoC is necessary to ensure that all portions of Chapter 7 of the application are complied with. The staff ensured that the language in Chapter 7 of the application was consistent with this condition of the CoC; therefore, any change to Chapter 7 of the application necessitates NRC’s approval.

8.0 ACCEPTANCE TESTS AND MAINTENANCE

The staff verified that fabrication, pre-shipment, maintenance, and periodic leakage rate tests are performed on all containment components, seals, and the associated the allowable leakage rates and test sensitivities, as stated and described in Table 8.1.2 of the application.

The applicant described, in Table 8.1.1 of the application, the seal acceptance criterion as leaktight, which is defined as a leakage rate of no greater than 1×10^{-7} reference cubic centimeter per second (ref-cm^3/s) of air, in accordance with American National Standards

Institute (ANSI) N14.5, "American National Standard for Radioactive Materials – Leakage Tests on Packages for Shipment."

Chapter 8 has been revised to reference the 2014 edition of ANSI N14.5 and now includes additional leak testing related requirements such as approval of leak rate testing procedures by an ASNT Level III specialist as well as the updated reference leakage rate conversion factor. The applicant described, in Sections 8.1.4 and 8.2.2 of the application, that leakage rate testing shall be performed by personnel who are qualified and certified in accordance with ASNT Recommended Practice No. SNT-TC-1A, "Personnel Qualification and Certification in Nondestructive Testing," the 2006 edition as cited in reference 8.1.2 of the application. The staff finds this to be acceptable based on its review of ANSI N14.5-2014. The staff finds that these changes associated with the new edition of ANSI N14.5 do not change the cask design, including the containment boundary and system as previously approved, and incorporates guidance for including leak testing expertise during the development and performance of leak test procedures.

Under NCT, the containment system of the package is designed to be leaktight, i.e., there is no leakage greater than 1×10^{-7} ref-cm^3/s of air with a test sensitivity of 5×10^{-8} ref-cm^3/s of air. The staff verified the applicant provided a definition of leaktight in the glossary of the application that was consistent with the definition in ANSI N14.5-2014.

The applicant also proposed to revise the conversion factor from air reference conditions to helium reference conditions from a factor of 2 to a factor of 1.85 to be consistent with ANSI N14.5-2014. The staff verified that multiplying the leakage rate acceptance criterion and leakage rate test sensitivity when using air as a tracer gas by a factor of 1.85 when using helium as a tracer gas, as specified in Note 1 of Table 8.1.1 of the application, is acceptable.

Basket welds connecting Metamic-HT panels shall be examined and repaired in accordance with NDE specified in the drawing package. These weld requirements are not applicable to welds identified as NITS or as Non-Structural on the drawing package referenced in the CoC. NITS (non-code) welds shall be examined and repaired in accordance with written and approved procedures.

Chapter 8 of the application has been revised to acknowledge fuel spacers (fuel shims or FIAs) including visual inspections. The applicant proposed adding the option to repair cask bolt holes by installing threaded inserts in place of damaged bolt holes. As specified in Holtec Drawing No. 4845 and in Chapter 8 of the application, the repaired fasteners, including the threaded inserts, are evaluated to ensure they meet the safety category and applicable stress limits used to qualify the original fastener. The materials and testing are required to comply with the requirements of the ASME B&PV Code Section III, Division I, Subsection NB or Subsection NF, as applicable. Based on the repaired joint configuration meeting the requirements of the original, the staff finds the use threaded inserts to repair cask bolt holes acceptable

The examination of the welds shall be performed in accordance with the drawing package referenced in the CoC, applicable codes and standards, and applicable code alternatives. All code weld inspections and Metamic-HT weld inspections (excluding NITS welds and non-structural welds) shall be performed in accordance with written and approved procedures by personnel qualified in accordance with SNT-TC-1A.

Containment boundary welds including any attachment welds (and temporary welds to the containment boundary) shall be examined in accordance with ASME Code Section V, with acceptance criteria per ASME Code Section III, Subsection NB, Article NB-5300. Although

ASME Code Section III, Subsection NB does not require visual examination of welds, the welds will be visually examined to ensure conformance with the fabrication drawings (e.g. proper geometry, workmanship etc.). NF welds on the cask (other than containment boundary welds) and on primary load bearing members of the impact limiter shall be examined in accordance with ASME Code Section V, with acceptance criteria per ASME Code Section III, Subsection NF, Article NF-5300. These weld requirements are not applicable to NITS (non-code) welds (e.g. seal welds).

The staff also verified that Condition 6(b) of the CoC states, “The package shall meet the acceptance tests and be maintained in accordance with Chapter 8 of the application.” This condition of the CoC is necessary to ensure that all portions of Chapter 8 of the application are complied with. The staff ensured that the language in Chapter 8 of the application was consistent with these two conditions of the CoC; therefore, any change to Chapter 8 of the application necessitates NRC’s approval.

CONDITIONS

Item No. 3(a) identifies the new address of Holtec International while Item No. 3(b) identifies the latest application dated March 25, 2020.

Condition No. 5(a)(2) has been updated to include the addition of quivers containing separated fuel rods

Condition No. 5(a)(3) has been modified to include the new revisions of the cask, F-32 and F-37 baskets, and impact limiter licensing drawings.

Condition No. 5(b)(1) has been updated to reflect the addition of dummy fuel assemblies and additional specifications and requirements associated with undamaged fuel assemblies. Table 1 has been relabeled as Table 1a. The “Fuel Assembly Width” has been deleted and the fuel spacer weight is included in maximum fuel assembly mass. The minimum cooling time for assemblies with Zr guide/instrument tubes is reduced from 3 years to 2 years. A new Table 1b was added for quiver and quiver Content Characteristics. Table 2 “Isotopic Composition for Pu239, Pu240 and U235 and U238” was updated. The updated Condition now reflects the requirements of the revised application and provided specifications and requirements for partially loaded casks, the allowance for dummy fuel assemblies, and the specifications and requirements for quivers.

Condition No. 5(b)(2) has been updated to provide the maximum quantity and material per package for the case of a package containing both fuel assemblies and quivers.

Condition Nos. 6(a) and (b) were re-written to ensure that any modification to Chapters 7 and 8 of the application requires staff’s approval. Condition No. 6(b) has been modified to remove the requirements for the bend test qualification of a representative friction stir weld sample since those are now included in the revised Metamic HT Sourcebook.

Condition No. 11 has been modified, after renewal of the CoC, to extend the CoC expiration date by 5 years.

The References section of the certificate was updated to reference the latest application.

CONCLUSION

Based on the statements and representations in the application, the staff finds that these changes do not affect the ability of the package to meet the requirements of 10 CFR Part 71.

Issued with CoC No. 9325, Revision No. 3.