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

February 11, 2016

Mr. Scott P. Murray
Manager, Facility Licensing
GE-Hitachi Nuclear Energy
3901 Castle Hayne Road
P.O. Box 780
Wilmington, NC 28402

SUBJECT: AUTHORIZATION FOR SHIPMENT OF THE MODEL NO. 2000 PACKAGE USING HIGH PERFORMANCE INSERT TO SHIP COBALT-60 SOURCE RODS

Dear Mr. Murray:

As requested by your letter dated December 12, 2014, as supplemented September 25, 2015, and January 15, 2016, pursuant to Title 10 of the *Code of Federal Regulations* Part 71, the Certificate of Compliance (CoC) No. 9228 for the Model No. 2000 package is amended by this letter to allow shipment of Cobalt-60 (Co-60) source rods to the General Electric-Hitachi hot cell facility in Vallecitos, California, using the High Performance Insert (HPI) with its dedicated materials basket. All other conditions of CoC No. 9228 shall remain the same. This authorization expires on April 29, 2016, and is limited by the following conditions:

1. The package shall be shipped in "configuration #1" as described in the application where the decay heat is 0 - 1,500 watts.
2. The maximum Co-60 activity is 96,750 Curies.
3. The Co-60 source rods shall be shipped in the HPI using the HPI Material Basket.
4. The separators, basket filler, Material Basket, barrel rack, and basket support, described in sections 5(a)(3)(ix), 5(a)(3)(vi), 5(a)(3)(v), and 5(a)(3)(x) of the CoC, shall not be used.
5. Co-60 is the primary radionuclide allowed to be shipped in the HPI. Co-60 encapsulated in zircalloy and other source rod activation products (such as zirconium) are the radionuclides allowed to be shipped in the HPI.
6. The package will be prepared for shipment and operated in accordance with the operating procedures prescribed in CoC No. 9228, Rev. 26, and supplemented by Chapter 7 of the application dated January 15, 2016.
7. The package shall be shipped in the upright position and will be an exclusive-use shipment.
8. The acceptance tests and maintenance program of the package shall follow the CoC and supplemented by Chapter 8 of the application dated January 15, 2016.
9. The HPI and HPI Material Basket shall be constructed and assembled in accordance with GE Drawing No. 001N8422G001, Rev. 1, "GE 2000 HPI and Material Basket Licensing Drawing," Drawing No. 001N8423G001, Rev. 1, "GE 2000 HPI Licensing Drawing," Drawing No. 001N8424G001, Rev. 1, "GE 2000 HPI Material Basket Assembly Licensing Drawing," Drawing No. 001N8425G001, Rev. 1, "GE 2000 HPI Body Licensing Drawing," Drawing No. 001N8427G001, Rev. 1, "GE 2000 Top Plug Assembly Licensing Drawing," and Drawing No. 001N8428G001, Rev. 1, "GE 2000 HPI Bottom Plug Assembly Licensing Drawing."

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10. Modifications to the cask shall be constructed and assembled in accordance with GE Drawing No. 101E8718, Sheet 1, Rev. 16, and Sheet 2, Rev. 15, "Model 2000 Shipping Cask S/N 2001," and Drawing No. 105E9520, Sheet 1, Rev. 8, and Sheet 2, Rev. 7, "Model 2000 Shipping Cask all S/N's Except S/N 2001."
11. The containment boundary of Model No. 2000 package (configuration #1) includes the steel-clad lead cylinder with a stainless steel forging at each end, the closure lid with O-ring combination, the pipe plugs at vent port and drain port, the containment welds, and the base metals. The O-rings at the vent port and drain port are not part of the containment boundary.

If you have any questions regarding this authorization, please contact me or Huda Akhavannik at (301) 415-5253.

FOR THE U.S. NUCLEAR REGULATORY COMMISSION

**/RA/ N. Garcia-Santos For**

Steve Ruffin, Acting Chief
Spent Fuel Licensing Branch
Division of Spent Fuel Management
Office of Nuclear Material Safety
and Safeguards

Docket No. 71-9228
CAC No. L24974

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Enclosures: 1. Safety Evaluation Report (Non-Proprietary)
2. Safety Evaluation Report (Proprietary)

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**OFFICIAL AGENCY RECORD**

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

SAFETY EVALUATION REPORT (NON-PROPRIETARY)
Docket No. 71-9228
Model No. 2000
Certificate of Compliance No. 9228

## SUMMARY

By application dated December 12, 2014, as supplemented September 25, 2015 and January 15, 2016, GE-Hitachi Nuclear Energy (GEH or the applicant) requested a one-time authorization to ship Model No. 2000 packages using the high performance insert (HPI) to ship Co-60 source rods. The HPI with its dedicated materials basket holding the Co-60 is not an authorized content in Certificate of Compliance (CoC) No. 9228.

A one-time letter authorization has been granted to authorize these shipments based on the statements and representations in the application. The staff agrees that the change does not affect the ability of the package to meet the requirements of 10 CFR Part 71.

## EVALUATION

### 1.0 GENERAL INFORMATION

The staff typically allows one-time special authorizations in accordance with 10 CFR 71.41(d). For the Model No. 2000, because of some technical issues the applicant suspended use of the lead shielding liner which caused subsequent changes to the CoC (Reference 5-2). NRC and GEH had a public meeting on February 12, 2014, to discuss the Model No. 2000 (Reference 5-3). At this meeting it was concluded that GEH would submit special authorization requests to ship contents not included in the revised CoC while they worked to submit a consolidated safety analysis report (SAR.)

The applicant requested a one-time authorization to ship **[[ ]]** Co-60 source rods from the **[[ ]]** to the GE-Hitachi hot cell facility in Vallecitos, California, using the Model No. 2000 containing the HPI with the HPI Material Basket. In this one-time authorization, the Model No. 2000 packaging consists of an overpack and cask which will ship the HPI, HPI Material Basket, and Co-60 rods. The HPI and HPI Material Basket are not an authorized content in CoC No. 9228, Rev. 26.

The Model No. 2000 plus HPI packaging design has two cask lid seal and port seal configurations. The application describes two shipping configurations: configuration #1 and configuration #2, but requests approval only for configuration #1. Configuration #1 features an already approved ethylene propylene diene monomer (EPDM) seal design with a maximum decay heat of 1,500 watts, or an activity of 97,200 curies of Co-60. This limit is administratively reduced to 96,750 curies. Configuration #2 is a 3,000 watt limit and introduces a new high temperature perfluorocompound seal design. Each of the **[[ ]]** Co-60 rods will be **[[ ]]**. The Model No. 2000 operating procedures will require that **[[ ]]**. The Model No. 2000 with the HPI has the volumetric capacity to carry **[[ ]]**. The actual number of Co-60 rods that will be transported in a single package is a function of the activity limit of the package and the source strength of the rods.

The Model No. 2000 may be transported either in the upright or horizontal position. In this letter authorization, the package must be shipped only in the upright position as requested by the applicant. The approximate overall packaging dimensions are 131.5 inches in height and 72 inches in diameter. The approximate total weight of the package (packaging plus the contents) is 33,550 lbs.

The HPI allows for increased shielding capability of the package. The HPI is **[[ ]]** tall and **[[ ]]** in diameter. The cavity is approximately **[[ ]]** in diameter and **[[ ]]** deep. The HPI body consists of two **[[ ]]** stainless steel (SS) concentric cylindrical shells. The annulus between the two shells is filled with **[[ ]]** thick depleted uranium (DU). The HPI body is positioned in the cask cavity by **[[ ]]** arranged **[[ ]]**. The **[[ ]]** are joined together by **[[ ]]** that function as the primary lifting fixture. The HPI body assembly is completed with the addition of **[[ ]]**. Closure of the HPI is provided by top and bottom plugs joined to the **[[ ]]**. The bottom plug is a stepped design comprised of a **[[ ]]** circular **[[ ]]** thick DU cylinder encapsulated by a ¼ inch **[[ ]]** shell. Holes are machined in the **[[ ]]** circular plate to align with the American Society of Mechanical Engineers (ASME) **[[ ]]** on the HPI body. The bottom plug is attached to the bottom **[[ ]]** cap screws and **[[ ]]**. The top plug is a **[[ ]]** comprised of **[[ ]]** shell. To facilitate lifting of the top plug, four hoist rings are recessed into the **[[ ]]** circular plate. The top plug is held in position by **[[ ]]**. Attachment of the top and bottom plugs does not produce a pressure boundary. Grooves are cut into the surface of the plugs to allow moisture to escape during the vacuum drying process.

The HPI Material Basket is used to carry the Co-60 rods. The HPI Material Basket is constructed of **[[ ]]**, which form a **[[ ]]** pattern. The outer **[[ ]]** of the HPI Material Basket form a composite section with the addition of stiffener plates welded to adjacent pipe with full penetration groove welds. The center location of the basket is a developed cell, which is created by the surrounding **[[ ]]**. To allow for the proper insertion of a rod holder and facilitate fabrication, **[[ ]]** are inserted at the top and bottom of the developed cell. **[[ ]]** evenly spaced in the axial direction facilitate loading and positioning of the material basket within the HPI cavity. In addition, dunnage (for example rod **[[ ]]** holders) may be used as a cask loading mechanism and to shore the rod **[[ ]]** during transport.

The applicant included drawings of the HPI and the HPI Material Basket. Additionally, the applicant included drawings for configuration #2 which is currently not approved in this letter authorization.

The staff has determined that the requested change to the packaging design does not affect the ability of the package to meet the requirements of 10 CFR Part 71.

## 2.0 STRUCTURAL

### 2.1 Review Objective

The objective of the evaluation is to verify that the structural performance of the Model No. 2000 shipping package is acceptable for transporting an added content, the Co-60 rod **[[ ]]** under the normal conditions of transport (NCT) and hypothetical accident conditions (HAC) to meet the 10 CFR Part 71 requirements. The rod **[[ ]]** are kept inside the HPI Material Basket, which, in turn, is held in place by the HPI for loading into the cavity of the packaging. Since no modification is made to the other packaging components, the following evaluations will only focus on the structural performance of the HPI and the HPI Material Basket to ensure that the package will continue to perform satisfactorily.

**2.2 Areas of Review**

2.2.1 Structural Design Features and Acceptance Criteria

Section 1.2.2.1 of the application presents design features of the HPI body, as a shielded insert, which measures **[[ ]]** tall by **[[ ]]** in diameter. The HPI has a cavity of approximately **[[ ]]** in diameter and **[[ ]]** deep. It is fabricated with two **[[ ]]** thick, concentric stainless steel cylindrical shells with an annulus space of **[[ ]]** filled with depleted uranium. The HPI body is capped with the **[[ ]]** at each end of the cylindrical shells. It is positioned inside the cask cavity by **[[ ]]** arranged **[[ ]]**.

Section 1.2.2.2 of the application includes design features of the HPI Material Basket composed of **[[ ]].** As depicted in drawing no. 001N8424, the **[[ ]]** of the HPI Material Basket form a composite section with the addition of stiffener plates welded to adjacent pipe with full penetration groove welds. **[[ ]]**, which are evenly spaced in the axial direction, facilitate loading and positioning of the material basket within the HPI cavity.

The staff reviewed the licensing drawings for the added content and finds the above design features descriptions acceptable in meeting the guidance in NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Material.".

Section 2.1.2 of the application presents the structural evaluation stress acceptance criteria for the packaging components. The applicant evaluated the HPI per the ASME Code, Service Levels A and D stress criteria for the NCT and the HAC, respectively. This includes the use of the ASME Code, Section III, NF-3221.1 and Section III, Appendix F provisions.

The staff reviewed the applicant's rationale on the use of applicable codes and standards to meet the guidance found in NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Material." The staff finds the applicant's approach acceptable because the HPI and HPI Material Basket are used primarily for positioning and supporting the rod **[[ ]]** in the analyzed configurations for shielding safety evaluation.

In section 2.1.3 of the application, the applicant provided a weight breakdown of individual package components and noted that weights and centers of gravity of the package with the HPI and HPI Material Basket are bounded by the values previously provided in CoC Rev. 26, and the Model No. 2000 safety analysis report. The staff reviewed the applicant's assessments and confirmed that the total cask contents weight of **[[ ]]** (including the HPI assembly, HPI material basket, shoring, and Co-60 rods), are bounded by those used previously for evaluating the package free drop conditions and tests. Therefore, the staff finds it acceptable for the applicant's packaging structural evaluation to focus primarily on the HPI and the HPI Material Basket.

Section 2.1.4 of the application considers the HPI Material Basket as dunnage. The applicant noted that the basket is not required for reducing impact loading on the containment boundary. Nevertheless, in Sections 2.6.7.8 and 2.7.1.5 of the application, the applicant evaluated the basket with the ASME Code, Section III, NF-3221, and Section III, Appendix F-1332 stress criteria to ensure that the basket will have adequate structural integrity for the NCT and HAC, respectively. For this reason, staff finds the criteria used by the applicant acceptable because it is in accordance with the guidance provided in NUREG/CR-3854, "Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety."

### 2.2.2 Materials

The Model No. 2000 design is constructed of the packaging: overpack and cask, and contents: HPI, HPI Material Basket and Co-60 rod **[[ ]],** which collectively make up the transportation package as discussed in section 1.2 of the application. The material review was comprehensive, however, the discussion will primarily focus on the non-proprietary structural components important to safety (ITS) as follows:

Packaging:
- Overpack
- Cask

Contents:
- HPI
- HPI Material Basket
- Radioactive contents: Co-60 rods

2.2.2.1 Packaging

2.2.2.1.1 Cask

The cask body is fabricated from two concentric cylindrical shells that are 1-inch thick Type-304 SS American Society for Testing and Materials (ASTM) A240, joined at the bottom end to a 6-inch thick Type-304 SS forging, ASTM A182, and between the two shells a 4-inch annulus filled with lead, QQ-L-171. The lid, Type-304 SS is stepped, fully recessed into cask top flange, filled with lead, QQ-L-171 and secured to the cask body by 15 1-1/4-7 UNC 2A socket head screws, ASME SA540, Grade B22. The cask contains a seal test port (side of cask body), a vent port (cask lid), and a drain port (bottom of cask). All penetrations are made up of a 1/2-inch hex socket head, Type-304 SS, ASME SA182, pipe plug followed by 1-3/4-12 UN-2A Type-304 SS, ASME SA479, plug cover, and O-ring material corresponding to the applicable configuration as described in Table 1-1 of the application.

Two cask lid seal configurations are associated with the two thermal limits. Configuration #1 (1,500 watts) is approved in this letter authorization and is made up of four rings of contoured EPDM material, bonded two on top and two on bottom of a 0.125-inch thick aluminum alloy 6061-T6, ASTM B209 retainer. Configuration #2 (3,000 watts), which is currently not approved in this letter authorization, is of similar design, but the retainer is Type-304 SS with four bonded high temperature material rings, as described section 1.3.2 of the application.

2.2.2.1.2 Overpack

The overpack is fabricated from two 1/2-inch thick Type-304 SS, ASTM A240, concentric cylindrical shells separated radially along the length of the shells, and by two tube sections around the perimeter of the shells. A toroidal shell impact limiter made of Type-304 SS, ASTM A240, is attached to each end of the overpack shells. The overpack opens just above the lower impact limiter for access to the cask and the top section is joined to the base by 15 13/8-inch diameter shoulder screws. Type-304 SS gussets on the top and bottom impact limiters provide tie-down points for the package. Additional impact protection is provided by aluminum honeycomb energy-absorbing material, MIL-C-7438F, permanently positioned on the inside of the overpack at the top and bottom ends of the cask. The cask sits on a 1/2- inch thick, Type-304 SS cask support plate including 8 square cross-section prongs welded to the plate perimeter to ensure cask concentricity.

2.2.2.2 Contents

2.2.2.2.1 High Performance Insert

The HPI is utilized to increase the shielding capacity of the package. The HPI body is fabricated from two austenitic SS concentric cylindrical shells filled with DU. The HPI body is positioned in the cask cavity and provided uniform support. These components are joined together by arms that function as the primary lifting fixture. Closure of the HPI is provided by top and bottom plugs with the bottom plug a stepped design. The bottom plug is attached to the bottom with cap screws. The top plug is comprised of DU encapsulated by a shell. To facilitate lifting of the top plug, four hoist rings are recessed into the circular plate. Attachment of the top and bottom plugs does not produce a pressure boundary. Grooves are cut into the surface of the plugs to allow moisture to escape during the vacuum drying process.

2.2.2.2.2 HPI Material Basket

The HPI Material Basket is shown in Figure 1-5 and Figure 1-6 in the application. The HPI Material Basket is constructed of **[[ ]]**. **[[ ]]** evenly spaced in the axial direction facilitate loading and positioning of the material basket within the HPI cavity.

2.2.2.3 Radioactive Material Contents

The contents requested in this application are based on the configurations described in Table 1-1 of the application. The Co-60 rods are further described in section 5.2 of the application.

Specifications and temperature dependent mechanical properties, including yield strength, tensile strength, allowable strength, modulus of elasticity, and coefficient of thermal expansion conform to ASME Code, Section II, Part D as presented in section 2.2.1 of the application, “Material Properties and Specifications.” Material properties used in the structural analysis of the HPI and HPI Material Basket are presented in Tables 2-3 through 2-5 of the application. Also provided are temperatures, density and Poisson’s ratio values. The staff reviewed the materials selected and determined that they are acceptable.

2.2.2.3 Chemical or Galvanic Reactions

Section 2.2.2 of the application discusses reactions due to chemical, galvanic or other reactions. The applicant states that the Model No. 2000 cask is fabricated from SS-304 and pig lead. The lead is completely encased in the SS. This construction excludes moisture at the SS boundary, thus assuring no galvanic or deleterious reactions could occur. The cask contents contact the SS cavity surface. The radioactive material contents are in solid form and typically are placed in an inner container. The applicant’s experiences in operating other transport packages with similar arrangements show that chemical, galvanic or other reactions between the cask cavity surface and the radioactive material containers, or between these containers and their solid contents, do not occur.

The structural components of the HPI and HPI Material Basket are fabricated from SS, which are chemically compatible. These materials are selected because of their strength, ductility, and high resistance to corrosion and brittle fracture over a broad temperature range and high levels of radiation. Therefore, no chemical or galvanic reaction will occur. The primary function of the

HPI body, including top and bottom plugs, is to encapsulate the DU shield. DU is cast and machined to precise tolerance to form the required shield geometry. To prevent potential oxidation, assembly of the shield is performed in an inert atmosphere. Once encapsulated, oxidation and galvanic reactions with stainless steel does not occur.

The staff concludes during normal operation the Model No. 2000 internals will not be subject to continuous or frequent exposure to moisture or that any water intrusion is not likely to occur in large quantities. The number of and galvanic potential between the different metals used in fabrication is low. Therefore, the conditions required to create the possibility for galvanic corrosion are minor. Further, visual inspections to be performed of the ITS payload cavity at various timed intervals provide reasonable assurance against any significant corrosion occurring unnoticed.

2.2.2.4 Brittle Fracture

The structural components of the Model No. 2000 with exception of the bolts are fabricated from austenitic SS Type-304. Since this material does not undergo a ductile to brittle transition in the temperature range of interest (down to -40 degrees F), it is not subjected to brittle fracture. Bolts are excluded due to NUREG/GR-1815, section 5 that states "bolts are generally not considered as fracture-critical components because multiple load paths exist and because bolted systems are designed to be redundant".

2.2.2.5 Effects of Radiation on Materials

Section 2.2.3 of the application discusses the effects of radiation materials. The applicant states that Gamma radiation has no significant effect on metal and therefore, the radiation produced by the contained radioactivity does not cause any measurable damage to the packaging metallic components (stainless steel, DU, and lead). Seals are inspected prior to each use. Leakage testing of the cask closure seal, vent, and drain are performed prior to each shipment. Seals incapable of passing the leakage test are replaced.

The staff finds that radiation effect on the elastomeric seals is not a concern as the seals are inspected and replaced on an as needed and annual basis. The contents of the package emit beta and gamma radiation. Austenitic SS, carbon steel and lead are durable materials that are able to withstand the damaging effects from the radiation. The O-ring seals fitted to the containment system are the only material on which the radiation may have an effect; however it has been shown that for the radioactive contents the maximum dose to the containment seal is $<1 \times 10^6$ rad whereas no change of physical properties of the containment seal is expected at radiation levels up to $1 \times 10^6$ rad.

2.2.2.6 Acceptance and Materials Testing

Section 8.1 of the application discusses acceptance and maintenance testing. The metallic materials of construction are procured and fabricated to consensus industry standards. The various safety important structural packaging components are fabricated from ASTM standard materials in accordance with ASME Code, Section IX. The staff concludes that the materials, acceptance testing and maintenance imposed by the applicant in accordance with ASME code and standards are acceptable based on the above discussion.

2.2.2.7 Conclusion

The staff finds that the Model No. 2000 transportation packaging meet the regulatory requirements for preventing or mitigating galvanic or chemical reactions, is unaffected by cold temperatures, and is constructed with materials and processes in accordance with acceptable industry codes and standards.

## 2.3 Normal Conditions of Transport

In Section 2.6 of the application, the applicant evaluated the Model No. 2000 package, with the HPI and Material Basket assemblies as added content, for the 10 CFR 71.71 NCT conditions. In Sections 2.6.2 through 2.6.6 of the application, the applicant noted that the NCT for the present package configuration fall within the bounds identified in CoC, Rev. 26, and the SAR documents (NEDO-31581 and NEDO-32318). The staff evaluated the applicant's identification of loading conditions and concluded that no new safety analysis needs to be performed for the conditions of cold, reduced and increased external pressures, vibration, and water spray. Therefore, the staff finds the applicant's approach of not reanalyzing those conditions acceptable because the packaging structural performance would either have been bounded by the results associated with the previous CoC revisions or would have negligible structural effects on the package. In the following, the staff reviews the applicant's analyses of the heat conditions and the free drop tests pertaining to the structural performance of the package with respect to the added content for meeting the NCT requirements of 10 CFR Part 71.

2.3.1 Heat and Cold - Differential Thermal Expansion

Section 2.6.1 of the application presents the evaluation of differential thermal expansions (DTEs) between package internals, including those between the HPI and the cask body inner shell, for the bounding temperatures. Using the bounding temperature conditions, the applicant calculated the minimum DTE in diameters at 0.19 inches between the HPI inner shell and the Material Basket alignment disks. Similarly, the applicant calculated a minimum difference of 0.23 inches between the HPI Material Basket and the HPI inner cavity.

The staff reviewed the underlying assumptions and determined that hand calculation methods followed the common thermal expansion calculation practice. Therefore, the staff finds the calculated results acceptable in that the DTEs will cause neither radial nor axial interference in unloading the HPI from the package.

2.3.2 One-Foot Free Drop

Section 2.6.7 of the application performed an ANSYS finite element analysis (FEA) of the HPI assembly for the 1-ft free drops. The inertia loads of 55.1 g and 15.5 g, which are based on a packaging drop FEA using the LS-DYNA code, for the cask side and end drops, respectively. Sections 2.6.7.2, 2.6.7.3 and 2.6.7.4 of the application provide the FEA modeling details, including the use of the contact elements to simulate interfaces among assembly components. By reviewing those details for their implementation, which followed typical FEA practices, the staff has reasonable assurance to conclude that the FEA calculated results are adequate for demonstrating the packaging structural performance.

Section 2.6.7.6 of the application presents the HPI side drop analysis, considering the inertia force exerted on the HPI body through the **[[ ]]** of the HPI Material Basket. The applicant considered two cases for applying the pressure equivalent inertia force on the HPI inner shell: the line-load and the area-load pressure distributions, which vary as a cosine function along the circumference of the bottom half of the shell. Similarly, a cosine function variation for the contact stiffness was also used, following also the common practice of assigning the gap size variation between two right cylindrical surfaces with slightly different diameters, to simulate the interaction between the five HPI **[[ ]]** and the cask inner shell. The staff reviewed the FEA modeling details, including the force and displacement interactions between the packaging components, for demonstrating the structural integrity of the HPI components by stress analysis. Since the applicant's approach followed typical FEA practices, the staff has reasonable assurance to conclude that the FEA results are adequate for demonstrating the packaging structural performance.

Tables 2-15 and 2-17 of the application summaries the FEA results for the top 30 most critically stressed sections of the HPI body for the two loading cases discussed above. The minimum margin of safety is 1.2. Tables 2-16 and 2-18 reports stress intensity results for seven **[[ ]]** section cuts for which the membrane and membrane-plus-bending stresses are computed. The minimum margin of safety is 1.3, which suggests an elastic structural behavior. As a result, the staff finds the side drop structural performance of the HPI body acceptable since the HPI components will continue to retain their original shape and, thus, maintain the configuration as analyzed after the NCT side drop test.

In Section 2.6.7.8 of the application, the applicant performed a side drop analysis of the HPI Material Basket by hand calculation, considering the integral spacer strips adjoining outer layer of the assembly **[[ ]]** for developing composite action associated with the basket bending-resistant behavior. The applicant's approach and assumption on identifying load bearing components followed the classic structural analysis practice and is, therefore, acceptable. The applicant computed large stress margins, which assures that the HPI Material Basket will behave elastically and the Co-60 rod **[[ ]]** will continue to be kept in the location and would remain in place as analyzed configuration.

In Section 2.6.7.7 of the application, the applicant performed an ANSYS FEA of the HPI subject to the 1-ft top end drop scenario. The staff reviewed the applicant's selection of the packaging top-end drop orientation for evaluating the bottom plug of the HPI. This selection followed the law of physics of imposing inertia forces on the components of the HPI assembly. The applicant noted the most critically stress component in the system is the interface between the bottom cover ring and bottom plug cover plate that surrounds and supports the depleted uranium shield. Table 2.19 of the application summarizes the stress results for the bottom plug with the maximum stress intensity of 0.2 ksi and 0.5 ksi for the membrane and membrane-plus-bending stress categories, respectively. The large stress margins of safety against the respective allowables of 15.9 ksi and 23.9 ksi assure that the HPI end plugs will function adequately to retain the HPI Material Basket and, thus, the Co-60 rod **[[ ]]** in the analyzed configuration after a package NCT end drop event.

**2.4 Hypothetical Accident Conditions**

2.4.1 Thirty-Foot Free Drop

Similar to the evaluations performed for the NCT 1-ft free drops, the applicant considered the HAC 30-ft free drop inertia loads of 162 g and 158 g for the respective side- and end-drop analyses of the HPI components.

In Section 2.7.1 of the application, the applicant evaluated the HPI using the same ANSYS FEA model for the NCT drop analyses. As a result, two pressure equivalent basket inertia force distribution cases, the line-load and the area-load, were considered for the side drop. Table 2-22 and 2-24 of the application list, for the top 30 most critically stressed sections, the HPI body is shown to have a minimum margin of safety of 0.8 for both the line-load and the area-load cases. Tables 2-23 and 2-25 summarize stress intensity results for seven section cuts of the **[[ ]]** with a minimum margin of safety of 0.2 for the two cases. The positive margins suggest an elastic structural behavior. Therefore, the staff finds the side drop structural performance of the HPI body acceptable since the HPI components will continue to retain their original shape and, thus, maintain the configuration as analyzed after the HAC free side drop test.

In Section 2.7.1.5 of the application, the applicant performed a side drop analysis of the HPI Material Basket by hand calculation, considering the integral spacer strips adjoining outer layer of the assembly **[[ ]]**, for developing composite action in resisting the basket bending. The applicant's approach and assumption on identifying load bearing components followed classic structural analysis practice and is, therefore, acceptable. The computed large stress margins are positive, which assures that the HPI Material Basket will behave elastically and the Co-60 rod **[[ ]]** will continue to be kept in the location and would remain in place as analyzed.

In Section 2.7.1.1 of the application, the applicant performed an ANSYS FEA of the HPI subject to the 30-ft top end drop scenario. The basis for selecting the top-end drop for evaluation is same as that for the NCT drop and is, therefore, acceptable. Table 2.21 of the application summarizes the stress results for the bottom plug with the maximum stress intensity of 2.7 ksi and 2.9 ksi for the membrane and membrane-plus-bending stress categories, respectively. The large stress margins of safety against the respective allowables of 23.9 ksi and 35.8 ksi assure that the HPI end plugs will function adequately to retain the HPI Material Basket and, thus the Co-60 rod **[[ ]]** in the analyzed configuration after a package HAC end drop event.

### 2.5 Conclusion

Based on the information provided by the applicant, the staff concludes that by the use of the HPI and HPI Material Basket, the Model No. 2000 shipping package is structurally adequate for transporting the Co-60 rod **[[ ]]** under the NCT and HAC in meeting the 10 CFR Part 71 requirements.

## 3.0 THERMAL

The applicant requested special authorization to use Model No. 2000 package with a new internal package configuration (configuration #1) to transport Co-60 source rods in not more than six shipments. The new internal package configuration uses a high performance insert (HPI) with its dedicated material basket.

The objective of this review is to verify that the package design and performance, with these requested changes, still satisfy the thermal requirements of 10 CFR Part 71 under NCT and HAC.

### 3.1 Thermal Design

The Model No. 2000 package (configuration #1 with maximum heat load of 1,500 watts) is designed with a thermally passive system. The package is enclosed in an overpack that serves as a fire shield. The overpack is designed to reduce heat flow from the fire environment into the package by using the enclosed air spaces. The package has lead shielding on the sides and a stainless steel forging at the base that functions as a heat sink to allow the heat flow through the bottom of the package. The Model No. 2000 package (configuration #1) is limited to heat load of 1,500 watts and is used for the exclusive-use shipment.

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

### 3.2 Material Properties and Component Specifications

The applicant provided the packaging component temperature limits in the section 3.2 and Table 3-2 of the application, and the package material properties in the Table 3-6 of the application for solid components and Table 3-7 of the application for gaseous regions in the package. The Model No. 2000 packaging component materials are mainly stainless steel, lead, and aluminum. The EPDM O-rings, used in the closure lid and the vent/drain/test ports has a workable range of -40°F - 400°F. The pipe plugs at the vent and drain ports serve as part of the containment boundary and have an allowable temperature limit of 612°F.

The staff reviewed the material properties and component specifications used in the thermal evaluation and checked the materials handbook for packaging materials, including EPDM O-ring and pipe plug. The staff concludes that the material properties and component specifications provided in the section 3.2 of the application are acceptable for thermal evaluations of the Model No. 2000 package (configuration #1) with heat load up to 1,500 watts.

### 3.3 Thermal Evaluation under NCT

As described in the application section 3.3, the applicant modeled the design heat load of 1,500 watts uniformly distributed among the **[[19]]** basket **[[tubes]]**. For NCT thermal analysis, the package and HPI are backfilled with helium at 70°F and 14.7 psia. Natural convection is modeled from the package surfaces to the 100°F ambient, but is neglected within the package cavity. Radiation emissivity of 0.22 is used for the package surface under NCT. Insolation is applied directly to the package surface per 10 CFR 71.71. The applicant also performed the NCT thermal evaluation without solar heat to address that the requirements of 10 CFR 71.43(g) is met.

The staff reviewed the NCT thermal model as described in the section 3.3 of the application, and accepted the thermal model used in the NCT thermal evaluations.

#### 3.3.1 Normal Hot Conditions

The applicant presented the package component temperatures in Table 3.5-1 of section 3.5.2 of the application. The applicant calculated the maximum temperatures of the lid seal, pipe plugs (located at vent port and drain port), lead shielding, and fill gas under 100°F ambient, insolation and heat load of 1,500 watts.

The staff reviewed the NCT thermal evaluation described in the application section 3.3 and the temperatures results shown in Tables 3.5-1 and 3.5-3 of section 3.5.2 of the application. The staff confirmed that the applicant's analysis is acceptable because the maximum temperatures of the packaging components are below their allowable limits, as shown in Table 3.5-3. The staff also confirmed that the overpack outer surface temperature is below 185°F at shade for an exclusive-use shipment.

3.3.2 Extreme Cold Conditions

The applicant performed analysis of the minimum seal temperature under -40°F ambient, no solar heat and heat load of 1,500 watts, and summarized the temperature results in Table 3.5-2 of section 3.5.2 of the application.

The staff reviewed the thermal evaluation presented in section 3.3.1.2 of the application, including the model description, thermal contact resistances, and boundary conditions, as well as the temperature results shown in Table 3.5-2 of section 3.5.2 of the application. The staff determined that the package meets the requirements in cold case and the EPDM O-ring seals are operable at the minimum design temperature of -40°F.

3.3.3 Thermal Expansion

The applicant described the thermal expansion in section 2.6.1.2 of the application and evaluated both radial and axial thermal expansions for HPI and the HPI Material Basket using initial component temperature of 70°F and maximum component temperatures from the worst-case thermal conditions. The applicant calculated a minimum difference of 0.19 inches in the final diameter and a minimum difference of 0.23 inches in the final height, as shown in Table 2-8 and Table 2-9 of the application, respectively, between the HPI and the HPI Material Basket.

The staff reviewed the equations, methodology and calculations for thermal expansion described in section 2.6.1.2 of the application, and determined that the thermal expansion results in no axial/radial interferences for the Model No. 2000 package.

**3.4 Thermal Evaluation under HAC**

The applicant described the HAC thermal model in the application section 3.4 which includes a heat load of 1,500 watts, damage due to a side drop, no insolation, and no natural convection within the package cavity for the HAC 30-minute fire. The package was assumed to be at a normal condition state with solar insolation prior to and following the 30-minute fire. The fire was modeled with an emissivity of 0.9 during the fire and 0.8 during post-fire cooldown. The applicant presented the maximum calculated component temperatures in Tables 3.5-4 (mixed contact between packaging components) and 3.5-7 (perfect contact between packaging components) of the application.

The staff reviewed the initial conditions, boundary conditions and thermal model described in section 3.4 of the application and the HAC temperature results shown in Tables 3.5-4 and 3.5-5 in section 3.5.2.3 of the application. The staff determined that the applicant's HAC model was acceptable based on the initial conditions, boundary conditions, and bounding parameters used in the model. The staff concludes that the package body is well below its service limits under HAC fire and meets the thermal requirements of 10 CFR 71.73.

**3.5 Thermal Contact Resistance/Conductance**

As described in section 3.3 of the application, the applicant modeled the thermal contact as thermal contact conductance (TCC) in an ANSYS model. TCC is defined as the reciprocal of the thermal contact resistance, i.e. a high TCC value implies low thermal contact resistance and a low TCC value implies high thermal contact resistance. The applicant referred to typical thermal contact conductive values from open literature (Table 3-8 of the application), used five TCC levels from low to high resistance in the thermal model (Table 3-9 of the application) and then assigned thermal contact resistance levels to the modeled contact elements (Table 3-10 of the application.) The applicant performed a sensitivity study and compared the temperature results for NCT with insolation that includes mixed contact versus perfect contact (Table 3-13 of the application.) The applicant noted that the analysis using perfect contact among components results in lower package temperatures because the mixed thermal contact resistances impede the flow of the decay heat from getting out of the package to the ambient.

The staff compared the temperature results between the case with mixed contacts and the case with perfect contacts (Table 3.5-6 for NCT and Table 3.5-7 for HAC of the application) and verified that a gap exists between HPI bottom plug and package bottom per review on the licensing drawing nos. 101E8718 (Sheet 1, Rev. 16.) and 105E9520 (Sheet 1, Rev. 8.) The staff concludes that with a gap between HPI bottom plug and package bottom, the package body is well below its service limits under both NCT and HAC fire.

### 3.6 Evaluation Findings

Based on its review, the staff determined that: 1) the thermal design features of the Model No. 2000 package (configuration #1) are adequately described and evaluated, 2) the thermal analyses are discussed and described in sufficient detail for verification of NCT and HAC, and 3) the temperatures, pressures, and thermal stresses fall within the regulatory limits with adequate safety margins. The staff concludes that with heat load limited to 1,500 watts and using EPDM O-ring seals, the Model No. 2000 package (configuration #1) meets the thermal requirements of NCT and HAC and are in compliance with 10 CFR Part 71.

## 4.0 CONTAINMENT

### 4.1 Review Objective

The objective of the containment review is to verify that the Model No. 2000 package containment design (configuration #1 with the maximum heat load of 1,500 watts) is adequately described and satisfies the containment requirements of 10 CFR Part 71 under NCT and HAC to transport Co-60 source rods in not more than six shipments under this special authorization request.

### 4.2 Description of Containment System

As described in the application section 4.1, the entire containment boundary of Model No. 2000 package (configuration #1) includes the steel-clad lead cylinder with a stainless forging at each end, the closure lid with O-ring combination, the pipe plugs at vent port and drain port, the containment welds, and the base metals. The O-rings at the vent port and drain port are not part of the containment boundary. The closure of the pipe plugs at vent and drain ports is designed for leak tightness as defined in ANSI N14.5-1997. The EPDM O-ring at closure lid, as part of the containment boundary, can operate in a temperature range of -40 - 400°F. The pipe plugs at vent and drain ports can maintain the containment function up to 612°F. The entire containment boundary, including the pipe plugs at vent and drain ports, the containment welds, and the base metals, are leakage rate tested for fabrication, maintenance, and periodic leak tests.

The staff reviewed the containment design features presented in the, “General Information,” and, “Containment,” chapters of the application and confirmed that the application defines the boundary of the containment system as well as adequately describes the package lid closure seal and port seals, in compliance with 10 CFR 71.33 and 71.43.

**4.3 Containment under Normal Conditions of Transport**

The applicant stated in section 4.2 of the application that Model No. 2000 package containment is designed so that no release of radioactive materials will occur under NCT and there will not be any significant increase in external radiation or reduction in package containment effectiveness. The applicant stated that the maximum gas pressure at 1,500 watts is bounded by the maximum gas pressure of 26.8 psia at 3,000 watts and is below the design limit of 30.0 psia under NCT with insolation and heat load of 1,500 watts.

The staff reviewed the package containment configuration in section 4 of the application and thermal evaluation in section 3.3 of the application. The staff verified that both maximum package gas pressure and peak seal temperature mentioned above are below the corresponding limits. The staff confirmed that the Model No. 2000 package meets the containment requirements of NCT, in compliance with 10 CFR 71.71 and 71.51(a)(1).

**4.4 Containment under Hypothetical Accident Conditions**

The applicant stated in section 4.3 of the application that the maximum gas pressure at 1,500 watts is bounded by the maximum gas pressure of 29.0 psia at 3,000 watts and is below the design limit of 30.0 psia under HAC with heat load of 1,500 watts.

The staff reviewed the pressure calculation in section 3.0 of the application and confirmed that the maximum package gas pressure is below the corresponding limits of 30 psia. The staff confirmed that the containment function is maintained and the Model No. 2000 package satisfies the containment requirements of HAC, in compliance with 10 CFR 71.73 and 71.51(a)(2).

**4.5 Leakage Rate Tests**

The applicant stated in sections 4.0, 7.0, and 8.0 of the application that the Model No. 2000 package is tested to leaktight criteria (1.0x10-7 ref-cm3/sec) for pre-shipment leakage rate test and a leak-tight criteria ($1x10^{-7}$ ref-$cm^3$/sec) for fabrication, maintenance and periodic leakage rate tests. All the leakage tests are performed in accordance with ANSI N14.5. An ASNT certification Level III examiner is required for approval of all leak testing procedures.

The staff reviewed sections 4.0, 7.0 and 8.0 of the application and accepts the leakage rate test descriptions, and confirmed that the fabrication, maintenance, and periodic leakage rate tests should be performed to the entire containment boundary of the Model No. 2000 package, in accordance with ANSI N14.5.

**4.6 Findings**

The staff reviewed the containment sections of Model No. 2000 package under this special authorization request and concludes that (1) the Model No. 2000 package has been described and evaluated to demonstrate that it satisfies the containment requirements of 10 CFR Part 71, and (2) the package is leak-tight and meets the requirements of 10 CFR 71.51(a)(1) for NCT and 10 CFR 71.51(a)(2) for HAC.

## 5.0 SHIELDING

The applicant submitted a request for shipment of Co-60 source rods (Reference 5-1, the application). The applicant defined two shipment configurations, configuration #1 and configuration #2 (Reference 5-8), however only requested approval for configuration #1 at this time. The details of the configurations are in Table 1-1 of Reference 5-8. The contents for configuration #1 and #2 are the same, except configuration #2 is for twice as much Co-60 as configuration #1. The shielding evaluation in Reference 5-7 is based on the higher amount of Co-60, 193,500 Ci, and therefore the staff reviewed the shielding evaluation to support approval of configuration #2, however, approval is also applicable to configuration #1.

This portion of the SER documents the staff's shielding review. The purpose of the shielding review is to verify that the package design meets the external radiation limit requirements of 10 CFR Part 71 for NCT and HAC. The NRC staff has reviewed the application to ensure it meets the external radiation limit requirements in 10 CFR Part 71. The staff performed its shielding review using the guidance in Chapter 5, "Shielding Evaluation" of NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Material."

### 5.1 Description of Shielding Design

5.1.1 Design Features

The Model No. 2000 cask is constructed of two concentric 1 inch thick stainless steel cylindrical shells joined at the bottom to a 6 inch steel plate. The annulus between the two shells is filled with 4 inches of lead. The cask is approximately 71.0 inches tall and has an outer diameter of 38.5 inches. The cask cavity is 26.5 inches in diameter and 54 inches deep. The cask lid has 5.38 inches of lead in addition to 1.74 inches of stainless steel above and 1.5 inches of stainless steel below the lead shielding.

For this authorization, GEH relied on internal shielding from a component called the High Performance Insert or HPI. The HPI is **[[ ]]** inches tall and **[[ ]]** inches in diameter. The cavity is approximately **[[ ]]** inches in diameter and **[[ ]]** inches deep. The HPI body consists of **[[ ]]** inch stainless steel concentric cylindrical shells. The annulus between the two shells is filled with **[[ ]]** inch thick DU.

The staff reviewed the figures, certificate drawings, and discussion describing the shielding features. The staff finds that the applicant included the shielding features, materials, and dimensions with tolerances and therefore the staff found that they are sufficiently detailed to support an in-depth evaluation.

5.1.2 Summary Table of Maximum Radiation Levels

The applicant presented a summary table of the maximum calculated external dose rates in Tables 5-3 and 5-4 in Attachment 2 of the application. The applicant analyzed surface dose rates (at the impact limiter surface) as well as dose rates at 2 meters from the edge of the vehicle for NCT and 1 meter from the cask surface for HAC. The staff reviewed this table and verified that the calculated dose rate levels meet the regulatory dose rate limits in 10 CFR 71.47 for exclusive use shipments and the dose rate limits for HAC specified in 10 CFR 71.51 for the specified content and shielding configuration.

**5.2 Radiation Source**

The contents are rods containing **[[ ]]** Cobalt (Co-59) targets that have been irradiated to generate Co-60 sources. **[[ ]]**

GEH calculated the activity of each rod as well as its axial profile in Revision 0 of the GNF document 001N8465 (Reference 5-4). **[[ ]]** GEH compared its prediction of Co-60 content calculated with the described method to measurements from a Co-60 rod after a single irradiation cycle. The comparison in Figure 5-4 of the application showed the calculated and the measured specific activity (Ci/g) as a function of elevation for a single rod. Figure 5-4 shows that the calculated values agree closely to the measured values, with calculated values over-predicting the measured Co-60 values slightly. **[[ ]]** based on the similarity and conservative nature of activities calculated with the method as compared to those determined from the actual measurements for a representative rod, the staff found the calculation method to be adequate to determine the proposed package contents' Co-60 activities.

The applicant uses the line source geometry with a uniform activation/Co-60 concentration profile for this analysis. To account for the axial Co-60 profile inherited from the axial neutron flux profile from the reactor core, in its shielding calculations, the applicant has hypothetically reduced the length of the line source, which concentrates the Co-60 source so that the Co-60 activity at any point is less than the highest peak concentration of Co-60 along any of the **[[ ]]** from the Co-60 activation. In addition, the applicant took into consideration the worst possible orientation of the source **[[ ]]**. The applicant discusses the source geometry in Section 5.3.1.1 of the application. The staff reviewed this information and found it acceptable due to it producing a conservative source.

For configuration #2, this package is limited by the thermal load of 3,000 Watts (1,500 Watts for configuration #1). In the application, the applicant used 64.8 Ci/Watt for Co-60 to convert from 3,000 Watts to curies of 194,400, to establish a package limit. The staff used the same procedure discussed in Section 3.1.2 of the application to confirm this value but used different nuclear data (Reference 5-5) and calculated a conversion value of 64.6 Ci/Watt. The difference between the staff's value and the applicant's value is small; however, it appears that accounting for the uncertainty in the applicant's best estimate value could bring the thermal load above 3,000 Watts. The applicant submitted a supplement to the application (Reference 5-4) reducing the allowable Co-60 Curies to 193,500 for configuration #2. This also gives the applicant margin when considering other non-Co-60 impurities present in the source rods (activated zirconium, CRUD, etc.). Since the allowable Co-60 for configuration #1 is exactly half of this value, the staff found the limit of 96,750 Ci acceptable for configuration #1.

**5.3 Shielding Model**

The following subsections discuss the package as modeled under NCT and HAC for the shielding evaluation. The staff reviewed the structural and thermal sections of the application and found that the package modeling as discussed in the following subsections was consistent with the results of the NCT and HAC tests.

5.3.1 Source and Shielding Configuration

The staff verified that the applicant used dimensions consistent with those in the drawings of the Model No. 2000 cask in their shielding model. The applicant used nominal cask dimensions to model the Model No. 2000 cask body. The staff notes that using nominal cask dimensions is a non-conservative assumption. Applicants should account for the possible loss of shielding due to the manufacturing tolerances; however the staff found it acceptable for this authorization as there are other conservative assumptions within the source calculation such as not including the impact limiter material. As discussed in Section 5.3.1.1 and 5.3.1.3 of this SER, the applicant credited the distance occupied by the impact limiter in both the radial and axial directions in determining locations for dose rate tallies, however they do not include the actual stainless steel material that encompasses the entire cask, both in the radial and axial direction. Given that the manufacturing tolerances are roughly 0.1 inches (0.254 cm) and the impact limiter covers the entire surface of the package and has about 1 inch of steel in the radial direction and 3 ½ inches of steel in the axial direction, it is the staff's judgment that accounting for manufacturing tolerances would be bounded by this conservative assumption and would not cause the package to exceed any normal or hypothetical accident condition dose rate limits. Therefore the staff found neglecting tolerances in the analysis to be acceptable for this application. Under HAC, the dose rates are less than 1/10$^{th}$ of the regulatory limit and therefore the staff found that accounting for package tolerances would not cause this dose rate to exceed regulatory limits.

In addition to the cask body shielding, the source will be loaded into the HPI for supplemental shielding. The applicant considered **[[ ]]** for this component and all dimensions are selected to **[[ ]]**. The staff found this acceptable.

5.3.1.1 Analysis Assumptions Under Normal Conditions of Transport

The applicant did not model the impact limiter materials for either of the NCT or HAC evaluations; however, for the NCT evaluations, the applicant credits the space occupied by the impact limiter when selecting a location for evaluating the dose rate. In Chapter 2 of the application (Reference 5-1) the applicant shows the effects of NCT on the material basket and the HPI. There is no effect on the impact limiter and HPI under NCT and therefore these components are modeled in their nominal as-loaded configuration for NCT. The material in the material basket is not modeled; however, the applicant does take some credit for the basket's geometry. The applicant modeled all of the activity coalesced into a single line source centered in the cavity and an array of line sources within the basket, similar to the actual planned loading of the **[[ ]]**. The staff found that a line source representation is conservative for performing this shielding evaluation because in reality these sources do have some dimension as well as some structural material that will act as self-shielding. The applicant modeled these sources at both the top and bottom of the cavity to determine the limiting dose rate location for the top, side, and bottom of the package. The staff found this acceptable as the applicant has considered the possibility of source reconfiguration on external dose rates.

5.3.1.2 Analysis Assumptions Under Hypothetical Accident Conditions

The difference between the NCT and HAC models is that the applicant includes the lead slump in the HAC model. The applicant estimated the lead slump for the Model No. 2000 in Appendix 2.12.2.3 of the application, "Elastic Deformation During Bottom Impact," and found that the value used in the shielding analysis is bounding with respect to what was calculated by the applicant. The staff finds this acceptable. The lead slump was applied to the top of the lead shield where there is the most streaming. The applicant did not discuss slump of the radial lead thickness, however it is in the staff's judgment that due to the large extent of the cask, that this would be insignificant, and would not cause HAC dose rates to exceed the regulatory limits given that current calculated HAC external dose rates are less than 1/10$^{th}$ of the regulatory limit.

The staff reviewed the information presented in section 2.7, “Hypothetical Accident Conditions,” of the application and found that all of the damage due to drop and puncture is limited to the impact limiter, which covers the entire surface of the package. The applicant does not credit the impact limiter in the HAC analysis. The staff found this appropriate.

The applicant showed in section 2.7 of the application that the HPI remains intact during HAC therefore the source will remain inside. The applicant did not perform an analysis demonstrating the integrity of the material basket during HAC and therefore they assume that it fails during HAC. The applicant has performed shielding evaluations using several reasonably bounding source geometries under HAC. This includes the source modeled as a disc at the top and bottom as well as a line source at the side at the top and at the bottom. The staff found this HAC source modeling acceptable as it neglects any structural material or self-shielding that further attenuate radiation. In addition, the applicant assumed that the source will reconfigure in such a way that gives a higher external dose rate over what would likely happen to the source and material basket, and therefore the staff found this conservative and acceptable.

5.3.1.3 Locations for Evaluating the Dose Rate Under Normal Conditions of Transport

The distances used by the applicant for calculating dose rates are listed in Table 5-9 of the application. The descriptions of the points for each of the tallies are in Table 5-8 of the application.

Under NCT, the applicant included the location of the impact limiter’s outer surface when determining the location for calculating the dose rate. In addition to covering the entire axial surface, the impact limiter additionally contains a toroid shape at the top and bottom of the package. In the center of this toroid there is a cover plate. This is reflected in Drawing No. 105E9521 Rev. 5. The applicant evaluates dose rate at the surface of the cover plate for the top, but inside the well of the toroid for the bottom. The staff verified that the locations used for evaluating dose rates under NCT are consistent with package dimensions and are in compliance with the distances prescribed in 10 CFR 71.47(b) for exclusive use.

5.3.1.4 Locations for Evaluating the Dose Rate Under Hypothetical Accident Conditions

As discussed in Section 5.3.1.2 of this SER, the applicant did not take credit for the presence of the impact limiter, and therefore all tally locations under HAC are in reference to the cask body. The staff verified that the locations used for evaluating dose rates under HAC are consistent with package dimensions and are in compliance with the distance prescribed in 10 CFR 71.55(a)(2).

5.3.1.5 Streaming Paths

The applicant calculated the dose rate profile at the top surface by subdividing the surface detector into radial ring segments to demonstrate that streaming is not an issue at the top of the cask in Section 5.5.2 of the application. The Model No. 2000 has historically been limited at the side of the package, near the top, where streaming is possible over the top of the lead shield.

As the applicant did not provide specific information on streaming at this location, the staff viewed the Monte Carlo N-Particle Transport Code (MCNP) input file for the HAC dose rate evaluations at the side surface to collect information on whether streaming was adequately accounted for. The staff found that there was not enough information from the application to adequately determine the effect of streaming over the lead shield. However based on large margins to HAC dose rates (over 90% margin) in conjunction with independent staff evaluations (discussed below), the staff found that streaming over the top of the lead shield would not cause external dose rates to exceed regulatory limits in the radial direction.

To confirm, the staff performed a crude sensitivity study using Microshield 9.06. The staff assumed a Co-60 point source and only represented the streaming path including the DU through the top of the HPI and the stainless steel on the side of the Model No. 2000 cask body over the lead shield. This is a very conservative way to represent the streaming path as it assumes all of the source material has coalesced into a point and there is no structural or self-shielding material to attenuate the source. Further it assumes that there is no lead at all, and all shielding is provided by the stainless steel path over the lead shield. In this very conservative configuration, the staff's results showed that there is adequate margin in meeting the HAC dose rate limit.

For NCT the staff is not concerned as the source will sit at the bottom of the package since the package is transported vertically. Therefore, the source would be well below the location of the streaming path. Thus, the staff found that additional increase in dose rates due to streaming paths would not cause dose rates to increase beyond regulatory limits for normal or hypothetical accident conditions.

5.3.2 Material Properties

The applicant's model used stainless steel, lead, and DU. The applicant modeled the materials for the HPI with densities equal to the values stated in Section 2.2.1 of the application and that are consistent with those listed in the drawings. The staff reviewed the sample MCNP input files provided by the applicant and verified that the applicant appropriately represented the materials used for the cask body (lead, stainless steel).

In Reference 5-6, a revision to the original application, the applicant included a sensitivity study on the effects that reduced DU density would have on the external dose rates. The applicant evaluated external dose rates using a reduced DU density of **[[ ]].** This is the minimum allowed density of this component as reflected in Drawing Nos. 001N8425, 001N8427, and 001N8428 (Reference 5-7). These evaluations use the reduced Co-60 activity of 193,500 Ci. The results of these evaluations show that although there is a reduction in margin to the regulatory limits as a result of this change, the package still meets regulatory dose rate limits in 10 CFR 71.47 and 10 CFR 71.51(a)(2).

The area with the least amount of margin to regulatory limits is the surface dose rate at the **[[ ]]**. Here, the applicant evaluated the margin as less than 10%. Although this reduces the margins, the staff finds that the dose rate still meets regulatory requirements. In addition, the applicant shows that the evaluation is very conservative with respect to the actual package configuration because they do not credit the 3 ½ inches of steel present in the impact limiter.

**5.4 Shielding Evaluation**

5.4.1 Methods

The applicant performed the shielding calculations for this authorization using MCNP6 version 1.0 using the photon transport library MCPLIB04, which compiles data from the ENDF/B-VI.8 data library. MCNP is a general-purpose, continuous-energy, generalized-geometry, time-dependent, coupled neutron/photon/electron Monte Carlo transport code. This code is widely used and accepted by the NRC for these types of applications. Given the code's capabilities and its extensive application in industry (ensuring the code is well-vetted), the staff found the code acceptable for use in the present application.

5.4.2 Input and Output Data

The applicant provided sample input and output files for the MCNP calculations. The staff reviewed a sample input file and found that the information regarding material properties and dimensions used in the calculations is consistent with descriptions and drawings given in the application. The staff reviewed the output file and found that proper convergence was achieved and the calculated dose rates agree with those reported in the application.

5.4.3 Flux-to-Dose-Rate Conversion

The applicant used flux-to-dose-rate conversion factors that were derived from the ANSI/ANS 6.1.1-1977 standard. These are standard factors and the version of the standard is consistent with the recommendations in NUREG-1609. They are shown in Table 5-12 of the application, and the staff verified that they are input correctly in the sample MCNP input files.

5.4.4 External Radiation Levels

The calculated external dose rate for both NCT and HAC meet the requirements in 10 CFR 71.47(b) and 10 CFR 71.51(a)(2), respectively. The applicant states that the reported values include two times the relative error of the calculated dose rate to account for the MCNP uncertainty.

The most limiting surface dose rate calculated by the applicant under NCT was on the side at 159.28 mrem/hr. This corresponds to all of the activity coalesced into a single line source at a length of **[[ ]]** inches (**[[ ]]** cm) pushed to the top of the package (Case 2). This meets the regulatory limit of 200 mrem/hr in 10 CFR 71.47(b)(1) and (2). The applicant calculated the dose rate at 2 meters from the package surface at 6.59 mrem/hr. This corresponds to all of the activity coalesced into a single line source at a length of **[[ ]]** inches pushed to the bottom of the package in the outer most tube (Case 1). This meets the regulatory limit of 10 mrem/hr in 10 CFR 71.47(b)(3). The most limiting dose rate for the truck cab (normally occupied space) is 1.4 mrem/hr. This meets the regulatory limit of 2 mrem/hr in 10 CFR 71.47(b)(4) for not requiring personnel to wear radiation dosimetry devices. This corresponds to all of the activity coalesced into a single line source at a length of **[[ ]]** inches pushed to the bottom of the package in the outer most tube (Case 1). Under HAC, the most limiting dose rate that the applicant evaluated at 1 meter from the package surface was at the top, using a disc source at the top of the HPI. This dose rate is 70 mrem/hr. This meets the regulatory limit in 10 CFR 71.51(a)(2) of 1000 mrem/hr.

### 5.5 Evaluation Findings

Based on its review of the statements and representations in the application and independent confirmatory calculations, the staff found reasonable assurance that the shielding design has been adequately described and evaluated and that the package meets the external radiation requirements of 10 CFR Part 71.

**5.6 References**

5-1 Attachment 2, “GE Model 2000 Special Authorization Request,” (ADAMS Accession No. ML14351A509) to Letter to Director, Division of Spent Fuel Management, US NRC, from S.P. Murray (GEH), “GEH Request for Letter Authorization to Use the Model No. 2000 Package, Docket No. 71-9228,” December 12, 2014 (ADAMS Accession No. ML14358A140)

5-2 Letter to T. A. Caine, Vallecitos Nuclear Center, from T. Lupold, US NRC, “Revision No. 26 of Certificate of Compliance No. 9228 for the Model No. 2000 Package (TAC No. L24690) and Closeout of Confirmatory Action Letter NMSS-2012-001,” August 29, 2014 (ADAMS Accession No. ML14245A209)

5-3 Memo to A. H. Hsia (US NRC) from J. Vera (US NRC), “Summary of February 12, 2014, Meeting with General Electric – Hitachi Nuclear Energy,” March 20 2014 (ADAMS Accession No. ML14083A566)

5-4 Attachment 2, “GNF Bulk Isotope Generation Report,” September 2014 (ADAMS Accession No. ML15022A145, proprietary), to Letter to Director, Division of Spent Fuel Management, NRC, from S.P. Murray (GEH), “GEH Response to NRC Request for Additional Information – Letter Authorization Request to Use the Model No. 2000 Package, Docket No. 71-9228,” January 22, 2015 (ADAMS Accession No. ML15022A144)

5-5 Laboratoire National Henri Becquerel, Atomic & Nuclear Data, Co-60, http://www.nucleide.org/DDEP_WG/Nuclides/Co-60_tables.pdf, 3/1/2010

5-6 Attachment 3, “GE Model 2000 Special Authorization Request,” (ADAMS Accession No. ML15268A483) to Letter to Director, Division of Spent Fuel Management, US NRC, from S.P. Murray (GEH), “GEH Model 2000 Package RAI Responses and Revised Authorization Request,” September 25, 2015 (ADAMS Accession No. ML15268A437)

5-7 Attachment 3, “GEH Model 2000 Special Authorization Request Revised Pages,” (ADAMS Accession No. ML15289A177), to Letter to John Vera, Project Manager, US NRC from S.P. Murray (GEH), “GEH Model 2000 Package Authorization Request Revised Pages,” October 16, 2015 (ADMAS Accession No. ML15289A176)

5-8 Letter from S.P. Murray (GEH) to H. Akhavannik (NRC), “GEH Model 2000 Package Authorization Request Revised Pages and RAI Responses,” January 15, 2016 (ADAMS Accession No. ML16013A365 and ML16013A376)

**6.0 CRITICALITY**

There is no criticality review required for this letter authorization.

**7.0 OPERATING PROCEDURES**

The operating procedures have been updated to include steps to ensure the correct seal is selected depending on the thermal range and configuration. Additionally, steps have been added to close, open, and load the contents of the package using the HPI. Steps to install the drain and vent plugs have been added.

The applicant stated in the application section 7.1.4 that the surface temperature of the overpack will be measured with particular attention to the bolting-ring area. However, as stated in Section 3.3.1 of this SER, the overpack surface temperature results for configuration 1 are below 185 degrees F at shade for an exclusive-use shipment. Therefore, use of the protective personnel barrier is not anticipated.
The Model No. 2000 package will be tested to less than $1 \times 10^{-7}$ ref-$cm^3$/sec on the package closure seal, the vent plug and the drain plug for the pre-shipment leakage rate test, in accordance with ANSI N14.5. An ASNT certification Level III examiner is required for approval of the leak testing procedures.

Staff reviewed the steps and concluded that they are appropriate and are in accordance with 10 CFR Part 71.

## 8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

The acceptance tests and maintenance program have been updated to contain steps to ensure the correct seal is selected depending on the configuration. Additionally, there are steps to ensure that the seals are tested correctly. Specifically, the entire containment boundary of the Model No. 2000 package is tested to a leak-tight criteria ($1 \times 10^{-7}$ ref-$cm^3$/sec) for fabrication, maintenance and periodic leakage rate tests, in accordance with ANSI N14.5. An ASNT certification Level III examiner is required for approval of the leak testing procedures.

Additionally, the applicant included steps that the thermal test is performed on the first unit built to determine the thermal performance of the system versus what is predicted by the analysis.

The staff concludes that the acceptance tests and the maintenance program meet the requirements of 10 CFR Part 71 and are adequate to assure packaging performance for this special authorization request.

## CONDITIONS

CoC No. 9228 has been amended by letter to authorize shipment of Model No. 2000 packages using the HPI to ship Co-60 source rods. The following conditions apply:

1. The package shall be shipped in “configuration #1” as described in the application where the decay heat is 0 - 1,500 watts.
2. The maximum Co-60 activity is 96,750 Ci.
3. The Co-60 shall be shipped in the HPI using the HPI Material Basket.
4. The separators, basket filler, Material Basket, barrel rack, and basket support, described in sections 5(a)(3)(ix), 5(a)(3)(vi), 5(a)(3)(v), and 5(a)(3)(x) of the CoC, shall not be used.
5. Co-60 is the primary radionuclide allowed to be shipped in the HPI. Co-60 encapsulated in zircalloy and other source rod activation products (such as zirconium) are the radionuclides allowed to be shipped in the HPI.
6. The package will be prepared for shipment and operated in accordance with the operating procedures prescribed in this CoC and supplemented by Chapter 7 of the application dated January 15, 2016.
7. The package shall be shipped in the upright position and will be an exclusive-use shipment.
8. The acceptance tests and maintenance program of the package shall follow the CoC and supplemented by Chapter 8 of the application dated January 15, 2016.

9. The HPI and HPI Material Basket shall be constructed and assembled in accordance with GE Drawing No. 001N8422G001, Rev. 1, “GE 2000 HPI and Material Basket Licensing Drawing,” Drawing No. 001N8423G001, Rev. 1, “GE 2000 HPI Licensing Drawing,” Drawing No. 001N8424G001, Rev. 1, “GE 2000 HPI Material Basket Assembly Licensing Drawing,” Drawing No. 001N8425G001, Rev. 1, “GE 2000 HPI Body Licensing Drawing,” Drawing No. 001N8427G001, Rev. 1, “GE 2000 Top Plug Assembly Licensing Drawing,” Drawing No. 001N8428G001, Rev. 1, “GE 2000 HPI Bottom Plug Assembly Licensing Drawing.”
10. Modifications to the cask shall be constructed and assembled in accordance with GE Drawing No. 101E8718, Sheet 1, Rev. 16, and Sheet 2, Rev. 15, “Model 2000 Shipping Cask S/N 2001,” and Drawing No. 105E9520, Sheet 1, Rev. 8, and Sheet 2, Rev. 7, “Model 2000 Shipping Cask all S/N’s Except S/N 2001.”
11. The containment boundary of Model No. 2000 package (configuration #1) includes the steel-clad lead cylinder with a stainless forging at each end, the closure lid with O-ring combination, the pipe plugs at vent port and drain port, the containment welds, and the base metals. The O-rings at the vent port and drain port are not part of the containment boundary.

All other conditions of CoC No. 9228 shall remain the same. This authorization expires April 29, 2016.

**CONCLUSION**

CoC No. 9228 has been amended by letter to authorize shipment of Model No. 2000 packages using the HPI to ship Co-60 source rods. This authorization expires April 29, 2016.

Based on the statements and representations in the application, and with the conditions listed above, the staff agrees that this change does not affect the ability of the package to meet the requirements of 10 CFR Part 71.

Issued on February 11, 2016.